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BIOMEDICAL AND ENVIRONMENTAL ASPECTS OF THE THORIUM FUEL CYCLE

A Selected, Annotated Bibliography

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Information Division

**BIOMEDICAL AND ENVIRONMENTAL ASPECTS OF THE THORIUM FUEL CYCLE:
A SELECTED, ANNOTATED BIBLIOGRAPHY**

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CONTENTS

Acknowledgments.	v
Highlights	.vii
Introduction	1
Citation Form	1
Services.	2
Sample Reference.	3
Bibliographic References	
Biological Aspects, Animals	7
Biological Aspects, Plants.	54
Chemical Aspects.	59
Ecological Aspects, Aquatic	69
Ecological Aspects, Terrestrial	73
Energy.	77
Environmental Assessment.	87
Geological Aspects.	89
Instrumentation	99
Legal and Political Aspects	101
Medical Aspects	103
Monitoring, Measurement and Analysis.	143
Physical Aspects.	169
Production.	171
Radiation Safety and Control.	179
Sources	189
Waste Disposal and Management	191
Indexes	
Author.	195
Geographic Location	207
Keywords.	213
Title	229
Publication Description	283

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N. P. Knox, ESIC, ordered, cataloged, and systemized the documents. K. A. Kirkscey, Health and Safety Research Division, assisted in providing documents for inclusion in the publication. A. F. Fletcher, S. T. Richardson, and the staff of the Information Sciences and Operations Department, ORNL, managed the computer production of this document.

HIGHLIGHTS

This bibliography was jointly compiled by the staffs of the Ecological Sciences Information Center of the Information Center Complex and the Health and Safety Research Division at Oak Ridge National Laboratory (ORNL). A data file was built to provide information support to the Nonproliferation Alternative Systems Assessment Program under sponsorship of the Department of Energy's Division of Fuel Cycle Evaluation. The bibliography has been compiled to assist in the evaluation of the health and environmental consequences of high specific activity thorium and related nuclides which could be released to the environment by activities related to the Thorium Fuel Cycle. This publication of 740 abstracted references highlights the biological and medical aspects of thorium 228 and thorium 232 in man and animals. Similar studies on related nuclides such as radium 224, radium 226, radium 228, and thorium 230 are also emphasized. Additional categories relevant to these radionuclides are also included. The references are arranged by subject category with leading authors appearing alphabetically within each category. Indexes are provided for: (1) author(s), (2) geographic location, (3) keywords, (4) title, and (5) publication description.

INTRODUCTION

The staff of the Ecological Sciences Information Center (ESIC), in cooperation with the staff of ORNL's Health and Safety Research Division, has been requested to provide information support to the Nonproliferation Alternative Systems Assessment Program (NASAP) under sponsorship of the Department of Energy's Division of Fuel Cycle Evaluation. This bibliography has been compiled to assist in the evaluation of the health and environmental consequences of high specific activity thorium and related nuclides which could be released to the environment by activities related to the Thorium Fuel Cycle. The general scope covers studies regarding potential releases, environmental transport, metabolism, dosimetry, dose assessment, and overall risk assessment for radionuclides specific to the NASAP project.

This publication of 740 abstracted references highlights the biological and medical aspects of thorium 228 and thorium 232 in man and animals. Similar studies on related nuclides such as radium 224, radium 226, radium 228, and thorium 230 are also emphasized. Additional categories relevant to these radionuclides are included as follows: Chemical Analysis; Ecological Aspects; Energy; Geological Aspects; Instrumentation; Legal and Political Aspects; Monitoring, Measurement and Analysis; Physical Aspects; Production; Radiation Safety and Control; and Waste Disposal and Management. Environmental Assessment and Sources categories have been used for entries which contain a multiple use of categories. The bibliography contains literature dating from December 1925 to February 1978. This is the second bibliography by ESIC related to the Thorium Fuel Cycle. The first bibliography, *Biogeochemical Aspects of the Behavior of Uranium and Thorium in the Environment* (ORNL/EIS-99), concentrated on the geochemical movement of uranium and thorium.

Citation Form

The references are arranged by subject category with leading authors appearing alphabetically within each category. Where authors are not provided, the corporate authority is listed alphabetically within each category. If these two levels of authorship are not given then the title is used as the identifying level. The subject category Ecological Aspects is subdivided to separately list the aquatic and terrestrial areas of the environment under field study conditions. Where a laboratory study exists, Biological Aspects is used, subdivided into animal and plant categories. Most of the references deal with several subject areas requiring multiple categories; however, each entry is chosen to be categorized according to the main subject area described. Indexes are provided for: (1) author(s), (2) geographic location, (3) keywords, (4) title, and (5) publication description. All the published literature references are contained in a computerized information file and are available for searching upon submission of specific requests.

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3. $10(E+3)$ or $X(E-3)$ (E denoting exponent) means 10^3 or X^{-3} respectively.
4. For units of measurement (e.g., centimeters, meters, and feet) X_3 means X^3 .

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(<i>Pertinent Numerical Data</i>)

¹⁺ ECOLOGICAL ASPECTS
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³⁺ Jaworowski, D., and D. Grazybowska, ⁴⁺ Central Laboratory for Radiological Protection, Warsaw, Poland. ⁵⁺ 1977, January.

⁶⁺ Natural Radionuclides in Industrial and Rural Soils. ⁷⁺ Science of the Total Environment, 7(1), 45-52.

⁸⁺ Radium 226, Pb 210, U and Th are dispersed in the environment by fly ash emitted by coal fueled power stations. Concentrations of these nuclides have been determined in fly ash from three power stations and in soils collected in six industrial and twenty rural regions. In industrial areas the concentrations of natural radionuclides, in a 5 cm thick surface soil layer, were found to be higher than in lower layers. With the exception of Pb 210 this effect was not observed in rural soils, which contained less Ra 226, U and Th. A mean concentration of Ra 226 of 1.0 pCi/g was found in the upper layer and 0.73 pCi/g in the lower one. The mean content of exchangeable Ra 226 in soil was usually similar in both layers in industrial and rural regions. The vertical distribution of Th in soil was similar to Ra. It was found that the type of coal, or combustion technology, influences the amount of Ra 226 dispersed in the environment which is accessible to plants. ⁹⁺ (RAF)

¹⁰⁺ The mean contents and range of Ra 226, exchangeable Ra 226, Pb 210, U, and Th in soils are given in tabular form.

BIBLIOGRAPHIC REFERENCES

BIOLOGICAL ASPECTS
MINIALS

<1>

Albert, R.E., New York University Medical Center, Institute of Environmental Medicine, New York, NY. 1966, November.

Metabolism of the Principal Isotopes in the Thorium 232 Decay Chain. Thorium: Its Industrial Hygiene Aspects, Chapter 6. Academic Press, New York, New York, (pp. 65-82), 222 pp.

This chapter summarizes the metabolism of Th 232 and some of its principal decay products (Pa 232, Ra 228, Ac 228, Th 232) which play a significant role in the radiological toxicity of Th. The metabolism factors which are important in the evaluation and control of radiological hazards include rates and routes of absorption and excretion, and patterns of organ deposition. These factors determine the magnitude and location of the internal radiation dose and provide the basis for estimating radioactivity levels in the body from analysis of excreta. Data given include information on gastrointestinal absorption of Th; Th burdens in rat organs; Th 232 in human blood after IV injection; plasma concentrations of Pa, Ra, Ac and Th after IV injection; organ distribution of Th in rats, rabbits and dogs; skeletal Th in rats; excretion and retention of Th in dogs and humans; gamma activity and excretion after Ra inhalation by humans; Ra 222 and Thoron in expired air; radon retention after radon injection. (Auth) (VC)

<2>

Albert, R.E., New York University Medical Center, Institute of Environmental Medicine, New York, NY. 1966, November.

A Summary of the Chemical and Radiological Effects of Thorium. Thorium: Its Industrial Hygiene Aspects, Chapter 5. Academic Press, New York, New York, (pp. 50-64), 222 pp.

Chemical toxicity of Th is low and appears dependent on the associated anions. Th(NO₃)₃ and ThCl₄ are both acidic and irritating and, because of the anions, are lethal by IB, IV, IT, and gavage. Examples of LD 50 for the nitrate and chloride are: IP, rats, 0.66-1 g/kg; gavage, rats, 1.0-3.5 g/kg. Both compounds are more toxic by IV. Inhalation produces minor lung lesions, changes in white blood cell levels, and abnormal bone marrow. Chronic feeding studies in rats and dogs produced some growth depression. The biological effects are cancer, genetic damage, and reduced life span. There are three major sources of information about radiation injury from Th. They are long-term refinery workers exposed to Th and thoron; patients receiving Thorotrast; luminous dial painters. Industrial exposures involve external sources; skin contamination; inhalation, ingestion, and occasional traumatic introduction into deep tissues. Thorium is hazardous from alpha-, beta-, and gamma-radiation. Absorption of Th through skin and gastrointestinal tract is negligible. Inhalation is the most important route of entry. The major hazard is cancer of lung and bone. (VC)

<3>

Arnold, J.S., University of Utah, College of Medicine, Radiobiology Laboratory, Salt Lake City, UT. 1955, September 30.

Radioautographic Studies of Plutonium and Radiothorium in Testis. AECU-3109, Semiannual Progress Report, (pp. 57-61), 80 pp. (AECU-3109).

The pattern of plutonium and radiothorium (R₂₃₈) deposition in the sandblasted teeth was studied using Pu dogs and R₂₃₈ dogs. In R₂₃₈ dogs there is complete cessation of bone growth at an early stage following injection while in the comparable plutonium dogs, growth continues for a considerably longer period and there is an abnormal filling in of the periodontal membrane space by proliferating subperiosteal alveolar bone. The etiology of this remarkable proliferation of bone is no doubt connected with the double layer of Pu initially deposited in this region, one layer being on the surface of the cementum and the other on the surface of alveolar wall periosteum. The rapid removal of alveolar bone could be normal and only accentuated in this toxic situation. The proliferation of dentine cannot be considered abnormal until compared adequately to benches observed in nontoxic situations and normal controls. (LCU)

<4>

Arnold, J.S., University of Utah, College of Medicine, Radiobiology Laboratory, Salt Lake City, UT. 1955, September 30.

Pathology and Detailed Radioautography Report. AECU-3109, Semiannual Progress Report, (pp. 51-56), 80 pp. (AECU-3109).

The skeletal changes in the two high level plutonium dogs that died at 500 and 536 days after injection are discussed. The bone marrow of the two plutonium dogs showed evidence of rapid but progressive bone marrow regeneration. Found in the Pu dogs were large sheaths of connective tissue seen to enclose irregularly the trabeculae of the ribs and to a lesser extent those of the vertebral bodies. The bone showed advanced evidence of death with loss of osteocytes from almost all trabecular bone of ribs and vertebrae. The skeletal changes of some radiothorium dogs that died are also discussed. (LCU)

<5>

Atherton, D.B., F.W. Greener, and E.J. Storer, University of Utah, College of Medicine, Division of Radiobiology, Department of Anatomy, Salt Lake City, UT. 1971.

The Interaction of some Actinide Elements with Blood Constituents. COO-119-224, Annual Report of Work in Progress in the Internal Irradiation Program, (pp. 211) (COO-119-224).

The distribution of a number of actinide elements in canine and human blood were studied and compared to extensive, already existing data on Pu 239 (IV) and Ra 226 (II) in dogs. Ac 227, Th 228, Pa 233, Th 233 (IV), Th 233 (VI), Sp 232 (IV), Sp 232 (VI), and Pu 239 (III) were used in these studies. Each actinide in 0.08 M citrate, pH 3.5, was incubated in VITRO with canine and/or human whole blood. Cells were removed and evaluated for actinide retention. Except for Pu 239 (III), the concentration of the actinide in the plasma was at least 10% that found with cells. This factor was about 5 for Pu 239 (III). Following gel-chromatography on G-25, varying percentages of the actinides were associated with the peak eluting at the void volume. These are Ac 227-42 percent, Th 228-76 percent, Pa 233-69 percent, Th 233 (IV)-7 percent, Th 233 (VI)-9 percent, Sp 232 (IV)-20 percent, Sp 232 (VI)-21 percent and Pu 239 (III)-65 percent. Actinides forming strong complexes with inorganic entities (HCO₃⁻)

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BIOLOGICAL ASPECTS MAMMALS

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show limited binding to protein constituents. Further separation of protein-bound nuclides was achieved by gel-chromatography on gels of lower cross linkage and by anion-exchange procedures. Regions of protein-complex stability were determined in some cases by difference-spectrophotometry. (Auth)

(6)

Atherton, D.B., E.J. Stover, and R.A. Van Dilla, University of Utah, College of Medicine, Radiobiology Laboratory, Salt Lake City, UT. 1957, September.

Absorption of Radium and Thorium through the Gut as a Function of Chemical Form. A-1. ARCS-3583; Radiobiology Laboratory Semi-Annual Progress Report, September 30, 1957, (pp. 91-93) (ARCS-3583).

Analysis of guinea pigs fed "home made dial milk" show a greater relative absorption of radium than of thorium. Excreta after 11 days contained over 90% of the dose. Ashed samples of bone, gut and liver-spleen were analyzed. Average percentages of dose absorbed for Ra 226 and Th 228, respectively were: skeleton, 0.41, 1.6×10^{-3} (R-3); gut, 0.10, 0.11; liver and spleen, 3.6×10^{-3} (R-3), 0.92×10^{-3} (R-3). Skeletal retention at 10 days was measured for chlorides, citrates and sulfates of Ra and Th in the rat, monkey and guinea pig. There was considerable variation in relative absorption among different species, which appears related both to the chemical state of the elements and the condition of the animals. (Auth) (VC)

(7)

Ballou, J.R., University of Rochester, Department of Radiation Biology and Biophysics, Rochester, NY. 1969.

Studies with Radiothorium (Thorium 228) Enriched Thorium Dioxide and Its Radioactive Progeny. OR-69-1153; Ph.D. Thesis, University of Rochester; 140 pp.

Ra 226 and Pb 212 daughters in ThO₂ were preferentially solubilized and translocated from deposits in muscle, reticuloendothelial organs, and lung. Usually, Pb 212 was depleted (relative to Th 228) twice the extent of its Ra precursor. Much of the Pb 212 deficit (80% of that from the lung deposit) was from loss of the parent, thoron, in the expired air. The rest accumulated in red blood cells and liver at a ratio of 5:1. The concentration of Pb 212 in blood reflected the amount of ThO₂ in the dog, regardless of deposition site, and maintained a ratio of blood Pb 212 (nCi/g) / lung Th 228 (nCi) of 0.083 during 3-150 days. After inhalation of ThO₂, this ratio was 0.80. Ra 226 from ThO₂ deposits accumulated in bone (approx 90%) or was excreted (approx 5%). Ra 226 in bone was depleted in Pb 212 (Pb 212/Ra 226 was 0.8) due to the combined losses of thoron by diffusion and Pb by mobilization. Bone depletion was evident by day 3 after inhalation. Thoron was released into the lung space to the extent of 18% of that produced by the Ra 226. Thoron release was approximately 1/2 this value from deposits that originated from systemically injected material; even less was found primary deposits in muscle. Values for the clearance half-life of ThO₂ from lung were estimated during a 150 day retention period at 235 and 290 days for the long-term component. Relative concentrations of Th 228, Ra 226 and Pb 212 tissues at "steady state" were

expressed in terms of initial LRT burden extrapolated from the long-term clearance phase. These concentrations were discussed in terms of their application to the estimation of industrial exposures and calculation of subsequent radiation dose. (Auth) (VC)

(8)

Ballou, J.R., and R.A. Gies, Battelle-Pacific Northwest Laboratories, Richland, WA. 1977, May.

Early Deposition of Inhaled Transyl Nitrate (Uranium 232 and Uranium 233) in Rats. BNWL-2100 (Part 1); Annual Report for 1976, (pp. 91-93), 316 pp. (BNWL-2100, Part 1).

Rats exposed to aerosols of U 232 and U 233 nitrate were used to study retention. Protocol and aerosol parameters are tabulated; sacrifices were made at intervals between 7 and 200 days postexposure. At 30 min, with a mean total initial U 233 deposition of 2.06 nCi, 21.5% was in the upper respiratory tract, 0.11% was translocated to tissues, 22.7% in lung and 56.3% in pelv. Listed in the same order are values for an initial deposition of 71 nCi, 48.3%, 0.49%, 10.1%, 33.7% and for an initial deposition of 510 nCi, 62.1%, 3.40%, 7%, 27.5%. Larger particles were deposited in the upper airways and later translocated to stomach and jejunum. The amount of U 233 translocated to tissues in 30 min was similar to those for Ra 226, Th 232, Pu 239, and Pu 238. Excretion of U 233 nitrate in feces was similar to that for Pu 239 nitrate. Urinary excretion of U 233 was enhanced compared to that of Pu 239. Major deposition sites were lung, skeleton, pelv and kidney. Lung and skeleton retention predominated after 60 days. Uranium 232 retention in the lung did not differ greatly from that of U 233. Pulmonary retention of Pu 238 and 239 is similar to that for U early after inhalation. Pulmonary clearance of U may be influenced by U mass when more than 0.1 ug is deposited in the lung. (VC)

(9)

Ballou, J.R., R.A. Gies, and J.L. Ryan, Battelle-Pacific Northwest Laboratories, Richland, WA. 1977, May.

Long-Term Effects of Inhaled Transyl Nitrate in Rats. BNWL-2100 (Part 1); Annual Report for 1976, (pp. 94-95), 316 pp. (BNWL-2100, Part 1).

Rats were exposed to aerosols of U 232 and U 233 nitrate in a study of long-term biological effects. The study has been in progress 200 days and is expected to continue for 3 years. Details of nitrate solution and aerosol production are given. Exposure groups and estimated radiation dose to major tissues (based on preliminary distribution data) are listed. Preliminary radiation dose estimates show doses in decreasing order to lung, skeleton and kidney in each dose group. Estimated 500-day accumulated doses for U 233 are: for lung burdens of 0.65, 10, and 36 nCi - lung, 2, 30, 100; skeleton, 0.5, 6, 20; kidney, 0.1, 1.2, 8. The estimated doses for U 232 are: for lung burdens of 0.70, 5.0, and 53 nCi - lung, 2, 10, 160; skeleton, 0.5, 4, 30; kidney, 0.1, 1, 6. Dose estimates for U 232 are minimum, since they do not include contributions from daughter products. After 500 days, the immediate product of U 232 decay, Th 228 will build up to 80% of the equilibrium level. Its exact amount and retention kinetics will depend on the amount of the parent present and on the actual site

BIOLOGICAL ASPECTS
ANIMALS

(9) CONT.

where it is produced. Thorium 228 produced in bone will have different kinetics and produce a different biological effect than that produced in the lung. The situation is similar for the Th 228 daughters, except they will achieve equilibrium before the end of the experiment. The patterns of distribution and retention of daughter products will be used to refine estimated dose values. (VC)

(10)

Fallon, J.E., P.A. Cies, and E.A. Wogman, Battelle-Pacific Northwest Laboratories, Richland, WA. 1978, February.

Retention and Translocation of Inhaled Uranyl Nitrate (Thorium 232 and Uranium 232) in Rats. PNL-2500 (Part 1); Annual Report for 1977, (pp. 1.79-3.80) (PNL-2500, Part 1).

The experimental protocol and preliminary metabolic results for rats exposed to uranyl nitrate aerosols were described in the Annual Report for 1976. Additional results reported here of U 232 analysis in tissues supplement the earlier report. Tissues from male Wistar rats sacrificed after exposure to U 232 ⁹⁰²(⁹⁰³)₂ and U 232 ⁹⁰²(⁹⁰³)₂ aerosols were analyzed by liquid scintillation counting U 232 or with an anticoincidence-shielded Ge(Li) diode detector (U 232). Retention curves for major tissues were analyzed to obtain parameters for estimating radiation dose and describing retention kinetics. Results suggest that lung and skeleton may be the major target tissues for biological effects following inhalation of the high-specific-activity uranium isotopes. Comparatively less uranium is translocated and retained in kidney; however, the kidney is known to be uniquely sensitive to uranium poisoning. (Auth)

(11)

Fallon, J.E., P.A. Cies, and E.A. Wogman, Battelle-Pacific Northwest Laboratories, Richland, WA. 1978, February.

Disposition of Uranium 232 Decay Products Following Inhalation of Uranium 232 ⁹⁰²(⁹⁰³)₂ Aerosols. PNL-2500 (Part 1); Annual Report for 1977, (pp. 1.83-1.84) (PNL-2500, Part 1).

Evaluation of biological response to U 232 requires consideration of radiation dose by decay progeny. The report describes work done to determine amounts of decay product in fresh tissue samples from rats after inhalation of uranium nitrate. The Th/U ratio in the aerosol was 0.03 representing a 30 day-ingrowth of Th 228 into U 232. The ratio of 0.12 at day zero apparently results from preferential translocation of U 232 from the lung during the inhalation period and the delay during removal and sacrifice. The Th/U ratio continued to increase with time after inhalation, illustrating the greater solubility of U 232 compared to Th 228. After 617 days the Th/U ratio in lung increased about 20-fold over the ratio in the starting material. Buildup of Th 228 through radioactive decay of U 232 would yield a ratio of 0.36, or only 12 times the starting ratio. The distribution of U 232 and several decay products in lung, skeleton and kidney after 100 and 200 days postexposure is tabulated. Uranium 232 in the major tissues equaled or exceeded the amount of any individual decay product at these time points. After 100 days Th 228 (T_{1/2} = 3.64 days) should be in equilibrium with the parent, Th 228; however, there is only about

1/2 the equilibrium level in lung and more than that level in skeleton. These suggest rapid clearance of Th 228 from lung and translocation to bone. Lead 212 in lung is difficult to predict, since one precursor is a gas, Th 228 (T_{1/2} = . min). Since Th is lost through expiration, the value for Pb 212 in lung should be less than that for Th 228, the immediate parent. This is the case in lung but not in skeleton, where Pb 212 exceeds Th 228 by a factor of 3. It is reasonable to expect greater retention of Th in skeleton because of the lower diffusion coefficient in compact bone. The value for Pb 212 is higher than the supporting precursor, Th 228, a finding for which we have no satisfactory explanation. (Auth) (VC)

(12)

Wanley, T.B., C.L. Osterberg, and T.H. Jones, Oregon State University, Department of Oceanography, Corvallis, OR; Battelle-Pacific Northwest Laboratories, Richland, WA. 1969.

Natural and Artificial Radionuclides in Seafoods and Marine Protein Concentrates. Waters, 221, 1207-1209.

The concentrations of various radionuclides were measured in samples of commercially packed seafoods and fish protein concentrates. Values are reported for Ra 226, Th 228, Co 60, Hg 50, Cs 137, Po 55, Po 210, Pb 210, Zn 65 and K 40. Concentrations of Pb 210 and Po 210 (average value of 0.85 d.p.m./g dry weight) in seafoods are significantly higher than those in beef muscle or vegetable products. Although the levels of the radionuclides are far below those which would constitute a radiological hazard, continued use of such products could result in the Pb 210-Po 210 pair becoming the principal source of the skeletal radiation dose. (BAP)

(13)

Beloborodova, N.L., 1970.

Changes in the Peripheral Blood Following Chronic and Acute Poisoning with U308. The Toxicology of Radioactive Substances: Thorium 232 and Uranium 238, Vol. 4, A.A. Letavet and E.B. Kariyandskaya (Eds.), Pergamon Press, New York, New York, (pp. 101-108), 198 pp.

After oral administration of U308 (100 mg/kg 5-6 times a week for 2-4 months) the condition of the dogs remained good. Blood changes were insignificant and essentially expressed in some increase in the absolute number of lymphocytes and monocytes. repeated intratracheal administration of U308 in doses not causing symptoms of intoxication (to a total of 10-20 mg per kg animal weight) produced more or less marked absolute lymphopenia and periodic monocytosis and eosinophilia. In the majority of animals we observed moderate neutrophilic leucocytosis. Disturbance in leucopoiesis was indicated by the cytological changes in leucocytes; an increase in the fragmentation of the neutrophils and vacuolization of the nuclei of the lymphocytes and monocytes. With acute poisoning of the dogs with U308 via the trachea they developed leucocytosis but the shift to the right and the increase in fragmentation of the nucleus of the neutrophils suggests disturbance in leucopoiesis. This was accompanied by absolute and relative lymphopenia, eosinopenia and monocytosis. Considerable cytological changes were observed (segmentation of the monocytes, vacuolization

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BIOLOGICAL ASPECTS ANIMALS

<13> CONT.

of the nuclei of the lymphocytes and monocytes, mitotic focus or division of monocytes) indicating disturbances in formation of lymphocytes and monocytes. In the acute period of intoxication there was a fall in polychromasia with disappearance of the reticulocytes indicating depressed erythropoiesis. The signs of disturbance in leucopoiesis after single acute poisoning with ⁹⁰Sr disappeared comparatively rapidly. Erythropoiesis apparently was disturbed to a considerable extent, which may subsequently lead to development of anemia. (Auth)

<14>

Remmett, P.C., Health and Safety Laboratory, New York, NY. 1970, December.

Estimation of Gonadal Absorbed Dose Due to Environmental Gamma Radiation. Health Physics, 19(6), 757-767.

Analytical transport theory was used to investigate the procedures for converting free-air exposure measurements to absorbed doses in the reproductive organs of populations exposed to various natural and fallout environmental radiation fields. Calculated air-over-ground environmental gamma-ray spectra for uniformly distributed ²³⁸U, ²³²Th, and ⁴⁰K, and ¹³⁷Cs plane and exponentially distributed sources in the soil are the inputs for the gamma-ray transport calculations in tissue slabs. Corrections are made to account for the finite width and surface curvature of the body. Anatomical drawings of actual body cross sections, showing the ascent of overlying tissue and bone, are then used with these results to obtain gonadal absorbed dose estimates for uniform exposure around the body. Though the results indicate that a single screening factor is valid for various environmental fields, more satisfactory gonadal dose estimates would be obtained if the 0.6 screening factor recommended in 1962 by the United Nations Scientific Committee on the Effects of Atomic Radiation were revised to 0.8. Independent experimental measurements with a realistic man phantom support these conclusions. (Auth)

<15>

Pensted, J.P.B., Institute of Cancer Research, Department of Biophysics, Sutton, Surrey, England. 1967, December.

Experimental Studies in Mice on the Late Effects of Radioactive and Nonradioactive Contrast Media. Annals of the New York Academy of Sciences, 145(3), 728-737; CONF-660422: Distribution, Retention, and Late Effects of Thorium Dioxide, R.L. Swann (Ed.), Proceedings of a Conference held in New York, New York, April 20-22, 1966, (pp. 728-737), 336 pp. (CONF-660422).

Further experimental studies in mice with Thorotrast and Zircotrast have been undertaken and contrary to our previous experience, numerous vascular tumors of the spleen, but not of the liver, have been observed in the Thorotrast but not in the Zircotrast group. These tumors tended to occur very late and as survival was poor with Zircotrast, few of these tumors could be expected in this group. Experiments with ionium-enriched Thorotrast are still in progress. All that can be said at this stage is that at high dose levels there are numerous deaths from anemia. An interesting feature is the apparently high incidence of

spontaneous leukemia at the lower dose levels. Some of the nonradioactive properties of Thorotrast which may be related to its carcinogenicity are discussed. (Auth)

<16>

Burdjia, C.C. (Ed.), Armed Forces Institute of Pathology, Washington, DC. 1971.

Pathology of Irradiation. Williams and Wilkins Company, Baltimore, Maryland: 710 pp.

The book presents the current knowledge of the effects of radiation on man and animals and reviews the latest literature available on the subject. Attempts have been made to correlate the structural and often the ultrastructural features of tissue reaction to irradiation with the clinical biophysiological, genetic and functional aspects as they are manifested during and after irradiation. The problems of extrapolating animal data to man are discussed. Two chapters, one dealing with bone-seeking radionuclides, such as ²³⁹Pu, ²²⁶Ra, ²²⁸Ra, ²²⁸Th and ⁹⁰Sr, and the other with toxicity aspects of internally deposited ²³⁹Pu have been abstracted separately for the data base. Other chapters include the effects of irradiation in mammalian cells in vitro, clinical uses of radioisotopes, radiation carcinogenesis, the effects of radiation on skin, the nervous system, salivary glands, gastrointestinal tract, liver, cardiovascular system, endocrine glands, hematopoietic system, lymphatic system, thymus, pulmonary system, genitourinary tract, kidneys and organs of special senses. The effects of acute irradiation in man are described as well as treatment for the restoration of the hematopoietic system, such as by transfusions of compatible autologous or isogenic bone marrow. (PWS)

<17>

Berke, R.L., and P.J. Palazzolo, Wayne State University, School of Medicine, Department of Occupational and Environmental Health, Detroit, MI. 1974, April.

The Blastogenic Effect of Transyl Nitrate on the Peripheral Lymphocyte of the Rat. American Industrial Hygiene Association Journal, 35(4), 207-217.

A micro method has been developed for the separation and concentration of peripheral blood lymphocytes of the rat for the purpose of observing morphological changes at frequent intervals following exposure to various noxious agents without adverse effect on the small animal. The ratio of large to small cells based on the control median diameter was used as an index of size distribution changes. When this criterion of response was applied to the uranium-poisoned animal it proved to be a very sensitive test of the exposure. The median cell size increased almost immediately after intraperitoneal injection even at the lowest level (0.1 mg/kg of body weight), reaching peak values in about a week. This response correlated well with the dose except at the highest level (3.0 mg/kg). The toxicant induced a blastogenic effect which may be specific in terms of the cell membrane-blastogen interaction. Uranium is a more efficient blastogenic agent *in vivo* at least by a few orders of magnitude than is mercury. The index may also be applicable to many other toxic agents as a diagnostic test of intoxication, injury, or exposure. (Auth)

BIOLOGICAL EFFECTS
RADIATION

<18>

Berliner, D.L., P.L. Berliner, and T.F. Dougherty, University of Utah, College of Medicine, Division of Radiobiology, Department of Anatomy, Salt Lake City, UT. 1962.

The Effects of Chronic Irradiation by Internally Deposited Radionuclides on Corticosteroid Biosynthesis. Some Aspects of Internal Irradiation, T.F. Dougherty, et al (Eds.), Proceedings of a Symposium held at The Forestead, Uster, Utah, May 8-11, 1961. Pergamon Press, Oxford, England, (pp. 179-186), 529 pp.

The influences of various internal emitters (Sr 90, Th 229, Pa 226, and Pu 239) on the biosynthetic capabilities of the adrenal glands of dogs which were sacrificed from 14 hr to 6 years after injection were studied. The effect on adrenal steroidogenesis was a decrease in 11, 17, and 21 hydroxylations. The most marked effect was the reduction of 17 hydroxylation. The addition of coenzyme, glucose 6 phosphate and TPPH, corrected the inhibitory effect on 17 hydroxylation. Chronically irradiated dogs stimulated with Sr 90 24 hr prior to sacrifice responded with increased corticosterone synthesis. The site of 17 hydroxylation in the adrenal is the reticuloendothelial cells. (57)

<19>

Berliner, D.L., W. Stevens, C.J. Nabors, Jr., and P.W. Maxwell, University of Utah, Division of Radiobiology, Department of Anatomy, Salt Lake City, UT; University of Utah, Computer Center, Salt Lake City, UT. 1969.

Biochemical Changes Induced by Internally Deposited Radionuclides in Beagle Dog Blood. A Statistical Study. COG-119-240; Research in Radiobiology, Annual Report of Work in Progress in the Internal Irradiation Program, T.F. Dougherty (Ed.), (pp. 243-261) (COG-119-240); COG-677938; Delayed Effects of Bone-Seeking Radionuclides, C.W. Mays, et al (Eds.), Proceedings of a Symposium held in Sun Valley, Idaho, September 12-18, 1967; University of Utah Press, Salt Lake City, Utah, (pp. 671-698), 519 pp. (COG-677939).

Biochemical studies on the effects of internally deposited radionuclides in beagle dogs have been pursued for the past 13 years. The radionuclides used in this study were Pu 239, Pa 226, Th 228, and Sr 90. Certain biochemical parameters were subjected to multivariate regression analysis. These were serum glutamic pyruvic transaminase, serum alkaline phosphatase, total serum protein, serum albumin and serum globulins. Changes with age in control animals were evaluated statistically. Control animals showed increases in blood levels of alkaline phosphatase, total serum proteins, and total serum globulins with increasing age. Changes in the biochemical parameters studied are related to the individual radionuclide with respect to the site of its deposition, the dosage, and the elapsed time after injection. (Auth)

<20>

Blair, W.A., University of Rochester, School of Medicine and Dentistry, Department of Radiation Biology and Biophysics, Rochester, NY. 1968.

Radiation Dose-Time Relations for Induction of Bone Tumors in the Dog and This Tumor in the Rat. Radiat. Environ. Health, 30, 501-522.

There are two mutually exclusive routes of tumor induction by radiation both in rat skin

from brief doses of external beta radiation and in dog bone from Pa 226, Pa 226, or Th 228 injected at age 530 days. In the one process oncogenesis occurs directly on attainment of high radiation dose. In the other process oncogenesis follows a long latent period which is initiated by lower dose. Subsequent development time is the same in both cases. With protracted dosage the latent period is initiated at relatively low dose, but if exposure is continued the high-dose process will supersede the low if the high-dose threshold is exceeded during the latent period. Otherwise the low-dose process will govern. For those radionuclides in the dog yielding relatively constant dose rates the data are represented by equations relating survival time, initiating high dose, development time and dose rate to the skeleton. The relative values of the initiating high dose provide a scale of toxicities. (Auth) (577)

<21>

Bochar, I.A., I.P. Veirns-Parkus, and P.V. Pestov, Institute of Biology, Academy of Sciences, Komi Branch, 1972.

External Beta-Irradiation of Mouselike Rodents in Soil with an Increased Content of Nuclides of the Uranium and Thorium Radioactive Families. Zoologiya, 6, 75-78; Soviet Journal of Zoology, 10(1), 565-567.

External beta- and gamma-irradiation of mouselike rodents in burrows in areas with an elevated content radionuclides of the uranium and thorium series in the soil is well described by an exponential law, which permits the use of the usual formulas for energy flux in calculations of the doses. An experimental determination of the contribution of the beta-radiation was performed with the aid of thermoluminescence dosimeters, and it was shown that this contribution is negligible in the investigated region. In the case of local concentrations of radionuclides of the Th and U series in the soil, the burden from external beta-radiation on voles living in burrows may prove greater than that from gamma-radiation. (Auth) (7C)

<22>

Boecker, B.H., University of Rochester, Atomic Energy Project, Division of Radiation Chemistry and Toxicology, Rochester, NY. 1972, July 29.

Thorium Inhalation Studies. 79-605; 263 pp.

The distribution and excretion of thorium following inhalation of thorium chloride was investigated with emphasis on the effect of the size of the initial lung thorium burden. Experimental procedures included whole-body counting, excretion collection and serial sacrifice over periods of 1 to 90 days post-exposure. Soon after exposure, a fraction of the thorium in the lungs was absorbed into the body and the largest portion of this absorbed fraction was deposited in the skeleton. Following the initial uptake, the organ thorium burdens remained approximately constant or decreased with time after exposure. The remaining lung burden decreased with time after exposure accompanied by excretion of thorium predominantly in the feces. The fraction of the thorium lung burden that was absorbed and the fractions excreted in the urine and feces did not appear to be affected by a variation in the size of the initial lung burden by a factor of 1.1 X 10² (P=5). Median values for

<22>

BIOLOGICAL ASPECTS
ANIMALS

<22> CONT.

the skeletal thorium burden varied from 4 to 25 per cent of the initial lung burden with 70 per cent of the values being less than 20 per cent. Rats exposed 1 to 5 times to thorium chloride aerosols also had skeletal thorium body burdens proportional to the total exposure. A comparison exposure was made with a thorium citrate complex aerosol and the above results were also compared with published results for the inhalation of plutonium citrate aerosols. (Aeth)

<23>

Boecker, B.Z., University of Rochester, School of Medicine and Dentistry, Department of Radiation Biology, Rochester, NY. 1961, March-April.

Thorium Distribution and Excretion Studies. 3. Single Inhalation Exposure to the Citrate Complex and Multiple Inhalation Exposures to the Chloride. Industrial Hygiene Association Journal, 24, 155-163.

Rats were given single or multiple exposures to Th citrate or Th chloride (ThCl) respectively. Lower respiratory tract depositions within 1 hr of ThCl exposure was 90-98% of the body burden. Values for Th citrate were 31-72%. Some lung burden after ThCl was 1.6×10^{-7} g/kg body wt and 1.6×10^{-7} (B-7) for Th citrate. There was an initial drop in lung burden and a more gradual decline over the next 32 days; this decline was a single exponential function. Th burden data for muscle and connective tissue, skeleton, and liver were also fitted with straight lines by the least squares method. More Th was accumulated from the citrate inhalation. Fecal and urinary excretion dropped sharply and then leveled off to 1.0-1.8% of the body burden for the next 32 days. The rate of the fecal citrate excretion was only 50-65% of that for the chloride in the last 10 days. Urinary data were similar for both groups, excretion from day 10 to 32 being 0.1-0.3% of the body burden. Multiple exposures to ThCl showed similar retention kinetics in groups exposed 1-5 times. Similar values for 1 of total body burden 21 to 40 days after first of 5 tidally exposures to ThCl for lungs, skeleton, muscle, liver, pelt, and kidneys were determined. Forty-day values were lower because of clearance. Since similar fractions of the lung burden were absorbed regardless of the number of exposure times, it would seem that single exposure data are valid for calculations related to multiple exposures. The data indicated that the MFC(sub a) should be 1×10^{-11} uc/cu cm for natural Th and Th 232 compounds. (VC)

<24>

Boecker, B.Z., B.G. Thomas, and J.R. Scott, University of Rochester School of Medicine and Dentistry, Department of Radiation Biology, Rochester, NY. 1963.

Thorium Distribution and Excretion Studies. 2. General Patterns Following Inhalation and the Effect of the Size of the Inhaled Dose. Health Physics, 9, 165-176.

A series of single, short-term inhalation exposures of rats to thorium chloride aerosols was conducted to study thorium distribution and excretion patterns and the effect of the size of the initial lung thorium burden on these patterns. Soon after exposure, a fraction of the thorium in the lungs was absorbed into the body and the

largest portion of this absorbed fraction was deposited in the skeleton. Following this initial uptake, the organ thorium burdens remained approximately constant while the lung burden decreased with time after exposure accompanied by excretion of thorium predominantly in the feces. The fraction of the lung thorium burden that was absorbed and the fractions excreted in the urine and feces did not appear to be affected by a variation in the size of the initial lung burden by a factor of 1.1×10^{-5} . Calculations of the Maximum Permissible Concentration (MPC) values based on these data yielded a value of 1×10^{-11} uc/cm³ for both soluble and insoluble natural thorium and soluble Th 232 compounds. The corresponding value for insoluble Th 232 compounds was found to be 2.5×10^{-11} uc/cm³. (Aeth)

<25>

Boone, I.S., J.S. Rogers, R.C. White, and P.S. Harris, Los Alamos Scientific Laboratory, Los Alamos, NM; U.S. Army, Los Alamos, NM. 1958.

Toxicity, Excretion and Tissue Distribution of Iodine (Thorium 230; in rats. American Industrial Hygiene Association Journal, 19, 285-295.

Excretion, distribution, and acute toxicity of Th 230 were studied following IV doses of 19.3-130 uCi/kg. Median survival times at extreme doses were 120 and 8 days, respectively. The 30-day median lethal dose was 42.7 uCi/kg. Urine, the first day after the highest 3 doses, contained 10-27% of the injected dose, most during the first 8 hrs. Feces, at day 1, contained 0.3-0.6% of the dose. Urinary values were below 0.005 by day 5; fecal-urinary ratios were 5-15, varying with dose. After day 10, comparable values were below 0.01% and 1. At lower doses, to 38.6 uCi/kg, 6-10% was in urine on day 1, 0.004 on day 3 when the ratio was 30-65; at 30 days, these values were 0.007% and 5. Seventy eight percent of the dose was found retained at death. At high doses, this was equally divided between bone and soft tissues, particularly liver. At lower doses, only 1/3 was skeletal. Histopathology showed cellular loss and atrophy in kidney, bone marrow, and lymphoid system. Degenerative kidney lesions were particularly drastic at 130 uCi/kg; there was some epithelial regeneration by 8 days. At this dose, bone marrow was devoid of usual cells. Hyperplasia was evident at 5 wks and marrow was normal after several months. The spleen, at higher doses, was depleted of lymphocytes and much cellular debris was evident. Collapsed sinuses in the red pulp were devoid of erythrocytes. Hemosiderin was commonly seen. Results were similar at 19.3 uCi, except for progressive increase in follicular lymphocytes. Radioautography localized label (Th) in spleen, liver, kidney, bone and bone marrow. It is suggested that maximum permissible dose levels be the same as for Pu. (VC)

<26>

Bruenger, F.W., D.H. Atherton, V. Stevens, and R.J. Stover, University of Utah, College of Medicine, Division of Radiobiology, Department of Anatomy, Salt Lake City, UT. 1971.

Interaction Between Blood Constituents and some Actinides. COO-119-224; Annual Report of Work in Progress in the Internal Irradiation Program, (pp. 212-227) (COO-119-220).

The interaction of a number of actinide

BIOLOGICAL ASPECTS ANIMALS

<26> CONT.

elements with constituents of canine and human blood was studied and compared to extensive, already existing data on Pu 239 (IV) and Am 241 (III) in boneless. Th 230, Pa 233, U 233, U 237 and Cf 249 were used in these experiments. Each of these neclides in 0.005 M citrate buffer was incubated in VITRO with canine and/or human blood. Some of the neclides had a marked affinity for blood cells. High and low molecular weight components of plasma were separated by gel chromatography on Sephadex G-25 and amounts of neclide associated with each fraction were evaluated. Binding to plasma proteins was further evaluated by gel chromatography on columns of ion cross linkage and by anion exchange chromatography. Neclides forming strong complexes with inorganic constituents of plasma showed only limited binding to protein constituents. The pH-ranges of protein complex stabilities were determined in some cases by difference spectrophotometry. (Auth)

Table 1 gives association of neclides with blood cells. Table 2 gives G-25 Sephadex separation. Table 3 gives gel chromatography of tagged human plasma on Sephadex G-100-G-200. Table 4 gives ion exchange chromatography of tagged human plasma on DEAE Sephadex.

<27>

Casper, F., F.A. Hellstrom, and L. Lundberg, Karolinska Institute, Department of Environmental Hygiene, Stockholm, Sweden; National Environment Protection Board, Stockholm, Sweden. 1973, November.

Coating Five Micron Particles with Carbon and Metals for Lung Clearance Studies. Archives of Environmental Health, 27(5), 331-333.

By an evaporation in vacuum technique, 5μ Teflon particles (density, 2 g/cc) were coated with aluminum, beryllium, carbon, chromium, lead, manganese, silver, and uranium. After retention for one week in 0.9 percent sodium chloride solution at 37°C, most of the particles were coated more than 50 percent with all elements. The coatings remained after one month, except for lead and uranium. Aerosols of the coated particles were produced, and about 90 percent of the particles occurred in single form. The thickness of the coats was calculated to be a few hundredths of one micron and the increase in aerodynamic diameter a few tenths of one micron. As the particles coated with different elements are similar in size and in aerodynamic diameter, they should be useful in the study of the elimination mechanisms for inhaled particles. Phagocytosis in vitro by alveolar macrophages during 1.5 hours of exposure to particles coated with lead, silver, and carbon was studied. The carbon-coated particles were phagocytized at a significantly higher rate than silver- and lead-coated particles. (Auth)

<28>

Catsh, A., Nuclear Research Center, Institute of Radiobiology, Karlsruhe, German Federal Republic. 1967.

Radioactive Metal Mobilization. Federation Proceedings, 26, 206-219.

The mechanism of action and effectiveness of various chelating agents is described. Bismacroglycerol (BAG) was ineffective against radionuclides of practical interest, with the exception of Pu 239. Radiocyttrium

and Pu respond fairly well to EDTA but there is marked dependence on the time of administration. The significance of relative chelate stability is pointed out as in the case of 1,2-diaminocyclohexanetetraacetic acid (CDTA) which has substantially higher stability constants than EDTA for most metal ions, but only slightly different relative stabilities. Its biological effectiveness is then comparable to EDTA and not superior in tests done with Pu, radiocyttrium and radiocyttrium. Results from experiments with rats show the considerable differences in effectiveness between EDTA and DTPA, the latter being more effective in retention studies with Y 91, Co 106, Th 230, Pa 239, Pu, Cr, Co, Zn, Ba and U. The higher homologues of EDTA, tetraacetate triethylenetetraaminoethanoic acid (TTTA), when administered early, inhibits deposition of radiocyttrium, and radiocyttrium in the skeleton much more than DTPA. In experiments on the influence of chelating agents in the acute toxicity of strychnine it was seen that when a single dose of the chelating agent was administered early, the LD 50 of S was increased from 6.7 mg/kg to 12.4 mg/kg by EDTA and to 16.2 mg/kg by DTPA. However, the toxicity of TTTA was 100% lethal to 3 injected animals within one hour of administration. In the case of radiocyttrium, DTPA proved to be just as ineffective as EDTA. The greatest reduction in radiocyttrium deposition in the skeleton has been obtained with Diamand Fast Blue, but since this dyestuff is effective doses has proved strongly toxic and sometimes lethal, it has no practical importance. The role of the kidneys in the effectiveness of chelating agents is discussed and experiments with nephrectomized animals are described. DTPA causes a marked increase of radiocyttrium excretion in the fetus also, especially in the case of those, which like radiocyttrium, are deposited to a large extent in the liver. The differences in the extent to which the radionuclide in the liver and skeleton can be depleted by DTPA were shown for Pu: daily administration of DTPA over 2 weeks reduced the Pu content of the liver to 35% of the control, while that of the skeleton fell to 50%. It is suggested that the effectiveness of DTPA is due to its penetration into the intracellular space, particularly in the liver, and it is expected that if this process were intensified, there would be a corresponding increase in effectiveness. The question of DTPA toxicity is discussed briefly. (FHM)

Table 1 shows effect of CaNa2-DTPA and CaNa2-EDTA on retention of different radioactive metals (Y 91, Co 106, Th 230, Pa 239, Am 241) in rats. Table 2 shows effect of sodium polyphosphate on retention of Y 91, Co 106 and Pu 239 in rats.

<29>

Catsh, A., Nuclear Research Center, Institute of Radiobiology, Karlsruhe, German Federal Republic. 1967.

Principles and Trends in Therapeutic Removal of Internally Deposited Radionuclides. Health Physics, 8, 723-730.

The general principles governing the therapeutic removal of radionuclides by chelating agents are outlined. Experimental data are presented demonstrating the dependence of chelate effectiveness on the number and the nature of ligand atoms as well as on the molecular configuration of the ligand. Implications derived from

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TOXICOLOGICAL ASPECTS OF PLUTONIUM

<29> CONT.

Experimental data and from the multicompartmental nature of a body organ for working out an optimal dosage schedule are discussed. Several experimental results are discussed, for example, those dealing with the effectiveness of chelating agents (EDTA, DTPA, TTHA and TPBA) on retention of ^{239}Pu , ^{240}Pu and ^{241}Pu in rats when treatment is early or delayed. The effectiveness of multiple chelate doses is also discussed and experiments cited, among them studies on the removal of monomeric ^{239}Pu by multiple DTPA doses (^{239}Pu 500 $\mu\text{g/kg}$) from liver and skeleton of the mouse. The effect of esterified polyaminocarboxylic acids is also briefly discussed. (Auth) (PRA)

Figure 6 shows removal of monomeric ^{239}Pu by multiple DTPA doses (500 $\mu\text{g/kg}$) from organs of the mouse. Figure 7 shows effect of EDTA, DTPA, TTHA, and TPBA on the retention of ^{239}Pu in rats (15 μCi , ^{239}Pu 100 and ^{240}Pu 200) by organs of the rat. The calcium chelates (250 $\mu\text{g/kg}$) were administered a few minutes post-injection (early treatment) or on the third day (delayed treatment.)

<30>

Catani, A., Nuclear Research Center, Institute of Radiobiology, Karlsruhe, German Federal Republic. 1963.

Toxicology: Radioactive Metals. Annual Review of Pharmacology, 3, 243-266.

A review is given of the toxicity of internally deposited radioactive metals. The behavior of a given radionuclide in the organism can ultimately be explained by certain chemical, particularly coordination-chemical and ion exchange processes. An exact mathematical formulation of retention and excretion of a radionuclide is of great practical importance in so far as it is a requisite for the calculation of MPC values. The temporal distribution of the radiation dose seems to have different importance for radionuclides with different LET. A quantitative analysis of radiotoxicity requires a determination of the radiation doses which accumulate in the organ after administration of a given amount of radionuclides. In this, knowledge of the retention fractions as well as the microscopic distribution in the organ is needed. Possibilities of therapeutic treatment are mentioned, the most promising being the use of chelates. Sections are devoted to individual radionuclides including the transuranic elements, the rare earths and yttrium, thorium, polonium, the alkaline earths, and miscellaneous metals (Ir 192, Ca 137, In 114, In 65, Ba 133, Zr 90, Co 60). For the transuranics, the metabolic behavior of ^{241}Am in rats is compared with ^{239}Pu . There is faster removal of ^{241}Am from the liver and reduced initial deposition in the skeleton. Several experimental results are cited. About 20% of an inhaled $^{239}\text{PuO}_2$ aerosol with a mean particle size of 0.2 μ was retained by lung of mice. Using experimental data the MPC for man is computed as 1.6×10^{-10} $\mu\text{Ci/ml}$ air compared to the value of 1×10^{-11} $\mu\text{Ci/ml}$ recommended by the ICRP. Concerning the dependence of ^{239}Pu toxicity upon the dose rate, it is reported that single doses are significantly more effective than fractionated ones in the induction of hematological reactions, and the reduction of the life-span in rats. The therapeutic effectiveness of EDTA and DTPA in man following contamination by ^{239}Pu is reported. (PRA)

<31>

Chipperfield, A.P., and D.W. Taylor, Institute of Cancer Research, Department of Biophysics, Belmont, Sutton, Surrey, England. 1979.

Binding of Plutonium to Glycoproteins in Vitro. Radiation Research, 53, 393-402.

The binding of plutonium by a sialoprotein isolated from bovine cortical bone and by transferrin has been compared using a gel filtration procedure. The pH at which maximum binding of plutonium to bone sialoprotein was observed, pH 6, was different from that for transferrin, pH 7, and the magnitude of the binding was greater for bone sialoprotein. The effects of added iron and bicarbonate ions, and of removal of sialic acid on the binding of plutonium to these two glycoproteins, were also dissimilar. These results show that plutonium binds to the carboxyl groups of bone sialoprotein, and this may be responsible for the high stability of the plutonium-bone sialoprotein complex. For the plutonium-transferrin complex, the results obtained suggest that the plutonium is bound at the iron binding sites, tyrosyl groups, and probably at other sites in the transferrin molecule. (Auth)

Table 1 gives effects of ferric and bicarbonate ions on the binding of ^{239}Pu and ^{240}Pu to glycoproteins. Table 2 gives effects of removal of sialic acid on the binding of ^{239}Pu to glycoproteins.

<32>

Chipperfield, A.P., and D.W. Taylor, Institute of Cancer Research, Department of Biophysics, Sutton, Surrey, England. 1972.

The Binding of Thorium (IV), Plutonium (IV), Americium (III) and Curium (III) to the Constituents of Bovine Cortical Bone in Vitro. Radiation Research, 31, 15-30.

By means of a gel filtration technique it has been shown that thorium (IV), plutonium (IV), americium (III) and curium (III) bind to five glycoprotein fractions isolated from bovine cortical bone and to certain other substances. The effects of pH on the binding of plutonium to poly-L-glutamic acid and to bone chondroitin sulfate and of curium to bone sialoprotein and chondroitin sulfate-protein complex are described. Plutonium, americium, and curium were found to bind to bone glycoproteins in the presence of a 30-fold greater mass of bone mineral than glycoproteins. Some experiments on the precipitation of calcium phosphate in vitro in the presence of plutonium and americium are also presented. These observations are discussed in the light of the hypothesis that certain actinide elements are localized at bone surfaces by binding to glycoproteins. (Auth)

Table 1 gives binding of actinides to isolated proteins from bovine cortical bone. Table 2 gives binding of actinides to proteins. Table 3 gives inhibition of ^{239}Pu , ^{240}Pu and ^{241}Pu deposition into bone mineral. Table 4 gives effect of citrate on the filterability of ^{239}Pu and ^{241}Pu in serum.

<33>

Christensen, W.R., C.C. Smith, C.R. Rehfeld, and D.W. Taylor, University of Utah, College of Medicine, Department of Radiology, Salt Lake

BIOLOGICAL ASPECTS
OF RADIATION

(33) CONT.
City, UT. 1962.

Pathographic Changes in Internally Irradiated Dogs. Some Aspects of Internal Irradiation. T.F. Dougherty, et al (Eds.), Proceedings of a Symposium held at The Homestead, Haver, Utah, May 9-11, 1961. Pergamon Press, Oxford, England, (pp. 63-77), 523 pp.

Diagnostic criteria established as evidence of radionuclide injury to skeletal structures of dogs receiving intravenous injections of radium (0.34 to 10 $\mu\text{Ci/kg}$), thorium (0.096 to 0.90 $\mu\text{Ci/kg}$), and plutonium (0.096 to 2.0 $\mu\text{Ci/kg}$) were: structural changes in the mandible, destructive changes in the teeth, pathological fractures--with and without healing, distortion of cortex of long bones, disturbance of metaphyseal trabeculation, osteolytic rarefaction, rib end demarcation, aseptic necrosis, and tumor formation. Alterations in the mandible were the earliest detectable and most consistently visualized evidences of injury. Earliest changes occurred in animals receiving the highest doses. There was no specificity or consistency in the skeletal changes produced and it was impossible to identify a specific nuclide on the basis of radiological evidence. Th 228 and Pu 239 appeared to produce pathological changes somewhat more rapidly than Pu 239 and Pu 226. Osteolytic resorption and irregular bone overgrowth appeared to follow vascular injury. Tumor incidence at high levels of toxicity was low because of early death from general radiation injury. Experimental results are still accumulating. (37)

(34)
Cochran, T.H., University of Utah, College of Medicine, Radiobiology Laboratory, Salt Lake City, UT. 1957, March 31.

Histopathological Findings. AECT-3522; Annual Progress Report, (pp. 73-85), 177 pp. (AECT-3522).

The soft tissue histopathology of 51 toxicity beagle dogs are described. The acute toxicity changes are most evident in the kidney, liver, and intestine in plutonium injected animals. The long term plutonium animals show regenerative nodules of the liver. Partial destruction or atrophy of lymphoid tissue is seen as early as 20 hours after injection of plutonium and this moderate atrophy persists to a relative degree throughout the duration of the studies. Reticuloendothelial response, namely extramedullary hematopoiesis and hemosiderin deposition, is most evident in long term 5 level plutonium and 8 level thorium animals. (Auth) (LCW)

Table 1 gives the relative sites of blood formation in toxicity dogs with the categories in the table being time post injection in days, vertebral marrow, femoral marrow, hematopoiesis spleen, hematopoiesis liver and hemosiderin spleen.

(35)
Cochran, T.H., W.S.S. Jee, and J.S. Arnold, University of Utah, Department of Pathology, Salt Lake City, UT; University of Utah, Department of Anatomy, Salt Lake City, UT; Veterans Administration Hospital, Salt Lake City, UT; U.S. Naval Radiological Defense Laboratory, San Francisco, CA. 1959, March 31.
Radiation Induced Osteogenic Sarcoma in Dogs.

CCO-218; Annual Progress Report, C.W. Stover, Jr. (Ed.), (pp. 219-224), 229 pp. (CCO-218).

Osteogenic sarcomas are produced in beagle dogs following a single intravenous injection of several bone-seeking radionuclides, Pu 239, Pu 226, Th 228, and Sr 90. Some of the isotopes show a uniform distribution in bone. Pu 226 and Sr 90 are primarily deposited in areas of bone formation at the time of the injection with some diffuse distribution. Pu 239, Th 228, and Pu 226 localize on endosteal bone surface with subsequent concentration in osteoclasts and reticuloendothelial cells. The retained dose level of each isotope determines what pattern of changes will be present. 0.27 $\mu\text{Ci/kg}$ of Th 228 is comparable to 2.5 $\mu\text{Ci/kg}$ of Pu 239. These changes can be categorized as response to alpha emitters by endosteal and bone marrow cells, disturbances in normal bone growth, and disturbances in normal bone removal or reconstruction. Survey of at least one-half of the whole skeleton of each dog sacrificed reveals occult osteogenic sarcoma, frequently multiple, and atypical cellular lesions. Osteogenic sarcoma have occurred with all isotopes. (38)

(36)
Colman, S., and B. Alexander, Beth Israel Hospital, Vascular Research Laboratory, Boston, MA; Harvard Medical School, Department of Medicine, Boston, MA. 1960.

The Effect of Lanthanides and Actinides on Blood Coagulation. I. Evidence for and Properties of a New Serum Thromboplastin Factor. Journal of Clinical Investigation, 39(4), 705-719.

Thorotrast in vivo promptly induces retarded coagulation and in vitro a profound inability of both plasma and serum by thorium chloride and the related elements, neodymium, lanthanum, cerium, and uranium. The plasma defect consists of progressive inactivation of Factor V. The serum defect involves an entity distinct from any hitherto known clotting factor or intermediate. It is absorbable by BaSO₄, elutable by citrate, and it is demonstrable in the protein fraction precipitated at 50 to 60% (NH₄)₂SO₄. The vulnerable factor in serum (TVF) is relatively labile, has been separated from the other coagulation factors by physicochemical means, and can be markedly activated by trypsin. Replacing inosithin by normal platelets in the thromboplastin generation mixture corrects the thorium-induced defect, but EDTA is ineffective. It is suggested that the lanthanides and actinides produce a defect in serum by forming a reversible complex with a serum protein, which is a hitherto unrecognized clotting factor necessary for thromboplastin generation. The mechanism by which the biologic function of this protein is comprised by this group of elements, structurally similar atomically, appears to be reversible chelation at specific sites on the protein essential for its clotting activity. (Auth)

(37)
Copp, D.W., D.J. Amelrod, and J.G. Hamilton, University of California Medical School, Berkeley, CA; University of California, Radiation Laboratory, Berkeley, CA. 1967.

The Deposition of Radioactive Metal in Bone as a Potential Health Hazard. American Journal of Roentgenology, Radiology Therapy and Nuclear Medicine, 50, 10-16.

<37>

BIOLOGICAL ASPECTS
BIOASSAYS

<37> CONT.

The metabolism of bone was investigated to determine factors concerned in the absorption and deposition of Sr, Y, Co, and Pu in the skeleton and the precise sites of localization. Chronic elimination was studied in rats, and the effects of standard treatment for chronic radium poisoning were compared. A possible mechanism for reducing the toxicity of plutonium deposits in the bone was investigated. Strontium was the only element in the group to be absorbed from the intestinal tract. Age of the animal and adequacy of calcium in the diet had a marked effect on absorption of Sr from the gut. Retention of Sr was greatly reduced in phosphorus deficient animals, but no significant effect was observed for Pu, Co, or Y. Strontium appeared to follow the path of calcium metabolism and was deposited only in the bone salt, Pu, Y, and Co were laid down in the uncalcified organic matrix of bone and appeared to be unrelated to calcium in behavior. Strontium appears to be eliminated more readily, with a biological half-life of only three to four months. Plutonium, Y, and Co were excreted very slowly and biological half-lives ranged from one to three years. Standard treatment for radium poisoning, such as low calcium diet, parathyroxene, ammonium citrate and chloride, had no effect on Pu, Y, or Co excretion and caused a small increase in Sr elimination. A method was tried to fix Pu deposits in bone by producing bone resorption and then changing to a optimum diet calculated to restore bones with new nonradioactive bone. This caused the dense deposit of Pu to be buried deep in the shaft. The method has not been tested by actual toxicity studies in animals. (BBT)

<38>

Taves, C.B., London School of Hygiene and Tropical Medicine, London, England. 1960, July 25.

Labelled Radioactive Particles and Gases. The Harford Biology Symposium held in Richmond, Washington, May 6-8, 1964, (4 pp.); Nature, 203(4943), 352-355.

The risks of labeled radioactive particles and gases from nuclear auxiliary power units, and nuclear-powered rocket engines were discussed at the third Harford Biology Symposium. Handling aerosols of sized fission products and generation of laboratory clouds of aerosol sprays were also discussed. The problems relating from exposure to various particle sizes were subjects in the symposium. Phases of lung clearance were identified and lung studies involving dogs, rats, rabbits and man were included. (HBT)

<39>

Cougherty, J.N., University of Utah, College of Medicine, Division of Radiobiology, Department of Pathology and Anatomy, Salt Lake City, UT. 1962.

Some Hematological Responses to Internal Irradiation in the Dog. Some Aspects of Internal Irradiation, T.F. Cougherty, et al (Eds.), Proceedings of a Symposium held at The Newcastle, Newer, Utah, May 8-11, 1961. Pergamon Press, Oxford, England, (pp. 79-93), 529 pp.

The chronic hematological changes in dogs receiving intermediate and high level doses of Pu 239 (0.30 to 2.0 uCi/kg), Ba 226 (1.1 to 10 uCi/kg), Ba 228 (1.1 to 10 uCi/kg), Th 228 (0.30 to 2.0 uCi/kg), and Sr 90 (11 to

100 uCi/kg) were summarized. Bone levels were chosen as that retained amounts of radioactivity were closely related. A comparison of initial effects and recovery rate of blood cells indicated that Th 228 was the most toxic radionuclide. In general, there was a dose response effect on blood cells and particularly on polymorphonuclear neutrophils where the greatest initial effect was found. There was a lymphopenia in all dogs receiving high dose levels. Although there was a decrease in red cells and a reduced red cell volume with all nuclides, the pattern of change and dose level where changes occurred differed among them. Dogs receiving high level doses of plutonium and strontium showed transient anemia during the first month with plutonium dogs again developing progressive anemia after two years as they became terminal. The effects of metabolism of the radionuclides and its location in bone and soft tissues were discussed. A dose level effect on bone marrow myeloid to erythroid cell ratio was demonstrated. (37)

<40>

Cougherty, J.N., University of Utah, College of Medicine, Division of Radiobiology, Department of Anatomy, Salt Lake City, UT. 1972, March 31.

Toxicity to Blood Cells of Americium 241 Compared to Other Transuranium Nuclides. COO-119-204; Research in Radiobiology, Annual Report of Work in Progress in the Internal Irradiation Program, T.F. Cougherty, (pp. 272-281), 300 pp. (COO-119-204).

A comparison of the effects of the bone surface seekers Pu 239, Ba 226 and Th 228 and the bone volume seeker Ba 226 on leukocytes of dogs has been made for the first year following injection using the technique of probit analysis. Hematological responses for total white blood cells, polymorphonuclear leukocytes, lymphocytes and monocytes were evaluated at six time periods from 30-360 days postinjection. The probit of the percentage depression of the various cells when plotted against the log of the injected activity yielded approximately straight lines from which ED 50's (50% depression of leukocytes) were calculated. Using Ba 226 as a standard nuclide, toxicity indices (Ba 226 uCi per kg/nuclide uCi per kg for 50% depression) were determined. From these data the hematological RBE's (Ba 226 rads per day/nuclide rads per day for 50% depression) were computed for the various leukocytes over the first year. The surface seekers, Pu 239, Ba 226 and Th 228 showed considerably greater toxicity than Ba 226. The pattern of depression and recovery of leukocytes is most similar for Ba 226 and Pu 239 as shown by the probit method. (Anth)

<41>

Cougherty, J.N., and L.S. Rosenblatt, 1969.

The Comparative Toxicity of Radium 226, Plutonium 239, Thorium 228, Radium 228 and Strontium 90 to the Hematopoietic System of Dogs for the First Year Following Injection. COO-119-200; Research in Radiobiology, Annual Report of Work in Progress in the Internal Irradiation Program, T.F. Cougherty, (pp. 220-242) (COO-119-200).

The comparative toxicity of several internal emitters on blood leukocytes was studied in dogs for the first year post-injection. One of the following radionuclides: Ba 226, Pu 239, Th 228, Ba 228 or Sr 90, was injected

BIOLOGICAL EFFECTS MINIMALS

<41> CONT.

iv at six different injection levels into beagles approximately 1.0 years of age. The probit technique was utilized to linearly relate response to the logarithm of injected $\mu\text{Ci/kg}$. The occurrence of a dose-dependent depression in leukocytes was previously established for these radionuclides. Probit analysis allows calculation of 50 per cent leukocyte depression (ED50) and toxicity indices as well as SEE values for each radionuclide compared to Ba 226 as a standard. Alpha irradiation, particularly when deposited on bone surfaces, caused greater leukocyte depression than beta irradiation. Blood neutrophils showed the greatest percent loss followed by monocytes and lymphocytes. (Auth)

<42>

Dougherty, J.B., and L.S. Rosenblatt, University of Utah, College of Medicine, Division of Radiobiology, Department of Anatomy, Salt Lake City, UT. 1971.

Long-Term Hematological Effects of Internal Emitters in Beagles. Radiation Research, 40, 329-331.

The hematological effects of five internal emitters namely, Ba 226, Pu 239, Ba 228, Th 232 and Sr 90 injected into adult beagles have been analyzed for 8 years postinjection. Five to seven dose levels were utilized per radionuclide ranging from near permissible levels to levels causing bone tumors. The main hematological alterations were depression of granular leukocytes and, to a lesser extent, erythrocytes. The depressions of leukocytes were dose dependent. Some recovery was noted at higher levels for polymorphonuclear leukocytes but not for lymphocytes. Transient depressions of blood cells were seen at lower dose levels. For any type of cell, minimal values were similar for all radionuclides and at comparable dose levels. Relative toxicities of the radionuclides to the hematopoietic system were related to deposition patterns and type of particle emission. (Auth)

<43>

Dougherty, J.B., and L.S. Rosenblatt, University of Utah, College of Medicine, Division of Radiobiology, Department of Anatomy and Pathology, Salt Lake City, UT. 1970.

The Cooperative Toxicity of Radium 226, Plutonium 239, Thorium 230, Radium 228, and Strontium 90 to Leukocytes of Beagles. Radiation Research, 43, 56-76.

The effectiveness of five internal emitters in depressing blood leukocytes in young adult beagle dogs was studied during the first year postinjection. The radionuclides, Ba 226, Pu 239, Th 230, Ba 228, and Sr 90, were given as a single intravenous injection, at 6-7 injection levels per radionuclide. The occurrence of dose-dependent depressions in leukocytes has been previously established. The greatest depression was found in polymorphonuclear leukocytes (pmns), monocytes, and eosinophils while lymphocytes were depressed to a lesser extent. The probit transfers was used to linearly relate response to logarithm of the injected activity. Injected activities required to produce a 50% leukocyte depression (ED 50) were computed for eight time periods. Toxicity indices were also computed for four radionuclides relative to Ba 226 as a standard and converted to hematological SEE,

again relative to Ba 226. For pmns and lymphocytes median values of SEE estimated over the eight time periods were: Th 230 approximately 4; Pu 239 approximately 4; Ba 228 approximately 1.5, and Sr 90 approximately 0.5. Alpha emitters deposition on bone surfaces were more effective in reducing leukocytes than those which are volume emitters. The beta emitter, Sr 90, was less effective than the alpha emitters rad for rad. (Auth)

<44>

Dougherty, J.B., and E. Seymour, University of Utah, College of Medicine, Radiobiology Laboratory, Salt Lake City, UT. 1957, March 31.

Hematology Report. AECU-3522: Annual Progress Report, (pp. 57-72), 177 pp. (AECU-3522).

Work in progress since the last annual report is discussed. In the routine hematology program on the toxicity dogs, three control examinations are made during the month prior to injection. The hematological values determined are hematocrit (VPC), hemoglobin, HPC, sedimentation rate, reticulocyte count, WBC, direct eosinophil count, differential count of 400 cells and direct platelet count. To give trends and permit comparison of the effects of different isotopes on the hematopoietic system, tables are presented giving mean values of selected hematological determinations at yearly intervals for as many groups of dogs as have been on experiment for four years for each isotope. The isotopes used were Pu 239, Ba 226, Ba 228, Th 230 and Sr 90. Terminal hematology values for 7 of 8 dogs that died or have been sacrificed since the September 1956 report are tabulated and a summary of the findings is presented. Some marrow studies on a series of 5-level test-run Pu dogs sacrificed at intervals of 1 day to 2 years are tabulated and summaries of the findings are given. Additional toxicity dogs have been added to the blood volume studies and repeat determinations have been made on toxicity dogs which have shown a change in venous hematocrit since their last determination. A discussion is presented of the studies on concentration of steroids in blood and urine, and catabolism of ^{14}C ^{14}C Cortisol by osteosarcoma cells. The group working in the Cancer Research Laboratory, Department of Anatomy has shown that 1) malignant cells of certain types have a steroid conversion metabolism which differs from their normal cellular counterparts and, 2) certain of these conversion products appear in blood and urine and may be of diagnostic and prognostic significance. (GCU)

A table is included on hematological determinations of 1 to 5 level Pu 239 injected dogs. Tables are presented on pre-sacrifice blood findings and bone marrow myeloid-erythroid ratios on 5-level test-run Pu dogs. A table on the blood volume studies of toxicity dogs is also included.

<45>

Dougherty, J.B., University of Utah, College of Medicine, Division of Radiobiology, Department of Anatomy, Salt Lake City, UT. 1971, March 31.

Injection Tables. COO-119-248; Research in Radiobiology, Annual Report of Work in Progress in the Internal Irradiation Program, J.B. Dougherty, (pp. 9-109), 400 pp. (COO-119-248).

Injection tables for adult beagles injected with one of the radionuclides, Ba 226, Pu

<43>

BIOLOGICAL ASPECTS ANIMALS

<45> CONT.

239, Ra 226, Th 228, Sr 90, and Am 241, in a single intravenous injection at 17 months of age, are given. Injection level 1 is the basis of the scheme and is 10 times the maximum permissible concentration of Ra 226 in man. Actual injection levels differ, but the desired retained activities are the same for all radionuclides except Sr 90, in which case they are greater by a factor of 10. Present measurements indicate that: average Ra 226 retention is 0.75 at about 271 days; average Pu 239 retention is 0.90 at about 6 days; average Ra 226 retention is 0.25 at about 214 days; average Th 228 retention is 0.90 at about 6 days; average Sr 90 retention is 0.25 at about 134 days; average Am 241 retention is 0.90 at about 6 days; average Cf 249 retention is 0.90 at about 1 day; average Cf 252 retention is 0.90 at about 1 day; and average Co 267-268 retention is 0.90 at about 1 day. The injection tables include the calculated average dose in rads to the skeleton at death. (ST)

Tables 1 and 2 list the toxicity (animals maintained until sacrifice becomes a clinical necessity) and test animals (animals sacrificed as needed for special studies), respectively.

<46>

Dougherty, T.P., University of Utah, College of Medicine, Division of Radiobiology, Department of Anatomy, Salt Lake City, UT. 1962.

Incidence of bone cancer in internally irradiated dogs. Some aspects of internal irradiation, T.P. Dougherty, et al (Eds.) Proceedings of a Symposium held at The Homestead, Heter, Utah, May 8-11, 1961. Pergamon Press, Oxford, England, (pp. 47-61), 529 pp.

As part of a study to compare the toxicity of internally deposited Ra 226, Pu 239, Ra 228, Th 228, and Sr 90, the incidence of bone tumors in beagles given a single intravenous injection was studied. Among the various types of cancers produced by these radionuclides, bone cancer (osteosarcoma) appeared to be most common. Injected doses ranged from 1.1 to 10 $\mu\text{Ci/kg}$ for Ra 226 and Pu 228, 0.096 to 2.8 $\mu\text{Ci/kg}$ for Pu 239, 0.096 to 0.90 $\mu\text{Ci/kg}$ for Th 228, and 100 $\mu\text{Ci/kg}$ for Sr 90. At the same radionuclide dose level there were differences in survival times and in the absorbed skeletal dose. Survival time decreased with increasing dose. The earliest incidence of cancer occurred with Th 228. (ST)

Table 1 lists the incidence of osteosarcomas, number of days from injection to death, and the average absorbed skeletal dose of adult beagles injected with radium, plutonium, neptunium, radiothorium and strontium.

<47>

Dougherty, T.P., University of Utah, College of Medicine, Division of Radiobiology, Department of Anatomy, Salt Lake City, UT. 1962.

Study of the long term biological effects of internal irradiation in adult beagles. Some aspects of internal irradiation, T.P. Dougherty, et al (Eds.), Proceedings of a Symposium held at The Homestead, Heter, Utah, May 8-11, 1961. Pergamon Press, Oxford, England, (pp. 3-6), 529 pp.

In 1952 the Radiobiology Division of the Department of Anatomy, University of Utah, began a comparative study of the biological effects in adult beagles of the internal irradiation resulting from five different

radionuclides, Ra 226, Pu 239, Ra 228, Th 228, and Sr 90. Eighteen months old beagles received a single intravenous injection of one radionuclide at a specific dose level related to the human maximum permissible level for Ra 226. Injected doses were selected so that the desired retained doses, with the exception of Sr 90, would be the same. Injected dose levels, designated 1 to 5, ranged from 0.057 to 10 $\mu\text{Ci/kg}$ for Ra 226 and Ra 228, 0.096 to 2.8 $\mu\text{Ci/kg}$ for Pu 239 and Th 228, and 0.57 to 100 $\mu\text{Ci/kg}$ for Sr 90. Incomplete results indicated that average Ra 226 retention is 0.25 after 330 days, average Pu 239 retention is 0.90 after 6 days, average Ra 228 retention is 0.25 after 235 days, average Th 228 retention is 0.90 after 6 days, and average Sr 90 retention is 0.25 after 150 days. (ST)

<48>

Dougherty, T.P., University of Utah, College of Medicine, Division of Radiobiology, Department of Anatomy, Salt Lake City, UT. 1962, March 31.

Research in Radiobiology, Annual Report of Work in Progress on the Chronic Toxicity Program. COO-225; 135 pp.

Injection tables are given and explained for the chronic toxicity studies on dogs using the radionuclides Ra 226, Pu 239, Ra 228, Th 228 and Sr 90. Several related studies are reported and eight of these have been abstracted separately for inclusion in the data base. The studies include anatomical distribution of radiation-induced fractures in beagles, an electrophoretic study of serum protein fractions in Ra 226 and Pu 239 injected dogs, pathologic and normal bone remodeling as visualized by radioautographic distribution of Pu, the long-term effects of Pu 239 in adult beagles and comparative toxicity of Ra 226, Pu 239, and Sr 90 in adult beagles. (PHN)

<49>

Dougherty, T.P., University of Utah, College of Medicine, Division of Radiobiology, Department of Anatomy, Salt Lake City, UT. 1960, March 31.

Research in Radiobiology, An Annual Report of Work in Progress on the Chronic Toxicity Program. COO-220; 225 pp.

Progress is reported for the various sections of the chronic toxicity program. The project is designed to obtain information on the influences of internally deposited radionuclides on certain functions which occur during aging. Injection tables are presented for the toxicity and test animals used in the study with Ra 226, Pu 239, Ra 228, Th 228 and Sr 90. Eleven papers have been abstracted separately for inclusion in the data base. These include the distribution of the radionuclides in dog teeth and the histopathologic changes in teeth containing Pu, the effect of internally deposited radionuclides on the blood vessels of cortical bone, the localized distribution of Pu 239 in the lumbar vertebral centra of 5-level dogs and a case of bone tumor arising from the temporal bone. (PHN)

<50>

Dougherty, T.P., University of Utah, College of Medicine, Division of Radiobiology, Department of Anatomy, Salt Lake City, UT. 1960, September 30.

Research in Radiobiology, Semiannual Report of

BIOLOGICAL ASPECTS
ANIMALS

<50> CONT.

Work in Progress on the Chronic Toxicity Program. CCC-222; 180 pp.

Progress is reported for the chronic toxicity program involving dogs injected with Ra 226, Pu 239, Pa 228, Th 228 or Sr 90. The injection tables are shown in tabular form and give the age and weight of the animals, injected dose, date injected and dose to the skeleton. Reports are included on 15 test raising dogs and on soft tissue tumor incidence in beagles with long-term internal radionuclide burdens. (PNN)

<51>

Dougherty, T.F., University of Utah, College of Medicine, Division of Radiobiology, Department of Anatomy, Salt Lake City, UT. 1967, March 31.

Research in Radiobiology, Annual Report of Work in Progress in the Internal Irradiation Program. COO-119-236; 268 pp.

Injection tables are given for the toxicity and test animals involved in the internal irradiation study on dogs using the radionuclides Ra 226, Pu 239, Pa 228, Th 228, Sr 90, Pa 228 and Am 241. Included in the tables are the age and weight of the animals, injected dose, date injected, dose to the skeleton and pathological findings in dead animals. Special topics are discussed and eight of these have been abstracted separately for inclusion in the data base. Among these are studies on Pu 239 in liver, spleen and kidneys of the beagle, in vivo studies on the interactions of Pu (241) with blood constituents, americium metabolism in beagles, a comparison of the effects of Am 241 and Pu 239 on serum enzymes, alterations in androgen biosynthesis by canine testicular tissue after the internal deposition of some radionuclides and incidence of myelogenous and lymphatic tumors in irradiated and non-irradiated beagles. (PNN)

<52>

Dougherty, T.F., University of Utah, College of Medicine, Division of Radiobiology, Department of Anatomy, Salt Lake City, UT. 1961, March 31.

Research in Radiobiology, Annual Report of Work in Progress on the Chronic Toxicity Program. CCC-223; 30 pp.

The injection tables are given for the chronic toxicity study on dogs using the radionuclides, Ra 226, Pu 239, Pa 228, Th 228 and Sr 90. Included in the tables are the weight and age of the dogs, the injected dose, date injected, dose to the skeleton and pathological findings in dead animals. (PNN)

<53>

Dougherty, T.F., University of Utah, College of Medicine, Division of Radiobiology, Department of Anatomy, Salt Lake City, UT. 1965, September 30.

Research in Radiobiology, Semiannual Report of Progress in the Internal Irradiation Program. COO-119-233; 109 pp.

The injection tables are given for the studies on internal irradiation in dogs using the radionuclides Ra 226, Pu 239, Pa 228, Th 228 and Sr 90. The tables include the age and weight of the animals, injected dose, date injected, dose to the skeleton and pathological findings in dead dogs. Some special topics are discussed such as soft

tissue retention of Sr 90 in the beagle and the use of the chinchilla in the study of bone seeking radionuclides. (PNN)

<54>

Dougherty, T.F., University of Utah, College of Medicine, Division of Radiobiology, Department of Anatomy, Salt Lake City, UT. 1964, September 30.

Research in Radiobiology, Annual Report of Work in Progress on the Chronic Toxicity Program. COO-119-231; 172 pp.

Injection tables are given for the animals in the chronic toxicity program involving the radionuclides Ra 226, Pu 239, Pa 228, Th 228, Sr 90 and Na 228. Included in the tables are the age and weight of the dogs at injection, dose injected, date injected, dose to the skeleton and pathological findings in dead animals. Progress is reported for the studies; two papers have been abstracted separately for inclusion in the data base. Among the studies reported are the effects of ionizing radiations on endocrine cells, the low natural incidence of osteosarcomas in beagles, and the chemical state of Pu(241) in beagle blood, and serum lactic dehydrogenase levels in adult beagle dogs. (PNN)

<55>

Dougherty, T.F., University of Utah, College of Medicine, Division of Radiobiology, Department of Anatomy, Salt Lake City, UT. 1962, September 30.

Research in Radiobiology, Semiannual Report of Work in Progress on the Chronic Toxicity Program. COO-226; 133 pp.

Injection tables are given for the animals involved in the chronic toxicity studies using the radionuclides Ra 226, Pu 239, Pa 228, Th 228 and Sr 90. Included in the tables are age and weight of the animal at injection, injected dose, date injected, and dose to the skeleton. Other work in progress is reported and three papers have been abstracted separately for inclusion in the data base. Among the topics reported are the long-term effects of Pu 239 in adult beagles, radium studies in man soon after injection, effects of estradiol valerate and sulphated mucopolysaccharides on hyperostification in autogenous tibial transplants and liver injury in beagles with Pu 239. (PNN)

<56>

Dougherty, T.F., University of Utah, College of Medicine, Division of Radiobiology, Department of Anatomy, Salt Lake City, UT. 1963, September 30.

Injection Tables. COO-228; Research in Radiobiology, Semiannual Report of Work in Progress on the Chronic Toxicity Program, (pp. 3-55), 185 pp. (COO-228).

Dogs were put into toxicity study groups of six or seven of the same sex. Litter mates were used whenever possible. Each animal received the designated dose of one radionuclide in a single intravenous injection at about 17 months of age. The dose levels were specified as "retained" doses. The actual injected doses were four times the desired retained-doses of Ra 226, Pa 228, Sr 90, and 1.11 times the desired retained doses of Pu 239 and Th 228. Present measurements indicate the following average

<56>

BIOLOGICAL ASPECTS
ANIMALS

<56> CONT.

retention values for each of these radionuclides; Ra 226-0.25 after 330 days, Pu 239-0.90 after 6 days, Ba 228-0.225 after 235 days, Th 228-0.90 after 6 days, and 0.25 after 150 days. The numbering system for the dogs is discussed, and the toxicity and test animals are listed along with "Comments on Dead Dogs." (JTE)

<57>

Dougherty, T.F. (Ed.), University of Utah, Radiobiology Division, Salt Lake City, UT. 1969.

Injection Tables. COO-119-240; Research in Radiobiology, Annual Report of Work in Progress in the Internal Irradiation Program, T.F. Dougherty (Ed.), (pp. 7-85) (COO-119-240).

The tables list the toxicity and test animals, respectively. The animals are injected at approximately 17 months of age. Twelve such groups were injected for each of the five radionuclides, Ba 226, Pu 239, Ra 228, Th 228, and Sr 90. The current injection program involves Ba 226 and Pu 239 at low dose levels. The injection tables include the calculated dose in rads to the skeleton at death. Ba 226, Ra 228, and Sr 90 doses are calculated for each dog using his individually observed retention values; Pu 239 and Th 228 doses are from the average skeletal retention equations. (Auth)

<58>

Dougherty, T.F. (Ed.), University of Utah, College of Medicine, Division of Radiobiology, Department of Anatomy, Salt Lake City, UT. 1971.

Research in Radiobiology. COO-119-240; Annual Report of Work in Progress in the Internal Irradiation Program; 422 pp.

The annual report of work in progress in the internal irradiation program of the Radiobiology Division of the Department of Anatomy, University of Utah, College of Medicine for 1971 included work on Pu 239, Ba 226, and other actinides, Ce 144, N 16, Pb 210. Works on Pu 239 and Ba 226 are abstracted separately. (WP)

<59>

Dougherty, T.F., and C.E. Rags, University of Utah, Salt Lake City, UT. 1969.

Bone Cancer Induced by Internally-Deposited Emitters in Beagles. CONF-690404; IAEA-SM-118/3; Radiation-Induced Cancer, Proceedings of a Symposium held in Athens, Greece, April 28-May 2, 1969. (pp. 361-367) (CONF-690404, IAEA-SM-118/3).

Osteosarcomas were the chief cause of death in adult beagles injected intravenously with bone-seeking radionuclides in citrate solution. The effectiveness of each nuclide depends on the type of radiation emitted and where this radiation is absorbed. Alpha-radiation is more effective than beta radiation, and the alpha emitters which deposit on bone surfaces are more effective than those which deposit throughout bone volume. For death with osteosarcomas eight years after injection, values for SEE (relative biological effectiveness) based on average skeletal dose at one year before death and relative to Ba 226 equals 1 are: Pu 239 equals 6; Th 228 equals 8; Ba 228 (Auth) equals 2.5; and Sr 90 equals 0.07 to 0.20. In humans Ba 226 was observed to induce bone cancers above a skeletal dose of about

1200 rads. Adjusting to the SEE factors established in dogs, the predicted life-time doses above which bone cancers may occur in adult humans are: Pu 239 equals 200 rads; Th 228 equals 150 rads; Ba 228 equals 1200 rads; and Sr 90 equals 5000 to 17000 rads. (Auth)

<60>

Dougherty, T.F., S.J. Storer, J.E. Dougherty, R.S.S. Joe, C.E. Rags, C.E. Behfeld, W.B. Christensen, and R.C. Goldthorpe, University of Utah, College of Medicine, Division of Radiobiology, Department of Anatomy, Salt Lake City, UT. 1962.

Studies of the Biological Effects of Radium 226, Plutonium 239, Radium 228 (Mesothorium II), Thorium 228 (Radiothorium), and Strontium 90. Radiation Research, 17, 625-641.

The design of a long-term experiment to compare the biological effects of five radionuclides, Ba 226, Pu 239, Ra 228, Th 228, and Sr 90, in adult beagles is presented. Results of the first ten years of the study are briefly summarized. Injected dose (mCi/kg), time elapsed since injection, skeletal dose in rads, bone tumor incidence, and reasons for death are given in tabular form. Results are presented under the following headings: metabolism and dosimetry; clinical observations; hematology findings; blood chemistry findings; radiological findings; autoradiographic and histological findings in mineralized tissues; soft tissue, histopathologic and autoradiographic findings; and incidence of tumors. (ST)

Table 3 gives the summary of the experiment as of September 30, 1960, and includes injected dose, days since injection, dose to skeleton, bone tumor incidence, and reason for euthanasia or death.

<61>

Darbin, P., Lawrence Berkeley Laboratory, Berkeley, CA. 1974, December.

Behavior of Plutonium in Animals and Man. CONF-740115; Plutonium Information, Proceedings of a Symposium held in Los Alamos, New Mexico, January 4-5, 1974, (pp. 30-55), 96 pp. (CONF-740115).

There are several administration routes for Pu compounds such as inhalation, injection and application to skin. The transport of Pu in blood is summarized as follows: Pu is reversibly bound to transferrin; Pu occupies the same binding sites that are normally occupied by iron; the Pu-transferrin complex is not as stable as the iron-transferrin entity; uptake of Pu in bone occurs because the forming red blood cells reject the Pu that is transported to them. For gastrointestinal absorption it was seen that if the binding ion was citrate, absorption was increased, also if the Pu was given as Pu(+4). However if insoluble PuO₂ particles were given, Pu absorption was substantially reduced. If the animal was very young, Pu absorption was increased, whether the compound was the citrate or the citrate. For Pu inhalation a modified version of the ICRP lung model is shown. The biological half-times are given for an ideal particle of 1 um activity median aerodynamic diameter (AMAD). Of 100% inhaled, approximately 20% is deposited in the subglottic region, about 10% in the tracheobronchial region and about 30% in the deep lung or pulmonary region. The data show that absorption from an intramuscular or subcutaneous site follows

BIOLOGICAL ASPECTS ANIMALS

<61> CONT.

the same pattern as absorption of ingested or labeled Pu. Intramuscular Pu citrate is absorbed within a few hours to a few days. In industrial accidents, Pu metal fragments or PuO₂ particles have been embedded in wounds and absorption is nearly undetectable from months to years later. The initial distribution of soluble Pu in man and larger laboratory animals is described. Subcellularly in the liver, the Pu is in the hepatic cells associated with ferritin. As the hepatic cells die, Pu containing ferritin is released as part of the cellular debris. This debris is taken up by the phagocytic cells or it enters the circulation, recirculates, and is taken up again by new cells in the liver, closer to the origin of liver circulation. Bone has received much attention with respect to Pu uptake. Bone marrow damage is the underlying cause of acute Pu-induced mortality. Bone tumors are the best documented aspect of the pathology of chronic Pu burdens. Bone uptake of Pu is not limited to osseous. Any structure, invertebrate or vertebrate which contains Ca phosphate or Ca carbonate structures and which grow either a shell, an exoskeleton or an endoskeleton accumulates Pu in these mineralized materials. Radioisotopic studies show that the intensity of labeling in the areas close to the circulation is much greater than in the periphery and that there is no Pu in the body of the bone, as had been demonstrated for Ba. Some reasons for the long retention of Pu in the body are that it circulates in the blood complexed by molecules which are too large to be filtered by the kidney; both bone structures and liver cells are quite long lived; and Pu in liver is associated with a stable compound that is ordinarily not disturbed unless there is stress on the body's iron stores. The initial distributions of Pu in rats are compared to that of other actinide elements (Pu 239, Pu 237, Pu 238, Pu 239, Th 232 and Ac 227). Bone uptake was greatest for Pu(IV) and Th(IV) and least for U(IV). Liver deposition was greatest for the trivalent actinides. Metabolic data are also given for the entire lanthanide sequence and for the actinides through californium. (PNN)

Table 7 shows distribution of radioisotopes of the actinide elements in various tissues of the rat after intramuscular injection. Figure 23 shows intral deposition in the liver and skeleton of the rat of multivalent lanthanides and actinides, and the influence of ionic radius. Figure 24 shows whole-body retention of Pu 239 in man. Figure 25 shows calculated retention of Pu 239 in human liver and skeleton. Table 6 shows initial distribution of Pu in larger animals injected with Pu(IV) citrate. Table 3 shows absorption of Pu compounds from the GI tract. Figure 10 shows clearance of Pu from soft tissues.

<62>

Turbin, P.V., Lawrence Radiation Laboratory, Division of Medical Physics, Berkeley, CA. 1960.

Metabolic Characteristics Within a Chemical Family. *Health Physics*, 2, 225-230.

The available data have been reviewed for the biological behavior in rats of high specific-activity radioisotopes of seventy elements. Tracer quantities were administered in single intramuscular injections. Groups of rats were autopsied at various intervals, and tissues and excreta were assayed for radioactivity. Distribution data were arranged according to the grouping

of the periodic table of the elements. The anions (including the halogens), the oxygenated or halogenated ions of Groups 4, 5 and 6, and the transition metals were rapidly eliminated by the kidney. The monovalent alkali metals were distributed almost uniformly in soft tissue with subsequent excretion by the kidney. The bivalent cations, except Mg(II), Cd(II) and Pb(II), were deposited primarily in bone mineral and were eliminated slowly in both urine and feces. The tripositive elements of Group 3, the lanthanides, and the actinides were deposited in liver and bone. The liver fraction was excreted via the bile without recirculation, while that deposited in bone was turned over at a rate slower than that of normal bone remodeling. The quadrivalent cations such as Zr(IV), Th(IV) and Pu(IV) were deposited almost exclusively in bone and were bound more strongly than the Group 3 elements. The properties that determine biological behavior are: (a) the oxidation state stable at body pH; (b) the solubility of the stable state; (c) the tendency to be incorporated into organic compounds; and (d) the tendency to associate with specific proteins. (auth)

<63>

Eppechi, G.L.V., V. Riddleworth, and G. Cole, University of Nigeria, Enugu, Nigeria. 1975, January.

Natural Radium 226 and Thorium 232 in Thyroids of Cattle from Nigeria, W. Africa. *International Journal of Nuclear Medicine and Biology*, 2(1), 31-33.

Two analyses of the gamma spectra of samples of thyroid from 103 Nigerian cattle (at 4-6 weeks intervals) revealed that more than 80 per cent contained easily detectable quantities of Th 232 possibly mixed with Ra 226. Radioautographs of these thyroids showed highly concentrated sources of alpha particles distributed throughout the thyroid. Measurements of the alpha tracks suggested that each 6.5-MeV alpha particle produced 9200 rad along its track and many of these tracks traversed thyroid cells. The results contrast with the much lower published occurrences of Ra 226 and Th 232 in cattle in USA and Colombia. The bovine thyroid samples came from an area of Nigeria where both high levels of natural radioactivity and a high incidence of human goitre have been reported. The relationship between natural radioactivity to thyroid disease has yet to be established; however, this concentration of natural radium in the thyroid may be a contributory factor. (USA) (RAF)

<64>

Ellis, L.C., and D.L. Berliner, State University, Department of Zoology, Logan, UT; University of Utah, College of Medicine, Division of Radiobiology, Department of Anatomy, Salt Lake City, UT. 1966.

Internally Deposited Radionuclides and the Subsequent Alteration of Androgen Biosynthesis by Canine Testicular Tissue. *CONF-660212; Radiation Research Society, Proceedings of the 10th Annual Symposium held in Coronado, California, February 13-16, 1966, (pp. 687-550) (CONF-660212); Radiation Research*, 27, 549.

The data presented in this report were obtained from adult Beagle dogs which were sacrificed according to a pre arranged schedule. These animals were part of the comparative study on the biological effects

<64>

BIOLOGICAL EFFECTS
ANIMALS

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of some radionuclides in the basic program of the Radiological Division of the Department of Anatomy, University of Utah. The dogs were injected with the various radionuclides according to the project outline. Five animals were injected with 3.2 $\mu\text{Ci/g}$ of Ra 226, five animals received 0.016 $\mu\text{Ci/g}$ of Pu 239, three received 0.30 $\mu\text{Ci/kg}$ of Pu 239, five animals received 0.096-0.30 $\mu\text{Ci/g}$ of Th 228, two animals received 0.30 $\mu\text{Ci/g}$ of Ra 228 and one animal received 0.17 $\mu\text{Ci/g}$ of Sr 90. Four control animals were included for comparative purposes. Immediately after the animals were sacrificed, one-gross aliquots of the testes were sliced and incubated with 5-pregnenolone-7 α -H and progesterone-4-C 14. Isolation and quantification of the steroid intermediates showed that 5-pregnenolone was converted into 17 α -hydroxypregnenolone, androstenedione, and testosterone faster than was progesterone, as has been demonstrated by other workers. The conversion of the two androgen precursors into androstenedione, testosterone, and total androgens was markedly reduced for all of the injected animals. Thus, these data show that internally deposited radionuclides diminish androgen biosynthesis in vitro as has been previously reported for the adrenal glands of dogs, and testes from mice and rats after the latter had received various doses of irradiation. (Auth)

<65>

Ellis, L.C., and D.L. Berliner. University of Utah, College of Medicine, Division of Radiobiology, Department of Anatomy, Salt Lake City, UT. 1967, March 31.

The Effects of Ionizing Radiations on Endocrine Cells. 6. Alterations in Androgen Biosynthesis by Canine Testicular Tissue after the Internal Deposition of Some Radionuclides. COO-119-236: Research in Radiobiology, Report of Work in Progress in the Internal Irradiation Program. T.P. Dougherty. (pp. 218-251), 268 pp. (COO-119-236).

Male beagle dogs were injected intravenously with various radionuclides (Ra 226, Pu 239, Th 228, Pa 228 and Sr 90) when approximately 18 months of age. At various time intervals the testes were removed from the animals, and incubated with pregnenolone-7 α -H and progesterone-4-C 14. The resulting steroid intermediates were isolated by paper chromatography and derivative formation. The pathways observed for the synthesis of androgens were essentially the same as those observed from perfusion studies by other workers. The 17- α -hydroxylation of progesterone was diminished in all but one animal, which had received Sr 90. Similarly, less androstenedione, testosterone, and total androgens were produced by the tissues from the treated animals as compared to the control group. Pregnenolone was isolated from the incubations of at least eight dogs. The occurrence of this compound with respect to fertility in treated animals was discussed. When a HMG-generating system was added to incubation of tissues from both groups of animals, there was no increase in steroid biotransformations for both groups. Although the increase in excretion of testosterone and androstenedione production was greater for the control group after the addition of the cofactor-generating system, the percent increase in androstenedione, testosterone, and total androgen production was greater for the treated group. (Auth)

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Elovskaya, L.T., Ye.T. Kapitanov, P.P. Lyarskii, and Yu.P. Likhachev. Staatliche Zentrale fuer Strahlenschutz, Berlin, German Democratic Republic. 1973, March.

Maximum Permissible Concentrations of Natural Radioactive Materials (Thorium, Uranium) in Ore, Concentrate, and Milling Dusts of Rare Metals. SZS-148: COF-7206201: The Question of Radiation Protection, Proceedings of the German-Soviet Working Symposium held in Berlin, Germany, June 8-9, 1972, (pp. 68-80), 146 pp. (SZS-148, COF-7206201).

Problems of radiation protection arising in the production of rare metals are caused by the economically insignificant content of Th and U in the ore. The significance of the thorium content in industrial dusts is evaluated with regard to radiation protection. With experimentally produced pneumoconiosis an intensification of the pathogenic effects of dusts was observed after a single intratracheal application as well as a chronic aerosol exposure of 2000 virginal albino rats if the dose absorbed in the lungs was between 150 and 100 rem. It is concluded that in handling materials with activity concentrations less than 5.10(-10) Ci/g no additional radiation protection requirements are necessary if common industrial hygienic norms for permissible dust concentrations are observed. The problem of late effects after chronic exposure to dust with increased activity concentrations must be regarded as unsolved.

<67>

Erle, V., W. Goessmer, O. Hug, A. Lux, R.H. Margart, and W.A. Mueller. 1976.

Reports on the Heuberberg Long-Term Experiments with Short-Lived Alpha-Emitters. Part 1. The Dependence of Late Effects in Mice on the Temporal Distribution of Skeletal Alpha-Doses from Radium 224 and Thorium 227. AED-COF-76-430-005: COF-760992: Biological Effects of Radium 224, Proceedings of the 2nd International Symposium held in Heuberberg/Munich, Germany, September 20, 1976, (3 pp.) (AED-COF-76-430-005, COF-760992).

A survey is given of long-term experiments (10 years, and dosimetric studies on female mice four weeks old at the start of the experiment. After repeated injections of Ra 224 (maximum dose rate to the skeleton 12 rad/day) the maximum osteosarcoma incidence was about 80% in two experiments after an internal irradiation period of about six and nine months, respectively, and a total dose to the skeleton of 2160 and 1080 rad, respectively. After a single injection of Th 227 (maximum dose rate to the skeleton 4.7 rads/day) the maximum osteosarcoma incidence of 40 and 50% resulted at a mean skeletal dose level of about 1200 rad. Protracted application of the same total dose over nine months resulted in an osteosarcoma incidence of about 80%. Comparison of the effects of Th 227 and its daughter Ra 223 at levels of about 1200 and 2800 rad mean skeletal dose show a considerably lower bone tumor risk for Ra 223. (RAF)

<68>

Faber, H., Finssen Institute, Finssen Laboratory, Copenhagen, Denmark. 1973, June.

The Effect of Thorotrast Enriched with Thorium 230. CO F-730475; SISO-294: Toxicity of

BIOLOGICAL ASPECTS
RADIATION

<68> CONT.

Thorotrast. E. Faber (Ed.), Proceedings of the 3rd International Meeting held in Copenhagen, Denmark, April 25-27, 1973, (pp. 299-322) (CCNY-730475, B150-294).

To evaluate cancer mortality in Thorotrast-treated patients as a pure radiation effect, it is necessary to separate the radiation and particle carcinogenic mechanisms. A change in specific activity of the granules should help determine if the particle mechanism represents a minor factor in carcinogenesis. Thorotrast enriched with Th 230 to alpha activities 7 and 49 times normal and injected into rabbits at doses of 10 and 0.3 ml caused shortened latency periods for hemangioendotheliomas compared with commercial Thorotrast. The high dose was excessive; because of the shortened latency period, animals died from non-specific liver damage before tumors developed. With the low dose, uterine cancer was the most common cause of death when hemangioendothelioma was not present. The questions as to whether a theoretical non-radioactive Thorotrast might be carcinogenic cannot be answered with these data. (Auth) (VC)

<69>

Faber, H., and C. Johansen, Finsen Laboratory, Copenhagen, Denmark, 1967, December.

Leukemia and Other Hematological Diseases after Thorotrast. Annals of the New York Academy of Sciences, 145(3), 755-758; CCNY-660422; Distribution, Retention, and Late Effects of Thorium Dioxide, S.L. Swann (Ed.), Proceedings of a Conference held in New York, New York, April 20-22, 1966, (pp. 755-758), 336 pp. (CCNY-660422).

It is difficult to determine to what degree radiation (as opposed to chemical) toxicity is the causative agent in leukemia and bone marrow effects. In rabbits injected with "normal" Thorotrast there are no bone marrow effects. In animals dying 1 1/2 years after receiving alpha-enriched thorotrast, bone marrow which contained the Thorotrast was aplastic. Areas devoid of thorotrast, as well as peripheral blood, were normal. Accelerated dose-dependent decrease in lymphocyte count with increasing age occurred in rabbits after Thorotrast injection. In humans, the hematology is generally normal with some slight decrease in lymphocytes in spite of relatively large radiation doses to the bone marrow. In spite of this, a number of hematological disorders occur. Seven leukemia cases, most of the clinically typical leukemias, probably radiation-induced are discussed. In some cases, bone marrow atrophy may have been caused by thorotrast. In two cases, enlarged erythrocytes indicated a functional change in erythropoiesis with maturation arrest. Whether these bone marrow disorders are results of damage from thorotrast radiation or other complicating factors (such as x-ray or drug therapy) is not known. (VC)

<70>

Finkel, H.F., Argonne National Laboratory, Division of Biological and Medical Research, Argonne, IL. 1953, July.

Relative Biological Effectiveness of Radon and Other Alpha Emitters in CP No. 1 Female Mice (26394). Proceedings of the Society for Experimental Biology and Medicine, 83 (3), 490-498.

The relative biological effectiveness of radon and other alpha-emitting isotopes studied varies with the criterion of effect, and with the degree of the response being measured. Many factors such as biological half-times, isotope distribution, and tissue radiosensitivity must be considered. Pu 239, Po 210, Th 233 and Th 229 were twenty times as effective as Ra 226 in killing 50% of a population of CP No. 1 female mice in 70 to 100 days after intravenous administration. At levels approaching those which produced no effect, Pu was 3 times as effective, Po was equally effective, and Th 233 was slightly less effective than Ra in decreasing life expectancy. Ratios relative to Ra of the proportion of mice that developed malignant bone tumors after a latent period were 7:1 for Pu and 2:1 for Th 233. Th 233 and Po were less effective than Ra in this instance. On the basis of these criteria, the best estimate of the relative biological effectiveness at near tolerance levels in these mice is 7 (Pu 239):3 (Po 210):2 (Th 233):1 (Ra 226). (Auth) (VC)

<71>

Finkel, H.F., and G.N. Hirsch, Argonne National Laboratory, Division of Biological and Medical Research, Chicago, IL. 1952, April.

Progress Report: The Incidence of Malignant Bone Tumors in the Long-Term Toxicity Experiments with Uranium, Plutonium, and Radium. ARL-8794; Division of Biological and Medical Research, Quarterly Report, February, March, April, 1952, (pp. 71-84), 175 pp. (ARL-8794).

Studies of long-term toxicity of Th 233, Ra 226, and Pu 239, given intravenously to CP 1 mice have been in progress 600 days (Th) and 800 days (Ra, Pu). Preliminary results relating to malignant bone changes are presented; problems of analysis and data presentation are discussed. Uranium 233 doses of 53 uc/kg and higher caused early deaths. There was increased tumor incidence in animals receiving 22 to 5 uc/kg of Th 233. Ten and one uc/kg of Th 233 produced increased incidence of bone tumors. Uranium 233 was more carcinogenic than was Th 233. There was some indication of a relationship between toxicity and length of latent period; controls and animals receiving low levels of Th 233 (0.1 uc/kg) and those with highest levels of Th 233 (3.6 x 10³ uc/kg) had no tumors until 574 days. No bone malignancies had occurred by 231 days in animals receiving 288 uc/kg of Ra 226. Tumor incidence in the 100 uc/kg group was lower than those of the 50 or 28.8 uc/kg groups. These results are presumably related to debilitation of animals in the 288 and 100 uc groups. Tumors occurred in all groups by 325 days. By 800 days, large numbers of tumors had occurred in animals receiving 6.1 and 3.1 uc/kg of Pu 239. As early as 250 days, a tumor had been found in 0.69 and 0.34 uc/kg groups. A tumor appeared at 190 days in an animal injected with 6.1 uc/kg. (VC)

<72>

Fried, J.F., Argonne National Laboratory, Division of Biological and Medical Research, Argonne, IL. 1961.

Influence of Physical State on the Removal of Hydrolyzable Radioelements by Chelation. ARL-6637; Bioassay and Analytical Chemistry, Proceedings of the 7th Annual Symposium held in Argonne, Illinois, October 12-13, 1961, (pp. 5-8), 100 pp. (ARL-6637).

<12>

BIOLOGICAL ASPECTS
MISCELL

<72> CONT.

Experiments using Th 230, Pu 239, and Ca DTPA were done to determine the efficiency with which an extracellular agent could remove intracellular relatively insoluble deposits of radioactive esters. In one experiment mice were injected intravenously with two forms of Pu (ionic and colloidal) at a level of 1.3 $\mu\text{Ci/kg}$ for the ionic and of 2.6 $\mu\text{Ci/kg}$ for the colloidal. DTPA therapy, begun 3 days later, consisted of twelve daily IP injections at 500 mg/kg each. It was shown that the ionic Pu was divided almost evenly between liver and bone whereas the amount of colloidal Pu in the liver was over twice that in the bone. In the animals receiving DTPA therapy, ionic Pu was almost completely removed from the liver in 3 days, whereas in those receiving colloidal Pu, the liver still retained almost two-thirds of its initial burden after the entire treatment period was over. In summary, the total reduction of body burden brought about by DTPA therapy was considerably greater in those animals receiving ionic Pu (75% reduction) than in those receiving the colloidal form (40% reduction). (PNU)

<73>

Galibin, G.P., and I.K. Petrovich, 1972.

The Biological Action of Uranium Tetrafluoride in Chronic Inhalation Poisoning. *Gigiena i Sanitariya*, 17(2), 61-64.

Daily 8 hr chronic inhalation of uranium tetrafluoride at a concentration of 12 mg/cu m was definitely toxic for rats; a concentration of 1.2 mg/cu m approached the minimum efficient value of the threshold level of the substance. The early signs of the toxicity of uranium tetrafluoride were a decrease of body weight and disturbances of liver and kidney functions. Changes in the amount of uranium deposited in the organs showed that in chronic inhalation of uranium tetrafluoride at a concentration of 1.2 mg/cu m tissue doses (owing to gamma-radiation approaching the maximum permissible level of 15 mrem/yr may occur only in the lungs. In the rest of the organs and tissues these doses were lower than the maximum permissible dose, recommended by the International Committee on Radiologic Protection. (Traz) (BBV)

<74>

Gensiche, P., R.W. Hirschle, and A.A. (translator) Ternath, Lovelace Foundation for Medical Education and Research, Plasmion Product Inhalation Program, Albuquerque, NM. 1969, February.

The Inhalation of Radioactive Substances. Part 3. Uranium and Thorium (A Literature Review). *ISIS-3/69*; LP-tr-3; 21 pp.

Uranium (natural U, a mixture of U 238, 235 and 235) is used in nuclear weapons, technology and research, nuclear fuel, and in the glass and ceramic industries. Insoluble, labeled U can be detected in high concentrations in lungs even five years after inhalation. Soluble U is distributed in the blood to other organs. Most U is excreted in the urine. Lung half-clearance times vary between 120 and 300 days for U oxide; for U nitrate in rats, the time is less than one day. In man, some U trioxide and tetrachloride are eliminated within 20 hours, the rest, more slowly up to 200 hours. Poisonary retention data for chronic exposures to rats, dogs, and monkeys exposed

1, 5, and 5 years respectively were: Duration of clearance measurement 300, 800, 350 days; biological $t/2$ (days) - 200, 800, 320. The clearance constant for U 238 oxide in dogs was $k = 0.002$. Particles of smaller size in U dusts were more toxic than were larger ones. Thorium has been used in various industries. While not fissile, it can be transformed into U 239, a potential nuclear fuel. Thorium has low chemical toxicity and high radiotoxicity. There is high incidence of osteosarcoma in dogs 1500 days after 0.3 $\mu\text{Ci/kg}$. Such effects have also been noted in Thorotrast cases. In animals, years after inhalation highest activity is in lungs and lesser amounts in liver and skeleton. Retention data are reviewed. Thorium is eliminated in feces and urine. The biological half-elimination time for slow lung clearance is as for insoluble compounds is 4 years and from skeleton 700 years. The values for inhaled compounds are: Th dioxide and nitrate, 1000 days; Th chloride, 90 days. (WC)

<75>

Girardi, P., and M. Merlini, Euratec, Joint Nuclear Research Center, Ispra, Italy. 1963.

Studies on the Distribution of Trace Elements in a Mollusk from a Freshwater Environment by Activation Analysis. *ISIS-3/69*; CONT-304-1; Radioactivation Analysis and its Application to the Biological Sciences, Proceedings of a Symposium held in Saclay, France, September 26-28, 1963, (pp. 1-26) (ISIS-3/69; CONT-304-1).

A semi-automated system for the determination of trace elements in biological materials is described. The system is based on the chemical separation of elements in the irradiated specimens by chromatographic procedures, automatic gamma spectrometry, with the use of sample changers; and automatic treatment of the experimental data by computer techniques. Although the system has not yet been perfected, it appears that approximately 100 samples per month with 12 to 15 elements per sample, can be determined. It is possible, therefore, to use this system for an accurate and more thorough investigation of well-chosen, biologically significant, elements. The biological results obtained on *Unio*, a bivalve from Lake Maggiore, revealed the presence of elements never before determined in a mollusk from a freshwater environment. This fact points to the necessity of an adequate and accurate tool for the quantitative determination of the elementary composition of organisms and their environment. Activation analysis appears to satisfy all the necessary conditions. The elements determined in the mollusk were Sc, Au, Zn, Cd, Pb, Hg, Cr, Co, Th, Sr, and Ag. The Th concentration in 18 samples of mollusk shells ranged from 0.01% to 0.10 ppm (dry weight); in the soft tissues from 0.016 to 0.23 ppm. (PAP)

<76>

Gaidova, L.S., and Y. Syno-Shan, 1970.

Morphological Changes in the Lungs and Other Organs in Rats on Intratracheal Administration of Thorium Dioxide. The Toxicology of Radioactive Substances: Thorium 232 and Uranium 238, Vol. 6, A.A. Letavet and E.B. Kariyandakaya (Eds.), Pergamon Press, New York, New York, (pp. 66-82), 144 pp.

Single intratracheal administration of thorium dioxide to rats produces definite histological changes in the lungs and

BIOLOGICAL ASPECTS
ANIMALS

<76> CONT.

paraneoplastic organs; the intensity of these changes is directly related to the dose of substance administered and the time of its action. The changes in the lungs are of a uniform character and are expressed in the development of chronic suppurative lesions of the bronchi with sclerotic changes of peribronchial tissue, formation of bronchiectases, perifocal pneumonia, abscesses and adenomatous proliferations. In late stages (after 13, and chiefly after 19-21 months) the test rats developed tumors (13.6 per cent)--sarcomas and squamous-cell carcinomas of the lungs. The incidence of tumors increased with increase in the dose of thorium oxide as exposure time. The minimum carcinogenic dose for the lungs on intratracheal administration was 2 mg/kg (19.2x10⁶ Bq kg weight). In the liver, changes of the protein dystrophy type were observed and in a number of cases focal microscystoses; in the kidneys, protein dystrophy of the epithelium of the convoluted tubules and in individual cases a large number of hyaline cylinders in the lumen of the tubules. Distinct morphological changes and especially development of malignant tumors on admitting a single low dose of thorium oxide to the lungs via the trachea may serve as the biological basis for stricter standardization of the maximum permissible levels of insoluble thorium compounds in the atmosphere. (auth)

<77>

Goldman, H., F.D. Wilson, L.S. Rosenblatt, and S.A. Book, University of California, School of Veterinary Medicine, Radiobiology Laboratory, Davis, Ca. 1976.

Early Radiation Effects on Bone and Blood as Predictors of Osteosarcoma: A Late Effect. CCNY-751126; IAEA-SM-201/507; STI/798/409; Biological Effects of Low-Level Radiation Fertile to Protection of Man and his Environment, Proceedings of an International Symposium held in Chicago, Illinois, November 2-6, 1975, Vol. 1, (pp. 335-342), 451 pp. (CCNY-751126, IAEA-SM-202/507, STI/798/409).

Neutropenia in beagles consequent to injection of Pu 239, Pu 226 or Sr 90 has been observed to follow parallel dose responses during the first year post-administration. Calculations have shown that the subsequent marrow cumulative incidence rates (NCIR) for osteosarcoma in the same dogs also follow parallel responses. The slopes of the dosage effect curves for neutropenia were less steep than those for osteosarcoma, indicating a lower sensitivity to a change in dosage for the former effect, due possibly to a greater capability for repair in the hematopoietic system. Injected activities estimated to produce a 50% neutropenia (ED 50) were about 0.5, 3.2 and 80 uCi/kg for Pu 239, Pu 226 and Sr 90, respectively, whereas estimates of dosages to produce 50 % NCIR were approximately 0.01, 0.4 and 20 uCi/kg, respectively. The ratio of ED 50 to 50% NCIR was 50 for Pu 239, 8 for Pu 226, and 4 for Sr. While it proved difficult to see the neutropenia effect to predict osteosarcoma incidence accurately, it was of significance that the dosage-effect relationships were similar for each radionuclide. The similarities as well as differences in effects and the relationships of the two effects are probably related to the type of particles emitted by the three radionuclides, the patterns of deposition and retention in bone, and the likelihood of a similarity in their interaction with progenitors of

hematopoietic elements and bone. (auth)

Figure 3 gives an illustration of the suggested location and interactions for cells at risk for radiation injury.

<78>

Goldthorpe, H.C., University of Utah, College of Medicine, Division of Radiobiology, Department of Anatomy, Salt Lake City, UT. 1962.

The Effects of Aging and Internal Emitters on Blood Chemistry. Some Aspects of Internal Irradiation, T.V. Dougherty, et al (Eds.), Proceedings of a Symposium held at The Homestead, Beber, Utah, May 8-11, 1961. Pergamon Press, Oxford, England, (pp. 117-129), 529 pp.

The blood chemistry of normal beagle dogs and those given a single intravenous injection of Pu 239, Pu 226, Th 228, or Pu 226 was studied over a large period of their lifespan. In the normal aging controls, inorganic phosphates, total proteins, globulins, fibrinogen and glycoproteins all appeared to have a slight increase in value throughout life. Calcium, serum albumin, urea chloride and carbon dioxide capacity tended to show a slight decline throughout life. Alkaline phosphatase tended to remain fairly constant throughout life. Cholesterol appeared to decrease in value in early life and at about midlife started to climb to above normal values. Special emphasis was given those groups in which a large number of the dogs had bone tumors at the time the measurements were made. The most striking change was the elevation of the mean values of alkaline phosphatase for almost all the groups in which bone tumor incidence is high. Pu 239 dogs showed a slight decrease in calcium with a slight increase in inorganic phosphates. The latter change appeared in some of the Th 228 dogs also. An interesting finding in the study of the serum proteins was an advancement in time of the normal reversal of the albumin-globulin ratio. Pu 239 dogs with bone tumors showed a slight decrease in serum urea nitrogen. Some increase in cholesterol values was noted. Both fibrinogen and serum glycoproteins showed an increase in the case of most of the groups of dogs with bone tumors. Terminal values for the various serum constituents of the injected dogs are given in graphical form. (57)

<79>

Goldthorpe, H.C., S. Bennett, and B.A. Olson, University of Utah, College of Medicine, Radiobiology Laboratory, Salt Lake City, UT. 1957, March 31.

Biochemical Report. AECU-3522; Annual Progress Report, (pp. 115-131), 177 pp. (AECU-3522).

The report is divided into four parts. The first part presents the basic clinical chemistry following radioisotope injection. The basic clinical chemistry work of this group is reported in the same manner as in previous reports, that is at thirty and sixty days, six months and at yearly intervals postinjection. Plutonium shows more blood chemistry changes than radium, radiothorium or mesothorium but the average days of life after injection with plutonium before having to be sacrificed are longer than with any of the other isotopes being studied. As the number of dogs involved in each isotope series increases the striking changes seen in the values of the various serum constituents are less pronounced. There are still individual dogs showing striking changes but

<79>

BIOLOGICAL ASPECTS
RATIALS

<79> CONT.

they become modified in the average values obtained with comparably treated dogs. Changes in the blood chemistry values for serum do not necessarily mean that the isotope is more toxic than another one showing smaller changes in values. The next part discusses the effects of aging on the glycoproteins and serum albumin levels in the serum. A graph is presented showing the results of the study. In part three the effects of injected radioisotopes on the blood serum glycoproteins and serum albumin are discussed. Data is tabulated for Pu, Ba, Sr, Th, and Sr, giving the glycoproteins and serum albumin values in mg/100 ml serum. The final part is the report discusses glycoproteins and serum albumin blood serum levels of sacrificed dogs with data tabulated for individual dogs. (LCH)

Tables are included which give the serum chemistry values and the glycoproteins and serum albumin values in mg/100 ml serum for dogs injected with Pu 239, Ba 226, Ba 228, Th 228 and Sr 90. Another table gives the glycoproteins and serum albumin values in mg/100 ml serum for sacrificed dogs.

<80>

Goldthorpe, H.C., S. Bennett, and R. Smith, University of Utah, College of Medicine, Radiobiology Division, Department of Anatomy, Salt Lake City, UT. 1969, March 31.

The Terminal Blood Chemistry of Radioisotope Injected Dogs. CCO-220: Research in Radiobiology, Annual Report of Work in Progress on the Chronic Toxicity Program, T.F. Dougherty, (pp. 75-77), 225 pp. (CCO-220).

Results are given for the average values, found at death, of various constituents of the blood serum of dogs, due to the injection of Pu 239, Ba 226, Ba 228, Th 228 and Sr 90. There appears to be an upset in the calcium-phosphorus metabolism. Free nitrogen goes down in value except for radiothorium dogs which are higher. The question seems to be whether plutonium, radium, cesothorium, and strontium lower liver function while radiothorium decreases kidney function as is shown in the high inorganic phosphorus values. There seems to be an upset in the acid-base relationship in all categories. The increased glycoproteins and serum albumin values show either tissue destruction or neoplastic development. Increased fibrinogen values are not clear at this time; all globulin fractions are increased, so that this is perhaps a part of the overall picture. (Auth) (PNN)

<81>

Grampa, G., State University Medical School, Department of Pathology, Milan, Italy. 1974.

Lung Tumors in Rats after Thorium Dioxide Administration. Radiation Research, 59, 258.

Epithelial and connective tissue tumors (adenomas, adenocarcinomas, fibrosarcomas and fibrosarcomas) were observed in Sprague-Dawley rats injected intravenously with thorium dioxide and sacrificed from 10 to 22 months after treatment. Histological examinations and radiochemical analysis by alpha-spectrometry showed a dose effect response. The findings are compared with lung tumors observed in man after exposure to internal alpha-emitters. (Auth)

<82>

Grampa, G., Istituto di Anatomia e Istologia Patologica dell'Università di Milano, Milan, Italy. 1967, December.

Liver Distribution of Colloidal Thorium Dioxide and Development of Liver Epithelial Tumors in Rats. Annals of the New York Academy of Sciences, 185(7), 730-747: CCR-660422: Distribution, Retention, and Late Effects of Thorium Dioxide, R.L. Soren (Ed.), Proceedings of a Conference held in New York, New York, April 20-22, 1966, (pp. 730-747), 336 pp. (CCR-660422).

Male rats of Sprague-Dawley and Wistar strains have been injected intravenously with colloidal thorium dioxide. The pattern of colloidal thorium dioxide distribution in the liver has been studied with light microscopic, electron microscopic and autoradiographic techniques. Thorium dioxide is phagocytized very rapidly by Kupffer cells, as early as one minute after injection, and, later on, is seen in form of large aggregates, obscuring cellular details. Autoradiographic and electron microscopic observations show that hepatic parenchymal cells do definitely absorb thorium dioxide, even if to a much smaller extent than Kupffer cells. Foci of histiocytic hyperplasia, nodular adenomatous hyperplasia, adenomas and parenchymal cell carcinomas were observed after an observation period of up to 15 months. Rats injected with India ink, used to test the effect of the presence of particulate nonradioactive material in the liver, gave no remarkable findings in the liver. In order to stimulate the phagocytic activity of the reticuloendothelial system, groups of animals were castrated and treated with estrogens before thorium dioxide and India ink injection. The relationship between thorium dioxide and estrogen treatment and the possible interplay of radiation and hormonal factors, are at present investigated. (Auth)

<83>

Hall, R.E., University of Rochester, Rochester, NY. 1959.

Inhalation Toxicity of Thorium Oxalate. OR-182: Quarterly Technical Report, (pp. 72-75).

Rabbits and rats were exposed for four weeks, six hours daily, five days each week to 25 or 17 mg thorium oxalate/m³; dogs were exposed on a similar schedule to a concentration of 25 or 12 mg thorium oxalate. To determine subacute toxic effects of thorium inhalation the following toxicological indices were studied: body weight, blood WBC and calcium concentration, blood cell counts, hemoglobin concentration and hematocrit, histology of the lungs, pulmonary lymph nodes, liver, kidneys and spleens. The sole evidence of toxicity were decreases in serum calcium concentrations of the dogs and decreases in the number of circulating red blood cells with a concomitant increase of mean corpuscular volume. (HIF)

<84>

Hall, R.E., C.A. Stross, J.E. Scott, R.E. Root, L.T. Steadman, and R.E. Stokinger, University of Rochester, Atomic Energy Project, Rochester, NY. 1951, November 13.

Acute Toxicity of Inhaled Thorium Compounds. OR-190: 25 pp.

PHYSIOLOGICAL ASPECTS OF FISSION PRODUCTS

(84) CONT.

The low toxicities of $\text{Th}(\text{NO}_3)_4 \cdot 6\text{H}_2\text{O}$, ThO_2 , ThF_4 , and Th_2O_3 have been demonstrated by a series of tests in which animals breathed atmospheres containing these as dusts. The species exposed were dogs, rabbits, guinea pigs, rats, mice, and hamsters. Negative findings were reported for mortality, urinary proteins, blood WBC and area, plasma fibrinogen, and serum protein. Growth depression was observed in rats exposed to ThO_2 . Occasional vomiting was observed in dogs exposed to the nitrate. A thorough histological examination revealed practically no pathological changes attributable to the treatment; the exceptions were slight lesions of uncertain etiology in the lungs. The only positive findings were changes in the hematological picture, especially in the white cells, and somewhat abnormal bone marrow. Spectrographic analyses of the Th content of lung, feces, liver, and spleen show a tendency for increased Th content with increased exposure. (Complete Text)

(85)

Hassilton, J.C., University of California, Division of Medical Physics, Berkeley, CA; University of California, Division of Medicine and Radiology, San Francisco, CA. 1947, September.

The Metabolism of the Fission Products and the Heaviest Elements. Radiology, 49, 125-141.

Absorption, distribution, retention, and excretion by rats of Pu and fission products after ingestion, inhalation or injection were studied. Excreta were analyzed and, after sacrifice, organs studied by autoradiography. Most fission products and all actinides were not well-absorbed by the digestive tract. Sr, Ba, Te, I, Cs were absorbed by the digestive tract; Fe by lungs; Sr and Ba by skeleton; I by thyroid; Te by kidneys and blood; Cs uniformly with greatest accumulation in muscles. Except for Te, these distributions were the same after ingestion or parenteral injection. Most fission products of actinides studied had high accumulation and retention in skeleton. All elements, except Sr were localized in bone matrix rather than in the mineral structure; this was true for Y, Zr, Ce, Th, Pa, Am, and would be predicted for La, Pr, Nd, Element 61, Sm, Eu, Gd, Hf, Ta, Nb and Pu. Major amounts of La, Ce, Pr, Element 61, Am, Pu were rapidly excreted and apparently not related to reticuloendothelial system uptake. Similar behavior would be expected from Nd, Sm, Eu. In general, elements accumulated in bone are released very slowly, as with Pa. Most fission products are beta emitters and have shorter half lives than does Pa, factors which may make them less hazardous than Pa. Most actinides, like Pa, are long-lived alpha emitters and by virtue of their localization in bone matrix can readily enter the bone marrow thereby irradiating the blood-forming tissues. (VC)

Table giving element, half-life, fission yield, oral absorption, accumulation in principal organs of retention, and rate of elimination from those organs (half-time in the body) for rats and man is included. Graphic material and photomicrographs are also included.

(86)

Hassilton, J.C., J.N. Lawrence, P. Heysoth, C.A. Tobias, R.S. Stearn, E.W. Miller, B.V.A. Low-Beer, W.B. Garden, and B. Noyer, University

of California, Radiation Laboratory, Berkeley, CA. 1947.

Nuclear and Health Physics Section, Progress Report for May 1947. PP-47; 12 pp.

The status of the following studies was given: (1) radioautographic studies, the deposition in bone of thorium, plutonium, americium, barium, and element 61 was being studied. Experiments with curium, Th 231 and Pu 239 were planned; (2) tracer studies, summaries of 14 140 experiments in thorium, rats and one day experiments with element 61 was similar. It was noted that deposition of these rare earths is similar to calcium, praseodymium, americium, and cerium. Studies of the absorption of neptunium were also performed. The efficiency of the bone retractor procedure for isolation of Th 231 from animal tissue was increased up to 100%; (3) decontamination studies, the absorption of Pu from injection of 15 micrograms of Pu(4) in rats was reduced by pretreatment with $\text{Ba}(\text{C}_2\text{O}_4)_2$ -dithioglycerol. Zirconium did not reduce absorption of Pu after intramuscular injection, but urinary excretion increased 5 x and skeletal retention decreased 3 x. Rachitic rats retained significantly less thorium than controls, but a massive dose of phosphate increased retention; (4) uranium distribution studies, the liver and spleen removed 40-95% of the injected U in mice; other studies were: (5) radio-chemical isolations, (6) operative crossroads, (7) total body irradiation T-ray and P 32, (8) radiiodine studies, (9) health physics-chemistry section studies on monitoring, decontamination, personal, and research and development, and (10) health physics radiation field studies in monitoring, shielding, and neutron absorption. (JWE)

(87)

Hassilton, J.C., and B. Posaric, Northwestern University Medical School, Department of Anatomy, Chicago, IL. 1947, December.

The Distribution of Colloidal Thorium Dioxide in Mouse Liver after Intravenous Injection. Annals of the New York Academy of Sciences, 145(1), 533-544; CONP-660422; Distribution, Retention, and Late Effects of Thorium Dioxide, P.L. Sears (Ed.), Proceedings of a Conference held at New York, New York, April 20-22, 1946, (CONP-533-544), 116 pp. (CONP-660422).

The distribution in mouse liver at 1000 at ten minutes and one month after intravenous and intrasplenic injection was not significantly different for doses of 0.1, 0.25 and 0.5 ml. At ten minutes after injection, particles were still present extracellularly in sinusoidal lumens, in the space of Disse and in spaces between hepatocyte parenchymal cells. Many particles were bound to the plasma membranes of and within the cytoplasm of Kupffer cells. The particles did not appear to be bound to the plasma space of parenchymal cells but were taken up by them through vesicle formation both at the cell surface bordering upon that space of Disse and at the surface bordering intercellular spaces. At one month after injection sinusoids were occluded by large Kupffer cells packed with particles. The space of Disse surrounding occluded sinusoids was obliterated and often contained bundles of collagen. Dense aggregates of particles were found in parenchymal cells and occasionally in bile canaliculi. On rare occasions loose aggregates of particles were found in

<87>

BIOLOGICAL EFFECTS
MINIMALS

<87> CCRP.

parenchymal cell nuclei. (Auth)

<88>

Rodger, H.C., and R.C. Thomas, University of Rochester, School of Medicine and Dentistry, Department of Radiation Biology, Rochester, NY. 1958.

Health Hazards from the Inhalation of Insoluble Uranium and Thorium Oxides. Peaceful Uses of Atomic Energy, Proceedings of the 2nd United Nations International Symposium held in Geneva, Switzerland, September 1-13, 1958, Vol. 23, (pp. 102-105).

The health hazards from exposures to the dusts of soluble U and Th oxides are strikingly similar in many respects. These insoluble compounds present no chemical hazard; for example the deoxides of U and Th are remarkably inert physiologically. It is difficult to select a proper maximum allowable concentration (MAC) for insoluble U and Th compounds and predictions are made from controlled animal studies and chronic inhalation studies. From the animal studies it is seen that insoluble compounds such as U dioxide and Th dioxide are retained in high concentrations in the lungs of experimental animals and lung burdens increase with increasing air concentrations of dusts. Pulmonary lymph nodes ultimately may contain 30 to 50 times higher concentrations of U dioxide or Th dioxide than those found in lung tissues. From year-long studies of experimental animals inhaling U dusts, the MAC of U has been set at 50 $\mu\text{g}/\text{m}^3$, which is equivalent to 3.3×10^{-11} Ci/l. The same MAC has been suggested for Th 232 but there are suggestions that the Th 232 should be considerably lower than that of U. Results are reported for dogs and monkeys that received excesses of the tolerance rates for UO₂ (2) and yet no signs of injury were found in the lungs or lymph nodes. If it is assumed that the human lung handles UO₂ (2) like the dog lung, it can be calculated that if the individual inhales an atmosphere containing the MAC of U (50 $\mu\text{g}/\text{m}^3$), the pulmonary lymph nodes after 7 years would receive radiation at a rate of 1 rem/week and lungs at about 0.1 rem/week. The MAC therefore holds a considerable margin of safety. Because the rate of removal of ThO₂ from the lung may be much slower than that of UO₂ (2), the same margin of safety for the Th MAC is not guaranteed. (FNN)

Table 2 shows retention of UO₂ (2) in the lungs and pulmonary lymph nodes of dogs and monkeys exposed to 5 μg U/m³ as UO₂ (2) or 5 μg Th/m³ as ThO₂ (2).

<89>

Hyman, C., and R.L. Faldino, University of Southern California, Los Angeles, CA. 1967, December.

Influence of Sex Hormones and Tissues on Colloidal Thorium Dioxide Distribution and Effects in Rabbits. Annals of the New York Academy of Sciences, 145(3), 576-584; CCRP-660422: Distribution, Retention, and Late Effects of Thorium Dioxide, R.L. Swarc (Ed.), Proceedings of a Conference held in New York, New York, April 20-22, 1966, (pp. 576-584), 336 pp. (CCRP-660422).

The role of sex hormones in the modification of reticuloendothelial system response to Thorotrast has been studied in rabbits. The rate of protein escape from the circulation

was determined by spectrophotometric measurement of Evans Blue-labeled albumin in normal male and female animals as well as ones that had undergone ablation. The data presented bear on several related aspects of the interaction between Thorotrast and reticuloendothelial function: They support the argument that particle size of the colloid can significantly modify its influence on RES function. Only Thorotrast particles larger than one micron interfere with the disappearance of labeled protein from the circulation. The mechanism of this blockade is not clear, but may be related to the swelling of the Kupffer cells and consequent interference with perfusion of the liver sinusoids. This Thorotrast effect is not demonstrable in intact male or ovariectomized, hysterectomized, or panhysterectomized female rabbits. Removal of the testes or administration of exogenous estrogen to the ovariectomized animals restores the effect. The failure of the female sex hormone to restore the normal effect of thorium dioxide in animals lacking a uterus is a consistent finding that remains to be explained. Similar sex differences could not be demonstrated in rats; intact animals of both sexes respond in the same way to Thorotrast, and hysterectomy is without influence. Administration of estrogen in this species increases labeled protein disappearance rates in males and females about equally. Adrenalectomy in rats of either sex increased dye disappearance rates also. (Auth) (TC)

<90>

Jee, W.S.S., University of Utah, College of Medicine, Department of Anatomy, Salt Lake City, UT. 1962.

Histopathological Endpoints in Compact Bones Receiving Alpha Irradiation. Some Aspects of Internal Irradiation, T.V. Dougherty, et al (Eds.), Proceedings of a Symposium held at The Homestead, Heber, Utah, May 8-11, 1961. Pergamon Press, Oxford, England, (pp. 95-116), 529 pp.

As part of a study of histopathological changes in bone as a consequence of long term effects of bone seeking alpha emitters, tibial diaphyses from controls and beagle dogs receiving a single intravenous injection of Pu 239, Ra 226, Ra 228, and Th 232 were studied. The results indicated that the turnover rate of the compact of dogs between three and ten years old was slow and constant. Structural changes in compacts containing internally deposited alpha emitters appeared to be dose dependent. High radiation doses altered the circulation, produced bone necrosis and bizarre osteomas, stimulated bone resorption and inhibited bone formation. The increased accumulations of these structures indicated a more rapid turnover rate for the radionuclide bearing dogs when compared to controls. The ratio of canal plugs to blocked vascular channels in damaged compacts was as high as 1:35 as compared to 1:9 for controls. The high ratio was due to damage to main arterial channels supplying cortical bone in the marrow cavities. Time played an important role in that many of the changes were cumulative. Two groups of dogs showed nearly identical damage, although the radiation doses and burden times of radionuclides were 1711 days, 760 rads and 1178 days, 1665 rads, respectively. The circulation factor was mainly responsible for the altered remodeling. The response of compact bone to partial ischemia was massive resorption and endosteal and periosteal bone proliferation

BIOLOGICAL EFFECTS RATIALS

(90) CONT.
resembling changes induced by internally
deposited radionuclides in bone. (57)

(91)
Jee, W.S.S., University of Utah, College of
Medicine, Division of Radiobiology, Department
of Anatomy, Salt Lake City, UT. 1978, March 31.

Injection Tables. C00-119-209; Research in
Radiobiology, W.S.S. Jee, Annual Report of Work
in Progress in the Internal Irradiation Program,
(pp. 9-119), 332 pp. (C00-119-209).

Dogs were put into the toxicity study at
graded injection levels. Each animal received
one radionuclide in a single intravenous
injection at 17 months of age. Twelve such
groups have been injected for each of the six
radionuclides, Ra 226, Pu 239, Ba 220, Th
228, Sr 90, and Am 241. Since the injection
levels were originally specified in "retained"
activities, the actual injections were 4
times the desired retained uCi/kg of Ra 226,
Ba 220, and Sr 90, and 1.11 times the desired
retained uCi/kg of Pu 239, Th 228, Cf 249, Cf
252 and Pu 243 and 248. Injection level 1
was 10 times the maximum permissible
concentration of Ra 226 in man, all other
levels were multiples of level 1.

The tables included the calculated average dose
in rads to the skeleton at death.

(92)
Jee, W.S.S., University of Utah, College of
Medicine, Division of Radiobiology, Department
of Anatomy, Salt Lake City, UT. 1975, March 31.

Research in Radiobiology, Annual Report of Work
in Progress in the Internal Irradiation Program.
(C00-119-250; 201 pp.

Dog studies by the Radiobiology Division
are reported. Contents include a listing of
the availability of previous reports, a
consensus of the bone colony, injection tables
giving the calculated average dose in rads to
the skeleton at death and comments on dead
dogs, and individual topics. Of the
individual topics, 13 were chosen to be input
separately into the data base. Subjects
include plutonium studies of osteogenic
sarcomas, cellular distribution, blood plasma
concentrations, actinide and glycoprotein
interactions, urinary neoplasia, and
intravenous citrate injection. Americium 241
studies include WPA therapy and
deposition. Liver retention of
transuranic elements is included. (89) (C57)

(93)
Jee, W.S.S., University of Utah, Division of
Radiobiology, Department of Anatomy, Salt Lake
City, UT. 1968.

A Critical Survey of the Analysis of Microscopic
Distribution of Bone-Seeking Radionuclides
and Assessment of Absorbed Dose. CONF-688;
STI/P08/80; Assessment of Radioactive Body
Burden in Man, Proceedings of a Symposium held
in Heidelberg, Germany, May 11-16, 1968, Vol. 1,
(pp. 369-393), 1969 pp. (CONF-688, STI/P08/80).

Detailed microscopic dose distribution
studies describe the non-uniform distribution
of radiation in contrast to the assumed
uniform distribution derived from whole-body
retention data. Without some knowledge of
microscopic dose distribution in both space
and time, it is all too easy to reach
incorrect deductions and overlook important

conclusions in attempts to gather comparative
toxicity data. Due to the complexity of the
problem, the published literature of the
measurement of microscopic radiation dose
distribution is very limited. The present
techniques involve autoradiography and are
very laborious. They include track counting
and microdensitometry. A complete
distribution of dose in a given bone in space
and time is an immense task. The microscopic
distribution of bone seekers (Ra 226, Sr 90,
Pu 239, and Th 228) in the skeleton serves as
an excellent illustration of the complexity
of the problem. The initial radiation dose
pattern and the altered patterns with time
are described for Ra and Pu with particular
emphasis on the non-uniformity of the dose
distribution in bones and different sites
within a bone. For example, the maxillary
vertebral trabecular surface deposits of Pu
are 1.5 times better than the maxillary
concentrations on femoral metaphyseal
trabeculae. The ratio of dose-rates of
surface-deposited Pu in various sites within
the distal femur are: metaphyseal trabecular,
3; endosteal, 2.6; epiphyseal trabecular,
1.5; haversian, 1.2; and periosteal, 1. The
maximum localized surface deposit for
vertebral trabeculae is 35 to 65 times
greater than the calculated average wholebody
retention dose-rate. Alteration of the
initial non-uniform localization of Ra and Pu
with time is discussed in relation to the
character of the cellular remodeling of bone
and the loss of radionuclide by long-term
exchange. Finally, an example using local
radiation dose measurement of Pu and Ra with
consideration of volume of cells irradiated
correlated with the whole-body retention and
tumor incidence is used to derive a relative
toxicity of Pu to Ra and demonstrate the
value of some knowledge of microscopic
radiation dose distribution. (auth)

(94)
Jee, W.S.S., 1968; 1967.

The Effects of Radiation on Bone.
PNS-999-PM-33; CONF-670848; Guidelines to
Radiological Health Lectures, Proceedings of an
International Conference held in Montreal,
Canada, August, 1967, (pp. 59-60)
(PNS-999-PM-33, CONF-670848).

Both dysplasia and neoplasia are frequent
consequences of irradiation of the skeleton.
The most efficient bone cancer inducers are
the alpha-emitting bone-seeking
radionuclides. Radium 226, plutonium 239,
radon 220 and thorium 228, produced bone
cancer at dose rates 11 to 18 times those
corresponding to ICRP maximum permissible
body burden for radiation workers. This ratio
is the case of the beta-particle dose from
strontium 90 was found to be even greater and
induced osteosarcomas at an average dose rate
of 530 times the permissible rate. It is
probable that osteosarcomas may occur in
beagles at even lower dose levels and longer
survival times. Relative biological
effectiveness values relative to radium 226-1
are Pu 239-6, Ba 220-3, Th 228-10 and Sr
90-0.6. The actinides, Pu 239 and Th 228,
initially deposit on bone surfaces.
Approximately one-half of their alpha
particles bombard cells and the other
one-half the mineral, thus a large volume of
cells are at risk. (87)

Table 1 gives average values for osteosarcoma in
dogs in the lowest injection levels at which the
neoplasia has occurred.

(44)

PHYSIOLOGICAL ASPECTS OF BONE

(45)

Joe, W.S.S., University of Utah, College of Medicine, Medical Center, Radiobiology Division, Salt Lake City, UT. 1971.

Bone-Seeking Radionuclides and Bones. Pathology of Irradiation, C.C. Serdyja (Ed.), Chapter 11. Williams and Wilkins Company, Baltimore, Maryland, (pp. 146-212). 790 pp.

The chapter is divided into four sections: deposition of radionuclides, radiologically detected changes, histologically detected changes, and induction of malignancy in bone. A summary is given of the deposition of ^{239}Pu , ^{226}Ra , ^{228}Th and ^{90}Sr in bone. The calcium-like radionuclides (alkaline earths) are called volume seekers and deposit in sites identical to Ca in bone. In contrast to this pattern, both ^{239}Pu and ^{228}Th are deposited on bone surfaces and are called surface-seekers. However, radiothorium has a greater variety for reticuloendothelial cells and approximately 25% of the ^{239}Pu deposits in liver. Some of bone changes occurring in beagles following IV injection of ^{226}Ra , ^{239}Pu , ^{228}Th and ^{90}Sr are structural changes in the mandible, destructive changes in the teeth, pathologic fracture with and without healing, distortion of cortical of long bones, disturbance of metaphysical trabeculation, osteolytic rarefaction, rib end demineralization, asperic necrosis and tumor formation. The radioinduced histologic lesions in bones of beagles injected with ^{239}Pu are described and a histopathologic hypothesis of alpha irradiation induced bone dysplasia is presented. Some of the factors which influence the effectiveness of a given radionuclide in the induction of bone malignancy are summarized. It is pointed out that the bone surface-seeking alpha-emitters are more toxic than the bone volume seekers because more of their energy is absorbed in cells and less is absorbed in mineral. The critical of sensitive tissues in the induction of bone tumors and squamous carcinoma is probably the osteoprogenitor cells and basal layers of the squamous epithelium near bone surface. There is tentative agreement, that the current tumor data on man support the threshold dose-response hypothesis. On the contrary, the vice data still support the linear non-threshold dose-response hypothesis. (PST)

Table 11.3 shows the incidence of osteosarcomas and carcinomas following deposition of bone-seeking radionuclides in man.

(46)

Joe, W.S.S., and J.S. Arnold, University of Utah, College of Medicine, Division of Radiobiology, Department of Anatomy, Salt Lake City, UT. 1960.

Effect of Internally Deposited Radioisotopes Upon Blood Vessels of Cortical Bones. Proceedings of the Society for Experimental Biology and Medicine, 105, 351-356.

Adult beagle dogs were injected with ^{239}Pu (1.0 $\mu\text{Ci/kg}$), ^{226}Ra (10.0 $\mu\text{Ci/kg}$), and ^{228}Th (0.9 $\mu\text{Ci/kg}$) to study the effect of internally deposited radioisotopes upon blood vessels of cortical bones. After an extensive latent period following acquisition of plutonium, radiothorium and radium in cortical bone, plugging of the haversian canals occurred which in turn resulted in bone necrosis. Investigation of this phenomenon with a vascular injection technique and a bone-seeking alpha emitter (plutonium) which deposits on surfaces of

haversian canals and allows the remainder of the osteocytes and adjacent interstitial lamellae to be free of activity, showed that death of osteocytes was principally the result of disrupted blood supply rather than direct alpha ray killing. With radiothorium, concentration of alpha particles about haversian canals was sufficient to result in total plugging of the vascular tree within the haversian canals resulting in complete bone necrosis and inhibition of interstitial reconstruction of cortical bone. With radium and plutonium only about half of the canals were plugged, which allowed interstitial reconstruction to proceed; however, the nature of the remodeling in this environment was abnormal (formation of large cavities and abnormal osteons). It is suggested that both devitalization of bone and occurrence of large cavities weakens the bone which in turn results in spontaneous fracturing of long bones. (Ruth) (ST)

(47)

Joe, W.S.S., and J.S. Arnold, University of Utah, College of Medicine, Division of Radiobiology, Department of Anatomy, Salt Lake City, UT. 1963, August.

Radioisotopes in the Teeth of Dogs. 1. The Distribution of Plutonium, Radium, Radiothorium, Radiothorium, and Strontium and the Sequence of Histopathologic Changes in Teeth Containing Plutonium. Archives of Oral Biology, 7, 215-238.

Jaws and teeth containing radioisotopes from adult beagles were studied to determine the location of the activity and the sequence of histopathologic changes. Radioautography after a single intravenous injection of bone-seeking radioisotopes (plutonium, radium, radiothorium, radiothorium and strontium) in young adult beagles yielded the same distribution patterns in dental tissues. The sequence of changes observed in dogs injected with plutonium (specially sacrificed dogs and dogs allowed to live until moribund) involve the formation of secondary dentine, disturbance in cementum formation, resorption of cementum and dentine with metaplastic bone formation, damage to periodontal membrane, ankylosis of teeth and loss of teeth. There was a direct relationship between the sites of plutonium deposits and locations of dental lesions. No tumor arose from dental tissue, but a few osteogenic sarcomas occurred in the jaws. (Ruth)

(48)

Joe, W.S.S., and J.S. Arnold, University of Utah, College of Medicine, Division of Radiobiology, Department of Anatomy, Salt Lake City, UT. 1960, March 31.

The Effect of Internally Deposited Radioisotopes Upon the Blood Vessels of Cortical Bone. COO-220: Research in Radiobiology, Annual Report of Work in Progress on the Chronic Toxicity Program, T.V. Dougherty, (pp. 150-165), 225 pp. (COO-220).

The mid-diaphyses of tibiae from four normal and twenty-three beagles that died or were sacrificed from 1 to 1720 days following the administration of radium 226 (10.0 $\mu\text{Ci/kg}$), plutonium 239 (3.0 $\mu\text{Ci/kg}$) and radiothorium 228 (0.9 $\mu\text{Ci/kg}$) were studied. The young adult beagles of mixed sexes between 10 and 20 months were administered a single IV injection of the radionuclides. The injection solutions were prepared in citric-sodium citrate buffer, 0.08 M in total citrate and

(58) CONT.

pH 3.5. It was observed that after an extensive latent period following the acquisition of plutonium, radiothorium and radium in cortical bone, plugging of the Haversian canals occurred which, in turn, resulted in bone necrosis. Investigation of this phenomenon with a vascular injection technique and a bone-seeking alpha emitter plutonium which deposited on surfaces of Haversian canals and allowed the remainder of the osteons and adjacent interstitial lamellae to be free of activity, showed that the death of osteocytes was principally the result of disrupted blood supply and not from direct alpha ray killing. With radiothorium, the concentration of alpha particles about Haversian canals was sufficient to result in total plugging of the vascular tree within the Haversian canal, resulting in complete bone necrosis and inhibition of internal reconstruction of cortical bone. With radium and plutonium only about half of the canals were plugged which allowed internal reconstruction to proceed; however, the nature of the remodeling in this environment was abnormal (formation of large cavities and abnormal trabeculae). It was also suggested that both the devitalization of bone and the occurrence of large cavities weakened the bone which, in turn, resulted in the spontaneous fracturing of long bones. (Auth) (PUB)

(59)

Joe, W.S.S., J.S. Arnold, T.R. Cochran, J.A. Tumeo, and P.S. Nical, University of Utah, College of Medicine, Division of Radiobiology, Department of Anatomy, Salt Lake City, UT. 1967.

Relationship of Microdistribution of Alpha Particles to Canopy. Some Aspects of Internal Irradiation. T.P. Dougherty, et al (Eds.). Proceedings of a Symposium held at The University of Utah, Salt Lake City, UT. 1967. Pergamon Press, Oxford, England, (pp. 27-45), 529 pp.

Studies by autoradiography of the distribution of plutonium, radium, radiothorium, and radiothorium, the relationship of distribution to damage, and the consideration of dose parameters in relating dose to damage are summarized. Adult beagles were used to study the histological changes and incidence of tumors over a wide range of radiation doses. The pattern of distribution of Th 228 and Pu 239 was similar. The initial deposits were on mineralized bone surfaces and in the reticuloendothelial system. Bone remodeling altered the initial surface deposits by bone resorption and apposition. Radiation injury to the bone vascular system is reviewed and the problems involved in calculating local doses due to differential uptake of isotopes, bone remodeling, and change in cells at risk are discussed. Pu 226 and Pu 228 deposited in high concentration in rapidly calcifying bone matrix beneath osteoblastic surfaces and throughout the pre-existing old bone in areas of more uniform concentration. The deposition of the four radionuclides in tooth was similar. In general, there was a high concentration on newly formed dentinal surfaces of the pulp chamber, an intermediate concentration in the cementum and alveolar bone enveloping the periodontal membrane, and a much lower concentration in the enamel. Most of the initial deposition persisted. In soft tissues generalized vascular changes, nephroclerotic and regenerative liver nodules occurred in high level radiothorium dogs. Concentrations of alpha particles occurred within the aortic media. (57)

(60)

Joe, W.S.S., J.S. Arnold, P. Nical, R. Lowe, and J. Tumeo, University of Utah, College of Medicine, Division of Radiobiology, Department of Anatomy, Salt Lake City, UT. 1966, March 31.

Radiolabeled Isotopes in Dog Teeth. 1. The Distribution of Plutonium, Radium, Radiothorium, Radiothorium and Strontium and the Sequence of Histopathologic Changes in Teeth Containing Plutonium. COO-220: Research in Radiobiology, Annual Report of Work in Progress on the Chronic Toxicity Program, T.P. Dougherty, (pp. 99-103), 225 pp. (COO-220).

Dental tissues and jaws from forty-two adult beagles injected with a single intravenous dose of radium 226 (3.57-10.8 uCi/kg), plutonium 239 (0.26-3.30 uCi/kg), radiothorium 228 (9.97-10.1 uCi/kg), radiothorium 228 (0.89 uCi/kg) or strontium 90 (91.6-111.0 uCi/kg) were studied. The autoradiograms of the undecalcified sections of teeth and their supportive structures revealed that plutonium and radiothorium localized in high concentration on the surfaces of dentine and root canals of the pulp cavities and to a lesser degree at the surface of cementum and bone while radium, radiothorium and strontium were deposited intensely on the newly calcified surfaces of dentine, root canals, cementum and bone and, to a lesser degree and diffusely, in old bone. The dental lesions in 13 dogs injected with 3.0, 0.9 or 0.77 uCi/kg and 15 serially sacrificed dogs injected with 3.0 uCi/kg of plutonium were studied by collidine and radiographic methods. The sites of plutonium localization were observed to approximate the sites of roentgenographic and histopathologically detectable lesions. The lesions induced by the isotope included early changes in the formation of secondary dentine, death of cementoblasts and cementocytes, disappearance of cementoid tissue, apposition of abnormal cementum and resorption of cementum, dentine and alveolar bone. The late changes involved equivocal vascular disturbance, damage of periodontal ligament, fusion of bone to teeth (ankylosis), replacement of dentine by lamellar bone, cementum or gingiva and loss of teeth. A comparison of the relative toxicities of 3.0, 0.9 and 0.77 uCi/kg of injected dose of plutonium on dental tissue and supportive structures found that the changes were dose dependent. No tumor was observed arising from dental tissue but one osteogenic sarcoma occurred in the mandible of an animal given plutonium. The abnormal radioresistance of the odontoblasts under intense alpha ray bombardment and the sequence of histopathologic changes in teeth and the relationship of absorbed dose in rads to dental lesions were also discussed. (Auth)

(61)

Joe, W.S.S., R.H. Bartley, W.L. Dockett, J. Yee, and G.H. Kasper, University of Utah, College of Medicine, Division of Radiobiology, Department of Anatomy, Salt Lake City, UT. 1969.

Vascular Changes in Bones Following Bone-Seeking Radionuclides. COO-67030: Delayed Effects of Bone-Seeking Radionuclides, C.F. Hays, et al (Eds.), Proceedings of a Symposium held in San Valley, Idaho, September 12-14, 1967. University of Utah Press, Salt Lake City, Utah, (pp. 417-455), 519 pp. (COO-67030).

Vascular changes in bones from beagles burdened with bone-seeking radionuclides were studied by polar counting microphotographs

<101>

OROLOGICAL ASPECTS RESULTS

<101> CBT.

measured 70 times of areas of compacta and spongy bone of India ink-gelatin injected metatarsal. Significant vascular reduction occurred in the compacta (injected dose, days post injection, and accumulated dose) with 1.1 uCi/kg, 1900 days, and 2300 rads for Ba 226; 0.036 uCi/kg, 2200 days, and 350 rads for Pu 239; 0.17 uCi/kg, 2500 days, and 500 rads for Ba 226; 0.032 uCi/kg, 1900 days, and 250 rads for Th 228; and 100 uCi/kg, 1000 days, and 8000 rads for Sr 90. One dog receiving 0.005 uCi Th 228/kg had decreased vascularity after 1959 days and 64 rads. The lowest injected doses in uCi/kg with vascular depression in spongy bone (metatarsal metaphysis) were 1.1 for Ba 226, 0.016 for Pu 239, 0.17 for Ba 226, 0.019 for Th 228, and 32 for Sr 90. Lower vessels per unit area (mu/vu2) was the most sensitive measurement of depressed vasculature followed in order of decreasing sensitivity by percent of vessels recruited to bone, to area, and to marrow. (Auth)

<102>

Joe, W.S.S., T.R. Cochran, and R. Nical, University of Utah, College of Medicine, Division of Radiobiology, Department of Anatomy, Salt Lake City, UT. 1960, March 31.

Microscopic Distribution of Plutonium 239 and Thorium 228 in Beagles. COO-220; Research in Radiobiology, Report of Work in Progress on the Chronic Toxicity Program, T.F. Dougherty, (pp. 100-109), 225 pp. (COO-220).

Mineralized and soft tissues from young beagles that died or were sacrificed from 1 to 1125 days after the administration of a single intravenous injection of either plutonium(239) or radiothorium citrate (0.09 to 2.5 uCi/kg) were studied by radioautography. Microscopic distribution of radiothorium and plutonium in bone, teeth and calcified cartilage was observed to be similar. Calcified bone surfaces and diffusely in calcified cartilages while the deposition patterns in soft tissues were quite different. Radiothorium was located in the reticuloendothelial cells of all tissues and had a special affinity for blood vessels, kidney and lung. Plutonium differed from the microscopic distribution of radiothorium in that it deposited diffusely and intensely in the liver and had little or no avidity for lung tissue. (Auth) (PBR)

<103>

Joe, W.S.S., G.A. Kenner, W.H. Bartley, S.L. Cochran, R. Sob, R. Mueller, and R. Scheffrahn, University of Utah, College of Medicine, Division of Radiobiology, Department of Anatomy, Salt Lake City, UT. 1967, March 31.

Preliminary Report: Changes in Vascularity of Cortical Bones Induced by Bone Seeking Radionuclides. COO-119-236; Research in Radiobiology, Annual Report of Work in Progress in the Internal Irradiation Program, T.F. Dougherty, (pp. 97-123), 268 pp. (COO-119-236).

A technique of India ink-gelatin injected vessel hits per unit area of metatarsal shaft was used to determine the alteration in vascularity induced by graded, single intravenously injected dose of Pu 239, Ba 226, Th 228, Ba 226 or Sr 90 in adult beagles. Percent of cross sectional area of bone with vascular channels was 11.4 plus or minus 1.05 in 529 to 3946 day old controls. The reduction in vascularity was dose and time dependent. Significant reduction in

vascularity occurred at: 1.1 uCi of radium 226/kg after 1900 days and 2300 rads, 0.096 uCi of plutonium 239/kg after 2200 days and 350 rads, 0.17 uCi of neptunium 228/kg after 2500 days and 500 rads, 0.032 uCi of radiothorium 228/kg after 1900 days and 250 rads, 100 uCi of strontium 90/kg after 1000 days and 8000 rads. The values for estimates of the accumulated dose necessary for the reduction in vascularity to manifest themselves are as follows: 0.06 uCi of radium 226/kg and 260 rads, 0.016 uCi of plutonium 239/kg and 100 rads, 0.00162 uCi of radiothorium 228/kg and 10 rads, 32 to 100 uCi of strontium 90 and 7000 rads. (Auth)

Figure 5 shows effect of graded doses of Pu 239 on percent vascularity of bones of dogs as a function of accumulated dose.

<104>

Joe, W.S.S., P. Ottosen, R. Nical, and W. Love, University of Utah, College of Medicine, Division of Radiobiology, Salt Lake City, UT. 1957, March 31.

Bone: Histopathologic and Autoradiographic Findings. AECU-3522; Annual Progress Report, (pp. 86-110), 177 pp. (AECU-3522).

This preliminary report deals with the histologic survey of 47 beagles reaching autopsy to date. This includes 43 toxicity and 4 normal dogs. A brief summary and discussion of the important histopathologic findings are presented. The findings show that the four alpha emitters, plutonium, neptunium and radiothorium, and radium, produce identical types of histopathologic bone changes. These detectable changes are disturbances in normal bone metabolism which alter the normal microscopic architecture of bone. They fall under four major categories: 1) response to alpha emitters by endosteal and bone marrow cells 2) disturbance in normal bone growth 3) disturbance in normal bone remodeling or reconstruction and 4) formation of osteogenic sarcoma. The detail autoradiographic studies are in progress and will be summarized in the next report. (ICU)

Table 1 gives the positive histopathological findings in autopsied beagles for Pu, Ba, ThTh and SrTh. Table 2 gives the number of fractures, teeth lost and microscopic identification of osteogenic sarcoma found at autopsy in beagles which survived more than six months after isotope administration for Pu, Ba, ThTh, SrTh and Sr.

<105>

Johansen, C., Bispebjerg Hospital, Copenhagen, Denmark. 1967, December.

Tumors in Rabbits after Injection of Various Amounts of Thorium Dioxide. Annals of the New York Academy of Sciences, 105(3), 724-727; COOP-66022; Distribution, Retention, and Late Effects of Thorium Dioxide, E.L. Soren (Ed.), Proceedings of a Conference held in New York, New York, April 20-22, 1966, (pp. 724-727), 336 pp. (COOP-66022).

Thorotrast, intravenously injected into rabbits, induced disseminated reticuloendotheliomas in approximately two years. Perivascular deposits may give rise to local, metastasizing fibrosarcomas. Endometrial carcinoma was probably not directly provoked by the thorium, but was more likely a phenomenon of aging. Other tumors were considered accidental findings. (Auth) (VC)

BIOLOGICAL ASPECTS
ANIMALS

<106>

Justy, J., and S. Iush, Water Research Institute, Prague, Czechoslovakia; Czechoslovak Academy of Sciences, Institute of Vertebrate Zoology, Brno, Czechoslovakia. 1976.

Evaluation of Natural Radionuclide Contamination of Fishes in Streams Affected by Uranium Ore Mining and Milling. *Zoologické Listy*, 25(3), 265-270.

Increased U and Pa content was found in the twelve selected locations as compared with their natural background. Data are given for the actual status of contamination of the fish biomass and water in selected sections of the streams as well as comparisons of the Pa 226 content in water, non-soluble compounds, aquatic organisms, and bottom sediments; the fish biomass accumulated by one to four orders of magnitude less Pa and U, as compared with their total content in water. A positive correlation was found between the duration of fish exposure (age) and U content in their bodies. Smaller amounts of Pa 226 and U were deposited in muscle than in bones and intestines. Present levels of Pa and U contamination of brown trout do not present a hazard for human consumption. However, it is desirable that the accumulation of natural radionuclides be monitored in those areas where increased mining and/or milling is expected. (BAP)

<107>

Wabisch, W.T., American Association for the Advancement of Science, Washington, DC; University of Chicago, Department of Anatomy, Chicago, IL. 1967, December.

Phagocytosis of Colloidal Thorium Dioxide and Cobaltic Oxide by the Paticuloendothelial System of the Rat. *Annals of the New York Academy of Sciences*, 105(3), 585-590; CONF-660422; Distribution, Retention, and Late Effects of Thorium Dioxide, R.L. Sears (Ed.), Proceedings of a Conference held in New York, New York, April 20-22, 1966, (pp. 585-590), 336 pp. (CONF-660422).

Phagocytic characteristics of the several macrophagic organs were quantitatively studied in terms of dose-response (Morse-uptake) 24 hr after IV injection of Thorotrast in Wistar rats. After doses of 1.0 ml/kg body weight, mean counts/min $\pm$ 10 ($\pm$ 3)/g tissue for liver and spleen were 5.61 and 19.19 as compared with values of 9.50 and 44.76 after 5.44 ml/kg body weight. Animals were injected with different doses up to about 6 ml/kg and killed the next day. Liver had greater phagocytic activity than the other organs. With increasing dose, uptake by spleen and lungs increased. In terms of uptake/g tissue, at low doses, liver and spleen activity were similar, but with higher doses, spleen uptake increased and that of the liver leveled off. Lung activity, low at low doses, increased with highest doses. Bone marrow activity was similar to that of lung. The significance and implications of the presence of dialyzable radioactivity as well as the decay pattern of thorium are discussed. Circulatory dynamics can help explain the differences in uptake. Particle size may also be important. Removal of portions of phagocytic organs was done to see if changes in phagocytic uptake patterns might occur. Splenectomized rats showed no striking changes, while hepatectomized rats showed increased uptake by spleen, lung, bone marrow, and lymph nodes. These same organs, in rats which had combined procedures also showed increased uptake. The liver remained

the most effective phagocytic organ. Experiments with cobaltic oxide as the test substance supported the Thorotrast findings except that bone marrow and lymph nodes at highest doses did not regularly show significant radioactivity. (VC)

<108>

Karbo, L., C. Schmier, and H.O. Sievers, Institut fuer Hydrobiologie und Fischereiwissenschaft, Universität Hamburg, Hamburg, German Federal Republic; Institute fuer Physik, Gesellschaft fuer Fernenergieerwertung in Schiffahrt mbH, German Federal Republic. 1977.

Trace Elements in Mussels (*MYTILUS EDULIS*) from Coastal Areas of the North Sea and the Baltic. Multielement Analysis Using Instrumental Neutron Activation Analysis. *Journal of Radioanalytical Chemistry*, 37, 927-943.

Samples of the mussel *MYTILUS EDULIS* were collected from different sites of estuarine and coastal areas of the North Sea and the Baltic. The following elements were determined by instrumental neutron activation analysis: Ca, Sc, Cr, Fe, Co, Ni, Zn, As, Se, Br, Rb, Sr, Zr, Ag, Cd, Sn, Cs, Ba, Ta, Eu, Tb, Yb, Hf, Au, Hg, Th. Multielement correlation analysis was used for the evaluation of the data. Differences in trace element patterns are found and described calculating trace element ratios. Regional differences in trace element concentrations are superimposed by typical seasonal variations, with highest concentration levels found in late winter and spring, and lowest in summer and autumn. (Auth)

<109>

Shurkar, D.P., J. Thomson, K.K. Turekian, and S.O. Forster, Yale University, Department of Geology and Geophysics, New Haven, CT; Puerto Rico Nuclear Center, Mayaguez, Puerto Rico. 1976, March.

Strontium and Thorium Decay Series Nuclides in Plankton from the Caribbean. *Limnology and Oceanography*, 21(2), 290-299.

Zooplankton (predominantly calanoids and cyclopoids) from the Caribbean were analyzed for Th 230, U 234, Th 232, Th 228, Ra 226, Ra 228, Pb 210, and Po 210. The concentration factor in the zooplankton relative to seawater is highest for Po 210. Pb 210 and Th 228 have similar concentration factors and are comparable (when normalized to Ra 226) to reported fiber-scavenging experimental data on Pb 210 and Th 230. The average concentration factor relative to Ra 226 was calculated to be about 1). The dominant transport agent for Po 210 and Pb 210 from the mixed layer to depth cannot be unmodified zooplankton debris. Significant geographic differences were found in the concentrations of Ra 226 and Pb 210. (BAP)

<110>

Nisleski, W.E., S.G. Faraglas, and W.P. Morris, Argonne National Laboratory, Argonne, IL. 1950, November.

The Retention and Distribution of Uranium 233 in Mice. *ANCO-3057*; 2 pp.; ANL-4537; Division of Biological and Medical Research, Quarterly Report, August, September, October, 1950, (2 pp.), 199 pp. (ANL-4537).

In conjunction with the chronic toxicity program in the Biology Division the

<110>

BIOLOGICAL ASPECTS
MURALS

<110> CONT.

Radiochemistry Group undertook the study of the metabolism and organ distribution of ^{233}U injected intravenously in mice. The animals used for the study were CF 1 female mice, weighing approximately 25 g. The ^{233}U was injected intravenously via the tail vein at dose levels of 0.05 and 0.005 $\mu\text{Ci/g}$. Animals were sacrificed at intervals of 30 min, 1, 3, and 6 hours, and 1, 3, 10, 30, and 60 days. The organs taken for retention analysis were pelt, kidneys, soft tissues, liver, bladder, and carcass. The alpha measurement of the organs was made by drying and ashing the samples, dissolving the ash in HNO_3 and measuring aliquots on platinum discs. The discs were alpha counted on a parallel plate ionization chamber. By use of calibration data, the observed counts were corrected for mass absorption effects. The major portion of the injected material was rapidly excreted: about 56% was retained at 1 to 6 days and only about 20% at 6 days. This was true regardless of the amount injected. The excretion seemed to be mainly via the kidneys. The bone was the principal site of deposition, 7% of the injected dose was found in the femur as early as 30 min after injection, and this remained constant up to the 60-day interval. The kidneys also accumulated a sizable portion of the injected dose and contained 80% at 30 min. However, they retained only 1% after 60 days. The distribution of ^{233}U is similar to that of ^{238}U in that both accumulate principally in the bone and kidneys. It may be expected that chemical or radiation damage by ordinary uranium and the isotopes thereof would be mainly in these organs. After completion of the 129-day interval analysis a more detailed discussion of the problem and data will be prepared. (Complete Text)

<111>

Sisilewski, S.R., S.G. Pradhan, and S.P. Morris, Argonne National Laboratory, Division of Biological and Medical Research, Chicago, IL. 1950.

Progress Report: The Retention and Distribution of Uranium 233 in Mice. ANL-4531; Biological and Medical Research Division Quarterly Report, August, September, October, 1950, A.N. Bruce (Ed.), (pp. 190) (ANL-4531).

Female mice were injected intravenously with ^{233}U at dose levels of 0.05 and 0.005 $\mu\text{Ci/g}$. Animals were sacrificed at intervals of 30 min, 1, 3, and 6 hr, and 1, 3, 10, and 60 days. Pelt, kidneys, soft tissues, liver, bladder, and carcass were measured for alpha activity. The major portion of injected material was rapidly excreted: about 50% was retained three to four days, 20% six days regardless of dose. The bone and kidneys were the principal sites of deposition. (RAP)

<112>

Kuriyandskaya, E.B., 1970.

Certain Aspects of the Toxicology of Insoluble Compounds of Thorium 232 and Uranium 238. The Toxicology of Radioactive Substances: Thorium 232 and Uranium 238, Vol. 4. A.A. Letavet and E.B. Kuriyandskaya (Eds.). Pergamon Press, New York, New York, (pp. 1-8), 184 pp.

The chapter reviews toxicology of ThO_2 (^{232}Th) and urano-uranic oxide, U_3O_8 (^{238}U) administered by various routes to animals. Effects on blood, lungs, liver, and bone suggest that ThO_2 possesses low chemical toxicity since no marked changes occur soon

after administration. The late effects on these organs correspond to those produced by irradiation with different sources. Because of the late effects and appearance of neoplasms, ThO_2 is one of the most toxic radioactive substances. Results of studies using ^{238}U suggest that this compound has low, but marked short term toxicity. Studies were not long enough to demonstrate radiation effects which might appear at later stages. The early biological effects of both Th^{232} and ^{238}U result from their chemical toxicity and later ones from radioactivity. (Auth) (VC)

<113>

Kuriyandskaya, E.B., 1970.

The Effect of ^{238}U on the Body of the Pregnant Female and the Fetus. The Toxicology of Radioactive Substances: Thorium 232 and Uranium 238, Vol. 4, A.A. Letavet and E.B. Kuriyandskaya (Eds.). Pergamon Press, New York, New York, (pp. 109-119), 184 pp.

Following oral or intratracheal administration to the pregnant animal of practically insoluble ^{238}U , uranium was found in the placenta and tissues of the embryo. Uranium was found in the milk of lactating animals and in the tissues and urine of the puppies and young rabbits fed on the milk of the poisoned mother. Chronic exposure of animals to ^{238}U has an effect on their littering capacity and also on the intruterine and early extrauterine development of the young rabbits and puppies. (Auth)

<114>

Leach, L.J., C.L. Felle, H.C. Hodge, G.E. Sylvester, and E.B. Wilson, University of Rochester, Department of Radiation Biology and Biophysics, School of Medicine and Dentistry, Rochester, NY. 1973, September.

A Five Year Inhalation Study with Natural Uranium Dioxide (UO_2) Dust. Postexposure Retention and Biologic Effects in the Monkey, Dog and Rat. Health Physics, 25, 239-258.

Inhalation studies show that dogs, monkeys and rats can breathe a natural uranium dioxide (UO_2) aerosol of approximately 1 μm mass median particle diameter (MMAD), at a mass concentration of 5 mg $\text{U}/\text{cu m}$ (25 F TLV - 200 mg natural $\text{U}/\text{cu m}$ or 20 F MPC - 180 mg natural $\text{U}/\text{cu m}$) for periods as long as 5 yr with little evidence of serious injury. Some of these animals were observed for protracted postexposure periods during which pulmonary neoplasia developed in a high percentage of dogs examined 2-4 hr after exposure. Pulmonary and tracheobronchial lymph node fibrosis, consistent with radiation effects, apparently dose dependent, and were marked in monkeys than in dogs was also noted. No evidence of uranium toxicity was found in records of body weights, mortality, various hematologic parameters or the histologic condition of the kidneys. (Auth)

<115>

Letavet, A.A., E.B. Kuriyandskaya, A. (Translator) Crozy, and G.W. (Translator Ed.) Dolphin, 1970.

The Toxicology of Radioactive Substances, Volume 4, Thorium 232 and Uranium 238. Pergamon Press, New York, New York; 184 pp.

The volume includes chapters on comparative toxicity of insoluble and soluble compounds

ECOLOGICAL ASPECTS
ANIMALS

<115> CONT.

of thorium 232 and uranium 238, absorption, distribution and excretion of natural Th compounds, behavior and effects of thorium dioxide in rats, determination of Th in biologic materials, and the effects of uranoous-uranoic oxide (U3O8). The 12 chapters have been separately included in the data base. (VC)

<116>

Lindenbaum, A., J. Lafont, H.G. Rosenthal, H.S. Snyder, R.H. Taylor, R.C. Thompson, R. Izawa, Ye.I. Fopstalev, and J. S. Vaughan, International Commission on Radiological Protection. 1972, Pay.

The Metabolism of Compounds of Plutonium and other Actinides. ICRP Publication 19: 59 pp.

This document is a compilation of the major information available up to about January, 1971 dealing with the deposition of actinides in the animal following ingestion or parenteral administration. The compilation of metabolic data provides a general review for those studying metabolism and therapy and for those concerned with establishing radiological limits for organ and whole body contamination. The common physical and chemical properties of these compounds are delineated to show deposition patterns and distribution in animals. The report deals mainly with Pu compounds; few data on other actinide compounds are available. The emphasis on Pu reflects the general consensus that, in terms of amounts available, projected usage, and radiotoxicity, Pu is the most formidable radionuclide in the periodic table. The section on inhalation reviews those aspects of Pu metabolism in which deposition, retention and translocation may be altered by exposure to different physical-chemical forms of Pu. Other notable points follow. In the body the tendency toward polymerization is strong and "monomeric" Pu undoubtedly is converted to at least a slightly polymeric form. It is the colloidal and particulate character of actinides in tissues that provides the basis for differences in physiological behavior as compared with divalent alkaline earths. The chemical form after administration is obscure. Hydrolysis of Pu nitrate in the tissues may lead to formation of a hydrated and polymeric form of Pu hydroxide, or perhaps a sized salt. At low concentration there is no evidence of change in chemical form except for the phenomena of hydrolysis and polymerization. Specific subjects addressed are: chemistry with reference to biological behavior; inhalation of Pu; absorption of Pu and related elements from gastrointestinal tract and through skin; entry by injections or wounds and tissue distribution; retention of actinides. Studies of Th absorption in rats, guinea pigs and man are briefly reviewed. Percentages of doses absorbed were 0.07 for man, 0.7 in the guinea pig, and varied from 0-0.07 in the rat. (VC)

<117>

Lindenbaum, A., and J. Schubert, Argonne National Laboratory, Division of Biological and Medical Research, Lemont, IL. 1960, August 13.

Sustained Action of Injected Chelating Agents. Nature, 187(4737), 575-576.

Measurement of the ultrafilterability of tissue deposits of various radionuclides was made following treatment of animals with

chelating agents. The calcium salt of EDTA (315 mg/kg body wt. as the acid form) or saline was given intraperitoneally to rats three days after a single intravenous injection of a solution containing 35 µg Pu 239 in 1 percent sodium citrate at pH 5-6. The rats and their saline controls were killed at intervals of 1, 2, 3 and 7 days after injection. The ultrafilterability of Pu from the bone, liver, and plasma was measured. It was evident that Pu deposited in the tissues had been rendered diffusible by the chelating agent and that the diffusibility remained ten or more times greater than that of the control animals for at least 7 days after a single injection of Pu. The effectiveness of EDTA relative to EDTA in promoting the ultrafilterability of Pu was tested using plasma and heparinized whole blood. The Pu was injected intravenously into rats and 2 ml of blood was withdrawn 15 min later. Solutions of the chelating agents were added to the whole blood or to plasma to provide final concentrations ranging from 10(E-4) to 10(E-5) M. The superiority of EDTA over EDTA was shown by the sharper rise in the Pu content of the ultrafiltrates at concentrations of chelating agent in the range 10(E-4) to 10(E-5) M. Similar experiments were made with thorium using Th 230 as a tracer. A similar superiority of EDTA over EDTA in accelerating the excretion of Th from rats was demonstrated. (FWW)

<119>

Lucas, R.F., D.B. Waddington, and F.J. Colby, Argonne National Laboratory, Radiological Physics Division, Argonne, IL; Bureau of Commercial Fisheries, Great Lakes Fishery Laboratory, Ann Arbor, MI. 1970.

Concentration of Trace Elements in Great Lakes Fishes. Canada Fisheries Research Board Journal, 27, 677-686.

The concentration of 15 trace elements was determined by activation analysis of samples of whole fish and fish livers from three of the Great Lakes: Michigan, Superior, and Erie. The average concentrations of 7 elements in 19 whole fish from 3 species were as follows: U, 3 ppb; Th, 6 ppb; Co, 78 ppb; Cs, 94 ppb; As, 16 ppb; Cr, 1 ppm; and Cu, 1.3 ppm. The average concentrations of 8 elements in 40 liver samples from 10 species of fish were as follows: U, about 2 ppb; Th, about or less than 2 ppb; Co, 40 ppb; Cs, 9 ppm; As, 39 ppm; Br, 2.6 ppm; As, 30 ppb; and Cl 0.1 ppm. Other elements observed in most of the samples were: Sb, Se, La, Ba, Pb and Sn. Trace element concentrations varied with species and lake. Uranium and thorium varied with species, but not for the same species from different lakes. The levels of Co, Cs, Zn and Br varied little between species and lakes. The concentration of Cd, As, and Cr varied between species and with species between lakes. (auth) (BAP)

<119>

Luz, A., U.A. Mueller, W. Gressner, and W. Nag, Institute of Biology, Society of Radiation and Environmental Research, Neustadt, German Federal Republic. 1976.

Estimation of Tumor Risk at Low Dose from Experimental Results after Incorporation of Short-Lived Bone-Seeking Alpha Emitters Radium 226 and Thorium 227 in Mice. CRRP-751126; IAEA-SR-227/496; Biological Effects of Low-Level Radiation Pertinent to Protection of Man and his Environment, Vol. 2, Proceedings of an

<119>

BIOLOGICAL ASPECTS
RESULTS

<119> CONT.

International Symposium held in Chicago, Illinois, November 3-7, 1975, (pp. 171-181) (CONF-751126, IAEA-SM-202/406).

As a revision of older and recent data of experimental bone-tumor induction in mice after single and repeated incorporation of short-lived Ra 224 and Th 232, the following indications for estimation of tumor risk at low dose can be given. (1) Bone rate has considerable influence on tumor risk following internal irradiation, but the relative increase of risk with decreasing dose rate is dose dependent. (2) At a tumor risk of about 10% the range of incidence in repeated experiments is high. It therefore seems difficult to find the exact dose-effect relationships in low-risk experiments. (3) On the other hand, the lower incidence at lower dose level seems to be, rather, a risk of the second half of lifespan. In addition, the high range of the rate of spontaneously occurring neoplasms at greater age has not permitted exact statements about the whole lifespan. (4) However, one can tentatively assume that it should be possible to find dose limits for the tumor risk during the first half of the lifespan. (5) Besides radiation dose, other cofactors may interfere at the low-dose and low-risk level. There is no significant decrease in osteosarcoma risk if the incorporation period starts after starting of growth. The greater risk in female mice than in males indicates hormones as an example of cofactors for the pathogenesis of osteo-sarcoma. (Auth)

<120>

Fachis, L.J., F.P. Pearson, and C.A. Denton, U.S. Department of Agriculture, Bureau of Animal Industry, Beltsville, MD. 1952.

Relative Toxicity of Lanthanum, Tantalum, and Thorium Compounds in the Developing Chick Embryo. *Archives of Industrial Hygiene and Occupational Medicine*, 6, 481-488.

These studies indicated that lanthanum chloride, thorium chloride, and tantalum hydroxide were not highly toxic to developing chick embryos. The LD 50 values were as follows: lanthanum chloride, 18 mg per egg; thorium chloride, 46 mg per egg; tantalum hydroxide, 88 mg per egg. The toxicity of lanthanum chloride and thorium chloride for the developing chick embryo is of the same order of magnitude as it is when administered intraperitoneally into the growing rat. Hemorrhage was the most prevalent finding among dead embryos. A stiff hock syndrome is described. The incidence of this abnormality in the developing embryo appears to be exaggerated by injections of the thorium and tantalum compounds. An indication that bone metabolism might be disturbed was shown by some occurrence of soft bones in the thorium- and tantalum-inoculated embryos. Microphthalmia, ectopia, and beak deformities were other abnormalities that occurred to a limited extent. (Auth) (VC)

<121>

Makoyeva, L.G., and N.N. Pavlovskaya, 1973.

Metabolism of Thorium Saw Radionuclides in the Body of Rats after Intratracheal Introduction of Soluble Thorium Compound (TNC 18). *Gigiena i Sanitariya*, 38(8), 45-47.

The paper presents data on the rate of resorption in the blood of Th 228 and the products of its dissociation. After

intratracheal introduction of thorium chloride into the body of rats a significant disturbance of radioactive balance was noted to take place in the lungs and other internal organs. (Auth) (MP)

<122>

Makoyeva, L.G., N.N. Pavlovskaya, and T.B. Appich, Jr. (Translator), 1973.

The Metabolism of Radionuclides of the Thorium Family in Organs of Rats upon Intratracheal Introduction of a Dissolved Thorium Compound (TNC18). *OPHL-tr-0097*; 4 pp.; *Gigiena i Sanitariya*, 8, 45-47.

The metabolism of Th 228 and decay products, Ra 228, Pb 212, Bi 212 in rats following intratracheal injection of the soluble salt, ThCl₄ is described. The data obtained by gamma spectroscopy allowed monitoring of changes in content of the Th 232 family radionuclides in organs and tissues. The dynamics of accumulation of these elements were studied and equations characterizing changes in Th 228 and decay products were derived. The radionuclides are removed at various rates from the lungs: 3 hrs after injection 38% of Th 228, 77.5% of Ra 228, 53.2% of Pb 212 and 57.5% of Bi 212 were removed from lungs. Subsequently, the rate decreases. Thorium accumulates slowly in the bones, the maximum level (15.1%) being reached after 3 months. Maximum accumulation has also occurred within that time in the spleen, kidneys and liver. Resorption of Thorium in blood is slower than that for radium and lead; this can be explained by ion hydration theory. Thorium is removed from the lungs with effective half-time of 30-190 days, which is considered moderate retention. (WC)

<123>

Kaye, C.W., and T.P. Dougherty, University of Utah, College of Medicine, Division of Radiobiology, Salt Lake City, UT. 1972, June.

Progress in the Beagle Studies at the University of Utah. *CONF-710919*; Biological Implications of the Transuranium Elements, Proceedings of the 11th Stanford Symposium held in Richmond, Washington, September 27-29, 1971, (pp. 793-801) (CONF-710919); *Health Physics*, 22(6), 793-801.

Young adult beagles are given single intravenous injections of monomeric Cf 252, Cf 249, Am 241, Pu 239, Th 228, Ra 226, or Sr 90 in citrate solution to achieve reproducible deposition patterns in tissue. Injected transuranium atoms become attached to transferrin and other substances in blood plasma. The skeleton and liver are the primary sites of deposition, although high local concentrations of californium, berkelium and americium also occur in the thyroid and kidney, and radium also concentrates in the eye. The initial skeletal deposition of monomeric transuranium elements is on bone surfaces. The mean local dose-rate to the soft-tissue layer 0-10 μ from the mineralized bone surfaces of the beagle is about 20 times higher when Pu 239 is on bone surfaces than for an equal amount of Pu 239 randomly distributed throughout the bone mineral. Thus, the rate of bone-surface remodeling has a very important influence on the skeletal toxicity of the transuranium elements. The initial liver deposition of monomeric transuranium elements is rather uniform and mainly in the hepatic cells. Subsequently, much of the radioactivity shifts into the liver reticuloendothelial

BIOLOGICAL EFFECTS MINIMALS

<123> CONT.

cells that line the sinusoids. At long times after injection, the distribution is very non-uniform, being highest in the portal region and lowest in the regenerative nodules. All, or virtually all, of the life-shortening from sodium and low doses has been due to radiation-induced cancer. Bone sarcomas have been the most frequent form of malignancy, but bone sinus carcinomas, liver tumors, and eye melanomas have also been induced. On the basis of average skeletal dose, 1 rad from Pu 239 is the equivalent of 5-10 rads from Ba 226 in the induction of bone sarcomas. This is because in the skeleton a considerable fraction of the Pu 239 disintegrations occur on bone surfaces near cells, whereas most of the skeletal disintegrations from Ba 226 take place within bone mineral. Plutonium will continue to be the chief interest, not only at low doses, but perhaps at different ages and in different chemical forms. Other radionuclides of practical and fundamental importance will continue to be studied. This is the first experiment in which tumor induction by fission fragments (Cf 252) is being determined. (Auth)

<124>
Bays, C.W., T.P. Dougherty, G.H. Taylor, B.D. Lloyd, B.J. Stover, W.S.S. Jew, B.E. Christensen, J.S. Dougherty, and D.S. Atherton, University of Utah, Division of Radiobiology, Department of Anatomy, Salt Lake City, UT. 1969.

Radiation-Induced Bone Cancer in Beagles. CCRP-670938; Delayed Effects of Bone-Seeking Radionuclides. C.W. Bays, et al (Eds.), Proceedings of a Symposium held in San Valley, Idaho, September 12-14, 1967. University of Utah Press, Salt Lake City, Utah, (pp. 367-400), 519 pp. (CCRP-670938).

Osteosarcomas have been the chief cause of death in adult Beagles injected intravenously with bone-seeking radionuclides in citrate solution. The effectiveness of these nuclides depends on the type of radiation emitted and where this radiation is absorbed. Alpha radiation is more effective than beta radiation, and the alpha emitters which deposit on bone surfaces are more effective than those which deposit throughout bone volume. For death with osteosarcomas 8 years after injection, values for RBE (relative biological effectiveness) based on the average skeletal doses in rads a year before death and relative to Ba 226 = 1 are: Pu 239 = 6; Th 228 = 8; Ba 226 (RnTh) = 2.5, and Sr 90 = 0.07 to 0.24. (Auth)

Figure 6 shows the survival time vs dose for osteosarcoma beagles.

<125>
Bays, C.W., and K.A. Sears. University of Utah, Salt Lake City, UT. 1962, September.

Determination of Localized Alpha Dose III from Surface and Volume Deposits of Plutonium 239, Thorium 228, and Radium 226. COO-226; Semi-Annual Report of Work in Progress on the Chronic Toxicity Program, T.P. Dougherty (Ed.) (pp. 78-85), 135 pp. (COO-226).

The ranges of alpha particles of various energies in several different media are presented. Formulas are given for expressing the average dose rate to the 10 micron layer of soft tissue adjacent to a flat uniformly contaminated surface or volume. These formulas are applied to the localized

dosimetry of plutonium 239, thorium 228, and radium 226. (Auth)

<126>

Bays, C.W., B.J. Stover, B.W. Glad, and D.S. Atherton, University of Utah, College of Medicine, Division of Radiobiology, Salt Lake City, UT. 1959, March 31.

Skeletal Dosimetry in Utah Beagles. COO-218; Annual Progress Report, C.W. Stover, Jr. (Ed.), (pp. 121-145), 224 pp. (COO-218).

Values for the skeletal retention of Pu radiothorium and strontium in beagles were obtained. Equations were developed for the average skeletal radiation exposure at any time after injection in units of rads/day, rads, and rad-days. Values were plotted for a 1-level dog in each toxicity group. (Auth) (PBN)

<127>

Bays, C.W., and A.D. Tweller, University of Utah, Salt Lake City, UT. 1964, March.

Determination of Localized Alpha-Dose IV in Soft Tissue Near Radioactive Bone. COO-119-229; Annual Report of Work in Progress on the Chronic Toxicity Program, T.P. Dougherty (Ed.), (pp. 199-205), 213 pp. (COO-119-229).

Dose-rates are calculated for the soft tissues close to flat radioactive bone mineral containing plutonium 239; thallium 220 or radium 226 on its surface or throughout its volume. The dose-rates are evaluated at various distances from the contaminated bone. (Auth)

Table 2 shows average dose-rates in rads per day within 10 micron bands for volume deposits of plutonium 239, for thorium 228 and daughters, and for radium 226 and daughters.

<128>

McLean, F.C., and A.H. Rudy, University of Chicago, Department of Physiology, Chicago, IL. 1960.

Radiation, Isotopes, and Bone. Academic Press, New York, New York; 216 pp.

The book deals with radiation in all its aspects in relation to bone. A considerable amount of material concerning the physiology and biochemistry of skeletal tissue is included. The pathology of the effects of radiation, as well as the use of tracer amounts of radioisotopes in the study of pathological physiology are given consideration. The properties that lead radioisotopes to seek bone and to remain deposited therein are discussed. A few isotopes, more particularly some of the alkaline earths, including Ba, Sr and several of the isotopes of Ca, may substitute for stable Ca in the mineral of the bone and once deposited there may remain fixed indefinitely. Others, such as P, Y, and Th are deposited in the bone matrix rather than in the mineral, but they also may remain in the skeleton for long periods of time. Natural radioactivity, radioactive fallout and removal of radionuclides, including Pu, Th, Y, and Ce, from bone by chelates or carriers are also discussed. (PBN)

<129>

McNeill, H.G., H.A. Rab Holla, and J.E. Harrison, University of Toronto, Departments of

<129>

**BIOLOGICAL EFFECTS
IN ANIMALS**

<129> CONT.

Physics and of Medicine, Toronto, Ontario, Canada. 1973, April.

Distribution of Thorium Series Nuclides in Beagles after Intraspinal Thorotrast Injection. *Health Physics*, 20, 403-409.

Thorotrast (approximately 2 ml) has been injected intraspinal and intravenously into adult beagle dogs. Excretion rates of thorium daughters have been measured; distributions of thorium and its daughters in the dogs have been measured at times between injection and sacrifice ranging from 1 to 550 days. A significant but variable amount (10-60%) of the thorium escapes from the spinal cord and is picked up by the RES, largely by the liver. The "wash-out" of thorium daughters from Thorotrast retained in the CNS was similar to that from Thorotrast localized in the RES following i.v. injection--thus kinetic parameters derived from i.v. data can be used in calculating doses produced by intraspinal injection. Histological examination shows that after 100 days there is damage to nerve roots, and after 550 days considerable damage. At this time it is estimated that the dose to the cauda equina from alpha rays is about 1000 rads. (auth)

<130>

Retzger, G.V., University of Rochester, School of Medicine and Dentistry, Department of Radiation Biology and Biophysics, Rochester, NY. 1968.

Some Environmental Factors Influencing the In Vitro Phagocytosis of Inert Test Particles. Ph.D. Thesis, University of Rochester: 111 pp.

The effects and interactions of a variety of environmental factors on the *IN VITRO* phagocytosis of inert test particles were studied. Mononuclear cells derived from either rat peritoneum or lung were used as phagocytes, and the test particles consisted of heavy metal oxides and carbon. Removal of calcium and magnesium ions from a balanced-salt medium was shown to decrease the amount of phagocytosis, as measured by the percentage of cells participating and the mean number of ingested particles per cell. The effects of added calcium or magnesium ions to a simple saline medium were then measured. Calcium ions, in appropriate concentrations, were found to enhance the phagocytosis of the metal oxides but not carbon; added magnesium ions were without effect. The effects of other multivalent cations on phagocytosis were studied when added to a saline medium. Uranyl (UO₂·2) and thorium (Th·4) ions were both found to bring about significant enhancement of phagocytosis of the metal oxides but not carbon. For a given cell concentration the relative concentrations of cations needed to bring about significant enhancement of phagocytosis over that obtained in the saline controls were found to occur in the descending order (Th·4) < (UO₂·2) < (Ca·2). The influence of "non-chemical" environmental factors (e.g., length of incubation, particles and cell concentrations) on phagocytosis was also studied. These parameters were not only studied in saline, but their influence on the extent of multivalent-cation enhancement and glucose uptake were also investigated. Among the findings was the depression of phagocytosis in saline and the depression of multivalent-cation enhancement of phagocytosis by increasing cell concentration (with or without equivalent particle to cell

ratio). Glucose uptake per cell was also depressed. A saturation phenomenon has also been illustrated at high particle concentrations and is discussed. (auth) (VHM)

<131>

Bori, T., T. Okamoto, N. Ueda, K. Saito, and N. Okazaki, Yokohama City University, School of Medicine, Second Department of Pathology, Yokohama, Japan. 1973, June.

Thorotrast-Induced Spindle Cell Sarcoma and Hepatic Cholangiocarcinoma in Syrian Hamsters. CONF-730475; B15C-294; Toxicity of Thorotrast. N. Faber (Ed.), Proceedings of the 3rd International Meeting held in Copenhagen, Denmark, April 25-27, 1973, (pp. 267-269) (CONF-730475, B15C-294).

By injecting Thorotrast into the subcutaneous of the cheek pouch of Syrian hamsters, spindle cell sarcoma were induced at the site of injection. It was also possible to induce hepatic cholangiocarcinoma in Syrian hamsters by systemic Thorotrast administration. Both of the induced tumors were transplantable, and could also be converted into the ascitic form. In addition, the former was established as a stable strain through culture in vitro. Histopathological and radiological examination of the tumors demonstrated that the carcinogenesis of the former proceeds from Thorotrast foreign body inflammation to thorotrastoma formation to spindle cell sarcoma development, and that of the latter from Thorotrast deposition in the liver to adenomatous proliferation of intrahepatic bile ducts to the development of hepatic cholangiocarcinoma. In both tumors, shortening of the period from Thorotrast administration to tumor recognition was observed as the Thorotrast dose was increased. Also abnormal proliferation of alveolar epithelial cells of the lung was observed following systemic Thorotrast. (auth)

<132>

Kuller, R.A., Institut für Biologie der Gesellschaft für Strahlen- und Umwelt-Forschung mbH, Neuberberg, German Federal Republic; Euratom, Ispra, Italy. 1971.

Studies on Short-lived Internal Alpha-Emitters in Mice and Rats. Part 2. Thorium 227. International Journal of Radiation Biology, 20(3), 233-243.

Th 227 is an interesting model for a short-lived bone 'surface-seeker' with alpha-emission. The distribution after intraperitoneal injection of Th 227-citrate in the different organs is described. About 70 per cent of the injected Th was retained in the skeleton. The total dose burden depends to a high degree on distribution of decay products, especially Ra 223. Calculations were done for the skeletal dose burden in mice. They yielded 200 rads per 1 uCi of Th 227 injected. The highest skeletal dose-rate (7 rads/day per 1 uCi/Rg) was reached at the third day after injection. The possibility of bone sarcoma induction is discussed by comparison with dose relationships after incorporation of Th 228. A provisional mechanical technique is described for estimation--to a certain extent--of the activity at bone surface and volume separately. (auth)

<133>

Novikov, Yu.V., and T.V. Tulin, Leningrad

BIOLOGICAL ASPECTS
ANIMALS

<133> COBY.
Research Institute of Hygiene, Moscow, 1952.
1970, January.

Data on the Biological Effect of Small Amounts
of Natural Uranium in Water. Hygiene and
Sanitation, 25(1-2), 63-71.

Investigation of kidney function during
chronic external entry of uranium in small
concentrations into the body showed no
significant changes in levels of urea,
creatinine and chlorides in sera of
experimental animals in comparison with
controls. Serum alkaline phosphatase
activity increased in the 11th month of
poisoning with uranium at concentrations of 5
and 60 mg/l. Increased acid phosphatase
activity was noted in spleen homogenates from
rabbits treated with uranium concentrations
equivalent to 50 MPC (maximum permissible
concentration) of the substance. Nucleic
acid metabolism was inhibited in kidneys and
livers of animals given chronic external doses
of uranium in concentrations of 50 and 100
MPC. (Tx) (VC)

<134>
Kawara, S., Nagoya University, School of
Medicine, Nagoya, Japan. 1973, June.

Distribution of Thorotrast and Its Daughter
Nucleides and Estimation of Absorbed Dose in the
Human Organ. COBY-730875; BISO-290; Toxicity
of Thorotrast, S. Faber (Ed.), Proceedings of
the 3rd International Meeting held in
Copenhagen, Denmark, April 25-27, 1971, (pp.
72-89) (COBY-730875, BISO-290).

Thorotrast was injected intravenously into 90
SD mice in 0.1 ml and 0.5 ml quantities.
Twenty of the animals given 0.1 ml and an
equal number of those given 0.5 ml were
sacrificed three months after injection. The
gamma activity in their organs was measured
during a 20-day period under identical
conditions. The remainder of the animals was
sacrificed five months after injection.
Build-up curves indicated that approximately
20% of the injected ThO₂ had deposited in the
liver, spleen and bone in a ratio of
67:22:11, respectively. Twenty four percent
of the Th daughter products were retained in
the liver and 21% in the spleen five months
after injection. The amount of daughter
elements is now increased to 130%,
presumably owing to the translocation of
radioisotopes from other organs. The
absorbed dose of internal radiation was
smaller than values reported in the past. No
significant difference was noted in
measurements of animals given 0.1 ml or 0.5
ml Thorotrast. (BAP)

<135>
Park, J.F., F.B. Howard, B.O. Stuart, A.P.
Seiber, and J.V. Willey, Battelle-Pacific
Northwest Laboratories, Richland, WA. 1970,
December.

Cocarcinogenic Studies in Pulmonary
Carcinogenesis. COBY-700501; Morphology of
Experimental Respiratory Carcinogenesis, P.
Wettersheim, et al (Eds.), Proceedings of a
conference held in Gatlinburg, Tennessee, May
13-16, 1970, (pp. 817-836) (COBY-700501).

Epidemiologic studies have shown an increased
incidence of pulmonary neoplasia in asbestos
workers and uranium miners, especially in
those workers with a history of cigarette
smoking. These studies suggest that
cocarcinogenic action may be involved in the

pathogenesis of pulmonary neoplasia.
Cocarcinogenic experiments are currently in
progress to determine the pathogenesis of
several potentially carcinogenic materials on
the induction of pulmonary neoplasia in
experimental animals. The role of
plutonium-induced lymphopenia and lymphatic
pathology is being evaluated in the
pathogenesis of pulmonary neoplasia induced
by inhalation of plutonium dioxide in beagle
dogs. Hamsters and dogs are being exposed to
combinations of uranium mine air contaminants
including radon daughters, uranium ore dust,
diesel engine exhaust, and cigarette smoke.
The cocarcinogenicity of inhaled asbestos,
nickel oxide, and cigarette smoke is being
investigated in hamsters. (Auth)

<136>
Parkinson, J., University of Utah, College of
Medicine, Division of Radiobiology, Salt Lake
City, UT. 1955, September 30.

Plasma Iron Study. AECU-3109; Semiannual
Progress Report, (pp. 71-73), 87 pp. (AECU-3109).

A study of plasma Fe values in normal beagle
dogs was carried out followed by a toxicity
study of dogs injected with various dosages
of Pu, Pa, Np and Pm. Large variations
of plasma Fe were observed in normal dogs.
In the animals administered Pu, Np, and
Pm cyclic fluctuations in the plasma Fe
were noted in the early weeks after
injection. Wide swings from subnormal to
supernormal values were observed. These
changes did not correlate with hematologic
changes during this period. The Fe group did
not show these changes. A preliminary report
is given on a study dealing with potential
anemia and decreased survival time of red
blood cells produced by Pu, Pa, Np and Pm
in beagles. (BAP)

<137>
Zaslavskaya, N.A., N.S. Zeltser, and A.P.
Medvedovsky, 1975, October.

The Thoron Content (Thoron 230) of the Air
Expired by Rats After Intratracheal
Administration of Thoron Compounds. Gigiena i
Sanitariya, 10, 45-48.

The content of thoron was determined in the
air expired by rats after intratracheal
administration of insoluble (Th 232 dioxide)
and soluble (Th 229 tetrachloride) compounds
of Th. It was found that the coefficients of
expiration of thoron from the bodies of rats
depended on the solubility of the Th
compounds and the time after administration.
In case of entry into the respiratory organs
by thorium dioxide, the expiration
coefficients of thoron [E(sub 1) and E(sub 2)]
in the first 24 hours after injection
attain 0.32 and in the following periods
decrease to 0.08. In case of entry of a
soluble thorium compound, E(sub 1) and
E(sub 2) attain 0.88 and then fall to 0.13
and 0.22 respectively. (Auth)

<138>
Bekfeld, C.E., University of Utah, Radiobiology
Laboratory, Salt Lake City, UT. 1959, March 31.

Toxicological Aspects of Ionizing Radiation Due
to Bone-Seeking Radioisotopes. COO-218; Annual
Progress Report, C.W. Stover, Jr. (Ed.), (pp.
213), 229 pp. (COO-218).

Studies are being made of the effects on
beagle dogs of intravenous administration of

<138>

BIOLOGICAL ASPECTS OF RADIATION

<139> CONT.

5 bone-seeking radioisotopes, the beta emitter Sr 90 and alpha emitters Pu 226, Pa 228, Th 228, and Po 210. When these radioisotopes are incorporated into the body structure they introduce extra energy which the body is unable to dissipate harmlessly. The toxic effect of this ionizing radiation is to break chemical bonds, create highly reactive substances such as H₂O₂ and H₂O and to inactivate enzymes. Toxicity is expressed in this study by formation of bone tumors, destruction of bone resulting in spontaneous fractures, aplastic anemia, lesions of the eye, renal changes, liver pathology, and premature loss of teeth. Each isotope produces its individual pattern. (BMM)

<139>

Stöckli, U., P. Müller, and A. Kaul, Universität Berlin, Klinik für Radiologie und Radiochemie - Schöneberg, Physik und Strahlenschutz, Berlin, German Federal Republic. 1975, June.

Non-Radiation Effects of Thorotrast and Other Colloidal Substances. CONT-730475; BISO-294; Toxicity of Thorotrast, H. Faber (Ed.), Proceedings of the 3rd International Meeting held in Copenhagen, Denmark, April 25-27, 1973, (pp. 201-292) (CONT-730475, BISO-294).

The literature on the pathogenic effects of some non-radioactive colloidal substances in animals is reviewed. The effects of these substances suggest that apart from the radioactivity other etiological factors operate in the pathogenesis of Thorotrast. Experiments on the preparation of ThO₂-aqueous according to peptization and condensation methods are described. The methods failed to produce Thorotrast like particle size distribution. Thorotrast was produced following the method of a former manufacturer with a particle size distribution in agreement with that of commercial Thorotrast. A possibility of the enrichment of Thorotrast by Th 232 is described. (PSP)

<140>

Blash, N.S., Academy of Sciences, Institute of Biology of Southern Seas, USSR. 1970.

Uranium in Organisms of Animals from the Adriatic Sea. Vestnik Zoologii, 4(2), 12-15.

To elucidate the role of uranium in radioecological processes and its effect (as alpha emitter) on the living organisms it is necessary to study the accumulation of this element in organisms under natural conditions. The data obtained permitted determining the coefficients of uranium accumulation and its radioactivity in the organisms of some animals in the Adriatic Sea. The concentration factors can be of various magnitude from units and tens in MYTILUS GALLOPROVINCIALIS to hundreds in ARBACIA sp. In the body of VERRUCARIA AEROPHORA the microconcentrations of uranium are found in which its concentration is higher by two-three orders than the average contents in the organisms. In places of localization of such microconcentrations higher doses of radiation can be created. (TR)

<141>

Rosenthal, N.S., Argonne National Laboratory, Division of Biological and Medical Research, Argonne, IL. 1960.

Radioisotope Absorption and Methods of

Elimination: Factors Influencing Elimination from the Body. Radioisotopes in the Biosphere, N.S. Caldwell and L.A. Snyder (Eds.), Proceedings of a Symposium held in Minneapolis, Minnesota, 1959, (pp. 541-543), 597 pp.

The important factors involved in radioisotope removal and their many interrelationships are reviewed and illustrated by recent works. The emphasis is on basic, theoretical factors rather than on strictly clinical considerations of the subject. The principal factors influencing elimination of radioactive metals from the body are: inherent factors such as physiologic state of the animal and route of entry; surgical excision of contaminated area; therapy; species differences in metabolism which alter the response to therapy; and induction of changes in body function such as nutritional state, endocrine balance and kidney function. The two most successful approaches to the removal of retained radioisotopes involve the use of carriers of chelating agents. The carriers are usually hydrolyzable metals, such as zirconium, which form colloidal aggregates in the blood that remove circulating radioisotopes from the body through the urine. Complexing and chelating agents form soluble, anionic, readily excreted complexes with the radioisotope. The most effective carriers are those that have a particle size range small enough to be excreted rapidly through the kidneys and to escape being caught in the reticuloendothelial system. Zirconium has been successfully used to remove plutonium, yttrium, cerium, americium, zirconium and sized fission products from a number of mammalian species. In the rat after intravenous injection of .50 mg of Zr/kg following IV injection of plutonium citrate, the level of Pu in blood was reduced within 5 minutes to one-half and within 30 minutes to about one-tenth of the control level. The chelating agents, especially polyamine acid chelating agents such as EDTA and the more recently used diethylenetriaminepentaacetic acid (DTPA), have proved very useful for removing a number of radioisotopes from the body, including plutonium, thorium, yttrium and the rare earths such as cerium. DTPA was found to be much superior to EDTA in the removal of plutonium from cases of chronic deposition in humans. Daily urinary excretion of plutonium was increased with DTPA therapy about 50- to 100-fold over pretreatment levels, in comparison to a factor of 10 following EDTA. Additive therapy, for example combined Zr carrier therapy with EDTA therapy for the removal of Pu is also discussed. (PMS)

<142>

Bowland, R.E., and J.E. Farnham, Argonne National Laboratory, Radiological Physics Division, Argonne, IL. 1969.

The Deposition of Uranium in Bone. Health Physics, 17, 139-140.

Quantitative autoradiography was employed to study the distribution of two isotopes of uranium in the bones of dogs. U 237 or U 233 was injected intravenously as the nitrate into adult dogs, and the animals were sacrificed serially at times ranging from 2 to 72 days after injection. The femora and tibia were taken at the time of sacrifice for autoradiographic analysis. The results showed that at 2 days after injection, the uranium had a distribution pattern very similar to that seen with plutonium, i.e. it was localized on bone surfaces. By 6 days,

PHYSIOLOGICAL EFFECTS **OF PLUTONIA**

<102> CONT.

however, a diffuse distribution of this element was present. Seventy-two days after isotope administration the distribution pattern was remarkably like that of calcium, with intense hot spots over the growth regions and a diffuse distribution throughout all of the preexisting bone. (WC)

<103>

Potomovskaya, A.A., 1970.

The Effect of Uranous-Uranic Oxide (U3O8) in Experimental Work. The Toxicology of Radioactive Substances: Thorium 232 and Uranium 238, Vol. 4, A.A. Letavet and E.S. Kuriyandskaya (Eds.). Pergamon Press, New York, New York, (pp. 87-100), 196 pp.

The introduction into the canine gastrointestinal tract for 30-50 days of U3O8 (17, 33 and 100 g) did not influence the general state of health of the animals. The compound was almost completely removed in the feces. The substance did not dissolve in the gastrointestinal tract and was consequently only absorbed to a very limited degree. Histology indicated a minor degenerative process in the kidneys and local disturbances in blood circulation in the intestinal wall. Single introduction into the lungs of U3O8 (up to 1 g) produced severe intoxication in dogs. The particles of U3O8 were vigorously removed from the lungs through the air passages, a considerable proportion of them entering the regional lymph nodes. The bulk was removed from the lungs in the early stages after poisoning. Some particles from the lungs were swallowed and excreted in the feces. Formation in the lymphoid tissue of compact conglomerations of U3O8 resulted in less vigorous removal in the rabbit than in the dogs. Rabbits in which 7.2 to 76.9 mg of U3O8 was found at death had remained virtually normal for 5.5-10.5 months. Examination showed a minor degeneration in the kidney and a chronic interstitial process in the lungs with accumulation of the product in the form of compact demarcated nodes. The dogs which survived severe intoxication subsequently remained outwardly normal and put on weight. The morphological changes in the kidneys and lungs were of the same nature as in the rabbits. A depot under the skin of U3O8 (1 and 1.4 g per rabbit) for 7 months had no toxic effect and except for the kidneys did not lead to accumulation of U in the organs. Pathological lesions in the organs were weakly marked. On subcutaneous administration of 2.5-3.5 g U3O8 severe intoxication developed. (Auth)

<104>

Schuman, A.G., and D.L. Berliner, University of Utah, College of Medicine, Division of Radiobiology, Department of Anatomy, Salt Lake City, UT. 1964, September 30.

1. Canine Lactic Dehydrogenase Levels in Adult Beagle Dogs. COO-119-231; Research in Radiobiology, Annual Report of Work in Progress on the Chronic Toxicity Program, T.F. Dougherty, (pp. 85-90), 172 pp. (COO-119-231).

Serum lactic dehydrogenase (LDH) determinations were performed on 101 beagles from a colony used in the study of long range effects of internally deposited radionuclides, namely Th 230, Ra 226, Ba 226, Sr 90 and Pu 239, all of which had been injected intravenously as a single dose of varying levels of radioactivity. Statistical analysis of results revealed no

significant differences among groups separated by radionuclide injected, number of days elapsed since nuclide injected, and disease state. Sera from moderately hemolyzed blood samples were significantly higher in LDH level than sera from nonhemolyzed or slightly hemolyzed blood samples. Dogs who received high doses of radionuclides had blood LDH levels significantly higher than those of control dogs. It is concluded that serum LDH is not a consistent indicator of pathologic states in the adult beagle dog. (Auth) (FHM)

<105>

Sanders, C.L., and R.E. Adee, Battelle-Pacific Northwest Laboratories, Biology Department, Richland, WA. 1969, October 6.

The Ultrastructure of Mononuclear Phagocytes Following Intraperitoneal Administration of Plutonium 239 PuO2. Journal of the Histochemical Society, 6, 1-23.

The ultrastructural changes in rat peritoneal phagocytes during the first 7 days after intraperitoneal administration of plutonium dioxide, uranium dioxide, and latex particles are described. Female albino Sprague-Dawley rats (200-360 g body weight) were injected with 1.4 uCi Pu 239 PuO2 particles (mean diameter, 0.72 u) suspended in zinc saline. Other rats were injected with thorium oxide (8 mg, approximately 30 u diameter, Thorotrast or 25 mg), latex particles (mean diameter 0.13 u) or saline. The animals were sacrificed at 2, 3, 6 hours and at 1 and 7 days after injection. The results show that numerous particles were localized within cytoplasmic vacuoles of phagocytes. The subcellular localization of plutonium particles was demonstrated by electron microscopic autoradiography. Only minimal alterations were found during the 6-hour period after plutonium. Significant alterations found at 1 and 7 days after plutonium included a marked increase in phagocyte size, and increased number of "pseudopodial" projections, necrosis of peritoneal cells and their subsequent engulfment by phagocytes. Plutonium and thorium particles were found lining the interior surface of lysosomes at 7 days. No significant degeneration of peritoneal phagocytes was observed at 7 days after thorium or latex. Phagocytes exhibited a relative radioresistance to alpha irradiation from plutonium particles. (Auth) (FHM)

<106>

Schwartz, S., and R. Zargaria, University of Minnesota, Department of Medicine, Minneapolis, MN; Argonne National Laboratory, Health Services Division, Argonne, IL. 1951.

Studies of Porphyrin Metabolism. The Effect of Metals on Coproporphyrin Excretion. Toxicology of Uranium, Survey and Collected Papers, Paper 16, A. Tannenbaum (Ed.). McGraw-Hill Book Company, Inc., New York, New York, (pp. 290-326), 333 pp.

The effect of various metals on urinary porphyrin excretion was studied in 116 rabbits. In many of the animals the nearly 3,000 quantitative analyses made were correlated with studies of total fecal and red-blood-cell porphyrin, with the ratio of urinary and fecal coproporphyrin isomers, with urinary urobilinogen and routine urinalysis studies, and with weight data. The studies confirmed the occurrence of several hundred to several thousand per cent

<100>

BIOLOGICAL ASPECTS ANIMALS

<106> CONT.

increase of the urinary coproporphyrin III excretion in rabbits injected with lead and of significant increases in their red-cell protoporphyrin concentration. These increases persisted for several months. In addition, it was found that certain metals such as thorium, zirconium, and lanthanum, which themselves caused no increase in the urinary excretion of coproporphyrin, did produce marked elevation of urinary porphyrin excretion in animals given lead several months previously. Uranium administered in large doses produced a precipitous drop in excretion of urinary coproporphyrin in both control and lead-injected rabbits. The injection of arsenic was followed by a considerable increase in porphyrin excretion lasting only a few days. No consistent significant change in porphyrin excretion was found following the administration of beryllium. Most of the metals studied produced a variable degree of liver dysfunction as indicated by elevated excretion of urinary urobilinogen. One hundred twenty-five quantitative isomer determinations were made on urines from 30 control and treated rabbits. All showed over 70 per cent of the total urinary coproporphyrin to be the type III isomer. (Auth)

Based on Metallurgical Laboratory Report
CM-3600, October 17, 1966.

<107>

Scott, J.H., W.F. Youman, and J.F. Bonner, University of Rochester, School of Medicine and Dentistry, Division of Pharmacology and Toxicology, Department of Radiation Biology, Rochester, NY. 1952.

The Distribution and Excretion of Thorium Sulfate. *Journal of Pharmacology and Experimental Therapeutics*, 106, 786-790.

When a soluble thorium compound, thorium sulfate, was administered intravenously to animals, it was removed from the blood slowly and most of the thorium was found in the liver, spleen and bone marrow. Following intramuscular injection, thorium remained in the injected muscle and following intratracheal injection it remained in the lung. When the compound was given by gavage, it was recovered in feces and no absorption could be demonstrated by the procedures used. (Auth)

<108>

Stemmer, J.H., University of Rochester, School of Medicine and Dentistry, Rochester, NY. 1973.

Toxicology of Radionuclides. A real Review of Pharmacology, 13, 325-357.

This review emphasizes carcinogenesis, dose-response relationships and dosimetry as well as environmental aspects of radionuclide toxicology. Effects of such substances are generally from ionizing radiation; chemical toxicity may also be significant in cases of low specific activity. Chemical properties determine localization and thereby control biological effects. Pathology is generally from malfunction of dividing cells. Long term effects include carcinogenesis, genetic changes, nephroclerosis, pneumoconiosis, fibrosis, vascular pathology, hypertension, endocrine and immunologic disorders, hematopoietic disturbances and life-span shortening. Animal and human population studies on carcinogenesis by alpha emitters

are reviewed. Radionuclides discussed include Ra 226, Ra 228, Th 230 (Thorium U), Th 232, Th 234, Th 236, Th 238, Th 240, Th 242, Th 244, Th 246, Th 248, Th 250, Th 252, Th 254, Th 256, Th 258, Th 260, Th 262, Th 264, Th 266, Th 268, Th 270, Th 272, Th 274, Th 276, Th 278, Th 280, Th 282, Th 284, Th 286, Th 288, Th 290, Th 292, Th 294, Th 296, Th 298, Th 300, Th 302, Th 304, Th 306, Th 308, Th 310, Th 312, Th 314, Th 316, Th 318, Th 320, Th 322, Th 324, Th 326, Th 328, Th 330, Th 332, Th 334, Th 336, Th 338, Th 340, Th 342, Th 344, Th 346, Th 348, Th 350, Th 352, Th 354, Th 356, Th 358, Th 360, Th 362, Th 364, Th 366, Th 368, Th 370, Th 372, Th 374, Th 376, Th 378, Th 380, Th 382, Th 384, Th 386, Th 388, Th 390, Th 392, Th 394, Th 396, Th 398, Th 400, Th 402, Th 404, Th 406, Th 408, Th 410, Th 412, Th 414, Th 416, Th 418, Th 420, Th 422, Th 424, Th 426, Th 428, Th 430, Th 432, Th 434, Th 436, Th 438, Th 440, Th 442, Th 444, Th 446, Th 448, Th 450, Th 452, Th 454, Th 456, Th 458, Th 460, Th 462, Th 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BIOLOGICAL ASPECTS
OF THORIUM
ISOTOPES

(149) CONT.
90-1197, 1966, with the exception of Table 2 which differs in its values.

(150)
Stover, E.J., D.B. Atherton, F.B. Brueser, D.S. Foster, and E. Belt, University of Utah, College of Medicine, Division of Radiobiology, Department of Anatomy, Salt Lake City, UT. 1966, March 21.

Preliminary Report on the Effect of Number of Atoms on Thorium Distribution Following Intravenous Injection. COO-220; Research in Radiobiology, Annual Report of Soc. in Progress on the Chronic Toxicity Program, T. J. Dougherty, (pp. 275-286), 225 pp. (COO-120).

In comparing the biological behavior of Pa 239 and essentially carrier-free Th 228 in adult beagles some interesting differences were observed. The question arose as to whether the observed differences resulted from chemical differences in the two radionuclides or whether they resulted from the differences in amounts injected. To investigate this question three dogs were injected with Th 228 to which varying amounts of long-lived thorium (Th 232) had been added, the doses being 60, 8 and 6.4 μ g Th. A significant difference in the relative deposition in the soft tissues and the skeleton was observed. The results suggest that the differences in beagle metabolism of Pa 239 and Th 228 do not result from the difference in the number of atoms. (20th)

(151)
Stover, E.J., D.B. Atherton, E. Keller, and J.S. Foster, University of Utah, Department of Anatomy, Radiobiology Laboratory, Salt Lake City, UT. 1966.

Metabolism of the Th 228 Decay Series in Adult Beagle Dogs. I. Thorium 228 (26Th). Radiation Research, 12, 657-671.

The metabolism of carrier-free Th 28 (26Th) in adult beagle dogs has been studied for 1.5 years after a single intravenous injection of the radionuclide in a citrate buffer solution. Initially urinary excretion predominates, but the fecal and urinary excretion ratio gradually increases so that the two rates are about the same several years after injection. After a few months, decrease in retention from radioactive decay becomes greater than that by excretion. For t greater than or equal to 100 days, retention determined from excretion measurements, is $R = (R_0 - \epsilon e^{-\lambda t}) / (1 - \epsilon e^{-\lambda t})$, where the decay constant $\lambda = 7.00 \times 10^{-4} \text{ day}^{-1}$. About 60% of the retained Th 228 is in the skeleton; about 20% is widely distributed in soft tissues, with significant amounts in kidneys and liver. The soft-tissue Th 228 decreases more rapidly than that in the skeleton. Comparison of these findings with those from studies with chemically similar tetravalent Pa 239 shows general similarities in beagle metabolism of Th 228 and Pa 239 but also some significant differences. Chemical analysis of Th 228 solutions showed the presence of small amounts of longer-lived thorium. The number of plutonium atoms was about 100 times the number of thorium atoms at each dose level. (227)

(152)
Stover, E.J., D.B. Atherton, and C.V. Rags,

University of Utah, College of Medicine, Division of Radiobiology, Department of Anatomy, Salt Lake City, UT. 1967.

Studies of the Retention and Distribution of Radium 226, Plutonium 239, Radium 228 (Radium 226) Thorium 228 (Radium 226) and Strontium 90 in Adult Beagles. Some Aspects of Internal Irradiation, T.V. Dougherty, et al (Eds.), Proceedings of a Symposium held at The Banstead, Herts, May 2-11, 1967. Pergamon Press, Oxford, England, (pp. 7-25), 529 pp.

The biological behavior of Ra 226, Pa 239, Th 228, and Sr 90 in young adult beagles for the first 1000 days following a single intravenous injection was studied. Plasma concentration, excretion, fractional retention, distribution, metabolic fate of the decay products, if any, and the average radiation dose rate to the skeleton were determined. The results are considered in terms of the nuclear and chemical characteristics of the radionuclides and the biological organism. The results for the pair of alkaline earth radionuclides are, in general, similar with interesting small differences, and this pair differs markedly from the pair of actinide element radionuclides, which in turn show some interesting similarities and dissimilarities. The combined effect of nuclear and chemical properties and the biological organism result in markedly different average radiation dose rates to the skeleton when compared on the basis of equal injected activities. These empirical relations are presented as useful interpolation formulas to describe a specific case. (20th)

Table 4 shows concentrations of radionuclides in eyes and plasma. Table 6 gives empirical equations for retention, skeletal retention, and skeletal dose for 20-1000 days after injection.

(153)
Stover, E.J., E. Fyring, and D.B. Atherton, University of North Carolina, Department of Pharmacology, Chapel Hill, NC; University of Utah, Department of Chemistry, Salt Lake City, UT; University of Utah, Division of Radiobiology, Department of Anatomy, Salt Lake City, UT. 1972.

Effects of Plutonium 239 and Related Radionuclides on Survival of the Adult Beagle. Radiobiology of Plutonium, P.J. Stover and U.S.S. Jee (Eds.), J.W. Press, Salt Lake City, Utah, (pp. 385-407), 552 pp.

Survival data for groups of dogs at six dose levels of Pa 239 or Pa 226 are compared with survival data from a group of protected controls. Less extensive results on survival of dogs given Th 228, Th 226, and Sr 90 are also compared. Each nuclide was given in a single intravenous injection of a 7.00 N citrate buffer solution of pH 7.5. Each control dog was injected with an approximately equal volume of the buffer. Over a range of five dose levels of Pa 239, survival times increased as the dose level decreased. At the lowest of the six dose levels there was no life-shortening relative to the controls. However, the occurrence of osteosarcoma, which is induced by Pa 239, greatly exceeded the occurrence in the controls even at this lowest dose level. In the case of Th 226, progressive life-shortening was observed at the three higher dose levels, but at the three lower levels there was little life-shortening. Osteosarcoma were observed at all but the lowest dose level. The degree of

<153>

**TOXICOLOGICAL ASPECTS
MURMALS**

<153> COWY.

Life-shortening at high dose levels was similar for all five radionuclides, but this similarity was not observed at the lower levels. The steady state theory of mutations (or other critical cellular alterations) was used in the analyses of the survival data. This theory yields two parameters, one related to cellular reserves and one related to the overall rates at which the reserves are being depleted. Theoretical calculations have also been made on the effect on survival of age at injection, and on the analysis of composite populations. (Auth)

<154>

Stover, B.J., C.B. Taylor, and D.B. Atherton, University of Utah, College of Medicine, Division of Radiobiology, Department of Anatomy, Salt Lake City, UT. 1963, September 30.

Completion of the Injection Phase of the Basic Toxicity Experiment. COW-728: Research in Radiobiology, Semiannual Report of Work in Progress on the Chronic Toxicity Program, T.F. Tomphey, (pp. 64-65), 185 pp. (COW-728).

The 644 young adult beagles planned for the long-term study of the effects of Ra 226, Pu 239, Pa 228, Th 228, and Sr 90 have received their single intravenous injections. Injection of the toxicity dogs began in December 1952 and was concluded in July 1963. Thus nearly 11 years were required to introduce this number of dogs into the experiment. As of September 30, 1963, there are 268 of the 644 dogs (66.5%) still living. Osteosarcomas have been found in 112 of the 176 dead dogs (63.7%). Of the 176 dead dogs, 9 lived 10.0 years or more. (Auth) (FNU)

<155>

Stover, C.B., Jr., University of Utah, College of Medicine, Division of Radiobiology, Salt Lake City, UT. 1959.

Annual Progress Report, March 31, 1959. COW-718: 274 pp.

Progress is reported on the studies in dogs injected with Ra 226, Th 228, Pa 228, Sr 90 or Pu 239. Seven papers have been abstracted separately for inclusion in the data base. These include studies on histopathologic bone changes in bones containing Pu, determination of Pu 239 content of bone tissue, radiation induced osteogenic sarcoma in dogs and the biochemistry report. (FNU)

<156>

Strohal, P., J. Tota, and Z. Kolar, Rudjer Boskovic Institute, Zagreb, Yugoslavia. 1969.

Investigations of Certain Microconstituents in Two Tunicates. Limnology and Oceanography, 14, 265-268.

Concentrations of 11 trace elements - Sc, La, Ce, Eu, Th, Pb, Cs, Sr, Fe, Zn, and Co - have been determined by activation analysis in two tunicates (MICHOCOSMUS SULCATUS and PHALLUSIA MURMILATA). Their concentration factors were calculated and are discussed in relation to radioecology and to seawater pollution with radionuclides. The treatment of samples and the radiochemical procedure are described. The calculated concentration factors in M. SULCATUS and in P. MURMILATA for Th were 60 and 23, respectively. (BAP)

<157>

Stuart, B.O., and T.H. Bensley, Battelle-Pacific Northwest Laboratories, Biology Department, Richland, WA. 1965, January.

Selective Tissue Accumulation of Uranium and Thorium in Rats After Inhalation of Uranium Ore Dust. HWU-122; Battelle Biology Research Annual Report for 1964, B.C. Thompson and S.W. Woods (Eds.) (pp. 21-24), 216 pp. (HWU-122).

Groups of rats inhaled uranium ore aerosols semiweekly for two months. Th 230 activity levels in the lungs were twice those of U 230 by the end of exposures, increasing to nine times after four months due to selective removal of uranium. Levels of Th 230 in tracheobronchial lymph nodes were also higher than U 230. Uranium levels in the kidneys and femurs were initially higher than thorium, but by two months postexposure thorium activities were equal to or greater than those of uranium. This rapid in vivo separation of uranium and thorium is important for permissible limit considerations. (Auth)

<158>

Stuart, B.O., and T.H. Bensley, Battelle-Pacific Northwest Laboratories, Richland, WA. 1965.

Non-Equilibrium Tissue Distributions of Uranium and Thorium Following Inhalation of Uranium Ore by Rats. COW-650986; Inhaled Particles and Vapors: Proceedings of the 2nd International Symposium held in Cambridge, England, September 27-30, 1965, (pp. 291-297) (COW-650986).

If each radioactive daughter comprising the uranium decay chain is considered individually, daughter products such as Th 230 with unusually high pulmonary retention, may contribute to a lower calculated permissible limit for uranium ore than that based on the levels of insoluble natural uranium. To determine whether such a lower limit is valid from a hazard view point, it is necessary to know whether a given daughter, Th 230, does indeed have a high retention when inhaled with the parent radionuclide as a constituent of uranium ore dust. Both single and repeated exposures of rats to high grade (25% U3O8) pitchblende ore resulted in increasing thorium-to-uranium ratios in the lungs with increasing times post-exposure. Highly sensitive analytical procedures (allowing precise measurements on 10 ug of ore) have shown significant departures from initial equilibrium levels as little as one week after three 2-hr exposures, rising to a ratio of nearly three after 8 weeks. During repeated exposures occurring over two months a gradual rise in mean Th/U ratios to 1.5 was observed, in spite of the repeated deposition of fresh ore (in secular equilibrium). This ratio was found to be about nine of the lungs of animals sacrificed four months after the last exposure. These data suggest a preferential retention of thorium in the lungs. Analyses of bronchial and mediastinal lymph nodes have also shown selective accumulation of thorium, while initial uranium concentrations in the kidneys were higher than those of thorium. Femurs and liver also accumulated higher thorium radioactivities. (Auth) (BAP)

<159>

Stuart, B.O., and P.O. Jackson, Battelle-Pacific Northwest Laboratories, Richland, WA. 1974, August.

Disposition of Long-Lived Uranium Chain Alpha

BIOLOGICAL EFFECTS
ANIMALS

<159> CONT.

Findings Following Repeated Inhalation Exposures of Laboratory Animals to Uranium Ore. BWL-1050 (Part 1): Annual Report for 1973, D.C. Thompson, et al (Eds.), (pp. 97), 162 pp. (BWL-1050, Part 1).

Thorium 230 was found to separate readily in vivo, from gaseous uranium, following inhalation of either pitchblende or carnotite uranium ore by rats, beagle dogs, and hamsters. Thorium 230 should be considered as an individual hazard in uranium mining and milling operations. (Auth)

<160>

Stuart, D.O., and T.H. Jones, Battelle-Pacific Northwest Laboratories, Biology Department, Richland, WA. 1960, May.

In Vivo Separation of Uranium and Thorium After Inhalation of Uranium Ore by Beagles. BWL-710: Annual Report for 1967, D.C. Thompson, et al (Eds.), (pp. 227-230), 253 pp. (BWL-710).

Four beagle dogs were exposed to uranium ore dust aerosols (approximately 1 mg/liter, 20% U3O8) for 8 days. Two animals were sacrificed at 13 and 16 days following the last exposures and representative tissue and excreta samples were analyzed for U 238, Th 230 and Po 210. The results showed separation of U 238, Th 230, and Po 210 in the lungs, tracheobronchial lymph nodes, liver, kidneys, spleen, and urine and suggest that in vivo mobilization of uranium was greater than that of Th 230 and Po 210. (FHM)

Table 1 shows distribution of uranium 2 weeks after inhalation of uranium ore dust by beagle dogs. Table 2 shows concentrations of U 238, Th 230 and Po 210 in organs of beagle dogs 2 weeks after inhalation of uranium ore dust.

<161>

Stuart, D.C., D.V. Perkins, and T.H. Bensley, Hanford Atomic Products Operation, Biology Laboratory, Richland, WA. 1960, January 15.

Preliminary Studies of Inhaled Uranium Ore. HW-20500: Hanford Biology Research Annual Report for 1963, D.A. Kernery and E.G. Sorens (Eds.), (pp. 50-51), 202 pp. (HW-20500).

Preliminary studies of inhaled uranium ore in rats indicate that daughter radionuclides deposited in the lungs do not remain in secular equilibrium. Thorium 230 to U 238 ratios increased from 1.0 to more than 2 or 3 within eight weeks after exposure. (Auth)

<162>

Stuart, D.C., D.H. Willard, and E.H. Howard, Battelle-Pacific Northwest Laboratories, Environmental and Life Sciences Division, Richland, WA. 1970.

Studies of Inhaled Radon Daughters, Uranium Ore Dust, Diesel Exhaust, and Cigarette Smoke in Dogs and Hamsters. COM-700931; BWL-51-3019; Inhaled Particles, Proceedings of the 3rd International Symposium held in London, England, September 21-23, 1970, (24 pp.) (COM-700931, BWL-51-3019).

Current results of long-term multiple exposure studies with hamsters and dogs are given. Daily six-hour exposures of groups of 100 hamsters to either 30 WL of radon daughters, 600 WL of radon daughters, 600 WL of radon daughters with 15 mg/m3 uranium ore dust (carnotite), or laboratory air have been

underway for 19 to 23 months. After six months or more of exposure, hamsters receiving 600 WL radon daughters or 600 WL radon daughters with 15 mg/m3 uranium ore dust showed signs of lung changes, including edema, emphysema, and occasionally hyperplasia and metaplasia of the bronchial epithelium. Continuing experiments involve life-span exposure of hamsters to diesel exhaust with or without 600 WL radon daughters plus ore dust. Sixty-nine beagle dogs have been placed on daily life-span exposures. Forty dogs in two groups are smoking 10 cigarettes over a 16-hour period daily. Forty dogs are receiving daily 6-hour hand-only exposures to 600 WL of radon daughters with 15 mg/m3 of uranium ore dust. No significant biological effects have been observed after six months of these exposures. (BAP)

<163>

Stuart, D.O., D.H. Willard, and E.H. Howard, Battelle-Pacific Northwest Laboratories, Biology Department, Richland, WA. 1970.

Uranium Mine Air Contaminants in Dogs and Hamsters. BWL-51-3027: 20 pp.

The current status of long-term multiple exposure studies is given. The possible synergistic or contributory actions of short-lived radon daughters, carnotite ore dust, and diesel engine exhaust in the development of respiratory tract pathology are being tested with six groups of 100 hamsters each. Each group is exposed for 6 hr daily to aerosols of: 30 WL of radon daughters; 600 WL of radon daughters; 600 WL of radon daughters with 15 mg ore dust/m3; diesel exhaust fumes; diesel exhaust with 600 WL of radon daughters and ore dust; and controls. Experiments with beagle dogs have been initiated to determine whether radon daughters and cigarette smoke inhalation may jointly cause respiratory tract damage. Three groups of 20 dogs are receiving daily exposures to: the smoke of 10 cigarettes over a 16-hr period; cigarette smoking plus 4 hr exposure to 600 WL of radon daughters with 15 mg ore dust/m3; 600 WL of radon daughters with ore dust plus sham smoking. Preliminary observations in the 30 WL group of hamsters (after 6-9 months) revealed lung congestion, edema, and early hyalineization. After 6 months of daily exposure to 600 WL edema, emphysema, and inflammation of mononuclear and polymorphonuclear cells was noted. The lungs of animals exposed to 600 WL plus carnotite showed significant areas of alveolar septal breakdown with resulting emphysema. There was a severe generalized interstitial pneumonitis in this exposure group. (BAP)

<164>

Stuart, D.O., D.H. Willard, E.H. Howard, P.L. Clary, and D.H. Craig, Battelle-Pacific Northwest Laboratories, Biology Department, Richland, WA. 1970, August.

Chronic Exposure of Dogs to Simulated "Uranium Mine Atmospheres. BWL-1306 (Part 1): Annual Report for 1969, D.C. Thompson (Ed.), (pp. 60-61), 90 pp. (BWL-1306, Part 1).

Twenty beagle dogs were exposed daily to 600 WL of radon daughters plus carnotite ore dust. An additional 20 dogs were similarly exposed, but in addition smoked 10 cigarettes per day. No significant differences in respiratory rate, minute volume, tidal volume, thoracic radiographs, hematology, or

<160>

ECOLOGICAL EFFECTS ANIMALS

<160> CGST.

clinical chemistry, have been observed between groups at 2 months after beginning daily exposures. Two dogs were sacrificed 15 months after conclusion of 1/2 hr, twice daily exposures to pitchblende U ore dust (0.1 mg/liter). Radiochemical analysis revealed nonequilibrium ratios of U 238, Th 232, Pu 239, and Po 210 in the lungs, tracheobronchial lymph nodes, kidney, liver, spleen, and skeleton, with Th 232/U 238 ratios ranging from 2 to 10. Po 210/U 238 ratios in the lungs and tracheobronchial lymph nodes varied from 5 to 20. The highest concentrations of Th 232 were found in the lungs, skeleton, and tracheobronchial lymph nodes. (PBB)

<165>

Stuart, G., and F.C. Jackson, Battelle-Pacific Northwest Laboratories, Biology Department, Richland, WA. 1973.

In Vivo Separation of Long-Lived Uranium Chain Alpha-Emitters in Experimental Animals During and After Chronic Inhalation of Uranium Ores. Health Physics, 25(3), 318-319.

In previous studies the biological dispositions of individual long-lived alpha emitters of the uranium chain (U 238, U 234, and Th 232) were determined during a following repeated inhalation exposures of rats to pitchblende (26 percent U3O8 ore). Although finely dispersed ore in secular equilibrium was inhaled, Th 232/U 238 radioactivity ratios in the lungs rose from 1.0 to 2.5 during 8 weeks of exposures and increased to 9.2 by four months after cessation of exposures. Marked non-equilibrium levels were also found in the tracheobronchial lymph nodes, kidneys, liver and feces. Daily exposures of beagle dogs to high levels of this ore for 8 days resulted in Th 232/U 238 ratios of 2.0. Daily exposures of dogs to lower levels (0.1 mg/l) for 8 months, with sacrifice 2 years later, resulted in lung and thoracic lymph node Th 232/U 238 ratios ranging from 2 to 13 and 2 to 20, respectively. The lungs of hamsters exposed to carnotite ore (4 percent U3O8) in recent lifespan studies show Th 232/U 238 ratios as high as 2.0 during daily inhalation of this ore in secular equilibrium. Beagle dogs sacrificed after 6 months of daily inhalation of the same carnotite ore plus radon daughters also showed marked non-equilibrium ratios of Th 232/U 238, ranging from 4.2 to 6.8 in lungs and 2.9 to 21 in thoracic lymph nodes. This pattern of higher retention of Th 232 than U 238 in lungs, thoracic lymph nodes, and other tissues is thus consistent for 2 types of uranium ore across several species and suggests a reevaluation of maximum permissible air concentrations of ore, currently based only on uranium content. (Auth)

<166>

Syao-Shan, Y., 1970.

Comparative Toxicity of Soluble and Insoluble Compounds of Thorium 232. The Toxicology of Radioactive Substances: Thorium 232 and Uranium 238, Vol. 4, A.A. Letavet and E.B. Furlyanskaya (Eds.). Pergamon Press, New York, New York, (pp. 5-16), 188 pp.

Important physical and physico-chemical properties of thorium are given and aspects of the toxicology of Th 232 compounds reviewed. Comparative study of the toxic

properties of various thorium compounds (nitrate, chloride and oxide) showed that thorium nitrate is most toxic. The difference in the toxicities of the thorium compounds studied is determined by the degree of their solubility and also by the higher toxicity of the NO3, than the Cl anion. Poorly soluble ThO2 is least toxic chemically. (Auth) (VC)

<167>

Syao-Shan, Y., 1970.

The Behavior of Thorium Dioxide in Rats after Intratracheal and Intraperitoneal Administration. The Toxicology of Radioactive Substances: Thorium 232 and Uranium 238, Vol. 4, A.A. Letavet and E.B. Furlyanskaya (Eds.). Pergamon Press, New York, New York, (pp. 37-41), 188 pp.

In the first days (up to 5) after intratracheal administration to rats, thorium dioxide is found in the lungs, trachea, bifurcation and cervical lymph nodes, the gastrointestinal tract and contents, liver, bones and kidney. The largest amount of thorium was found in the lungs and in the early stages after administration this was 68-77 per cent of the dose given. After 21 months the rat lungs still contained 15-30 per cent of the thorium administered, which indicates the prolonged retention of thorium dioxide in the lungs. This was also confirmed by histautoradiography. Histautoradiography of the lymph nodes of rats 13 months after intratracheal administration of thorium oxide showed accumulation of thorium, and alpha particle tracks were seen in lymphoid tissue. Excretion of thorium dioxide in the urine and feces was insignificant at late times after its intratracheal administration. Following intraperitoneal administration thorium dioxide is retained for a long time in the abdominal cavity. After 16 months 18.4-78.6 per cent of the amount administered was found in the abdominal cavity and 2.33-0.51 per cent was found in the femoral bone. (Auth)

<168>

Syao-Shan, Y., 1970.

The Effect of Thorium Dioxide on the Peripheral Blood of Rats. The Toxicology of Radioactive Substances: Thorium 232 and Uranium 238, Vol. 4, A.A. Letavet and E.B. Furlyanskaya (Eds.). Pergamon Press, New York, New York, (pp. 42-57), 188 pp.

Summing up the experimental study of the effect of thorium dioxide on certain aspects of hemopoiesis in rats, we note the following changes in the peripheral blood appearing 10 to 11 months after intratracheal administration of various amounts of thorium dioxide: Intratracheal administration of thorium dioxide in amounts from 300 to 800 mg/kg body weight produced a disturbance in erythropoiesis which manifested itself in changes in the number of reticulocytes. Thus, a dose of 300 mg/kg ThO2 produced a state of functional instability expressed in fluctuations in the reticulocyte count wider than in the control animals. Administration of 800 mg/kg caused some depression of erythropoiesis in the form of periodic reticulopenia. Changes in lymphopoiesis were indicated by the relative fall in the absolute numbers of lymphocytes observed even after administration of only 200 mg/kg ThO2 and also by the appearance of morphologically changed lymphocytes. No quantitative changes

BIOLOGICAL ASPECTS
ANIMALS

<169> CONT.

in the nuclei of neutrophils were observed. However, the various morphological changes in the nuclei of the neutrophils indicated some disturbance in granulocytopenia. The effect of thorium dioxide on thrombocytopenia is indicated by the increase, relative to the initial value, in the number of blood platelets after administration of 200 mg/kg thorium dioxide. One of the early reactions of the body to administration of thorium dioxide was instability of hemopoiesis, expressed in considerable variation in the number of reticulocytes, thrombocytes and lymphocytes. (Auth) (BAP)

<169>

Syao-Shan, Y., 1970.

The Effect of Thorium Dioxide on Arterial Pressure and Threshold of Stimulation of the Nerve-Muscle Apparatus in Rats. The Toxicology of Radioactive Substances: Thorium 232 and Uranium 238, Vol. 8, A.A. Letavet and E.B. Vasilyandskaya (Eds.), Pergamon Press, New York, New York, (pp. 55-65), 184 pp.

Intratracheal and intraperitoneal injection of thorium dioxide in doses of 2, 20, 200, 2000, 4000 and 10000 mg/kg produce a sharp and persistent fall in arterial pressure in rats. The stimulation threshold of the muscle-nerve apparatus of the hind paws in rats treated with thorium dioxide showed no significant changes during 10 months' observations. (Auth)

<170>

Tandon, S.N., A.K. Nath, J.B. Behari, and S.T. Chandra, Industrial Toxicology Research Centre, Lucknow, India. 1975.

Thorium Induced Testicular Changes in Rats. Acta Biologica et Medica Germanica, 30, 1935-1942.

Daily intraperitoneal administration of 10 mg thorium nitrate for 90 days produced progressive morphological and biochemical alterations with the increase in thorium concentration in rat testis. The degenerative changes in the seminiferous tubules increased with the duration of treatment and after 90 days calcification occurred in about 25% of the tubules and in the connective tissue of the tunica albuginea. The activity of adenosine triphosphatase and alkaline phosphatase increased markedly as a result of the thorium administration. An attempt has been made to interrelate histopathological and enzymatic changes and the thorium concentration in the testicular tissue. (Auth) (BAP)

<171>

Taylor, D.H., Institute of Cancer Research, Department of Biophysics, Belmont, Sutton, Surrey, England. 1967.

The Effects of Desferrioxamine on the Retention of Actinide Elements in the Rat. Health Physics, 13, 135-146.

The effectiveness of desferrioxamine (DFOA) and DTPA in reducing the retention of Pu 239, Am 241, Cs 244, Ac 227 and Th 228 has been compared in rats. DFOA is only slightly less effective than DTPA in reducing the retention of Pu 239 provided that treatment is commenced within a few hours of exposure. If the start of the treatment is delayed until 7

days after exposure to Pu 239 DFOA is ineffective. Unlike DTPA, DFOA does not reduce the retention of Am 241, Cs 244 or Ac 227 and produces only a slight reduction in the retention of Th 228. (Auth)

Table 3 shows the comparison of the effect of DFOA and DTPA on the retention of Pu 239 citrate in liver, spleen, femur and kidneys of rats.

<172>

Taylor, D.H., A.B. Chipperfield, and A.C. James, Institute of Cancer Research, Department of Biophysics, Sutton, Surrey, England; Royal Free Hospital, School of Medicine, Department of Medical Physics, London, England. 1971, August.

The Effects of Tetracycline in the Deposition of Plutonium and Related Elements, in Rat Bone. Health Physics, 21, 197-204.

Pretreatment of rats with tetracycline has been found to decrease the retention of Th 228 and Pu 239 in bone to about 60% of control values. The drug had no effect on the retention of Am 241 in bone. Tetracycline increased the initial rate of clearance of both Pu 239 and Am 241 from the plasma, and in vitro it reduced the deposition of both nuclides on bovine bone ash. The binding of Pu 239 to bone glycoproteins in vitro was reduced by tetracycline, but binding to transferrin was unaffected. Autoradiographic studies in tetracycline-treated rats showed that the drug reduced the deposition of Pu 239 on trabecular bone surfaces to a greater extent than on the epiphyseal plate of the femur. Treatment with tetracycline was found to have no effect on the distribution of intramuscularly-injected Pu 239, even when treatment was started immediately after contamination. (Auth)

<173>

Taylor, G.H., T.F. Dougherty, and L. Shabestari, University of Utah, College of Medicine, Division of Radiobiology, Department of Anatomy, Salt Lake City, UT. 1963, September 30.

Non-Skeletal Tumor Incidence Observed in Beagles with Retained Burdens of Radium 226, Radium 228, Thorium 228, Plutonium 239 or Strontium 90. COO-228; Research in Radiobiology, Semiannual Report of Work in Progress on the Chronic Toxicity Program, T.F. Dougherty (Ed.), (pp. 95-103), 185 pp. (COO-228).

By and six to seven years ago, a significant number of non-skeletal tumors have been observed in beagles receiving a single intravenous injection of Pu 226, Pu 228, Th 228, Pu 239, or Sr 90. Comparison with the control animals has tentatively indicated that most of these were naturally occurring tumors and were not radiation induced. The debility and premature deaths arising from this naturally occurring factor have been successfully minimized by early surgical care. Such measures to limit the losses from this and other non-radiation induced causes have become especially important at the lower dose levels where long latent periods are anticipated for some of the radiation induced lesions. (Auth)

<174>

Taylor, G.H., T.F. Dougherty, L. Shabestari, and J.E. Dougherty, University of Utah, Division of Radiobiology, Department of Anatomy, Salt Lake City, UT. 1969.

Soft-Tissue Tumors in Internally Irradiated

<170>

BIOLOGICAL ASPECTS
ANIMALS

<170> CONT.

Beagles. CCR-670930: Delayed Effects of Bone-Seeking Radionuclides. C.W. Hays, et al (Eds.), Proceedings of a Symposium held in Sun Valley, Idaho, September 12-14, 1967. University of Utah Press, Salt Lake City, Utah, (pp. 323-334), 519 pp. (CONV-670930).

In beagles injected in young adulthood with Pu 239, Ba 226, Sr 90, Ba 228 and Th 228, it appeared that the following 3 soft-tissue tumor types were induced: bile duct tumors (from Pu 239); intracocular melanomas (from Ba 226 and Ba 228); and carcinomas of the head sinuses (from Pu 239, Ba 226, and Sr 90). Each of the foregoing tumors occurred after long latent periods and arose from tissues that were irradiated rather heavily. Surprisingly, the observed hematopoietic tumors did not appear to be radiation induced. (Auth)

Table 2 shows the anatomical distribution of the 305 soft-tissue tumors observed in the Utah beagle colony.

<175>

Taylor, G.W., S.D. Lloyd, D.R. Atherton, C.W. Hays, L. Shabestari, and J. Williams, University of Utah, College of Medicine, Division of Radiobiology, Department of Anatomy, Salt Lake City, UT. 1970.

Radiation Induced Intracocular Melanomas. COO-119-242: Research in Radiobiology. Annual Report of Work in Progress in the Internal Irradiation Program, T.V. Dougherty (Ed.), (pp. 211-242) (CCC-119-242).

Prolonged retention of Pu 239, Ba 228 or Th 228 has resulted in a significant number of intracocular melanomas in beagles. Thus far, such tumors have occurred below the lowest presently observed osteosarcoma dose by factors of 3 and 6 for Ba 226 and Ba 228, respectively. They have developed at the lowest osteosarcoma dose in Th 228 dogs, but not below this level. Intracocular melanosis was induced by Sr 90 and Pu 239 but, thus far, intracocular neoplasms have not been produced by these radionuclides. (Auth)

Table 5 shows the general incidence of intracocular melanomas in the Utah beagle colony following treatment with Th 228, Pu 239, Ba 226, Ba 228 and Sr 90.

<176>

Taylor, G.W., C.E. Behfeld, P. Petersmann, and E. Crook, University of Utah, College of Medicine, Radiobiology Division, Department of Anatomy, Salt Lake City, UT. 1962, March 31.

Electrocardiogram Evaluation of Beagles with Retained Radionuclide Burdens. COO-225: Research in Radiobiology, Annual Report of Work in Progress in the Chronic Toxicity Program, T.V. Dougherty (Ed.), (pp. 43-67), 136 pp. (COO-225).

Evaluation of the electrocardiograms of beagles ranging in age from 480 to 3049 days, with retained burdens of Ba 226, Ba 228, Pu 239, Th 228, or Sr 90 did not reveal any significant effect on the respective wave patterns or the time intervals of the P wave, PR segment, PR interval, of QRS interval. Maximal injected dose levels studied were as follows: 3.0 micro Ci/kg Ba 226, 10.0 uCi/kg Ba 228, 0.3 uCi/kg Th 228, 0.3 uCi/kg Pu 239, and 100 uCi/kg Sr 90. (Auth)

<177>

Taylor, G.W., C.E. Behfeld, G. Schaeffer, and H.A. Johnson, University of Utah, College of Medicine, Division of Radiobiology, Department of Anatomy, Salt Lake City, UT. 1962.

Eye Changes Induced by Internal Irradiation. Some Aspects of Internal Irradiation, T.V. Dougherty, et al (Eds.), Proceedings of a Symposium held at The Hoechst, Weber, Utah, May 8-11, 1961. Pergamon Press, New York, New York, (pp. 163-177), 529 pp.

Grossly apparent iris and choroidal changes were induced in the dog (beagle) by the intravenous injection of Ba 226, Ba 228, Th 228 or to a lesser and variable extent by Pu 239. Alterations were not seen following treatment with Sr 90. Changes were limited to the pigmented parts which coincide with the studies of Stover and Atherton, who have shown these regions to retain relatively significant amounts of Ba 226, Th 228 or Pu 239. The principal symptoms included hyperpigmentation of the iris at low doses and depigmentation of the iris, choroid, and tapetum lucidum at higher doses. A dose-time-effect relationship exists except for Pu 239. Intracocular neoplasms or an abnormal incidence of cataracts were not observed. Loss of iris and choroidal pigment and degeneration or complete loss of the tapetum lucidum layer at higher doses were seen microscopically. (Auth)

<178>

Taylor, G.W., L. Shabestari, J. Williams, C.W. Hays, W. Hays, and S. McFarland, University of Utah, College of Medicine, Division of Radiobiology, Department of Anatomy, Salt Lake City, UT. 1975, March 31.

Mammary Neoplasia in a Closed Beagle Colony. COO-119-250: Research in Radiobiology, Annual Report of Work in Progress in the Internal Irradiation Program, W.S.S. Jee (Ed.), (pp. 197-209), 261 pp. (COO-119-250).

The report presents the incidence of breast tumors within a large colony of purebred beagle dogs born and reared at the Radiobiology Laboratory, University of Utah. Housing, diet and animal care factors were identical and remained unchanged throughout the life of each animal. A high percentage of the dogs have received carcinogenic radiation doses from internally deposited radioactivity in the skeleton (strontium 90, radium 226, radium 228) or in the skeleton plus the liver (plutonium 239, thorium 228). Direct irradiation of the breast tissue was negligible. Intercomparison of the irradiated and control groups with a correction for decrease in subjects at risk at increasing ages did not indicate any direct or indirect radiation effect on mammary tumor incidence. The relationship of mammary tumor incidence to age, relatively late ovariectomy (9 years and older), endometritis, parity status, and adrenal weight were examined. Of these factors, age was the only condition that was clearly correlated with changes in the mammary tumor incidence. The rate became significant at approximately eight years of age and increased progressively throughout the older age classes. Among the female dogs, the incidence of mammary cancer was higher than that of any other form of spontaneous malignancy. (Auth)

<179>

Tessmer, C.F., and J.F. Chang, H.D. Anderson Hospital and Tumor Institute, University of

<179> CONT.
Texas, Scovester, TX. 1967, December.

Thorotrast localization by Light and Electron Microscopy. Annals of the New York Academy of Sciences, 145(1), 545-575; COW-640422; Distribution, Retention, and Late Effects of Thorium Dioxide, D.L. Swann (Ed.), Proceedings of a Conference held in New York, New York, April 20-22, 1966, (pp. 545-575), 336 pp. (COW-640422).

Thorotrast presents a pattern of distribution in the rat liver following intravenous administration which has a major cycle in the Kupffer cell and a minor cycle in the hepatic cell. The Kupffer cell, which seems to be physically tolerant to the Thorotrast, nevertheless appears to undergo a multiplicative response, proliferative or accumulative, or both, and reacts with limited degeneration and fibrosis. Later response includes a less reactive stage with large amounts of thorotrast in clusters of limited numbers of cells. The two responses apparently occur in sequence in the rat, the subsequent one implying less active tissue response. This suggests a basis for the two general categories reported in the human—those with appreciable fibrous response, and those without such a response. Relative density of the Thorotrast aggregates by ultrastructure is believed to provide an index of redistribution. While the span of observation in the rat is approximately proporcional to those observed and reported in the human, further detailed observations by light and electron microscopy are indicated. (Auth)

<180>
Thomas, R.C., Lovelace Foundation for Medical Education and Research, Albuquerque, New Mexico. 1964.

Influence of Aerosol Properties upon Cross Distribution and Excretion. Health Physics, 10, 1013-1020.

Alteration of such aerosol properties as particle size and chemical composition may have profound effects upon overall distribution and excretion patterns. Results of experimentation with several different compounds will be used to exemplify this. These include studies with aerosols containing thorium, plutonium, niobium, uranium and polonium. The relative merits of certain bioassay techniques following inhalation exposure will be illustrated with experimental data. The influence which many of these variables have upon various aspects of hazards evaluation are referred to throughout. (Auth)

<181>
Thomas, R.C., Lovelace Foundation for Medical Education and Research, Albuquerque, NM. 1970.

An Interspecies Model for Detection of Inhaled Particles. Assessment of Airborne Particles, T.T. Mercer, P.E. Morrow and W. Steber (Eds.). Charles C. Thomas, Publisher, Springfield, Illinois, (pp. 405-420).

A model has been developed which may be applied to mouse, rat, and dog, to describe the kinetics of clearance of inhaled particles from the respiratory tract, and the uptake and excretion kinetics of this cleared material. Emphasis has been placed on the tracheobronchial lymph nodes as a storage site for cleared particles, with uptake being

described as a constant fraction of the amount of the deposited substance remaining in the respiratory tract at any time. First-order kinetics have been used to describe most of the translocation processes, and a very long life of retention (several thousand days) has been used for lymph nodes and one compartment of the lung. The rate constants have been described in terms of speculative physiological processes, as they may be affected by particle size and solubility. One advantage of this model is the ability to readily alter one or two constants and be able to obtain rather precisely a reasonable fit to experimental data points. Close agreement with results calculated from the model was attained with data from several sources, comparing lung and lymph node content of dogs with time after inhalation of various substances including PuO₂, Pu(NO₃)₃, ThO₂, and ThO₂. (Auth) (FMR)

<182>
Thomas, R.C., Lovelace Foundation for Medical Education and Research, Inhalation Toxicology Research Institute, Albuquerque, NM. 1964.

Influence of Aerosol Properties and the Respiratory Pattern Upon Hazards Evaluation Following Inhalation Exposure. COW-640422; STI/PUB/64: Assessment of Radioactive Body Burdens in Man, Proceedings of a Symposium held in Heidelberg, Germany, May 11-16, 1964, Vol. 1, (pp. 355-369), 1001 pp. (COW-640422, STI/PUB/64).

There are three important biological parameters which are necessary in evaluating the hazards from compounds entering the body by any route. These are (1) the amount deposited in the body; (2) the distribution and translocation kinetics within the body; and (3) the rate of excretion of the material. Sufficient quantitative data on these points are generally lacking in the case of an accidental exposure. Experimental animal studies correlating different physical and chemical characteristics of inhaled particles with the three biological variables mentioned above are described. Values for the amount and location of deposited material as a function of the particle size inhaled is presented for a tissue soluble compound (cesium chloride) and for a tissue "insoluble" compound (thorium chloride). Evidence is also given to substantiate the variations which occur in tissue distribution and excretion of an element, depending upon its physical and chemical state when breathed. Data from experiments with aerosols of many compounds, including those already mentioned, is used to show a unique correlation between body burden and fecal excretion during the first few post-exposure days. The advantages in performing analyses on both urine and feces for bioassay purposes are demonstrated. The fallacies in current methods of practical hazard assessment from air sampling and bioassay techniques are stressed throughout, using the above data as examples. (Auth)

Table 3 shows fecal to urinary ratios after inhalation of PuO₂ in dogs and niobium oxalate in rats.

<183>
Thomas, R.C., University of Rochester, Department of Radiation Biology, School of Medicine and Dentistry, Rochester, NY. 1961, April 20.

Distribution and Excretion of Thorium with Emphasis upon the Route of Injection and Amount

<183>

BIOLOGICAL ASPECTS
ANIMALS

<183> CCYT.

cf. Caquier Present. UR-592; 27 pp.

Four studies of the metabolism of thorium were reviewed and an attempt was made to establish qualitative differences in the distribution-excretion patterns as a function of the amount of thorium injected. After ingestion (gavage), thorium in either tracer or carrier amounts appears to be extremely insoluble and not appreciably (<0.5%) absorbed from the gastrointestinal tract. Most of the deposited fraction is deposited in the bone. Most thorium administered intravenously deposits to a large extent in soft tissue, mainly in the organs of the reticuloendothelial system, from which it is slowly solubilized either going to bone or being excreted. The amount found in the skeleton following this route is largely localized in the marrow. Following injection to the muscle, lung or other reservoir tissue, thorium behaves as a relatively insoluble material and enters the circulation very slowly as it is solubilized. The residence time in these reservoirs is extremely long, rendering the site of entrance to the body the choice for critical organ. The greatest practical exposure hazard appears to be to the lung because of the extreme lack of thorium solubility there. (NAT)

<184>

Thomas, R.G., Lovelace Foundation for Medical Education and Research, Albuquerque, NM. 1965. January; 1966.

Transport of Relatively Insoluble Materials from Lung to Lymph Nodes. LR-21; 15 pp.; Health Physics, 10, 114-117.

The concentration of relatively insoluble materials in the lung apparently bears a linear logarithmic relationship to that in the pulmonary lymph nodes after either single or repetitive inhalation exposures. This has been shown with experimental data in which compounds of uranium, thorium, plutonium and polonium have been inhaled by various species. Theoretical functions based upon logical postulates have been derived for predicting the concentration of materials in lung and lymph nodes following inhalation exposure. The calculations yield ratios between the two organs which closely approximate those from the experimental studies. An extremely long half-life component is postulated for lung (10,000 days) and an infinite residence time in lymph nodes has been assumed. Even though complicated biological processes may be involved in the transport from lung to lymph nodes, it appears that until more data are collected simple schemes like those presented could be employed. (NAT)

<185>

Thomas, R.G., R. Lie, and J.R. Scott, University of Rochester School of Medicine and Dentistry, Department of Radiation Biology, Rochester, NY. 1963.

Thorium Distribution and Excretion Studies. I. Patterns Following Parenteral Administration. Health Physics, 9, 153-163.

The distribution and excretion patterns of thorium administered in the citrated form to the rat have been determined after four routes of injection. These routes are intravenous (IV), intramuscular (IM), intraperitoneal (IP), and intratracheal (IT).

Two levels of thorium (thorium 234 and thorium 232) were used in the injections, one at a dose of 5.5×10^{-6} g/kg and the other at 6.6×10^{-6} g/kg body weight. Thorium at the higher level appeared to be more insoluble and of a particulate nature, either concentrating in tissues of the reticuloendothelial system or depositing in the tissue into which it was introduced (i.e. lung (IT), muscle (IM)). At the lower ("tracer") level, deposition was greater in bone (per g) than in other tissues, with the lung after IT injection being very nearly equal to it. The choice of a "critical" organ is clearly a function of the route of entrance to the body and of the concentrations of thorium involved. The pattern of deposition in the skeleton as a function of the level of thorium administered is discussed using data of several investigators from IV administration to rats. (NAT)

<186>

Thurman, G.B., University of Utah, College of Medicine, Radiobiology Division, Anatomy Department, Salt Lake City, UT. 1971.

Growth Dynamics of Osteosarcomas in Beagles. CGS-119-243; 127 pp.

This study presents an analysis of the growth dynamics, oncogenic skeletal doses and skeletal locations of radiolabeled osteosarcomas in beagles. Two hundred and fifty-six well-documented osteosarcomas were induced in 201 beagles, each receiving a single intravenous injection of Ra 224 (80 tumors), Pa 229 (64 tumors), Pa 228 (43 tumors), Th 228 (56 tumors), Sr 90 (8 tumors) or U 224 (5 tumors). Radiographs of each osteosarcoma were taken during the period of the tumor's growth. The growth dynamics of the osteosarcomas were estimated by measuring the tumor dimensions on as many radiographs as possible. It was clearly evident that the tumor volumes were increasing exponentially with time. Exponential growth constants were calculated for 289 tumors, the corresponding volume doubling times ranged from 8.7 to 60.3 days and averaged 12.4 days. Using individual exponential growth constants, a starting time for each tumor was estimated as the time when the extrapolated tumor's growth curve reached the volume of one cell 10^6 ($=10^{10}(2^{-3})$ cm) in diameter. The accumulated average skeletal dose during the time from injection to tumor starting time was calculated for each tumor and called the oncogenic skeletal dose. It was found that the larger the amount of radionuclide injected, the larger the oncogenic skeletal dose. High incidences of radiolabeled osteosarcomas in the beagles were noted in vertebrae, pelvic bones, humeri, femora and tibiae. Radiolabeled osteosarcomas of the vertebrae and pelvic bones had much higher incidences than the corresponding incidences of naturally-occurring osteosarcomas in dogs. (51 references) (NAT)

<187>

Thurman, G.B., C.W. Hays, G.W. Taylor, and T.F. Dougherty, University of Utah, Salt Lake City, UT. 1971.

Growth Dynamics of Osteosarcomas Induced in Beagles by Bone-Seeking Radionuclides. Radiation Research, 47(1), 258; CGS-119-228; Annual Report of Work in Progress in the Internal Irradiation Program, (p. 378) (CGS-119-228); Radiation Research Society,

PHYSIOLOGICAL ASPECTS OF THORIIUM

(1977) CONF.

Proceedings of the 19th Annual Meeting held in
Boston, Massachusetts, May 9-11, 1977, (p. 254).

This study reports an analysis of the growth
dynamics of 256 radiation-induced
osteosarcomas in adult beagles. The
osteosarcomas were induced by intravenous
injection of Ra 226 (80 tumors), Pa 239 (64
tumors), Th 232 (83 tumors), Th 234 (56
tumors), Sr 90 (5 tumors) or Ra 228 (5
tumors). Radiographs of each osteosarcoma
were taken during the period of the tumor's
growth. The growth dynamics of these
osteosarcomas were estimated by measuring
tumor dimensions on as many radiographs as
possible. During the period of measurements,
the tumor volumes appeared to enlarge
exponentially with time. Exponential growth
constants were calculated for 249 tumors, and
the corresponding volume doubling times
ranged from 4.7 to 61.1 days and averaged
12.4 days. The exponential growth constants
(rates of tumor growth) were not
significantly dependent upon sex,
administered radionuclide, injected
microCi/kg, tumor location, tumor
calcification, tumor volume at autopsy, or
age of the animal at death. (Auth)

(1980)

Tolidskaya, P.S., 1970.

Histomorphological Changes in Animals Following
Acute and Chronic Poisoning with ²³²Th. The
Toxicology of Radioactive Substances: Thorium
232 and Uranium 238, Vol. 2, A.A. L'etavet and
P.P. Kurlyanskaya (Eds.). Pergamon Press, New
York, New York, (pp. 127-136), 136 pp.

Morphological changes in internal organs of
dogs and rabbits subjected to acute and
chronic poisoning by ²³²Th were studied.
Acute intratracheal intoxication for a life
span of 4 to 20 days produced respiratory
lesions in lungs and bronchi. Lesions were
also observed in kidney, liver, spleen and
lymph nodes. Chronic intoxication for 250-315
days caused tumor-like depositions of ²³²Th
in lungs, bronchi and vessels. Hyperplasia
and metaplasia of bronchial epithelium
occurred. Effects were also noted in lymph
nodes, spleen, kidneys and liver. After
subcutaneous injection into fatty tissue,
free ²³²Th was found locally as was
disintegration of underlying muscle fibers.
Regional lymph nodes, liver and kidneys were
also affected. Dystrophic changes were less
pronounced than for intratracheal
administration, probably a result of less
absorption. Chronic oral studies (30-50
days) produced hemorrhage and thrombi in
gastrointestinal vessels. With chronic oral
and intratracheal administration (30-210
days) papillomatous proliferation of the
follicular epithelium of the thyroid
occurred. Acute intratracheal intoxication
(4-20 days) produced edema, hemorrhage, and
thrombi in vessels of the brain as well as
cellular damage in cortical and
thalamo-hypothalamic regions. Similar
effects occurred with chronic intoxication
(life span 70-825 days); dystrophic changes
in nerve cells were accompanied by focal
multiplication of glial and microglial
components. (VC)

(1989)

Trakovich, R., 1970.

Absorption, Distribution and Excretions of
Certain Soluble Compounds of Natural Thorium.
The Toxicology of Radioactive Substances:

Thorium 232 and Uranium 238, Vol. 2, A.A.
L'etavet and P.P. Kurlyanskaya (Eds.). Pergamon
Press, New York, New York, (pp. 22-29), 144 pp.

After intraperitoneal, intramuscular and oral
administration to rats, between 51 and 76 per
cent of the amount of thorium found in the
body is in the bone tissue. The amount in
other organs and tissues is much less and the
amount in the whole body does not exceed 2
per cent of that administered. On
intracardiac administration of thorium
nitrate and thorium nitrate the thorium
mainly accumulates in the liver (17 per cent)
and spleen (11 per cent). During the first
three days following intraperitoneal and
intramuscular injection of thorium nitrate
only 0.159-0.732 per cent of the amount
administered is excreted in the urine and
feces. The excretion in the urine varies
from 0.01 to 0.015 per cent of the amount
administered and does not depend on the route
of administration. During the first three
days following intracardiac administration of
thorium nitrate about 22 per cent of the
amount administered is excreted, 19 per cent
of this amount in the urine. Apparently,
absorption, distribution and excretion of
thorium on intraperitoneal, intramuscular and
oral administration have common
physicochemical and biological mechanisms.
On intracardiac administration there are
certain special features in the distribution
of thorium associated with the degree of
dispersion of its compounds. (Auth)

(1990)

Tril, C., Pinner Institute, Pinner Laboratory,
Copenhagen, Denmark. 1971, April.

The Retention of the Daughters of Thorium 232 in
the Soft Tissue in Animals. CONF-730875;
NISC-298; Toxicity of Thorium, V. Faber
(Ed.), Proceedings of the 1st International
Meeting held in Copenhagen, Denmark, April
26-27, 1973, (pp. 61-71) CONF-730875, NISC-298.

For percent of Pa 239 injected intravenously
into rabbits was deposited in the bones in
equilibrium with all of its daughters. No Pa
239 was found in soft tissue. About 10 or
41% of injected Th 232 was deposited in soft
tissue. Of the daughters formed by Th 232
about 80% were found in the body of the
sacrificed animals. Of the 41%, 15-20%
resulted from thoron which diffused into the
blood stream but decayed before the blood
arrived at the lungs. Of the 60% of Th 232
daughters in the living animal, 15-20% was
exhaled as Pa 239, about 40% as Pa 239, and
about 5% as Pb 212. (PAF)

(1991)

University of Utah, College of Medicine,
Division of Pathobiology, Department of Anatomy,
Salt Lake City, UT. 1962.

Radionuclides and Bone Strength. Some Aspects
of Internal Irradiation, T.F. Dougherty, et al
(Eds.), Proceedings of a Symposium held at The
Hemstead, Heber, Utah, May 8-11, 1961. Pergamon
Press, New York, New York, (pp. 145-162), 529 pp.

The dose-response relationship for the
induction of bone sarcoma by long-lived
beta-emitters is strongly sigmoidal. For
alpha-emitters such as Pa 239, Th 232, Ra
226 and Ra 228, the relationship appears
linear for rodents, but may be sigmoidal for
man and dog. In 10 intercomparisons of life
shortening and the induction of neoplasms
from low LET radiation, the effect per rad at
low dose-rates averaged 0.7 of that at high

<1911>

SYNTHETICAL ASPECTS ANIMALS

<191> CONT.

dose-rates. In contrast, for alpha irradiations from $\text{Ra } 226$, the incidence of bone sarcomas from a given dose increased as the dose-rate was lowered. (Auth) Slate, L.S.

Tables 1-3 give the calculated values obtained from the measurements of the three experiments.

<192>

University of Utah, College of Medicine,
Radiobiology Laboratory, Salt Lake City, UT.
1955, September 30.

Semiannual Progress Report. ARCU-3109; 80 pp.

Observations of the effects of various radionuclides on the bodies of dogs and rats were made. The radionuclides used are plutonium, radium, mesothorium, radiothorium, and strontium. Four parts of the progress report that concerned Pu were abstracted and entered separately into the data base. (LCW)

<193>

University of Utah, College of Medicine,
Radiobiology Laboratory, Salt Lake City, UT.
1955, September 30.

Injection Tables. ARCU-3109; Semiannual Progress Report, (pp. 4-12). 80 pp. (ARCU-3109).

The animals for the toxicity study were injected in groups of six with each animal receiving doses from 0 to 2.5 $\mu\text{Ci/kg}$ in a single intravenous injection. Injection tables are included for plutonium, radium, mesothorium, radiothorium and strontium. The tables include: the approximate retained dose in $\mu\text{Ci/kg}$, the experimental number of the animals, the age at injection in months, the weight at injection, the injected dose in $\mu\text{Ci/kg}$, the date injected and the days since injection. (LCW)

<194>

Van Cleave, C.D., University of North Carolina,
School of Medicine, Chapel Hill, NC. 1968, July.

Bone Tumors Induced in Animals. TID-28310; Late Stochastic Effects of Ionizing Radiation, (pp. 137-138), 310 pp. (TID-28310).

At the University of Utah, a comparative study is being made of the biological effects in adult beagles of the internal irradiation resulting from single graded injections of five different radionuclides: $\text{Ra } 226$, $\text{Pu } 239$, $\text{Pu } 224$, $\text{Th } 228$ and $\text{Sr } 90$. The primary aim of the study is to compare the toxicity of the five radionuclides, and many different end points are under observation. The pathological events include the induction of bone tumors, the fracturing of bone, and the acceleration of aging (Dougherty, 1962). Although all the radionuclides may produce different pathological changes, they all have in common the fact that they deposit in bone. Consequently, among the various types of tumor induced, osteosarcomas have been most frequent. At many injection levels the incidence of death from this cancer was 100 percent. On the basis of the mean dose to bone, $\text{Pu } 239$ and $\text{Ra } 226$ appear significantly more effective than $\text{Sr } 90$ in inducing osteosarcomas, but the data are preliminary, and the basis for the differences remains to be determined. Data from low injection levels will not be available for several years. (RP)

<195>

Vaughan, J., Medical Research Council, Churchill Hospital, Bone Seeking Isotopes Research Unit, Oxford, England. 1962.

Bone Disease Induced by Radiation.
International Review of Experimental Pathology,
S.W. Fichter and E.A. Epstein (Eds.), Vol. 1,
Academic Press, New York, New York, (pp.
283-349), 453 pp.

A comprehensive review of radioinduced bone disease is presented. Certain points of general biological interest were stated. The first is that although there was often an association between radiation dysplasia and radiation neoplasia the evidence showed that the relationship was not necessarily a causal one. Secondly, it was stated that radiation dose was only an effective factor in promoting radiation neoplasia in bone if other tissue conditions were favorable. Finally, in the case of bone, the tissue at risk, as far as neoplasia was concerned, was probably the osteogenic connective tissue, particularly on endosteal surfaces. The review was organized into several sections, the titles of which included: sources of skeletal irradiation, radiation dosimetry, the bone-seeking radioactive isotopes (giving the physical characteristics of $\text{Sr } 90$, $\text{Y } 90$, $\text{Ca } 45$, $\text{Pu } 239$, $\text{Ra } 226$, $\text{Th } 228$ and $\text{Th } 229$), pathological changes produced in bone by irradiation, external and internal irradiation describing the clinical and experimental studies of bone damage and the character of tumors produced by skeletal irradiation. (FHH)

Table 2 shows incidence of osteosarcomas in Utah Beagles as of March, 1961.

<196>

Vivjic, V., D. Fanov, and Lj. Novak, Institute of Occupational and Radiological Health, Belgrade, Yugoslavia. 1976, September.

Effects of Uranium Ore Dust, Radon and Products of its Decay in the Lungs of Rats. Health Physics, 31(3), 277-278.

Pathohistologic examination and measurements of hydroxyproline have been performed in the lungs of rats exposed to 50 μg of uranium ore dust (3.400 g of uranium/ton of ore) and to radon inhalation with products of its decay. (Radon concentration was 10 (E-7) Ci/l. , inhalation lasted 668 hr during 6 months.) After six months pneumoconiotic lesions of an uncollagenous nature were found in the exposed lungs. Radon inhalation in exposed lungs does not influence the character of pathologic changes. Microscopic examinations of lymphatic nodules showed faster evolution of coniotic lesions due to radon influence. In the lungs of exposed groups hydroxyproline content was found to be equal to the control group of the rats. (Auth)

<197>

Walsh, P.J., and P.E. Hamrick, National Institute of Environmental Health Sciences, Research Triangle Park, NC.

Radioactive Materials--Determinants of Dose of the Respiratory Tract

Determinants of radiation dosage received in the respiratory tract for persons exposed to radioactive aerosol are considered. Discussed in detail are: dose definition, aerosol characteristics, dose calculations, dose from radon daughters. In the latter,

BIOLOGICAL ASPECTS
ANIMALS

<157> CONT.

aerosol characteristics, deposition models, clearance, critical tissue, depth-dose calculations, relationship of working-level month exposure to dose in rads, assumptions in models and research needs are considered. The problems associated with determining dose to the respiratory tract from inhalation of radioactive materials are essentially the same as those associated with any inhaled toxic materials. Determination of dose, assuming reliable deposition calculations, is conceptually straight forward compared to chemical or biological properties of materials. The numerous assumptions and resulting uncertainties involved in deposition calculations and interspecies comparisons demonstrate the need for further work. The problem is further complicated by the possible interactions or effects of conjoint exposure to two or more agents. (Auth) (VC)

<158>

White, G.V., and J. Schubert, Argonne National Laboratory, Division of Biological and Medical Research, Chicago, IL. 1952, January-April.

The Action of Salts of Zirconium and Other Metals on Plutonium and Yttrium Distribution and Excretion. *Journal of Pharmacology and Experimental Therapeutics*, 100, 317-324.

Adult female rats were injected either intraperitoneally or intravenously with trivalent Pu 239 in a 1% sodium citrate solution, pH 6-7. Each rat received between 10 and 20 µg in different experiments. Approximately 1 µCi of Y 91 was added to the Pu solution in some experiments. Treatment solutions were injected intraperitoneally or intravenously at different tissues from 8 days before to 24 hours after the radioelement. Treatment of rats with zirconium prior to injection of plutonium and yttrium lowered the amount of Pu and Y subsequently deposited in the skeleton and increased the amount of Pu in the kidneys. The deposition of both Pu and Y in the bone was correlated with the length of time between pretreatment and their injection. Zr injected 24 hours after Pu and Y prevented further deposition of the radioelements in bone, but had no other observable effect on their organ distribution. In addition to Zr other hydrolyzable elements manganese, iron, titanium, aluminum, and thorium reduced bone deposition of Pu, but had various effects on the amounts deposited in other organs. Al and Th increased the Pu content of the liver and other soft tissues. Non-hydrolyzable magnesium had no significant effect on the distribution of either Pu or Y. The mechanisms by which salts of Zr and other hydrolyzable elements may affect Pu and Y metabolism is discussed. This includes adsorption of the radioelement on colloidal aggregates in the circulation and the relation between particle size and the resulting distribution of the aggregate plus adsorbed radioelement. (RAV)

The effects of pretreatment with Zr on the

distribution of Pu 239 and Y 91 are given in tabular form.

<159>

Woodhead, J.S., Ministry of Agriculture, Fisheries and Food, Fisheries Radio-biological Laboratory, Lowestoft, Suffolk, United Kingdom. 1974.

The Estimation of Radiation Dose Rates to Fish in Contaminated Environments, and the Assessment of the Possible Consequences. CBNP-740529; STI/P03/375; IAEA-SM-100/11; Population Dose Evaluation and Standards for Man and his Environment, Proceedings of a Symposium held in Portoroz, Yugoslavia, May 26-28, 1974, (pp. 555-575), 646 pp. (CNP-740529, STI/P03/375, IAEA-SM-100/11) pp.

The disposal of radioactive waste into coastal waters, rivers and lakes may produce localized conditions in which fish experience radiation dose rates in excess of that from the natural background. Reasonably realistic estimates of these dose rates may be obtained by combining data on the levels of radioactivity in the water, sediments and fish with simple dosimetry models. Where the dose rates are sufficiently high it has been possible to provide confirmation of the estimates, using *in situ* thermoluminescent dosimeters. A knowledge of the radiation regime, together with information on the effects of irradiation on fish, provides a basis for assessing the consequences for fish populations in contaminated environments. (Auth)

Tables on natural and discharged radioactivity in freshwater and seawater are presented.

<160>

Takcvleva, V.P., 1976.

Effect of Fallout Products on Biochemical Indices of Blood Serum in Cows. *Sel'skokhoziaistvennaia Biologia*, 11(3), 449-452.

The biochemistry of protein, carbohydrate, lipid, mineral metabolism and pigment function of liver was evaluated in the blood sera of cows which received products of uranium 235 of 9.5-10 hours' age (PP). The animals displayed a subacute radiation sickness. There was suppression of the transaminase activity of blood caused by dystrophic transformations in tissues of heart and liver. The increase of the indices of lipid metabolism is probably a sequence of the hypofunction of thyroid gland. The increase of the content of protein-bound carbohydrates in the blood serum of radiated cows was observed only during the period of the expressed clinical picture of the subacute radiation sickness. The decrease of the amount of iron in the blood serum was accompanied by a decrease of the concentration of hemoglobin; potassium and sodium content remained the same as did the pigment function of liver. (Tr) (RAV)

BIOLOGICAL ASPECTS
PLANTS

(201)

Shandari, S.C., and D.B. Sen, University of
Jodhpur, Department of Botany, Jodhpur, India.
1975, November-December.

Effect of Basic Acid and Benzyl Acetate on
Seedling Growth, Excised Cotyledons,
Chlorophylls, Proteins and Sugar Contents in
CITRULLUS Species. *Biologia Contemporanea*,
2(4), 166-170.

Basic acid favored the growth of seedlings in
75 ppm, in continuous light while all the
other concentrations favored this in total
darkness in *C. COLOCYNTHIS*. In case of *C.*
LAVATUS seedling growth was promoted only in
lower concentrations both in continuous light
and total darkness. Fresh and dry weights of
excised cotyledons increased with increasing
concentrations in *C. COLOCYNTHIS* while this
was so only in lower concentration in *C.*
LAVATUS. Benzyl acetate promoted the seedling
growth both in continuous light and total
darkness for both the spp. of *CITRULLUS*.
Fresh and dry weights of cotyledons were
found to be beneficially affected. Expansion
in area of excised cotyledons, proteins and
sugars increase only in lower concentrations
in both the spp. of *CITRULLUS*. (Auth)

(202)

Sharma, T.J., and K.B. Histry, Shabha Atomic
Research Center, Bombay, India. 1970.

Comparative Uptake of Thorium 230, Radium 226,
Lead 210, and Polonium 210 by Plants. *Radiation
Isotopy*, 11, 253-256.

Quantitative data are reported on the entry
and translocation of Th 230, Ra 226, Pb 210,
and Po 210 measured under closely comparable
conditions in nutrient culture experiments;
Sr 49 was included for comparison. It is
shown that the accumulation of Th 230, Pb
210, and Po 210 occurs predominantly in the
roots and only very small amounts of these
nuclides are translocated to shoots. Over
comparable periods, the accumulation of Ra
226 in roots is 2 to 3 times lower than that
of other nuclides of the uranium series. The
most significant difference between Ra 226
and other nuclides is that the upward
transport for radium is 50 to 200 times
greater and the ascent of radium translocated
to shoots is comparable to that of strontium.
(Auth)

(203)

Higginson, D.B., S.A. Gordon, W.H. Thomas, and
L.B. Alcock, Argentine National Laboratory,
Buenos Aires, 1969.

The Concentration of Radium, Thorium, and
Uranium by Tropical Algae. *IAEA-7615*,
Radiological Physics Division Annual Report,
July 1969- June 1969, (pp. 1-17), 233 pp.
IAEA-7615: Limnology and Oceanography, 15,
945-955.

Samples of twenty species of marine algae
collected between 1961 and 1968 in Puerto
Rico have been analyzed for total organic
material, protein nitrogen, calcium, radium,
thorium, and uranium. The results suggest
that the concentration of radium, thorium, or
uranium by these organisms may be controlled
by two mechanisms: (1) ion-exchange or
coprecipitation of the ion with the calcium
carbonate matrix, or (2) complex formation
with either the protein nitrogen or some
other component of the organic fraction.
Concentration of radium (and possibly
thorium) appears to occur by both mechanisms,

the dominant one being dependent upon the
division. For the *PHACOPHYCEAE* and the
highly calcified *CHLOREPHYCEAE* it is the
former, and for the *PHACOPHYCEAE* the latter.
Concentration of uranium occurs by the first
mechanism. This difference in behavior is
consistent with the chemical forms of the
ions of these elements in seawater. (Auth)

(204)

Erasmetsae, C., and I. Yliruutonen, Helsinki
University of Technology, Otanien, Finland.
1971.

Nitrogen, Molybdenum, Hafnium, Tantalum, Thorium,
and Uranium in Lichens and Mosses. *Scandinavian
Journal of Botany*, 24(1), 172-178.

The contents of N, Mo, Hf, Ta, Th, and U in
the ash of 12 lichen samples (8 species) and
22 moss samples (11 species) were determined
by spark source mass spectrometry. Nitrogen
concentrations were usually 1 to 20 ppm,
molybdenum 1 to 20 ppm, hafnium 1 to 10 ppm,
tantalum 1 to 10 ppm, thorium 0.5 to 20 ppm,
and uranium 1 to 7 ppm in the ash. Fifteen to
170 ppm Sb were present in samples from a
carbonatite phosphorite deposit and 65 to 4900
ppm T in samples from an atomized uranium
mine. (Auth) (PAP)

(205)

Kozlov, B.L., and D.N. Rubtsov, 1972.

Accumulation of Thorium, Uranium, and Radium by
Plants and Organogenic Horizons of Soils.
*Radiokologicheskie Issledovaniya v Prirodnykh
Biogeochemicheskikh, I.V. Verkhovskaya (Ed.),
Izdatel'stvo Nauka, Moscow, "SSR (pp. 112-123).*

The accumulation and distribution of thorium,
uranium, and radium in plants of the taiga
zone was studied in relation to the content
of radionuclides in the soil. Only radium is
accumulated by plants in substantial
quantities, its biological accumulation
coefficients as a rule exceeding 1.0. It was
found that the European mountain ash (*SCORPUS
HYCOPHYLLA* L.) has a selective capacity of
radium absorption, expressed in its high
absolute content (up to 10×10^3 g/g) and
characterized by a significant (up to 100)
accumulation coefficient. Uranium and
thorium accumulation coefficients are as a
rule lower than 1, decreasing to 0.09 to 0.21
with a considerable increase of thorium in
the soil. The study of the distribution of
radionuclides in plants showed that the
greatest quantities of these elements
concentrate in the older organs and tissues
(bark, branches, wood) and the least in young
ones (leaves, inflorescences). It is shown
that radium, uranium, and thorium are
elements with an acropetal distribution. The
accumulation of thorium in forest litter
follows the same trend as in the vegetative
cover, that is no enrichment of the humus
horizon with thorium is observed at a high
content of this element in the soil. (Auth)

(206)

Korovitz, C.F., R.H. Schock, and L.A.
Korovitz-Vasileva, Tuebingen University,
Institute for Chemical Plant Physiology,
Tuebingen, German Federal Republic; Tuebingen
University, Institute for Mineralogy and
Petrography, Tuebingen, German Federal Republic.
1970.

The Content of Scandium, Thorium, Silver, and
Other Trace Elements in Different Plant Species.
Plant and Soil, 40, 397-401.

BIOLOGICAL ASPECTS PART 2

(206) CONT.

Thirty five plant species, representing the main plant kingdom, as well as some soil samples collected under these plants, were analyzed for Sc, Th, Ce, Co, Nb, Cs, Pb, Zn, and Ag. Higher contents of Sc and Th as well as of other elements were found in some fungi and bryophytes, whereas a lower content was found in angiosperms and gymnosperms. A higher Ag content was found in some plant species. Analysis showed an average Th content of 0.45 ppm in 18 plant species. The highest Th content was registered in mosses. A correlation between Sc and Th was observed in some plants. (BAP)

(207)

Iskra, A.A., V.V. Felikhov, and V.G. Baturayev, Academy of Sciences of the USSR, Institute of Ecology of Plants and Animals, Ural Branch, USSR. 1970, March-April.

Role of Freshwater Vegetation in Processes of Migration and Distribution of Natural Radioactive Elements in the Reservoir. Ecology (USSR), 2, 157-162.

The accumulation of uranium 238, radium 226, and thorium 232 by various species of freshwater plants and the distribution of these elements among the principal components of a nonaccumulating reservoir were studied under experimental conditions. The coefficients of accumulation and concentration fluctuated from tens to hundreds of units depending on the plant species and the physicochemical properties of the element. For each element several plant species were specific accumulators. In a model system of freshwater reservoirs consisting of water and plants, the migrational ability of the elements in decreasing order was uranium, radium and thorium. In a model system consisting of water, soil, and plants, uranium accumulated predominantly in the plants, thorium in territes and soil, and radium was distributed evenly among the components. (ST)

Table 1 gives the accumulation coefficients of radioactive elements for 27 species of aquatic plants (dry wt). Table 2 gives the concentration coefficients of radioactive elements calculated on ash residue.

(208)

Kovalevskii, A.L., Siberian Scientific Research Institute of Geochemistry, Novosibirsk, USSR. 1962.

Natural Radioactive Elements in Plants. Izvestiya Sibirskogo Otdeleniya Akademii Nauk SSSR, 6, 108-110.

Selective absorption of Ra, U, and Th isotopes by plants and the radioactive equilibrium of Ra isotopes and their decay products were studied. The accumulation of U, Ra, and other rare-earth elements by plants is determined by chemical rather than radioactive properties. In spite of the fact that the number of beta decays from natural radioactive elements exceeds (by a factor of 2) the number of alpha decays, the ionization of living tissue by alpha particles exceeds that by beta particles, especially in leaves, flowers, and young shoots. The mesothorium and ThX (Ra 228) alpha emitters are prevalent in plants. (BAP)

(209)

Felikhov, V.V., Academy of Sciences, Institute of

Plant and Animal Ecology of the Ural Scientific Center, USSR. 1972.

Radioactive Isotopes in the System Water-Freshwater Plants. APC-tr-7606; Radioecology of Water Organisms. Vol. 2. Distribution and Migration of Radionuclides in Freshwater and Seawater Biocenosis, G.P. Ankrashaitis (Ed.), (pp. 25-31) (APC-tr-7606).

Radioecological studies on the migration and distribution of radionuclides in the system water/aquatic plants are reviewed. It is stressed that published data on the accumulation of radionuclides by freshwater plants deal predominantly with experimental aquarium studies. Results with a group of natural radioactive elements showed that the accumulation coefficients of U 238 and Ra 226 in higher plants are higher than in algae and only experiments with Th 232 showed an inverse dependence. Radionuclides mentioned are Sr 90, Cs 137, Ca, Y 91 and U 235. The highest accumulation coefficients are in plants floating on the surface of water, and the lowest are in plants growing in water near the shore. Data indicate that the accumulation of radionuclides by freshwater plants depends on the physicochemical state of nuclides in water and on the concentration of hydrogen ions in it. In spite of numerous available data, the role of plants in the overall balance of radioactive substances in water reservoirs under natural conditions cannot be evaluated. (BAP)

(210)

Turner, W.V., F.C. Turner, and J.M. Bailey, Institute of Cancer Research, Royal Cancer Hospital, Physics Department, London, England. 1970, July.

Alpha Activity of Certain Botanical Materials. Nature, 197, 229-231.

Alpha activity measurements were made of a number of plants, some of which are used directly as human foods while others, such as grasses, form the principal food of animals. Measurements include total alpha activity, the assessment of the relative contributions made by the uranium and thorium series and the precise identification of the nuclides present. Samples included soils, herbs, grasses, and fruit originating in different parts of Great Britain and Central Africa. In soils uranium contents ranged from 0.5 to 2.1 and thorium contents from 0.6 to 3.7 µCi/g soil at both geographic locations. No simple relation was found between the natural activity in vegetation compared to the corresponding specimens of soils. Widespread and predominant activity in plants was due to Po 210 present in specimens ranging from British grasses to plants of various species (bananas, mango, coconut, paw-paw, coffee, rubber, corn, cotton, pommes-sur-terre) from Central Africa. Leaf and bark generally showed higher activity than fruit. A preference of plants for radium rather than thorium isotopes was observed. An uncertainty of the degree of radioactive equilibrium in the plant-soil system at any particular time rendered generalizations difficult. (BAP)

(211)

Nikolaeva, A.V., 1969.

The Concentration of Thorium and Rare Earths by Plants at Different Times during Vegetation. GSI-tr-8592; 8 pp.; Trudy Byryatskogo Instituta Estestvennykh Nauk Buriat Vilial SO AN SSSR, 5.

<211>

BIOLOGICAL ASPECTS PLANTS

<211> COST.
191-195.

The Th and rare earths content of plants growing in or near highly mineralized areas was determined by spectral analysis of plant ashes. Plants studied included: reed bay, tarragon, curled dock, milk vetch, Tartar honey-suckle, golden ray, angelica, Turkestan bedstraw, Russian knapweed, cherry, rewan, tansy, sage, common reed, barberry, and apricot. Thorium and rare earth content was lower in grassy plants than in shrubs. Many plants growing in mineralized areas were found to undergo significant morphological changes such as stronger root systems, and larger stalks, leaves and flowers in comparison with plants growing beyond mineralized fields. Thorium and rare earth content of the dogrose in mineralized areas was 0.0039 and 0.0064, respectively, as compared to 0.00018 and 0.00058 in areas of lower mineral content. Morphological changes are attributed to the higher Th and rare earth content of plants. The maximum accumulation of these elements occurs in different parts for different plants. Many plants show highest concentrations in May; in June their content decreases substantially and increases in the fall. In the majority of plants a maximum accumulation of Th occurred with a maximum accumulation of rare earths. (BAP)

<212>

Foss, A.S., University of Keele, Department of Biology, Keele, Canada. 1975, March.

Some Effects of Heavy Metals on Fungal Cells. Transactions of the British Mycological Society, 66(2), 175-193.

Uranium dioxide, $UO_2(2+)$, is reversibly bound to the yeast cell surface, specifically to phosphoryl groups on the cell surface. Competition studies showed carboxyl groups were also binding sites which became involved when phosphoryl groups were saturated. There was no evidence that the ions entered the cell. Fermentation of sugar and invertase activity are inhibited by low and high concentrations, respectively, of the ions. Sugar metabolism is inhibited as a result of impaired sugar transport. Uranium dioxide has been used as an inhibitor in sugar transport studies and to identify binding sites for other metal ions. The effects of other heavy metals are also reviewed. These include manganese, zinc, cobalt, nickel, copper, mercury, lead, and silver. (VC)

<213>

Sarniok, J., Curie, Probeniotworczosc, Warsaw, Poland. 1972.

Studies on the Radioecology of MARCHANTIA POLYTRICHA L. in the Sudetes. Monographiae botanicae, 35, 161-203.

The radioecology of MARCHANTIA POLYTRICHA L. in the area of the Sudetes radiation anomalies has been studied. The ecological specificity of the habitats within the area is determined by high content of Th, U, and Ra in the soil as well as low-horizon radiation. The soils contain average 4.4 ± 1.5 cf soil values of $6.9 \times 10(E-3)$ Th; $16.5 \times 10(E-3)$ U; $40.1 \times 10(E-10)$ Ra. Gamma radiation is $0.06-1.08$ $\mu R/hr$. The amounts of total and assimilable Th, U and Ra in the soil of the habitats varies widely depending on soil type and substrate. Ashed samples of M. POLYTRICHA and accompanying PHYTOPLANKTON

species contain average 5 of $2 \times 10(E-3)$ U, $7.2 \times 10(E-3)$ Th, and $4.1 \times 10(E-8)$ Ra. M. POLYTRICHA and M. ALPESTRIS have the highest contents of the 3 elements. All PHYTOPLANKTON studied have high alpha- and beta-activity: the average beta is 1006.76 pc/g ash; alpha is $0.04 \times 10(E-10)$ c/g ash. M. ALPESTRIS and POLYTRICHA have the highest and P. COMPLANATA the lowest alpha- and beta-activity, the high values for beta are $2,500$ pc/g ash and the low value, 408.02 pc/g ash. Alpha activities for M. ALPESTRIS and POLYTRICHA average $10.70 \times 10(E-10)$ c/g ash. Natural continuous low-level radiation has effects on development of ecological populations of M. POLYTRICHA. These are in segmentation and size of the thallus. Gamma radiation ($0.76-0.91$ $\mu R/hr$) stimulates its growth and vegetative development and inhibits sexual development. In habitats with high radioactivity M. POLYTRICHA dominates. Individuals from such habitats tolerate Co 60 radiation. M. HIRTZ exhibits the highest tolerance (DL 100-60 kR), M. ALPESTRIS lower (DL 100-60 kR), and M. POLYTRICHA the lowest. Among M. POLYTRICHA populations, those from habitats with increased natural radiation have highest tolerance to radiation (DL 50-55 kR, DL 100-72 kR). (auth) (Trans) (VC)

<214>

Strobal, P., and T. Pinter, Puder Bontovic Institute, Center for Marine Research, Rijeka, Yugoslavia. 1973.

Thorium in Water and Algae from the Adriatic Sea. Limnology and Oceanography, 18, 250-253.

Thorium concentrations were determined in filtered (0.45μ millipore) and unfiltered seawater as well as in marine algae. In filtered seawater, values were $8 \times 10(E-13)$ g Th per liter and lower; for unfiltered seawater samples, values about three orders of magnitude higher were obtained. Thorium concentrations in marine algae were in the range of $10(E-6)$ to $10(E-9)$ g Th per gram ashed material. (auth)

The Th content in green, brown and red marine algae is given in tabular form.

<215>

Turner, R.C., J.R. Badley, and W.V. Mayneord, Institute of Cancer Research, Royal Cancer Hospital, Physics Department, London, England. 1969.

The Naturally Occurring Alpha-Ray Activity of Foods. Health Physics, 1, 268-274.

Most of the activity is due to members of the thorium and radium series. There is a factor of 20,000 between the most active and least active foods. The most active food so far measured is the Brazil nut; breakfast cereals have the next highest alpha activity. In general, values in milk products, fruits and vegetables are low. The alpha-activity seems to increase with the phosphorus content of foods. In general, an adequate diet will not contain less than $2 \times 10(E-12)$ Ci of alpha activity/day. (auth)

A table is given of the total alpha activity, radium 226 and radiothorium 228 activity in 109 foods.

<216>

Ylikorkanen, T., Helsinki University of Technology, Department of Chemistry, Helsinki,

BIOLOGICAL EFFECTS PLANTS

<216> CCST.
Finland. 1975.

Promium, Thorium, Lead, Lanthanoids and Uranium
in Some Plants Growing on Granitic and
Radioactive Rocks. Bulletin of the Geological
Society of Finland, 87(1-2), 71-78.

Spark source mass spectrometry with
electrical detection was used for the
determination of trace element contents in
the ash of 172 plants comprising 21 lichens,
42 mosses, 78 dwarf shrubs, and 31 trees. The
highest contents found in single samples were
2800 ppm U in one moss, 20 ppm Th in one moss
and one lichen, 1200 to 1000 ppm Pb in
lichens and mosses and in one CALLUNA
VITICARIA, 110 to 100 ppm Y and La in some
lichens and mosses, and 150 ppm Ce in one

moss; the moss contents were usually
significantly lower. No anomalies were found
in the lanthanoid distribution in these
plants and the influence of erosion and
lanthanoid mineralizations was detectable
only in the immediate vicinity of mineralized
spots. The U content was higher in some
mosses and dwarf shrubs growing directly on
mineralized pegmatite or very close to
syenites. The Th content was low in all
samples because the minerals are stable and
the mobility of Th is very low. In deciduous
trees the Th content was below detection
limit in all samples. In conifers the
highest contents (3 to 5 ppm) were found in
pine samples. (BAP)

CHEMICAL ASPECTS

<217>

Pilbert, R.E., New York University Medical Center, Institute of Environmental Medicine, New York, NY. 1966, November.

Physical, Chemical, and Radioactive Properties of Thorium and Thoron. Thorium: Its Industrial Hygiene Aspects, Chapter 2. Academic Press, New York, New York, (pp. 5-26), 222 pp.

The chapter includes information about the properties of Th metal, compounds of Th, Th complexes and solvent extraction, Th ion exchange, coprecipitation and colloid formation, radioactive properties, general properties of thoron, its compounds, and emanation. The properties of Th metal are tabulated. Soluble salts, including the nitrate, sulfate, chloride and perchlorate as well as insoluble compounds, the hydride, oxide, carbonate, fluoride, fluoride are discussed. The highly charged (+4) Th ion tends to form complexes with inorganic ions and organic ligands. At pH greater than 3, Th tends to behave as a colloid, a fact important in its metabolic behavior. Substances complexing with Th hinder colloid formation such as is the case with citrate in blood containing low Th concentrations. Properties of Th isotopes are tabulated. Of thirteen isotopes, four, Th 232, 228, 230 and 230, are industrially important as health hazards. Thorium 232, 228 are in Th minerals, Th 230, 230 in natural U. Thorium 231, 227 are in 2 minerals as a result of 235 decay. Growth and decay of Th 232 with alpha, beta, and gamma emissions are discussed; half-lives, energies, and abundance are tabulated and the alpha decay chain is diagrammed. Thoron, although having a stable electronic configuration may undergo limited types of chemical interaction. (NC)

<218>

Shorten, D.L., University of Utah, Salt Lake City, UT. 1966, March 11.

FFA-Scintillator Method for the Analysis of Biological Material for Small Quantities of Strontium 90, Thorium 228 and Plutonium 239. CCC-119-237; Research in Radiobiology, Annual Report of Work in Progress in the Internal Irradiation Program, L.F. Dougherty, (pp. 181-187) CCC-119-237.

The use of 4i-2 ethyl-hexyl phosphoric acid (ZHFA) and liquid scintillator for the analysis of biological material for Sr 90 and Pu 239 has been previously described. Here the previous methods are consolidated with yet another procedure--the analysis of biological material for Th 228. The general method, as it has evolved, and the specific considerations necessary for its application to each of the 3 radionuclides are reported. (Auth)

<219>

Fontietti, E.A., S.A. Reynolds, and W.H. Shanks, Oak Ridge National Laboratory, Environmental Sciences Division, Oak Ridge, TN; Oak Ridge National Laboratory, Chemistry Division, Oak Ridge, TN. 1975.

Interaction of Plutonium with Complexing Substances in Soils and Natural Waters. IAEA-SM-199/51; CONF-755105; Environmental Sciences Division Publication No. 758; Transuranic Nuclides in the Environment, Proceedings of an International Symposium held in San Francisco, California, November 17-21, 1975, (20 pp.) (IAEA-SM-199/51, CONF-755105).

The interaction of plutonium with complexing substances in soils and natural waters was determined. The reactions of Pu with selected organic substances found in the environment have been studied to evaluate the valence and metal complex behavior of Pu. Hexavalent Pu (and by inference pentavalent Pu) was unstable in the presence of fulvic acid, polygalactaronic acid, and alginate acid. Citrate-Pu(IV) complexes, however, were relatively more stable. Plutonium(IV) was the most stable valence upon interaction with these organics. Further reduction of Pu(IV) to Pu(III) occurred by fulvic and humic acids. The reduction, under aerobic conditions, does not appear to occur above pH 3.1. The reduction mechanism is probably similar to the Fe(III) reduction documented for phenolic humic substances. Data are presented that demonstrate that Pu is at least partially associated with humic materials in 2000 soil contaminated 30 years ago with trace levels of Pu. Desorption studies using cation exchange resins also showed that, while a cation exchange resin did not desorb Pu from soil after 12 weeks equilibration, chelation resin effected Pu desorption. The desorption rate was not constant, suggesting differential Pu forms. While the resin-extractable Pu was believed to originate from solid-phase organic complexes, over 90 % of the Pu in this soil was not readily resin-desorbable. This indicates that more inert soil-Pu reaction products effectively immobilize soil Pu. Some of these associations also appear to be organic. (Auth)

<220>

Brewer, L.W. (Ed.), Santa Corporation, Industrial Hygiene Laboratory, Environmental Health Department, Albuquerque, NM. 1966, February.

The Determination of Actinides in Urine. SC-M-67-1004; Analytical Procedures for the Environmental Health Laboratory, (pp. 3-1 - 3-2), 187 pp. (SC-M-67-1004).

Urine is ashed using nitric acid and hydrogen peroxide. The ash is dissolved in hydrochloric acid and the actinides, As 241, Th 230, Po 210, U 233, Np 237, Pu 239, and Pu 240, electroplated from an ammonium chloride plus hydrochloric acid electrolyte. The isotope is identified and quantitated by alpha spectrometry. (Auth)

<221>

Brats, V.J.B., and W.C.B. Sait, Atomic Energy Board, Chemistry Division, Pretoria, South Africa. 1977, January.

Determination of Uranium in Natural Water by Preconcentration on Anion-Exchange Resin and Delayed-Neutron Counting. Analytical Chemistry, 49(1), 67-69.

The traces of composite borehole and fresh seawater samples is extracted by sorption of the uranyl thiocyanide complex on an anion-exchange resin. The preconcentration step is largely independent of water quality and insensitive to experimental parameters. Uranium on the resin is directly determined by delayed-neutron counting, which is a specific and sensitive analytical method for uranium. The accuracy is 4% and the detection limit for a 1-liter sample is 2.03 ug/l. Because of the simplicity of the preconcentration step, large numbers of samples may be extracted in a suitably equipped field laboratory. (BAP)

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<222>

CHEMICAL ASPECTS

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Carpenter, E.S., National Bureau of Standards, Analytical Chemistry Division, Activation Analysis Section, Washington, DC. 1972.

Quantitative Applications of the Nuclear Track Technique. *Micron*, 20, 175-182.

The nuclear track technique has been applied to the quantitative determination of several elements that emit charged particles. The detector sample "sandwich" is exposed to the desired radiation source, fast or thermal neutrons, or high energy photons, and the charged particles emitted are registered in plastic detectors. The elements boron, lithium, nitrogen, thorium and uranium have been determined in various matrices; e.g., liver, orchard leaves, tomato leaves, blood, glass, soil, steel and minerals. The amount of material in these matrices is determined in three different ways: the absolute method, the method of standard additions and the comparative method. All three of these methods require that the plastic detectors be chemically etched and the resulting optically visible tracks are then counted with the aid of an image analyzing microscope. (Auth)

<223>

Colos, B.C., J.W.T. Meadows, and C.L. Lindken, Lawrence Livermore Laboratory, Radiochemistry Division, Livermore, CA; Lawrence Livermore Laboratory, Hazards Control Department, Livermore, CA. 1976, March.

The Direct Measurement of ppm Levels of Uranium in Soils Using High-Resolution Germanium-Lithium Gamma-Ray Spectroscopy. *Science of the Total Environment*, 5(2), 171-179.

The direct determination of ^{238}U in various soil samples was done by measuring the 63.3-keV transition from the decay of the first daughter ^{234}Th . Potential errors resulting from the chemical non-equilibrium of ^{238}U with its daughters are thus avoided. The method sensitivity is 1 ppm compared to the 35 ppm obtainable by employing the 1001-keV gamma-ray. A Ge(Li) gamma-ray spectrometer is the only analytical tool required. At uranium concentrations approaching the 50-ppm level, the 1001-keV ^{238}U peak can be used for the uranium analysis, but the lower sensitivity for the detection of this gamma ray increases the imprecision of the measurement by greater than a factor of two. Examples are offered that demonstrate the usefulness of the technique for routine, inexpensive environmental monitoring of uranium. The technique also has the capability of providing information on the $^{238}\text{U}/^{235}\text{U}$ isotope ratio. (PAF)

<224>

Sanjelson, R., E. Bennholm, L.E. Kjellstrom, and Y. Inagaki, Royal Institute of Technology, Department of Analytical Chemistry, Stockholm, Sweden. 1973.

Fluorimetric Method for the Determination of Uranium in Natural Waters. *Talanta*, 20, 185-192.

Ion exchange is used to preconcentrate the uranium by a factor of 22 and separate it from quenching ions in the sample. The fluorescence is measured in a medium that is 1.35 M in both sulfuric and phosphoric acids. The uranyl ions are excited by radiation of wavelength 280 nm and bandwidth 40 nm. The emitted signal is scanned from 470 to 510 nm. After spiking of the sample solution with a

small volume of standard uranium solution, the fluorescence signal is scanned again and the uranium content of the sample calculated from the two readings. The coefficient of variation is 8.5% for the determination of U in a synthetic water sample having a uranium content of 1.9 ppm. Destruction of organic matter in the eluate gives a 0.1 ppm detection limit. (Auth) (PAF)

<225>

Davis, E.D., General Electric Company, Research and Development Center, Schenectady, NY. 1977, June.

Continuous Mass Spectrometric Determination of Concentration of Particulate Impurities in Air by Use of Surface Ionization. *Environmental Science and Technology*, 11(6), 592-596.

The average concentration of particulate impurities in air is determined by impinging the particles on a heated Fe ribbon and analyzing the resulting ion current with a small magnetic sector mass spectrometer. Oxygen in the air raises the work function of Fe to about 7.2eV at 1000 °C allowing analysis of elements with ionization potentials as high as 8eV. In favorable cases, concentrations of $10(2-13)\mu\text{g}/\text{m}^3$ can be detected. By collecting the particles on the ribbon for short periods and then flashing the filament, increased sensitivity can sometimes be achieved. Natural air particles are analyzed for Li, Na, K, Rb, Cs, Sr, U, Pb, Cr, and Cu. Large amounts of organic compounds are detected, but the mixture is too complex to positively identify individual components. (Auth)

<226>

De Portoli, P.C., Euratom Ispra Establishment, Protection Service, Ispra, Italy. 1969, January-March.

Methods for Analysis of the Radioactivity in the Soil. CONF-680535: Italian Association for Health Physics and Protection from Radiation, Proceedings of the 18th National Conference held in Fieschi, Italy, May 29, 1968. (CONF-680535); *Ninerva Fisico-nucleare*, 11, 86-91.

Some analytical methods used at the Protection Service of the Euratom Ispra Establishment for the surveillance of soil radioactivity are described. The radioisotopes of strontium, cesium and plutonium can be determined on a single soil aliquot by appropriate chemical procedures. Measurements of the uranium concentration are performed through a fluorimetric technique. Some comments arising from the experience gained through the routine performance of the methods described are reported. (Auth)

<227>

Delle Site, A., Comitato Nazionale per l'Energia Nucleare, Radiotecnologico Laboratory, Cassaccia, Rome, Italy. 1973.

Analytical Applications of Neotridecanoic Acid as Stationary Phase in Extraction Chromatography. *Journal of Radioanalytical Chemistry*, 14, 45-51.

Some analytical applications of neotridecanoic acid used as stationary phase in extraction chromatography columns are reported. Separations of Am-U-Th and Np-Pu are obtained in aqueous solutions and under different experimental conditions. The hydroxamic acid

CORRECTIONAL ASPECTS

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shows a peculiar selectivity for $\text{U}(\text{VI})$ and $\text{Pu}(\text{IV})$ at $\text{pH} = 8$, and the two elements can be separated according to their respective valencies. A selective method for the determination of U 237 and Pu 239 in urine is also described. The final recoveries are 71.5% for plutonium and 82.7% for neptunium; the decontamination factors and the sensitivity limits are suitable for the radiotoxicological detection of both elements. (Auth)

<228>

Dele Site, A., G. Santori, and C. Testa, Comitato Nazionale per l'Energia Nucleare, Rome, Italy. 1970, February.

The Rapid Determination of the Transuranic Elements by Extraction Chromatography in Urines Containing DTPA. CCNY-700907 (Part 1): International Radiation Protection Association, Proceedings of the 3rd International Congress held in Washington, D.C., September 9-10, 1973, (pp. 532-537), 1973 pp. (CCNY-700907).

Micropercol polyethylene (Microthane-710) supporting tri-n-octylphosphine oxide (TOPO) and di(2-ethylhexyl) phosphoric acid (D2EHPA) has been used successfully to extract respectively Th , Pa , U , Pu , Am and Cm from the urine. As the extraction takes place in an HCl medium, DTPA up to 2 g/l does not interfere. A special investigation was carried out for Am in order to find out the best extraction pH. Finally it has been demonstrated that great losses of actinides occur when a coprecipitation with Ca and Mg phosphates are carried out in the presence of DTPA. (Auth)

<229>

Feldman, I., University of Rochester, School of Medicine and Dentistry, Department of Radiation Biology and Biophysics, Rochester, NY. 1976.

The Colloidal Nature of Radionuclides in Seawater. CCNY-750672; Environmental Toxicity of Aquatic Radionuclides: Models and Mechanisms, F.W. Miller and J.B. Stannard (Eds.), Proceedings of the 8th International Conference on Environmental Toxicity held in Rochester, New York, June 2-4, 1975, Chapter 9. Ann Arbor Science Publishers, Inc., Ann Arbor, Michigan, (pp. 183-190), 133 pp. (CCNY-750672).

There is considerable doubt that equilibrium calculations, i.e., employing solubility products and complex-ion stability constants, are valid for the submicro concentrations of radionuclides in seawater. The existence of radiocolloids should be expected in seawater. The great tendency of radiocolloids to adsorb onto finely-divided hydrous oxides makes their formation of significance in seawater, especially for artificial radionuclides. The subject of radiocolloid formation is reviewed in this chapter. It is shown that the Pa 234/ Th 230/ U relationship found in seawater can be explained from the fact that the tendencies of these elements to form radiocolloids in seawater should decrease in order $\text{thorium} > \text{radium} > \text{uranium}$. This explanation is much simpler than the prevailing oceanographic one. The theories for radiocolloid formation are discussed. The recent theory of Jones and Neely for the adsorption of hydrolyzable metal ions onto hydrous oxides is reviewed briefly, and its relevance to radiocolloid formation is pointed out. (Auth)

<230>

Vinber, D.E., University of Miami, Rosenstiel School of Marine and Atmospheric Science, Miami, FL. 1977, January.

Fission/Alpha Analysis of the Uranium, Thorium Families. Nature, 265(5591), 227-229.

A modification of particle track analysis is employed to measure U as well as Th and/or radioactive disequilibrium in the U and Th families in geologic materials. The method proposed is based on the slow neutron fission of U and on the natural alpha-decay of U , Th and their radioactive daughters. Cellulose nitrate (CNL) records alpha-tracks as other plastics such as Lexan record fission tracks. If a flat surface of a Th -bearing material is placed against a sheet of CNL, naturally occurring alpha-particles will impinge on the CNL and leave detectable tracks. The total alpha-activity is thus measured. The sample is then placed in contact with a sheet of Lexan and irradiated by slow neutrons for normal fission track analysis of the U alone. With known U content the Th content can be calculated from a derived equation. The method is applicable to any geological situation in which a precise disequilibrium is established at a particular time, and in which the total alpha-decay is dominated, aside from U , by one nuclide and its daughters. (Auth)

<231>

Francis, C.W., and J.B. Roshin, Oak Ridge National Laboratory, Environmental Sciences Division, Oak Ridge, TN. 1977.

High Nitrate Denitrification in Continuous Flow-Stirred Reactors. Water Research, 11, 289-294.

Continuous flow stirred reactors were used to estimate the maximum denitrification specific removal rates for influent solutions made from NH_4NO_3 , CaNO_3 , KNO_3 and NaNO_2 feed fabrication waste water. Nitrate substrate concentrations ranged from 0.01 to 20 kg NO_3/m^3 . Values for U_{max} (maximum specific substrate removal rate per unit mass of microorganisms per unit time, days (E^{-1})) were determined using graphical solutions to the Lineweaver-Burk equations. For NH_4NO_3 solutions at nitrate substrate concentrations < 6 kg NO_3/m^3 the value for U_{max} was found to be 1.73 days (E^{-1}) . At nitrate substrate concentrations > 6 kg NO_3/m^3 a nonlinear relationship was observed in the Lineweaver-Burk plots indicating nitrate substrate inhibition. Specific removal rates at nitrate concentrations > 6 kg NO_3/m^3 averaged 1.0 days (E^{-1}) . Ammonia toxicity may also have occurred as the pH of the sized liquor was near 8. Methanol concentrations as high as 11.6 kg CH_3/m^3 did not inhibit denitrification rates. The highest specific removal rates recorded (3.1) plus or minus 0.56 days (E^{-1}) were with influents made from NaNO_2 feed fabrication waste water. (Auth)

<232>

Freese, J., E. Fetter, and J. Harley, New York Operations Office, Health and Safety Division, Analytical Branch, New York, NY. 1952, August.

Radiometric Properties of the Thorium Series. Neutronics, 10(8), 60-64.

The relatively rapid decay of the members of the thorium series following Th 232 makes it necessary to consider the effect of time on the activity of many thorium preparations.

<232>

CHEMICAL ASPECTS

<232> CCWT.

The decays are not simple processes. A practical method of evaluating counting results is by means of a graphical representation of the Bateman solution of the partial differential equation for the part of the chain being measured. With the aid of the curves, the activity of any preparation may be measured and the corresponding activity at any time in the past or the future may be calculated. For the calculation of approximate beta surface dose rates the ascent of thorium in the substance and the range of the radiation in the substance must be considered to determine the total energy leaving the surface. (NAP)

<233>

Gladney, E.S., J.W. Owens, and J.W. Starnes, Los Alamos Scientific Laboratory, Los Alamos, NM. 1976, June.

Determination of Uranium in Natural Waters by Neutron Activation Analysis. Analytical Chemistry, 49(7), 973-975.

Uranium was measured using thermal neutron activation analysis and anion-exchange separation of radio-uranium from ethanol-HCl solvent mixtures. Detection limits of 0.05 ppb have been achieved with analytical precisions of 10-30%. Results of uranium analysis by this procedure and by fluorometry are compared for natural waters from Alaska and New Mexico. The principal advantage of this method is its insensitivity to unknown levels of chromophores which quench the U fluorescence and cause substantial underestimation of U concentrations by fluorometry. (Auth) (NAP)

<234>

Faggag, A., S.A. El-Feky, M. El-Hasson Yehia, and W. Sanad, Atomic Energy Establishment, Nuclear Chemistry Department, Cairo, Egypt. 1976.

Solvent Extraction Studies on Thorium Sulphate and Halides. Journal of Radioanalytical Chemistry, 22, 139-152.

The effect of water-miscible alcohols, acetone and haloacids in the aqueous phase of sulphuric acid solutions has been studied on the extraction of thorium sulphate and halides by bis(2 ethylhexyl) phosphoric acid and tri-n-butyl phosphate. The partition coefficient is greatly affected by these additives, and this gives useful separations from many other elements. Besides, the log-log relationship between the partition coefficient values and solvent concentration leads to some suggestions on the extraction mechanisms of this mixed system. (Auth)

<235>

Pedra, V.P., and R.E. Garney, Scripps Institution of Oceanography, Mt. Soledad Laboratory, La Jolla, CA. 1975, September.

Semi-Quantitative Determination of Uranium, Plutonium, and Americium in Sea Water. Analytical Chemistry, 47(11), 1866-1868.

Liter-sized volumes of seawater were analyzed semi-quantitatively, without time-consuming ion exchange or solvent extraction, for U, Pu, and Am by precipitation of these elements with small amounts of sodium hydroxide. The precipitate was dissolved in HCl and directly plated onto stainless steel planchets in a form suitable for alpha counting. Generally

high yields were obtained. This procedure can be conveniently incorporated into a more complete monitoring program of contaminated sea water as a guide to sampling the proper volume of sea water to obtain desired activity levels. (NAP)

<236>

Ishihara, S., and T. Hachiriki, 1969.

Chemical Characteristics of River Water in the Eastern Part of Shikoku Prefecture -- with Special Emphasis on Cause of Uranium Anomaly. Geological Survey of Japan, Bulletin, 20(7), 435-449.

River waters of tributaries of Iii-gawa and Iinashi-gawa in the eastern part of the Shikoku Prefecture were analyzed for P, sulfate, and U. The surveyed area is composed mainly of early Tertiary granitic rocks and Miocene andesite and its p...eolastic rocks in the north. The Miocene rocks occasionally accompany massive sediments in which a banded-type uranium deposit can be locally found. A weak anomaly, 0.10 ppb U, was detected near an edge of the Miocene rocks. Distinct anomalies of U along the Ayo river are due to mining operations of uraniferous and pyrite-bearing molybdenite quartz vein deposits, which are the largest source of molybdenum production in Japan. The U decreases downward at a rate of 0.07 ppb/km along the Ayo river. Small amounts of disseminated pyrite in Miocene andesitic rocks increased the sulfate content of the water and lowered the pH to 6.6. Except for the mining area, the water of the granite region is neutral, higher in U and lower in sulfate compared to that of the andesite region. (Auth) (NAP)

<237>

Kalani, D.K., Industrial Toxicology Research Center, Lucknow, India. 1972, October.

Analysis of Indian Monazite Sand in Animal Tissues, Part 2. Indian Medical Journal, 64(10), 191-195.

The feasibility of using a direct colorimetric method for the analysis of mineral samples for uranium content was investigated. The method is based on the yellow color produced by uranyl ions and NH₄SCN in dilute mineral acid solution. Results of monazite sand analysis for rare earths, thorium, cerium, phosphorus and uranium are given. (ST)

<238>

Kanuth, P.V., I.S. Bhat, F. Budras, H.A.B. Iyengar, E. Koshy, U.S. Naingankar, and V.S. Shanolkar, Atomic Energy Establishment, Health Physics Division, Trombay, Bombay, India. 1966.

Recent Radiochemical Procedures for Bioassay Studies at Trombay. CCWT-448; STI/PUB/84; Assessment of Radioactive Body Burdens in Man, Proceedings of a Symposium held in Heidelberg, Germany, May 11-16, 1964, Vol. 1, (pp. 195-215), 1963 pp. (CCWT-448, STI/PUB/84).

This paper gives some methods and details of tracer studies developed at the bio-assay laboratory at Trombay for the rapid analysis of different radionuclides in urine. Isotopes of interest are Th 232, Th 228, Ra 226, Ra 228, Ra 228, U natural, fission products and Pu 239. Radon 228 was analyzed by measuring mesothorium in urine after separation of Ac 228, followed by

CHEMICAL ASPECTS

<138> CONT.

coprecipitation with BaSO₄. The precipitate is dissolved in perchloric acid after the addition of Pb, Bi and La carriers. The insoluble sulfates are precipitated with sulfuric acid. Actinium 228 in the supernate is carried as La F₃ and counted for beta activity and for decay. Radium 228 is calculated from observed Ac 228 activity. Thorium is co-precipitated with calcium oxalate without wet washing urine. Data on interference studies from phosphates and calcium in the final extraction of Th with TTA are given. Thorium 232 is estimated spectrophotometrically and Th 230 in the associated Th fraction by separation of Ra 226 after equilibration. Determinations of Ca 137, P 32, Co 60 and I 131 are also reported. (Auth) (BAP)

<139>

Kaneth, V.R., and P.P. Firoh, Shabha Atomic Research Center, Analytical Division, Bombay, India. 1965.

Analysis of Isotopic Radium in Thorium Mill Effluents. *Talanta*, 10, 305-350.

A simple and rapid method has been developed for the determination of isotopic radium, based on gamma-ray spectrometry. Ra 226 and Ra 228 are assayed by measuring the intensities of the photo-peaks in the 0.94 and the 2.62 MeV regions of the gamma-spectrum. The interference in these measurements, arising from the presence of the Pa 226-Pb 214 chain in the sample, is obviated by the almost complete expulsion of Pa 222 from the system. The precision of the method is plus or minus 2% and plus or minus 3% in the determination of Ra 226 and Ra 228 respectively, the absolute sensitivities being 2 and 0.5 nCi. The method has been applied to evaluate the distribution of these isotopes in the various products of the Indian Rare-Earths Factory, Alwaye. (Auth)

<140>

Slagert, R.C., S.P. Tolos, J.B. Becker, J.B. Mueller, and B.B. Leist, National Lead Company of Ohio, Cincinnati, OH. 1966, February.

Development of a Thorium Purification System. NRCO-970; Summary Technical Report for the period October 1, 1965 to December 31, 1965, (pp. 1.1-1.22) (NRCO-970).

Thorium distribution coefficients were determined in the laboratory for the tributyl phosphate (TBP)-thorium nitrate and the diisobutyl amyl phosphonate (DIBAP)-thorium nitrate systems. The data developed in these tests were used in pilot-scale (2-inch-diameter perforated-plate pulse column) development tests of a liquid-liquid extraction process for the purification of thorium. This process was subsequently implemented in bench-scale extraction equipment. DIBAP was found to be the superior extractant. Two additional solvent extraction systems were studied for the separation of thorium and uranium and/or rare earth elements to supplement the DIBAP extraction system. Both of these extractants, 4'-secondary butyl phenyl phosphonate (SBPP) and TBP, were evaluated in pulse column tests for the production of a thorium nitrate solution which contained less than 5 ppm uranium as a thorium basis. (Auth)

<141>

Kochisch, J., and D. Dimitriadis, University of

<138>

Vienna, Analytical Institute, Department of Raw Materials Analysis of Nuclear Fuels, Vienna, Austria. 1973.

Application of Ion Exchange Methods for the Determination of Trace Elements in Natural Waters Thorium. *Talanta*, 20, 1303-1306.

A method is described which separates ppb amounts of Th from natural waters. One-liter samples, previously filtered and acidified with nitric acid, are evaporated; Th is then separated from other elements in 6N nitric acid by adsorption on a strongly basic anion exchange column of Dowex 1-16 (nitrate form). The adsorbed Th is eluted in 6N hydrochloric acid and determined spectrophotometrically by the Arsenazo-III method. The method has been employed for the determination of Th in numerous Austrian natural waters with Th concentrations ranging from 0.5 to 4.5 ppb. (Auth)

<142>

Kochisch, J., and E. Krivanec, University of Vienna, Institute for Analytical Chemistry, Analysis of Nuclear Raw Materials Division, Vienna, Austria. 1976, April.

Application of Ion-Exchange Separations to Determination of Trace Elements in Natural Waters. 9. Simultaneous Determination of Uranium and Thorium. *Talanta*, 23, 295-300.

A method is described for the determination of uranium and thorium in samples of natural waters. After acidification with citric acid the water sample is filtered and sodium citrate and ascorbic acid are added. The resulting solution of pH 3 is passed through a 4-g column of Dowex 1 X 8 (citrate form) on which both uranium and thorium are adsorbed as anionic citrate complexes. Thorium is eluted with 6N hydrochloric acid and separated from co-eluted substances by anion-exchange in 8N nitric acid medium on a separate 7-g column of the same resin in the nitrate form. After complete removal of iron by washing with a mixture consisting of 10N, acetic acid and 18 hydrochloric acid (1:0:1 v/v) and treatment of the resin with 6N hydrochloric acid, the uranium is eluted from the 4-g column with 1N hydrochloric acid. In the eluate thorium is determined spectrophotometrically (arsenazo III method) while fluorimetry is employed for the assay of uranium. The procedure was used for the determination of uranium and thorium in numerous water samples collected in Austria, including samples of mineral-waters. The results indicate that a simple relationship exists between the uranium and thorium contents of waters which makes it possible to calculate the approximate thorium content of a sample on the basis of its uranium concentration and vice versa. (Auth)

<143>

Larson, R.P., and P.V. Urvoris, Argonne National Laboratory, Argonne, IL. 1976.

X-Ray Spectrometric Determination of Thorium in Bone and Other Biological Materials. ANL-76-80 (Part 2); Radiological and Environmental Research Division Annual Report, July 1975-June 1976, (pp. 94-95) (ANL-76-80, Part 2).

Bone or other biological materials are ashed and dissolved in acid; a known amount of Th 230 is added. Separation of Th from phosphate is effected by precipitation of 10% of the Ca as the oxalate; this carries nearly all the Th. The Ca oxalate is converted to

<243>

CHEMICAL ASPECTS

<243> CONT.

the calcinate at 600 degrees C and dissolved in nitric acid. The solution is passed through a Dowex-1 anion exchange column where Th is strongly adsorbed. Thorium is eluted with dilute HCl and coprecipitated with ferric hydroxide by ammonia hydroxide. The ferric hydroxide is counted and assayed in a secondary source, energy dispersive X-ray spectrometer. The amount of Th 230 is a measure of the Th recovery in the separation process. Recovery ranges from 70 to 80%. The detection limit is 20 ng which corresponds to a concentration of 2 ppb Th in a 10-g sample of ashed bone. (RAP)

<244>

Iyon, S.S. (Ed.), and I. Brodsky, Oak Ridge National Laboratory, Oak Ridge, TN. 1976, January.

Radioanalysis of Environmental Materials. ORNL-6930: Analytical Chemistry Division Annual Progress Report for Period Ending September 30, 1973, (pp. 39-40), 87 pp. (ORNL-6930).

Analytical and general radiochemical studies related to programs of the Environmental Sciences Division are in progress. An investigation of methodology for determination of actinides in environmental materials such as soil, water, and biological matter has begun. Plutonium is the element of primary interest at this time because of its radiological significance in the LSPBN and radioisotope-source programs. It was suggested that the National Bureau of Standards supply calibrated solutions of Pu 236 to be used for simultaneous evaluation of recovery and counting efficiency in plutonium analysis. However, NBS and the AEC Health and Safety Laboratory (HASL) have chosen to use Pu 242 for this purpose. Soils and vegetable table matter of known plutonium content are being obtained from the International Atomic Energy Agency (IAEA) and from C.W. Sill (AEC, Idaho), and ASTM D-19 is planning a "road robin" on plutonium in water. It was desired to have a substitute for plutonium to permit exploratory work outside containment. A review of the radiochemical behavior of similar elements led to the suggestion that thorium would probably be best, and Th 230 is a satisfactory tracer. Plutonium 237 is a useful isotope tracer and emits α and gamma radiations, thus avoiding complexities of alpha counting and permitting in situ measurements. Its properties and methods of production have been reviewed in anticipation of obtaining a supply. (PAM)

<245>

McBride, J.P., V.D. Allred, C.E. Schilling, and E.V. Jones, Oak Ridge National Laboratory, Oak Ridge, TN. 1957.

Preparation and Properties of Aqueous Thorium-Uranium Oxide Slurries. Advances in Nuclear Engineering, Vol 1, J.R. Dunning and E.R. Prentice (Eds.), Proceedings of the 2nd Nuclear Engineering and Science Conference held in Philadelphia, Pennsylvania, 1957. Pergamon Press, New York, New York, (pp. 27-32).

The effect of preparation method upon the properties of sized thorium-uranium oxides and their behavior as aqueous suspensions has been investigated. Specific surface areas, average crystallite sizes, sedimentation particle size, and abrasiveness were used as means of characterizing each sized oxide. Doose temperature sedimentation properties for

aqueous suspensions were obtained. (Auth)

<246>

McBee, W.J., B.T. Farrar, and H.V. Billings, Oak Ridge National Laboratory, Chemical Technology Division, Oak Ridge, TN. 1976, December.

Plutonium and Uranium Determination in Environmental Samples: Combined Solvent Extraction-Liquid Scintillation Methods. Talanta, 21(12), 1231-1245.

Assuming a sample count equal to background count to be the detection limit, the lower detection limit for these and other alpha-emitting nuclides is 1.0 dpm with a Pyrex sample tube, 0.3 dpm with a quartz sample tube using present detector shielding of 0.02 dpm with pulse-shape discrimination. Alpha-counting efficiency is 100%. With the counting data presented as an alpha-energy spectrum, an energy resolution of 0.2-0.3 MeV peak half-width and an energy identification to $\pm$ or $\pm$ 0.1 MeV are possible. Within these limits identification and quantitative determination of a specific alpha-emitter, independent of chemical separation, are possible. The separation procedure allows greater than 90% recovery of uranium and plutonium from solution samples containing large amounts of iron and other interfering substances. In most cases uranium, even when present in 10 (H:U) fold molar ratios, may be quantitatively separated from plutonium without loss of the plutonium. Potential applications of this general analytical concept to other alpha-counting problems are noted. Special problems associated with the determination of plutonium in soil and water samples are discussed. Results of tests to determine the pulse-height and energy-resolution characteristics of several scintillators are presented. Construction of the high-resolution liquid scintillation detector is described. (Auth) (PAM)

<247>

Seguchi, K., and T. Hamuro, Radiation Center of Osaka Prefecture, Osaka, Japan. 1975.

Detection of Environmental Contamination by Uranium. Part 1.. Annual Report of the Radiation Center of Osaka Prefecture, 16, 28-30.

The detection limit of a gamma spectrophotometric analysis using a planer type Ge(Li) detector was evaluated to establish an instrumental method of monitoring soil contamination near nuclear facilities. The activity of U 238 was determined at photopicks of 63.5 keV when equilibrium between Th 230 and U 238 was established. The concentration of U 235 was determined at 163.3 keV. The detection limit was 6 ppm for average soil samples containing 3.5 ppm U, 11 ppm Th, and 2.82% K. (PAM)

<248>

Nikhalova, O.A., N.S. Shvydko, and D.K. Popov, 1973, August.

Method of Determining Plutonium 239 in Urine. Gigiena i Sanitariya, 8, 69-71.

Since published methods for Pu 239 determination generally recommended reagents and resins not available commercially in the USSR, locally available materials were investigated. A method was developed in which Pu (IV) as the cupferrate is separated from matrix impurities by chloroform

CHEMICAL ASPECTS

<248> CCFT.

extraction from a nitric acid medium using zirconium carrier or no carrier. In 241, Th, and 242 of the Pu 239 remained in the aqueous phase. The Pu 210 was removed from the plutonium by precipitation on a nickel disk or with mercury. After removal of the chloroform from the organic phase, the Pu 239 was precipitated with ammonia, using a lanthanum carrier, and was counted after further processing. The Pu can also be electroprecipitated. (PNN)

<249>

Hoyes, E.W., and J.S. Fritz, Ames Laboratory, Department of Chemistry, Ames, IA. 1977, March.

Preparation and Analytical Applications of a Propyleneimine-tetraacetic Acid Resin. Analytical Chemistry, 49(3), 418-423.

A new chelating resin has been synthesized that contains a propyleneimine-tetraacetic acid functional group which is attached to a carboxylic acid divinylbenzene resin via an esterification reaction. The new resin retains polyvalent metal cations at pH 3 or higher. It retains copper(II), uranium(VI), thorium(IV), and zirconium(IV) from some acidic solutions. A scheme is given for clean, rapid chromatographic separation of the last three elements from each other. The resin is also able to retain quantitatively a number of trace elements from simulated sea water. (Auth)

<250>

Favlovalaya, N.G., Not given. 1974.

The Main Order of the Metabolism of Thorium 232 and that of its Dissociation Products in the Body. Gigiena i Sanitariya, 38(11), 55-58.

As a result of the analysis of published data and personal experimental research the author proves the main parameters that characterize the metabolism, to depend on the chemical nature of radionuclides, chemical properties of compounds and their route of entry. Resorption of the thorium family (Th 228, Pa 224 and Pb 212) depends first of all on the value of the ionic potential of ions. Distributions of radionuclides in the body is determined by the route of entry, solubility of the thorium compounds and stability of the complex ions. Kinetics of the radionuclides elimination is determined both by the chemical nature of the elements and by solubility of the thorium compounds in water. (Auth)

<251>

Favlovskaya, N.A., P.P. Lyarskiy, N.N. Mal'tseva, A.N. Goncharova, and G.D. (Translator) Lord, Academy of Medical Sciences of the USSR, Scientific Research Institute for Industrial Hygiene and Work-Related Illnesses, Moscow, USSR. 1976.

Solubility of Certain Thorium-Containing Substances in Media Resembling Physiologic Fluids. OSHL-tr-4503; 5 pp.; Gigiena i Sanitariya, 2, 112-114.

The solubility of ThO₂ was established in distilled water and in simulated physiological fluids at 37 degrees C. Values obtained in distilled water, 0.22% NaCl solutions, 0.3% NaCl solutions, physiological fluid, and gastric juice were 0.8×10^{-8} g/l, 0.7×10^{-8} g/l, 0.9×10^{-8} g/l, 3.6×10^{-8} g/l and 0.9×10^{-8} g/l, respectively.

leachability of Th 232 and Th 230 from a loparite concentrate and of Th 232 and Th 230 from a zircon concentrate in the same fluids was very low; only extremely small quantities of the thorium isotopes passed into solution. However, the leachability of daughter radionuclides such as Pa 224 and Pb 212 was significantly higher than that of the mother radionuclides. (NAP)

<252>

Percival, D.E., and D.J. Martin, U.S. Atomic Energy Commission, Health Services Laboratory, Idaho Falls, ID. 1974, October.

Sequential Determination of Radium 226, Radium 228, Actinium 227, and Thorium Isotopes in Environmental and Process Waste Samples. Analytical Chemistry, 46(12), 1742-1749.

A procedure is described for the sequential determination of Ra 226, Ra 228, Ac 227, thorium isotopes, and, in some cases, Pa 231 in environmental and process waste samples of 0.1 to 0.001 of the concentration guides specified by Federal regulations. The radionuclides are separated from gross sample constituents by coprecipitation with lead sulfate. Radium is separated on a small quantity of barium sulfate precipitated from a diethylenetriaminepentaacetate solution of the lead sulfate. Actinium 227 and thorium are then separated sequentially from the barium sulfate supernate by extraction into bis(2-ethylhexyl)phosphoric acid. Any one or more of the radionuclides may be excluded from the analysis by omitting certain independent steps. Over-all recoveries are 99 percent for radium and 95 percent for actinium and thorium. Accuracy, precision, and the effects of chemical and radiochemical interferences are discussed. (Auth)

<253>

Sill, C.W., and P.D. Hindman, U.S. Atomic Energy Commission, Health Services Laboratory, Idaho Falls, ID. 1974, January.

Preparation and Testing of Standard Soils Containing Known Quantities of Radionuclides. Analytical Chemistry, 46(1), 113-118.

A general procedure for preparation of standard soils containing a known quantity of any given radionuclide is described. Four separate standards have been prepared from three different soils using Pu 239 to demonstrate the reproducibility and reliability of the procedure. Extensive analyses using Pu 236 tracer show that the standards contain the exact concentration calculated to have been added, that they are not detectably inhomogeneous on samples as small as 1 gram, and that homogeneous standards of lower concentrations can be prepared exactly by weight dilutions with the unspiked soils. Of a total of 56 determinations made on 1 and 10 g aliquots of the four individually spiked standards and two others made by dilution, only four determinations showed distinct signs of inhomogeneity with the particular method of preparation and sample size employed. Of the remaining 52 measurements, all agreed with the calculated value within three standard deviations of the determination, and 42 were within two standard deviations. The dramatic effect of heat treatment on the leachability of the plutonium is demonstrated. Also, an alternative method for preparation of solid standards for members of the natural uranium and thorium series is suggested. (Auth)

<253>

CHEMICAL ASPECTS

<254>

Sill, C.W., R.W. Pophel, and P.D. Hindman, U.S. Atomic Energy Commission, Health Services Laboratory, Idaho Falls, ID. 1978, October.

Simultaneous Determination of Alpha-Emitting Nuclides of Radium through Californium in Soil. Analytical Chemistry, 56(12), 1725-1737.

A procedure is described by which virtually all alpha-emitting nuclides can be determined in soil, either singly or in any combination on a single sample. The sample is decomposed completely by a combination of potassium fluoride and pyrosulfate fusions with simultaneous volatilization of hydrogen fluoride and silicon tetrafluoride. The cake is dissolved in dilute hydrochloric acid and all alpha emitters are precipitated with barium sulfate. An option is provided by which uranium can be obtained in a separate fraction to eliminate mutual interference with Bi 213. The barium sulfate is dissolved in acidic aluminum nitrate and the elements from thorium through plutonium are extracted into Aliquat-336. Acid-deficient aluminum nitrate is then added to the aqueous phase to reduce the acidity, and americium, curium, and californium are extracted into fresh Aliquat-336. Thorium is removed by scrubbing the first organic extract with 10N hydrochloric acid, and protactinium, uranium, neptunium, and plutonium are stripped with a mixture of perchloric and oxalic acids. Americium, curium, and californium are stripped from the second organic extract with 7N nitric acid. Each fraction is electrodeposited and analyzed by alpha spectrometry with few interferences. Overall recovery excluding electrodeposition ranges from 88% for protactinium to 99% for plutonium. (Auth)

<255>

Sill, C.W., and C.P. Willis, U.S. Energy Research and Development Administration, Health Services Laboratory, Idaho Falls, ID. 1977, February.

Radiochemical Determination of Lead 210 in Uranium Ore and Air Dusts. Analytical Chemistry, 49(2), 352-356.

An improved procedure is described by which cellulose, glass fiber, and polystyrene filters can be wet-ashed and siliceous samples dissolved completely without loss of lead by either volatilization or spontaneous reduction to metal that occurs with dry ashing and/or treatment in platinum containers. The solution of Bi 210 used to calibrate the beta counter is prepared by chemical separation from a solution of Pb 210 which is much more convenient and results in a product of higher specific activity than one prepared by neutron activation of stable bismuth. After separation from the samples by conventional chemical procedures, the Bi 210 is precipitated on barium sulfate for beta counting which is more convenient and gives a more uniform and reproducible deposit than is obtained by most other means. (Auth)

<256>

Steinnes, E., Institute for Atomic Energy, Isotope Laboratories, Kjeller, Norway. 1973.

A Rapid and Sensitive Neutron Activation Method for Uranium in Water. Radiochemical and Radioanalytical Letters, 16(7), 25-29.

A neutron activation method based on 23.5 min Bi 213 using solvent extraction with

tri-n-butyl-phosphate as a selective separation step is described. The method is sufficiently sensitive and precise for the determination of uranium in natural fresh water samples. The separation time for two samples is 10 min, and no chemical yield determination is necessary. The over-all radionuclide purity of the separated fractions is adequate for Ge-63 measurements. Partially extracted elements such as Sc, Fe, Sb, Th, and the heavy rare earths do not interfere significantly in the application of the method to natural waters. (RAP)

<257>

Takebayashi, T., H. Matsuda, and S. Uemoto, Kyushu University, Department of Chemistry, Hakozaki, Japan. 1973, September.

Application of the Fission Track Technique to the Determination of Uranium in Natural Waters. Talanta, 20, 892-895.

Analytical techniques prior to fission track analysis are given. To 100 ml samples of natural waters, 200 ml of concentrated HCl are added; the solution then is passed through a 6-ml column of Dowex 1-X8. The U is eluted with 60 ml 0.1N HCl and the eluate is evaporated to dryness. The residue is subjected to fission track analysis. The U in samples high in minerals should be separated before dissolution in HCl to avoid interference with the absorption of U by the ion exchange resin. The U content of river waters of Fukuoka city was determined. (RAP) (Auth)

<258>

Tanabe, T., and Y. Kondo, Kyoto University, Faculty of Engineering, Department of Metallurgy, Kyoto, Japan. 1976.

Solvent Extraction of Thorium Nitrate and Nitric Acid by Tributyl Phosphate-Carbon Tetrachloride Solution. Transactions of the Japan Institute of Metals, 17(7), 826-834.

The extraction equilibrium of Th(NO₃)₄ and HNO₃ in tributyl phosphate-carbon tetrachloride (TBP-CCl₄) solution was studied. The vapor pressures of H₂O and HNO₃ over the aqueous solution containing HNO₃ and Th(NO₃)₄ were measured, and the activity of each component in the ternary aqueous solution was calculated. Conventional distribution measurements of Th(NO₃)₄ and HNO₃ between organic and aqueous phases were conducted in addition to the measurement of infrared absorption spectra of the extracted species containing Th(NO₃)₄ and HNO₃ and the apparent equilibrium constants of extraction were determined, respectively: it was assumed that the extracted species in the organic phase are TBP, TBP·H₂O, Th(NO₃)₄·2TBP and 2TBP·HNO₃. The results were as follows: Th(NO₃)₄·2TBP, K_{sub} = 35.0 and (TBP·HNO₃)₂, K_{sub} = 0.32. (Auth) (RAP)

<259>

Tandon, S.K., J.S. Gaur, A.K. Jaisraj Behari, A.K. Nathur, and G.B. Singh, Industrial Toxicology Research Center, Lucknow, India. 1977.

Effect of Monazite on Body Organs of Rats. Environmental Research, 13, 347-357.

Biochemical and histological alterations in lungs, liver, and kidney of albino rats at different time intervals after an intratracheal administration of monazite, the

CHEMICAL ASPECTS

<259> COST.

Chief source of thorium and some rare earth elements of industrial significance, were investigated. The mild enzymatic and morphological changes observed in the lung suggest an inert behaviour of the monazite dust towards this tissue. However, biochemical alterations in liver and kidney indicate slight dissolution of some constituents of this naturally occurring mineral from the pulmonary tissue to other body organs. (Ruth)

<260>

Iesta, C., and G. Santori, Comitato Nazionale per l'Energia Nucleare, Radiotoxicology Laboratory, Occupational Medicine Service, Rome, Italy. 1972.

Sensitive Method for the Determination of Low Urinary Plutonium Levels in Occupationally Exposed Workers. *Giornale di Fisica Sanitaria e Protezione Civile*, 16(1), 1-6.

The perfection of a sensitive and selective method for the periodic control of occupationally exposed personnel is presented. A liter of urine was used. Batch extraction of Pu(IV) is carried out in a nitric atmosphere with Microtense-710 (a microporous polyethylene) supporting tri-n-octylphosphine oxide (TOPO). Separation is obtained by reduction to Pu(III) with a mixture of hydrochloric and hydroiodic acid. After drying and recovery with sulphuric acid, plutonium is electrodeposited on a steel disk after 5 hr, using (NH₄)₂SO₄. The disk is then counted with a solid state detector with a background of about 0.001 cpm. When high values are present, alpha spectrometry can also be carried out. The method gives a yield of 72.5%. Polonium, thorium, neptunium, uranium, protactinium, americium, curium and radium decontamination factors range from 30 to 10,000. Blanks activity (0.07 pCi/24 hr) was in line with the reference value adopted (0.2 pCi/24 hr). By comparison with anionic exchange resin analysis, the new method offers improved thorium and uranium decontamination. It also gives comparable chemical yield in a shorter execution time. (Ruth)

<261>

Thomas, C.W., Battelle-Pacific Northwest Laboratories, Richland, WA. 1974, December.

Procedure for Measuring Uranium, Thorium, Radium, Plutonium, and Americium in Soil Samples. *ESWL-1950* (Part 2); Annual Report for 1974, E.L. Vaughan (Ed.), (pp. 153-154), 238 pp. (ESWL-1950, Part 2).

A procedure was developed to determine naturally occurring radionuclides of uranium, thorium, and radium as well as pollutant radionuclides of plutonium and americium in soils. This method allows accurate measurement of low concentrations of radionuclides through chemical separation and alpha energy analysis. The procedure begins by thoroughly drying the soil sample and then a 30 g aliquot is weighed and placed in a container of suitable counting geometry. The gamma emitting radionuclides including ²⁰⁴Pb, ²²⁶Ra, and ²²⁸Ac were measured using a low background anticoincident shielded Ge(Li) diode that has the capability of separating the radionuclides with coincidence gamma photons from those radionuclides that emit non-coincidence gamma photons. The soil sample is then removed from the counting container and Pu 236 and Ac 228, as tracers

for chemical yield, are added. Following chemical separation, Pu, Th, and U are electroplated onto stainless steel discs at 1.1 amps for 2 hr. Individual isotopes are measured using alpha energy analysis. (Ruth)

<262>

1959, October.

Thorium and Its Compounds. *Industrial Hygiene Association Journal*, 20, 438-436.

Information is presented concerning the hygienic standards. The recommended maximum atmospheric concentration varies from 3×10^{-11} to 9×10^{-11} micro C/cc or 130-400 micrograms/cu m. Hazards are discussed. Chemical toxicity is low and Th compounds tend to remain at deposition sites. Excretion of injected compounds is almost complete; after injection, compounds tend to concentrate in liver, spleen and bone marrow. Throughout injections have produced cancer in animals and man. Powdered Th metal is pyrophoric and potentially explosive. When dispersed as a dust, or dispersed as a cloud, it ignites spontaneously at 270-280 deg C. Significant properties (decay series, etc.), industrial hygiene practice (evaluation of exposures and recommended control procedures), and specific procedures for thorium and its compounds are discussed in detail. (RHP)

<263>

1932.

Thorotrast. *American Medical Association Journal*, 99(26), 2183-2185.

Thorotrast was presented by the Heyden Chemical Corporation for consideration by the Council on Pharmacy and Chemistry as a colloidal thorium dioxide preparation suitable for use in retrograde pyelography and for roentgen visualization of the liver and spleen by intravenous administration. The composition, properties, administration, distribution, toxicity, elimination from the body, and radioactivity of Thorotrast are discussed.

<264>

Van der Sloot, H.A., P. Hassee, and H.A. Das, Reactor Centrum Nederland, Petten, Netherlands. 1975.

Determination of Uranium in Sea and Surface Waters by Neutron Activation Analysis after Adsorption on Charcoal. *Journal of Analytical Chemistry*, 25(1), 99-105.

A method is described which offers an attractive alternative for the direct neutron activation of water samples. Three advantages are mentioned: 1) after adsorption, the sample is unaffected by losses due to adsorption on the wall of the container; 2) adsorption leads to a good decontamination from NaCl; 3) the sample becomes more compact, which is of interest for the simultaneous irradiation of many samples. The blank-value of the charcoal is a disadvantage but it can be kept low with proper choice and pretreatment of the materials. During an investigation of the adsorption isotherms of various inorganic ions on activated charcoal, it was found that uranium is adsorbed with a high and constant efficiency from water samples to which L-ascorbic acid has been added. This is probably due to complexation of hexavalent

<260>

CHEMICAL ASPECTS

<260> CCVT.

uranium. The chemical yield of the adsorption has to be determined for different types of water using a spike of ^{239}U . After decay of the spike the η is determined by thermal neutron activation using the (n, gamma) reaction to ^{239}U ($T_{1/2}$ equals 23.3 min). Losses of ^{239}U from water samples during storage are negligible, when the sample has been acidified to pH less than or equal to 2, or when the storage time does not exceed a few days. (Aeth) (777)

<265>

Silhelm, H.A., and E.A. Rogers, Iowa State College, Institute for Atomic Research, Ames, IA. 1956.

The Physical Metallurgy of Thorium. Nuclear Metallurgy, IRI Special Report Series No. 1, (pp. 39-63).

Because of its low strength, poor resistance to corrosion and high cost, Th has not been considered as a structural material. Thorium has become of interest because of its nuclear properties and the possibility of using it as

a constituent in certain alloys. The physical metallurgy of Th is of interest to those who work with it. This review includes discussions of the following: preparation of Th metal; physical properties: crystal form, density, thermal coefficient of expansion, thermal conductivity, electric and magnetic properties, emissivity, melting point, heat of fusion, vapor pressure, heat of vaporization, boiling point, and heat capacity; heat treatment and recrystallization; fabrication: forming operations, machining, powder metallurgy; mechanical properties: hardness, tensile properties, modulus of rigidity (shear modulus), properties in impact, creep behavior, fatigue properties, damping capacity; metallography; binary alloy systems with Al, Be, Bi, C, Cr, Cu, Fe, Pb, Si, Ag, Ti, V, W, and Zr. The hazards encountered in handling Th relate primarily to its radioactivity. Precautions should be taken to prevent inhalation and ingestion as well as long external exposure. Another hazard is that, in the finely divided state, Th is explosive. (WC)

ECOLOGICAL ASPECTS NATURAL

<266>

Shelly, R.J., Kerr-McGee Nuclear Corporation.
1978.

Environmental Concerns in Uranium Mining,
Milling, and Conversion. Transactions of the
American Nuclear Society, 79, 211.

Environmental concerns related to the 9 fuel
cycle include those intrinsic in any mineral
extraction process consuming resources as
well as those unique to chemistry and
radioactivity of U and its decay products.
Natural U concentrates and compounds do not
present serious radioactive hazard to biota
or humans. Its chemical toxicity is similar
to other heavy poisons. The greatest hazard
is from inhalation of soluble compounds or
fine fests of natural U. Such soluble
compounds can damage kidneys or nervous
system. Compounds containing fluoride or
chloride ions can hydrolyze to toxic acids.
Daughter products may be hazardous; Ra 226,
for example, is carcinogenic. Processing may
release U or daughters to the soil, water or
air thereby restricting land use. Radium, a
daughter released during mining, can, when
inhaled, produce radiation damage. Water
associated with ore deposits may contain high
U and Ra concentrations. Milling processes
release radon as well as dusts and fluids
containing Ra; dust is also generated from
abandoned tailings ponds. Conversion of
yellowcake to uranium hexafluoride (UF₆)
concentrates decay products into liquids and
solids disposal of which is by burial.
Uranium hexafluoride is a soluble gas which
is chemically toxic by its hydrolysis to the
corrosive HF. Another hydrolysis product,
UO₂F₂ is also chemically toxic. Conversion
produces a concentrated form of Ra which
requires disposal. The secondary effects of
the consumption of resources common to all
metal extraction processes are not discussed.
(UC)

<267>

Blaylock, R.G., and J.P. Witherspoon, Oak Ridge
National Laboratory, Environmental Sciences
Division, Oak Ridge, TN. 1975.

Dose Estimation and Prediction of Radiation
Effects on Aquatic Biota Resulting from
Radioactive Releases from the Nuclear Fuel
Cycle. CONF-750662; IAEA-SR-198; STI/PUB/406;
Radiological Impacts of Releases from Nuclear
Facilities into Aquatic Environments,
Proceedings of a Symposium held in Otaaniemi,
Finland, June 30-July 4, 1975, (18 pp.) 524 pp.
(CONF-750662, IAEA-SR-198, STI/PUB/406).

The radiation dose received by aquatic biota
from different nuclear processes and the
major dose-contributing radionuclides, and
the impact of the estimated doses on aquatic
biota have been determined. Dose estimates
are made by using radionuclide concentration
measured in the liquid effluents of
representative facilities. Where
measurements of concentrations are not
available, predicted radioactive releases to
the aquatic environment are used for dose
calculations. Although radioactive releases
from reactors used to generate electrical
energy have received the most attention, and
are the best documented, this evaluation
indicates the potential for a greater
radiation dose to aquatic biota from the
nuclear fuel supply facilities (i.e., mining
and milling). The effects of chronic
low-level radiation on aquatic organisms are
discussed from somatic and genetic
viewpoints. Based on the body of
radiobiological evidence accumulated up to

the present time, no significant deleterious
effects are predicted for populations of
aquatic organisms exposed to the estimated
dose rates resulting from routine releases
from conversion, enrichment, fabrication,
reactors and reprocessing facilities. At the
doses estimated for mining and milling
operations it would be difficult to detect
radiation effects on aquatic populations;
however the significance of such radiation
exposures to aquatic populations cannot be
fully evaluated without further research on
effects of chronic low-level radiation.
(Auth) (UD)

Tables on estimated radionuclide doses to
aquatic organisms from nuclear facilities are
included. See also Nuclear Safety, 17(3),
351-361 (1976).

<268>

Blaylock, R.G., and J.P. Witherspoon, Oak Ridge
National Laboratory, Oak Ridge, TN. 1976,
May-June.

Radiation Doses and Effects Estimated for
Aquatic Biota Exposed to Radioactive Releases
from LWR Fuel-Cycle Facilities. Nuclear Safety,
17(3), 361-362.

The effects of chronic low-level radiation
from uranium mining and milling, conversion
facilities, uranium enrichment, fuel
fabrication, light-water reactors, and fuel
reprocessing on aquatic organisms are
discussed from somatic and genetic
viewpoints. Dose estimates are made by using
measurements of radionuclide concentrations
in the liquid effluents of representative
facilities. Where such measurements are not
available, predicted radioactive releases to
the aquatic environment are used. Although
radioactive releases from reactors used to
generate electrical energy have received the
most attention and are the best documented,
this evaluation shows the potential for a
greater radiation dose to aquatic biota from
the nuclear fuel-supply facilities (i.e.,
mining and milling), with Ra 226, Po 210, and
Th 230 being the greatest dose-contributing
radionuclides. On the basis of the body of
radiobiological evidence accumulated to date,
no significant deleterious effects are
predicted for populations of aquatic
organisms exposed to the estimated dose rates
resulting from routine releases from
conversion, enrichment, fabrication, reactor
and reprocessing facilities. The
significance of radiation exposures to
aquatic populations due to mining and milling
operations cannot be fully evaluated without
further research on effects of chronic
low-level radiation. (Auth) (JTE)

Estimated internal doses to aquatic organisms
from the various processes in the enriched
uranium dioxide fuel cycle are presented
tabularly. See also CONF-750662, Part of
Proceedings of a Symposium on the Radiological
Impacts of Releases from Nuclear Facilities into
Aquatic Environments held in Otaaniemi, Finland,
June 30-July 4, 1975.

<269>

Cherdyn'tsev, V.V., and J. (Translator) Schmorak,
Geological Institute of the Academy of Sciences
of the USSR, Dating Laboratory, Moscow, USSR.
1971.

Uranium 238 in the Ocean. Uranium 238, Chapter
7. Keter Press, Jerusalem, Israel, (pp.
177-234), 234 pp.

<269>

ECOLOGICAL ASPECTS MARINE

<269> CONT.

A review is given of U in seawater corals, mollusk shells, and deep sea deposits. Studies were made on the isotopic composition of U in 20 specimens of water from the Pacific, Indian, and Atlantic Oceans, the Mediterranean and the Red Sea, sampled both at the surface and at depths up to 5,000 meters. The gamma-value (U 234/U 238 activity units) varied between 1.13 and 1.17. Corals and mollusk shells displayed the same uranium isotopic ratio as the seawater, since they use seawater to build up their skeletons. One study showed that the gamma value of seawater increased with depth, the minimum value occurring at 2 kilometers depth which corresponds to the minimum oxygen content. The average content of U in fluid waters of the world is unknown but is probably not less than $1.10(E-7)$ g/l. By estimating the time taken for river water to fill the ocean basin, it is suggested that 1,500,000 years is the minimum time for the existence of U in seawater. The ocean contains about 5 billion tons of U of which tens of thousands of tons escape every year. The content of Th and also of Radium and protactinium in ocean water have also been determined. The dating of corals and mollusk shells is discussed with mention made of the use in level of the seas as a result of deglaciation which followed the main quaternary glaciation. Studies on benthic deposits show that they do not contain excess amounts of U 234 and in most cases are even deficient with respect to the equilibrium value. The gamma values varied between 0.76 and 1.07 with gamma = 0.93 as the average value. The sea coxes however are remarkable for their very high Th/U ratio; these may be as high as 10 in isolated cases while the average value is 5.1. The average content of U in coxes is quite high— $2 \times 10(E-6)$ to $3 \times 10(E-6)$ g/g and the uranium leached out of the cox may act as an important source of supply of U to the sea water. The U cycle in the sea may be roughly represented as follows: elements enter the sea with river waters, both as true solution with colloidal particles or as matter absorbed on these particles. They then form deep water deposits. The U which is then leached out of these particles again becomes only dissolved in water in the form of orange salts. (PMM)

Table 72 shows isotopic ratio of U, Th and Ra in benthic deposits of the world ocean. This is a translation of Report, TRAV-238.

<270>

Cherry, R.D., and I.M. Gericke, University of Cape Town, Physics Department, Rondebosch, South Africa; Division of Sea Fisheries, Sea Point, South Africa. 1969.

Thorium 228 in Marine Plankton and Sea-Water. Earth and Planetary Science Letters, 6, 451-456.

Data are given for thorium 228 in zooplankton, phytoplankton and sea water from seven different oceanographical water masses in the South Atlantic and around the Southern African coast. The levels in plankton are easily detectable (up to $27 \times 10(E-18)$ g thorium 228 per g wet zooplankton and up to $65 \times 10(E-18)$ g thorium 228 per g wet phytoplankton). What appear to be real variations from one water mass to another are observed, and the possible utility of thorium 228 as a natural oceanographic tracer is noted. The levels in sea water are in general at or below the sensitivity level of the technique used, but for one set of

samples a particularly high thorium 228 content of $2.7 \times 10(E-15)$ g thorium 228 per liter sea water is obtained. This set originated from the Walvis Ridge area; attention is drawn to the fact that this region is likely to be particularly interesting as far as thorium and certain other trace elements are concerned. (Auth) (BAP)

<271>

Cherry, R.D., and I.V. Shannon, University of Cape Town, Physics Department, Rondebosch, Cape Province, South Africa; Division of Sea Fisheries, Sea Point, Cape Province, South Africa. 1970.

The Alpha Radioactivity of Marine Organisms. Atomic Energy Review, 12(1), 1-45.

The important role played by alpha-radioactive nuclides in the marine radiation environment were discussed. Detailed surveys of the alpha-emitting nuclides and their relevant nuclear properties, and of the concentration and distribution of these nuclides in seawater, in marine organisms and in the organs thereof were presented. Data were compiled in tabular form to show that the total alpha activity in seawater is typically about 3.2 pCi/liter. Of this, the uranium series nuclides contribute about 96%, while the three uranium nuclides contribute about 76%. It was also shown that Po 210 is by far the dominant contributor to the alpha radioactivity of all the categories of marine organisms included, except phytoplankton where it is replaced by Ra 226. However, in this category the Po 210 contribution is substantial also. Brief comments were made on experimental techniques, the biochemical balance problem and radiation dosimetric considerations. Suggestions for future lines of research were included. (Auth) (JTE)

One-hundred fifty references are contained in this article.

<272>

Higashi, S., University of Kyoto, Department of Chemistry, Kyoto, Japan. 1955.

Estimation of the Microgram Amount of Thorium in Plants, Shells, and Corals. Japan Analyst, 7, 441-444.

A colorimetric method was adopted for determination of the microgram amount of thorium in some organisms. The thorium contents in these samples were estimated as follows: plant ashes 1 to 5 ug/g, duckweed ashes 3 to 4 ug/g, seaweed ashes 0.3 to 0.4 ug/g, shells and corals 0.07-0.8 ug/g. (Auth)

<273>
1972.

High Uranium Content in Rivers Due to Fertilizers. Umschau in Wissenschaft und Technik, 70(20), 803.

Uranium concentrations in North American rivers are higher than those reported 20 years ago. This increase is attributed to applications of large amounts of phosphate fertilizers, containing appreciable concentrations of uranium. A linear relationship was found between the U content and P2O5 content of fertilizers. Analysis of grain and soybeans in the Brazos river area showed very little uptake of U. The

ECOLOGICAL ASPECTS
AQUATIC

<273> COST.

radioactive decay products Ra, Pb, and Po, however, are taken up by plants and may present a health hazard to man. (NAT)

<270>

Izai, T., and N. Sakagawa, Kanazawa University, Radiochemical Laboratory, Department of Chemistry, Kanazawa, Japan. 1973, April.

Content of Plutonium, Thorium and Protactinium in Sea Water and Recent Coral in the North Pacific. *Journal of the Oceanographical Society of Japan*, 29, 76-83.

The contents of plutonium isotopes ($Pu\ 239$ and $Pu\ 240$), thorium isotopes ($Th\ 232$, $Th\ 230$ and $Th\ 228$) and protactinium-231 in sea water collected in the North Pacific, the East China Sea and the Japan Sea were determined. These nuclides were sequentially analyzed by alpha-ray spectrometry after separating them mainly with solvent extraction technique. The contents of $Pu\ 239$ in surface sea water ranged from 0.6 to 1.6 pCi/1000 l. $Pu\ 238/Pu\ 239$ activity ratios being 0.2 to 0.7. The $Th\ 228/Th\ 232$ activity ratios for the North Pacific waters varied between 7.6 and 30, whereas the sample from the East China Sea showed the very high value, 65. The contents of $Pu\ 239$ are less than six percent of that in equilibrium with its parent ^{235}U . Furthermore, the analysis of plutonium isotopes in recent coral from Toron Island was carried out and it was confirmed that plutonium isotopes have concentrated in recent coral with the concentration factor of about 1 to 2x10 (2-3). (Auth)

<275>

Iskra, B.A., B.V. Kelikov, and V.G. Bakherov, 1969, August.

Behavior of Natural Radioactive Elements in Standing Reservoirs. Communication I. Atomic Energy, 27(2), 283-287.

A simulated system including all three basic components of a freshwater reservoir (water, soil, and plants) proved to be most effective in removing natural radioactive elements from the water. In the simulated system investigated, the predominant buildup of uranium occurred in plant materials, that of thorium occurred in detritus and soil, and an equilibrium distribution of radium occurred in the components of a standing reservoir. With the introduction of natural radioactive elements into a standing reservoir, there is observed migration of uranium and radium in soluble form while migration of thorium, and probably of radon D also, is practically excluded. In simulated systems of a standing reservoir, the greatest specific activity and buildup capability is possessed by detritus; they are present to a lesser extent for plant materials and to an insignificant degree for soil. The phenomenon investigated may find commercial application for secondary purification of liquid radioactive wastes in artificially constructed storage ponds in which (as a supplement to the main process of physical deposition of the radioactive impurities) are cultivated certain types of aquatic plants. (Auth)

<276>

Folde, R., J.J. Griffin, and E.D. Goldberg, Scripps Institution of Oceanography, La Jolla, CA. 1975, October 20.

Records of Plutonium Fallout in Marine and

Terrestrial Samples. *Journal of Geophysical Research*, 80(36), 8151-8162.

In coastal marine sediments from western North America there is a continuing increase in $Pu\ 239$ and 240 concentration from the early 1950's to the present. Most of these transuranic isotopes have entered our surroundings following nuclear weapons testing from direct stratospheric fallout which went through a maximum around 1961. Since no maximum level in the sediments corresponding to the maximum stratospheric fallout was observed, another source of plutonium to these deposits was sought. It has been identified through the analyses of atmospheric aerosols as crystal rock debris transferred from the continents to the oceans by winds. A transport of soil debris, containing sorbed artificial radionuclides, to the oceans by winds and/or by rivers may explain the greater $Sr\ 90$ fluxes to the marine environment, compared to those of the continents, after the fission product is produced in nuclear explosions. (Auth)

Tables on lead, thorium, and plutonium basin sediment concentrations are given. A table on the lead and plutonium concentration in atmospheric dust samples is given.

<277>

Miyake, T., Y. Sugimura, and E. Matsunoto, Meteorological Research Institute, Fuchu-ku, Saitama, Tokyo, Japan; Tokyo Kyoiku University, Ohtsuka, Bunkyo, Tokyo, Japan. 1968, March.

Ionium-Thorium Chronology of the Japan Sea Cores. *Records of Oceanographic Works in Japan*, 9(2), 149-195.

The rate of deposition of two cores collected at the depth of about 3,000 m in the central part of the Japan Sea Basin was studied by means of the ionium-thorium method. Results showed the rate of deposition of $18.5m/10(E+3)$ y for the core 864-19 and $15.2m/10(E+3)$ y for the core 864-21, respectively. Uranium content in the surface layer was about 3 ppm. An abrupt increase in uranium content was found below 15 cm-20 cm from the surface which continues to the bottom of the core of 1 m long. This may be related to the great sea level change during the last glacial period. (Auth)

Table 1 shows activity ratios of $Th\ 230/Th\ 232$ and $Th\ 228/Th\ 232$ and total amounts of Th and U in Seifu core 864-19 in the Japan Sea. Table 2 shows total amounts of U and activity ratios of $U\ 238/U\ 235$ and $Th\ 230/Th\ 232$ in Seifu core 864-21.

<278>

1973.

Radioecology of Freshwater Plants and Animals. *Radioecology*, V.N. Khechovskii, et al (Eds.), Chapter 15. John Wiley & Sons, New York, New York. (pp. 232-227).

Sections of this review deal with the accumulation of artificial and natural radionuclides by hydrobionts, the accumulation of radionuclides as related to physicochemical factors of the environment, the distribution of radionuclides among the components of a water body and the effects of radionuclides by hydrobionts. Among the elements discussed are the natural radionuclides $U\ 238$, $Th\ 232$ and $Pu\ 226$. Accumulation coefficients are given for some representatives of freshwater flora. The

<278>

ECOLOGICAL ASPECTS
AQUATIC

<279> COWI.

Mean accumulation coefficients of ^{238}U were found to be greater in higher plants than in algae. *SAUWICHLUS* and *POTAMOGETON PERFORATUS* were shown to be specific accumulators of ^{238}U . The accumulation coefficients of ^{238}U were also found to assume somewhat greater values on the average in higher plants than in unicellular and multicellular algae. The most active accumulator of this radionuclide was *SCYTHESSES QUADRICAUDA*, and lesser duckweed. In contrast to ^{238}U and ^{232}Th , ^{232}Th was more intensively accumulated by algae than by higher plants. The highest accumulation coefficients were in the unicellular algae *SCYTHESSES ACUMINATUS* and *CHLOROKYLLA FLUPESCIBER*. On the average ^{232}Th showed greater accumulation by plants than ^{238}U and ^{238}U . With respect to the accumulation of all three actinides, the strongest accumulator of all groups of freshwater plants studied were the unicellular algae. (PAP)

Tables are given for accumulation coefficients of ^{238}U , ^{232}Th , and ^{232}Th for different species of freshwater plants and mean accumulation coefficients for the three radionuclides in higher plants, multicellular algae and unicellular algae.

<279>

Shamon, L.V., Division of Sea Fisheries, Cape Town, Republic of South Africa. 1972.

Marine Alpha-Radioactivity off Southern Africa. 2. Thorium in Marine life. Division of Sea Fisheries Investigational Report No. 99. 15 pp.

The $^{232}\text{Th}/^{238}\text{U}$ activity ratio in plankton was determined by chemical extraction followed by semi-conductor alpha-spectroscopy to be about 15, i.e., similar to published ratios for seawater. The concentrations of the thorium series in 387 samples of marine life are presented. Thorium ^{232}Th levels in most marine groups were about 20×10^{-18} g/g wet material. Measured by the alpha pairs technique the thorium series contributed 5-20% of the total alpha activity of marine organisms. Phyto- and zooplankton concentrate thorium from seawater by factors of 2000 and 800 respectively. The biological removal time for thorium from the upper 100 m mixed layer was calculated to be about eight years. Highest values of ^{232}Th were found in plankton from the Agulhas Current and in zooplankton from the Walvis Ridge region (no phytoplankton from the latter area was measured) whereas values were low in plankton from the Subtropical Convergence and the Benguela Current. The possible utility of ^{232}Th as a natural oceanographic tracer is discussed. (Auth)

<280>

Woodhead, E.S., Fisheries Radiobiological Laboratory, Ministry of Agriculture, Fisheries and Food, Lowestoft, Suffolk, United Kingdom. 1971.

Levels of Radioactivity in the Marine Environment and the Dose Commitment to Marine

Organisms. CSRP-720708; IAEA-SR-154/31; Interaction of Radioactive Contaminants with the Constituents of the Marine Environment, Proceedings of a Symposium held in Seattle, Washington, July 10-14, 1972. (pp. 499-525) (CSRP-720708, IAEA-SR-154/31).

The published data on the levels of radioactivity in seawater, the sea bed and marine biota from natural sources, fallout and waste-disposal operations, have been reviewed. As a starting point for calculations of dose-rates to marine organisms the data have several deficiencies. First, a complete set of data for all the isotopes (natural and artificial) is not available for either a single species or even for groups of organisms. It has been found convenient therefore to summarize the data in terms of the following groups of organisms: phytoplankton, zooplankton, mollusca, crustacea, and fish. Secondly, within the groups of organisms the data refer to widely differing or unknown geometries, and there is little information on the differential distribution within organisms. Therefore, to calculate the dose-rates, simple idealized models have been employed to represent each of the five groups, despite their obvious limitations as a description of the real situation. Within the limitations imposed by the data and the dosimetry models, the results of the calculations show that, in a global context, the dose-rates to marine biota from artificial radionuclides are of the same order as those from natural background sources, and that weapons-test fallout is the major contributor. The practice of marine disposal of radioactive waste leads to locally high dose-rates, but in population or global terms the dose-rate contribution is and will probably remain negligible. (Auth)

<281>

Dzenko, A.Ya., and A.S. Nazarov, Ukrainian SSR Academy of Sciences, Institute of the Biology of the South Seas. 1973.

On Thorium ^{232}Th Accumulation by Marine Organisms. AEC-tr-7604; Radioecology of Water Organisms. Vol. 2. Distribution and Migration of Radionuclides in Freshwater and Seawater Biocenosis, G.P. Andrusheits (Ed.), (pp. 163-166) (AEC-tr-7604).

Thorium ^{232}Th accumulation by 4 species of marine algae, macrophytes, 2 species of zooplankton and one species of phytoplankton in experimental conditions was studied. The various concentration factor ($20,000$) was found in phytoplankton. Other concentration factors were: for *ULVA FIGIDA* 1200, for *ENTEROMORPHA* sp. and *LITIA* 700 and for *CYSTOSPHERA SAPPHATA* 60. Theories of the distribution of ^{232}Th between seawater and sediments are discussed. From a comparison of accumulation factors of ^{232}Th and ^{238}U it is proposed that marine organisms play a substantial role in the shifting of equilibrium in an analogous pair of actinides such as $^{238}\text{U}/^{232}\text{Th}$. (PAP)

ECOLOGICAL ASPECTS TERRESTRIAL

<282>

Aleksakhin, B.S., Academy of Sciences, Forestry Laboratory, Moscow, USSR. 1971.

Migration of Natural Radionuclides and Their Effects in Terrestrial Biocenoses. Soviet Journal of Ecology, 2(4), 567-583; Zhologiya, 6, 197-198.

A brief summary of papers presented at the section "Migration of Radionuclides in the Biosphere and Problems of Radiocology" of the USSR Academy of Science is presented. One paper by Vainsterg revealed no significant differences in the U, Ra, Th, and K contents between soil types and distribution of these elements in soils. Other papers discussed the distribution of U, Ra, Th, and Po 210 in plants of northwest European USSR and movement of Ra 226 through soils. (COP)

<283>

Cherry, B.D., University of Cape Town, Physics Department, Rondebosch, South Africa. 1964, July.

Alpha-Radioactivity of Plankton. Nature, 203, 137-143.

Different groups of phyto- and zooplankton samples at various dates from 1959 until early 1962 were analyzed for total alpha-activity. Measurements were also taken for pairs resulting in percentage contributions to the total alpha-activity by the activity due to the thorium series alone. The samples were taken at a number of locations in the waters around the Cape of Good Hope. In general fresh plankton contained upwards of 4 pCi alpha-activity/g dried sample. For several of the zooplankton samples some of the initial activity was often short-lived (smaller or equal to 2 years). This short-lived activity contributed an activity considerably in excess of the basic 4 pCi/g. No such short-lived activity was observed in phytoplankton samples. Some phytoplankton showed extremely high alpha-activity persisting for a five-year period or more. Measurement of the elemental abundances of Po, Th series isotopes, and U and Ra permitted the following deductions: Po 210 in some cases was responsible for a substantial portion of the initial activity for phytoplankton specimens; thorium series elements contributed upwards of 0.8 pCi/g of dried plankton based on an alpha-activity of about 2×10^5 (3-5) pCi/g in sea water resulting in a concentration factor of about 1,250; and uranium and radium were found to contribute upwards of 1-2 pCi/g alpha-activity. (BAP)

<284>

Bill, C.D., Institute of Cancer Research, Physics Department, Royal Cancer Hospital, London, England. 1962.

Identification of Alpha-Emitters in Natural Biological Materials. Health Physics, 8, 17-25.

Preliminary results are reported of a program of alpha-spectrometry that is being carried out on natural levels of alpha-activity in humans and their environment. The natural fallout mechanism for Pb 210 and Po 210 leads to a rather high, rainfall-dependent concentration of these nuclides in foliage, and their subsequent uptake into the tissues of grazing animals has been detected. A limited number of samples of human foods and drinking waters has been examined and the

presence in them of varying proportions of Ra 226, Ra 228, Po 210 and uranium is reported. In bone and many of the soft tissues of normal, unexposed human subjects, Po 210 appears to be responsible for a large part of the total natural activity, while thorium and uranium isotopes, and possibly Po 239, have been detected in normal lungs. Results are also reported of similar measurements on the tissues of two subjects with histories of occupational exposure to uranium ore and radium. (BAP)

Tables are given of alpha-activity in some foods and human tissues.

<285>

Jaworski, B., and D. Grzybowski, Central Laboratory for Radiological Protection, Warsaw, Poland. 1977, January.

Natural Radionuclides in Industrial and Rural Soils. Science of the Total Environment, 7(1), 45-52.

Radium 226, Pb 210, U and Th are dispersed in the environment by fly ash emitted by coal fuelled power stations. Concentrations of these nuclides have been determined in fly ash from three power stations and in soils collected in six industrial and twenty rural regions. In industrial areas the concentrations of natural radionuclides, in a 5 cm thick surface soil layer, were found to be higher than in lower layers. With the exception of Pb 210 this effect was not observed in rural soils, which contained less Ra 226, U and Th. A mean concentration of Ra 226 of 1.0 pCi/g was found in the upper layer and 0.73 pCi/g in the lower one. The mean content of exchangeable Ra 226 in soil was usually similar in both layers in industrial and rural regions. The vertical distribution of Th in soil was similar to Ra. It was found that the type of coal, or combustion technology, influences the amount of Ra 226 dispersed in the environment which is accessible to plants. (BAP)

The mean contents and range of Ra 226, exchangeable Ra 226, Pb 210, U, and Th in soils are given in tabular form.

<286>

Marston, E., Dominion Physical Laboratory, New Zealand. 1960, July.

Radioactivity of Soils, Plants and Bones. Nature, 187, 192-195.

Observations and discussions are presented on high natural radioactivities which might be expected to produce radiation hazards. Polonium 210 is identified as the radionuclide responsible for the very high recorded activity from a slow-growing mountain pasture in England. Plant uptake studies from soils for radium and lead are given. Comparative studies are described on wheats grown in the United Kingdom, New Zealand and Victoria. Total variations of nearly 1:20 were observed in the alpha activity/gram ash, the activity being mainly controlled by pH and calcium availability status, with genetic variety as a significant, but quantitatively less important factor. Reference is made to the high activity of soils of Blue Island. A 30% increase was noted after nine months in plants such as taro, kumara, cassava and yams. Observations were extended to parent soils, human and animal bones and body organs. The average activity of Blue

(204)

ECOLOGICAL ASPECTS
TRUSTS

(205) CONT.

tooth/yr on ash was some ten times that of tooth of leopards. The bones of "beach" bones gave 60 bec./gram bone ash while values for Made Island bone were 70 and a single sample of two eggs from the latter gave a value of 1.5. Genetic studies dealing with infertility, abnormal sex ratio and infant mortality are mentioned. Due to the low population of the island (4500) statistical findings need to be interpreted with caution. (BAP)

(207)

Ruslov, V.I., B.I. Grudov, A.I. Maslova, V.S. Vikhorev, and I.B. Vekhovskaya, Academy of Sciences, Biological Institute Leningrad Branch, Sybtykhar, USSR; Academy of Sciences, Bach's Physicochemical Institute, Moscow, USSR. 1970.

The Role of Benthic Rodents in the Biogenic Migration of Uranium, Sodium and Thorium under Different Radioecological Conditions.

CONF-690910; Radioecology, Proceedings of a Symposium held in Fontenay-aux-Roses, France, September 8-11, 1969, Vol. 2, (pp. 923-940) (CONF-690910).

Three species of rodents inhabiting radium and uranium-radium sites in different zones of the northern tundra were studied in relation to the accumulation and transport of these radionuclides. Findings show that as a result of their burrowing activity benthic rodents not only displace great amounts of radioactive elements within the different soil horizons but bring them onto the surface, changing thereby the radiation environment of their habitat and contribute to the further migration of the elements over great distances (transport by wind, washout, etc.). Due to the intensive accumulation of radionuclides in the organisms of benthic rodents as compared with other animals, substantial amounts of U, Na and Th are carried away from sites of high radioactivity with the feces of the animals. (BAP)

Sixteen tables and thirteen figures give a detailed account of this study.

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By, Y.C., C.A. Norton, S.E. Thompson, B.K. Tandy, B.N. Kretzsch, and R.V. Pratt, Lawrence Radiation Laboratory, Livermore, CA. 1968, May.

Prediction of the Maximum Dose to Man from the Fallout of Nuclear Devices. 6. Handbook for Estimating the Maximum Internal Dose from Radionuclides Released to the Biosphere. UCRL-50163 (Part 6): 123 pp.

Part 6 of this series is a special purpose handbook for estimating the maximum internal dose to man from radionuclides released to the biosphere. This handbook, which is to be continuously updated and is to be expendable, lists the pertinent data for all isotopes whose half-lives are greater than 12 hours. The first issue and first addition are devoted to the estimation of the dose resulting from contamination of agricultural lands as described in UCRL-50163, Part 2, and the dose resulting from contamination of aquatic environments described in UCRL-50163, Part 5. Of specific interest are listed concentrations of U, Pu, Th, Sr, and Ba in soils, plants, salt water, salt water fish, salt water plants, fresh water, fresh water fish, and fresh water plants. (BAP)

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Johnson, R.S., Colorado State University, Department of Radiology and Radiation Biology, Fort Collins, CO. 1965.

Primordial Radionuclides: Their Distribution, Movement, and Possible Effect within Terrestrial Ecosystems. Health Physics, 11, 1275-1295.

An attempt is made to trace the pathways of several naturally occurring radionuclides from their source or point of origin into environmental and biological systems until they decay to stable nuclides. The world-wide distribution of these radionuclides is summarized and a more detailed account of their occurrence and movement within specific ecosystems is provided. Major environmental and biological transport mechanisms to which radionuclides are subjected during the course of their life span are discussed. Thus, the biology of these naturally occurring nuclides is reviewed. The ecological life history of various plants and animals are considered and the radioactivity of the various stages are considered. Where statistically high radioactivity are coincident with exposure to relatively high levels of background radiation, possible biological effects are discussed. Special attention is given to the interaction of ionizing radiation with other environmental stresses. (BAP)

(210)

Shanon, B., Commissariat à l'Energie Atomique, Centre d'Etudes Nucléaires de Cadarache, Département de Protection, St-Paul-lès-Durance, France. 1973.

The Behavior in Underground Environments of Uranium and Thorium Discharged by the Nuclear Industry. CEH-CENP-2336; IAEA/SA/172-55; CONF-730503; Environmental Behavior of Radionuclides Released in the Nuclear Industry, Proceedings of a Symposium held in Aix-en-Provence, France, May 18-19, 1973, (pp. 333-346) (CEH-CENP-2336, IAEA/SA/172-55, CONF-730503).

Following various studies on the radioactive contamination of soil by fission products from a variety of effluents, it has been found necessary also to establish in what way long-lived heavy radionuclides could be diffused in underground environments. A proposal is made for the study of the behavior in the soil of uranium and thorium originating from outside, as compared with the uranium and thorium existing as natural constituents of the soil. Use was made of various types of soil (acid and alkaline) and of various minerals (argillaceous minerals, calcite and quartz). Uranium in solution, or uranyl ion to be more precise, has a certain degree of mobility in soils. The coefficient for the distribution of uranyl ion between the solution and the mineral was measured at various concentrations. The influence of the pH of the soil-water solution is very considerable; the retention of uranium by the soil shows a marked increase within certain narrow pH ranges. Thorium is subject to high retention by argillaceous and calcareous soils, some of the latter strongly fixing the whole amount. The influence of various parameters (pH, concentration, soil composition) is also substantial, as retention can be very much reduced under certain extreme conditions. The risk of the spread of thorium in dilute solution over long distances is negligible in most soils. On the other hand, a certain degree of

ECOLOGICAL ASPECTS TERRESTRIAL

<290> CONT.

uranium diffusion under the influence of ground-water movements is to be anticipated; diffusion evaluations are presented. (Auth)

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Jones, R.W., V.G. Hale, A. Wallace, O.B. Lunt, J.B. Childress, E. Katz, G.V. Alexander, J.Z. Vimmer, and I.L. Scherman, University of California, Laboratory of Nuclear Medicine and Radiation Biology, Los Angeles, CA. 1973, June.

Some Characteristics of Soil and Perennial Vegetation in Northern Mojave Desert Areas of the Nevada Test Site. UCLA-72-946; 349 pp.

The report is a compilation of data from several interrelated projects conducted at the Nevada Test Site as part of a team effort to obtain more information on soil and plant relationships in the desert ecosystem in order to better understand the impact of nuclear testing on the environment. It ties together the masses of acquired data into one convenient volume and serves as a basis for the continuing systems analysis work involved with these projects. Included are results from the chemical and physical characterization of soil profiles at 79 study sites located in some northern Mojave Desert areas of the Nevada Test Site. These profiles were characterized under clumps of perennial vegetation and under bare desert pavement in order to determine the modifying influence of shrubs on desert soil. Ecological attributes of perennial vegetation determined by non-destructive, dimensional analysis are reported in terms of density, area, volume and biomass according to the existence of shrubs as solitary plants or as members of a shrub clump. Mineral element composition of leaves and stems are reported for the most common plant species at each study site. Also included are the concentrations of Cs 137, and the natural K 40 (as total K), uranium and thorium found in the surface fractions of the soil profile. Abiotic data compiled during a five year period from nine sampling stations are reported for rainfall, air temperature, soil temperature and soil moisture. (Auth)

<292>

Verkhovskaya, I.M., P.P. Vavilov, and V.I. Malov, 1972.

Distribution and Redistribution of Uranium, Radium, and Thorium in Natural Biogeocoenoses. BPP-Trans-162: Radiokologicheskie Issledovaniya v Prirodnykh Biogeotsenozakh. Izdatel'stvo Nauk, Moscow, USSR, (pp. 243-256) (BPP-Trans-162).

The distribution and redistribution of naturally radioactive elements in soils, water, plants, and animals was investigated. In various zones of the northern taiga in regions with elevated radiation levels it was established that the distribution of uranium, radium, and thorium through horizons of the soil profile depends on the type of soils, the character of soil formation, and phytocoenoses. Plants, trees, shrubs, grassy growths, and mosses along with the upward flow of water (together with other mineral substances) take up from the soil soluble forms of radium, uranium, and thorium into their above ground parts. It is important to note that the relation of radioelements entering the plants does not correspond to their relation in the soil. In order of amount of uptake, they are radium, uranium, then thorium. An acropetal gradient of radioelement distribution is noted for all plants, as well as a higher content of these elements in older portions of plants. All the radioelements (including even radium, the most mobile of them) are practically incapable of being reutilized within plants. They remain deposited in the same spot at which they initially arrived along with the ascending water flow. The radioelement content of a large number of wild animals inhabiting radium, uranium-radium, and thorium sectors makes it possible to determine the movement of radioelements incorporated into the organism of animals through the food chain. The degree of participation of individual groups of animals in the removal of radioelements from the soil and their dispersal over the land surface was established. (LCL) (WAT)

ENERGY

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Albert, B.F., New York University Medical Center, Institute of Environmental Medicine, New York, NY. 1966, November.

Thorium and Nuclear Power. Thorium: Its Industrial Hygiene Aspects, Chapter 8. Academic Press, New York, New York, (pp. 46-57), 222 pp.

Characteristics of nuclear power reactors are outlined. Fuel is arranged to produce a controlled fission reaction which produces neutrons for converting fertile to fissionable materials and heat to generate electricity. Reactor cores, where fission occurs, contain moderators and are surrounded by reflectors, which slow the neutrons and decrease their loss. Reactor control is by neutron absorbing rods. In "fast reactors" there are no moderators; most fissions are produced by fast neutrons. Fuel is more enriched than in thermal reactors. In thermal reactors, various coolants, moderators, and enrichment levels can be used. In breeders and converters, neutron capture by U 238 or Th 232 (fertile) produces Pu 239 and U 233 (fissionable). This production depends on the efficiency of neutron capture as well as the intrinsic efficiency of neutron production by the fuel. In a breeder, conversion of fertile to fissionable material exceeds consumption of fissionable material. In a converter, the ratio is less than 1. Possible breeding cycles for thermal and fast reactors are Th 232 to U 233 and U 238 to Pu 239, respectively. Demand for recycled fuel will probably increase as ore is exhausted. Fuel elements comprised of Th include Th slugs with Al, Th-U carbide sleeves, and ThC₂-UO₂ pellets and rods. The latter type characteristically increases fuel burnup and has been used for breeding U 233. Fabrication of UO₂ Borex-IV pellets, sol-gel process for ceramic fuel elements, and Th-U carbide fuel is described. Fuel is chemically processed when reactivity has deteriorated or there is danger of mechanical disruption by radiation damage. Specific methods depend on the chemical characteristics of the particular fuel and its cladding. (VC)

<294>

Albert, B.F., New York University Medical Center, Institute of Environmental Medicine, New York, NY. 1966, November.

Thorium: Its Industrial Hygiene Aspects. Academic Press, New York, New York; 222 pp.

This monograph summarizes the major technical uses of thorium, the hazards common to the various industrial processes, the techniques and objectives for the control of these hazards, and the biological and medical foundations on which these hazard controls are based. It is intended to be of use to persons in the field of health protection (industrial hygienists, health physicists, and industrial physicians), as well as those concerned with the technical aspects of production and research who may wish to gain some insight into the nature of the health problems associated with the use of thorium. Thorium is unusual in that the radiological health hazards encountered in industry are not caused by Th 232, which is the long-lived parent isotope of the naturally occurring radioactive decay series and constitutes virtually the entire mass of natural thorium. Rather, the hazards arise from isotopes of a variety of elements that are present in the decay chain of Th 232. The fact that these

isotopes encompass such a wide range of metabolic, physical, and radiological properties posed the special challenge of this monograph; the control of thorium hazards involves almost every type of radiological health protection problem that is encountered in the atomic energy industry. Eleven chapters have been abstracted for the data base. (auth) (VC)

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Almgren, B., AB Atomenergi, Stockholm, Sweden. 1966.

Swedish Work on the Thorium 232-Uranium 233 Fuel Cycle. Technical Reports Series No. 52: Utilization of Thorium in Power Reactors, (pp. 169-171).

Sweden has great resources of uranium but no thorium. Therefore Swedish reactor development has been concentrated on uranium-fueled reactors such as pressure vessel reactors moderated and cooled by D₂O. The first power reactor Agesta, fuelled by natural UO₂, with a thermal power of 65 M started to deliver power in 1966. After Agesta, reactors have been developed along two lines. One type is represented by Barsebäck which is a boiling water reactor with the possibility of nuclear superheating. The other is a pressurized heavy water reactor (PHWR). A joint Indian-Swedish program was initiated to study the Th-U 233 fuel cycle in PHWR. The program includes development of calculational methods, measurement to check the calculations, and calculations of different possibilities to use thorium in PHWR. (IAF)

<296>

Arthur, W.B., Oak Ridge Gaseous Diffusion Plant, Oak Ridge, TN. 1977, October.

Uranium Production in Thorium/Denatured Uranium Fueled PHWR. E/OF-241; 15 pp.

Uranium 232 buildup in a thorium/denatured uranium fueled pressurized water reactor, PHWR (Th), was studied using a modification of the spectrum-dependent zero dimensional depletion code, LEOPARD. The generic Combustion Engineering System 80 (exponent Th) reactor design was selected as the reactor model for the calculations. Reactors fueled with either enriched natural U and self-generated recycled U or U from a Th breeder and self-generated recycled U were considered. For enriched natural U, concentrations of U 232 varied from about 135 ppm (U 232/U weight basis) in the zeroth generation to about 260 ppm (U 232/U weight basis) at the end of the fifth generation. For the case in which Th breeder fuel (with its relatively high U 232 concentration) was used as reactor makeup fuel, concentrations of U 232 varied from 411 ppm (U 232/U) at discharge from the first generation to about 512 ppm (U 232/U) at the end of the fifth generation. Concentrations in freshly fabricated fuel for this later case were 20-35% higher than the discharge concentration. These concentrations are low when compared to those of other Th fueled reactor types (HTGR and HTR) because of the relatively high U 238 concentration added to the fuel as a denaturant. Excellent agreement was found between calculated and existing experimental values. Nevertheless, caution is urged in the use of these values because experimental results are very limited, and the relevant nuclear data, especially for Pu 231 and U 232, are not of

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High quality. (Auth)

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Rahcock and Wilcox Company, Atomic Energy Division, Lynchburg, VA. 1966, August.

Thorium Fuel Cycle for Heavy Water Moderated Organic Cooled Reactors, Technical Progress Report No. 5, April-June, 1966. BAW-393-8; 25 pp.

The primary effort during this report period was related to the selection of a thorium fuel element for future development. Three types of fuel were studied in detail: thorium metal nested cylinders, thorium oxide clustered pins, and thorium carbide clustered pins. On the basis of extensive parameter studies, an optimum design of each type was selected for final evaluation. The economics and fuel utilization of the three fuel element types were evaluated for use in a 1000 MWe Heavy Water Organic Cooled Reactor (HWOCR). Technical feasibility, development costs, and compatibility with a uranium-optimized HWOCR were also considered in the selection process. A test program was planned in conjunction with the optimization studies to define key technical problems and the development required for their solution. On the basis of technical considerations alone, both the oxide and metal fuel elements should be carried through several phases of irradiation testing before a final selection is made. If practical considerations require selection of one type, priority should be given to the development of the thorium dioxide element. (BAP)

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Hell, H.J., and H.S. Dillon, Oak Ridge National Laboratory, Chemical Technology Division, Oak Ridge, TN. 1971, November.

The Long-Term Hazard of Radioactive Waste Produced by the Enriched Uranium, Plutonium-Uranium 238, and Uranium 233-Thorium Fuel Cycles. ORNL-TN-3548; 21 pp.

In evaluation has been made of the long-term hazards of "high-level" and "alpha" radioactive wastes generated by irradiation of three fuels representative of those which will be used to generate electrical power in the next several decades. In this evaluation the composition and radioactivity of the wastes generated by typical LWR, LBRW, and molten-salt breeder reactors utilizing the enriched uranium, Pu-U 238, and U 233-Th fuel cycles, respectively, have been computed for times up to 30 million years after discharge. The volumes of water necessary to dilute the various types of high-level waste to the radiotoxic concentration guidelines (RCG) for ingestion in unrestricted areas have been computed as a function of age of the waste. It was found that the volumes required to dilute the three types of waste were similar when evaluated at the same age and exposure. The volume of water necessary to dilute any of the three wastes aged 1000 years and the associated salt in the proposed Federal Repository to the RCG for unrestricted uses is less than that required to dilute the same amount of uranium ore tailings to the RCG. The high-level waste deposited in the Federal Repository will result in an alpha activity of less than 10 uCi/kg at 10,000 years after burial when averaged over the total mass of the Repository. The hazard of a number of types of waste contaminated to 10 uCi/kg (the upper limit assumed for surface burial) of

initial parent alpha activity was also calculated as a function of time, and the time of maximum relative hazard was determined. Transuramics or alpha wastes contaminated to this level will present a maximum ingestion hazard similar to naturally occurring uranium ores. (Auth)

<299>

Brogli, R.E., and R.E. Schultz, General Atomic Company, San Diego, CA. 1970.

Thorium Utilization in an FBR/HTGR Power System. CONF-7406100; American Power, Proceedings of a Conference held in Chicago, Illinois, April 29-May 1, 1970, Vol. 36, (pp. 267-250) (CONF-7406100).

It has been shown that a fast breeder reactor/thermal burner reactor power system has the ability to significantly extend fission energy resources. To utilize the world's thorium reserves, it is desirable that the power system be able to convert thorium to U 233. Since U 233 as a thermal reactor fuel is far superior to plutonium, the concept of a fast breeder reactor, fueled with plutonium, producing U 233 for use in a thermal reactor is particularly attractive. The size of a self-contained fast breeder/thermal burner power system is dictated by the breeding ratio of the fast breeder and the conversion ratio of the thermal burner. To utilize fuel reserves efficiently, it is desirable to maximize both of these parameters, which leads to the selection of the thorium blanket GCR for the fast breeder and the U 233-fed HTGR as the thermal burner. The GCR/HTGR symbiotic power system will maximize conservation and full utilization of the world's fission energy resources. It is essential that any power system be economically viable. The GCR/HTGR symbiotic system will produce power more cheaply than any other system and is thus economically attractive. Further, its fuel-cycle cost is relatively insensitive to changes in the value of uranium and plutonium. The GCR/HTGR symbiotic power system is being given serious study as a source of plentiful and economical energy for the future. (Auth)

Uranium 233 requirements versus conversion ratio, U 233 requirements versus time, growth potential of symbiotic systems and fuel cycle costs of fast breeder reactors are given in graphic form.

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Msall, J.T., Harvard University, Biological Laboratories, Cambridge, MA. 1970.

Hazards of Nuclear Fission Power and the Choice of Alternatives. Environmental Conservation, 1(1) 21-30.

This article holds that the hazards of nuclear fission reactors, in comparison with other energy sources, are unacceptably high. The biological effects of ionizing radiation, as analyzed in the recent BEIR Report (1972), are briefly reviewed; the effects include genetic mutations, induction of cancer, and developmental abnormalities. Hazards are encountered at many stages in the process of nuclear power production: mining and processing of uranium, design and operation of the reactors, and handling, shipping, and storage of radioactive wastes. Grave questions have been raised concerning the safety of the emergency core-cooling systems of present reactors; breeder

ENERGY

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reactors, which will contain great quantities of Pu 239, are likely to be even more hazardous. Storage of radioactive wastes, away from all risks of environmental contamination, is order to be acceptable must be secure for about half-a-million years. No place on Earth has yet been found for which such safety can be guaranteed. Hazards of theft, sabotage, and war, are threats to the future of nuclear power. Use of fission power is not compulsory; present supplies of coal are adequate for two or three centuries, though its mining and use will require drastic steps to protect the environment, thereby raising costs. Alternative, and far less dangerously polluting, sources of large-scale energy production (solar energy and probably nuclear fusion) exist or can be developed. Geothermal energy, though more limited in amount, is also promising. Great savings can also be made by various conservation measures. (Auth) (VC)

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Fleischman, H.W., and R.C. Lihala,
Pattelle-Pacific Northwest Laboratories,
Richland, WA. 1975.

Isotopic Composition and Radiological Properties of Uranium in Selected Fuel Cycles.
CONF-750405; H998-93; Occupational Health
Experience with Uranium. Proceedings of a
Symposium held in Arlington, Virginia, April
28-30, 1975, (pp. 35-64), 861 pp. (CONF-750405,
H998-93).

Isotopic compositions of nuclear fuels and mass flows are given for reference light water reactor, high temperature gas cooled reactor, and liquid metal fast breeder reactor fuel cycles. The properties of the uranium isotopes are defined relative to their respective roles in the nuclear fuel cycles. The toxicities of the various radiological wastes that originate in the fuel cycles are compared to gain perspective on the relative importance of uranium and its radiological daughters as environmental pollutants. Contributions from the reference fuel cycles to the accumulation of high level waste are given, based on projected growth patterns to the year 2000. Finally, the toxicity of radiological wastes generated in the various LWR-B fuel cycle components are compared as an indication of their relative importance. (Auth)

Properties of uranium isotopes are given. Radioactivity and toxicity indices of radioactive daughters in equilibrium with U of natural uranium are tabulated. Reactor flow charts are also included.

<302>

General Atomic Company. 1977, March.

Thorium Utilization Program, Quarterly Progress Report for the Period Ending February 28, 1977.
GA-A74304; 205 pp.

General Atomic Thorium Utilization Program activities progressed on schedule with continuation of the head-end reprocessing equipment testing program. Individual testing of tertiary oversize crushers and the screener was completed. Equipment is being prepared for testing as a system. Tests on the tertiary crusher revealed no operating problems. Design modifications were completed on the secondary crusher. The initial issue of a functional level diagram for the Fuel Element Size Reduction System

has been prepared for preliminary review. Results of calculating heat transfer coefficients from data obtained in 0.40-m primary burner startup runs indicated smaller wall-to-bed heat transfer for deep beds heated with dual induction coils than with shallow beds and the single, lower coil. Six runs were made to test different aspects of the 0.20-m primary burner. Additional work included fabrication and initial testing of an electrical resistance probe and level sensor and preliminary heat transfer design calculations for determining cooling requirements. The 0.10-m secondary burner is ready for burning tests. The conceptual design of the engineering-scale dissolver-centrifuge for incorporation into the head-end line was completed. Bench-scale dissolution runs were made on ThO₂. Three solvent extraction feed adjustment runs and three solvent extraction scrub maintenance system. Progress with dry solids handling component and system testing continues. The work plan for the Maintainability and Reliability Phase I study was prepared and methodology development was initiated. The HT conceptual design has been completed to the 90% level and the Conceptual Design Report is in progress. HT Technical Review meetings were held. System description and design criteria activities were initiated for an integrated HST-Reprocessing Head-End and Solvent Extraction waste maintenance system. Efforts have been focused on completion of HT fuel shipping conceptual design report, development of detailed costs, and identification of all system interfaces. Various reports are in preparation, review, or are available for distribution. (Auth) (VC)

<303>

General Atomic Company. 1977, June.

Thorium Utilization Program, Quarterly Progress Report for the Period Ending May 31, 1977.
GA-A74401; 205 pp.

The program activities progressed on schedule. Head-end reprocessing equipment continues. Testing of THIPAN B and crushing of 1950 kg of scrap graphite for primary burner feed were completed. There were no significant operating problems with any of the equipment in the Phase II tests. Two runs were made on the 0.40-m primary burner and design evaluation was completed. Four attempts to complete the 48-hr run on the 0.20-m burner were made; necessary repairs and modifications will be made. Four runs were made on the 0.20-m secondary burner to complete a parametric study of process variables. Overall system operation was excellent. The 0.10-m secondary burner was used to successfully burn 12 kg of crushed PSV THISO fissile fuel particles. Design of the engineering-scale dissolver-centrifuge system is 75% complete. Three solvent extraction feed adjustment runs and five solvent extraction runs were completed. Preliminary tests on ruthenium and fluoride volatility from bench-scale feed adjustment operations have been made. Progress with testing components and subsystems of the solids handling system continues. Further experimental data have been obtained for several of the transport systems. The conceptual design of an engineering-scale off-gas treatment system has begun. Availability requirements for major dry head-end systems were calculated as a function of reliability and maintenance downtime and similar calculations were indicated for major wet head-end systems. HT conceptual design work was completed. HT

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Technical review meetings were held. Various reports were in preparation, review or were published. Alternate fuel cycles were defined for, GCFR, and heavy water reactors (HWRs) as part of a nonproliferation study. Specification trees and functional flow diagrams for fabrication and reprocessing of alternate fuels were prepared. A brief assessment of the state of the art of various thorium fuel cycles was made to determine future development requirements. (Auth) (UC)

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Gift, F.E., (Oak Ridge Gaseous Diffusion Plant, Oak Ridge, TN. 1977, January.

An Assessment of 7308 Requirements and Fuel Cycle Costs Resulting from Thorium Fuel Cycle in HWRs (CAH904). 6/07-219; 33 pp.

The 7308 requirements of CANDU thorium fueled reactors were compared as a function of conversion ratio with uranium fueled CANDUs (with and without plutonium recycle) and with uranium fueled PWRs (with and without plutonium recycle). The CANDU heavy water reactor requires a significantly lower lifetime 7308 supply than a comparably operated light water reactor. Thorium utilization in the CANDU system has the potential of requiring only 30 to 35% as much fuel, at realistic conversion ratios (0.85 to 0.9), as a no recycle CANDU. This advantage is partially offset by the much higher initial 7308 and fissile requirements of the thorium fueled options. The effect of an expanding nuclear power system tends to amplify these higher front end 7308 requirements. For example, at a growth rate of five reactors per year, 11 years are required before the fuel requirements for a thorium fueled CANDU (conversion ratio = 0.85) become less than those of a CANDU-no recycle and between 27 and 30 years before they are less than those of a CANDU system on plutonium recycle. The economics of thorium utilization seem to be marginal (as a consequence of high recovery costs) for plutonium makeup recovered from CANDU fuels, but may be competitive operating on U 235 makeup. A definite economic optimum seems to exist for conversion ratios between 0.88 and 0.9, based on present cost concepts. (PAF)

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Gurek, H.F., and H.J. Hallsall, Atomic Energy of Canada Limited, Chalk River, Ontario, Canada. 1966.

A Preliminary Assessment of Thorium as a Fuel for Thermal Reactors. Technical Reports Series No. 52; Utilization of Thorium in Power Reactors, (pp. 55-76).

In Canada nuclear power is generated by irradiating natural uranium as long as the fuel reactivity allows. The spent fuel is stored. This fuel contains about 0.4% Pu, of which about 69% is fissile. To indicate its 'real' worth in terms of familiar numbers we note that CANDU, a 200-MW (e) station produces 90 kg of Pu a year. About 70% of this, if separated, can be fissioned in a single further irradiation of about 3 m/kb. If Pu burn-up rate is 90 kg/yr it will produce (at a station efficiency of 30%) a further 66 MW (e) of power, i.e. 30% of the reactor power producing it. If this Pu is used to prolong the irradiation of natural U to 3 m/kb the power obtained by burning 90 kg/yr is 160 MW (e) greater than would be obtained by burning natural U alone. The

importance of Pu to the overall power program will thus depend on how it is used. The real problem is economic, and other fuels say compute effectively. Various combinations of the fissile materials U 235, U 233, Pu and the two fertile materials U 238 and Th 232 in thermal reactors having a neutron economy similar to that of CANDU are compared. We assume that fuel burn-up is limited only by reactivity. The basis for this comparison is the fuel cost, so attention must be paid to factors such as manufacturing cost, interest on fuel inventory and processing costs. The operating fuel cost depends on manufacturing cost and the burn-up. The inventory charges depend on manufacturing cost and fuel rating. The processing contribution to power cost depends on the concentration of fissile material in the fuel at the end of the irradiation and its value which is determined to some extent by its radioactivity and the consequent handling difficulties. The interrelation of these costs with reactor parameters is shown schematically. A single once-through fuel cycle followed by processing has been considered. The effect of further recycling is taken into account by ascribing a value to the irradiated fuel. (Auth) (UC)

<106>

Batcher, S.R., S. Banerjee, A.D. Lane, H. Tass, and J.I. Veeder, Whiteshell Nuclear Research Establishment, Pinawa, Manitoba, Canada. 1976, May.

Thorium Cycle in Heavy Water Moderated Pressure Tube (CANDU) Reactors. AECL-5398; CONF-751101; American Nuclear Society and the Atomic Industrial Forum Joint Meeting held in San Francisco, California, November 16-21, 1975, (28 pp.) (AECL-5398, CONF-751101).

The use of fuel cycles in heavy water moderated, pressure tube reactors (CANDU) will allow such more energy to be extracted from a given amount of fuel than is possible with the present natural uranium cycle. The extent to which various factors affect thorium fuel cycle economics and resource consumption with equilibrium U 233 levels in the fuel is discussed. Also considered is the resource consumption in growing nuclear power systems. It is shown that considerable savings can be achieved even under conditions of rapid growth. The main elements of the development program necessary to provide the technological base for thorium fuel cycles in CANDU reactors are: 1) fuel reprocessing for the recovery of Pu from U, and Pu and U 233 from Th, 2) recycle fuel fabrication for the production of Pu and U 233 fuels, 3) reactor demonstration of the recycle fuels, and 4) supporting activities in areas such as fuel transportation, safeguards, health and environmental aspects, waste packaging and management. (PAF)

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Bove, J.P., Atomics International, Canoga Park, CA. 1956.

The Role of Thorium Metal in the Nuclear Field. The Metal Thorium, H.A. Wilhelm (Ed.), Chapter 1, Proceedings of a Symposium held in Cleveland, Ohio, October 11, 1956. American Society for Metals, Cleveland, Ohio, (pp. 1-19).

Thorium may contribute more energy in the future than fossil fuel reserves. It is possible that much of this thorium will be used in a fluid-fuel reactor in which optimum neutron economy breeding gain and utilization

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of material may be obtained. In the shorter range, solid-fuel reactors using thorium will use the most metallic thorium. The net demand per year for metallic thorium will be less than a hundred kilograms. The future of an SGR utilizing thorium awaits results of the Sodium Reactor Experiment during 1957. The SGR will probably not be built before the 1960's and if built will require at least 12 tons of thorium gross. The LMFBR, also scheduled for the early 1960's will require reduction of 20 to 30 tons of metal. After the 1960's the growth of the use of thorium will probably follow an exponential pattern, with a fueling time shorter than ten years. If the predictions about utilization of atomic power are realized, and if thorium cycles bear half the burden of producing nuclear power, then the total net investment of thorium in reactors may be 11,000 tons in 1975, with a replacement rate of 2 to 4 tons per year. If it proves impossible to achieve a breeding gain of unity or better in solid-fueled reactors, this type will pass out of the picture after 20 to 40 years and the breeding cycles will take over. If liquid-metal fueled reactors achieve a breeding ratio greater than unity, this concept would seem to be the best possibility since it produces power at temperatures comparable with good steam practice today. Thorium metal appears to have an important role in the nuclear power field, but the amounts used yearly will not be large for some time to come. (Auth)(VC)

<199>

Rasten, P.F., Oak Ridge National Laboratory, Oak Ridge, TN. 1970.

Evaluation of Thorium Fuel Cycles. Education and Research in the Nuclear Fuel Cycle, Chapter 15, D.R. Elliott and L.E. Weaver (Eds.). University of Oklahoma Press, Norman, Oklahoma, (pp. 263-287).

In this discussion it is assumed that fission power is an economical energy source. Under such circumstances, the use of the thorium fuel cycle depends upon how it competes with the uranium fuel cycle. This follows because uranium is the essential source of initial fissile fuel, therefore application of the thorium cycle implies that the uranium cycle can also be considered. Thus, various reactor types presently available or under development will be considered and evaluated relative to their ability to economically utilize the thorium or the uranium fuel cycle. Reactor types considered here are thermal reactors (light water, heavy water, gas-cooled, and molten-salt reactors), and fast reactors. First of all, a brief discussion of the two fuel cycles is given, along with a summary of pertinent physics features, some associated physical and chemical properties, some unit cost features, and estimates of fuel resources. In addition, the economic bases and ground rules used in evaluating the relative performance of the two fuel cycles are summarized. The relative evaluation of thorium and uranium fuel cycles in specific reactor types is then presented, followed by a brief discussion of fuel utilization aspects associated with thorium use. In summary, the thorium fuel cycle appears to be economically the preferred cycle in RTGR's and MSR's, and use of these reactors rather than LWR's leads to improved fuel utilization. Further, MSR's have the potential of operating as economical breeders with good fuel utilization characteristics on the thorium cycle.

Finally, use of sized uranium-thorium fuel cycles in fast reactors can improve safety characteristics of such reactors while still retaining good fuel utilization and economic characteristics. (Auth)(VC)

<209>

Rasten, P.F., P.J. Roman, A.L. Kottz, A.F. Olsen, E.J. Allen, J.D. Jenkins, J.E. Washton, W.L. Tobias, D.E. Bertine, E.L. Carter, R.J. Katz, P.E. Rainey, and E.H. Giff, Oak Ridge National Laboratory, Oak Ridge, TN. 1977, January.

Assessment of the Thorium Fuel Cycle in Power Reactors. CNWL/TS-4565; 252 pp.

To evaluate Th fuel cycles, three thermal reactor systems were considered: Light Water Reactors (LWRs); High-Temperature Gas-Cooled Reactors (HTGRs); and Heavy Water Reactors (HWRs) of the Canadian Deuterium Uranium Reactor (CANDU) type. Thorium and U fuel cycles in Fast Breeder Reactors (FBRs) were compared. Better UGR utilization is possible using Th cycles than with U cycles. Thorium cycle use does not change the need for FBRs so long as significant increases in nuclear power generation are needed for long times. Commercialization of Th cycles and recycle, would add flexibility to deal with delay in FBR introduction or commercialization of a low-gain FBR. Thorium fuel cycles under certain circumstances can produce lower cost power than U cycles. It appears economically desirable to recycle Pu with Th rather than with U in thermal reactors. However, limitations on the amount of Pu would limit improvements in fuel utilization. The most direct vehicle for taking advantage of improved fuel utilization capabilities are LWRs which will be generating most power in the next two decades. However, the Th cycle does not appear to compete economically in present LWRs. Of the thermal reactors, Th fueled HTGRs and HWRs have the best fuel utilization performance, while HTGRs offer the best opportunity for economic use of Th cycle. Heavy Water Reactors (TH) have similar fuel utilization characteristics as HTGRs, but higher power cost. In FBRs, Th or Th/U cycles provide a more negative void coefficient of reactivity than does U cycle; sized cycles provide alternative fuel in the event that a full recycle Pu economy is limited. Metal fuel provides the best nuclear performance from Th cycles, and superior physical properties of Th metal might lead to an economic FBR with high fuel-utilization. Thorium in FBRs can provide desirable fuel for thermal and fast reactors while increasing the ratio of thermal-to-fast reactors that can be maintained in an FBR economy. (Auth)(VC)

<310>

Lane, J.A., Oak Ridge National Laboratory, Oak Ridge, TN. 1966.

Economic Incentive for Thorium Reactor Development. Technical Reports Series No. 52; Utilization of Thorium in Power Reactors, (pp. 199-211).

Most present-day reactors have poor fissile production characteristics which influence the economics of the nuclear industry. Possible solutions to the energy supply problems are to either improve these characteristics, or, better, to develop fast breeder reactors. A third alternative is to develop reactor systems, such as Th fueled

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reactors which can then be developed into efficient breeders. As recycle converters, they can reduce fuel cycle costs, U requirements, and allow technological development of thermal breeders which have lower specific inventories and doubling times than do fast breeders. Fuel utilization, U requirements, and costs for different systems are compared. Resource data and influence of U costs on prices of electric power are tabulated. Because of the additional expense of low-cost U sources are exhausted, there is great incentive to develop breeders which can supply fuel for additional plants. Introducing fast breeders by 1990 would limit U requirements to that still low in cost. Use of natural U heavy-water reactors would also reduce U 235 use and supply Pu for fast breeders. The influence of thermal breeders on ore and separation requirements is discussed. Advanced Th converters may solve the fissile shortage since they make such good use of U 235 that the high cost material might not be needed and there would be enough U 235 to inventory a self-sustaining breeder industry. Such converters would supply electricity more cheaply than do present reactors. Replacement of the latter by advanced converters in 1975-1990 would increase present worth of future savings to \$9.2 billion. A discussion of Th resources and costs is included. (WC)

<193>

Saeft, P., and E. Zinner, Kernforschungsanlage Juelich, Institut fuer Chemische Technologie, Juelich, German Federal Republic. 1976, April.

Fuel Concepts for the High Temperature Thorium Reactor and Their Consequences for Fuel Recycling. JNL-1286; Auswirkungen des Brennstoffkonzeptes auf den Brennstoffkreislauf des Thorium-Reichtemperatur-Reaktors, (1 pp.) (JNL-1286).

The fuel cycles utilizing the feed/breed concept and the single particle concept are described and compared. With block diagrams and process descriptions it is shown that the refabrication of fissile particles is more complicated than that of the sized oxide particles although the total throughput of heavy metals is less. The waste problems connected with the various processes of particle production are discussed. A possible contamination of the reprocessed heavy metal solutions with plutonium or fission products is taken into consideration. (RAF)

<192>

Sevill, V.L., Esso Corporation. 1975, September.

Health Effects and Energy Choices. Journal of the Air Pollution Control Association, 25(9), 510-517.

It is the author's opinion that the United States will continue to have a high per capita energy demand. In the short or near term there are really only three major fuels, oil, coal and uranium, available to supply this demand, and the assumption that we will rely more completely on domestic sources means we will use all three maximally. Thus health effects information will not be decisive in choosing the energy alternatives but rather the marginal costs of health protection, first, to the worker in the industry, and second, to the general public will help determine the mix of alternatives

after supply exceeds demand. The present national air pollution control program has been successful if judged by the fact that the population exposure to the major air pollutants has decreased in the past 10 years. However, the program still has great difficulties since the strategy for photochemical oxidant control will not achieve the standards in a few areas of the country and since there is insufficient knowledge about the formation and specific species of fine particulates to develop an appropriate and feasible strategy for their control. Finally there is a strong need for an explicit national health policy statement which could serve to focus the environmental health research programs and serve as the basis for coordination of all Federal environmental regulatory programs that take action in the name of environmental health. (Auth)

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Orsengo, G., Comitato Nazionale per l'Energia Nucleare, Rome, Italy. 1964.

Thorium-Uranium Fuel Cycle in Italy. Technical Reports Series No. 52; Utilization of Thorium in Power Reactors, (pp. 127-137).

The most recent evidence indicates that there is a trend for the reevaluation of the thorium-uranium cycle, but no one at the present time can anticipate any reactor experiment based on thorium-uranium fuel in Italy. The use of the thorium-uranium fuel cycle in Italian reactor experiments is therefore mentioned here merely as a possibility. Much more realistic appears to be the future utilization of the PCUT (Programma Ciclo Uranio Thorio) facility to re-work thorium-uranium fuels, both in the form of oxide fuels from water reactors and in the form of carbide fuels from high-temperature, gas-cooled reactors, on the behalf of foreign customers interested in the development of these cycles. CNEN is prepared to accept any suggestion in this field and to plan the operation of the plant accordingly. Details of the construction status of the PCUT facility, specifically, civil work, chemical and mechanical equipment, analytical facility and laboratories, heating and ventilation system and utilities are given. Research and development in support of the facility is outlined as well as that on the sol-gel process and thorium-uranium carbides. The future program of PCUT facility use is outlined and fuel cycle costs discussed. (Auth) (VC)

<194>

Paranjpe, S.R., Atomic Energy Establishment, Trombay, Bombay, India. 1964.

Role of Thorium in a Nuclear Power Programme. Technical Reports Series No. 52; Utilization of Thorium in Power Reactors, (pp. 106-110).

If transition from fossil fuels to nuclear power is to be attained within 50 years, U requirements would far exceed the Indian reserves. Using Th will not alter the situation; for example, a direct Th cycle based on U 235 needs as much U as a cycle which does not use any Th. Fast breeders reduce U requirements by about 30%, but again, use of Th and Pu or of Pu only schemes require similar amounts of U as do breeders fed depleted U and so it is the use of fast breeders and not Th which helps in this reduction. The important factor for 2nd and

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1st generation reactors in the specific power and net breeding, e.g. the Th-U 235 scheme 80% of the U required is accounted by inventory. Similarly, for the CANDU plus breeder scheme the installed capacity of fast breeders and hence U 233 production largely depends on Pu feed from 1st generation reactors and not on self-bred Pu, due to relatively large doubling times. The same is not true for the 1st generation reactors. Here, because of low inventory of U per kW(e) installed (i.e. 0.105 t/KW(e)), 75 % of the U is needed to feed the reactors (2.100 t/KW(e) yr at 80% load factor). The major load will be shared by 1st-generation CANDU-type reactors and fast breeders will carry only about 25% of the load. The share of breeders will increase with time, but in the next few decades, the 1st generation reactors will dominate. This can change only if radically improved designs of the fast breeders or Th-U 233 reactors become available. If for Th-U 235 thermal reactors a specific power of 1 MW(e)/kg and a breeding ratio of 1.05 can be attained, U requirements would be reduced to 75.3×10^{12} t for the first 40 yr compared to 199×10^{12} t. Similarly, if a specific power of 0.33 MW(e)/kg (Pu) and a breeding ratio of 1.5 can be achieved for fast breeders, U requirements for schemes using feeds of Th, then Pu reduced to 111×10^{12} t for the same period. It is necessary that more attention be devoted to high performance reactors for Th to make a significant impact on U requirements. (Auth, VC)

<315>

Rosenthal, H.W., H.P. Bauman, L.L. Bennett, H.S. Carlsmith, and D.H. Vandy, Oak Ridge National Laboratory, Oak Ridge, TN. 1966.

Technical and Economic Characteristics of Thorium Reactors. Technical Reports Series No. 52; Utilization of Thorium in Power Reactors, (pp. 353-373).

There are Th cycle reactors which can have both lower power cost and better fuel utilization than a PWR. The HTGR and the MSR's appear to have the lowest costs. Estimates represent what costs would be if the reactors were successfully developed, and do not reflect uncertainties in technology. The molten-salt reactors have the lowest power costs resulting from their low fuel cycle cost, but there are design and development problems needing to be solved. The MSR appears to violate the rule that technology used in the designs be limited to that which could be used in a prototype to go on line in 1970. However, use of on-site processing for MSR's does eliminate one economic uncertainty in that achievement of low fuel cycle cost would not await the growth of a large support industry. In spite of the development problems, the MSR can breed and could have low enough power costs to make it attractive to power system operators. Of the solid fuel reactors, the HTGR is particularly promising, but both graphite fuel elements and "all-inside" concrete pressure vessel require demonstration in a power reactor. Thus while the HTGR concept is flexible and alternate design approaches are available, its success will depend on the favorable outcome of tests of its important features and on creation on an adequate scale of the unique fabrication and processing facilities required. The heavy-water reactor has good fuel utilization but high power cost. Studies using organic or boiling light-water coolants have shown

appreciable reductions in capital costs, including D2O inventory. By substitution of coolant the power cost possibly could be lowered significantly. Since the SSCR offers neither lower power costs nor significantly better fuel utilization than the PWR and has heavy water in the coolant, further development seems unlikely. The MSR has good fuel utilization but high power cost. It is difficult to compare it with the other reactors, since it was designed for a particular breeding ratio and was not optimized for conditions of our study. (Auth, VC)

Discussions include reactor descriptions, engineering performance requirements, economics, physics of Th reactors, fuel utilization, and fuel cycle, capital and operating costs. There is a table of reactor design characteristics. Reactor performance in terms of feed enrichments, exposure, breeding ratio and index of fuel consumption are tabulated. Cumulative ore requirements are given. 30-year-average fuel cycle costs as well as capital and operating costs are tabulated.

<316>

Santos, J.C., S.S. Brito, J.C. Nello, and C.V. Urban, Comissão Nacional de Energia Nuclear, Rio de Janeiro, Brazil; Universidade de Minas Gerais, Instituto de Pesquisas Radioativas, Brazil. 1966.

Thorium-Cycle Possibilities in the Brazilian Nuclear Power Programme. Technical Reports Series No. 52; Utilization of Thorium in Power Reactors, (pp. 46-54).

The Th cycle has good prospects in the Brazilian Nuclear Power Program. If start-up reactors are similar to the heavy-water under-moderated, SM reference reactor, total natural U requirements and the extent of the U-dependent, start-up program could be as low as in the most optimistic assumptions under the Pu-U 238 conditions. The technology involved in developing the SM concept is basically conventional natural-U heavy-water-reactors technology which is simpler than fast or other advanced reactors technology. This reactor concept offers Brazil the possibility to develop original ideas on nuclear power plant technology, aiming at a program that could be independent of a foreign supply of nuclear fuel. The preliminary results must be confirmed by more intensive work on reactor physics and technology and on chemical and metallurgical problems in Th fuel cycles, before an enlarged and more objective program can be defined. In all cases, a coherent program on research and development and on nuclear power production, cannot be realized before domestic U and Th resources are estimated to some degree of confidence. Aware of these results, CNEP is actively considering the formulation of a 12-month program to prepare a more objective long-range research and development program on thorium reactors, including assessment of Th reserves and intensive U prospecting studies on Th reactors, feasibility studies on the SM concept, to be compared with those on other Th reactors at present being developed in other countries, research on fabrication and reprocessing of Th fuel elements, and experimental facilities for Th reactor research (foreign experience and Brazilian possibilities). (Auth, VC)

<317>

Sisselman, B., Engineering and Mining Journal.

<117>

1976

<117> CCWR.
1977, March.

Thorium-RTG Setback Stunts Growth. Engineering and Mining Journal, 262-264.

Prospects for increased Th sales were less favorable after the 1975 cancellation of US orders for high-temperature gas-cooled reactors (HTGR). Thorium consumption dropped from 50 tons in 1975 to 45 in 1976. Production of commercial grade ThO₂ and research and development of the RTG have decreased. However, successful operations of a commercial reactor started in 1976 in Colorado; reloads will require 3 tons of Th/year. United States also production of Th apparently dropped in 1976 and imports of monazite, Th compounds and alloys declined. Thorium nitrate purchases from the government stockpile were below those for 1976 (4 tons vs 30 tons). United States consumption in 1976 is estimated to be 45 tons (ThO₂ equivalent), 5 tons less than in 1975. Estimates in 1978 were that demand would increase by 12.5 % annually; now, the projected increase through 1980 is 18. Monazite imports, \$207/ton in 1975, cost \$233/ton in 1976. Estimates of producer prices are: sinter grade nitrate, \$1/lb; oxide, \$8/lb; metal, \$15/lb. Setbacks in the reactor program have dimmed the Th growth picture; however, opposition to current reactors could actually stimulate use of RTG reactors which use more Th. The future of RTG's is not clear; in 1976, EMDA continued studies on Th-fueled breeders. Thorium fuel in a modified Canadian deuterium-uranium reactor was also investigated. (VC)

<118>

Stock, R.W. (Ed.), 1977, August.

U.S. Leans Toward Denatured Thorium Cycle. Electric Light and Power, 23-26.

The Nonproliferation Alternative Systems Assessment Program of EMDA is studying fuel cycle options which will reduce the possibility of the spread of nuclear weapons; the options must not have unrestricted streams of nonradioactive, separated fissile material and must have a U utilization at least as good as the LWR. Possibilities, in addition to the once-through cycle now used included: a modified once through cycle which would boost energy extracted from U by 10% by either higher fuel enrichment or better fuel management; LWR fuel cores of fissile U and Th would reduce U requirements by at least 25%; use of spent LWR fuel for a HWR which could extend U resources by 25%; a modified RTG using a fuel with only 10% U; use of a denatured Th fuel cycle in breeders such as LWR's could increase the energy value of U almost as much as would Pu; other breeder schemes (MSR or a gaseous fuel reactor) which would avoid shipping of Pu by having onsite reprocessing. With a denatured fuel cycle, sensitive facilities could be located inside energy centers with the reactors outside. Such a cycle can be introduced into the present cycle and permit breeding. The system would be more proliferation resistant than the Pu cycle. The energy center concept with LWRs and denatured Th as well as with HWRs is described. There are still questions about practicality and efficiency of operating on denatured U 233 or on how well LWRs or RTGs would operate on such fuel. Uranium 233 is inferior to Pu as a fissile material and Th inferior to U 238 as a fertile material. In addition, the Th cycle is not fully diversion- or theft-proof.

Uranium 233 denatured to only 15% fissile content is close to weapons- grade material. Other problems include Th supplies sitting of energy centers, public acceptance of them, and the fact that the 7 233 cycle will not be usable for at least 20 years. Until the international political framework has been established, the installation of a proliferation-resistant alternative fuel cycle in the U.S. is seen by the nuclear industry as a futile gesture that threatens to endanger our energy supply. (Auth)(VC)

<119>

Sonderwayer, R.W., 1973.

Thorium. Minerals Yearbook, 1974, (pp. 1269-1274).

Supplies from two mines in Florida and imports (Malaysia) were adequate for the 1974 Th demand. Despite 38% decline in production, about 30% of the newly mined and imported Th residues was stored in holding areas. Monazite, the source of Th was a byproduct of Ti mining and recovered for its rare-earth content. The 1974 market was weak, but long-range potential for Th use was good. Energy shortages stimulated search for new energy sources. Large Th resources in the US and worldwide encouraged research on use of Th as fuel in reactors. Lower demands for power and increased costs of Th-fueled high-temperature gas-cooled reactors (HTGR) caused cancellations of orders for new reactors, a trend which could adversely affect future Th demand. In 1976, research continued on improving the RTG and on its use as an industrial source for process heat and power generation. Work continued on the light water breeder reactor concept. A demonstration Th core was scheduled to operate in a pressurized water reactor in 1976. Preliminary work started on a General Atomic Co. plant for production of Th-U fuels and on an Atomic Energy Commission facility for reprocessing Th fuels. At the beginning of the year, 10 RTG's with a total capacity of 8,000 megawatts electrical (MWe), were on order. At the end of the year, one RTG, a 40-MWe plant at Peach Bottom, Pa. terminated production of electric power and orders for two RTG's had been cancelled. The 330-MWe RTG at St. Vrain, Colo. was rescheduled for initial operation in 1975. Included are tabulations of companies processing and fabricating Th, status of RTG development, US foreign trade, world production of monazite concentrate, and resources of Th in market economy countries. (Auth) (VC)

<120>

Spiewak, I., and D.E. Sartine, Oak Ridge National Laboratory, Engineering Technology Division, Oak Ridge, TN. 1977, October.

Thorium Assessment Study Quarterly Progress Report for Third Quarter Fiscal 1977. ORNL/TN-6025; Engineering Technology Division Quarterly Progress Report for Third Quarter Fiscal 1977, (pp. 1-52) (ORNL/TN-6025).

The objective of this program is to contribute to the ongoing assessment of the potential role of thorium fuel cycles for alleviating safeguards concerns. Scenarios include no fuel recycle permitted, fuel recycle permitted only in secure regions ("energy parks") with denatured (chemically non-separable) fuels only outside these regions, and no limits on fuel recycle. A further objective is to provide nuclear mass balance data on RTGs required by EMDA

SUBJECT

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Contractors for comparative cost-benefit studies. The report discusses the following items: thermal reactor calculations, standard HTGR reference design fuel cycle informatics, mass balances for a PWR operating on the denatured UO_2/ThO_2 fuel cycle; fast reactor calculations, mass balances for alternate LWR fuel cycles, synthetic reactor systems, cross section sensitivity; advanced LWR systems, general considerations, thorium base metal fuels, thorium base carbide fuels; flow of nuclear material for restricted fuel cycle scenarios. (auth)(UC)

<329>

Spiewak, I., D.E. Portnoy, T.J. Burns, J.C. Cleveland, R.L. Thomas, and J.E. White, Oak Ridge National Laboratory, Oak Ridge, TN. 1977, June.

Thorium Assessment Study Quarterly Progress Report for Second Quarter Fiscal 1977. (ORNL/TM-5985; 82 pp.)

The objective of this program is to contribute to the ongoing assessment of the

potential role of thorium fuel cycles for alleviating safeguards concerns. Options include (1) no fuel recycle permitted, (2) fuel recycle permitted only in secure regions (energy parks) with denatured (chemically non-separable) fuels only outside these regions, and (3) no limits on fuel recycle. A further objective is to provide nuclear mass balance data on HTGRs required by EPRA contractors for comparative cost-benefit studies. Mass balances were calculated for the reference design HTGR and for a current design PWR operating on the denatured UO_2/ThO_2 fuel cycle with self-generated ^{233}U recycle. Comparisons were made of Pu production in PWR and CANDU reactors, and of ore and separative work requirements for several fuel cycles in PWR and HTGR reactors. Preliminary LWR equilibrium cycle mass balances were obtained for two denatured ^{233}U reactors for dispersed location and for two ^{233}U production reactors to be located in the energy center. Potential symbiotic systems coupling reactors inside and outside the energy center were developed. (PAP)

ENVIRONMENTAL ASSESSMENT

<322>
Pondietti, J.J., C.T. Gorton, Jr., C.W. Francis,
and L.P. Eymon, Oak Ridge National Laboratory,
Environmental Sciences Division, Oak Ridge, TN.
1978.

Uranium and Thorium in the Biosphere: A Review
Emphasizing Behavior Applicable to the Thorium
Fuel Cycle. To be published in Journal of
Environmental Quality, 1978.

The Th/U 233 breeding cycle is an alternative
nuclear energy technology which may have
waste management and nuclear proliferation
advantages over the 3/Pu fuel cycle.
However, the fissile component, U 233,
contains U 232 which is potentially more
radioactively hazardous than Pu. Because
both U and Th are naturally present in man
and his environment, their behavior in the
biosphere has been reviewed. In aerobic
environments, U is more mobile than Th,
mainly because U is an oxyanion [UO₂(H₂O)₂]
while Th is tetravalent. Uranium moves from
landscapes to oceans both in solution and
sorbed to particulates, while Th transport is
largely with particulates. Because of the
role of carbonate ion in complexing uranyl
ion, U is more concentrated in carbonate
minerals than Th. Terrestrial plants
assimilate relatively more U than Th as
evidenced by plant analyses and dietary
intakes by man. In aquatic environments,
however, Th may become relatively more
concentrated in lower trophic levels than U.
Man, at equilibrium, contains about 100 ug of
U, deposited mainly in the skeleton. This U
is derived from a daily dietary intake of
about 1.3 ug. Although Th is more abundant
in soils than U and accumulates in man
throughout his lifetime, the skeletal Th
content is less than that for U. Based on
measured U and estimated Th dietary intakes,
gastrointestinal tract assimilation
coefficients of 20% (U) and 0.6% (Th) are
necessary to account for observed lifetime
body burdens. These values are substantially
higher than values currently used for
radiological assessments. (Auth)

<323>
Fahlman, W.C., Oak Ridge National Laboratory,
Environmental Sciences Division, Oak Ridge, TN.
1976, August.

Nuclear Materials Transport. ORNL-5193;
Environmental Sciences Division Annual Progress
Report for Period Ending September 30, 1975,
(pp. 99-115), 753 pp. (ORNL-5193).

Two projects on the environmental behavior of
U and Th as related to the Thorium Fuel Cycle
are underway. First, the existing literature
is being evaluated to determine the extent to
which the consequences of U and Th releases
from this fuel cycle can be evaluated. The
second research task involves the collection
and processing of environmental samples to
standardize analytical procedures and to
determine if existing releases of enriched U
at Oak Ridge facilities can be used as tracer
simulants for determining environmental pools
of biologically available uranium. (RAF)

<324>
Klein, D.W., Hope College, Chemistry Department,
Holland, MI. 1975, March.

Fluxes, Residence Times, and Sources of Some
Elements to Lake Michigan. Water, Air, and Soil
Pollution, 9(1), 3-8.

Fluxes of 28 elements to Lake Michigan are

calculated from literature data on
sedimentation rates and concentrations in
sediments and water. Lake Michigan residence
times are roughly 13(±4) lower than oceanic
residence times. A mass balance has been
formulated for 28 elements, with soil and
aerosol as the only sources. These sources
provide fourfold excesses of Ca, Mg, Sb, Sc,
and V, and order of magnitude deficits for
Cu, Ag, Na, and Cl, but account (to within 50
percent) for the observed inputs of Al, Al,
As, Br, C, Co, Cr, Fe, K, La, Mn, S, Si, Sr,
Ta, and Zn. Except for Al, Co, La, Si, and
Th, deposition from aerosol accounts for at
least one-fifth of the total input. (Auth)

<325>
Klement, A., U.S. Atomic Energy Commission,
Division of Biology and Medicine, Washington,
DC. 1965.

Natural Radionuclides in Foods and Food Source
Materials. Radioactive Fallout, Soils, Plants,
Foods, Man, E.P. Fowler (Ed.). Elsevier
Publishing Company, New York, New York, (pp.
113-115).

This review deals with the occurrence of
natural radionuclides in soils and natural
waters as well as their occurrence in human
foods and other biological materials.
Considerable information is available with
respect to some nuclides of the uranium,
thorium and actinium series and K 40, C 14,
and H 3. Fewer data of interest are
available for Pb 210. Inferences may be made,
with caution, for the occurrence of the
radioisotopes of lead, including Pb 206. Few
data appear to be available for other natural
radionuclides. Some information is given for
concentrations of natural radionuclides in
agricultural and other biologic materials
which form parts of the food chain. Reference
is made to some recent investigations into
the dietary intake of some nuclides,
especially Sr 90. Further research is
suggested in the areas of artificial and
natural radionuclides as they relate to the
food chain. (RAF)

<326>
Schultz, V., Washington State University,
Department of Zoology, Pullman, WA. 1975.

Ecological Techniques Utilizing Radionuclides
and Ionizing Radiation: A Selected Bibliography.
BIO-2213 (Suppl. 2): 67 pp.

The supplement contains approximately 200
references on ecological techniques utilizing
radionuclides and ionizing radiation in
freshwater, marine and terrestrial systems.
Primary sources of the references come from
bibliographies of Klement and Schultz
(TID-3910, Supplements 8, 9, and 10;
TID-3915, Supplement 1); and Edmondson,
Schultz and Klement (TID-1917, Supplements 1
and 2); and Nuclear Science Abstracts,
Volumes 25-28. Additional references to
non-ecological information on studies
utilizing tracers in pesticide studies and
agricultural research are also included in
this bibliography. (CSF)

<327>
Thomson, B.J., and A. Walton, Yale University,
Department of Geology and Geophysics, New Haven,
CT; Bedford Institute, Atlantic Oceanographic
Laboratory, Dartmouth, Nova Scotia, Canada.
1972.

Natural Radioactive Decay Series Elements in the

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ENVIRONMENTAL ASSESSMENT

<327> CONT.

Oceans and Sediments. Royal Society of Edinburgh, Series B, 72, 167-182.

A review is presented of studies of the three naturally occurring radioactive decay series (^{232}Th , ^{238}U and ^{235}U) daughter radionuclides in the oceans and sediments. The origin of high radium concentrations in sediments and the migration of radium in sediments are discussed. Studies of thorium and protactinium are reviewed under the following headings: analytical advances--direct measurements of U , Th and Pa isotopes; the thorium isotope ratio ($^{230}\text{Th}/^{232}\text{Th}$) approach; the thorium/protactinium ($^{230}\text{Th}/^{231}\text{Pa}$) approach; the uranium isotope ratio ($^{238}\text{U}/^{235}\text{U}$) deviation; leaching versus solution of sediments; and comparisons of age determination methods. (PWS)

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Yumoto, Y., H. Yanakawa, and T. Yamamoto, Hygienic Laboratory of Okayama Prefecture, Okayama, Japan. 1976.

Studies on Environmental Contamination by

Uranium. Seasonal and Regional Variations of Uranium Content in Daily Diet and Urine. Journal of Radiation Research, 17(1), 43.

Uranium contents in daily diets and urines were determined by analysis of variance. Investigations were carried out at Ten-no, Wakatsubo hamlet located in the vicinity of a uranium mine in Kamisakura Village, and at control regions (Furuyoshi in Tsudaka Town and Okunishi in Sitsu Town), Okayama Prefecture. The mean uranium contents in the daily diet were 4.55 ± 0.33 (89 samples), 2.87 ± 0.25 (36 samples) and 0.96 ± 0.16 $\mu\text{g/day}$ (33 samples) in Ten-no, Wakatsubo and control regions, respectively. The mean uranium contents in urine samples were 0.18 ± 0.03 (197 samples), 0.07 ± 0.03 (174 samples) and 0.01 ± 0.01 $\mu\text{g/day}$ (133 samples) in Ten-no, Wakatsubo and control regions, respectively. The results of the F test with a 95% confidence level indicate that seasonal variations of uranium content in the daily diet and in urine cannot be observed but that there are clear regional variations. (auth) (JAF)

GEOLOGICAL ASPECTS

<329>

1977, June.

Socioeconomics Week, 20 (26), 7.

A new assessment of U.S. thorium reserves is being started by the U.S. Geological Survey for ERDA, with the aim of producing estimates by next May. This will be in time to make a contribution to the alternative fuel cycle evaluation now going ahead within ERDA and scheduled for completion by the end of 1978. USGS will make field trips to several parts of the U.S., including the Lenah Pass region of Idaho where the largest thorium deposits are believed to lie. The only estimates that ERDA presently has are old AEC ones made in 1960; they say that reasonable assured U.S. ThO₂ resources at \$10/lb forward cost total 65,000 tons, with possible additional resources of 335,000 tons. These are reckoned to meet hypothetical demands for several decades. The Bureau of Mines will do metallurgical work as part of the study and ERDA may let further contracts. (Complete Text)

<330>

Amayan, V.L., B.R. Nantakanyan, and T.V. Apikh, Jr. (Translator), Armenian Academy of Sciences, Institute of Agrochemical Problems and Hydroponics. 1973.

The Radioactivity of Edaphonic Air.

CBU-tr-8896; 4 pp.; Akademiya nauk Armyanskoy SSR, Biokhicheskii Zhurnal Armenii, 25 (17), 66-70.

Radioactive emanations were determined in various types of soils under natural conditions in the Armenian Republic. Edaphonic (soil) air is distinguished from atmospheric air primarily by its level of carbon dioxide and oxygen. It also contains radioactive gases which are more highly concentrated than in atmospheric air. Emanations affect plant life and nitrification processes of soils. Radioactive emanations are an intermediate product of the decay of uranium, thorium and actinides. Emanation is clearly a function of soil moisture. Dry soils have more emanations than soils containing up to 20% moisture. In soils with 20-25% moisture or more, there is a reduction of emanation due to the solubility of the gases in water. With depth, the concentration of emanations increases reaching a constant value at about 5 m. The emanation of radon in three types of soils taken from surface horizon A to the lower C horizon ranged from 0.16-0.54 x 10 (E-12) Ci/g soil. (R&P)

<331>

Paltakmas, T., National Radiation Laboratory, Department of Health, Christchurch, New Zealand. 1976.

Uranium 230 and Radium 226 Equilibria and Thorium: Uranium Ratio in New Zealand Soils--their Relationship to Iron and Potassium Content. New Zealand Journal of Science, 19, 375-382.

Concentrations of the principal naturally occurring long-lived radionuclides U 238, Ra 226, Th 232 and K 40 have been determined in over 200 New Zealand soils, representing a wide range of soil types. It was found that in these soils the Th/U ratio and the state of the radioactive equilibrium between U 238 and Ra 226 is affected by the iron content. It was also found that the type of

relationship between natural radioactivity and iron concentration depends on the nature of the parent rocks from which the soils have been formed, i.e. whether the parent rocks are basic igneous, other types of igneous, sedimentary, or metamorphic. (Auth)

<332>

Bloomfield, C., and W.I. Kelso, Rothamsted Experimental Station, Harpenden, Hertfordshire, England. 1973.

The Mobilization and Fixation of Molybdenum, Vanadium, and Uranium by Decomposing Plant Matter. Journal of Soil Science, 24 (3), 360-379.

Aerobically decomposing plant matter was found to mobilize Mo, V, and U as anions. The behavior of the dissolved metals differed in several respects from what would be expected in inorganic systems. After dialysis through cellophane, between pH 1 and 4 the mobilized Mo was fixed by colloidal organic decomposition products, with maximum retention at pH 1.5; V was retained between 1.5 and 7.0, with a maximum at pH 3. The specific fixation of Mo and V by soil organic matter was considerably less, and persisted over wider pH ranges, 1.5-6.5 and 1.0-9.0, respectively. The fixation of U by both forms of humified organic matter increased sharply to a maximum around pH 4-5, and thereafter decreased slightly up to pH 8. The anionic forms of the three elements persisted when MoO₄(E-2), VO₃(E-1), and UO₃(E-1) were incubated with anaerobically decomposing plant matter; under these conditions V(V) was probably reduced to V(IV) with the formation of an anionic V(IV) complex. Although the molecular size of the colloidal decomposition products of lucerne was somewhat less than that of organic matter extracted from Rothamsted top soil, acid hydrolysates of the two humic acids contained the same twenty three amino acids, in such the same relative proportions. (Auth) (R&P)

<333>

Burnett, R.C., State University of New York, Department of Earth and Space Sciences, Stony Brook, NY. 1976.

Growth Rates of Pacific Ferromanganese Deposits as Deduced by Uranium-Series and Hydration-Rind Dating Techniques. Earth and Planetary Science Letters, 33, 208-218.

Growth rates of four Pacific ferromanganese deposits have been determined by uranium-series and hydration-rind dating techniques. This represents the first time these two methods have been applied to the same samples. Of the four samples analyzed, two agree in both techniques and two show a wide disparity. The samples that do not agree have uranium-series ratios which are low compared to those deduced by the hydration-rind techniques. The same samples also display steep Th 232 activity gradients in the outer layers of the ferromanganese material. Since the half-life of Th 232 is extremely long (10 (E+10) yr), these gradients could not be due to radioactive decay. This suggests that the distribution of Th 230, at least in these cases, may also be a result of some process other than radioactive decay. One of our samples which has a steep Th 232 gradient produces a Th 230 "exposure age" which is indistinguishable to the calculated hydration age within the analytical uncertainty. The rate of growth calculated on the basis of the slope of the decline of Th 230 within the deposit,

<333>

GEOLOGICAL ASPECTS

<333> CONT.

however, is low by over one order of magnitude when compared to the rate determined by the hydration-rind method. Although previous results indicated that the distribution of Th 232 is usually quite random within ferromagnesian deposits, our results indicate that caution should be exercised when assessing their growth rates on the basis of uranium-series results. (Auth)

<334>

Televaux, H.W., and R.B. Dow, U.S. Geological Survey, Denver, CO. 1974.

Preliminary Report on Uranium, Thorium, and Lead Contents and Lead Isotopic Compositions in Sediment Samples from the Red Sea

Data are presented on uranium, thorium and lead contents and lead isotopic composition of sediments from metalliferous mud at Site 226 (SW Atlantis II Deep) 0.5 m depth, from the post evaporate deposits at Site 227 (eastern flank of Atlantis II Deep) 153.5 m depth, and from dark siltstone within the evaporates at Site 228 (southern Red Sea on the Eudamene or western side) 322 m depth. Also included are U-Th-Pb data on pore water and basalt from Site 226. Leads in the near-surface sediments of the Atlantis II and Discovery deeps and from a deeper shaly fraction of an evaporate sequence in the southern Red Sea contain lead dominantly of mantle derivation. Because the evaporite sequences appear to be an ideal source for derivation of at least some of the metalliferous sediments in the deeps, the mantle-derived lead could appear to be more likely derived through weathering of young mantle-derived volcanics of the Red Sea region rather than through a recent influx of lead from the underlying mantle. Leads from deeper sediments in the Red Sea cores such as the sample from Site 227 appear of pelagic sediment derivation as previously determined in other studies. There is the suggestion from three samples of an inverse relationship between both uranium and thorium contents with lead content. (Auth)(PC)

<335>

Tobbs, J.Y., and R.N. Matthews, Department of Health, National Radiation Laboratory, Christchurch, New Zealand. 1976.

A Survey of Naturally Occurring Radionuclide Concentrations in New Zealand Soils. New Zealand Journal of Science, 19, 243-247.

Results of a survey of concentrations of naturally occurring Ra 226, Th 232, and K 40 in New Zealand soils are presented. Mean concentrations are: Ra 226--620 picocuries/kg; Th 232--780 picocuries/kg; K 40--40 nanocuries/kg. A linear correlation between Th 232 and Ra 226 concentrations, with a mean Th 232:Ra 226 ratio of 1.2 was observed. The variability of radionuclide content, even in soils of the same type, was found to be so great that conclusions regarding the radionuclide contents of particular soil types were not possible. Radionuclide content of a commonly used agricultural fertilizer was also assessed, and its contribution to the radioactivity of soils found to be negligible. (Auth)

<336>

El Shazly, F.H., United Arab Republic Atomic Energy Establishment, Cairo, United Arab

Republic. 1966.

Thorium Resources in the United Arab Republic and their Possible Utilization. Technical Reports Series No. 52; Utilization of Thorium in Power Reactors, (pp. 186-198).

Potential deposits of thorium are found in three geographical areas. Two are discussed briefly, the third, which is the most important thorium resource, in more detail: 1) thorium-uranium mineralizations in the basement rocks of the Eastern Desert; 2) monazite-bearing beach placers on the Mediterranean Sea coast of Sinai; and 3) monazite bearing beach placers on the Mediterranean Sea coast derived from the Nile and localized between Sidi Barrani and Port Said, East Suez and West Suez. Th/U ratios in mineral deposits of the Eastern Desert range from 1 to 15 although they vary normally between 1 and 6; highest values so far recorded are 0.645 Th and 0.335 U. The monazite in the samples from the Sinai range from 2.23% to 0%. The ThO₂ content of monazite for a Suez sample examined is 5.92% while the U₃O₈ content is 0.05%. An estimation of the distribution of economic minerals as a whole and monazite containing ThO₂ and U₃O₈ in particular in the beach placers of the Nile is given. The estimation is based on aerial radiometric surveys as well as sampling and mineralogical analyses of the beach sands. (RAF)

<337>

Ellis, J.P., S.B. Austin, and R.P. Drusellard, U.S. Atomic Energy Commission, Grand Junction Office, Resource Investigation Division, Grand Junction, CO. 1968, November.

Magnetic Susceptibility and Geochemical Relationships as Uranium Prospecting Guides. AEC-RID-4; TID-26582; 21 pp.

Select chemical and physical variables for 48 observations along a 7000m ground traverse are compared statistically by use of a correlation program written for the IBM 1631. A comparison of the airborne gamma spectrometry with the ground data is also presented. Highly significant correlations exist between U₃O₈ or U₃O₈ and σ_{Fe} , σ_{Th} , σ_{K} , loss on ignition, and a significant correlation with combined P and V. Magnetic susceptibility has a highly significant correlation with Fe, Mn and negatively with U₃O₈. The negative correlation with uranium offers a possible prospecting method to delineate areas favorable for uranium. (Auth)

<338>

Floeter, B., Braunsberg-GmbH, and Co. K.G., Bonn, German Federal Republic. 1976.

Uranium Mining and Milling. AEC-COUP-76-660-020; Nuclear Power Project Planning and Implementation, Proceedings of an Interregional Training Course held in Karlsruhe, Germany, September 6-November 30, 1976, 48 pp. (AEC-COUP-76-660-020).

Part one of this review deals with the following aspects of uranium mining: mining and milling in the fuel cycle, different types of uranium ore deposits, most important uranium minerals, concentration factors for ores mined, open cast mining (equipment), underground mining (development and methods), mining cost, solution mining, and radiation protection (equipment). In the second part the milling of uranium ores is discussed including process technology, acid and

GEOLOGICAL ASPECTS

<330> CEPT.

alkaline leaching, standard and advanced processes for physical and chemical treatment of the ores, manpower, cost, construction period, and radiation protection. Detailed figures, flowcharts, diagrams, and tables are included. (HAF)

<339>

Forzac, J., *Mineralogical Institute of Geology, Bratislava, Czechoslovakia*. 1975, November.

Geochemistry of Radioactive Elements in Rhyolites in the West Carpathians

Rhyolites are developed in the Central and Eastern Slovakia. This paper deals with the distribution of radioactive elements, including U, Th, in the Slovakian rhyolites, their mutual relationships and the relationships to other elements as well. Differentiation in the content of studied elements in rhyolites from the Central and Eastern Slovakia is pointed out and also the relationships of these elements in fresh and melt-rhyolites. Remarkable differentiations have been found in the content of radioactive elements in minerals and in the matrix of the studied rocks. (Auth)

<340>

Goldberg, E.D., C. Patterson, and T. Chow, *Scripps Institution of Oceanography, La Jolla, CA; California Institute of Technology, Division of Geological Sciences, Pasadena, CA*. 1958.

Ionium-Thorium and Lead Isotope Ratios as Indicators of Oceanic Water Masses. Paper No. 1980: Peaceful Uses of Atomic Energy, Proceedings of the 2nd United Nations International Conference held in Geneva, Switzerland, September 1-13, 1958, Vol. 18, (pp. 347-350).

A technique for studying circulation of deep-water masses involves isotopic analyses of certain elements in components of the deep-sea sediments underlying the water masses. Transfer of dissolved chemicals characteristic of the water mass to one or more solid phases on the ocean floor may record the movement of bottom waters. Depth distributions of isotopes could give information about behavior and character of deep waters in past ages. Preliminary results of studies on Pb and Th distribution in surface layers of recent Pacific Ocean sediments are compared with oceanic circulation patterns from other types of studies. The $^{106}\text{Th}/^{232}\text{Th}$ ratios in the surface samples of analyzed cores fall into 2 groups: a set in the region between the Aleutians and Hawaii (values averaging about 15) and a group between 120 and 180 degrees W longitude from 40 degrees N to 20 degrees S (values about 35). The fall-off in ratio with depth is continuous within cores. The amounts of Th and Pb in the lithogenous component, detrital quartz were negligible with respect to their concentrations in clay and ferro-manganese minerals. Lead, Co, Zn, Cd, Cu and Th occur in ferro-manganese mineral components of sediments in concentrations one to two orders of magnitude greater than the corresponding average values in crustal rocks. The results are discussed in relation to present ideas concerning deep water circulation in the Pacific Ocean. (VC)

<341>

Graetzer, H.C., and O.W. Leisure, *South Dakota State University, Physics Department, Brookings, SD*. 1975.

Determination of Trace Elements in Soil Samples by Neutron Irradiation. Proceedings of the South Dakota Academy of Science, 50, 247-248.

Soil samples were collected during May and June of 1974 at eleven locations in northeastern South Dakota and Minnesota, within a ten-mile radius of the Big Stone Power Plant. The purpose of this project was to determine the normal level of various trace elements in the soil before the new power plant begins its scheduled operation in 1975. The soil will be sampled again at the same locations after a period of several years, to monitor any environmental effect of fly ash from the stack. The soil samples together with several standards and blanks were irradiated in the Ames Laboratory Research Reactor for periods of 30 minutes to 18 hours. The resulting radioactivity was analyzed with germanium crystal detectors. The average results for 15 elements are as follows: potassium (1.48 percent), sodium (.87 percent), iron (1.77 percent), cobalt (5.3 ppm), lanthanum (31 ppm), antimony (0.45 ppm), scandium (6.49 ppm), tantalum (0.18 ppm), hafnium (2.8 ppm), chromium (36 ppm), bromine (7.8 ppm), thorium (8.9 ppm), arsenic (10 ppm), and mercury (0.2 ppm). In addition to these, molybdenum was analyzed by atomic absorption (0.8 ppm). Further work is being done to determine cesium, europium, and zinc, as well as to obtain more precise values for selenium and mercury. (Auth) (HAF)

<342>

Wirtzman, G., G.R. Friedman, and E.S. Miller, *Rensselaer Polytechnic Institute, Troy, NY*. 1977, December.

Control and Distribution of Uranium in Coral Reefs during Diagenesis. *Journal of Sedimentary Petrology*, 47(4), 985-997.

The concentration of about 2 ppm of uranium in the aragonitic skeletons of modern scleractinian corals is a constant value, regardless of occurrence, anatomy, or taxonomy. The presence of cement of aragonite or high-magnesian calcite usually raises the concentration of bulk samples to about 3 ppm. Modern corals may contain up to 50% of cementing minerals. Organisms, such as corals and coralline algae, while secreting their skeleton, discriminate against the uptake of uranium, whereas the uptake of uranium by mineral cements is less restrained. Aragonite cement contains about 3.6 ppm and high-magnesian calcite cement 26 ppm uranium. During leaching by freshwater, the aragonite of the skeletons of corals dissolves out. This creates hollow solids which fill with druse low-magnesian calcite. In emergent reefs from the shores of the Red Sea which display the effects of progressive diagenesis this calcite is enriched in uranium (3.9 ppm) beyond that found in marine cements. Second-generation calcite which fills original voids in the corals from the emergent reefs contains a lower level of uranium concentration (1.3 ppm). The level of concentration of uranium in low-magnesian calcite of diagenetically altered corals is a function of the availability of uranium in meteoric waters. In aragonite as well as in high- and low-magnesian calcite uranium replaces calcium or occupies lattice vacancies in the crystal lattice. (Auth)

<383>

GEOLOGICAL ASPECTS

<384>

Monroe, D.C., University of California, Kearney Foundation of Soil Science, Davis, Ca. 1970.

Radioactivity of a California Terrace Soil. Soil Science, 110(1), 31-36.

A Yontgallier soil profile was sampled to 2'3" below the surface and the radioactivity per unit area and depth was calculated. This is of use when assaying background activities with detectors above the soil surface or in airplanes. Individual nuclide activities were determined by an isotopic detection technique where tracer nuclides ^{232}Th and ^{230}Th were used to determine the percentage recoveries of the individual nuclides of U and Th. When freed from minerals by weathering, uranium is leached more rapidly than is thorium, although thorium also shows evidence of movement. The degree of loss of uranium versus ^{230}Th is calculated and knowing the age of the sedimentary deposit, the rate of loss of uranium was estimated. Determinations of thorium by two independent means (alpha and gamma spectrometry), show reasonable agreement. Radium(^{226}Ra) activities are close to those of ^{230}Th as might be expected. Uranium concentrations varied from 1.9 to 2.6 ppm, and thorium concentrations from 9 to 11 ppm in the soil profile. The isotopic activities of the soil horizons ranged from 1.5 to 2.9 dpm/g. (Auth) (PNS)

<385>

Samson, R.C., and P.V. Stout, University of California, Kearney Foundation of Soil Science, Davis, Ca. 1968.

Isotopic Distributions of Uranium and Thorium in Soils. Soil Science, 105(1), 44-50.

Both uranium and thorium tend to concentrate as a result of rock weathering. Uranium and thorium losses from soils occur, but differential leaching favors uranium in one instance and thorium in another. Thorium concentrations are higher than uranium in the E horizons, but in the upper horizons of the upland primary soils uranium concentrations increase. The alluvial soils of the San Joaquin Valley tend to have higher and more evenly distributed concentrations of thorium. There are instances where U and Th become separated as a result of soil-forming processes, such as movement of uranium into lime nodules with calcium, or thorium from topsoils where organic content is highest. In these instances measurements of decay and of accumulation of ^{230}Th can give clues to the rates of soil-forming processes and for determining the ages of soil fractions. Isotopic analyses of uranium and thorium by alpha-particle spectrometry appears to be a useful means of acquiring informative mechanisms and rates of soil formation. (Auth)

<386>

Jackson, R.L., S.Y. Lee, P.C. Gollai, and P.A. Helke, University of Wisconsin, Department of Soil Science, Madison, WI; University of Washington, College of Forest Resources, Seattle, WA. 1977, April.

Age and Uranium Content of Soil Nicas from Antarctica by the Fission Particle Track Replica Method. Soil Science, 123(4), 241-248.

A replica method was developed for fission particle track age dating and determination of uranium content of nicas in a Wright Valley, Antarctic, soil and parent rock.

The nica particles in the soil were relatively small, fragile, and easily dissolved by chemical etchings. Muscovite mica flakes were therefore used as a replicating substrate to register induced fission tracks of the soil nica. The nicas from three soil horizons (0-10, 10-30, and 30-50 cm depths) and parent rock, in four size fractions (100-500, 2-5, 0.2-2, and <0.2 μm) were examined to illustrate use of the method. The fission track age of the soil nica particles was 4.1 ± 0.2 million years (MY), slightly older than the minimum landscape (glacial bench) age of 3.7 ± 0.2 MY obtained previously by K-Ar dating of a volcanic cone formed after the glacial valley was formed. The ages of the 2-5, 0.2-2, and <0.2 μm fractions were the same as for the 100-500 μm flakes, when the spontaneous track density was calculated from that of the latter, in proportion to the U content. The fission track age of parent rock nica was 151 million years. The U content of the soil nica was 0.5 to 1.6 ppm which is 20 to 50 times higher than that of nica from the parent rock (0.03 ppm). The nica in the soil appears from age and petrographic thin-section results to be of pedogenic origin, formed by replacement in feldspars after the bench was carved. The fission particle track replica method is useful for age-dating of nicas in soils, for determining trace amounts of uranium in nicas, and for study of soil genesis in the Antarctic cold desert. (Auth)

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Joshi, I.U., and A.K. Ganguly, Bhabha Atomic Research Center, Division of Radiological Protection, Bombay, India. 1978.

Anomalous Behavior of Thorium and Uranium Isotopes in the Marine Environment off the West Coast of India. COMF-741120, STI/PUB/382; IAEA-SR-191/3; Isotope Ratios as Pollutant Source and Behavior Indicators, Proceedings of a Symposium held in Vienna, Austria, November 18-22, 1978, (pp. 169-178), 889 pp. (COMF-741120, STI/PUB/382, IAEA-SR-191/3).

The coastal regions of India offer a unique advantage for studying the geochemistry and transport of natural radioactivity. Data can be correlated with the transport and deposition of artificially introduced radioactivity or any run-off terrestrial pollutants in the region. In the southern part of the West Coast there are extensive placer deposits containing thorium- and uranium-bearing minerals (monazite) whereas the northern part is relatively free of such deposits. The surface layers of the coastal sediments are leached with 5% EDTA for the extraction of thorium and the saturated solution of ammonium carbonate for the extraction of uranium. The leaching agents are so chosen that they have high efficiency for leaching thorium and uranium and at the same time do not in any way attack the mineral core of the sediment particles. The thorium and uranium isotopic activities and the ratios $\text{Th } 228/\text{Th } 232$, $\text{Th } 230/\text{Th } 238$, $\text{U } 238/\text{U } 238$ and $\text{U } 235/\text{U } 238$ are calculated. The $\text{Th } 228/\text{Th } 232$ activity ratios in the Bombay region and in the monazite areas are in the range 0.55 to 0.67 while the ratios between Bhatnagiri and Monavar are in the range 2.00 to 2.19. The $\text{Th } 230/\text{Th } 232$ activity ratios are in the range 0.13 to 0.15 in the Bombay region 0.95 to 1.07 in the region between Bhatnagiri and Monavar, and 0.23 to 0.25 in the monazite areas. However, such large variations are not observed in $\text{U } 238/\text{U } 238$ activity ratios. The $\text{U } 238/\text{U } 238$

GEOLOGICAL ASPECTS

<306> CCRT.

activity ratios are in the range 1.12 to 1.18 in the coastal sediments from the regions between Bombay and Kottilypad. The activity ratios $U\ 238/U\ 235$ in coastal seawater are in the range 1.15 to 1.16. The $U\ 235/U\ 238$ activity ratios in sediments and seawater are 0.004, which is the same as that of natural uranium. (Auth) (IAP)

<307>

Joshi, L.V., and A.K. Ganguly, Bhabha Atomic Research Center, Health Physics Division, Bombay, India. 1973.

Enriched Thorium 228/Thorium 232 and Thorium 230/Thorium 232 Activity Ratios in Backwater Sediments along the West Coast of India. (CSP-720700; IAEA-SR-156/50; Interaction of Radioactive Constituents with the Constituents of the Marine Environment, Proceedings of a Symposium held in Seattle, Washington, July 10-14, 1972, (pp. 747-755) (CSP-720700, IAEA-SR-156/50).

Recently, remarkable disequilibrium between $Th\ 228$ and $Th\ 232$ activities has been observed in the top layer sediments of the backwaters along the Indian Coast. The $Th\ 228/Th\ 232$ activity ratios in Bombay harbor region (19 deg N, 73 deg E) and Kerala belt (8 deg-10 deg N, 76 deg-77 deg E) have been found to be in the range of 0.55 to 0.67, while this ratio is in the range of 2.00 to 2.10 along the rest of the West Coast of India between Bombay and Kerala region (19 deg-15 deg N, 76 deg-77 deg E). The $Th\ 230$ and $Th\ 232$ activities also show anomalous behavior in these regions. The $Th\ 230/Th\ 232$ activity ratio in the Bombay region is about 0.133, while the ratio lies between 0.23 to 0.25 in Kerala belt. In the coastal region between Ecclay and Kerala, the ratio lies in the range of 0.95 to 1.07. The variation in the $Th\ 228/Th\ 232$ activity ratio is attributed to preferential leaching of $Th\ 228$ by water flowing over the sediments. Thorium 230/Thorium 232 activity ratio is governed by the $Th\ 230$ activity in waters adjacent to the sediments. In the dynamic processes in marine environment, the sediment and the water interface are the most important and equilibria are expected to be established only among the chemical species occurring at the surface of the sediment and the ambient medium. A geochemical study of these sediments is being carried out by leaching the samples with 1 percent EDTA at pH 3.00 in order to investigate the processes occurring on the surface and the distribution of natural thorium isotopes in backwater sediments. (Auth)

<308>

Joshi, L.V., and A.K. Ganguly, Bhabha Atomic Research Center, Division of Radiological Protection, Bombay, India. 1977.

Natural Radioactivity and Geochemical Processes in the Marine Environment of the West Coast of India. Proceedings of the Indian Academy of Sciences, 85B(4), 171-256.

In studies related to the geochemistry of thorium and uranium, it was observed that disequilibrium between $Th\ 232$ and $Th\ 228$ and between $U\ 238$ exists on the surface of the labile organic layer of the sediment particles. As the surface organic matter is removed, the core of the particles show equilibrium activities. In studies related to sedimentation and geochemistry of elements in coastal waters, it is important to

recognize the physicochemical equilibrium between labile chemical species present on the particle surface and the chemical species in the ambient medium. The thickness of the labile organic layer on the sediment particles has been calculated and found to be in the range of 2.5 x 10⁻⁶ cm to 10.0 x 10⁻⁶ cm. The values are comparable to the values obtained by electron microscopy. (Auth) (IAP)

<309>

Katsuraya, K., Kyoto University, Kyoto, Japan. 1968.

Accumulation of Radioactivity in Rice Fields. Annual Reports of the Research Reactor Institute, Kyoto University, 1, 293-297.

The adsorption capacity of the following radioactive isotopes in the soil is discussed: Li, Na, K, Rb, Cs, Ca, Co, Ba, Sr, B, La, and Th. Equations are given for coefficients of distribution and exchange. Ion exchange capacity of the soil is discussed. Estimation of radioactive concentration in the root zone of rice fields is based on the following phenomena: introduction of water into the rice field; percolation in the superficial soil of the rice field; disintegration of radioactive elements; and accumulation of radioactivity in cultivable soil. A method for estimating the quantity of radioactivity carried by irrigation water into the rice field in the course of a year is described. (ISA)

<350>

Krishnaswami, S., B. Lal, B.S. Anis, and A. Sontar, Tata Institute of Fundamental Research, Colaba, Bombay, India; Scripps Institution of Oceanography, La Jolla, CA. 1973, September.

Geochronological Studies in Santa Barbara Basin: Iron 55 as a Unique Tracer for Particulate Settling. Limnology and Oceanography, 18(5), 763-770.

Sediments accumulate in the Santa Barbara Basin relatively rapidly: about 3-4 cm/yr based on the analysis of varves. These deposits are ideal for studying the applicability of nuclear geochronological techniques in a natural situation. Studies of the depth distribution of several radionuclides, man-made $Fe\ 55$ and naturally occurring $Pb\ 210$ and Th isotopes, in recent Santa Barbara sediment layers permit an evaluation of the geochemical behavior of Fe , Pb , and Th in coastal waters and have established the usefulness of $Fe\ 55$ and $Pb\ 210$ for dating coastal or near coastal sediments deposited during the last decade and half-century respectively. A measurable excess of $Th\ 228$ activity over its parent $Th\ 232$ in the acid leaches of the cores was observed. From measured $Th\ 228/Th\ 232$ activity ratios, a crude estimate of the sedimentation rate was made. The estimated sedimentation rate corresponds to about 0.5 - 0.6 cm/yr for the 1960 - 1971 strata, compared to an average value of about 0.7 cm/yr based on annual varve counting for the same period. (IAP)

<351>

Kurat, G., J. Korkisch, G. Fiedernayr, and B. Soenns, Mineralogisch-petrographische Abteilung Naturhistorisches Museum, Vienna, Austria; Analytisches Institut, Universität Wien, Vienna, Austria. 1976.

GEOLOGICAL ASPECTS

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Uranium-Thorium-Geochronology of Persian and Triassic Sediments of the Braunsay, Carlsbad, Austria

The Persian-Triassic series of the western Braunsay and the Liens Dolomites are very similar to equivalent deposits in Northern Italy. Assuming a lateral displacement of 120 km along the Periadriatic Lineament the former represent the northern marginal part of the latter and therefore are inferior in thickness and thus not favorable for larger U mineralizations. Geochemical investigations have yielded the following results: U is mobile and therefore depleted in the red (oxidized) varieties of sediments and immobile in the gray ones, which, however, mostly only retained their U. Enrichments are rare and are related to plant remains. Depletions, retention, and enrichments of U are post sedimentary and part of the diagenesis. Copper, Vanadium, and Scandium behave somewhat similarly to U. Copper is apparently enriched in the gray varieties above normal sedimentary levels. It is clear that sizeable U mineralizations cannot be expected within the area investigated. (Auth)

<352>

Hindken, C.L., D.G. Coles, and J.W. Meadows, Lawrence Livermore Laboratory, Livermore, CA. 1975.

Gamma-ray Lithium Spectrometric Measurements of Isotopic Uranium Ratios in Soils Treated with Apatite-Derived Fertilizers. CONF-761120; STI/PUB/302; IAEA-SM-791/13; Isotope Ratios as Pollutant Source and Behavior Indicators, Proceedings of a Symposium held in Vienna, Austria, November 18-22, 1974, (pp. 255-265), 989 pp. (CONF-761120, STI/PUB/302, IAEA-SM-791/13).

Soil samples collected in an agricultural region of the Sacramento-San Joaquin Delta in central California contained levels of uranium as high as 17 ppm. Isotopic uranium analysis, determined by mass spectrometry, showed U 235, U 238 ratios of $7.1 \pm 10(\pm 3)$, typical of natural uranium. However, the U 238 content inferred from gamma counting of the Ra 226 daughters disclosed marked disequilibrium in the U 238 decay series. The elevated levels of uranium were attributed to its presence in ammonium phosphate fertilizer produced from apatite ($\text{Ca}_5(\text{PO}_4)_3\text{F}$). The U 238 daughter disequilibrium was due to removal of Ra 226 by coprecipitation with CaSO_4 during conversion of the raw material to phosphoric acid with sulphuric acid. A more direct method for U 238 measurement based on detection of the 63-keV transition gamma of Th 234 and using Ge(Li) gamma spectrometry is described. This method is independent of Ra 226 daughters and can detect U 238 down to about 0.1 µg/g in soils. A comparison with U 238 measurements using mass spectrometry shows agreement within plus or minus 10%. (Auth)

<353>

Timarhenko, E.P., V.F. Brichko, T.M. Poniikova, and D.K. Pajcv, 1975.

Concentration of Radium 226 and Thorium 230 in Soviet-Made Phosphorus Fertilizers. CNU-TR-6498; 4 pp.; Khimiya v shkol'nykh i vuzovskikh laboratoriakh, 13(2), 70-71.

The concentration of the natural radionuclides Ra 226 and Th 230 in phosphorus

fertilizers was determined as a function of sources of raw material, type of fertilizer and manufacturing technology. The concentration of Ra 226 in the tested fertilizers varied significantly: the Th 230 concentration changed little and did not differ significantly from average Th 230 concentrations in soils. Various Ra 226 and Th 230 concentrations were observed, as a rule, in fertilizers manufactured from industrial waste. The isotopic composition in the fertilizer is a function of the isotopic composition of the raw material and the technology used to produce the fertilizer. The use of phosphorus fertilizers, even with various observed Ra and Th concentrations, has practically no influence on the concentration of natural radionuclides in the soil due to their extreme dilution. (ABT)

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Miyake, K., and T. Masuro, Radiation Center of Osaka Prefecture, Sakai, Japan. 1976.

Concentrations of Uranium Series Nuclides in Soil Particles in Relation to their Sizes. Journal of Radiation Research, 17(1), 21-22.

A soil sample containing about 50 ppm uranium was sieved into several parts according to the size of soil particles. Concentrations of uranium series nuclides (Th 230, Th 232, Ra 226, Pb 210) in each part were determined by gamma-ray spectrometry. It was found that activity ratio of Th 230 to U 238 was about 5 in soil particles smaller than about 100 µm and about 3 in soil particles larger than 100 µm. Activity ratios of Ra 226 to U 238 and Pb 210 to U 238 were found to be about 2, being independent on particle size. An explanation for the observed enrichment of Th 230 in soil particles is that during weathering processes some of the uranium compounds in soil are dissolved in water, but Th 230 compounds are very liable to be retained in soil particles. Such an explanation is also generally accepted for the well-known fact that the activity ratio of Th 230 to U 238 in river water is around 0.02. The observed radioactive disequilibrium of Ra 226 with U 238 can be explained by the conspicuous enrichment of its parent nuclide, Th 230. (Auth)

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Wenzel, B.G., U.S. Department of Agriculture, Beltsville, MD. 1968.

Uranium, Radium, and Thorium Content in Phosphate Rocks and their Possible Radiation Hazard. Journal of Agricultural and Food Chemistry, 16, 231-238.

A survey of phosphate rock samples from all major phosphate producing areas of the world showed that phosphate rocks from Florida, the main source of fertilizer phosphates in the United States, ranked relatively high in content of uranium, radium, and thorium. In areas where crops are fertilized with high rates of phosphate from Florida, the addition of uranium and radium may equal the amounts occurring naturally in the plow layer of soils, but the addition of thorium would be less than the amount occurring naturally. The radiation hazard, which might result from uptake of radium into food plants, appears to be negligible. (Auth)

<356>

Miyake, K., T. Sugisawa, and T. Yasujima, Tokyo

GEOLOGICAL ASPECTS

<356> CCRT.

Fyohke University, Tokyo, Japan; Meteorological Research Institute, Tokyo, Japan. 1970, June.

Thorium Concentration and the Activity Ratios Thorium 230/Thorium 232 and Thorium 228/Thorium 232 in Sea Water in the Western North Pacific. Journal of the Oceanographical Society of Japan, 26(3), 116-126.

The concentration of thorium isotopes and the activity ratios of Th 230/Th 232 and Th 228/Th 232 in sea water collected in the Kurashiki region, the mining area of Okushio and Kuroshio, the Japan Sea and the East China Sea in the western North Pacific were determined. Thorium isotopes were analyzed by alpha-ray spectrometry after separating them with an anion exchange resin. The average content of thorium (Th 232) of 2.2×10^{-10} g/l was obtained in the open Pacific waters. The ratio of Th 230/Th 232 is in accord with that of the top layer of the sediment in the same area. The high values of Th 228/Th 232 ratio up to 36 were observed in sea water. The excess Th 228 in sea water may be due to the migration of Th 228 through the water-sediment interface. Thorium content in suspended matter was 10 to 20% of the total thorium content in the Pacific water. (auth)

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Bakiforova, Ye.S., 1967.

СФУП-тр-0501; 10 pp.; Географическое Исследование 550 Издательский Физмат. Известия Чита, 3(2), 67-81.

The average "clark" content for upland-steppe soils and upland chernozems equals 27.3×10^{-10} g/g for thorium, 1.10×10^{-10} g/g for radium, 3.5×10^{-10} g/g at a Th/U ratio equal to 7.8 which is near the average content of radioactive elements in primary rocks (Th= 2.8×10^{-10} g/g, Ra= 1.85×10^{-10} g/g, U= 4.5×10^{-10} g/g at Th/U=6.8); this indicates high radioactivity in soils, insignificant binding of the radioactive elements in them and their faint geochemical contrast in comparison to primary rocks of the region. The variation limits of the concentration in primary rocks and soils are small and total one order of magnitude for thorium: 0.97×10^{-10} g/g, and two orders for radium: from 2.0×10^{-11} to 2.2×10^{-10} g/g. The total content of the natural radioactive elements thorium, radium and uranium in upland-slope chernozemois (fragmentary) and shallow upland chernozems is completely determined by the radiochemical composition and concentration of radioactive elements in soil-forming and primary rocks. The nature of the distribution of thorium and uranium in the vertical soil profile is determined by the type of soil-forming process and the properties of the soil such as the special natural formation and has regional aspects inherent in the given bioclimatic province. (Trans.)

<358>

Mishisaki, Y., Y. Honda, Y. Minura, H. Morishima, Y. Koga, Y. Miyaguchi, and H. Kawai, Atomic Energy Research Institute, Ninki University, Higashi-Osaka City, Osaka, Japan. 1972.

Behavior and Distribution of Radioactive Substances in Coastal and Estuarine Waters. CONF-720708; IAEA-SR-158/11; Interaction of Radioactive Contaminants with the Constituents of the Marine Environment, Proceedings of a Symposium held in Seattle, Washington, July

10-14, 1972, (pp. 177-193) (CONF-720708, IAEA-SR-158/11).

To understand the problems of environmental radioactive contamination due to continuous discharge of low-level liquid radioactive waste into the seawater, a study must be made of the behavior and distribution of various nuclides which may occur in both ionic and colloidal or particulate state in the coastal and estuarine waters. However, the behavior and distribution of the various radionuclides in the estuarine water are much more complicated than those in the open sea, because of the complex topographical and marine meteorological variations and the changes in salination and pH of the water. Since thorium and rare-earth elements had been continuously discharged through a small river into the estuarine water at Osaka Bay, a study was made of the variation of concentration of these elements under various natural conditions. Experimental studies on adsorption of these elements on some bottom sediments were also carried out in the water with different salinities and pH. One important factor influencing the concentration of the elements in the water is tidal oscillation. The gross beta activities in water at the same location in the estuary widely varied at each time of sampling. The average values from April to December in 1966 were 9.5 ± 0.9 pCi/liter at higher tidal level, 80 ± 60 pCi/liter at middle tidal level and 157 ± 106 pCi/liter at lower tidal level respectively. However, the concentrations of thorium and total rare-earth elements in the water were not observed to change regularly with the tidal change. The dispersion of the elements in the estuarine water were not interpreted by simple dilution and diffusion of the element in water mass. The presence of the mud flats, as well as the marine meteorological conditions, seem to affect markedly the distribution of the element in the estuarine water. The adsorption of the element on the bottom sediment was influenced not only by the coarseness of the sediment but also by the salinity and pH of the water. The higher distribution coefficients of Y 91 and Ce 144 in the clay sediment were obtained at the chlorosity of 100/liter and pH 7.3 of the water. (auth)

<359>

Popper, S.G., and J.P. Quirk, University of Western Australia, Institute of Agriculture, Department of Soil Science and Plant Nutrition, Nedlands, West Australia. 1976, February.

The Alpha Activity of Soils in Relation to Landscape Development. Australian Journal of Soil Research, 14(1), 25-32.

The alpha activity of soils and the degree of the equilibrium of the thorium series has been related to the age of soils developed on a truncated laterite landscape in south-western Australia. The uplift of the old lateritic plateau has forced a sequence of erosional and depositional surfaces which form the parent materials of the present-day soils. These surfaces because of their different relative ages have been subjected to different degrees of weathering and leaching. The alpha activity of the soils formed on these different landscape surfaces is influenced by the amount of weathering that the surface has undergone and by the degree of leaching that the soil has undergone as evidenced by profile development. It has been shown that the soils formed on the younger surfaces have high

GEOLOGICAL ASPECTS

<359> COTZ.

alpha activities and contain soluble daughter nuclides of the thorium series. These are adsorbed onto the clay and silt particles and are exchangeable with sodium during mechanical analysis. The presence of these daughter nuclides is also supported by the low ratio of count to pairs (C/P ratios) for these soils. The low activity soils developed on the older lateritic surfaces lack soluble daughter nuclides as evidenced by their higher C/P ratios. (RAT)

<360>

Sejbovic, I., Geological Institute of the Slovak Academy of Sciences, Bratislava, Czechoslovakia. 1975, June.

Geochemical Characterization of Uranium-Copper-Lead Mineralization in the Fergana of the Choc Nappe in the Vikartovsky Chrbat Area (the West Carpathians). *Geologica Carpathica*, 26(1), 105-110.

Stratiform mineralization occurs in the upper Fergana of the Choc nappe in the Vikartovsky chrbat area. The distribution of U, Cu, Pb, Zn, Bi, Co, Sb, As, Sn, Cs, V, Sr, Zr, Y, Th, W and Ti is discussed. Dominant elements of ore association are U, Cu, Pb. Copper is more abundant than Pb in the western part of Vikartovsky Chrbat area, while Pb is more abundant in the eastern part. The ore concentrations were found mainly during the process of diagenesis due to the presence of organic carbon. (Auth) (RAT)

<361>

Fejtsov, D.N., 1972.

Distribution of Uranium and Radium in the Podzolic Mountain Soils of Thin Forests. *Radioekologicheskoe issledovaniye v Prirodnykh Slogotsevozakh*, Izdatel'stvo Nauka, I.B. Verkhovskaya (Ed.), Moscow, USSR, (pp. 42-53).

The content and distribution of uranium and radium in the profiles of podzolic mountain soils of thin forests were determined. A tendency was discovered to a preferential accumulation of uranium and radium in the products of soil formation (aluminite as compared with base rocks) by sericitic shists with quartzite intercalations. The presence of uranium and radium in the vegetative objects of forest litter confirms the already established fact that uranium and radium are involved in the biological cycle of matter exchange in nature. The distribution of radium and uranium in soil profiles reflects the zonal features inherent in the given bioclimatic zone. In base rocks and soils, the equilibrium between radium and uranium is disturbed in favor of radium. In the order of decreasing energy of their absorption by vegetative objects radioactive elements form the series: radium > uranium > thorium. (Auth)

<362>

Fejtsov, D.N., 1972.

Thorium and Radium Content in the Silt Fraction of the Podzolic Mountain Soils of Thin Forests. *Radioekologicheskoe issledovaniye v Prirodnykh Slogotsevozakh*, Izdatel'stvo Nauka, I.B. Verkhovskaya (Ed.), Moscow, USSR.

Investigations have shown that in zones of ore manifestation, thorium is associated with the coarse dispersed part of aluminite. In

the zone of the halt of dispersion and the zone of background areas, thorium represented by the fine dispersed fraction prevails. The distribution of the silty thorium fraction in different soil profiles is determined by the nature of soil forming processes and the thorium content of aluminite and correlates in a certain measure with the composition of the plant association. The presence of thorium in separate fractions of organic matter was ascertained. The amount of uranium in the soils considered varies within the range of the geochemical background of uranium content in the soils of the Russian plains. Uranium is confined mainly to the fraction greater than 0.001 mm. The distribution of the uranium of the silty fraction along soil profiles is determined, like that of thorium, by the nature and trend of the process of soil formation. Uranium enters the vegetative objects of forest litter far more intensely than thorium. (Auth)

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Fejtsov, D.N., Not given. 1966.

Distribution of Thorium in Various Soils. *Soviet Soil Science*, 2(3), 290-302; *Pochvedenie*, 3, 55-67.

Different concentrations of thorium and its decay products in soils cause different levels of gamma radiation output above the surface of the soil mantle. The concentration of thorium in fine grain soil, that is in products of weathering and soil formation, is higher than in basement rock-schists with layers of quartzite. Increased concentration of thorium in the fine grain soil is related to processes of weathering and soil formation. The fluctuating concentration of thorium in the soil determines basically the concentration of thorium in the air near the ground. The presence of thorium in plants indicates that it is a part of the biological cycle in nature. The uptake of thorium in vegetative objects is determined not only by the concentration of thorium in the fine grained soil but is also regulated by the species and by the trend in the soil-making process. The processes of soil formation, characteristic of a bioclimatic zone, appear as the basic source of the redistribution of thorium in the soil profile. (tr-Auth) (RAT)

<364>

Fejtsov, D.N., and E.I. Pravdina, 1972.

Content and Distribution of Uranium, Radium, and Thorium in Mountain Tundra Soils. *Radioekologicheskoe issledovaniye v Prirodnykh Slogotsevozakh*, Izdatel'stvo Nauka, I.B. Verkhovskaya (Ed.), Moscow, USSR.

Investigations of the content and distribution of thorium, uranium, and radium in mountain tundra soils showed a differentiation of their content according to genetic soil horizons, determined by the nature of the processes of formation. The absolute biological accumulation of thorium and uranium was found to be lower in the soils of mountain tundra as compared with the more southern mountain tundra soils of thin forests. Against a background of a reduced absolute biological accumulation of thorium and uranium in mountain tundra soils, an increase is observed of the relative coefficient of the participation of thorium and uranium in the biological cycle of matter exchange. (Auth)

GEOLOGICAL ASPECTS

[365]

Sachett, W.R., T. Ho, R.F. Spalding, and R.E. Erner, Texas A & M University, Department of Cosmography, College Town, TX. 1973.

A Reevaluation of the Marine Geochemistry of Uranium. CCRP-720700; IAEA-SM-150/51; Interaction of Radioactive Contaminants with the Constituents of the Marine Environment, Proceedings of a Symposium held in Seattle, Washington, July 10-18, 1972, (pp. 757-769) (CCRP-720700, IAEA-SM-150/51).

Approximately $10(±15)$ ng/yr of dissolved uranium are being removed from the ocean by each of the generally accepted significant sinks for uranium carbonate deposits and deep atoxic basin sediments. However, these sinks account for only 10 percent of the estimated present-day input of uranium. Possible explanations for this discrepancy are: (1) contemporary input values are too high owing to a significant contribution from man's effects, such as uranium input via phosphate fertilizers or world-wide cultivation leading to premature leaching of uranium from soils, or (2) there are other important uranium sinks such as the abundant siliceous oozes or continental shelf anoxic sediments. (Auth)

[366]

Finha, R.N., Virginia Polytechnic Institute and State University, Department of Geological Sciences, Blacksburg, VA. 1976.

Tectonic Significance of Thorium/Uranium Ratios from Archean Basalts. Chemical Geology, 10, 215-225.

Observed Th/U ratios from Archean basalts have been altered by metamorphism and/or recent weathering. Experimental leaching of Th and U from these basalts suggests that great care is necessary in using directly observed ratios for any petrogenetic models. Calculated Th/U ratios (based on Pb isotopic composition) when used with an index oxide (SiO₂) may reveal the depth of formation of these basalts. (Auth)

[367]

Sorensen, B., J. Bone-Hansen, R.L. Nielsen, L. Lovborg, E. Sorensen, and T. Lundgard, 1970.

The Uranium Deposit at Kvanefjeld, the Ilseassag Intrusion, South Greenland. Grønlands Geologiske Undersøgelse Rapport No. 60; 54 pp.

The uranium-thorium deposit is located in part of an alkaline intrusion consisting of peralkaline, apatitic nepheline syenites. The radioactive minerals are stromatolite, uranium-rich monazite, thorite and pigmentary material. The radio-element content varies from 100 to 3000 ppm U and 300 to 15000 ppm Th. Reasonably assumed ore in the main area with a grade of 310 ppm U is calculated to 5800 metric tons of uranium in 10.6 million metric tons of ore. Estimated additional reserves with a grade of 292 ppm U are 29.0 million tons of ore with 8700 tons of uranium and 3.5 million tons of ore with a grade of 350 ppm U yielding 1200 tons of uranium. Estimates of amounts of thorium ore are 2.6 times those of uranium. A method of recovery of the uranium based on sulphating roasting and subsequent leaching with water is described. (Auth)

[368]

Iyryukhanova, E.B., and V.A. Kalogina, Academy of Sciences of the USSR, V.I. Vernadskii

Institute of Geochemistry and Analytical Chemistry. 1972, May; 1971, September-October.

The Behavior of Thorium in Soils. Soviet Journal of Ecology, 2(5), 867-869; Ekologiya, 2(5), 867-869.

Studies on the behavior of Th in soils has been limited. Data on Th content of soils in any regions of Russia is lacking. Thorium content has been determined based on soil type, forest floors and forest vegetation. Thorium was determined chemically with arsenazo III. The average content in soils was 4 ng/g (range 0.2-9.5). In fluvio-glacial and ancient alluvial sand, the level was 2 ng/g. In order of decreasing Th content soils can be arranged as follows: soddy-gley, water meadow, sandy, ferruginous, podzolic, sandy, peaty. Thorium distribution is non-uniform in the soil profiles. The low content in peaty horizons may be due to low biogenesis and weak assimilation by bog plants. Knowledge of absorption by plants is limited; the Th content in plant ashes normally does not exceed that of the soils. Thorium concentrations were detected in forest floors, mosses, lichens and grasses. There may be considerable Th in individual plants, an indication of the possibility of including Th in the biological migration cycle. (Trans) (VC)

[369]

Wollenberg, H.A., and J. L. Smith, Lawrence Berkeley Laboratory, Berkeley, CA. 1972, July.

Geologic Factors Controlling Terrestrial Gamma-Ray Dose Rates. IRL-918; CCRP-720805; Natural Radiation Environment, Proceedings of a Symposium held in Houston, Texas, August 7-11, 1972, (50 pp.) (IRL-918 CCRP-720805).

The gamma-ray dose rates measured at nearly all terrestrial locations depend mainly on the uranium, thorium, and potassium contents of the rock or soil. Thus, a knowledge of the geologic character of an area aids greatly in the choice of measurement sites and in the interpretation of observed results. Over the past decade we have measured U, Th, and K in many rock types by gamma ray spectrometry. Igneous rock types measured range from ultramafics to granitoids; sedimentary rocks measured include sands and clays, limestones, and eugeosynclinal sandstones; metamorphic types range from low-grade blueschists to eclogite and Precambrian granulites. From the rocks radioelement contents we have calculated the gamma-ray dose rates at sampling locations; these agree well with dose rates measured by a portable NaI (Ti) detector unit, and by other types of instrumentation operated on intercalibration surveys. Data are adequate to characterize rock types and some of their derived soils by radioelement contents and associated radioactivities. Variation in radioelement contents within the batholithic and eugeosynclinal sedimentary rocks studied as, result from geochemical factors controlled to some extent by features of plate tectonics. Some examples are given: The west to east increase in U, Th, and K in granitic plutons of the Sierra Nevada batholith matches an increasing F(Th)/SiO₂ ratio, indicating the replacement of magma of increasing alkalinity, derived from increasing depths of an eastward-dipping subduction zone. Systematic differences in radioactivities of eugeosynclinal graywackes of the Franciscan Formation match zones of low-grade metamorphism, resulting from different pressures on material caught

<369>

GEOLOGICAL ASPECTS

<369> CONT.

between subducting and continental plates. In the San Francisco Bay area, soils derived from granitic and metamorphic rocks of the continental Salinian block have appreciably greater radioactivities than soils developed on or derived from lower radioactivity Franciscan rocks. Th/U ratios of the soils are quite similar to ratios in the parent rocks, indicating no appreciable fractionation between Th and U during formation of these soils. (Beth)

<370>

Vastrebov, N.T., Moscow State University, Soil Behavior Department, Moscow, USSR. 1973.

Natural Radioactivity of Some Soils in Landscapes of the Kolchanskaya Forest-Steppe of the Tashov Region. GSNL-tr-4518: 10 pp.: Vestnik-Moskovskogo Universiteta, Ser VI, Biol. Razvedenie, 28(6), 91-96.

Using gamma spectrometry, it was shown that the soils of meadow complex of superaquatic calcic-sodic landscapes of Tashov plain (swamp and meadow solons, solodic solonchaks and chernozem meadow soils) contain by 1.5-2 times more U 238 and Ra 226 than the typical chernozems of eluvial calcic landscapes. The U 238 and Ra 226 are accumulated in humus and illuvial horizons, and Th 232 in solodic and illuvial horizons. Uranium 238 shows a notable migration from

98

the upland into the floodplain of Sitjag river. Radium 226, Thorium 232 and Potassium 40 are mainly redistributed by elements of relief, accumulating in soils of depressions. (Beth)

<371>

Vastrebov, N.T., 1971.

Natural Radioactivity of Some Black-Earths in the European Areas of the USSR. Vestnik Moskovskogo Universiteta, Biologiya, Razvedenie, 28, 91-96.

The radionuclides U 238, Ra 226, Th 232, and K 40 in black earth were determined by gamma spectrometry with a maximum error of 11 percent. The order of absorption of these heavy nuclides by plant roots is Ra 226 > U 238 > Th 232. In the southern chernozems the U 238 content in the humus-accumulating layers was a factor of 1.3 to 1.8 lower than in rock because of the loss of this isotope by being taken up in plant roots. The Ra 226, Th 232, and K 40 contents of the southern chernozem layer is 1.3 to 1.5 times that in rock, apparently because of less intense removal by plants. In distinction from the leached soils, the U 238 accumulation in carbonate illuvial layers of the southern chernozems is small. Analytical data are tabulated. (B34)

INSTRUMENTATION

<372>

Fecher, R., and J.S. Jun, Oak Ridge National Laboratory, Health Physics Division, Oak Ridge, TN. 1976.

Transfer Dosimeters for Fast Neutron Sources. Physics in Medicine and Biology, 21(1), 52-59.

The increasing use of fast neutron sources in radiobiology, radiotherapy, etc. makes dosimetry intercomparisons (intercalibrations) by mail desirable. After comparing the relative advantages and disadvantages of the various available integrating fast neutron detectors, fission fragment track etching was chosen because such detectors can be made sufficiently small, rugged, fading resistant, inexpensive and accurate. Using several combinations of Th 232 or U 237 as fissile materials, and organic and inorganic track detectors, it was established that both automatic spark counting and visual track counting techniques can be developed to cover the desirable dose range (about 50-500 rad) with sufficient accuracy (signs equal or less than 5 percent). One possible source of errors is the overlapping size distributions of fission fragment and recoil particle tracks in organic films exposed at high neutron energies. Several approaches to reduce this problem are discussed. (Auth)

<373>

Gammage, R.P., G.C. Kerr, and L. Busley, Oak Ridge National Laboratory, Health Physics Division, Oak Ridge, TN; DePauw College, Ceflance, CN. 1975, December.

Exploratory Study of the Use of TSEE Dosimeters in Radon Monitoring. Health Physics, 29(4), 906.

Beryllium oxide (BeO) ceramic used as an electron emitter is a sensitive detector of alpha particles emitted by radon daughters. Laboratory tests with a device based on this principle show that it can be used to sample air in a uranium mine with a minimum sensitivity of about 1 PL-liter. Gamma radiation produces TL and TSEE signals whose intensities are of the same order of magnitude. Alpha radiation produces a TSEE reading two orders of magnitude more intense than the TL reading. After exposure to a radon containing atmosphere, both the TL and TSEE are read from the same BeO disk. The TSEE signal can subsequently be corrected for the effect of external photon radiation to obtain a response due to decay of the radon daughters. It remains to be seen if the TSEE dosimetry system can be adapted to withstand the rigors of a mine atmosphere and manipulation by mine personnel. (Auth)

<374>

Hiller, B.H., E.L. de Pont de Nemours and Company, Pigeons Department, Newport, NZ. 1966.

A Thoron Monitor. Health Physics, 12, 333-340.

A commercial ionization chamber device has been adapted and calibrated to serve as an accurate, rapid and convenient thoron monitor for experimental and health physics applications. Calibration was achieved by (1) deriving a general expression by which the alpha counting rates of two dust samples (prompt and delayed) can be interpreted in terms of the thoron concentration at the sampling point and (2) building and using a dual dust collector to obtain necessary data. The monitor can sense pure thoron concentration as low as 3.7×10^{-6} uc/l,

and can sense pure radon at 0.42 of its thoron sensitivity. (Auth)

<375>

Hodge, V.F., and R.E. Garney, Scripps Institution of Oceanography, Mt. Sealed Laboratory, La Jolla, CA. 1975, September.

Semi-quantitative Determination of Uranium, Plutonium, and Americium in Seawater. Analytical Chemistry, 47(11), 1066-1069.

A semi-quantitative method for estimating the concentrations of alpha emitters (uranium, plutonium, and americium) in contaminated seawater has been developed. These radioelements can be precipitated from seawater by the addition of small amounts of sodium hydroxide. Uranium, plutonium, and americium have now been found to plate directly from the dissolved precipitate onto stainless steel planchets, with high yields, in a form suitable for high resolution alpha counting--thereby avoiding the time-consuming isolation and purification procedures usually employed. (Auth)(UD)

<376>

Kotrappa, P., D.P. Bhandi, and V. Dhondayathan, Bhabha Atomic Research Center, Health Physics Division, Bombay, India. 1975, July.

Diffusion Sampler Useful for Measuring Diffusion Coefficients and Unattached Fraction of Radon and Thoron Decay Products. Health Physics, 29, 155-162.

A diffusion sampler is designed based on Mercer's theory of diffusional deposition from a fluid flowing rapidly between two coaxial, parallel circular plates. Experimental measurement of the diffusion coefficient for Th-B atoms indicated that the distortion of the flow patterns at the entrance and at the vicinity of the exit does not have a significant effect. It is, therefore, useful for measuring the diffusion coefficients. The diffusion coefficient for the Th-B atoms measured in condensation nuclei free atmosphere comes out to be 0.055 cm²/sec. This instrument when used at a sampling rate of 1.41 l/min is found to collect 65% of the unattached decay products of thoron on the collection plates suitable for direct analysis. It is, therefore, useful for measuring the unattached fractions of radon and thoron decay products in mines and mills, a measurement of significance in assessing the hazards of radon and thoron. Such measurements done in thorium processing areas indicated an unattached fraction as defined by ICRP to be (0.027 plus or minus 0.021)% compared to 0.05% assumed by ICRP in arriving at the HPCs for thoron. Data reported also include the measured concentrations of thoron (Tn) and the ratios, Tn: Th-B: Th-C. (Auth)

<377>

Quao, V., J. Houk, and L. Yohr, EG&G, Santa Barbara Operations, Goleta, CA. 1976, February.

Low Background Germanium-Lithium Detector with Anticoincidence Veto Assembly (Revised). EGC 1103-2326 (Rev): 26 pp.

A low background gamma-ray counter for the assessment of environmental soil and vegetation samples is described. The manually operated Ge(Li) detector is capable of handling samples up to 350 g and 225 cm³ volume. The primary intent of this counter is

<1977>

BIBLIOGRAPHY

<1977> CCWT.

the determination of U, Th, K 40, and Cs 137 in soil samples obtained routinely during Aerial Radiological Measuring System (ARMS) surveys throughout the country. Calibrations have been performed with a variety of sources. Special attention was paid to volume source techniques in addition to the usual point source methods. Detectabilities in a 350-g sample are 0.03 ppm U, 0.09 ppm Th, 30 pCi K 40, and 3 pCi Cs 137. (NAP)

<1978>

Schlager, E.J., Colorado State University, Department of Radiology and Radiation Biology, Fort Collins, CO. 1978, March.

Integrating Radon Progeny Air Sampler. American

Industrial Hygiene Association Journal, 35(3), 165-174.

An air sampler that utilizes a thermoluminescent dosimeter to obtain a time-integrated measurement of airborne radon progeny was developed as a personal monitor for uranium miners. The sampler was adapted for use in homes in Grand Junction in connection with the uranium mill tailings survey. The requirements for a tamperproof, inexpensive sampler, with a noise level not exceeding 35 dB at one meter, introduced challenging design problems. The design, construction and subsequent operation of the samplers are discussed. (auth)

LEGAL AND POLITICAL ASPECTS

<379>

Foley, L.W. (Ed.), J.L. (Ed.) Zarris, and B.C. (Ed.) Pittman, Battelle-Pacific Northwest Laboratories, Richland, WA. 1976, December.

Assessment of Uranium and Thorium Resources in the United States and the Effect of Policy Alternatives. WP-20314; 166 pp.

Uranium and thorium resources in the U.S. are extensive but new and improved technology and higher prices are required before they will become economically viable. Five specific conclusions reached during this study were: 1) Reasonably assured uranium reserves recoverable at a 1976 forward cost of \$15/lb U308 should be adequate at least through 1985. 2) Uranium resources from conventional sandstone deposits recoverable at a 1976 forward cost of \$30/lb U308 should be adequate to the year 2000. Thorium resources should be adequate to supply all conceivable needs through the year 2000. 3) Capital and manpower resources may be inadequate in the near future. 4) Production capacity may be inadequate in the short term. Alternative policy options available to the Federal government to influence uranium supply can be classified into those options which primarily affect uranium price and those which affect the quantity of uranium available for domestic consumption. The most significant options are those which influence the quantity. The options include: 1) retention, or immediate elimination, of the policy excluding enrichment of foreign uranium for domestic use; 2) curtailment of uranium export; 3) government purchase and stockpile of foreign uranium; 4) changes in the availability of public lands for uranium exploration and production; and 5) changes in the 9235 content of enrichment plant tails. (BAP)

Section 6.5 deals with environmental effects of uranium mining and milling which includes biological rehabilitation of mined lands, biological disturbances of mining and milling, revegetation of mined land, radiocological aspects of fissile material, and demographic and geographic considerations.

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Kastner, J., U.S. Nuclear Regulatory Commission, Office of Standards Development, Division of Siting, Health, and Safeguards Standards, Washington, DC. 1976.

The Rationale for and Implementation of ALARA for the Nuclear Fuel Cycle. CONF-760806; Controlling Airborne Effluents from Fuel Cycle Plants, Proceedings of the NRS-ATCER Topical Meeting held in Sun Valley, Idaho, August 5-6, 1976, (pp. 11-1 - 11-9), 340 pp. (CONF-760806).

The U.S. Nuclear Regulatory Commission ensures that radiation exposures to the public are kept within established radiation protection limits and as low as is reasonably achievable (ALARA). Important steps in the process range from the issuance of a radiological impact assessment prior to the construction permit to establishment of relevant and sensitive monitoring programs to be activated prior to and during operation. The radiological impact assessment examines the pathways by which living organisms can be exposed to ionizing radiations from routine releases of gaseous and airborne particulate effluents, as well as from liquid effluents. The assessment includes a calculation of anticipated radiation doses from each pathway and source for humans and other organisms. The implementation of ALARA for environmental exposures requires a cost-effectiveness analysis of effluent control technology which may or may not be quantifiable on a generic basis. In the case of light water reactors, NRC has been able to develop generic numerical design objectives that are amenable to the same cost-effectiveness analysis regardless of the station and site. On the other hand, from the lessons learned in the process of rulemaking for the control of releases from LWRs, it seems that for the time being application of the principle of cost-effective control of effluent releases from other components of the nuclear fuel cycle will have to be carried out, as in the past, on a case-by-case basis. (Auth)(VC)

MEDICAL ASPECTS

<381>

Abbott, J.P., Department of National Health and Welfare, Radiation Protection Division, Ottawa, Ontario, Canada. 1967, December.

Leukemia and Other Fatal Blood Dyscrasias in Thorium Dioxide Patients. *Annals of the New York Academy of Sciences*, 145(3), 767-775; CCRP-660422; Distribution, Potention, and Late Effects of Thorium Dioxide, R.L. Swann (Ed.), Proceedings of a Conference held in New York, New York, April 20-22, 1966, (pp. 767-775), 336 pp. (CCRP-660422).

The history of hematologically oriented epidemiological studies on Thorotrast is briefly reviewed, and the sources and nature of recent data from current surveys is assembled. Fatal blood diseases have been reported due to leukemia and a group of nosoleukemic but fatal blood dyscrasias, most of which are aplastic anemia. These conditions occur with a long latent period of 15-17 years. The contrast between external "radiation" leukemias, "latent" period of 5-7 years and "internal" radiation (from internal emitters), "latent" period 15-17 years, is noted. The difference is probably related to quality factors of radiation and to dose rate. It is suggested that miscellaneous "blood dyscrasia deaths" are misdiagnosed and are probably aberrant forms of leukemia. It is also concluded that long-term low-dose radiation as opposed to acute irradiation, does not produce hypoplasia and aplastic anemia. This interpretation is consistent with both the ankylosing spondylitic data as well as that derived from Thorotrast studies. The question of risk, particularly for extrapolation is briefly discussed and it is concluded that a combined and controlled collaborative study is necessary for a valid estimate of the incidence of long-term hematological effects after Thorotrast: physical dosimetry is complex but probably adequate for such a study; diagnostic criteria must be established and coordinated within such a study to how if dyscrasia deaths have been misdiagnosed. Thorotrast data suggest that development of leukemia in people with appreciable Sr 90 burdens may be just as or more likely than development of osteogenic sarcoma. (Auth)(VC)

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Abbott, J.C., Department of National Health and Welfare, Health Protection Branch, Human Cytogenetics Division, Ottawa, Ontario, Canada. 1973, June.

Human Leukemic Risk Data Derived from Portuguese Thorotrast Experience. CCRP-720505; Radionuclide Carcinogenesis, C.L. Sanders, et al (Eds.), Proceedings of the 12th Annual Hanford Biology Symposium held in Richland, Washington, May 10-12, 1972, (pp. 451-464), 500 pp. (CCRP-720505).

Thorium dioxide in colloid solution injected for radioactive contrast purposes was widely used throughout the world up to 1945. The Portuguese population of 2028 individuals who had been injected between 1930 and 1955 with such a solution for radiographic purposes has been identified and traced together with an approximately matched control population. This population and its fate have been reviewed again up to the end of Dec. 31, 1970, and more adequate risk data are now available. They indicate that in the population investigated the risk of developing an acute fatal blood dyscrasia following the systemic injection of Thorotrast is a 12- to 16-fold increase in

risk over the natural risk of developing such diseases. This is to be compared with a 6- to 8-fold increase over the natural risk of developing leukemia in therapeutically irradiated ankylosing spondylitics. Portuguese data are of particular interest because, in addition to providing risk data, they also provide evidence that under the conditions of irradiation obtaining in this population the period between the injection of the Thorotrast and the development of first symptoms and signs of leukemia is very long. In the Thorotrast patients this period is about 20 years, which may be compared to a 5- to 7-year period observed in the ankylosing spondylitics and Japanese bomb survivors. The incidence of lung cancer is not markedly elevated, and the incidence of osteogenic sarcomas is only slightly elevated over the expected incidence. This latter observation is at variance with a number of predictions made in the past. In addition to data on the acute fatal blood dyscrasias and those types already mentioned, there is a wealth of information now available on the induction of fatal primary mammary adenocarcinomas, particularly hemangioendotheliomas of the liver and spleen. This information on local tumor induction is compatible with the hypothesis of cancer induction by "cancerization."

See also *Journals, Lancet*, 1965, and *Proceedings of the New York Academy of Sciences*, 1967

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Moss, W., and W.L. Spoor, National Radiological Protection Board, Harwell, Didcot, Oxon, England. 1974, July.

Kidney and Bone Retention Functions in the Human Metabolism of Uranium. *Physics in Medicine and Biology*, 19(4), 460-471.

The retention of uranium by bone and kidney has been re-evaluated taking account of recently published data for a man who had been occupationally exposed to natural uranium aerosols and for adults who had ingested uranium at the normal dietary levels. For lifetime occupational exposure to uranium aerosols the new retention functions yield a greater retention in bone and a smaller retention in kidney than the earlier ones, which were based on acute intakes of uranium by terminal patients. Hence bone replaces kidney as the critical organ. The occupational (MPC) values for U 238 and the (MPC) values for U-nat based on radiological considerations using the ICRP (1959) lung model and the new retention functions are slightly lower than for the earlier ones. For U 238 the (MPC) value determined by chemical toxicity remains the more restrictive. (Auth)

Occupational (MPC) values for U 238, U 235 and U-nat (mCi cm³) and critical values for (MPC) values with bones and kidneys as reference organs are listed in tabular form.

<384>

Albert, B.E., New York University Medical Center, Institute of Environmental Medicine, New York, NY. 1966, November.

Inhalation Hazards. Thorium: Its Industrial Hygiene Aspects, Chapter 7. Academic Press, New York, New York, (pp. 84-113), 222 pp.

The various factors determining radiation hazard from inhaled Th and thoron decay products are discussed. Particular emphasis is on the dose from radioactive particles in

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<182>

MEDICAL ASPECTS

<184> CURT.

the lung and the relationship of the lung dose to radiation injury. Deposition of inhaled Th particles tends to be in the upper respiratory tract. Deposition of thoron and radon daughters depends largely on particle size distribution of the aerosol to which they are attached. Numerous specific data related to distribution, retention, and clearance are graphically presented. Doses, dose-response relationships, and radiation-induced fibrosis and cancer are discussed. Epidemiological data indicate that exposure for many years to radon at about 10 (E-9) c/l produces a high risk of cancer. There are only suggestive data on the Ra levels that will not produce an added lung cancer risk. The lung dosimetry from radon and thoron is not well established. Current estimates indicate the bronchial dose for equivalent air levels of radon R, radon C, thoron B, and thoron C is about the same. One study of a Th refinery did not demonstrate definite evidence of radiation injury in a comparatively few long-term workers. (Auth) (VC)

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Albert, H.F., New York University Medical Center, Institute of Environmental Medicine, New York, NY. 1966, November.

Skeletal Hazards. Thorium: Its Industrial Hygiene Aspects, Chapter 8. Academic Press, New York, New York, (pp. 114-135), 222 pp.

Standards for Th are based on data from skeletal radiation injury. The MPC of soluble Th 232 is 10 (E-12) uc/cu cm; the hazard is similar to that of Pu 239. Bone-seeking isotopes such as Th deposit on mineralized surfaces, especially endosteum, around trabeculae, and in vascular channels. Surface deposits may be buried by new bone or resorbed. Distribution of isotopes (e.g., Ra, Sr) is non-uniform with localization in areas of growth. A diffuse, less concentrated component is more uniformly distributed. Because of distribution factors, and their variation with time, bone dosimetry is complex. Dose is usually calculated assuming uniform distribution in the skeleton. Skeletal radiation injury is similar in man and animals. Patients receiving high Ra levels have widespread histological lesions including prominent vascular injury, bone necrosis, fibrosis, scarring of bone marrow, calcification, ossification, and, in severe cases, pathological fractures after minimal trauma. Skeletal damage is correlated with Ra body burden and occurs at lower doses than do tumors. In skeletal cancer, dose response relationships are non-linear. In mice, tumorigenic effectiveness of Ra 226 is 5-50 times that of Sr 90 depending on incidence level. In beagles, Th 228 is 10 times more carcinogenic than Ra 226, and Pu is 5 times more so than Ra 226. In human Ra cases and dial painters, most bone tumors are sarcomas. Incidence is correlated with body burden. The lowest teratoma burden reported is 0.45 uc Ra 226 with a 22-yr latent period. In Thorotrast patients, a rare liver tumor, hemangioendothelioma occurs. Overall tumor incidence is low (83% cases, 21 cancers in 10 yrs). The average patient has 4 g Th, equivalent to 0.40 uci Th 232 (equivalent to 0.5 uc Ra 226). No bone tumors were reported. Bone cancer risks at low radiation levels are discussed. The incidence from a burden of 0.1 uc Ra 226 could be 1-20 times the normal bone cancer incidence. (VC)

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Altshuler, B., B. Nelson, and T. Fanchner, New York University Medical Center, Institute of Environmental Medicine, New York, NY. 1966, December.

Estimation of Lung Tissue Dose from the Inhalation of Radon and Daughters. "Health Physics, 12(12), 1137-1171. (COWP-561); Inhaled Radioactive Particles and Gases, Proceedings of the Hartford Symposium held in Richmond, Washington, May 4-7, 1964, (26 pp.) (COWP-561).

The radon hazard is presumed to be lung cancer induced by alpha irradiation of basal cells in the bronchial epithelium. The effective dose is calculated by a relatively complete analysis which includes (1) the distribution of atmospheric activity by size and daughter, (2) the prediction of alpha decay in the bronchial regions from a model of mucus flow superimposed on calculated regional deposition, (3) measurements of epithelial thickness to determine accessibility of basal cells, and (4) classification of dose by inhaled daughter size, alpha particle, region, and tissue depth. The cancer-related dose, taken as the largest dose to exceptionally shallow basal cells, associated with one working level of radon daughters is estimated to be 20 rads/yr for nose breathing at 15 l/min, and it may be higher. Comparison with animal experiments suggests that the working level may not be safe and that 10 pc/l of daughters (2.1 WL) may not be too conservative for the MPC. (Auth)

<187>

Avory, H.I., and B.F. Busch, Walter Reed General Hospital, Radiological Service, Washington, DC. 1966.

Perivascular Injection of Thorotrast and Its Sequelae. Radiology, 51, 831-839.

Seven case histories involving Thorotrast injection into perivascular tissues during attempted arteriography are reviewed. In six, the involved tissue was in the neck, with subsequent Thorotrast movement down fascial planes into the mediastinum. In one case, injection was into the arm. Symptoms of fibrosis and scarring were present in three cases. Two cases had no symptoms at three and seven months, respectively and one patient had only minor neck pain at eight months after injection. However, symptoms generally worsened and finally resulted in disability after longer periods of time. Roentgenologic results were similar in all cases. Irregular calcific like densities were in soft tissues (possibly myositis ossificans after large doses). Distribution in fascial planes and the small associated nodules are diagnostic. Progressively increasing density, sizes of areas, and nodularity in later films are also diagnostic. Biopsies revealed cellular fibrosis with collagenous degeneration and hyalinization with scattered refractile granules (both intra- and extracellular). In 2 cases, the alpha radiation measured could account for the progressive, irreversible tissue destruction. Apparently, radiation from Thorotrast has more potential dangers than advantages. Its use as a contrast medium for clinical radiology should be discontinued. (VC)

<188>

Andreeva, O.S., and N.S. Egorova, 1973.

MEDICAL ASPECTS

<389> CONT.

Assessment of the Content of Concentrated and Natural Uranium in the Body and Critical Organs. *Cigars i Sanitariya*, 39(3), 53-58.

Assessment of uranium content in the body of workers and comparison of the data obtained with the permissible standard levels may serve as a reliable criteria of hygiene labor conditions and bases for organizing necessary preventive measures. (Trans.)

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Archer, V.E., R.F. Brinton, and J.K. Wagoner, U.S. Public Health Service, Division of Occupational Health, Occupational Health Field Station, Salt Lake City, UT; U.S. Public Health Service, Division of Occupational Health, Biometrics Section, Washington, DC; National Cancer Institute, Epidemiology Branch, Bethesda, MD. 1964, December.

Pulmonary function of Uranium Miners. *Health Physics*, 10(12), 1183-1198.

Analysis has been made of several ventilatory function field measurements made on uranium miners in 1957 and in 1960. Results show that cumulative exposure to the atmosphere in uranium mines adds to the loss in ventilatory function which results from aging and from cigarette smoking. The data indicate that high radon daughter levels are associated with transient improvement in ventilatory function. Two possible explanations of this "transient improvement" are discussed. Long exposures within uranium mines are definitely detrimental to ventilatory function. (Auth)

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Abb, J.C., R.C. Evans, L.W. Kneppelmann, and H.S. Bartland, Massachusetts General Hospital, Boston, MA; Massachusetts Institute of Technology, Department of Physics, Cambridge, MA; University of Rochester, School of Medicine and Dentistry, Division of Experimental Radiology, Rochester, NY; City Hospital, Office of the Chief Medical Examiner, Newark, NJ. 1952.

The Late Effects of Internally-Deposited Radioactive Materials in Man. *Medicine--Analytical Reviews of Internal Medicine, Dermatology, Neurology, Pediatrics and Psychiatry*, 31, 221-329.

Part 1 of this report deals with the late effects of internally deposited Ra and HsTh in 30 patients. Most of the individuals were exposed at least 25 years ago. Standardized measuring techniques were employed. Chronic poisoning by Ra, alone or combined with HsTh, is characterized by bone destruction, often complicated by infection, and neoplasms in or near the bone. Roentgenograms from 22 of 26 cases who stored 0.7 micrograms or more Ra were obtained. All but one showed evidence of radiation osteitis. Of the 26 patients whose Ra content was 0.7 micrograms or more, 21 had symptoms believed to be due to internally deposited radioactive materials such as jaw disease, pathological fractures, neoplasms, and osteomyelitis. The illness of the patients containing large amounts of Ra (8 to 23 micrograms) was more severe than that of patients containing smaller amounts (0.7-7 micrograms). Ten of the patients in this series have died. Death in seven of the cases was due to neoplasms. The latent period between exposure to the radioactive materials and appearance of symptoms increased somewhat with diminishing Ra content except for patients with tumors. Part 2 of the study deals with physical

aspects of Ra and HsTh toxicity. Physical and chemical properties of HsTh, units and standards, HsTh content of self-luminous compounds, body gamma radiation due to HsTh, measurements of Ra and Th exhaled by patients, Th measurements on biological samples, relative radiation dose due to HsTh and Ra, and average radiation dose due to alpha radiation are discussed. (SAP)

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Blanchard, B.L., and J.B. Moore, T.S. Environmental Protection Agency, Radiation Office, Radiological Engineering Laboratory, Cincinnati, OH. 1971, October.

Body Burden, Distribution and Internal Dose of Lead 212 and Polonium 210 in a Uranium Miner Population. *Health Physics*, 21(4), 499-518.

Concentrations of Pb 210 and Po 210 in tissues from 41 uranium miners and 11 unexposed individuals are reported. The tissues studied were bone, liver, lung, kidney, spleen, testes, heart, muscle, pancreas, lymph nodes, small intestine, stomach, aorta, brain, spinal cord, adrenal gland, prostate, thyroid and blood. Observations relative to individual tissue types are discussed, and comparisons are made between the levels observed in the exposed and unexposed populations. Relative tissue concentrations and the fractional body burdens of each tissue are determined. The largest amount of Po 210 and Pb 210 in the body was observed to be in skeleton, about 78%, while the important soft tissue reservoirs were the lung, liver, muscle, lymph nodes, kidney and blood. Body burdens of the miners were 4-50 times those of the non-miners, approaching 37 nCi and 23 nCi Po 210; the latter was 46% of the maximum permissible body burden. The dose calculated for Po 210 to bone assuming an ICRP of 10 and a relative damage factor of 5 may exceed in some cases the maximum permissible dose-rate of 30 rem/yr. The doses to soft tissues were in all cases below the maximum permissible limits set by ICRP. Relationships observed between the concentrations of Pb 210 and Po 210 in the blood and various body organs are discussed, and the results indicate that blood may be a reasonable index of these nuclides in the body. (Auth)

Exposure data of uranium miners and non-mining adult males sampled include age, exposure (WLM), end of mining to death (yrs), uranium mining (yrs), hard rock mining (yrs), cigarettes smoked per day, and years of smoking.

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Blomberg, R., L.E. Larsson, B. Lindell, and E. Lindgren, National Institute of Radiation Protection, Stockholm, Sweden. 1967, December.

Late Effects of Thorotrast in Cerebral Angiography. *Annals of the New York Academy of Sciences*, 145(3), 853-858; CONF-660422; Distribution, Retention, and Late Effects of Thorium Dioxide, R.L. Swens (Ed.), Proceedings of a Conference held in New York, New York, April 20-22, 1966, (pp. 853-858), 336 pp. (CONF-660422).

A follow-up study has been performed on part of a total material of about 1000 patients who received Thorotrast injections during the years 1932-1947. Twelve patients, half of the number with extravascular deposits, developed severe late complications at the site of injection. Nine cases of hepatic malignancy were found, the incidence

<192>

VEHICAL ASPECTS

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apparently being related to the amount of thorotrast injected. (Auth)

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Promer, F., and E. Fighi, CNR, Division of Health and Controls, Rome, Italy; CNR, National Laboratories, Frascati, Rome, Italy. 1973.

Toxicology of Transportable Uranium: A Critical Contribution to Health Protection of Workers. CNR-730907 International Radiation Protection Association, Proceedings of the 3rd International Congress held in Washington, D.C., September 9-18, 1973, Part 1, (pp. 736-742) (CNR-730907).

The chemical toxicity of uranium has a remarkable importance in the evaluation of the risk of internal contamination due to transportable compounds of this element. The risk becomes most relevant when one has to deal with natural uranium or long-lived uranium isotopes. The maximum permissible concentrations recommended by ICRP and the other limit values proposed are based on the results of experiments that, though complete and valid in their general outline, are affected by the limited technical possibilities available when effected. Since the possibilities of detecting and evidencing renal lesions are remarkably increased, it could be useful to review the problem of the chemical toxicity of uranium both on the basis of the advanced techniques available and on the experience gained in the field of health protection in nuclear environments. In fact modern techniques allow a relatively easy detection of even slight modifications and of their characteristics; at the same time they permit to carry out the analysis of very small biological samples. In the present work it is also stressed that studies carried out on other renal toxic substances, like cadmium, are giving very interesting results. (Auth)

<194>

Fackton, K.L., and A.C. Langlands, Western General Hospital, MRC Clinical and Population Cytogenetics Unit, Edinburgh, Scotland. 1973, June.

The Edinburgh Thorotrast Series--Report of a Cytogenetic Study. CNR-730475; B130-294; Toxicity of Thorotrast, N. Faber (Ed.), Proceedings of the 3rd International Meeting held in Copenhagen, Denmark, April 25-27, 1973, (pp. 114-125) (CNR-730475, B130-294).

The study deals with cytogenetic damage in peripheral blood leukocytes of patients injected with thorotrast. By the end of 1972, there were 60 deaths, 19 (17.3%) cancer, 41 (37.3%) other causes; 8 of the cancer deaths were from primary liver tumors occurring 19-37 years post-injection of 18-78 ml Thorotrast. One death resulted from blood dyscrasia, 22 years after 30 ml of Thorotrast. An association between the number of chromosome breaks and the volume of Thorotrast had a correlation coefficient of 0.3121 (significant at the 5% level). Plotting the number of breaks in 100 cells from 41 patients as a function of ml Thorotrast x years since injection gave a coefficient of 0.3008 (significant at the 10% level). Confidence limits are wide and chromosome break frequencies are not good measures of dosimetry. Whole body counting of gamma emissions was done along with blood sampling and the two types of data were compared. There was no direct correlation

between these parameters. Of interest is the finding of lymphocyte clones in 3 Thorotrast patients. One suffered from blood dyscrasia and, after death, was found to have had lung cancer. Another was treated for bladder cancer and a third, who has 2 clones remains well. It is possible that clones may serve as early indications of developing malignancies. Further study is warranted. (VC)

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Radin, E., and J. Gershon-Cohen, Albert Einstein Medical Center, Northern Division, Department of Radiology, Philadelphia, Pa. 1956, June.

The Danger of Cancer from Thorotrast as a Diagnostic Medium. American Journal of Roentgenology, Radium Therapy and Nuclear Medicine, 75, 1188-1193.

Thorotrast, a radioactive, radiopaque agent has been shown by experimental work to be carcinogenic. The American Medical Association Council on Pharmacy and Medicine as well other authorities have repeatedly warned against the use of Thorotrast because of this danger. Despite this, Thorotrast is still used for easy diagnostic procedures in radiology, recommended in current literature, and advertised for multiple uses. The limited clinical evidence of its carcinogenicity is chiefly the result of the long latent period between injection and the appearance of malignant changes. This accounts for the relatively few cases of malignancy reported. A direct causal relationship is difficult to prove even when the malignancy is at the site of residual retention. Two cases are presented, one of a breast carcinoma developing 17 yrs after local injection of Thorotrast and another of a cancer which appeared in the colon adjacent to a spleen heavily infiltrated with Thorotrast 16 yrs previously. Thorotrast should not be used at all in those instances where satisfactory alternatives are available, especially in such procedures as retrograde pyelography, arteriography, aortography, urography, etc. Its use in cerebral angiography should be restricted and its replacement by recently developed media should be accelerated. (Auth) (VC)

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Casper, J., Beilinson Hospital, Department of Pathology, Petah-Tiqva, Israel. 1967, December.

Peritoneal Mesangioendotheliosis after Salpingography with Thorotrast. Annals of the New York Academy of Sciences, 145(3), 798-805; CNR-660422; Distribution, Retention, and Late Effects of Thorium Dioxide, R.L. Sears (Ed.), Proceedings of a Conference held in New York, New York, April 20-22, 1966, (pp. 798-805), 336 pp. (CNR-660422).

A case is reported in which, after salpingography, Thorotrast was accumulated for years, mainly in the pelvic region. A diffuse tumor of the peritoneal serosa was induced: Thorotrast surrounding both ovaries caused pathological changes in them. Biopsy samples showed tumor nodules of varying sizes embedded, along with Thorotrast, in dense fibrous connective tissue. Tumors originated near Thorotrast deposits. The diagnosis, after microscopy was diffuse mesangioendotheliosis of the peritoneum. Mesothelial acites suggested that the lesion was proliferating and malignant. Other reports are briefly reviewed. The case presented here is unique, whereas sporadic

SPECIAL ASPECTS

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Development of diffuse hemangioendotheliomatosis of the peritoneum with rare hemangiosarcomas and hemangioendotheliomatous tumors related to Thorotrast deposits, particularly in liver and spleen, are well known. The proximity of tumors and Thorotrast imply that the tumors were produced by the radioactive material. The ovarian pathology was also probably related to radiation from the Thorotrast surrounding them. (VC)

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Casper, J., Beilinson Hospital, Department of Pathology, Petah-Tiqva, Israel. 1967, December.

The introduction in 1928-1929 of Thorium Dioxide in Diagnostic Radiology. *Annals of the New York Academy of Sciences*, 105(3), 527-529; CC9F-660822; Distribution, Retention, and Late Effects of Thorium Dioxide, R.L. Swarc (Ed.), *Proceedings of a Conference held in New York, New York, April 20-22, 1966*, (pp. 527-529), 336 pp. (CC9F-660822).

The history of Th dioxide use is reviewed. This compound, an excellent contrast medium because of its high atomic weight, positive charge in colloidal suspension, great stability, heat resistance and presumably low toxicity, was first used for radiography in man in 1928. Numerous German workers recognized the diagnostic value of Th dioxide and were not cognizant of the adverse effects resulting from radiation. As early as 1925, there were reports regarding the effects of radiation; these were in the English literature and were not utilized by German and Japanese workers. Thus, numerous papers emphasizing the advantages of Thorotrast as a contrast medium were published. It was many years before the serious effects, particularly neoplasms were seen and understood. The author states that "...if the German investigators in 1928 and 1929 had had better information about the American literature, thorium dioxide would not have gained such a widespread popularity and that these first investigators certainly would have recommended that this excellent contrast medium be used only with the utmost care." (VC)

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Chamberlain, A.C., and E.D. Dyson, Atomic Energy Research Establishment, Harwell, Didcot, Berkshire, England. 1966, June.

The Dose to the Trachea and Bronchi from the Decay Products of Radon and Thoron. *British Journal of Radiology*, 29, 317-325.

When air containing radon or thoron is breathed some of the decay products are deposited on the surface of the respiratory system, and the radiation from this active deposit then gives a dose to the epithelium. The alpha radiation is probably of greatest importance because of its relative biological efficiency and also because the alpha dose is so greatly localized. For this reason an estimate of the dose requires a knowledge of the distribution of the active deposit in different parts of the respiratory system, with particular reference to the bronchi where the majority of lung cancers are first seen. Recently it has become clear that the active deposit formed in the outside air and breathed in along with the radon or thoron contributes more to total dose than does the active deposit formed within the lung. This report investigates the deposition of the

decay products of radon and thoron on the epithelial walls on the human windpipe, larynx, and bronchi. (Auth) (BNC)

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Chhabra, A.S., Atomic Energy Establishment, Trombay, Bombay, India. 1966, February.

Radon 226 in Food and Man in Bombay and Kerala State (India). *British Journal of Radiology*, 39, 141-146.

Data are presented on the ^{226}Ra content of various food samples collected from Bombay city and high background areas of Kerala State in India. The experimental technique consisted in measuring the activity of the gaseous daughter product ^{222}Rn in a ZnS-coated alpha-scintillation counter. Comparison of data for the samples of these two areas, having wide differences in their background radiation level, shows that the Kerala samples have a ^{226}Ra ash content which is, on an average, a factor of five to ten times higher. An exception is the coconut sample which is grown profusely in Kerala State; this does not show a higher concentration of ^{226}Ra in spite of the higher availability of ^{226}Ra in the Kerala State soil. From a tentative model formulated for the food habits of the people of these two regions, their ^{226}Ra burden has been estimated. The determination of ^{226}Ra in bones and other organs of the human body indicates that a man from high background areas of Kerala State contains about ten times more of this radioisotope than a Bombay citizen. A value of 0.85×10^{-10} g/g ash of bone was found from direct measurements of a single subject from Bombay. (Auth)

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Costa-Pimenta, C., M.A. Barcinski, W. Pignatelli, E. Penna-Franca, W. Lobo, and R. Krieger, Instituto de Biofísica, Universidade Federal do Rio de Janeiro, Centro de Ciências Médicas, Ilha do Fundão, Rio de Janeiro, Brazil; Universidade de Brasília, D.F., Departamento de Genética, Brasília. 1975, March.

Radiobiological Aspects and Radiation Levels Associated with the Milling of Monazite Sand. *Health Physics*, 28, 225-231.

One of the chief problems in industrial radiological health in Brazil concerns 420 people in a plant processing monazite sand, a rare earth mineral containing up to 6 percent ThO_2 and 0.3 per cent U_3O_8 . Radiation hazards associated with ore concentration and chemical treatment were assessed by sampling and measurement of airborne radioactivity. Po 210 bioassay in urine and chromosomal analysis in peripheral blood lymphocytes collected from plant personnel. Results showed that Pb 212($t_{1/2} = 10.6$ hr) airborne concentrations range from 0.002 up to 3.9 pCi/l. A size distribution analysis showed that 68 per cent of Pb 212-bearing aerosols the mean count diameter is below 2.5 microns. Calculated values of airborne long-lived activity as Th 232 ranged from 6×10^{-6} up to 1×10^{-4} pCi/l. A few workers had a slight increase in the urinary concentration of Po 210, although results did not show a statistically significant difference between these values and those found in control population. Chromosomal analysis revealed a statistically significant difference in the yield of aberrations for the ore mill workers in one of the plant sections, showing the highest airborne Pb 212

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concentration. (Auth)

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Corry, J.L., W.G. Johnson, S.H. Feinberg, and J.B. Spiegoren, Eastern Hospital, Department of Radiology, Internal Medicine and Surgery, Boston, MA. 1975, November.

Thorium Induced hepatic Hemangioendothelioma. Roentgen-angiographic Findings in Two Additional Cases with Clinical Infirm and Consent Problem. American Journal of Roentgenology, Radiology Therapy and Nuclear Medicine, 125(3), 671-677.

Two additional cases of presumed, thorium-induced hemangioendothelioma occurring 26 and 28 years after cerebral angiography of the liver are reported. The angiographic pattern of large venous lakes conforms closely to the pathologic descriptions of this malignancy. To our knowledge, angiography of the thorotrast (and vinyl chloride) liver, before the clinical evaluation of malignancy, has not been recorded and may provide information of prognostic and therapeutic value. Incidental identification of thorium deposits in the tissues of clinically healthy patients creates perplexing "infirm and consent" problems. Presumably, these must be solved on an individual basis. Because of the use of Thorotrast has been discontinued since early 1950s, all physicians reviewing chest and abdominal roentgenograms should be aware of the characteristic appearance of human Thorotrast deposits, especially in the liver, spleen, and pelvic lymph nodes. The number of living thorotrast "carriers" and previous deaths from Thorotrast related malignancy seems highly uncertain at this time. (Auth)

<002>

Da Notta, L.A.C.B.C., Ministry of Health and Welfare, Directorate General of Health, Lisbon, Portugal. 1967, December.

Follow-Up Study of Portuguese Patients Given Thorium Dioxide in the Perineural Sinuses. Annals of the New York Academy of Sciences, 165(3), 811-816; CONF-660822; Distribution, Retention, and Late Effects of Thorium Dioxide, P.L. Swann (Ed.), Proceedings of a Conference held in New York, New York, April 20-22, 1966, (pp. 811-816), 336 pp. (CONF-660822).

Because carcinogenic local effects of thorium dioxide (thorotrast) deposits in man have been described and because of a few cases of malignant tumors of the perineural sinuses have been reported after instillation for radiological studies, it seemed advisable to survey the 500 cases who underwent this procedure in Portugal. Data on administration, age, and socioeconomic group are tabulated. Tracing and follow-up have been done on 177 patients (35.4%). 17 of these patients have died of causes not attributed to thorotrast. In some of the group has there been evidence of Thorotrast involvement. In these patients, the drug was eliminated naturally or artificially, a fact which probably explains why no local malignancies have been found. Preliminary results of a retrospective survey of 133 ENT specialists have revealed 70 patients with malignant neoplasms of perineural sinuses: none of these patients had ever received thorotrast. Similar results have been obtained from clinical archives of otorhinolaryngology departments in major Portuguese hospitals in the previous 20

years. The authors concluded that under the conditions used, thorotrast did not cause serious local or general side effects. They attributed the lack of effects to the fact that Thorotrast had not been allowed to stay in perineural sinuses for more than six days. (VC)

<003>

Da Silva Norta, J., L. Cayula De Norta, and V.S. Tavares, Faculty of Medicine, Pathology Department, Lisbon, Portugal. 1970, October.

Thorium Dioxide Effects in Man. Epidemiological, Clinical, and Pathological Studies (Experience in Portugal). Environmental Research, 8, 131-159.

The Portuguese Thorotrast series comprises 1230 traced individuals of a total of 2032 who received Thorotrast for diagnostic purposes between 1930 and 1955, and have been followed since then. Of these, 1039 received the drug systemically (most of them for cerebral angiography), and 191 locally. Among the 1230 traced cases, 901 individuals have died up to 31 December 1971, 23 from fatal blood dyscrasias (12 of which were acute leukaemias), 104 from malignant tumors, 64 of which were liver tumors, the hemangioendotheliomas being the most frequent histological type found; 23 from liver cirrhosis and 13 from the late effects of cervical granulomata occurring after cerebral angiography. The follow up of these cases and of 726 controls roughly matched for age and sex, and the statistical analysis performed on the results have shown that the incidence of malignancies to general, particularly of acute leukaemias and malignant neoplasms of the liver and of liver fibrosis was significantly higher among the traced Thorotrast cases than among the controls and the general Portuguese population, even allowing for the peculiarities of the diseased series, after correction of the respective death rates by a calculated factor. The clinical symptoms were frequently found among the patients still alive, besides the local complaints due to granulomata, were general gastrointestinal complaints and also pain in the right and/or left upper abdomen. Laboratory tests have disclosed an appreciable percentage of abnormal results of the protein electrophoresis, with low serum albumin (in 70% of the cases) and increased alpha 2 (in 67.7%) and gamma (in 69.6%) globulins and of an increased level of alkaline phosphatase (in 68.4% of the cases). In a few cases special studies, such as bone marrow, chromosome, and body burden determination studies have been made. The main morphological lesions found in pathological studies of this series (autopsies and biopsies) are local granulomata developed in the tissues where the drug had been spilled, liver fibrosis, and liver tumors. Of these, the most frequent types found are hemangioendotheliomas and cholangiocarcinomas. A multicentric hemangioendothelioma was found in the reticuloendothelial organs in 7 cases. Bone marrow lesions found have been leukaemias or aplastic anaemias. (Auth) (AP)

<004>

Da Silva Norta, J., and L.C. Da Notta, Faculty of Medicine, Pathology Department, Lisbon, Portugal; Ministry of Health and Welfare, General Directorate of Health, Medical Statistics Section, Epidemiology Branch, Lisbon, Portugal. 1967, December.

MEDICAL ASPECTS

<404> CCYT.

Follow-up Study of Thorium Dioxide Patients in Portugal. *Annals of the New York Academy of Sciences*, 145(3), 630-642; CONF-660422; Distribution, Retention, and Late Effects of Thorium Dioxide, N.L. Sears (Ed.), Proceedings of a Conference held in New York, New York, April 20-22, 1966, (pp. 630-642), 336 pp. (CONF-660422).

Provisionary main results of a follow-up study of more than 1,000 Portuguese patients who received ThO₂ are given. On the basis of epidemiological, clinical, pathological and other studies, the following side effects of thorotrast on man can be described: local fibrosis - Thorotrast granuloma; diffuse fibrosis, particularly of the liver; malignant tumors (sarcomas and carcinomas adjacent to big local deposits); and other malignancies such as hemangioendothelioma; leukemia, most of which are the acute myeloid or aplastic; dysproteinemia. The relationship between dose and some of the more serious results, as well as the implications of the different latent periods need to be considered in evaluation of the possibility of untoward side effects of thorotrast. The importance of follow-up studies is discussed. (VC)

<405>

Dahlgren, S., Karolinska Sjukhuset, Department of Pathology, Stockholm, Sweden. 1967, December.

Late Effects of Thorium Dioxide on the Liver of Patients in Sweden. *Annals of the New York Academy of Sciences*, 145(3), 718-723; CONF-660422; Distribution, Retention, and Late Effects of Thorium Dioxide, N.L. Sears (Ed.), Proceedings of a Conference held in New York, New York, April 20-22, 1966, (pp. 718-723), 336 pp. (CONF-660422).

Thorotrast was used as a contrast medium in Sweden during 1930-1945. Cases of liver malignancy began to appear in the 1960's; in a review of 1000 Thorotrast patients (1963), six had liver tumors. Ten cases of liver malignancy are reported here. Correlation of tumors with ThO₂ treatment requires that particles be found near the tumor, the latency period be sufficiently long, and the radiation dose sufficiently high. The tumor types reported here include adenocarcinoma, liver cell carcinoma, undifferentiated carcinoma, adenocarcinoma, and hemangioendothelioma. Doses, not known in all cases, ranged from 30-45 cc and latent periods averaged about 23 years (range 19-29 years). Four patients had, in addition, liver fibrosis and in five cases cirrhosis was found in connection with ThO₂ deposits. Most ThO₂ deposits were in the periportal connective tissue. Some patients also had alterations in the pancreas (fibrosis, diabetes mellitus, pancreatitis). A continuing study is planned for patients with Thorotrast cirrhosis and those who had large ThO₂ doses. (VC)

<406>

Dahlgren, S., Karolinska Sjukhuset, Department of Pathology, Stockholm, Sweden. 1967, December.

Effects of Locally Deposited Colloidal Thorium Dioxide. *Annals of the New York Academy of Sciences*, 145(3), 786-790; CONF-660422; Distribution, Retention, and Late Effects of Thorium Dioxide, N.L. Sears (Ed.), Proceedings of a Conference held in New York, New York, April 20-22, 1966, (pp. 786-790), 336 pp. (CONF-660422).

Of 1,000 cerebral angiographies with thorium dioxide done in Sweden between 1930-1945, an estimated 3% had extravasation. So far, 11 patients have had alterations of subcutaneous tissues in the neck after extravascular ThO₂ injection: ten of these had thorotrastomas; two had malignant tumors (neurofibrosarcomas) at injection sites; one had a metheloma associated with ThO₂ particles; in three cases there were necrotic ulcerations of the pharynx and associated problems. Appropriate average latent period was 20 years. In cases of ThO₂ in urethrography, two patients had leakage of contrast media from the urethra. Both cases developed squamous cell carcinoma of urethra with latent periods of 20 and 29 years. In cases in which ThO₂ was injected under the hard palate to study lymphatic anatomy, at least two patients developed granulomas as well as destruction of underlying bone. Systems of fistulas had developed to the maxillary sinus. Histology was similar to that of fibrotic thorotrastomas. Numerous micrographs are included; they illustrate the association of ThO₂ deposits with granulomas and carcinomas. (VC)

<407>

De Silva Norta, J., Faculty of Medicine of Lisbon, Pathology Department, Lisbon, Portugal. 1967, December.

Late Effects of Thorotrast on the Liver and Spleen, and their Efferent Lymph Nodes. *Annals of the New York Academy of Sciences*, 145(3), 676-699; CONF-660422; Distribution, Retention, and Late Effects of Thorium Dioxide, N.L. Sears (Ed.), Proceedings of a Conference held in New York, New York, April 20-22, 1966, (pp. 676-699), 336 pp. (CONF-660422).

More than 2000 persons in Portugal were injected with Thorotrast since 1930. The histology of late effects on liver and spleen and their efferent lymph nodes has been studied. Histological procedures used included: H & E, Unna-Papanicolaou, MacManus, Mallory, Kossa, VanGieson, Silver impregnation, Weigert fuchsin-resorcin for elastic fibers, and Weigert for fibrin. Dark field and direct fluorescence microscopy as well as autoradiography were used. Morphological observations are reported for spleen and liver fibrosis. Tumors discussed include hemangioendothelioma, reticular cell sarcoma, hepatoma, cholangiocarcinoma, and carcinoma of the extrahepatic bile ducts. Particular morphological observations on spleen and its lymph nodes are included. A classification of tumors in thorotrast-injected patients, a modification of that by Dahlgren is presented. The first group includes those tumors at the injection site: tumors at the edge of Th granuloma - sarcoma, carcinoma. Tumors may also occur after deposition of Thorotrast in cavities: carcinoma, sarcoma, and possibly mesothelioma. The third group includes tumors in individuals systemically injected with thorotrast. These tumors are: HES tumors, seen clinically as liver tumors (hemangioendothelioma, reticuloendothelioma); liver carcinomas - cholangiocellular carcinoma (cholangiosarcoma), hepatocellular carcinoma (hepatocarcinoma); extrahepatic biliary duct carcinoma; carcinomas of other organs. (VC)

<408>

De Silva Norta, J., Faculty of Medicine of Lisbon, Pathology Department, Lisbon, Portugal. 1967, December.

MEDICAL ASPECTS

<408> CCNY.

Effects of Colloidal Thorium Dioxide Extravasates in the Subcutaneous Tissues of the Cervical Region in Man. *Annals of the New York Academy of Sciences*, 145(3), 776-785; (CCNY-660422; Distribution, Retention, and Late Effects of Thorium Dioxide, R.L. Swarc (Ed.), Proceedings of a Conference held in New York, New York, April 20-22, 1964, (pp. 776-785), 336 pp. (CCNY-660422).

Thorotrast, injected into carotid arteries for visualizing cerebral blood vessels was sometimes extravasated and produced granulomas and malignant neoplasms in the adjacent soft tissues. Studies of the histogenesis of thorotrast granulomas have been done on 10 cases of cervical granulomas and 12 cases in which granulomas had not yet formed. The granulomas are tumor-like and fibrotic and of variable size. They may be calcified and adherent to adjacent structures. Surfaces are white and sometimes softening zones may be present. Microscopically, Thorotrast is present either free in the very dense connective tissue, or in histiocytes. Synthesis occurs early and various collagen modifications occur with time. Collagen disintegration occurs in areas with low levels of thorotrast. Tumors occur at the edge of cervical granulomas; two cases of spindle cell sarcoma are described. Symptomatology depends on the extension of granuloma, amount of thorotrast, the site of injection and the function of the adjacent structures. Symptoms in cases of cervical granuloma include dysphagia, pain, Claude Bernard-Horner syndrome, asphyria, hemorrhage, and cyclotherax. The fibrosis results from fibroblast proliferation. Thorotrast can spread, either by gravity or migration of histiocytes. Five reported cases of malignant neoplasms near thorotrast granulomas in Portuguese patients include two neck sarcomas, an adenocarcinoma of the common bile duct, liver carcinoma, and an undifferentiated carcinoma of rectum and sigmoid colon. (VC)

<409>

Tedley, R.A., International Atomic Energy Agency, Department of Research and Isotopes, Vienna, Austria. 1973, June.

Thorium Series Radionuclides in Compact Bone of Thorotrast Cases - Results of Measurements at IAEA. CCNY-730475; IIAO-294; Toxicity of Thorotrast, R. Faber (Ed.), Proceedings of the 3rd International Meeting held in Copenhagen, Denmark, April 25-27, 1973, (pp. 81-94) (CCNY-730475, IIAO-294).

The activity of thorium-series radionuclides in compact bone of Thorotrast cases is of interest because of the possibility of extracting skeletal dose-effect relationships in this population for comparison against similar data from populations containing Ra 226, Ra 228, or Ra 228. Estimates of activity levels in compact bone can be obtained directly from measurements on such tissues collected at autopsy, or indirectly from measurements on the release of radium isotopes from the primary Thorotrast deposits in other tissues combined with calculations of skeletal deposition based on the new ICRP model of alkaline earth metabolism in adult humans. Autopsy samples from 5 Thorotrast cases have been measured in the laboratory of the IAEA. The results of these measurements suggest that: (1) Th 232 concentrations (mCi/g wet tissue) in compact bone are about 7% of those in liver, 2) Ra 226 and Ra 228 translocate to compact bone in amounts about

equal to or less than those predicted by the ICRP model, and (3) Th 232 translocates to compact bone at dosimetrically inconsequential levels. The measured compact bone activities reside near the low end of the spectrum of previously reported results. (Auth)

<410>

Tedley, R.A., International Atomic Energy Agency, Vienna, Austria. 1967, December.

A Survey of Radiation Dosimetry in Thorium Dioxide Cases. *Annals of the New York Academy of Sciences*, 145(3), 595-607; CCNY-660422; Distribution, Retention, and Late Effects of Thorium Dioxide, R.L. Swarc (Ed.), Proceedings of a Conference held in New York, New York, April 20-22, 1964, (pp. 595-607), 336 pp. (CCNY-660422).

The paper presents an overview of problems, techniques and results of radiation dosimetry as related to Thorotrast burdens. Thorotrast dosimetry is important for work in the area of radiation protection and for understanding of radiation effects in liver, spleen, lung, skeleton, kidneys, lymph nodes, and blood. Problems associated with Thorotrast dosimetry include variation in distribution with different routes of administration, non-uniformity of distribution, self-absorption of alpha rays, and influences on dosimetric pattern of the ten isotopes following Th is the decay series. A variety of measurements are used in Thorotrast dosimetry. In living cases measurements can be made of gamma rays from the body. Such rays are useful for counting Ac 228, Pb 212, Tl 208. Spatial distribution can be roughly quantified by collimated scanning and x-ray coincidence methods. Studies on exhaled and excreted isotopes (e.g. Ra 226) give information about translocation of daughter products from primary deposits. Measurements at intervals down on extra can be extrapolated to activities present at excretion. Biopsy samples are also useful. Metabolic studies in man and animals give data about translocation of isotopes from blood to various organs. Measurements on tissue samples can provide the most reliable dosimetric data. Techniques include macroscopic assays of isotopes and their ratios and microscopic methods such as autoradiography, radiography, light and electron microscopy. Estimation of dose rates in tissues have been made using data from these techniques. A table of Th series activity and dose rate in various organs is included. (VC)

<411>

Duggan, E.J., National Radiological Protection Board, Belsont, Sotter, Surrey, England. 1972.

The Toxicity Classification of Thorium-232 and Uranium-232. *Health Physics*, 22, 102-103.

One of the most widely used classifications of toxicity of radionuclides and one that puts natural thorium (Th-232) and natural uranium (U-238) into the lowest toxicity group, is that published by the I.A.E.A. This classification considers inhalation to be the significant route of entry and it is argued that, because the dose due to a given intake is independent of the duration of the intake, the toxicity classification to be derived is equally valid for single or continuous intake. For each nuclide, the intake required to give the appropriate maximum permissible annual dose is calculated

MEDICAL ASPECTS

<810> CONT.

from the HPC, and this intake is expressed in terms of mms. It is then assumed that the mass likely to be inhaled during a year is no greater than that inhaled during a single short exposure (i.e. one lasting only about an hour) and that this mass is 10 mg. In consequence any nuclide for which the maximum permissible annual intake is greater than 10 mg is placed in the lowest toxicity group. This means that Th-232 and U-235 are in the lowest toxicity group, although considerations of HPC alone would place them in the highest group. It is possible, however, for an occupationally exposed worker to inhale the maximum permissible annual intake of Th-232 (which is only about 50 mg if the most restrictive HPC is used) in a period much less than a year; the same is true in respect of U-235 even though its maximum permissible intake is about 10 times larger, i.e. 500 mg. It is therefore concluded that in any toxicity classification of the radionuclides, which is to be applied in situations where continual exposure in industrial conditions is envisaged, both Th-232 and U-235 should be one of the more toxic categories and not (as in the IAEA classification) in the group of lowest toxicity. (auth) (BB)

<812>

Ivans, R.J., Massachusetts Institute of Technology, Cambridge, MA. 1966, May.

Radium and Mesothorium Poisoning and Dosimetry and Instrumentation Techniques in Applied Radioactivity. MIT-952-3: Annual Progress Report for 1965; 317 pp.

Studies on 56 cases of radium and/or mesothorium poisoning are reported as well as results of 9 exhumation studies. Two subjects have developed carcinoma of the sinuses during the past year. Alpha spectroscopy has been used for studying microscopic distribution of Ra and its daughters. Studies have been initiated on two willed bodies, cases previously under study by group members. Breath radon analysis has continued. Experimentation has been done to determine the relative absorption of Th to Ra in the human gastrointestinal tract. Each of a group of elderly men and women were given intravenously Ra 226 or Th 230, and metabolic studies on blood, urine, feces, breath samples, whole body and upper body with GI tract shielded were done. Whole body Ra retention decreases to 15% in 20 days; blood volume decreases to 0.3% in 4 days; Th in breath drops rapidly in 2 days and is 1.5% of the total in 20 days. Radium is excreted in feces, the feces:urine value averaging about 30. The time at which blood and skeletal specific activities are equal is approximately 75 days (range 40-150). Whole body Th retention is 90% at 2 months; in blood, Th is 0.3% in 10 days. Excretion is primarily in urine, the urine:feces value being 10 for males, 20 for females. There is a disproportionately smaller amount of Th in the upper body for males than for females. Ingestions studies indicated transport of 15-20% of Ra across the gut wall. The detection of Th transport is borderline at approximately 0.1% that of Ra. The absorption of Th 228 from dial paints in the 1920's was unlikely to have been high; in the painters, the contribution to the integrated radiation dose by the initially absorbed Th 228 is approximately 5% or less than that of Ra 226. The use of "minims" in the concept of pure Ra equivalent is no longer necessary and all

toxicity correlations can be evaluated in terms of pure Ra equivalent. Additional sections of the report include information on the following: General Radiobiology, Nuclear Physics, Instrumentation Techniques, Nuclear Geochemistry, and Publications. (VC)

<813>

Faber, R., Finsen Institute, Finsen Laboratory, Copenhagen, Denmark. 1973, June.

Jose Effect Relations in Myeloid Carcinogenesis. CONF-730475; NIS-294: Toxicity of Thorotrast, R. Faber (Ed.), Proceedings of the 3rd International Meeting held in Copenhagen, Denmark, April 25-27, 1973, (pp. 308-316) (CONF-730475, NIS-294).

A significant problem regarding Thorotrast-induced tumors is to what extent their effect is from the granules themselves as opposed to the radiation. Animal studies have shown the radiation effects to be significant in terms of latency periods and thus, probably also significant for rate of appearance of malignancies. Human data indicate the possibility that higher Thorotrast doses increase risk for tumors. For a number of reasons, calculation of precise radiation dose is difficult. At present, while it is possible to correct for some of these factors, it is not possible to do so for temporary ThO₂ uptake by hepatocytes. The dose to liver is considered in this treatment of dose dependency. Doses to liver from Thorotrast are as follows. Doses, in rads, are given for each case within the category. The first figure given is the cumulative dose, the second, the mean: dead without cancer, 38,655 and 328, 20,629 and 308, 55,284 and 318; dead from cancer (not liver or leukemia), 8,173 and 430, 8,333 and 394, 12,506 and 417; dead from leukemia, liver cancer, hemangioendothelioma, 6,270 and 427, 5,090 and 509, 6,000 and 600; living, 121,433 and 607, 121,126 and 618, 242,559 and 612. From these data, evaluation of the role of radiation as a carcinogenic agent is difficult. An attempt to give a risk estimate on the basis of calculated doses to the liver is presented. The results fit the published risk estimates for other types of radiation-induced tumors. The procedure for the calculation of absolute risk is given. The risk is calculated to be 0.02/10⁶ (±6) "persons"/year/Bq. Thus, results indicate that Thorotrast effects result from radiation rather than from toxicity of the colloid. (auth) (VC)

<814>

Faber, R., Finsen Institute, Finsen Laboratory, Copenhagen, Denmark. 1973, June.

Follow-Up of Danish Thorotrast Cases. CONF-730475; NIS-294: Toxicity of Thorotrast, R. Faber (Ed.), Proceedings of the 3rd International Meeting held in Copenhagen, Denmark, April 25-27, 1973, (pp. 137-147) (CONF-730475, NIS-294).

The temporary results of the follow-up of 1005 Thorotrast injected patients are presented. Thorotrast was used in Denmark from 1935 until 1947; the follow-up of the group was started in 1949. Observations obtained 25 years later showed an increase in leukemias and certain liver tumors. Two main groups of Thorotrast induced liver tumors were the haemangioendotheliomas and the more common hepatocellular carcinomas both with a latency period well above 15 years. Latency periods for leukemias ranged from 5 to 7

<418>

TECHNICAL ASPECTS

<419> CJPT.
years. (BAP)

<425>
Faber, H. (Ed.), Finssen Laboratory, Finssen
Institute, Copenhagen, Denmark. 1973, June.

Proceedings of the Third International Meeting
on the Toxicity of Thorotrast. CONF-730475;
NISC-294; Toxicity of Thorotrast, H. Faber
(Ed.), Proceedings of the 3rd International
Meeting held in Copenhagen, Denmark, April
25-27, 1973, 340 pp. (CONF-730475, NISC-294).

The papers presented at the Symposium on the
Toxicity of Thorotrast are arranged according
to the following areas: physics and dosimetry
of thorium daughters, biological effects,
follow-up and epidemiological surveys
including human and experimental
carcinogenesis. All thirty-one papers were
abstracted separately for the data base.
(BAP)

<436>
Faber, H., Finssen Laboratory, Copenhagen,
Denmark. 1967, December.

Thorium Dioxide Patient. in Denmark. Annals of
the New York Academy of Sciences, 145(3),
643-648; CONF-660422; Distribution, Retention
and Late Effects of Thorium Dioxide, R.L. Swann
(Ed.), Proceedings of a Conference held in New
York, New York, April 20-22, 1966, (pp.
643-648), 336 pp. (CONF-660422).

Thorotrast was used, primarily for cerebral
arteriography in Denmark from 1932-1947. A
follow-up of 1001 patients determined numbers
living, dates of deaths. The dead were
categorized as to whether death resulted from
1) neurosurgical disease 2) non-malignant
disorder or 3) malignancies. At present, the
numbers in 1) are equal to the total in 2)
and 3). In the case of neurosurgical
disease, the peak of mortality was during the
first year post-injection, whereas deaths in
the other groups were more evenly spread out
in time. Determination of cancer incidence
indicated no significant difference from the
general population, a result which may be
biased because of the small sample. One can
get more information by looking at tumor
type. There is a high incidence of
hemangioendothelioma, a tumor generally
limited to thorotrast cases. In addition,
leukemia incidence is high. Such facts
indicate that thorotrast is acting as a
carcinogen. Incidence of primary liver
tumors and lung tumors is also high. The
author concludes that a larger sample would
give more precise information. Surveys of
other Thorotrast cases are needed. The long
latency period (20 or more years) and the
increased cumulative incidence of cancer (the
curve rises steeply with time after
injection) indicate that a large increase in
malignancies, particularly liver tumors and
leukemia, can be expected in the coming
years. (VC)

<417>
Finch, S.C., Yale University School of Medicine,
New Haven, CT. 1967, December.

Recognition of Radiation-Induced Late Bone
Marrow Changes. Annals of the New York Academy
of Sciences, 145(3), 749-754; CONF-660422;
Distribution, Retention, and Late Effects of
Thorium Dioxide, R.L. Swann (Ed.), Proceedings
of a Conference held in New York, New York,
April 20-22, 1966, (pp. 749-754), 336 pp.

(CONF-660422).

Hematologic effects of radiation are
discussed. For acute, single doses, the
early acute changes occurring in the first
four to six weeks include pancytopenia,
degenerative and abnormal leukocytes,
disturbed leukocyte function, leukocyte
chromosome aberrations and altered leukocyte
chromosome numbers. Chronic low doses
produce no early acute changes. Later
subclinical changes for both acute single and
chronic low doses include lymphocyte
chromosome aberrations, abnormal leukocyte
mitoses, changes in lymphocyte morphology,
changes in leukocyte enzymes and metabolism,
possibly altered leukocyte function and
myeloproliferative changes. Late
irreversible changes (latent period 3-73
years) for both exposure types include
refractory (aplastic) anemia,
myeloproliferative disease (leukemia,
myelofibrosis, possibly polycythemia vera)
and possibly lymphoma. The difficulties
involved in detecting subtle changes are
discussed. Better understanding of the
effects of chronic low-dose irradiation may
be helpful in understanding pathogenesis of
myeloproliferative disorders. Several
questions which are medically challenging are
raised. One relates to possible early
identification of qualitative and
quantitative biochemical, enzymatic and
genetic changes prior to development of overt
diseases. Another question addresses the
problem of determining factors which increase
the threshold for radiation-induced disease.
(VC)

<418>
Fischer, L., E. Golob, E. Kuzel-Tell, and T.
Waller, Universitäts-Frauenklinik;
Universitäts-Institut fuer Allgemeine Biologie;
International Atomic Energy Agency, Section of
Medicine, Department of Research and Isotopes,
Vienna, Austria. 1967, December.

Chromosomal Aberrations in Thorium Dioxide
Patients. Annals of the New York Academy of
Sciences, 145(3), 759-766; CONF-660422;
Distribution, Retention, and Late Effects of
Thorium Dioxide, R.L. Swann (Ed.), Proceedings
of a Conference held in New York, New York,
April 20-22, 1966, (pp. 759-766), 336 pp.
(CONF-660422).

Twenty patients who were known to have
received Thorotrast about 19 to 27 years
previously, and whose residual body burden
has been measured by whole-body counting,
were examined for the presence of chromosome
aberrations in dividing cells from short-term
peripheral blood cultures. Aberrations were
present in 19 of the 20 persons examined. The
one patient in whom no aberrations were
observed had received Thorotrast for
retrograde pyelography. His residual body
radioactivity was very low. Statistical tests
of the data for evidence of a dose-effect
relationship revealed a significant
correlation between the number of chromosome
breaks and the radioactive body-burden. The
high rate of chromosome breakage, and its
possible relationship to radiation-induced
carcinogenesis in these cases is briefly
discussed. (Auth)

<419>
Fushbaugh, C.C., B.J. Cloutier, G. Hanson, J.
Langham, and S. Gutzik, Oak Ridge Institute of
Nuclear Studies, Oak Ridge Division, Oak Ridge,
TN; Los Alamos Scientific Laboratory, Health
Division, Los Alamos, NM; Dow Chemical Company,

TECHNICAL ASPECTS

<419> CCNY.

Parky Flats Division, Medical Department,
Golden, CO. 1967, December.

Histopathologic Study of Intrafemoral Plutonium
Metal Deposits: Their Conjectured Fate. *Annals
of the New York Academy of Sciences*, 145(3).
191-197. CCNY-660427; Distribution, Retention,
and Late Effects of Thorium Dioxide, S.L. Swann
(Ed.), *Proceedings of a Conference held in New
York, New York, April 20-22, 1966*, (pp.
11-797), 336 pp. (CCNY-660427).

Autorecographic and histologic study of
eight femoral lesions, caused by accidentally
implanted particles of metallic plutonium,
revealed that a minute granuloma resulted in
which, after four or more years, collagenous
fibrinogenesis and liquefaction occurred. A
comparison of the lesions with granulomatous
and fibrotic lesions induced by Thorotrast
suggested that softening of the granuloma in
the thorium cases was more likely due to the
chronic effect of the radiation exposure of
the blood vessels than to the collagen fibers
themselves. The breakdown of collagen fibers
around Pu deposits, however, seems to be
related to the relatively enormous dose rate
to which these fibers are exposed. (Auth)

<420>

George, A.C., and A.J. Broskin, Health and
Safety Laboratory, New York, NY. 1967.

Deposition of Natural Radon Daughters in Human
Subjects. *Health Physics*, 13, 375-378.

The fractional deposition of radioactive
particles inhaled by humans was determined by
scintillation counting. The breathing
apparatus consisted of a modified filter
respirator, rubber bag, sample filter holder,
air flow meter, and air pump. Measurement of
such deposition is important for estimating
radiation doses to the body organs. The
percent deposition of radon daughters from
New York City air in the respiratory systems
of four subjects averaged 27.4, 27.9, 33.1,
30.6, 42.5. Averages in two subjects
breathing nasally versus orally were
respectively for one, 27.9, 21.6 and for the
other, 42.5, 39.7. In tests with one subject
breathing at different rates, the fraction of
radon daughter particles being deposited
tended to increase from an average of 28.7%
during a normal interval after inhalation and
before inhalation (0.5-1.0 sec) to 42.5% with
a breath holding time of 4 sec. (VC)

<421>

Geldin, A.S., P.J. Nagao, V. Geiger, and H.L.
Janover, Northeastern Radiological Health
Laboratory, Winchester, MA; Massachusetts
General Hospital, Boston, MA. 1972, May.

Radionuclides in Autopsy Samples from Thorotrast
Patients. *Health Physics*, 22, 471-482.

The radionuclide content of various organs of
two Thorotrast patients was measured. Gamma
spectrometric determinations less than 24
hours after death were made. In one case,
the highest concentrations of Ra 226, Th 228,
Ra 224 and Pb 212 were found in the spleen
(1369, 1205, 1085, and 878 pCi/g,
respectively) and in the periportal lymph
node (983, 851, 716, and 433 pCi/g,
respectively). Corresponding high values,
listed in the same order, in the other case
were, for spleen, 729, 637, 501, and 122
pCi/g and for the periportal lymph node,
1391, 1213, 1094, and 870 pCi/g. Th 232 and
228 were determined radiochemically and by

alpha spectrometry, as was Th 230. One-third
of the Ra 226 formed remained in the body.
About 10% of the Th 228 and 29% of the Ra 224
were eliminated. Relatively high
concentrations of Th 232 were found in
cortical bone (31 and 47.3 pCi/g in the two
cases); the ratio of this nuclide to Th 228
was the same as in other organs. The high
levels of Pb 212 in the blood strongly
suggested that substantial amounts of Ra 226
migrated from the organs into the blood.
Highest radionuclide levels were in liver,
spleen, and periportal lymph nodes while
lower levels were present in marrow and
cortical bone. Dosimetry was estimated,
tabulated and discussed. With
self-absorption corrections, the absorbed
doses in one case varied from 9 rad/yr to
bone to 169 rad/yr to spleen and, in the
other case, from 11.5 rad/yr to bone to 294
rad/yr to periportal lymph node. There are
considerable variations in the dosimetry as
well as distribution of nuclides between the
two cases. (VC)

<422>

Geldin, A.S., P.J. Nagao, R.E. Kauffman, and
C.I. Coats, U.S. Public Health Service,
Northeastern Radiological Health Laboratory,
Division of Radiological Health, Winchester, MA.
1967, December.

Measurement of Thorium and Daughter Products in
Tissue: Effect of Time on the Results. *Annals
of the New York Academy of Sciences*, 145(3),
654-659. CCNY-660427; Distribution, Retention,
and Late Effects of Thorium Dioxide, S.L. Swann
(Ed.), *Proceedings of a Conference held in New
York, New York, April 20-22, 1966*, (pp.
654-659), 336 pp. (CCNY-660427).

General principles relating to tissue
analysis as well as data on samples from two
autopsies are discussed. The 11
radionuclides of the Th decay series have
varying chemical properties, half-lives, and
energies. Almost all have half-lives long
enough to allow movement in the body; only
two polonium isotopes decay where they are
formed. Dosimetry is greatly influenced by
isotope movements between and within organs.
Five potentially separated alpha sources are
Th 232, 228, Ra 226, Ra 228-Po 216, Bi 212
and Po 212. The effects of different
half-lives on analytical determinations as a
function of time are tabulated. In samples 1
month old, only Th 232, Ra 226 and Th 228 can
be considered as independent entities. All
other isotopes are in equilibrium with their
parents. At earlier times more isotopes can
be independently determined. Another
complication is that, for repetitive
measurements over time only Th 232, Ac 228
and Pb 212 can be measured directly; the
rest, except Th 232 can be determined
indirectly. After these determinations, Th
232, 228 and Ra 226 can be chemically
determined in ashed samples. Data from
autopsy samples, in one case 35 hrs after
death, then at intervals, and in another at
28 hrs and then at intervals, are tabulated.
Samples were from spleen, liver, heart,
kidney, and bladder. It would be desirable
to have bone, lung, lymph node, and blood
samples and to carry out analyses within a
few hours of death. (VC)

<423>

Gottlieb, A.I., H.E. Kirk, and J.L. Hutchison,
Montreal General Hospital, Departments of
Pathology and Hematology, Montreal, Canada;
McGill University, Department of Pathology,
Montreal, Canada. 1976, September.

<423>

TECHNICAL ASPECTS

<423> CONT.

Hodgkin's disease following Thorium dioxide angiography. Canadian Medical Association Journal, 115(5), 833-834.

Hodgkin's disease occurred in a 53-year-old man who, 21 years previously, had undergone cerebral angiography, for which thorium dioxide suspension (Thorotrast) was used. Deposits of thorium dioxide were noted in reticuloendothelial cells in various locations. An association between thorium dioxide administration and the subsequent development of malignant tumors and neoplastic hematologic disorders has previously been reported. (Auth)

<424>

Crampa, G., 1971.

Radiation Injury with Particular Reference to Thorotrast. Pathology Annual, S. Sommers (Ed.), Vol. 6, (pp. 147-169).

The lesion most frequently observed after Thorotrast injection is fibrosis, both local and diffuse in the organs where Thorotrast is deposited (liver, spleen, lymph nodes and bone marrow). Thorotrastoma, a distinctive form of fibrosis is produced by extravascularly deposited thorium dioxide. The majority of cases of thorotrastoma are located in the cervical region, as cerebral angiography is by far the most frequent diagnostic procedure involved. The most severe damage induced by Thorotrast is the development of malignant tumors of the liver, kidneys, and other organs. Approximately 200 pathologically confirmed cases are reported. Over half of these tumors are located in the liver. A definite correlation between the amount of the contrast medium and the development of hepatic tumors was found. In peripheral granulocytes of persons treated with Thorotrast, chromosomal aberrations and polyploid cells have been observed. Thorotrast-induced lesions resemble closely the lesions induced by other radioactive substances. Tissue reactions however are not different than those from other fibrogenetic substances. Radiation could therefore reinforce a nonspecific foreign body tissue reaction; fibrosis may, in part, be related also to the property of ThO₂ to become bound to serum albumin. (RAP)

Histautoradiographs of fibrosis of the liver and spleen, Thorotrast deposition in bone marrow, liver hemangioendothelioma, cervical thorotrastoma, cholangiocellular carcinoma, and fibrosarcoma are shown.

<425>

Grillmair, R., H. Nuth, and E. Oberhausen, Universitaet des Saarlandes, Institut fuer Physik, Saarburg, German Federal Republic, 1972.

Measurement of Thoron in the Breath of Thorotrast Patients and Evaluation of the Results. CERN-711104; STI/PSI/290; Assessment of Radioactive Organ and Body Burdens, Proceedings of a Symposium held in Stockholm, Sweden, November 22-26, 1971, (pp. 473-485) (CERN-711104, STI/PSI/290).

Results of measurements of ²²⁰Rn Thorotrast patients including those of whole-body counting of thorium 228 are presented. A short description of method and equipment is given. The patients were measured under physiological conditions. The average thoron concentration in the breath of Thorotrast

114

patients with a thorium 228 body burden of 1×10^4 (E-6) c was 5.6×10^4 (E-9) c Th/l. The fraction of exhaled thoron to the total thoron produced in the body was 8% when Thorotrast was deposited mainly in the reticuloendothelial system; and 4% when it was deposited mainly outside the reticuloendothelial system in paravascular infiltrates. The various circulation rates are held responsible for these findings. The rate of thoron escaping from the site of deposition into blood, and the rate of thoron in blood which is excreted by breath was determined. The fraction of thoron decaying inside the lungs was estimated. The mean value of the exhalation rate was found to be 7%. (RAP)

<426>

Centafson, P.F., L.O. Marinelli, and E.A. Mathew, Argonne National Laboratory, Lemont, IL, 1957.

A Case of Accidental Puncture Contaminated with Thorium 227. Studies on Elimination and Residual Body Activity. Radiology, 68, 358-365.

As a result of an accidental puncture with forceps contaminated with Th 227 ThCl₄ a few microcuries of the element gained interior access to the body of a laboratory worker, a woman 35 years of age. Clinical management and radioactivity studies instituted are described in detail. A single intravenous injection of CaEDTA on the fourth day increased the urinary excretion of thorium but did not significantly reduce the body burden. Spectroscopic investigation of the gamma radiation in vivo and excretion data definitely demonstrate that (a) thorium is the form of a chloride is readily removed from the puncture, (b) the Th 223 daughter is removed preferentially from the wound, (c) thorium is slowly eliminated in the excreta, and (d) Th 223 produced in various parts of the body by the decay of Th 227 is retained in quantity roughly consistent with the equation $0.3t(E-0.7)$ where t is the time in days. (Auth)

<427>

Maquet, A.E.W., and A.J.L. Collinson, Borough Polytechnic, Department of Physics, London, England, 1967.

Radiation Dose to the Respiratory System Due to Radon and its Daughter Products. Health Physics, 13, 831-841.

Annual radiation doses to the respiratory system due to radon and its daughter products have been calculated in various working environments of London (U.K.). The method is based on an accurate calculation of the energy dissipation of alpha-particles in the vulnerable tissue, 1 μ -diameter and located at various depths, from the daughter activity deposited on the walls of the respiratory system; the equilibrium daughter activity has been calculated from the deposition rates and the mucous movement. The proportions of the daughter activity present as free ions in air have been calculated from extensive published theoretical and experimental results. As a more realistic lung model, an extensive set of experimental data on aerosols and a more precise calculation of energy dissipation, among others, have been employed in the present study; it is claimed that the method is an advance on those of Altshuler, Wilson and Neuchner and Jacobi. The radiation dose is found to be highest in segmental bronchi; in comparison with Altshuler et al.'s

MEDICAL ASPECTS

<427> CC47.

results, the present calculation almost always gives higher values. The annual radon dose at a depth of 30 μ from the top of mucous layer in sequential bronchi is 13.6 rad for the highest radon concentration met in our study viz. $10.1 \times 10^{(E-12)}$ Ci/l. In view of the findings of the present study, it is felt that the present WPC value of $3 \times 10^{(E-11)}$ Ci/l for radon should be revised downwards. (Auth) (VC)

<428>

Passon, V., and B.D. Cherry, University of Cape Town, Department of Physics, Rondebosch, South Africa. 1966, May 7.

Alpha-Radioactivity of Human Blood. Nature, 210, 591-592.

Human blood samples used in the study were, in most cases, of expired blood from normal donors to the local blood transfusion service. Thus, they contained standard anticoagulants; appropriate corrections for alpha-activity of these chemicals were made. The results of preliminary studies surveying the alpha-radioactivity in human blood are presented. The activity values are surprisingly high: total pc/hq whole blood by direct measurement ranged from 39 to 109. Values were several times higher than those previously reported for human soft tissues. Furthermore they indicated a surprisingly high percentage of thorium series activity. If substantiated, these results raise intriguing problems concerning disposition and metabolism of radioactive trace elements in the body. The freeze drying technique is recommended as satisfactory for sample preparation. (Auth) (VC)

<429>

Reid, K.V., and P.A. Puqua, Battelle-Pacific Northwest Laboratories, Richland, WA; Hanford Environmental Health Foundation, Richland, WA. 1976, May.

Review of Uranium Inhalation Case. Health Physics, 26, 399-403.

A case involving chronic exposure to natural uranium-contaminated atmosphere over a 14 yr period is discussed. *IN VIVO* examination data, including some obtained following an extended absence from work, are used, along with other supporting data, to evaluate the resulting lung dose. *IN VIVO* chest examination data are compared to results of four samples of lung tissue; and three lymph nodes which were analyzed for uranium content using both neutron activation and fluorometry techniques. As a result of the study, the routine surveillance program for uranium workers was changed. (Auth)

<430>

Boegmans, S.F., Argonne National Laboratory, Center for Human Radiobiology, Argonne, IL. 1976.

Chromosome Aberrations in the Peripheral Lymphocytes of Thorium Workers with Low Body Burdens of Plasmuth 212. ARL-76-88 (Part 20); Radiobiological and Environmental Research Division Annual Report, July 1975 through June 1976, (pp. 30-37), 183 pp. (ARL-76-88, Part 2).

Cytogenic analysis of cultured peripheral lymphocytes from eight thorium workers and three controls has not shown a significant elevation in the level of chromosome

breakage. Body burdens of the Th workers ranged from -0.01 plus or minus 0.20 to 3.49 plus or minus 0.35. Two had stable deleted chromosomes. These findings are consistent with an estimate of the amount of damage to be expected in these cases, based on the level of chromosome breakage observed in fluorotrac cases with measured Th 212 burdens. (Auth) (VC)

<431>

Holgye, A., Institute of Industrial Hygiene of the Uranium Industry, Pribram, Czechoslovakia. 1969; 1970, August.

Urine Excretion of Radioactive Polonium 210 by Czechoslovakian Uranium Miners. ARL-TRANS-667; 16 pp.; Casopis Lekara Ceskych, 1968(48), 1850-1855.

Polonium 210 was estimated in the urine of 3 groups of miners. Miners in the first group worked for an average period of 11.1 years in an average radon concentration of $0.92 \times 10^{(E-10)}$ Ci/l, in the second group for a period of 2.4 years at a concentration of $1.07 \times 10^{(E-10)}$ Ci/l, and in the third group for a period of 4.8 years at a concentration of $4.2 \times 10^{(E-10)}$ Ci/l. Urine concentrations in the first, second and third group, respectively, were $0.84 \times 10^{(E-12)}$, $0.9 \times 10^{(E-12)}$, and $0.92 \times 10^{(E-12)}$ Ci/l. Theoretical calculations attribute 4.9%, 16.8%, and 16.8% of the assessed Po in the three groups to come from Ra and its breakdown products. Additional sources of Po were found in mine dust containing Pb 210, Bi 210, and Po 210. (NAT)

<432>

Motta da Silva, J., and J.V. Nunes, University of Lisbon, Department of Pathology, Lisbon, Portugal. 1971, June.

Histodiagraphies and Autoradiographies from Pieces of Organs of People Injected Systemically with Thorotrast. CSHF-730475; RISC-294; Toxicity of Thorotrast, N. Faber (Ed.), Proceedings of the 3rd International Meeting held in Copenhagen, Denmark, April 25-27, 1972, (pp. 259-266) (CSHF-730475, RISC-294).

Autoradiographic and histodiagraphic studies following Thorotrast injection were done on human liver, spleen, lymph nodes, pancreas, thyroid gland, lung, bowel, and stomach. Large numbers of alpha tracks were found in liver and spleen, while the remaining organs showed little or no activity. Labelling in the liver was from Kupffer cells and histiocytes which contained thorium. Identification of cell types in the spleen is more difficult because labelled cells are so numerous; alpha tracks are probably from spliroth cortex, sinus endothelium, and histiocytes. Alpha tracks in other organs are usually from perivascular histiocytes. In the lung, macrophages in the alveolar spaces are labelled. The activity seen in liver and spleen correlates well with histological data regarding tumors. A few alpha tracks were seen in gallbladder. Cases of adenoma of both liver and gallbladder suggest that one of the organs could have been the site of the primary tumor which then metastasized to the other organ. In the lung, the few alpha tracks observed could not be correlated with a high tumor incidence. (VC)

<433>

Motta, J.S., Faculty of Medicine, Pathology Department, Lisbon, Portugal. 1973, June.

<833>

PHYSICAL ASPECTS

<833> CONT.

Tumors Developed in People Injected with Thorium Dioxide (Thorotrast) (Portuguese Experience). CISP-730475; BISO-294; Toxicity of Thorotrast, R. Faber (Ed.), Proceedings of the 3rd International Meeting held in Copenhagen, Denmark, April 25-27, 1973, (pp. 233-247) (CISP-730475, BISO-294).

Fifteen cases of liver hemangioendothelioma, one hemangioendothelioma of the bone marrow, one reticulosarcoma, nine cholangiocarcinomas, two hepatomas, and five cases of tumors developed on the edge of Thorotrast deposits are examined. All of the cases were histologically confirmed by biopsy or autopsy. Some aspects of Thorotrast tumorigenesis are discussed. (RAP)

<834>

Porta, J.S., L. Cayolla Da Gotta, and R.H. Tavares, Institute of Pathology, Lisbon, Portugal. 1973, June.

Epidemiological Follow-Up Studies of the Portuguese Thorotrast Series (Up-Dated Results). CISP-730475; BISO-294; Toxicity of Thorotrast, R. Faber (Ed.), Proceedings of the 3rd International Meeting held in Copenhagen, Denmark, April 25-27, 1973, (pp. 193-211) (CISP-730475, BISO-294).

Epidemiological studies in Portugal of 514 of 2500 patients injected with Thorotrast between 1930 and 1955 and of a smaller control group were followed up until the end of 1972. An excess of malignancies and severe fibrosis of the liver and around blood vessels was noted. Statistical analysis of the data showed that the excess malignancies are leukemias and other rapidly fatal blood dyscrasias, and liver tumors. Hemangioendothelioma was the most frequently found type of liver tumor. A slight excess of lung cancer was also noted. The significance of local granulomata, liver fibrosis, liver tumors, lung cancer, and malignant bone tumors is discussed. (RAP)

<835>

Porta, J.S., E.L. Cristina, and A.S. Baptista, Faculty of Medicine, Pathology Department, Lisbon, Portugal. 1973, June.

Liver Ultrastructural Findings in Patients Injected with Thorotrast. CISP-730475; BISO-294; Toxicity of Thorotrast, R. Faber (Ed.), Proceedings of the 3rd International Meeting held in Copenhagen, Denmark, April 25-27, 1973, (pp. 219-232) (CISP-730475, BISO-294).

Liver biopsies from patients injected with Thorotrast were examined by electron microscopy. Alterations of the mitochondria, smooth and endoplasmic reticulum, bile canaliculi and hypertrophic Golgi complexes were found. Numerous multivesicular bodies were noted. The Thorotrast structure is described. Aggregates of this material were found in the Kupffer and histiocytic cells accompanied by needle like structures and surrounded by dense collagen. Thorotrast was seldom seen in the hepatocyte. These findings were identical in all the cases but more intense in the patient injected the longest time ago. An adaptive reaction to Thorotrast is suggested. (RAP)

<836>

Frost, V.P., F.P. Radford, Jr., and A. Segall, Harvard School of Public Health, Departments of

Physiology and Epidemiology, Boston, MA. 1970, August.

Naturally Occurring Concentrations of Alpha-Emitting Isotopes in a New England Population. Health Physics, 19, 235-243.

Concentrations of polonium 210, radium 226 and radon 222 were measured radiochemically in extracted teeth obtained from a population in New Hampshire and Vermont, U.S.A. Polonium 210 is indicative of the concentration of lead 210 and radon 222 is taken to be a measure of radium 226. Radium values in teeth were found to be 0.059 pCi/g ash (N = 219) for lead 210, 0.016 pCi/g ash (N = 210) for radium 226 and 0.008 pCi/g ash (N = 55) for radon 222. Differences in the radiological character of the two states were not markedly reflected in the skeletal concentrations of the radioelements in the population studies. Only radium 226 was significantly higher in the New Hampshire population. However, there was considerable variability for each of the three radioelements measured in the total sample and skeletal levels of lead 210 in males were significantly higher than those found in females. An estimate of the skeletal dose delivered by the alpha-emitting isotopes and their daughters to bone marrow and osteocytes has been made and polonium 210, the daughter of lead 210, was found to be the major background source of alpha radiation. (Auth)

<837>

Mursh, J.B., University of Rochester Medical School, Department of Radiation Biology, Rochester, NY. 1965.

Body Content of Thorium 232 Daughters After Thorotrast Injection. British Journal of Radiology, 38, 776-784.

Whole-body gamma counting procedure has been used to study the fate, up to four years' post injection, of Th 232 daughters in four volunteer subjects who received intravenous injections of 24 ml Thorotrast. Thoron expired in the breath was measured in two subjects yielding 9 % of thoron formed. A decreasing rate of excretion of the radium daughters was inferred for the time interval of the study. Calculations are made to show that at least 16 % of the thoron formed moves out from its site of origin and that the lung dose from expired thoron, depending on time after injection, and on Th 228 build up may vary from 15 to 45 rems per year. (Auth)

<838>

Mursh, J.B., University of Rochester School of Medicine and Dentistry, Department of Radiation Biology and Biophysics, Rochester, NY. 1967, December.

Loss of Thorium Daughter by Thorium Dioxide Patients. Annals of the New York Academy of Sciences, 145(3), 634-641; CISP-660422; Distribution, Retention, and Late Effects of Thorium Dioxide, R.L. Swarc (Ed.), Proceedings of a Conference held in New York, New York, April 20-22, 1966, (pp. 634-641), 336 pp. (CISP-660422).

Dose calculations are complicated because some of the dose is from Th 232 daughters, which become distributed, and display excretion patterns dependent on their own chemical properties. Thorium 232 excretion rates are considered negligible. Estimates of excretion of Ra 228, Th 228, and Ra 226 have been made by direct measurements on

MEDICAL ASPECTS

<438> COST.

excreta, and by measurement of daughter: parent ratios in tissue or whole body. It is usually found that Th 229:Ra 226 in liver and spleen are less than one, implying preferential translocation or excretion. It had been assumed from limited evidence that translocation was occurring. Other data, however, suggest that excretion is important; some studies show excretion rates of 0.014%/day. Some data suggest that Ra 226 and 228 excretion rates decrease with time after injection and become more sequestered from the circulation. A fraction of Thoron (Ra 220) is lost in expired air. A detector for measuring the isotope is described and measurements by others reviewed. Lead 212 may be excreted at an average rate of 0.36% of the Th 228 total body burden/day. The activity concentrations of Th and its daughters with time in liver, spleen, and bone marrow must be used for estimation of organ dosage. Excretion rate data are important only as they relate to changes in nuclide concentrations in the RES. (VC)

<439>

Mursh, J.E., A. Schraub, E.L. Sattler, and H.P. Hofman, Justus Liebig Universität, Institut für Physik, Strahlenzentrum, Gießen, German Federal Republic. 1969.

Fate of Lead 212 Inhaled by Human Subjects. Health Physics, 16, 257-267.

Ten human subjects inhaled Pb 212 carried on natural aerosols. Deposition in the lung varied from 14 to 43% of the amount inhaled. Clearance from the lung to the systemic tissues occurred with an estimated half-time of 6.5 hr. The average 24-hr urinary excretion of Pb 212 was 2.8 plus or minus 0.15% of the body content. The total loss by fecal excretion adjusted to zero time averaged 31 body content. The lead absorbed from the lungs into the blood is in part fixed by the circulating red cells and is part distributed to other tissues. The red cell Pb 212 burden grows to a steady state level which averages 50% of the total body burden. The results are interpreted to indicate that the clearance of radon daughters from the lung parenchyma by absorption into the blood has little dosimetric significance, whereas, in the case of thoron daughters, the average lung dose is reduced to less than half. (Luth)

<440>

Mursh, J.E., L.F. Steadman, W.B. Looney, and N. Colodzie, University of Rochester, School of Medicine and Dentistry, Department of Radiation Biology, Rochester, NY; U.S. Naval Hospital, Naval Medical Center, Radioisotope Laboratory, Bethesda, NE. 1956.

The Excretion of Thorium and Thorium Daughters after Thorotrast Administration. Acta Radiologica, 47, 481-498.

The thorium and thorium daughter product content of excreta were analyzed for the early period after administration of 75 and 60 ml of Thorotrast respectively to two human subjects. Autopsy tissues from four Thorotrast patients were analyzed for thorium. It was found that less than 1 % of the administered thorium was excreted in the early period and a biologic half-life of more than 400 years is calculated. Ra 226 excretion is modified by the physical nature of the injected material and it is estimated that 0.026 % of the body content is excreted

per day in the 'steady state'. Ra 228 excretion is at the rate of 2.6 % of the body content per day after a state of transient equilibrium has been established. The total body gamma ray measurements and gamma ray distribution studies gave results which were similar to the excretion results of the radium isotopes. Dosage calculations are safe for the organs of maximum thorium deposition, i.e., the liver, spleen, bone marrow, and lung. The average of Th 232/g tissue were follows: liver or spleen wet wt and the average dose/day (in rads: 1 rep = 95 ergs/g 6.5, 0.3; bone marrow, 3.6, 0.03; lung, 0.2, 0.01. (Luth)(VC)

<441>

Isaich, H., University of Heidelberg, Department of Medical Documentation and Statistics, Heidelberg, German Federal Republic. 1973, April.

Aspects of Collaboration Relating to Follow-Up Studies. COST-730475: EISC-294: Toxicity of Thorotrast, H. Faber (Ed.), Proceedings of the 3rd International Meeting held in Copenhagen, Denmark, April 25-27, 1973, (pp. 317-319) (COST-730475, EISC-294).

The necessity of international collaboration to get relevant and valid information on Thorotrast-administered patients is stressed. Usual statistical models are not suitable for the evaluation of data obtained by follow-up studies. Investigational techniques as well as a data recording system should follow standardized basic procedures. Publication of original data is recommended. (RAY)

<442>

International Atomic Energy Agency, Vienna, Austria. 1968, March 16.

Thorotrast: A Bibliography of Its Diagnostic Use and Biological Effects. WP/42: 145 pp.

This bibliography has been compiled primarily to support a study of Thorotrast toxicity which is being conducted in the Medical Section of the International Atomic Energy Agency. The limited resources of staff and time available for its compilation have dictated a practical compromise between completeness and freedom from error on the one hand and effort on the other. While neither complete nor free of error, it has been stencilled so as to be available to other groups with similar interests. Additions and corrections would be gratefully received. The chief concern of the bibliography is with the toxic effect of Thorotrast. Papers on the diagnostic use of Thorotrast have also been included, both because of their relevance to the subsequent toxic effects and because of the light they shed on the possible hazards and location of Thorotrast cases. Papers on various related topics such as ThI (Ra-226) and ThII (Ra-228) have been included when found, but no special search for them has been made. Papers are classified under the topics shown in the Table of Contents. In many cases papers have been listed under two or more categories, but a unique classification is obviously impossible. Since a rather abrupt change in outlook on the biological significance of ionizing radiation took place with the advent of nuclear energy, papers are given separately under each topic according to publication date: 1945 and earlier, 1946 and later. Original titles (if available) are given along with their English translations.

<442>

TECHNICAL ASPECTS

<443> CONT.

Author's addressees are listed for papers of which reprints have been obtained by the Agency. (Auth)

<444>

International Atomic Energy Agency, Vienna, Austria. 1966.

Assessment of Radioactivity in Man Gama-Ray Spectra for Uniformly Distributed Uranium 238, Thorium 232, Potassium 40, and Cesium 137. (CONF-648; STI/PUB/84; Assessment of Radioactive Body Burdens in Man, Proceedings of a Symposium held in Heidelberg, Germany, May 11-16, 1964, Vols. 1-2, 1043 pp. (CONF-648, STI/PUB/84).

Sixty-seven papers were presented at the symposium, and twenty-two have been abstracted separately for the Data Base. The Proceedings are produced in two volumes. Volume 1 includes papers which deal with problems generally common to many isotopes: IV VIVO counting, bioassay techniques, sample counting and analysis of data. Volume 2 includes those papers concerned with radioisotopes of specific elements: Ca, Ra, Pu, Sr, Th, U, Pa and rare earth elements. The studies on uranium dealt with the detection and evaluation of U exposures, a case of inhalation of enriched U dust and the estimation of internal contamination with U from urine analysis results. The papers on Pa are concerned mainly with the estimation of body burden and interpretation of the results obtained following Pa contamination.

<445>

International Commission on Radiological Protection. 1967, April.

A Review of the Radiosensitivity of the Tissues in Bone. ICRP Publication 11; 36 pp.

Carcinogenesis (including leukaemogenesis) is the dose-limiting factor for bone. Tissues considered at risk are: (1) osteogenic tissue particularly endosteal surfaces, (2) hematopoietic marrow, and (3) epithelium on bone surfaces. Dose to certain identifiable tissues within an associated with bone is the important parameter determining maximum permissible levels rather than dose to "bone" regarded as a single uniform medium. Plutonium concentrated particularly on endosteal surfaces and under certain circumstances has a significant marrow distribution. Osteogenic cells on endosteal surfaces can receive a high radiation dose owing to the pattern of retention of plutonium in marrow. Both hematopoietic marrow and osteogenic cells are at risk. Experimental results for Pu 239 and Sr 90 showed that there are differences in radiation dose, dose-ratio and dose distribution in bone and bone marrow when single administration is compared with repeated administration of these bone-seeking radioisotopes. (RP)

<446>

International Commission on Radiological Protection, Committee 4. 1969, April.

The Assessment of Internal Contamination Resulting from Recurrent or Prolonged Uptake. ICRP Publication 10A; 34 pp.

Work was done as an extension of the ICRP report on "Evaluation of Radiation Doses to Body Tissue from Internal Contamination Due to Occupational Exposure." That report

considered the single exposure, but this report is applicable to a wider range of situations. Included are calculations of the radiation dose to the critical organ, the excretion of various times after intake and derived investigation levels. An equation is given which relates the body organ content of a radioisotope to the uptake or deposition as a function of time and the retention as a function of time. The report is concerned mainly with the application of the formula. Various patterns are shown for uptake and the resulting changes in organ content with time. Equations are derived for the amount of radioisotope retained in the compartment or critical organ, the exposure resulting from this content and the excretion coming from the critical organ. Among the examples considered are the deposition of insoluble Th or Pa oxides in lung; with the subsequent translocation of the radioisotope to pulmonary lymph nodes, skeleton and excreta, and the deposition of non-transportable bone-seeking radioisotopes in a wound with the subsequent translocation to the skeleton and excreta. In considering several uptakes in a limited period, calculations were done for the retentions and excretions from a total intake of 1 uCi distributed over 10 or 100 days for HTO, Sr 90, I 131, Cs 137, Ra 226 and U and the results are displayed in graphical form. Included in the appendices are the derivation of basic equations, the fractions of the total excretion by urine and feces for elements taken up by the extracellular fluid and derived investigation levels for excretion following periods of constant uptake for seven radioisotopes (including Pu 239). (PNN)

Table 6 shows derived investigation levels for excretion following periods of constant uptake for HTO, Sr 90, I 131, Cs 137, U 233, U 238, Pu 239 and Ra 226.

<447>

Jaskols, T., and M.E. Wrenn, New York University Medical Center, Institute of Environmental Medicine, New York, NY. 1972.

Lead 210 Concentrations Measured in the Bone and Excreta of a Former Uranium Miner. Health Physics, 23(3), 416-417.

A series of 5 daily analyses for Pb 210 has been made in urine, feces and blood of a former uranium miner with an estimated cumulative radon daughter exposure of 6900 working level months. Also, in vivo counting was performed with 2 six-inch diameter thin NaI-CsI dual crystals operated in the anti-coincidence mode, positioned on both sides of the subject's head and selectively shielded from the rest of the body. These measurements clearly show the characteristic gamma and X-ray spectrum of Pb 210. Extrapolating from the measured activity present in the head (using skull phantoms and Pb 210 skeletal deposition data from non-human primate studies), a skeletal burden of 8.2 uCi of Pb 210 was estimated. Urine, feces and blood samples were collected on each day of the 5 day measurement period. Using creatinine measurements as an indicator of excretion time, not more than 21 percent variation was observed from the average daily urinary excretion of 2.19 pCi Pb 210. The corresponding mean value of daily Pb 210 excreted in feces was 1.00 ± 0.18 pCi/day. Using the total rate of excretion and the measured body burden, the calculated effective half time of Pb 210 in the body of this man exposed over a 10 year period, which terminated 11 years ago, is approximately 8

PHYSICAL ASPECTS

<446> CCNY.

years. This is consistent with the value of 5 years obtained by sequential in vivo measurements performed over the last 5 years. This corresponds to a biological half life of 11 years. (Auth)

<447>

Jacobi, W., Zahn-Zister-Institut für Kernforschung, Abteilung Strahlungsphysik, Berlin, German Federal Republic. 1968.

The Dose to the Human Respiratory Tract by Inhalation of Short-Lived Radon 222 and Radium 220-Decay Products. Health Physics, 19(12), 1163-1174; (CNSF-561; Inhaled Radioactive Particles and Gases, Proceedings of the Sanford Symposium held in Hickland, Washington, May 4-6, 1968. (11 pp.) (CNSF-561).

The deposition of Ra daughters in the different regions of the human respiratory tract is derived from the particle size of their carrier aerosol in ordinary, unfiltered air. The resulting mean distribution of the radioactivity in the respiratory tract is estimated, taking into account the alpha-absorption in the mucus layer and the variation of stopping power with alpha-energy. The resulting mean absolute alpha-dose in different regions of the respiratory tract is given for each inhaled nuclide, especially at their natural level in atmosphere air and their various permissible level. The results indicate, that owing to the ciliary transport, a considerable fraction of the dose in the upper respiratory tract is due to the transfer of activity from the bronchioli and lower bronchi in the mucus stream. The highest dose should be expected in the lower bronchi. (Auth)

<448>

Janover, H.L., St. Vincent Hospital, Worcester, MA. 1973, June.

Yellow-Tp of Thorotrast Patients from Boston, Massachusetts and Ann Arbor, Michigan, USA. (CNSF-730475; S150-294; Toxicity of Thorotrast, P. Faber (Ed.), Proceedings of the 3rd International Meeting held in Copenhagen, Denmark, April 25-27, 1973, (pp. 126-137) (CNSF-730475, S150-294).

Seven hundred and twenty four patients who received Thorotrast for cerebral angiography and 315 control patients who underwent similar examinations were followed up to determine the incidence of radiation related morbidity and mortality. Forty two of the Thorotrast patients and 29 of the controls were subjected to extensive clinical and laboratory examinations. In the Thorotrast series, one case each of liver tumor, granulocytic leukemia, and non-alcoholic hepatic cirrhosis were found as well as two cases of localized thorotrastomas. The Thorotrast patients revealed evidence of early liver dysfunction by elevations in bromsulphalein retention and alkaline phosphatase tests. The most sensitive indicator of radiation exposure was the high frequency of chromosome aberrations. Anemia, elevated white counts, and abnormalities in red cell morphology were not found. (Auth)

<449>

Janover, H.L., V.W. Sidel, and H.J. Flynn, Massachusetts General Hospital, Boston, MA. 1967, December.

Preliminary Report from Boston on the Follow-up

of Patients with Thorium Dioxide Deposits. Annals of the New York Academy of Sciences, 145(3), 849-852; (CNSF-660422; Distribution, Retention, and Late Effects of Thorium Dioxide, H.L. Swann (Ed.), Proceedings of a Conference held in New York, New York, April 20-22, 1966. (pp. 849-852), 336 pp. (CNSF-660422).

Approximately 270 patients received thorium dioxide for cerebral arteriography at two institutions in Boston, Mass. Preliminary follow-up has been completed on the 151 patients treated at the Massachusetts General Hospital; of these 61 are still alive and 92 are dead. A total of five tumors, three in the living and two in the dead groups, thought to have developed since the arteriography, have been discovered. Plans for physical, laboratory, x-ray, radiation dosimetry and pathological examination of the patients are presented. (Auth)

<450>

Joe, W.S.S., H.L. Doctson, H.S. Nical, J.S. Arnold, and W.E. Looney, University of Utah, College of Medicine, Division of Radiobiology, Department of Anatomy, Salt Lake City, UT; Kansas City General Hospital and Medical Center, Departments of Pathology and Radiology, Kansas City, MO; University of Virginia School of Medicine, Department of Radiology, Charlottesville, VA. 1967, December.

Distribution of Thorium Daughters in Bone. Annals of the New York Academy of Sciences, 145(3), 660-673; (CNSF-660422; Distribution, Retention, and Late Effects of Thorium Dioxide, H.L. Swann (Ed.), Proceedings of a Conference held in New York, New York, April 20-22, 1966. (pp. 660-673), 336 pp. (CNSF-660422).

Studies of qualitative and quantitative autoradiographic localization of the daughters in cancellous and cortical bone from two patients and a dog injected with Th22 were done. The autoradiographic study showed the following: The total skeletal activity of Th 228 as percent of injected Th 232 was 1.7% after 17 days (58 year old woman) and 2.9% after 19 years (85 year old woman). The Th 228 and daughters were found to be diffusely but unevenly distributed in bone tissues of both patients. More macrophage-thorium dioxide aggregates lined endosteal surfaces of the patient with the longer burden times. Higher concentrations of alpha tracks were found in trabecular and cortical bone surfaces lined with aggregates and was interpreted that some Ra 226 atoms were translocating from macrophage-thorium dioxide aggregates to adjacent bone tissues. The quantities in cortical and cancellous bones were about 0.62 and 49.0 pCi/g of bone in both patients. The total skeletal activity of Th 228 as percent of injected Th 232 was 2.9% after 51 days in a 30 pound mongrel dog. A diffuse and hotspot distribution was found in both cortical and cancellous bones of the dog. The average quantity of Th 228 was 1.67 and 120 pCi/g of cortical and cancellous bones. The average hotspot to average diffuse ratios were 11.4 for cortical bone and varied between 4.4 to 9.9 for spongy bone. The average diffuse to uniform ratios were between 0.29 to 0.55 for compacta and 0.69 to 1.28 for spongiosa. The computed values for thorium per gram of bone for the present study compared quite favorably with previous spectrochemical analyses of bones from the same patients. (Auth) (VC)

<451>

MEDICAL ASPECTS

<451>

Kahn, R.L., Institute of Anatomical Pathology, Department of Pathology, Faculty of Medicine, Lisbon, Portugal. 1967, December.

Two Cases of Carcinoma after Thorotrast Administration. *Annals of the New York Academy of Sciences*, 145(3), 700-717; COSP-660422; Distribution, Retention, and Late Effects of Thorium Dioxide, R.L. Swarc (Ed.), *Proceedings of a Conference held in New York, New York, April 27-29, 1966*, (pp. 700-717), 336 pp. (COSP-660422).

Pertinent literature about carcinoma after Thorotrast administration is reviewed. Two case histories are reported: one was of a 54-year old woman injected 28 years previously with 20 cc of Thorotrast (cerebral angiography) who died in hepatic coma due to a coarse granular cirrhosis. Autopsy and microscopy showed areas similar to "granuloma of thorotrast" in the right lobe, surrounded by an adenocarcinoma; the second case involved a 29-year-old man who received 60-100 cc Thorotrast (intraoperative portography for removal of an echinococcus cyst). He died 26 years later after a second operation. Autopsy and microscopy showed a portal Thorotrast granuloma and a second adenocarcinoma of the common hepatic bile duct near the granuloma. Twelve figures, most of them light micrographs and a tabular summary of cases in the literature are included. (10)

<452>

Faustmann, H., H. Wesch, and K. Segenec, 1971.

Quantitative Thorium Determination in Thirty Organs During Human Thorotrastosis. *SWP-Trans-222*; 7 pp.; *Nuclear-Medizin, Supplementum*, 9, 579-585.

In human thorotrastosis, substantial Th deposits are present in liver, spleen, hepatolienal lymph nodes and bone marrow. The amount of Th present in other organs has not been studied. Autoradiography and neutron activation analysis were used to study this question. Tissue samples were: cerebrum; pituitary, thyroid, adrenal, prostate glands; testes; tonsils; trachea; bronchus; lungs; liver; gall bladder; spleen; pancreas; esophagus; stomach; small intestine; rectum; kidneys; bladder; muscle; bone marrow; heart; blood vessels; "A. coronaria cordis dextra et sinistra"; connective and fatty tissue. All organs and tissues examined contained Th in varying concentrations. Quantitatively measurable Th could be observed in 29 organs. In the cerebrum Th concentration was below the 0.2 $\mu\text{g/g}$ detection limit. Samples containing less than 10 $\mu\text{g Th/g}$ were negative in autoradiographs. Classified as strongly positive, with more than 500 $\mu\text{g/g}$ were liver, bile duct, liver carcinoma, spleen and bone marrow. The rest of the organs were grouped in four categories including concentrations from less than 0.2 μg to 500 μg . Spleen had the highest Th concentration (900-45000 $\mu\text{g/g}$) followed by liver (1700-5600 $\mu\text{g/g}$) and bone marrow (110-1300 $\mu\text{g/g}$). Organs with intermediate concentrations include lymph nodes, adrenal, lungs, testes. Gastrointestinal tract organs, prostate, and kidney are among the organs in a group containing little Th. The results agree well with experimental and clinical studies. (10)

<453>

Kaul, A., Max-Planck-Institute for Biophysics,

Frankfurt, German Federal Republic. 1966.

Gamma-Spectrometric and Histo-Autoradiographic Investigations of the Distribution and Excretion of Thorium and Its Daughters in Thorotrast Patients. COSP-444; STI/PUR/84; Assessment of Radioactive Body Burdens in Man, *Proceedings of a Symposium held in Heidelberg, Germany, May 11-16, 1966*, Vol. 2, (pp. 665-671), 1963 pp. (COSP-444, STI/PUR/84).

The estimation of the internal radiation dose from thorium and its daughters in Thorotrast patients presupposes the knowledge of the distribution of the nuclides of the thorium series within the organism. Moreover, the knowledge of the excretion of the thorium daughters with feces, urine and exhalation is of importance. In a series of cases of a ThO₂ incorporation 10-20 years ago mainly two kinds of distribution patterns could be observed: (a) deposition of thorium 232 and its daughters mainly within the organs liver and spleen (and bone marrow); (b) simultaneous deposition of the T-ray contrast medium at the location of the former injection. The Thorotrast deposits were analyzed quantitatively *in vivo* and localized with the Frankfurt Wai(71)-total body gamma-ray spectrometer (HCO). In addition it was possible from excretion measurements to estimate the radioactive equilibrium state between thorium 232 and its daughters in the physiological steady state. Parallel analyses of section materials of former Thorotrast patients showed similar results. Question of the radioactive equilibrium state between thorium 232 and its daughters radium 226 and thorium 228 was mainly investigated. The thorium 232 and thorium 228 content of different samples of soft tissue (liver, spleen), bone marrow and marrow-free bone were determined with the so-called siring method and the obtained thorium 228 activities compared with results of gamma-spectrometric analyses. The observed activity ratios thorium 232/thorium 228 served as a base for calculations of both the thorium 232 and thorium 228 content of samples by histo-autoradiographic investigations. Both methods and the results of the gamma-spectrometric and histo-autoradiographic investigations are discussed in detail. (Auth)

<454>

Kaul, A., Universität Berlin, Klinik für Radiologie und Nuklearmedizin-Nuklearmed. Physik und Strahlenschutz, Berlin, German Federal Republic. 1973, June.

Tissue Distribution and Steady State Activity Ratios of Thorium 232 and Daughters in Man Following Intravascular Injection of Thorotrast. COSP-730475; IASO-29; Toxicity of Thorotrast, N. Faber (Ed.), *Proceedings of the 3rd International Meeting held in Copenhagen, Denmark, April 25-27, 1973*, (pp. 14-30) (COSP-730475, IASO-29).

Published and experimental data on tissue distribution and steady state activity ratios of Th 232 and daughters were compiled to get "best estimates" per dose rate calculations in patients with long-term Thorotrast burdens. About 95% of intravascularly injected ThO₂ is retained in the reticuloendothelial system (liver 59%, spleen 26.5%, bone marrow 9.3%). Only 0.7 and 0.1% are distributed in lungs and kidneys, respectively. The fractional retention of Th 232 in marrow-free skeleton was about 4%. Activity ratios between Th daughters and Th 232 in tissues of patients and in sealed

TECHNICAL ASPECTS

<850> CONT.

Thorotrast activity varied due to recoil. In case of long-term Thorotrast burdens, Ba 228 is only up to 40% in equilibrium with its parent Th 232 in the RES, and in the order of 20% in excess to Th 232 in marrow-free bone. The same holds true for Th 232 which is eliminated from the Thorotrast deposits of the RES and partly translocated to the marrow-free skeleton. The corresponding activity ratio between Ba 228 and Th 232 was 0.25-0.36 for liver, spleen and bone marrow, and was almost 2 for the marrow-free skeleton. In the lungs it is assumed to be in excess to its parent Pb 212 bound to the cellular fraction of blood, and due to decay of Ba 228 which has escaped from the RES into the general circulation. The average steady state activity ratios of Th 232 within the RES in the standard Thorotrast patient were comparable to those observed in animal experiments. (BAP)

<855>

Kael, A., U. Abmayr, and B. Hindringer, Universität Berlin, Klinik für Radiologie und Nuklearmedizin - Nuklearmedizin. Physik und Strahlenschutz, Berlin, German Federal Republic; Institut für Strahlenschutz und Abteilung für Hygiene und Experimentelle Pathologie, München, German Federal Republic. 1973, June.

Pean Organ Dose Rates in Man Following Intravascular Injection of Thorotrast. CCRP-730475; BISO-294; Toxicity of Thorotrast, F. Faber (Ed.), Proceedings of the 3rd International Meeting held in Copenhagen, Denmark, April 25-27, 1973, (pp. 40-51) (CCRP-730475, BISO-294).

Estimates of mean dose rates for patients with long-term burdens of intravascularly injected Thorotrast (10, 30, and 50 mCi) were performed based on present best estimates on tissue distribution and steady state activity ratios of Th 232 and daughters. Self-absorption of emitted radiation due to aggregation of ThO₂ particles in tissues was taken into account. Correction factors were calculated by an empirical method. For intravascular injections of 5 mCi Thorotrast the mean alpha dose rate in liver, spleen, and bone marrow was 40, 120, and 23rd/yr, respectively. Long-term animal experiments in rabbits indicate that the process of aggregation of ThO₂ particles in the liver tissue is continuing for tissues of more than 400 days after Thorotrast injection. In the spleen, however, the aggregate size distribution remained nearly constant at times of more than 150 days after Thorotrast application. (BAP)

<856>

Kemper, W., H. Rath, F. Tranekjer, and U. Portenbagen, Boris Rajevsky Institut, Institut für Biophysik, Universität des Saarlandes, Saarberg, German Federal Republic. 1973, June.

Chromosome Aberrations Caused by Thorotrast. CCRP-730475; BISO-294; Toxicity of Thorotrast, F. Faber (Ed.), Proceedings of the 3rd International Meeting held in Copenhagen, Denmark, April 25-27, 1973, (pp. 104-113) (CCRP-730475, BISO-294).

An attempt was made to find a dose-effect relationship between radiation dose (Ba 228-equivalent) and chromosome aberration yield (dicentric and accompanying fragments). Chromosome aberrations were found in all (70) patients with Thorotrast deposits. The aberration rate was higher in

comparison to a control group. The mean rate was 1 dicentric/100 cells, the maximum 25 dicentric/100 cells. Although a statistically significant relationship was found, it is suggested that it is impossible to establish a valid dose-effect relationship in Thorotrast patients because the number of dicentric scatters within large limits in different patients exposed to equal or similar doses. (BAP)

<857>

Knoop, U., and O. Gatz, Children's Hospital of the City of Cologne, Pediatric Clinic and Children's Surgical Clinic, Cologne, German Federal Republic. 1974.

Pulmonary Metastases from a Thyroid Carcinoma in Childhood after Thorium-X Treatment. Zeitschrift der Kinderheilkunde, 118, 117-127.

Chest X-rays of a girl, who in her infancy was treated with Thorium-X, showed changes in her lung which after 2 years were identified as multiple metastases from a thyroid carcinoma. After a total thyroidectomy, radioactive iodine therapy was started; this is being continued since no noticeable changes have been observed and the metastases are continuing to store radioactive iodine. Substitution therapy using thyroid hormones is being administered. The different methods of treatment for thyroid gland metastases occurring in childhood are discussed. (Auth)

<858>

Kotrappa, P., University of Rochester, Department of Radiation Biology and Biophysics, Rochester, NY. 1969.

Calculation of the Burden and Dose to the Respiratory Tract from Continuous Inhalation of Radioactive Aerosols. Health Physics, 17, 829-832.

The recently proposed ICRP Lung Model can be used to calculate the burden and dose to the respiratory tract from the inhalation of a known radioactive aerosol. Snyder has given analytical expressions and curves for the case of continuous intake. The use of these curves is illustrated by an example in which burdens and doses to various compartments of the respiratory tract are computed for the chronic inhalation of plutonium oxide aerosol making use of the aerosol data available from Hanford Laboratories. Examples of typical data for radiation resulting from Pu oxide inhalation for 70 years by workers are: inhalation rate, 0.19 pCi/day; retention in pulmonary region, 21.81 pCi and in lymph node region, 48.50 pCi; dose to lung region, 0.95 rem and in lymph node region, 38.40 rem; dose to nasopharynx region, 2.27×10^{-3} rem and to the tracheobronchial region, 1.15×10^{-4} rem. The comparable values for office workers, given in the same order as above are: 0.035, 5.90, 126.60, 0.24, 9.51×10^{-5} , 2.79×10^{-5} . (Auth) (VC)

<859>

Looney, W.H., 1955.

Late Clinical Changes Following the Internal Deposition of Radioactive Materials. Annals of Internal Medicine, 42, 379-387.

Clinical changes after deposition of radioactive materials are discussed and the following conclusions drawn. The small amount of Ba not eliminated from the body is retained by bone in small areas of high

MEDICAL ASPECTS

<459> CONT.

concentration. Roentgenographic changes develop many years after administration. Decreased densities in compact bone result from bone destruction. Increased density in cancellous bone is from atypical osseous tissue formation. Decreased densities may be the first clinical sign of malignancy. Increased skeletal fragility occurs: fractures and aseptic necrosis are more frequent. Minor hematologic changes may be present; infrequently, aplastic anemias may develop. Skeletal malignancies may develop after a 10-30 year latent period. Almost all Th from Thorotrast is indefinitely retained in liver, spleen and bone marrow; less is retained in lungs, adrenals, etc. Histopathologic changes have been reported. There is little clinical reaction to Thorotrast and resulting irradiation. Erythrocytes were in spleen and sites where extravasation into soft tissues occurred. Thorotrast can be seen roentgenographically in liver, spleen and extravasation sites. Thickening of shafts and trabecular markings with endosteal irregularity have been seen. Symptoms from contraction and induration at injection sites may develop. Minor hematologic changes as well as a few anemias have been reported. There may be abnormal liver function tests. No conclusion can be drawn relating Thorotrast with the malignancies and leukemias thus far reported. Little is known about late effects of internally deposited radioactive materials in man. By location and reevaluation of many individuals more accurate details of late effects can be found; thus, members of the population who may be exposed can be better protected. (VC)

<460>

Looney, W.E., J.S. Arnold, R. Levi, and W.S.S. Jee, U.S. Naval Hospital, National Naval Medical Center, Bethesda, MD; University of Utah, School of Medicine, Department of Radiology, Salt Lake City, UT; University of Copenhagen, Department of Biological Isotope Research, Copenhagen, Denmark. 1955.

Autoradiographic and Histopathological Studies of Thorium Dioxide Patients. American Medical Association Archives of Pathology, 60, 173-178.

The eventual utilization of thorium as a breeder material in the production of atomic energy has made information about the effects of thorium dioxide (Thorotrast) one of considerable importance. Material from patients who died 10 and 19 years after thorium dioxide administration has been studied by histological, autoradiographic, radiochemical, and spectrochemical means. These newer and more refined techniques give a better understanding of the distribution, rate of elimination, and mode of action of thorium and the members of the thorium decay series. The deposition of thorium and/or the daughter radioelements of the thorium decay series in the skeleton and soft tissues is demonstrated by autoradiographic and histopathological means. Histopathological changes have been reported in the liver, spleen, bone marrow, bone, lymph nodes, adrenals, lungs, and kidneys. Problems relating to the calculations of the amount of irradiation received by the body and the various organs are discussed. (Auth) (MS)

<461>

Looney, W.E., and H. Colodzin, U.S. Naval Hospital, National Naval Medical Center, Bethesda, MD. 1956, January 7.

Late Followup Studies After Internal Deposition of Radioactive Materials. Journal of the American Medical Association, 149(1-3).

The late effects of internally deposited radioactive materials are of increasing concern to radiologists. Such deposits occur in patients who have worked with radioactive materials, have received radium salts orally or parenterally, or have been given thorium dioxide for diagnostic purposes. Radium is deposited in the skeleton in small areas of high focal concentration. Malignant tumors and roentgenographic changes and symptoms resulting from increased fragility of the skeleton may occur many years after deposition. Thorium is deposited in the reticuloendothelial system and remains throughout the life of the patient. The major sites of deposition are the liver, spleen and bone marrow. A small number of primary hepatic tumors, leukemias, and hematological disorders have been found in studies made thus far. Patients known to have received radioactive materials in such ways should be referred to laboratories equipped to evaluate their status. Physicians should be on the alert for bone changes, blood dyscrasias, and malignant tumors that might be the results of radioactive deposits in the body. (HAF)

<462>

Lorenz, B., W.J. Lorenz, and C. Van Haich, Institute of Nuclear Medicine, German Cancer Research Center, Heidelberg, German Federal Republic. 1973, June.

Medical Problems Concerning the Central Group. CONF-730475; NISG-294; Toxicity of Thorotrast, S. Faber (Ed.), Proceedings of the 3rd International Meeting held in Copenhagen, Denmark, April 25-25, 1973, (pp. 167-178) (CONF-730475, NISG-294).

The German research project THOROTRAST deals with patients who have received Thorotrast injections and with patients belonging to a control group who have been hospitalized at approximately the same time. Problems of follow-up physical examinations of control patients are reported. Difficulties encountered were: resistance of clinical directors to reveal medical histories of patients on ethical grounds; hesitation of patients to join the program; incomplete diagnostic data for out-patients due to lack of complete follow-up; and less than perfect liaison with the family physician. A number of previously undiagnosed diseases were discovered in the control group which lead to therapeutic measures. (HAF)

<463>

Lucas, H.F., D.W. Edgington, and F. Marken, Argonne National Laboratory, Argonne, IL. 1949.

Natural Thorium in Human Bone. ARL-7615; Radiological Physics Division Annual Report, July 1948-June 1949, (pp. 56-58), 233 pp. (ARL-7615).

The Th 232 concentration in rib bone from 36 humans ranged from less than 0.1 to 72 mg/g ash. Values increased with age and were fitted by the expression Y equals $(0.16 \text{ plus or minus } 0.02) T$, where T is the Th 232 concentration in mg/g bone ash and Y is the age in years. Evaluation of retention of the Ra 226 produced by decay of Th 232 is not feasible because direct intake of naturally-occurring Ra 226 is too large. (Auth)

MEDICAL ASPECTS

<463> COST.

Age of human bones tested in years ranged from 3 to 51.

<464>

Lucas, H.P., and P. Barken, Argonne National Laboratory, Argonne, IL. 1970.

Thorium and Uranium in Blood, Urine, and Cigarettes. ANL-7760 (Part 2): Radiological Physics Division Annual Report, July 1969-June 1970. (pp. 47-52) (ANL-7760).

A previously developed analytical method for bone was shown to be applicable to blood and urine with little modification (removal of interference from sodium and bromine). The thorium in the red cell fraction from human blood was 0.17 ppb, which was at least 4 times that for plasma. The uranium content was less than 0.4 ppb in both blood and urine. Thorium in urine ranged from 0.2 to 5 ppt but was detectable in only one half of the samples. Both the thorium and uranium content were 0.15 ug/king size cigarette without filters or 3 ug/pack. (347)

<465>

Lucas, H.P., Jr., P. Barken, H. Fay, B.S. MacDonald, and J. Sweeney, Argonne National Laboratory, Radiological Physics Division, Argonne, IL; University of California, School of Medicine, Los Angeles, CA; Memorial Hospital of Long Beach, Long Beach, CA. 1972, October.

Thorium Daughters in the Spleen of a Thorotrast Case. Health Physics, 23, 575-576.

Concentrations of Th 232 and its daughters vary with time after injection of Thorotrast. Little is known about relative concentrations of daughters. In this study, delays between surgery and radiochemical analysis have been minimized to allow more accurate estimation of ratios for species with half-lives greater than 1 hr. Emission spectroscopy of spleen indicated a value of 0.67 g Th 232 for the whole spleen. Another portion of spleen was freeze dried, ashed, and dissolved. Aliquots were irradiated and stored to allow decay of short-lived components. Th was determined from counting rates of Pa 233. This method gave values for the whole spleen of 0.6 plus or minus 0.04 g or 0.067 plus or minus 0.004 uCi of Th 232. Ra 228/Th 232 and Th 230/Th 232 were 0.36 and 0.32, respectively and Th 230/Ra 228 was 0.89. Whole-body counts after surgery showed 1.69 g Th 232 in equilibrium with its daughters. Amount of Thorotrast injected was estimated at .5 cc. Ac 228, Ra 228, Bi 212 at surgery were obtained from growth curves of Ac and Bi measured over 36 days. Activity ratios of daughters were: Ra 228/Th 232, 0.36; Ac 228/Ra 228, 1.0; Th 230/Ra 228, 0.87; Ra 228/Th 230, 0.77; Pb 212/Ra 228, 0.39; Bi 212/Pb 212, 1.18. All values agree with those in the literature with the exception of Bi 212 for which there are no other human data. The value here is about twice that for rats, rabbits, and dogs. (9C)

<466>

Kaletova, I., and V. Dvorak, Institute of Radiation Hygiene, Prague, Czechoslovakia. 1970.

Results of the Whole-Body Counting of Patients with Known Amount of Injected Thorotrast. Health Physics, 18, 831-832.

There is little information relating injected amounts of Thorotrast and results of

whole-body counts on the patients. Data are available on persons who received one or two i.v. Thorotrast injections at a clinic in Prague. Femoral arteriography diagnosis was the Thorotrast procedure performed. All applications, done by the same physician, consisted of 20 ml per injection. The patients, all males, are now at about the same time post injection; their ages differ. No paravascular deposits were present. Whole-body activation for each of the seven patients are as follows: Bi 212 (uCi), 0.100, 0.175, 0.097, 0.094, 0.095, 0.189, 0.126; Ac 228 (uCi), 0.14, 0.25, 0.14, 0.15, 0.15, 0.20, 0.17; ratios of Bi 212 to Ac 228, 0.71, 0.70, 0.69, 0.62, 0.63, 0.68, 0.74; ratios of Ac 228 to Th 232, 0.32, 0.29, 0.32, 0.35, 0.35, 0.32, 0.39. These data were obtained 17-21 years post injection. Details concerning the whole-body counter, calibration procedures, and calculations used in the determinations are given. (9C)

<467>

Malotash, C.J., R.F. Keene, W.C. Tollen, and R.D. Evans, Cancer Research Institute, New England Deaconess Hospital, Harvard Medical School, Department of Pathology, Boston, MA; Massachusetts Institute of Technology, Department of Physics, Cambridge, MA; National Center for Radiological Health, Radiation Bio-Effects Program, Rockville, MD. 1968.

Retention and Absorption of Radium 226 and Thorium 230 and Source Dosimetric Considerations of Radium 226 in Human Beings. CONF-670938; Delayed Effects of Bone-Seeking Radioisotopes, C.V. Rags, et al (Eds.), Proceedings of a Symposium held in Sun Valley, Idaho, September 12-18, 1967. University of Utah Press, Salt Lake City, Utah. (pp. 29-49), 519 pp. (CONF-670938).

When normal human subjects (aged 63-83 yr) ingested rock radium dial paint containing Pa 226 Ra 504, Th 230 Th (904)2, Ra 504 carrier, and Zn phosphor, intestinal absorption was about 20% for Ra but only 0.02% for Th 230. Thus, Th 230 in real dial paints is unlikely to have contributed a significant radiation dose (less than 5%) to those of those ingesting them. Similar subjects were injected intravenously with Th 230 citrate or with Ra 226 chloride. The excretion of Th 230 was low, the urine-to-feces ratio 12 for males and 24 for females. It appeared from the 100 day observation time that about 93% would be retained with a biological half-time greater than 5 years. The excretion of Ra 226 was high, with a feces-to-urine ratio of 30. During the 20 day observation time, biological retention of Ra can be expressed as $R(t) = 84e^{(-0.266t) \cdot 16}$. These results are in agreement with those of other workers, and higher during the first few days than the retention functions found by others. Measurements in man indicate that soft-tissue Ra retention is high. This finding, combined with the whole-body biological retention, points to a skeletal retention which may be as low as 10% of the injected dose and relatively constant in the first few weeks. Average adult skeletal radiation dose estimates vary between reasonable limits of 0.05 to 0.5 rad/uCi Ra 226 injected. The median value is 0.25 rad/uCi and a probable value is 0.15. For children the estimated average skeletal dose ranges from 0.3 to 0.9 rads/uCi multiplied by the factor of (70 kg/body weight of child) to account for their smaller weight. (Auth)

<668>

CRITICAL ASPECTS

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Snally, P.J., J. Schuit, R.W. Ryan, and D. Pulesch, Pearl Harbor Naval Shipyard, San Francisco, CA; National Lead Company, Nuclear Metals Division, Albany, NY; Rensselaer Polytechnic Institute, Troy, NY; Rensselaer Polytechnic Institute, Department of Environmental Engineering, Troy, NY. 1972.

The Use of Thermoluminescent Dosimeters (TLD) for Hand Dosimetry in a Depleted Uranium Operation. Health Physics, 21, 437.

Depleted uranium is an alpha, beta, and gamma emitter. For calculations of the dose to the hands of workers handling depleted uranium, only the beta particles contribute significantly to the dose. A theory for the dose from a semi-infinite source of beta-particle emitters was developed from an exponential approximation of the attenuation of a beam of beta particles by an absorber. It was found that the theory predicted the correct value for dose at 7 mg/cm², the skin dermal layer depth, but that it predicted the dose would fall off with depth faster than it did experimentally. A method for using thermoluminescent dosimeters (TLD's) for measuring hand dose was developed, and experiments were run in a depleted uranium fabrication plant to determine doses to workers. Results showed that the doses were near the maximum permissible dose values set by the National Commission on Radiological Protection, but that the standard deviations for the experimental values were almost as large as the values themselves. (Auth)

<669>

Farr, B.S., A. Chaudhry, S. Thaler, and A. Sachdev, University of Louisville School of Medicine, VA Hospital, Louisville, KY. 1976, April.

Hepatitis Induced by Thorium Dioxide. Southern Medical Journal, 69(4), 510-512.

A 74-year-old man complained of anorexia, malaise, easy fatigability, epigastric distress, and weight loss. Twenty-six years earlier he had received a 50-ml injection of Thorotrast. Laboratory tests were normal except for a high alkaline phosphatase level of 19.5 Bodansky units (normal range is 2.5-4.5). Abdominal roentgenogram showed Thorotrast in spleen and liver. Tc 99 scan showed a shrunken spleen, reduced isotope uptake in the right liver lobe, and absence of uptake in the left lobe. A needle biopsy of the liver showed periportal fibrosis and the presence of ThO₂ particles. Laparotomy showed the right liver lobe to be shrunken and adherent to the diaphragm; the left lobe was hard, fibrotic and a vascular. Biopsy of the left lobe revealed the presence of ThO₂ and malignant hepatoma cells. Hepatic malignancy should be considered possible in any patient showing abnormal liver function tests, and particularly if a patient has a history of Thorotrast injection in addition to an elevated alkaline phosphatase level. (VC)

<670>

Portland, J.S., P. Canlon, and J.P. Knaf, St. Mary's Hospital, Orange, NJ; City Hospital, Pathologic Department, Newark, NJ; Office of the County Physician of Essex County, Essex County, NJ. 1975, December 5.

Some Unrecognized Dangers in the Use and Handling of Radioactive Substances. Journal of the American Medical Association, 235(23),

1765-1776.

Radioactive elements are among the most powerful known agents affecting the hematopoietic system. From the moment of introduction into the body by any channel, they act spontaneously and, according to the element and its quantity, irritate the blood-producing centers to various degrees. Small doses increase temporarily red and white cell production. After a shorter or longer time, small or larger doses cause partial or almost total destruction of leukocytes and a diminution in the erythrocytes, producing a severe anemia that simulates the pernicious anemias of regenerative and aplastic types. The anemias described in case histories here resulted from ingestion of radioactive elements and their deposition in cells of the reticuloendothelial system. Necrosis of the jaw as well as appearance of buccal lesions resulting from local irritative radiation usually precede the anemia. Radioactivity in the body during life was measured by electrometers. By the same method, radioactivity from mesothorium, radium, and decay products was demonstrated in expired air. I.V. injections of long lived radioactive elements or ingestion of mesothorium or radiothorium produces late harmful effects and are not generally warranted in any medical condition. A pernicious type of anemia may be caused by minute amounts of radioactive tracers. It is advisable to test expiratory air in all who work with radioactivity and develop symptoms. (Auth) (VC)

<671>

Hanson, T.J., C.F. Fraumeni, Jr., F.W. McFay, National Cancer Institute, Epidemiology Branch, Bethesda, MD. 1972.

Granite Mill Tailings and Cancer Mortality in Colorado. Journal of the National Cancer Institute, 69(3), 661-666.

A sandlike residue from uranium mills widely used as a construction fill material since 1951 in the Western Slope counties of Colorado was recently reported to be carcinogenic. County-specific mortality statistics for cancer were studied through 1967. No significant excess in mortality from lung cancer or leukemia attributable to residential radiation exposure was detected. Mortality from malignant neoplasms other than lung cancer and leukemia was significantly greater among males in the Western Slope but the reason for this geographic difference is unclear. Continued monitoring of the population for radiation effects is recommended. (RAF)

<672>

May, R., L.D. Marinelli, and J.B. Corcoran, Argonne National Laboratory, Argonne, IL. 1967, December.

In Vivo Counting of Thorium Dioxide Patients: Special Techniques and Preliminary Results. Annals of the New York Academy of Sciences, 165(3), 623-633; CONF-660422: Distribution, Retention, and Late Effects of Thorium Dioxide, E.L. Svars (Ed.), Proceedings of a Conference held in New York, New York, April 20-22, 1966, (pp. 623-633), 336 pp. (CONF-660422).

Although experience with living Thorotrast patients is limited to a small number of patients, considerable attention has been paid to improved methods of extracting either

MEDICAL ASPECTS

<472> CCST.

more information, or more accurate information, from the data obtained by IVVC counting. Three techniques which possess unique advantages and merit further investigation are described. They are: the ratio method, the coincidence counting technique, and the sum coincidence method. Final validation of many of the measurements must await recovery of suitable autopsy or biopsy specimens. (Auth) (VC)

<473>

Payne, C.W., University of Utah, Radiobiology Division, Salt Lake City, UT. 1973, March 31; 1973, December.

Cancer Induction in Man from Internal Radioactivity. COO-119-248; Research in Radiobiology, Annual Report of Work in Progress in the Internal Irradiation Program, T.F. Dougherty (Ed.), (pp. 378-400), 400 pp. (COO-119-248); Health Physics, 25, 585-592.

Literature on the induction of malignancies in uranium miners by Ra 226, dial painters by Ra 226, Thorotrast cases by Th 232, German patients by Ra 226, polycythemia patients by P 32, and Marshall Islanders by I 131 is reviewed. Almost all of the induced malignancies arose within the irradiated tissue. (ST)

<474>

Payne, C.W., University of Utah, Radiobiology Laboratory, Salt Lake City, UT.

Endosteal Dose to Thorotrast Patients. Radion 226 and Thorotrast, Proceedings of an International Symposium held in Alta, Utah, (7 FF-).

For a 70-kg man injected intravenously with a typical 25 ml of Thorotrast (about 0.6 uCi Th 232), the dose-rate to the endosteum, 0 to 10 cm from bone surfaces, is estimated at roughly 16 rad/yr, of which 7 rad/yr is from Ra 226, Th 232, and Ra 228 translocated from Thorotrast to calcified bone, and about 9 rad/yr is from Thorotrast on bone surfaces and in red marrow. Additional dosimetric analyses are needed to refine these provisional estimates. For the induction of osteosarcomas in the Thorotrast patients, it is possible that the most important dose is from the Ra 226 continually deposited on all bone surfaces, rather than from the focal aggregates of Thorotrast which irradiate fewer bone cells but kill with multiple alpha-particles a higher fraction of those cells that are irradiated. (Auth)

<475>

Payne, C.W., T.F. Dougherty, G.E. Taylor, B.J. Stover, B.S.S. Jew, B.B. Christensen, J.B. Dougherty, B. Stevens, and C.J. Mahors, Jr., University of Utah, College of Medicine, Division of Radiobiology, Department of Anatomy, Salt Lake City, UT. 1970.

Bone Cancer Induction by Radionuclides: Incidence vs. Dose. COO-119-242; Research in Radiobiology, Annual Report of Work in Progress in the Internal Irradiation Program, T.F. Dougherty, (pp. 385-401) (COO-119-242).

Dose-response relationships are reviewed for several bone-seeking radionuclides in dogs, rodents and man. This includes beagles injected with Pa 239, Th 230, Ra 226 (RaTh), Ra 226, or Sr 90 at the University of Utah; rats injected with Sr 90 by T.I. Bonkalev et

al.; mice injected with Sr 90 or Ra 226 by E. Finkel et al.; dial painters and other persons containing Ra 226 and Ra 228 (RaTh) and studied by E.S. Evans et al. and A.J. Finkel et al.; and German patients injected with Ra 226 (Th-X) who are being followed by E. Spiess. For the beta-emitter Sr 90, a sigmoid dose-response relationship is seen, characterized by a low-risk region in which few if any bone cancers have been induced. This suggests that considerable recovery from beta-irradiation is possible, provided that the dose-rate is sufficiently low. For the alpha-emitters, data on Ra 226 in man support a practical threshold, below which few if any cancers should be induced; while data on Ra 226 in mice support a linear relationship in which cancer induction increases in direct proportion to dose, provided that the dose is not excessive. The other alpha-emitter results, each considered separately, can rule out neither the linear nor the threshold models although taken collectively, the threshold model seems better supported. It is possible that in general the most probable response at low dosage is a sigmoid relationship somewhere in between the linear and threshold models. (Auth)

Graphs are given for dose response in rats, dogs and man for the radionuclides.

<476>

Payne, C.W., B. Haldin, and H.A. Van Dilla, University of Utah, Radiobiology Laboratory, Salt Lake City, UT. 1958.

Thoron Exhalation in Radiothorium-Breathed Beagles. Radiation Research, 9, 438-444.

The effects of internal emitters was studied by injecting separate groups of young adult beagles with radium (Ra 226), mesothorium (Ra 228), and radiothorium (Th 230). The metabolism and effects of these bone-seeking radionuclides and their daughters was then studied by measuring thoron exhaled in the animal's breath. Thoron, a chemically inert gas that does not chemically combine with other elements, lies in the thorium decay series. Thoron produced in the body from the decay of Ra 226 reaches the circulation, where it is carried to the lungs and is exhaled in the breath. The dogs were injected, and then fitted with a snug mask into which they breathed for 20 minutes. The mask connected to a 16-liter tank in which most of the thoron atoms decayed to form positively charged Pb 212 atoms. These atoms were collected on a negatively charged stainless steel rod and measured on an alpha-particle scintillation counter. Results showed that dogs injected with Th 230 or Ra 228 exhaled only a small portion of the thoron produced in the body which is due to the 54 second half-life of thoron, dogs injected with Th 230 showed an exhaled thoron decrease as time increased which could be due to progressive "burial" of Th 230 and Ra 228 atoms in locations less to circulation, and dogs injected with large amounts of Th 230 showed less exhaled thoron than dogs receiving lesser doses. The third conclusion could be due to a radiation damage effect which would impair circulation. (GAB)

<477>

Payne, C.W., and B.D. Lloyd, University of Utah, College of Medicine, Division of Radiobiology, Salt Lake City, UT. 1972.

Bone Sarcoma Incidence vs. Alpha Particle Dose. Radiobiology of Plutonium, B.J. Stover and

<477>

MEDICAL ASPECTS

<477> CCVT.

B.S.S. Jee (Eds.). J.E. Press, Salt Lake City, Utah, (pp. 409-430), 552 pp.

The incidence of bone sarcomas was analyzed in 12 studies involving graded doses of alpha-emitters in humans, dogs, mice and rats. A linear dose-response relationship anchored to control incidence at zero dose, was fit through each set of data over the wide dosage range extending up to, or near, the region of peak incidence. Then in the low dose regions the observed cases of bone sarcoma were compared to those from "wide dose" linear predictions. At low doses the observed cases were significantly fewer (P is less than 0.1) than predicted for Ra 226 plus Ra 228 in humans; for the summed studies of Ra 226, Ra 228, and Th 230 in dogs; and for Pu 239 in mice. However, the low dose results agree better with the indicated linear predictions than with the expected natural incidence for Ra 226 and Ra 228 in mice, and for Pu 239 in rats. The induction of bone sarcomas by alpha-emitters appears to increase linearly with dose in some cases, but to follow threshold or sigmoid relationships in others. This is in sharp contrast to the induction of bone sarcomas by beta-emitters where the observed dose-response over a wide dosage range was non-linear in every known case. (Auth)

Table 6 gives Pu 239 induced bone sarcomas in eagles, April 1970. Table 8 gives Pu 239 induced bone sarcomas in mice, 1962. Table 10 gives Pu 239 induced bone sarcomas in rats, 1970.

<478>

Mays, C.W., and H. Spiess, University of Utah, Medical Center, Radiobiology Laboratory, Salt Lake City, UT; University of Munich, Children's Poliklinik, Munich, German Federal Republic. 1977.

Bone Tumors in Thorotrast Patients. Toxicity of Thorotrast and other alpha-Emitting Heavy Elements, Proceedings of an International Meeting held in Lisbon, Portugal, June 28-July 2, 1977, (18 pp.).

Among the Thorotrast patients throughout the world, nine bone sarcomas (six histologically confirmed and three possible) were reported as of 1974. Their appearance times ranged from 16 to 33 years, averaging 26 years after Thorotrast injection. In some countries the population at risk is uncertain, but in Denmark, Germany and Portugal, about 3000 patients have been followed more than ten years (45000 person-years at risk beyond the first ten years). In these 3000 patients, three to six bone sarcomas have occurred, compared with 0.5 case expected naturally. Using the dosimetric results of Howland and Bando, and assuming that translocation Ra 226 was mainly responsible, the provisional risk coefficient is 55 to 120 bone sarcomas/10(± 6) person-rad of average dose to the skeleton without marrow. This risk coefficient is highly tentative because it is based on only three to six bone sarcomas, all reported since 1972. If additional bone sarcomas occur among the living Thorotrast patients, the risk coefficient could increase appreciably. For comparison, the risk coefficient for lung protracted injections of Ra 224 is about 200 bone sarcomas/10(± 6) person-rad, based on 54 cases of bone sarcoma. (Auth)

<479>

McNeill, K.G., J.E. Harrison, K.P. Mirza, J.

Tal-Pov, D.C. Goule, and R.J.V. Barnett, University of Toronto, Departments of Physics and of Medicine, Toronto, Ontario, Canada; Government of Ontario, Department of Health, Radiation Protection Laboratory, Ontario, Canada. 1968. October.

Thorium Body Burdens in Humans Following Thorotrast Myelography and the Incidence of Myelopathy. British Journal of Radiology, 41, 755-761.

Toronto General Hospital records show that 26 persons received Thorotrast myelography in the years 1940 and 1941. Of these, 15 have been located and the activity in nine has been measured for residual thorium activity using a whole-body counter and thoron exhalation techniques. For comparison, measurements of thorium burdens of nine subjects who had Thorotrast arteriograms are presented. Of the 15 myelography cases located, 12 have had serious progressive cauda equina deficit. Even on the assumption that the 11 allocated are all well, the incidence of myelopathy is still nearly 50 percent. On certain assumptions the thorium burdens of the nine measured are ascertained to be between 0.03 and 1.0 g, with a mean value of 0.45 g. It is pointed out that these levels are all comparable to, and in some cases less than, the maximum permissible body burdens (ICRP) and yet severe effects have occurred. (Auth)

<480>

Mole, R.H., Medical Research Council, Radiobiology Unit, Harwell, Didcot, Berkshire, England. 1971, May.

Radiation Effects in Man: Current Views and Prospects. Health Physics, 20, 485-490.

Radiation protection is concerned with only a small number of possible kinds of late somatic damage and of these malignant disease is the most important. Non-specific ageing is probably irrelevant. Accumulated information suggests that after uniform whole-body exposure cancers will be an order of magnitude more frequent than leukemias. A linear dose-response relationship is compatible with the data on leukemia induction in Japanese survivors and on thyroid cancer in Americans irradiated in childhood. Cancers following external exposure to penetrating radiation have not yet occurred frequently enough for estimation from this point of view. Two observations tell against a simple linear hypothesis: the exponential increase in susceptibility in ankylosing spondylitis to leukaemia with linear increase in age at the time of exposure and the synergistic action of cigarette smoking and uranium mining. The dose-response relationship for lens opacification is highly sigmoid and definitely non-linear. There is no general answer to practically important questions about the existence of a threshold, the form of the dose-response relationship, the effect of dose rate etc. These questions have to be considered separately for each different kind of late somatic damage. (Auth)

<481>

Molla, N.A.R., J.E. Harrison, and K.G. McNeill, University of Toronto, Departments of Physics and of Medicine, Toronto, Ontario, Canada. 1976, August.

Doses to the Cauda Equina Due to Thorotrast Myelography. Health Physics, 31, 109-114.

MEDICAL ASPECTS

<481> CONT.

Estimates have been made of the long term doses received by the cauda equina of subjects who had Thorotrast myelograms around 1960. These estimates are based on previously published data from beagles concerning the spatial and temporal distribution of thorium and its daughters following intrathecal injection, on published data on human body burden, and on new data on concentrations of radioactivity in human cauda equina. The results show that in those subjects whose long term body burdens were about 0.5 g Th, or 0.05 uCi, the cauda equina tissue typically received 10 k rad in the years between myelography and onset of myelopathy. (Auth)

<482>

Forberg, Ye. L., I. L. Shalayev, and G. B. (Translator) Lord, 1973.

Method of Evaluating the Content of Natural Radioactive Isotopes of the Uranium and Thorium Family in Drinking Water and Food. CNR-tr-4499: 5 pp.; Gijóna i Sanitariya, 9, 57-66.

A table is given (Appendix to HHS-69) which lists the annual intake limits of mixtures of isotopes of various or partially unknown composition by man. The isotopes include members of the uranium-radium, actinium-uranium, and thorium families. The concentrations of these isotopes are listed in bone, gastrointestinal tract, liver, spleen and kidneys. An equation is developed to determine the annual intake limits in food and drinking water of mixtures of isotopes of identical organotropism and of isotopes of different organotropism. A sample calculation is given for a case where contamination is caused by uranium and decay products originating in uranium ores or natural waters. (BAP)

<483>

Fiori, T., Y. Borue, T. Miyazi, and S. Takahashi, Yokohama City University, School of Medicine, Department of Pathology and Surgery, Yokohama, Japan. 1973, June.

Thorotrast Injury in Japan. CNR-730475; HSO-294; Toxicity of Thorotrast, N. Faber (Ed.), Proceedings of the 3rd International Meeting held in Copenhagen, Denmark, April 25-27, 1973, (pp. 175-192) (CNR-730475, HSO-294).

A survey of Thorotrast-administered autopsy cases in Japan disclosed a high incidence of malignant hepatic tumors, along with frequent occurrence of blood diseases, and fibrosis of liver and spleen in nearly all of the cases. In a follow-up study on 187 Thorotrast-administered war-wounded ex-servicemen, after a lapse of 31 to 36 years, six cases of malignant liver tumors, one case of leukemia, one case of thrombocytopenic purpura and five cases of cirrhosis of the liver were found. The incidence of the diseases was significantly higher than in a control group. In liver function tests of 45 cases a lowering of the protein metabolic rate and foreign body discharge function was observed, while blood examination indicated a decrease of erythrocytes, leukocytes, hemoglobin value and thrombocyte count. The total number of Thorotrast-administered persons living in Japan as of 1972 was estimated to be 5000. (BAP)

<484>

Muth, H., and T. Oberhausen, University of the Saar, Homburg, German Federal Republic; United States Medical Research Unit, Lindstuhl, German Federal Republic. 1961, June.

Measurement of Radium and Thorium Burdens. CNR-730475; HSO-294; Toxicity of Thorotrast, N. Faber (Ed.), Proceedings of the 3rd International Meeting held in Copenhagen, Denmark, April 25-27, 1973, (pp. 320-333) (CNR-730475, HSO-294).

In 1960, the University of the Saar and the United States Medical Research Institute started a joint research program on the measurement of persons with deposition of radionuclides of the natural uranium-radium and thorium series, especially of Thorotrast patients. The examination of each person included an evaluation of the body burden of the different radionuclides with the help of a Los Alamos scintillation counter, measurement of radon and thoron concentrations in expired air, and measurements of different radionuclides in blood, urine, and feces. Results are reported for 21 persons. The activity of the deposits was in the range of $3 \times 10^{10} (E-7) - 5 \times 10^{10} (E-9)$ c for persons with Ra 226 or Ra 228 deposits and in the range of $12 \times 10^{10} (E-7)$ to $2 \times 10^{10} (E-7)$ c for Thorotrast patients. (BAP)

<485>

Muth, H., T. Oberhausen, B. Kinkel, and U. Herzfeld, University of the Saar, Institute for Biophysics, Homburg, German Federal Republic; University of Heidelberg, Department of Clinical Radiology, Heidelberg, German Federal Republic. 1973, June.

Expected Late Effects in Thorotrast Patients. CNR-730475; HSO-294; Toxicity of Thorotrast, N. Faber (Ed.), Proceedings of the 3rd International Meeting held in Copenhagen, Denmark, April 25-27, 1973, (p. 320-333) (CNR-730475; HSO-294).

Measurements were taken of the total-body radioactivity and of the thoron concentration in exhaled air of about 540 Thorotrast patients. Using the results of special animal experiments and direct measurements on patients, both the dose rate as a function of the age of the Thorotrast burden and the accumulated radiation dose in different organs of the patient was calculated. The average values as well as the upper limits of the radiation exposure of the different organs (liver, spleen, marrow-free skeleton, bone marrow and lungs) are given. Using these data and the most probable values for risk coefficients published, the expected radiation induced late effects (leukemia, bone tumors, lung tumors, and liver tumors) in a Thorotrast group were estimated and discussed. The results show quantitatively the importance of follow-up studies of Thorotrast patients for gathering optimal and useful radiobiological data. (BAP)

<486>

National Commission on Radiological Protection, Subcommittee on Permissible Internal Dose, Washington, DC. 1953, March 20.

Maximum Permissible Amounts of Radioisotopes in the Human Body and Maximum Permissible Concentrations in Air and Water. National Bureau of Standards Handbook No. 52: 45 pp.

MEDICAL ASPECTS

<486> CGPT.

The increased use of radionuclides by industry, the medical profession, and research laboratories, made it essential that minimal precautions were taken to protect the users and the public. This was the first official published report of the Subcommittee on Permissible Internal Dose of the National Committee on Radiation Protection. The recommendations contained in this handbook represented the best available opinions on the subject as of that time. The values given were derived on the basis of continuous exposures for a lifetime or for the equilibrium condition in which the rate of elimination had become equal to the rate of deposition in the body in all cases except for ^{226}Ra , ^{232}Th , and ^{239}Pu . Therefore, their use as intake values for a period of several years was believed to be justified. The values were chosen by the Subcommittee as the most acceptable values after considering a preliminary report which gave values recommended by various radiation protection committees as were listed in this report, and after making comparisons with values calculated by use of the data which was summarized in tabular form. This report considered the radionuclides that were of interest at that time. Others were to be considered in subsequent reports as information about them was needed and data became available. (JTE)

<487>

Botem, A., and Y. Segal, Technion - Israel Institute of Technology, Department of Nuclear Science, Haifa, Israel. 1972, December.

Eye Exposure by Thorium Contained Lenses. Health Physics, 23, 860-861.

In certain lenses Th is added to achieve special optical properties. Th found in one set of lenses was 20% in weight. These lenses can expose the face, and especially the eyes, to radiation from the Th series. Energies of photon, beta, and alpha radiations amount to 2.62, 2.26, and 8.78 MeV, respectively. The major contributor to the absorbed dose is the alpha radiation. Lenses with high Th delivered up to 0.15 mS/hr of gamma rays, 0.29 mS/hr of low energy photon and beta radiations, and 180 alpha particles/sec to the eye (1.8 sq cm) at 3.0 cm from the lens. Low energy photons result in part from inelastic scattering in the lens, but most are from I-ray fluorescence of heavy elements excited by the energetic radiations. A typical spectrum from a lens containing natural Th and La is shown. The dose to the eye by alpha radiation for a plane absorber (B20) 3 cm from the lens may be 120 res/hr. At less than 3 cm, the absorbed dose increases due to the higher flux of isopropyl alpha particles. The change of alpha flux as a function of eye-lens distance is given. A more careful estimate reveals that a fraction of the alpha energy is lost in the tear film and the delicate conjunctival membrane. It is believed that this layer of 7-9 μ , 98.2% water, acts as an absorber and radiation damage there is important. The alpha particles do not penetrate the cornea more than 0.05 μ . The corneal surface is exposed to 60 res/hr and the inner layers to a dose lower by a factor of 2×10^4 (8%). A layer of transparent material less than 1 μ thick removes the alpha flux. (Aeth) (VC)

<488>

Govak, L., and D. Pasor, Institute of

Occupational and Radiological Health, Belgrade, Yugoslavia. 1972, March.

Polonium 210 in Blood and Urine of Uranium Mine Workers in Yugoslavia. American Industrial Hygiene Association Journal, 33(3), 192-196.

Two groups of uranium miners were studied to determine the correlation between the concentrations of atmospheric radon to which they were exposed and the concentrations of polonium 210 in their blood and urine. Radon exposures were of the order of $7.61 \pm 0.25 \times 10^6$ (E-10) Ci/liter. The excretion of Po 210 in urine was 1.03 pCi/liter for miners exposed 3 years, and was 1.63 pCi/liter for miners exposed for 10 to 12 years. For one group the concentrations of Po 210 correlated with the radon exposures but for the other group the correlation was not statistically significant. It was established that no correlation between the concentration of radon in the air and the concentration of Po 210 in blood and urine. Therefore, the determinations could not help in evaluating the effect of exposure to radon on the health of uranium miners. (Aeth)

<489>

Oberhausen, E., H. Reth, and F. Grillmaier, Universität des Saarlandes, Institut für Biophysik, Homburg, German Federal Republic. 1972.

Measurements and Clinical Findings on Thorotrast Deposits in the Kidney. COOP-711104: STI/PUB/290: IAEA-SM-150: Assessment of Radioactive Organ and Body Burdens, Proceedings of a Symposium held in Stockholm, Sweden, November 22-26, 1971, (pp. 491-503) (COOP-711104, STI/PUB/290, IAEA-SM-150).

Seven cases of Thorotrast deposits in the kidneys are discussed. Histological examination showed five carcinomas and advanced degenerative changes in one kidney. The time between the deposition of Thorotrast and the appearance of clinical symptoms caused by the carcinoma was more than twenty years in all cases. Two patients were subjected to whole-body counting, measurement of radioactive substances in the urine, and measurement of thoron in the breath. All measurements were done before and after nephrectomy. The gamma radiation of the isolated organ was also measured. From these data the radiation dose was estimated. (RAP)

<490>

Pašek, V., J. Adríková, and V. Wágner, Health Institute of Uranium Industry, Research Department, Příbram, Czechoslovakia. 1975.

Serum Immunoglobulins in Uranium Miners after a Workload. Physiologia Bohemoslovaca, 24(5), 459.

In two groups, each consisting of 22 miners, exposed for 5.5 and 10.8 years to the highest of uranium mines the serum levels of immunoglobulins (Ig G, Ig A and Ig M) were measured before and after a work shift. In the group exposed for the longer period of time the work load significantly decreased all three classes of Ig. In the group with the shorter exposure, only the Ig G decreased significantly. In the group with longer exposure the initial levels of Ig G were significantly lower in comparison with the group exposed for a shorter period of time. (Aeth)

MEDICAL ASPECTS

<491>

Fallister, K.F., and J.H. Green, University of New South Wales, Department of Nuclear and Radiation Chemistry, Sydney, Australia. 1965.

Environmental Radioactivity in New South Wales. NRS-10: 24 pp.

The inhalation and ingestion of the natural alpha-emitting nuclides of U, Th, Po and Ra the natural beta-emitter, K 40, and the artificial beta-emitters, Cs 137 and Sr 90 are discussed. Emphasis is put on the somatic effects in lungs and bone of the presence of these radionuclides. Difficulties in the assessment of the tissue dose levels arising from the inhalation of radioactive aerosols and in understanding the precise nature of the aerosol are noted. The natural water contents of Ra 226, Ra 228 and daughters in water from Australia, United Kingdom and the United States of America are compared. The attempt to measure body burdens of Ra 226 by the analysis of teeth in the Illinois area is considered. Fallout of natural nuclides arising from Ra 222 is reviewed and the significance of coal combustion is added to the fallout is treated in a general account of mining hazards. It is possible that these are contributing factors in the production of lung carcinoma in mining. The discovery of minute amounts of alpha-emitters in tobacco in Australia and England has led to the confirmation of the presence of Po 210, a daughter of Ra 226, in tobacco smoke and the human lung and to an estimate of tissue dose rates. It is suggested that the Po 210 content is in excess of that required for equilibrium with Ra 226, and that the excess could arise from natural fallout and subsequent absorption from the ground. High values of the Sr 90 content of tea consumed in Australia suggest a plant specificity for this nuclide. Levels of Sr 90 and Cs 137 in rainfall at Sydney and Millford Haven (U.K.) are compared for 1963. (Auth)

<492>

Farr, R.N., International Atomic Energy Agency, Vienna, Austria. 1967, December.

Information on Thorotrast Dosimetry Supplied by the Radiochemical Analysis of Tissue Specimens. Annals of the New York Academy of Sciences, 145(3), 644-653; CONF-660422: Distribution, Retention, and Late Effects of Thorium Dioxide, R.L. Swann (Ed.), Proceedings of a Conference held in New York, New York, April 20-22, 1966, (pp. 644-653), 336 pp. (CONF-660422).

Questions important in considerations of Thorotrast dosimetry relate to distribution of Th and its daughter products among and within organs, radioactive equilibrium status of daughter isotopes in various organs and the extent of self-absorption. Information from analyses of macroscopic tissue specimens is reviewed. Methods are discussed; the importance of carrying out analyses as rapidly as possible is stressed. Measurements of decay and growth of radioactivity can be used in estimating activities that existed in vivo. After intravascular injection, Th 232 is distributed to and retained in the reticuloendothelial system (RES). Precise distribution in specific organs is not known. The liver generally contains the major fraction of the body burden. Recent studies indicate that Th 232 can be 10 times as concentrated in lymph nodes as in the liver. More than 50% of total radioactivity may be present in perivascular deposits at injection

sites. Great variation among individuals probably is related to pathological conditions of the patients. Little is known about microscopic inhomogeneities, although they are known to occur in liver and bone marrow. Relative activities and translocation of Th series isotopes (Ra 226, Ac 228, Th 228, Pa 228, Pb 212, Bi 212) in various organs (skeleton, kidneys, lung, blood cells) are discussed and typical equilibrium values tabulated. Lead 212 and Bi 212 are concentrated in animal kidneys. This cannot be assumed true in man, however it is clear that a substantial amount of the total burden is outside the RES. Large amounts have been detected in blood cells (17%) and lungs (Pb 212). A model to explain the disproportionate movement of daughter isotopes from the Th 232-containing particulate phase is presented. The mechanism of escape is considered to be recoil, the energies of which are sufficient to explain the necessary movement of isotopes. The model is discussed and the point made that isotopes in the original injection solution do not necessarily metabolize in the same way as they do in vivo. (VC)

<493>

Parr, F.N., R.F. Lucas, Jr., and W.L. Gries, Argonne National Laboratory, Argonne, IL; Argonne Cancer Research Hospital, Chicago, IL. 1969.

Metabolism of Thorium 232 Decay Series Radionuclides in Man and Other Animals Following Intravascular Administration of Thorotrast. ARL-7615: Radiological Physics Division Annual Report, July 1968-June 1969, (pp. 97-115), 233 pp. (ARL-7615).

The activities of Th 232 decay series radionuclides have been studied in tissue samples from 6 human patients and 9 experimental animals to whom Thorotrast had been administered intravascularly. In favorable cases where analyses could be commenced before extensive in vitro radioactive growth or decay had occurred, the in vitro activities of seven nuclides, Th 232, Ra 226, Ac 228, Th 228, Pa 228, Pb 212, and Bi 212, were determined. The available information on the translocation of these nuclides within the body is reviewed and current best-estimates are derived for the distribution of activities and consequent dose rates in the tissues of typical long-term Thorotrast patients. The anomalous behavior of Ra 228, which is retained in the reticuloendothelial system in high concentrations, is explained by a model which postulates that atoms are trapped within the Thorotrast particles unless the recoil distance through which they move at the moment of their creation is sufficient to allow their escape. (Auth)

<494>

Pavlovskaya, N.A., and N. (Translator) Gerrard, Academy of Medical Sciences, Institute of Industrial and Professional Hygiene, Moscow, USSR. 1973.

Basic Patterns of Metabolism of Thorium 232 and Its Dissociation Products in the Body. Gigiena i Sanitariya 11, 55-58; ORNL-tr-2905; 5 pp.

Results of the analysis of published data and experimental research show that the metabolism of Th 232 and its decay products depends on the chemical nature of the radionuclides and their route of entry.

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130

PHYSICAL ASPECTS

<894> CONT.

Absorption of thorium and daughters (Th 228, Ra 226 and Pb 212) depends primarily on the ion potential. The distribution of radionuclides in the body is determined by the route of entry, solubility of thorium compounds, and the stability of complex ions. Kinetics of the radionuclide excretion is determined both by the chemical nature of the elements and by the solubility in water. Thorium is bound in the body primarily to high-molecular polymers such as nucleic acids and proteins with a high density of carboxyl and hydroxyl groups. (SAR)

<895>

Penna-Franca, E., Brazil University, Instituto de Biofisica, Rio de Janeiro, Brazil. 1968.

Radioactivity in the Diet of the Inhabitants of the Brazilian Regions of Elevated Natural Radiation. SP-18670; 43 pp.

Studies are reported on populations dwelling on high natural radioactivity areas in Brazil. Two such areas studied included the monazite sand region, along the coast of the State of Espirito Santo, and the volcanic intrusive complex, in the State of Minas Gerais. The main objective of the study was to evaluate the extent of the radioactive intake and internal contamination of the selected populations in both regions, in order to determine whether biological effects of ionizing radiation could be identified and investigated. Two villages were surveyed in the monazite sand region: Guarapary and Resende. The local production of food was found to be significant and their radioactive contents were practically within normal ranges. No statistically significant differences were observed between average Ra 226 and Th 228 contents in teeth and placenta from inhabitants of the two villages and controls. External beta and gamma radiations from the soil are the main source of human irradiation in the region. Inhalation of dust and thoron and daughter production, are secondary sources of irradiation. In the State of Minas Gerais, the villages of Tapira and Barro Preto, near Araxa, were selected for having extensive agriculture production cultivated, to a large extent, in radioactive soil. A complete survey of the radioactive contamination of local produce demonstrated high Ra 226 and Ra 228 contents in many types of foodstuff, reaching in some cases two orders of magnitude above average normal values. A dietary inquiry was conducted in a representative sample of the population which led to classify the inhabitants in groups, according to certain ranges of radioactive intake. The inquiry demonstrated that the internal radioactive contamination of the local population was of less magnitude than the levels in food had indicated. Only 12% of the inhabitants had daily intake of alpha emitters above five times the average in normal regions. Analyses of Ra 226 and Th 228 in teeth and placenta were carried on concomitantly, as a sensitive method for the detection of people with above average radium body-burdens. Body burden in these individuals will be measured using whole-body counters. Considering the relatively low levels of external and internal radiation doses to which the inhabitants of the surveyed areas are exposed, and also the small size of the population, it was concluded that the only biological effect of radiation that could possibly be of significance would be chromosome aberrations. (NSA)

<896>

Penna-Franca, E., Brazil University, Instituto de Biofisica, Rio de Janeiro, Brazil. 1968.

Radiochemical and Radioecological Studies on Brazilian Areas of High Natural Radiation. STO-3273-9; 125 pp.

Studies were conducted in three Brazilian areas of high natural radioactivity: Guarapary-Resende in the monazite sand region, Araxa, and Morro do Ferro, both located in areas of volcanic intrusives. Body burdens of Ra 226 and Ra 228 were estimated in selected individuals receiving known doses of external radiation within the range of 0.5 to 2.0 rad/yr in the monazite sand area. The frequency of somatic chromosome aberrations was estimated in selected individuals with higher than normal radium and thorium body burdens in the Araxa area. Radioecological studies are being conducted at Morro do Ferro. (NSA)

<897>

Penna-Franca, E., N. Fiszman, N. Lobao, N. Trindade, C. Costa-Silveira, and P. L. Santos, Universidade Federal do Rio de Janeiro, Instituto de Biofisica, Rio de Janeiro, Brazil. 1970, November.

Radioactivity in the Diet in High Background Areas of Brazil. Health Physics, 19, 657-662.

Two types of high background regions have been studied in Brazil: the monazite sand region along the Atlantic coast and the zone of volcanic intrusive in the inland state of Minas Gerais. In both regions people are living on variable fields of radiation ranging from 0.03 to 1.0 mR/hr. To evaluate the extent of the radioactive intake and internal contamination of representative populations, an extensive survey was carried out. In villages in the monazite sand region, the local production of food was found to be insignificant and the radioactive contents were practically within normal ranges. In the volcanic intrusive zone, two villages were selected for having extensive agriculture production cultivated, to a large extent, in soils containing thorium and uranium minerals. The radioactivity in local produce is appreciable, mostly due to Ra 226 and daughters, which in some types of foodstuff reach two orders of magnitude above average normal values. A dietary inquiry conducted in a representative sample of the population allowed the classification of the inhabitants in groups, according to certain ranges of radioactive intake. In spite of the high levels in some local foods, mostly root vegetables, only 13% of the inhabitants presented daily intake of alpha emitters above 5 fold the average in normal regions. The maximum daily intake observed was elevated by a factor of 20. For the high intake group, the estimated Ra 228 body-burdens were in the range of 1-3 mCi. (Auth)

<898>

Plamer, E.E., R.W. Perkins, and B.O. Steart, Hanford Atomic Products Operation, Hanford, WA. 1964, December.

The Distribution and Deposition of Radon Daughters Attached to Dust Particles in the Respiratory System of Humans Exposed to Uranium Mine Atmosphere. Health Physics, 10(12), 1125-1133; CONF-64: Inhaled radioactive

TECHNICAL ASPECTS

(498) CCST.

Particles and Gases, Proceedings of the Sanford Symposium held in Richmond, Washington, May 4-6, 1968, (8 pp.) (CONF-56-1).

A mobile whole-body counting facility was used to study deposition of inhaled airborne particles with adsorbed radon daughters in human beings exposed in two uranium mines. Comparison of air samples with whole-body counting data obtained for 0.5-2.5 hr exposure in mines indicated nearly 100% deposition of radon daughters. The count median diameters of the airborne dusts were 0.1 and 0.2 μ and the mass median diameters were 0.3 and 0.7 μ in a non-operating and an operating mine, respectively. Longitudinal scans showed that 20% of total deposited radioactivity was in the head, 17% in the neck region and 70% in the chest 15 min following exposure. There was little apparent translocation up to 2 hr after exposure. (Auth)

(499)

Fohl, R.O., Cornell University, Department of Physics, Ithaca, NY. 1976, August.

Health Effects of Radon 222 from Uranium Mining. Search, 7(8), 345-353.

Health effects of radon 222 and its short-lived daughters arising from tailings in mill operations are discussed. The decay product of thorium 230, radon 222, along with polonium 218, polonium 214, lead 214 and bismuth 214 are predicted to cause approximately 400 lung cancer deaths/giga-watt year of electrical energy produced in light water reactors. This figure is high in comparison to those for other isotopes: Krypton 85 has a health impact of 0.034 fatal cancer cases and genetic defect/GB (gy) in a world population of four billion. The 400 lung cancer deaths dwarfs previous estimates of health impact of nuclear power generation, making it comparable to that of power generation from coal. (VC)

(500)

Preryna, A.P., W.W. Ayres, and W.C. Hulry, T.S. Naval Medical School, National Naval Medical Center, Department of Pathology, Bethesda, MD. 1953.

Late Effects of Thorotrast in Tissues. Radiology, 60, 573-578.

From the studies and case history reviewed here, it is apparent that Thorotrast is responsible for serious disease, which is often late in appearing. Continued, increasing radioactivity from decay of Th is responsible for the effects. The material is retained in the reticuloendothelial system; rarely, it results in aplastic anemia or malignancy. Most commonly, complications arise from accidental perivascular deposition which causes destruction and scarring of the tissue. In general, doses are 25-75 cc; gamma ray activity of 75 cc is equivalent to 1.37 ug of radium. The alpha radiation effect in an average dose is equal to 2 ug of radium, an amount causing serious poisoning. The maximum permissible amount of Thorotrast for deposition in the body is 0.5 ug - 75 cc contains 0 g. After 10 years, total radioactivity is 50% of the original solution and increases for the next 15 years. A case report described is of a 53-yr-old man who received a Thorotrast injection 12 yrs prior to swelling and pain in his arm. A large,

firm, radiopaque mass was found on the lateral brachialis muscle and antecubital region. Pathological study showed muscle atrophy, fibrous material and, in macrophages, or free in the stroma, Thorotrast. Its presence was confirmed by autoradiography and Geiger-Muller counting. Twenty-five percent of gamma activity in a 25 cc vial was still present in the soft tissue. Radioactivity was also in lymph nodes, liver and spleen. Activities were as high as 100 times the permissible level for the whole body. The possibility of late Thorotrast treatment should be considered when there is a radiopaque mass in soft tissue. (VC)

(501)

Sancitelli, L.A., F.W. Perbiss, and A.D. Sanzetti, Jr., Battelle-Pacific Northwest Laboratories, Richland, WA. 1969, June.

The Multielement Analysis of Human Lung Tissue. BNWL-1051 (Part 2): Annual Report for 1968, D.S. Pearce (Ed.), (pp. 6-9) (BNWL-1051, Part 2).

Human lung tissues obtained from individuals with experience in copper ore processing, uranium mining, uranium processing, and heavy metals processing have been analyzed by instrumental neutron activation analysis. The concentrations of 19 elements are reported in the lungs of these individuals and are compared with the concentrations measured in a normal individual. The uranium miner was found to have 2 ppm U and the uranium processor 27 ppm U, compared to 0.101 ppm U in the normal individual. The lung from the subject with a heavy element exposure had a normal uranium concentration but contained eight times the normal Th. (Auth)

(502)

Reynolds, J.C., P.P. Gustafson, and L.D. Marinelli, Argonne National Laboratory, Lemont, IL. 1951, November.

Retention and Elimination of Radium Isotopes Produced by the Decay of Thorium Parents within the Body-Calculations and Comparison with Experimental Findings. ANL-5449; 43 pp.

Radium daughters are produced in vivo by radioactive decay of thorium isotopes in the body and partially eliminated by metabolic processes. If the assumption is made that the radium formed gains access to the general circulation and it is retained according to the law $R(t) = (1-b)e^{(E-b)t}$, it is possible to calculate the elimination of Ra from the body of time, and the radioactive equilibrium of Ra to Th in vivo. These calculations have been performed for the case of a single administration of thorium (masses 227, 229, 229, 230, and 232) and for values of b extending from 0.1 to 0.9. Comparison with results reported in the literature shows good agreement in cases on noncolloidal deposits of thorium. In the case of Thorotrast (Th 232 ThO2) patients the agreement is poor, but it can be improved by making the assumption that only a fraction of the radium formed in soft tissue is available to the general circulation. These calculations, in conjunction with some reported observations, imply that the radioactivity present in the skeleton of an average Thorotrast patient is equivalent to 0.5 - 1.0 M.P.L. (average permissible level) on a dosimetric basis; hence, follow-up of these patients should aid materially to the subject of the chronic toxicity of bone-seekers in humans. To facilitate eventual analysis in terms of metabolic compartments, the radium retention

<502>

MEDICAL ASPECTS

<502> CONT.

Functions have also been expressed as the sums of four exponential terms for periods of time <200 days; the ratios of the activity of the radium daughters to that of the thorium parents, as calculated by this procedure, agree with the calculations based on the power function. (Auth)

<503>

Roberts, J.C., Jr., and K.E. Carlson, University of Pittsburgh, School of Medicine, Department of Pathology, Pittsburgh, PA. 1956.

Hepatic Duct Carcinoma Seventeen Years after Injection of Thorium Dioxide. Archives of Pathology, 62, 1-7.

A case of carcinoma of the hepatic duct is reported. This tumor developed 17 years after intravascular injection of thorium dioxide into an extremity for demonstration of a peripheral vascular abnormality. Although no direct cause and-effect relationship can be proved, thorium dioxide was extremely prominent in portal lymph nodes and in the portal aspect of the liver. The presence of thorium dioxide was diagnosed before death by an abdominal roentgenogram and proved by spectrochemistry after death. Radioactivity was demonstrated by gamma-counting and autoradiographs. The estimate of the quantity of thorium dioxide retained, based on calculations of the amount found at autopsy in liver, lymph nodes, and spleen, is in remarkable agreement with the usual dosage for peripheral vasculography. (Auth)

<504>

Forblat, J., and G. Ward, Medical College of St. Bartholomew's Hospital, Physics Department, London, England. 1956.

The Radioactivity from Thorotrast and Its Retention in Tissues. Physics in Medicine and Biology, 1, 125-137.

The retention of thorium and its decay products in tissues, after the administration of Thorotrast, has been investigated. The activity of each of the alpha-emitting products present in the Thorotrast at various times after preparation has been measured by mixing Thorotrast with a nuclear emulsion and analyzing the lengths of the alpha-particle tracks. The deposition of Thorotrast in the reticulo-endothelial system after injection and the activity of tissue samples in vitro have been investigated by means of alpha-track autoradiographs. By comparing this activity with that of the Thorotrast at the same time, the escape of RaThI and ThI in vivo could be deduced. The results obtained with sections of spleen, liver, bone marrow and other tissues from five patients show that from 50 to 100% of all alpha-emitting products are retained in the tissues. There are considerable variations from organ to organ and even in the various parts of the same organ. (NAP)

<505>

Bouland, R.E., and J. Rundo, Argonne National Laboratory, Center for Human Radiobiology, Radiological and Environmental Research Division, Argonne, IL. 1973, June.

The Skeletal Dose from Radium 226 Following Intravascular Administration of Thorotrast. CONF-730875; NISO-298; Toxicity of Thorotrast, N. Faber (Ed.), Proceedings of the 3rd

International Meeting Held in Copenhagen, Denmark, April 25-27, 1973, (pp. 95-121) (CONF-730875, NISO-298).

With the use of a set of "best estimates" of the distribution of Th 232 and its daughters in the marrow-free skeleton following intravenous administration of Thorotrast, the dose to bone from "translocatable" Ra 226 has been calculated. "Translocatable" Ra 226 is that radium created *IN VIVO* that is free to translocate, i.e., equivalent to systemically injected radium. The accumulated dose to bone from this Ra 226 25 years after injection of 25 μl of Thorotrast is of the order of 25 rads. A linear dose-effect relationship for the appearance of bone tumors in man has been postulated from the observed tumor incidence in the series of patients injected with Ra 226 in Germany. This linear hypothesis predicts more bone tumors in Thorotrast cases than are observed, implying either that the relationship is not linear at low doses, or that at very low dose rates the effect per rad is lower than predicted. (Auth)

<506>

Bouland, R.E., and A.P. Stehney, Argonne National Laboratory, Center for Human Radiobiology, Argonne, IL. 1973.

Radiological and Environmental Research Division Annual Report, July 1972 through June 1973. ARL-8060 (Part 2): 336 pp.

During the report period medical examinations and radioactivity measurements of 302 radium patients were made at the Center for Human Radiobiology. The papers deal primarily with patients who have carried measured burdens of radium for many years. The parameters studied include characteristics and distribution of malignant tumors, immunity, tumor viruses, chromosome breakage, cytogenetic studies, excretion rates, blood levels, plasma clearance, and bone concentrations. In addition, x ray examination doses, techniques of bone study, radioisotope concentration determinations, instrumentation for monitoring and measurement, bone tumor induction in mice, and a radiological environmental survey are included. Radioisotopes studied were Ra 226 , Pb 210 , Po 210 , Th 228 , Bi 220 , Pa 231 , Bk 249 , and Cf 249 . Twenty-seven papers are included; two were selected for separate abstracts for the data base. (ST)

At the end of this volume is a complete list of 1386 radium cases with detailed exposure data, including body burdens, updated to December 31, 1972. During the past year 118 cases measured only by the New Jersey Radium Research Project were added.

<507>

Rundo, J., 1957.

The Determination of the Distribution of Internally Deposited Thorium by Means of Studies with a Realistic Phantom. Acta Radiologica, 47, 65-78.

A full-size realistic phantom "man" is described; it is made of Perspex, and filled with water. Models of the lungs, liver and spleen, and a skeleton are incorporated. Measurements of the gamma-radiation from known amounts of thorium in the liver and spleen of the phantom enable estimates to be made of the thorium contents of liver and spleen of patients, years after intravenous

MEDICAL ASPECTS

<507> CC87.

injection with colloidal thorium dioxide, solely from external gamma-ray measurements. The results are shown to be in good agreement with the amounts recorded at the time of injection, or with the amounts estimated on the basis of measurements of radioactivity without reference to phantom studies. Thorium deposits occasionally found at the site of the injection (common carotid artery) have also been studied and the results of measurements can be interpreted in terms of the amounts present. The amount of thorium in the red bone-marrow is discussed in the light of the amounts found elsewhere. (Auth)

<508>

Sando, J., Atomic Energy Research Establishment, Fawcett, Rickot, Berkshire, England. 1955, November.

Considerations of the Limits of Radiation Dosage from Thorotrast. British Journal of Radiology, 28, 615-619.

Colloidal thorium dioxide (thorotrast) has been used as a radiological contrast medium for angiography, hepatography, arthrography, etc. with an immediate undesirable side effects. The possibility of delayed deleterious radiation effects from Th deposited in the reticuloendothelial system requires serious consideration. Because of long, but variable delays before symptoms are observed, it is important to calculate the possible limits of dosage to determine the significance of initial isotopic composition. These extremes correspond to Thorotrast initially containing either isotopically pure Th 232 (the lower limit), or Th 232 with its equilibrium amount of Th 228 (RdTh). The basis of and calculations for alpha emitters are discussed. The calculation of the cumulative dose in vivo is extremely uncertain unless details of the exact RdTh content of the Thorotrast can be ascertained. An alternative would be to determine the Th:RdTh ratio in biopsy material. The application of calculations to dose and dose-rate determinations is discussed. (Auth) (VC)

<509>

Sando, J., Pinesen Laboratory, Copenhagen, Denmark. 1956.

The Radioactivity of Thorotrast. Physics in Medicine and Biology, 1, 138-146.

Thorotrast, a colloidal solution of thorium dioxide, has been widely used as a radiological contrast medium for the vascular system. Its radioactivity and its retention by the reticulo-endothelial system make it potentially hazardous and its study is important in assessing the effect of radiation on human beings. Because of the radiometric properties of the thorium series, and the tendency for the longer-lived daughter-products to be treated by the bloodstream and the body according to their different chemical properties, several reinterpretations of published measurements of radioactivity of Thorotrast patients have become necessary. These are discussed in the light of recent results, and some measurements of concentrations of daughter-products in vivo are reported. (Auth)

<510>

Sando, J., A.B. Sato, and P.G. Jensen, Pinesen

Laboratory, Copenhagen, Denmark. 1956.

Measurement of Thoron in the Breath. Physics in Medicine and Biology, 3, 191-196.

A method of measuring the thoron content of the breath of patients who have been injected with colloidal thorium dioxide as a radiological contrast medium is described. The levels are sufficiently high for the decay of the thoron to be observed using only four liters of breath in the range from 250 to 2000 nuc per liter, and they can be used to estimate the volumes of colloid injected many years previously. It is also shown that not more than about 10% of the thoron produced in the liver and spleen (the organs containing the major part of the thorium) is exhaled. The average radiation dose rates to the lung are estimated to be in the region of 0-3 rads per week (RBE for alpha particles assumed to be 10), but the dose rates to the bronchus and trachea are 10 to 15 times as great. A patient injected with 75 ml colloidal thorium dioxide may thus receive a cumulative dose to the bronchus of about 1000 rads in 16 years. (Auth)

<511>

Saccomanno, G., V.E. Archer, R.P. Saunders, L.A. James, and P.A. Beckler, St. Mary's Hospital, Grand Junction, CO; Veterans Administration Hospital, Grand Junction, CO; U.S. Public Health Service, Occupational Health Field Station, Salt Lake City, UT. 1964, December.

Lung Cancer of Uranium Miners on the Colorado Plateau. Health Physics, 10(12), 1195-1201; CONF-561; Inhaled Radioactive Particles and Gases, Proceedings of the Hanford Symposium held in Richland, Washington, May 4-6, 1964, (7 pp.) (CONF-561)

Previous reports have shown a small but definite increase of cancer of the lung among uranium miners in a defined study group. In the present study all men with cancer of the lung found during a 16-yr period were analyzed. The cases were collected in an area covering 15 counties, embracing the uranium industry in Western Colorado and Eastern Utah. Comparison of the tumor cell types revealed the uranium miners to have a high proportion (57 per cent) of the undifferentiated variety of tumors; 76 per cent of these were of the oat cell type. The comparison group, matched for age and smoking, had only 18 per cent of the undifferentiated cell type tumors. Only 37 per cent of the lung tumors of the uranium miners were of the epidermoid variety in contrast to 62 per cent for the control group. The difference in cell type cannot be attributed to cigarettes or age. Differences in survival time, symptoms and tumor location were also noted. (Auth)

<512>

Saragoca, A., M.N. Tavares, P.B. Barros, and J. Da Silva Motta. University of Lisbon, School of Medicine, Institute of Pathology, Lisbon, Portugal. 1972, April.

Some Clinical and Laboratory Findings in Patients Injected with Thorium Dioxide. American Journal of Gastroenterology, 57, 301-310.

One hundred and fifty five patients injected years ago with a colloidal suspension of thorium dioxide were clinically investigated for gastrointestinal pathology and biochemical aberrations. General dyspeptic

<512>

MEDICAL ASPECTS

<512> CCST.

Disorders were found in 91 patients, with a histological diagnosis of hepatic fibrosis in eight. Malignant liver tumors caused the death of 18 patients, seven of which were histologically diagnosed as hemangioendotheliomas and cholangiocarcinomas. Increased levels of alkaline phosphatases, alpha 2, and gamma globulins, and low serum albumin levels were noted. (BAP)

<513>

Schmidt, H., W. McCannock, Jr., and R. Brown, University of Missouri, Columbia, MO. 1931, April.

Dangers in Refining Radioactive Substances. Journal of Industrial Hygiene and Toxicology. 19(4), 117-134.

In the laboratory used for the refining of radium and mesothorium the intensity of the radiations from all sources has been reduced to a practical minimum. The ways of attaining these favorable circumstances have been described. Only two radiations remain which may be regarded as potentially harmful: gamma rays not removed by the shields and other screening devices, and alpha rays from emanations present in the air. The effects of the such reduced intensity of gamma radiations have never become apparent. The consequences to the body glands of exposure to this intensity over years have not been investigated. Radon and thoron in the air were measured quantitatively, the latter by an original application of a continuous flow method. The thoron content was of the order of $10(E+3)$ times greater than the radon, which in turn was $10(E+3)$ to $10(E+6)$ times greater than that of the earth's atmosphere. It was calculated that the number of atomic disintegrations in the lungs of a worker was approximately 25 of the number in a person carrying an amount of radium just within the limits of tolerance. For protecting workers the electroscopic examinations give a timely warning of danger, far more sensitive than any other method. Since the blood was not abnormal, it is concluded that the exposures in the refining laboratory have produced no injury to the hematopoietic organs. None of the five workers has experienced any debilitating effects. Indeed, none were anticipated, for the refining process had been carried out in the past at a time when the precautions here described were unheard of, without any harmful results to the workers, even ten years after ceasing work. Exposure to the radiations may be reduced to such an extent that the effects over a period of two or three years are negligible. (Auth)(VC)

<514>

Scheidlin, P., and G. Wagner, Institute of Nuclear Medicine, German Cancer Research Center, Heidelberg, German Federal Republic; Institute for Documentation, German Cancer Research Center, Heidelberg, German Federal Republic. 1973, June.

Development and Improvement of the Questionnaires. CCRP-730475; BISO-298; Toxicity of Thorotrast, R. Faber (Ed.), Proceedings of the 3rd International Meeting held in Copenhagen, Denmark, April 25-27, 1971, (pp. 151-156) (CCRP-730475; BISO-298).

Complete acquisition of all important data and suitable coding for statistical evaluation by computer are necessary for documenting data

in the Thorotrast research project. For data acquisition, questions are answered in code or free text. The data set includes 5 questionnaires relating to medical record, clinical aspects, and deceased or lost patients. Data processing involves collection of medical record data, examination of the patient, recording data on deceased or lost patients, recording data about re-examinations. The code used distinguishes among controls who received no Thorotrast, group 1 which probably received no Thorotrast and group 2 for which there is sure evidence of Thorotrast. The major groups of data include: patient's case history with respect to Thorotrast injection. Clinical symptoms which might reflect liver damage, granulomas, or loss of nervous function from paravascular deposits, thoracic X-rays, dosimetry of thallium 208 in body, liver and spleen and of radon 220 in expired air, hemogram, bilirubin, "excreta" and bromsulphthalein test. Other measurements included in the routine include liver scintigraphy, alpha-fetoprotein and ultrasound diagnostics. (Auth)(VC)

<515>

Schubert, J., Argonne National Laboratory, Division of Biological and Medical Research, Lemont, IL. 1961.

Internal Contamination and Its Treatment. Radiology, B. Pajevsky (Ed.), Proceedings of the 9th International Congress held in Munich, Germany, July 23-30, 1959. Georg Thieme Verlag, Stuttgart, Germany, (pp. 1251-1257), 1625 pp.

The action of chelating agents in hastening the elimination of radioelements deposited in the body is described. Specifically, the effectiveness of the well-known chelating agent, ethylenediaminetetraacetic acid (EDTA) is compared to that of diethylenetriaminepentaacetic acid (DTPA) with respect to its ability to hasten the elimination of plutonium and thorium from rats. The data show that DTPA is more effective than EDTA against trivalent and tetravalent radioelements. Ultrafiltration studies of the radioelements deposited in tissues before and after treatment with a chelating agent prove that diffusible chelate is formed within the tissues, and that the diffusibility of the chelate remains well above the control levels for at least a week. This explains the observation that, following a single injection of chelating agent, the urinary excretion of the radioelement remains well above control levels for several days afterward. While a chelating agent may act efficiently against the nonpolymerized forms of hydrolyzable radioelements such as thorium, it is shown that when the polymerized form of the radioelement is injected, the chelating agent is much less effective. This is attributed to the slow rate at which the chelating agent depolymerizes the inorganic polymer. On the other hand, subsequent injections of the chelating agent cause the urinary excretion of the polymerized element to be greater than that following earlier injections--the opposite effect is observed with the nonpolymeric or ionic form of the same radioelement. The question of the possible effectiveness of chelating agents such as EDTA against Sr 90 is discussed. Calculations based on mass action equations show that it is highly improbable that these chelating agents can affect the excretion of Sr 90. Other calculations show that it is impractical to effect the removal of Sr 90 by the administration of the stable isotope.

MEDICAL ASPECTS

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Scott, L.T., Union Carbide Corporation, T-12 Plant, Cat Fidge, TX. 1975, September.

Comparison of Thorium Gamma Spectra in Smokers and Nonsmokers. Health Physics, 29, 418-419.

The presence of thorium and thorium daughters in tobacco has been previously reported in the literature. Joyet (1973) reported positive evidence of thorium in the lungs of 5 of 10 Swiss smokers monitored by IX VIVC gamma spectroscopy. Joyet asked the U.S. Atomic Energy Commission to conduct a study demonstrating the presence or absence of thorium in lungs of smokers in the U.S. Smokers tested had smoked for at least 15 years and had not worked with radioactive materials. The energy region examined was as follows: Pb 212, 0.239 MeV, range 0.168-0.266 MeV, range 0.168-0.266 MeV; Ac 228, 0.338 MeV, range 0.298-0.360 MeV; Tl 208, 0.543 MeV, range 0.528-0.588 MeV; Ac 228, 0.911, 0.969 MeV, range 0.804-1.032 MeV; Tl 208, 2.614 MeV, range 2.428-2.736 MeV. IX VIVC gamma spectra for 42 smokers and 21 non-smokers were evaluated to determine if there was any buildup of thorium in the lungs. Statistical evaluation of the count data indicated no differences between smokers and controls at the 95% confidence level. (Auth)(VC)

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Simmons, D.J., A.T. Keane, R.B. Holtzman, and J.W. Marshall, Argonne National Laboratory, Center for Human Radiobiology, Radiological and Environmental Research Division, Argonne, IL. 1975, November.

Plugged Haversian Canals and Skeletal Dose in Radium Cases. Health Physics, 29, 767-775.

The fraction of haversian canals plugged or partially plugged by hypercalcified matrix in skeletons from 30 cases of radium poisoning was found to correlate well with dose, especially as expressed in cumulative rad-yr. There was no significant correlation with age at exposure, age at death, or duration of radium intake either directly or in multiple regression analysis. For 14 of the cases exposed predominantly to Ra 226, cumulative rads (CR) and cumulative rad-yr (CRY) correlated about equally well, but when all 30 cases were considered, including 14 cases exposed predominantly to Ra 228 the correlation coefficient between plugging and CRY was 0.61 ($P < 0.01$), while that with CR was only 0.38 ($P < 0.01$). Plugging varied approximately as the square root of either CR or CRY within the range of doses observed (1-30 krad and 10-700 krad-yr). The expression, (% plugs) 1.6, predicts the observed CRY in krad-yr within a factor of two in two-thirds of the cases. Plugging due to radium can probably not be detected below a CR of 1000 rads or a CRY of 10 krad-yr because the normal incidence is the order of 1%. Reduced X-ray score for the same 30 cases also correlated with CRY, but not as well as did the plugged canals. (Auth)

Extensive data, as well as references for each case are tabulated.

<518>

Spies, H., and C.W. Nays, University of Munich, Röntgenphysik, Munich, German Federal

Republic; University of Utah, Salt Lake City, UT. 1970, December.

Bone Cancers Induced by Radium 226 (Th II) in Children and Adults. Health Physics, 19, 713-729.

The average skeletal dose in rads was calculated for 217 juveniles and 708 adults injected with Ra 226 (mainly during the years 1946-1951) for the treatment of tuberculosis, ankylosing spondylitis and other diseases. For each 1000 mCi state by the supplier, about 140 mCi Ra 226 was injected. For each injected mCi Ra 226, the average dose in rads to the narrow-free skeleton was calculated to be: 0.6 for children aged 1-15 yr; 0.4 for adolescents aged 16-20 yr; and 0.2 for adults, with each of these values multiplied by the ratio 70 kg/body mass to adjust for body size. The dose from long-lived contaminants appears small compared to that from Ra 226. The total incidence of infarct bone sarcomas increased with dose in approximately linear fashion at 1.4% per 100 rads average skeletal dose for the combined juveniles and 0.7% per 100 rads average skeletal dose for the adults. Among the 44 patients developing bone sarcomas as of April 1969, the lowest average skeletal dose was 90 rads, and this patient was an adult. This is much less than the lowest average skeletal dose at death (1200 rads) among the American dial painters who developed bone sarcomas following injection of long-lived 1600-yr Ra 226. This difference seems mainly due to the short 3.82 day half-life of Ra 226 which causes a large fraction of the skeletal Ra 226 to decay while still on bone surfaces. The mean local dose to the cells 0-10 μ from the mineralized bone surfaces is perhaps 4 times the average skeletal dose for Ra 226 (assuming half of the skeletal Ra 226 decays on bone surfaces and half within the mineral volume), whereas for long-lived Ra 226 randomly distributed throughout the mineral volume, the mean local dose 0-10 μ from the bone surface is about 0.61 times the average skeletal dose. The effectiveness of Ra 226 was similar in males and females, and was similar in patients with and without bone disease at the time of Ra 226 injection. Bone sarcomas occurred in 1% of the 402 German spondylitis patients whose skeletal doses from Ra 226 averaged 180 rads. This incidence equals the 1% combined incidence of excess leukemia plus excess cancers in the British spondylitis patients whose X-ray doses to the spinal marrow averaged about 1000 rads. None of the 21 soft-tissue tumors seems positively related to irradiation (at this time) but correlations may emerge as additional tumors develop. No carcinomas of the head cavities have yet appeared. Two leukemias are recorded, but it is uncertain whether or not these were radiation-induced. (Auth)(RAD)

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Stahlhofen, W., Max Planck-Institut fuer Biophysik, Frankfurt am Main, German Federal Republic. 1972.

Measurement of the Natural Content of Thorium 228, Radium 226 and their Daughters in the Human Body. CONF-7111104; STI/PDB/290; Assessment of Radioactive Organs and Body Burdens, Proceedings of a Symposium held in Stockholm, Sweden, November 22-26, 1971, (pp. 505-519) (CONF-7111104, STI/PDB/290).

Both the content and the distribution of alpha emitters Ra 226, Th 228 and Po 210 in the human body was determined. The content

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MEDICAL ASPECTS

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of Ra 226 in bones and soft tissues was determined by the emanation method, the content of Po 210 by chemical enrichment followed by measuring the activity in a methane flow counter. The Th 232 content as well as the total alpha activity was measured by means of a specially developed scintillation method, the so-called mixing method. Measurements of Ra 226 in bones and organs related to the patients age were performed to obtain information on the incorporation of this nuclide during continuous administration of extremely low levels. The specific activity of Ra 226 in bones and soft tissues was constant from the fourth month of pregnancy up to an age as high as 90 yr. The content of Po 210 and Pb 210 in femur and tibia was measured in order to determine the ratio of Po 210 and Pb 210 in the human skeleton of the living organism. This ratio was found to be 0.8 on the average. The ratio of Th 232 and Ra 226 in human bone ashes was about 3.4. The age of the examined persons ranged from 5 to 70 yr. Human radiation burdens caused by the Ra 226, Th 232 and Po 210 content were estimated. (PAB)

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Stammart, J.B., University of Rochester, School of Medicine and Dentistry, Rochester, NY. 1958.

Ba Evaluation of Inhalation Hazards in the Nuclear Energy Industry. A/CONF.15/P-738; Peaceful Uses of Atomic Energy, Proceedings of the 2nd United Nations International Symposium, held in Geneva, Switzerland, September 1-13, 1958, Vol. 23, (pp. 306-312).

Power reactors are potentially a greater inhalation hazard than weapons fell-out. While external radiation hazard is important, conditions can exist where deposition of I 131 in thyroid, Sr 89 or Sr 90 in bone or of mixed fission product insoluble oxides in lung or lymph nodes would be limiting. Mining and processing of ore, may involve the largest number of individuals and be the most likely source of radioactive inhalation hazard. Ventilation or respiratory protective equipment can aid in relieving this hazard. It is unsafe to extrapolate from chemically toxic to radioactive aerosols. The hazard may be related more to numbers of particles than to mass of material, and count distributions and specific activities are needed. It is not safe to predict a serious hazard from particles in the 0.2- to 0.3-micron range even though this represents a maximum in mass deposition for the total respiratory tract. Submicron particles may be the most hazardous because of their numbers. The importance of the GI tract as a critical organ may have been overestimated. Accumulation of material in pulmonary lymph nodes after prolonged inhalation may exceed that in lungs. Lymph nodes may limit exposure under many conditions. Calculation of maximum permissible doses on this basis may be required. The lung is moderately radiosensitive. The external radiation dose to produce clear damage is 1000 - 2000 r. The real tissue dose is difficult to estimate. Calculations assume uniform distribution and are likely to yield minimal doses. Induction of invasive cancer by radioactive materials deposited in lung tissue has been proved and dosage can be estimated. Similar doses produce fibrosis, pneumonitis, etc. Use of a general model for behavior of aerosols probably does not lead to serious errors in estimating pulmonary

deposition. It is a useful guide for lung clearance and retention. Data for hazard evaluation are never available in toto. Approximations must be made. For example, a variety of assumptions can be made, meteorological conditions, particle sizes, activity released, deposition, resuspension, pulmonary deposition, clearance, turnover and excretion. By making conservative assumptions, maximal and average hazards can be estimated. Laboratory and model field studies in progress should permit further evaluation of these approximations. (auth) (VC)

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Stehney, A.P., Argonne National Laboratory, Lemont, IL. 1960.

Radioisotopes in the Skeleton: Naturally Occurring Radioisotopes in Man. Radioisotopes in the Biosphere, R.S. Caldwell and L.H. Snyder (Eds.), Proceedings of a Symposium held in Minneapolis, Minnesota, 1959, (pp. 366-381), 597 pp.

Small amounts of radioactivity from K 40, C 14 and members of the U and Th decay chains level have been widely distributed in nature for as long a time as the present distribution of living matter has existed. These "naturally-occurring radioisotopes" have several properties which offer hope that studies of their interaction with the biosphere may aid in solving the related problems of man-made radioisotopes. Useful chemical analogies can be compared to Pa, Cs 137, K 40 and Pu 239 to Th. None of the members of the radioactive decay series of U or Th are known to have any physiological function in the body. Their presence in humans is a consequence of intake of environmental materials in which they are widely distributed in small concentrations, the average activity in granite being about 1.4×10^{12} c/g of the for U 238 and Th 232. Several nuclides on these decay series are too long-lived to require individual consideration as radioisotopes in the body. These are U 238, Th 230, Ra 226, and Pb 210 in the U 238 chain, and Th 232 and Pa 231 in the Th 232 chain. Ra 226 and Ra 228 are studied because being gases, they are readily found free of long-lived ancestors in air and in water. A summary of natural radioisotopes in the human skeleton is given in tabular form. Preference was given to the value of 0.4×10^{10} (E-10) g of Ra 226 because of the large number and wide geographical distribution of samples analyzed. This in turn fixed the value for Pa 231 which was considered to be one-half that of Ra 226. Inclusion of a value of 10^{10} (E-10) g of Pb 210 for bone was somewhat inconsistent, but it does provide an upper limit for bone in the samples analyzed. All of these values are low compared to estimates of about 100 rad/yr for irradiation from cosmic rays and natural environmental radiation. Radiation from Ra 226 and Pa 231 for subjects with a body content of 4×10^{10} (E-10) g Pa 231 may approach the importance of external gamma-rays. However, detailed study of body radius and incidence of bone cancer in humans showed that populations totalling more than 10^{10} (E-6) having similarly high natural radius burdens would have to be located in order to obtain significant data on increases of bone cancer from small increases of radius in bone. (PNN)

Table 5 shows natural radioisotopes (including U 238 and U 235) in the human skeleton. Table 3 gives mean values of body radius for groups of

MEDICAL ASPECTS

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subjects. Table 4 gives mean values for rate of excretion of Ba.

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Suzuki, F., National Institute of Radiological Sciences, Chiba, Japan. 1973, May.

Uranium. *Shin Shokko*, 18(5), 118-123.

Uranium poisoning was examined histologically including reports on poisoning in the Manhattan Project in the United States. In human and animal experiments, the essential poisoning of uranium has been demonstrated to be chemical poisoning and to cause nephritis with uraemia, and other diseases related to it. If fuels containing thorium-uranium 233 series are used in the future, radiation injury will appear in the following occasions: 1) when uranium is accumulated in the organs of humans, especially in the lungs and 2) when the human body gets near the place where a great amount of uranium with daughter radionuclides is a great quantity is present. There are differences in the level of poisoning between uranium with valences of 4 and 6; above all, uranium with valence of 6 in aqueous solutions has the ability to produce anionic complexes. The amount of uranium in mouse tissue was examined in order to study the kinetics of uranium compounds in the body. The effect of uranium poisoning on nephrons of the kidney during its metabolism is caused by combination of uranium ions with carbon monoxide anion of monoxide proteins in the cells, which denatures the proteins and destroys the epithelial cells to necrosis. (JA)

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Swann, R.L. (Ed.), University of Cincinnati, Department of Pathology, College of Medicine, Cincinnati, OH. 1967, December.

Distribution, Retention, and Late Effects of Thorium Dioxide. *Annals of the New York Academy of Sciences*, 145(3), 523-558; CONF-660422; CONF-660422: Distribution, Retention and Late Effects of Thorium Dioxide, Proceedings of a Conference held in New York, New York, April 20-22, 1966, 336 pp. (CONF-660422).

The chemically inert colloidal Th dioxide was used as a contrast media in arteriography for diagnostic radiology. During this time, the biological effects of alpha radiation were not known. With increasing understanding of radiation effects, coupled with the awareness of human exposure to permanently retained ThO₂ after parenteral administration, the use of this compound was reduced. Colloidal ThO₂ injected into the blood stream is incorporated and retained by the phagocytes of the reticuloendothelial system; these cells are located in spleen, liver, bone marrow, and lymph nodes. Much of the colloid remains in these organs and its retention is associated with later development of neoplasms. Thus, this compound is of considerable interest to the experimental and clinical oncologist. The use of colloidal ThO₂ in man has declined, thus making the existing data about its effects particularly valuable. Follow-up studies should be continued since it is unlikely that there will be as large a group of patients with body burdens in the future. The papers presented by investigators in this New York Academy of Sciences conference on Distribution, Retention, and Late Effects of Thorium Dioxide are included in the data base. (VC)

<524>

Taranenko, N.Ye., 1965, May.

Industrial Health in Handling Thorium. ABC-tr-6536 (Rev.); 79 pp.

This review on thorium includes discussion of the following: properties, uses and occurrence in nature; biological aspects including distribution, excretion, and toxicity; hygienic and health aspects of working conditions; maximum permissible concentrations of thorium and its decay products and exposure levels. The final section deals with prophylactic and protective measures specifically relating to: equipment, locations, finishing, ventilation, protection, medical dosimetric control, detection of thorium and its products in air, deactivation of equipment and building construction, personal hygiene and protection, protection and cleaning of integuments, and medical prophylactic measures. The bibliography includes 106 references. (VC)

<525>

Tavares, H.R., A. Saragoca, and J.S. Motta, University of Lisbon, Department of Pathology, Lisbon, Portugal. 1973, June.

Liver Studies in the Thorotrast Patients--Laboratory and Clinical Findings (Study of 175 Cases). CONF-730475: RISO-294; Toxicity of Thorotrast, H. Faber (Ed.), Proceedings of the 3rd International Meeting held in Copenhagen, Denmark, April 25-27, 1973, (pp. 212-218) (CONF-730475, RISO-294).

Clinical studies and laboratory tests were performed on 175 patients who had been injected with 4-70 ml Thorotrast 10 to 41 years previously. Clinical findings most often showed gastrointestinal disorders and pathologic changes in the liver. Laboratory tests disclosed a serum dysproteinemia (low albumin and increased alpha-2 and gamma globulin) and increased levels of alkaline phosphatase. No alpha-fetoprotein was found in ten tested cases. Among 25 cases with histological liver examinations, 11 tumors were found (four hemangioendotheliomas, five cholangiocarcinomas and two adenocarcinomas); the remaining 14 cases showed hepatic fibrosis. (HAF)

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Telles, B.C., U.S. Department of Health, Education, and Welfare, Research Branch, Division of Radiological Health, Rockville, MD. 1967, December.

Follow-Up of Thorium Dioxide Patients in the United States. *Annals of the New York Academy of Sciences*, 145(3), 674-675; CONF-660422: Distribution, Retention, and Late Effects of Thorium Dioxide, R.L. Swann (Ed.), Proceedings of a Conference held in New York, New York, April 20-22, 1966, (pp. 674-675), 336 pp. (CONF-660422).

A pilot study has shown that Thorotrast patients are willing to undergo liver studies and bone marrow biopsies. A large roster of patients has been prepared. The number and sources of cases available for study are: 275 in the Boston area, 61 in the Massachusetts General Hospital roster still alive; University of Michigan, 425, 150-200 still living. Rosters from other

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MEDICAL ASPECTS

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Institutions bring the total of cerebral arteriogram patients potentially available for study to over 1,000. The Division of Radiological Health of NRPB, working with 20 medical centers, is hoping to add more cases to the roster. Thorotrast is implicated not only in liver tumors, but also in connection with problems related to leukemogenesis, lung tumors and osteogenic sarcomas. Followup studies of Thorotrast patients is desirable. Such studies can provide information about radiation effects; these data would be of interest in relation to the increased production of fission products by the nuclear energy industry and the possible increase in contamination. (VC)

<527>

Tesluk, S., and V.A. Vordina, Henry Ford Hospital, Department of Pathology, Detroit, MI. 1955.

Hemangioendothelioma of Liver Following Thorium Dioxide Administration. Archives of Pathology, 60, 493-501.

Thorium dioxide (Thorotrast) by virtue of its radioactivity has the potentiality of producing neoplastic changes in man. Although such cases are rare, most patients receiving the material have not provided a sufficient time of exposure, since the latent period is longer than 10 years. A case is presented in which hemangioendotheliomatous lesions were encountered in the liver of a man given ThO₂ 16 years previously. On autopsy, there was evidence of weight loss, jaundice, oozing of bloody fluid from abdominal incisions, subcutaneous and subperitoneal ecchymosis. The enlarged liver was hemorrhagic, fatty and had central tubular necrosis. Spleen was pink-gray and firm. The microscopic pathology of the liver showed angiomatous structures, apparently from portal areas. Larger ones had cyst-like center surrounded by fibrous tissue. Spaces were lined with proliferating endothelial cells. Spleen was fibrotic and depleted of lymphoid cells. Lymph nodes were adenomatous with lymphadenitis. The bone marrow was very cellular. Numerous pigment laden macrophages were seen. The pigment was ThO₂. Cases of neoplasms described in the literature are similar. (Auth) (VC)

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Testa, C., Comitato Nazionale per l'Energia Nucleare, Medical Service, CSN-Casaccia, Rome, Italy. 1972.

Indirect Methods Used at CERN for the Evaluation of Internal Contamination. CONF-711104; STI/PUB/290; IAEA-SM-150/10; Assessment of Radioactive Organ and Body Burdens, Proceedings of a Symposium held in Stockholm, Sweden, November 22-26, 1971, (pp. 405-421), 698 pp. (STI/PUB/290, IAEA-SM-150/10, CONF-711104).

The radiotoxicological analyses used at the CERN nuclear centers are described. The different techniques for the determination of alpha, beta and gamma emitters in biological samples are briefly given, e.g. the determination of Po 210, Ra 226, natural thorium, enriched uranium, plutonium, gross alpha activity, Sr 90, gross beta activity and gamma emitters in samples of urine, nose blows and feces. Original methods are used for the rapid isolation of natural thorium, enriched uranium, plutonium and Sr 90 from urine by means of reversed-phase chromatographic techniques with Microthene

710 (microporous polyethylene) in powder form supporting some selective extractants. Special chromatographic columns and batch-extraction processes are used to shorten the mineralization and the isolation procedure. A Microthene-TOPO (tri-n-octylphosphoric oxide) slurry is used to extract uranium, thorium and plutonium from urine that has been wet-mineralized with nitric acid; suitable eluting agents are then used to strip the particular radionuclide. A Microthene-DBEP, di-(2-ethylhexyl) orthophosphoric acid, slurry is used for the selective extraction of Y 90 from the urine at pH 5. Sr 90 in equilibrium can then be calculated. All these methods are simple, selective and rapid; the chemical recoveries range from 70 to 90 percent, with acceptable blanks; the chemical yields were confirmed also with metabolized ions by using urine from rats injected with the radionuclides. Examples of internal contamination with polonium 210 and thallium 170, and wound contamination with plutonium and americium 241 are also reported. (Auth)

Figure 9 shows the plutonium activity in a contaminated wound as a function of time.

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Thompson, D.L., U.S. Department of Health, Education, and Welfare, Public Health Service, Food and Drug Administration, Bureau of Radiological Health, Division of Radioactive Materials and Nuclear Medicine, Rockville, MD. 1976, September.

Uranium in Dental Porcelain. NUREG(PDR)-76-0061; 28 pp.

The radiological health aspects of the use of uranium in dental porcelain are presented. The concentration of uranium is reported for 16 sets of porcelain teeth and 23 samples of porcelain powder. Particle emission rates were obtained for uranium and for the potassium 40 also present in the teeth. These data are used to calculate the annual doses to the individuals who wear porcelain prostheses and to persons who are occupationally exposed to the teeth and powders. Dose modifying factors are discussed for both alpha and beta particle exposures. Recommendations are presented regarding substitution of nonradioactive agents and interim guidelines on the maximum permissible concentration of uranium in dental porcelain. (Auth)

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Turner, R.C., J.H. Hadley, and W.V. Rayneord, Institute of Cancer Research, Royal Cancer Hospital, Physics Department, London, England. 1958, August.

The Alpha-Ray Activity of Human Tissues. British Journal of Radiology, 31, 397-406.

A method of alpha-ray detection and its preliminary application to human bone and teeth is described. A detailed discussion of theoretical considerations is given. Four case studies are given having radioactive burdens of pure radium, a mixture of radium and radiothorium and exclusively thorium dioxide. Measurements on numerous samples from a radium worker who around 1910 ingested radioactive material showed a calculated total skeletal Ra 226 burden of 0.47 mg. Measurements on human samples from a worker exposed to both Ra 226 and Th 232 eight to ten years earlier resulted in a Ra 226 Th content of 2.3 ± 10 (R-11) CI/g ash and in a

MEDICAL ASPECTS

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Pa content of $2.5 \times 10(E-11)$ Ci/g ash. The analysis of breath and blood of a patient who had been given Thorotrast 20 years earlier showed an exhaled thoron concentration of $1.5 \times 10(E-9)$ Ci/l and a thorium level in blood of $1.5 \times 10(E-9)$ Ci/l. Some measurements of a patient, one week previously given 20 to 30 cc of Thorotrast, were $1.5 \times 10(E-11)$ Ci Th 232/g wet bone. Also mentioned are examples of normal radioactivity in man. High levels of activity were noted in teeth extracted in normal dental procedures. (HAF)

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Turner, B.C., J.B. Badley, and B.V. Hayneord, Institute of Cancer Research, Royal Cancer Hospital, Physics Department, London, England. 1968, February.

Alpha-Ray Activities of Humans and their Environment. Nature, 181, 518-521.

This article outlines the results of investigations on many hundreds of samples dealing with normal and abnormal radioactivity in humans, and radioactivity in animals, soils and other environmental materials. The main conclusions from this pilot experiment are: food is the important factor determining the daily intake of naturally occurring radioactive material. Intake from soil and water is negligible. The levels of alpha-activity in foodstuffs are extremely variable, but, in general, high values are obtained for cereals and flours. The daily intake from food, even for a 4-year old child, say approximate the whole body burden. The ratios of radiothorium to radium in the intake and in the fecal excretion are substantially the same (0.75). This ratio is higher than that found in human bones studies (0.6) possibly because of the relatively higher values of radiothorium in organs such as liver and spleen. The daily retention of radiothorium and radium is a small fraction of the intake. The mechanisms controlling the reduction are of great importance in estimating possible biological effects since the bulk of the daily intake of the radium and thorium series is excreted during the first 48 hours. From values found in foods it is evident that persons on apparently normal diets may differ in total daily radioactive intake by factors of hundreds. (HAF)

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Valentin, B., CERN, Centre d'Etude de l'Energie Nucléaire, Brussels, Belgium. 1966, April.

Analysis of Nose Blow Samples for the Detection of Alpha Emitters. ILC-371; 6 pp.

An analytical procedure for the determination of Th, U, Pu and Am in nose blow samples is described. Nose blow sample filter papers are wet ashed; direct deposition is used for alpha emitters other than U, Pu and Am; U, Pu and Am are electrodeposited. The result of the analysis can be obtained in two hours. A relationship between the Pu activity of the nose blow sample and the amount of Pu activity found in the first four consecutive fecal samples following the incident was found. If a nose blow result is less than 250 pCi and there is no other firm evidence of a significant release, it is not felt that there is sufficient justification for fecal samples, as the retained lung burden will almost be certainly less than 1/10 of the maximum permissible value. (HAF)

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Van Kaick, G., D. Lorenz, and I. Driegen, Institute of Nuclear Medicine, German Cancer Research Center, Heidelberg, German Federal Republic. 1973, June.

Special Clinical Findings Among Thorotrast Patients. COSY-730475; NISO-294; Toxicity of Thorotrast, H. Faber (Ed.), Proceedings of the 3rd International Meeting held in Copenhagen, Denmark, April 25-27, 1973, (pp. 163-168) (COSY-730475; NISO-294).

The outstanding, probably Thorotrast-induced, diseases among the 800 examined patients are 4 tumors of the liver, many liver cirrhoses, one case of chronic myeloid leukemia and a number of long term sequelae caused by paravascular injection. Since the liver is the most commonly injured organ of Thorotrast carriers we developed a step-wise diagnostic schedule consisting of laboratory tests, X-ray examinations, sonography, colic arteriography and laparoscopy. For the necessary follow-up studies we hope, in this way, to keep the diagnostic stress within tolerable limits, while obtaining satisfying diagnostic results. (Auth)

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Van Kaick, G., and K.E. Scherz, Institute for Nuclear Medicine, German Cancer Research Center, Heidelberg, German Federal Republic. 1973, June.

Actual Status of the German Thorotrast Study. COSY-730475; NISO-294; Toxicity of Thorotrast, H. Faber (Ed.), Proceedings of the 3rd International Meeting held in Copenhagen, Denmark, April 25-27, 1973 (pp. 157-162) (COSY-730475; NISO-294).

The German Thorotrast study is a supra-regional "compound-research program", containing clinical and biophysical examinations of Thorotrast patients and a control group. The causes of death were ascertained for those Thorotrast patients who died later than three years after the injection of Thorotrast or three years after their hospitalization. A follow-up study was started in 1972. Up to now, 12000 patients belonging to the Thorotrast and control group were researched; 800 Thorotrast patients and 600 members of the control group were examined. The causes of death were ascertained for approximately 950 Thorotrast carriers and 88 persons of the control group. At the present time it appears that Thorotrast carriers have a higher incidence of liver tumors, liver cirrhosis, leukemias and aplastic anemias. (Auth)

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Vaughan, J., Churchill Hospital, Oxford, England. 1971, April.

Haematological Consequences of Radioisotope Incorporation with Particular Reference to Plutonium, Thorium, Radium, Iron and Gold. STI/DOC/10; Technical Reports Series No. 123; Manual on Radiation Haematology, Chapter 21, (pp. 215-242) (STI/DOC/10).

The technical report reviews the tissue distribution and chemistry, dosimetry and blood dyscrasias of Pu 239, Th 232 and radium isotopes in humans and animals. Also discussed are the absorption, utilization measurements of blood loss plasma turnover and thermal range of T 1/2 plasma clearance and surface coating of Fe 59. Haematological data of man and animals exposed to Pu are.

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HISTICAL ASPECTS

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Inadequate. However, in view of the distribution is narrow, severe blood dyscrasias are to be expected. More detailed information is available on Th which is widely used as a contrast medium in the form of its oxide. Cases of leukemia and non-leukemic blood dyscrasias are well documented in the literature. Humans and animals exposed to radium isotopes may develop leukemia, severe anemias and osteosarcomas. Colloidal gold used for bone marrow scanning has no known hematological effects. (BAP)

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Vich, Z., V. Dovesed, and V. Brychtova, Health Institute of Uranium Industry, Pribram, Czechoslovakia. 1970.

Erythrocytes of Uranium Miners: the Activity of the Pentose Phosphate Pathway. British Journal of Industrial Medicine, 27, 287-290.

The activity of the pentose phosphate pathway was examined in 431 persons (221 uranium miners, 42 employees of a uranium ore tramping station, 36 former uranium miners, 32 coal miners, and 100 persons working in mines with no previous exposure). A colorimetric technique was employed which consisted of the determination of the ribose formed and the glucose utilized in a standardized sample of washed erythrocytes. In the groups exposed to long-term occupational radiation, the activity of the pentose phosphate cycle was found to be enhanced. This finding was interpreted as evidence for a change in the functional state of the erythrocytes in exposed persons due to the effects of radiation on the genesis of red cells in the bone marrow. (Auth) (BAP)

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Vleggaar, C.H., and D. Van As, Atomic Energy Board, Pretoria, South Africa. 1975, November.

General Radiation Exposure of the Population. Health Physics, 29(5), 826-827.

Ionizing radiation is not unique to nuclear power production: in man's environment there are various sources of radioactivity and radiation which all contribute to the exposure of the population. Major sources of exposure are naturally occurring long-lived radionuclides, e.g. uranium 238, thorium 232, their radioactive daughter products as well as potassium 40, cosmic radiation--either directly or via induced radionuclides such as tritium, beryllium 7 and carbon 14--nuclear bomb debris and diagnostic and therapeutic use of artificially produced radiation and radionuclides. In order to evaluate the increase due to nuclear power production in the dose consistent of the population, the extent of both external and internal doses resulting from the above mentioned sources are analyzed in the light of South African values. (Auth)

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Waddell, C.C., J.A. Brown, and D.L. Rueb, Baylor College of Medicine, Department of Medicine, Houston, TX; Veterans Administration Hospital, Hematology Section, Houston, TX. 1977, August.

Erythroleukemia (Di Guglielmo's Disease) Occurrence Twenty-Eight Years after Thorium Administration. Journal of the American Medical Association, 239(5), 423.

The origin of erythroleukemia, as in all types of acute leukemia, remains obscure. Ionizing irradiation and subsequent development of acute leukemia has been well documented. Use of thorium dioxide has been associated with development of a variety of malignant diseases especially hepatic neoplasms. Sporadic instances of hematologic malignant disease have also been reported. In all of these neoplasms, a prolonged latent period (10 to 20 years) was noted from radionuclide injection until diagnosis. Thorotrast, a colloidal suspension of thorium dioxide Th 232, was widely used in the 1930s and 1940s in the United States as a radiographic contrast medium. However, its safety was seriously questioned because of recognition that prolonged retention within the body would result in a permanent source of irradiation. Use of thorium dioxide was eventually halted in the United States. Thorium dioxide is principally an alpha emitter whose biologic half-life is more than 600 years. Liver, spleen, and other reticuloendothelial tissues take up the intravenously injected material, where it is retained indefinitely. In the case presented here, development of malignant disease of the bone marrow 28 years after administration of this contrast medium illustrates the hazardous long-term effects of chronic, low-dose radiation from radioactive material retained within the body. Demonstration of opaque densities having the appearance of residual thorium dioxide in the region of spleen, liver, or other reticuloendothelial sites should alert the physician to the possibility that a variety of malignant neoplasms may ultimately develop in such a patient. (Auth)

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Wagner, V., J. Andrlíkova, R. Sagnerova, and E. Schoen, Institute of Industrial Hygiene, Health Centre of the Uranium Laboratory, Pribram, Czechoslovakia; Regional Hygiene Station, Central Bohemian Health Centre, Prague, Czechoslovakia. 1975.

Immunoglobulin (Ig G, Ig A, Ig M) Values in a Few Population Groups. Journal of Hygiene, Epidemiology, Microbiology, and Immunology, 19(2), 237-245.

Certain significant differences were found between the mean Ig G levels in four different population groups. No differences were found in the Ig A and Ig M classes. The highest Ig G levels were found in food workers and the lowest levels in coal miners working at the face. Surface mine employees and employees just taken on for underground work had intermediate values. On dividing the population groups in age subgroups, significant differences were found between some of the latter. Physical stress, differences in exposure to infections, the influence of the macro- and micro-climate and spontaneous and controlled selection for given occupations are regarded as possible causes of the observed differences. (Auth)

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Wegener, K., H. Wesch, H. Kampmann, and R. Zahner, University of Heidelberg, Institute of Pathology, Heidelberg, German Federal Republic; German-Cancer-Research-Center, Institute of Nuclear Medicine, Heidelberg, German Federal Republic; Versorgungsärztliche Untersuchungsstelle, Stuttgart, German Federal Republic. 1977, April.

Pathological Findings in the Reticuloendothelial

<541> COST.

System (Liver, Spleen, Lymph Nodes, Bone Marrow) of Thorotrast Patients (Histological and Autoradiographic Investigations). CONF-730475; EISO-294; Toxicity of Thorotrast, H. Faber (Ed.), Proceedings of the 3rd International Meeting held in Copenhagen, Denmark, April 25-27, 1973, (pp. 240-250) (CONF-730475, EISO-294).

Pathological and autoradiographical findings are given of 17 patients who had been injected intravenously with unknown quantities of Thorotrast. Late lesions included fibrosis of the liver, cirrhosis of the liver, hepatocellular carcinoma of the liver, cholangiocarcinoma and hepatocellular carcinoma, fibrosis and atrophy of the spleen, fibrosis and atrophy of the lymph nodes near the porta of the liver, and thorotrastoma. Thirteen patients died from complications of thorotrastosis. No tumors were found in lymph nodes, bone marrow and thorotrastoma. (347)

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Neag, W., University of Heidelberg, I-ray Department, Surgical Clinic, Heidelberg, German Federal Republic. 1967, December.

Tumors of the Kidney Following Retrograde Pyelography with Colloidal Thorium Dioxide. Annals of the New York Academy of Sciences, 145(2), 806-810; CONF-660422; Distribution, Retention, and Late Effects of Thorium Dioxide, H.L. Swann (Ed.), Proceedings of a Conference held in New York, New York, April 20-22, 1966, (pp. 806-810), 336 pp. (CONF-660422).

Up to the present 24 malignant Thorotrast tumors of the kidney have been described following retrograde pyelography. The major causes for the retention of the contrast medium in the kidneys are: reflux, hydronephrosis and out-flow obstruction. The relatively long latent period of 27 years in the case is put down to the very small amount of retained Thorotrast. The malignant tumors are found practically exclusively in kidneys which have given rise to ill-defined renal complaints due to chronic inflammatory changes and granulomas. There is a quantitative relationship between tumor incidence, latent period and dosage of the administered Thorotrast. (Auth)

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Wesch, H., H. Kaspermann, and K. Segener, Institute for Nuclear Medicine, German Cancer Research Center, Heidelberg, German Federal Republic; Institute for Pathology, University of Heidelberg, Heidelberg, German Federal Republic. 1973, June.

Assessment of Organ Distribution of Thorium by Neutron Activation Analysis. CONF-730475; EISO-294; Toxicity of Thorotrast, H. Faber (Ed.), Proceedings of the 3rd International Meeting held in Copenhagen, Denmark, April 25-27, 1973, (pp. 52-60) (CONF-730475, EISO-294).

The thorium content of 2500 specimens was determined by means of neutron activation analysis. The samples were taken out of the different regions of the body from 17 Thorotrast-patients after death. The highest concentrations were found in the main organs of the reticuloendothelial system (RES) (up to 90 µg Th/g). The least concentrations was found in the brain (0.05 µg/g). The variation of thorium within the organs were remarkable. In the liver of one and the same patient the variation could be up to a factor

of 50, in the bone marrow up to 100 and in the lymphatic nodes up to 1000. From this we can draw the following conclusions: 1. The radiation injury is not only different between the different organs but also within one organ. 2. A calculation of the radiation dose of the total organ is difficult. 3. The concentration of thorium in a sample, which is obtained by needle biopsy, gives no clue of the weight of the thorotrastoma. 4. Conclusions about the development of the tumor in the liver of a Thorotrast-patient are not possible only on the basis of the quantitative determinations of the thorium. (Auth) (NFB)

<543>

Woodliff, H.J., G. Cohen, and W. Gallon, Royal Perth Hospital, Australia. 1971.

Chromosome Aberrations in Lymphocytes from Patients Exposed to Thorium Dioxide. CONF-710324; Human Cytogenetics, Proceedings of a 3rd Symposium held in Sydney, Australia, March 16, 1971, (9 pp.) (CONF-710324).

Two case histories are reported of patients who received Thorotrast used as a contrast medium in radiography. The first patient, a male borne in 1917, received an arteriogram in 1947. In 1950 he developed a mass in the left neck but no further symptoms were reported until 1968. After surgery on the neck area in 1969, some biopsy material was subjected to liquid scintillation counting and showed the properties of Thorotrast. After his death in March of 1970, autopsy revealed widespread haemangioendothelial deposits in the bone marrow, with probable metastases in the liver. There was a metastasized brain tumor. The second patient, a female born in 1928, received a phlebogram in 1957 (using Thorotrast as part of the investigation) for a post-partum venous thrombosis and pulmonary embolism. Following a traffic accident in 1970, radiological investigation revealed a 'Thorotrast spleen'. Blood cultures on these patients revealed chromosome damage in 15% of cells in Case 1 and 12% in Case 2 indicating considerable radiation damage. (NFB)

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Young, I., W.N. Cherry, S. Wiener, and D.R. Sklaroff, Albert Einstein Medical Center, Departments of Laboratories and Radiology, Philadelphia, PA. 1967, December.

Chelation-Enhanced Excretion of Radioactive Daughters of Thorium. Annals of the New York Academy of Sciences, 145(2), 642-643; CONF-660422; Distribution, Retention, and Late Effects of Thorium Dioxide, H.L. Swann (Ed.), Proceedings of a Conference held in New York, New York, April 20-22, 1966, (pp. 642-643), 336 pp. (CONF-660422).

A 67-year-old man had a substantial body deposit of thorium dioxide as determined by x-ray of liver and spleen, and by the presence of thorium dioxide deposits in liver tissue removed by needle biopsy. The feasibility of mobilizing these deposits and promoting their excretion with a chelating agent was investigated. Excretion of radioactive material was measured in 24-hour collections of urine for several days prior to treatment. The patient was then given Ca EDTA in doses up to 3 g per day IV in glucose and water. Two courses were given. By the 8th day there was a 10-fold increase in the gamma radiation in this 24 hour urine specimen as compared to the baseline. Some fall-off was seen during the second course,

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MEDICAL ASPECTS

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but the excretion continued for several days after cessation of treatment. The half life of 10.6 hours indicated that the isotope was Pb 212. Weekly counts on the same sample over two months following excretion fell to background levels. This indicated the absence of appreciable Th 228 excretion. Were any Th 228 eliminated, formation of Bi 212 might have been expected. Samples giving high gamma counts and analyzed by

colorimetric and spectrophotometric methods were negative for thorium and lead within 10 parts per million. A chelating appreciably enhanced urinary excretion of the gamma emitting isotope Pb 212 from an individual carrying a long-standing thorium burden. It is probable that the burden of thorium dioxide was not appreciably reduced.
(Ruth) (VC)

CONTRIBUTING, DISSEMINATION AND ANALYSIS

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Idanchuk, I.P., D.B. Pachadzhayev, V.J. Pol'nikova, and V.I. Vainberg, Institute of Chemistry, Academy of Sciences of the Tadzhik SSR, Dushanbe, USSR. 1977, February.

X-Ray-Fluorescence Analysis of Powdered Rock Samples. Determination of Thorium, Uranium, Zirconium, and Hafnium. Journal of Analytical Chemistry (USSR), 32(2), 251-257; Zhurnal Analiticheskoi Khimii, 32(2), 321-326.

Procedures have been developed for the x-ray-fluorescence determination of Clarke amounts of thorium, uranium, zirconium, and hafnium in powdered rock samples on a VFA-2 spectrometer. The respective detection limits (g/ton) are: thorium-1.0; uranium-0.3; zirconium-24; and hafnium-0.7. The results of the quantitative determination of uranium, thorium, zirconium and hafnium show good agreement with the results obtained by other methods such as spectrophotometry and neutron activation. Programs are being compiled for converting instrument readings to concentration by means of a "MIR-1" computer. (auth)

<546>

Adams, J.A.S., Rice University, Houston, TX. 1969.

Total and Spectrometric Gamma-Ray Surveys from Helicopters and Vehicles. CCRP-681117; CEA-CORP-1185; IAEA/SH-112/10; Use of Nuclear Techniques in the Prospecting and Development of Mineral Resources, Proceedings of a Symposium held in Buenos Aires, Argentina, 1969, (pp. 147-161) (CORP-681117, CEA-CORP-1185, IAEA/SH-112/10).

A single-channel gamma-ray spectrometer has been built and tested in surveys from the air and from vehicles. Using a 5 in. x 5 in. sodium iodide (thallium-activated) scintillation crystal, thorium, uranium and potassium anomalies can be detected in the upper 10 to 52 cm of soil or rock. Thorium and uranium anomalies are of interest as pathfinder elements to locate and define placer deposits, changes in lithology, changes in sedimentary facies, and differences in soil type. e.g. tropical iron and aluminum ores. The 750 km of modern beach in the state of Texas were completely surveyed by helicopter in five flying days. Anomalies containing as little as 6 ppm thorium and 3 ppm uranium as determined by analysis of ground samples were readily detected against a background of beach sand containing 1 to 2 ppm thorium and 0.3 to 0.6 ppm uranium at ground speeds of 105 km/h (60 knots) and elevations of 17 plus or minus 1 m. At such altitudes and ground speeds the instrumentation has application for the direct exploration for potassium, thorium and uranium, and for the pathfinder applications, e.g. bedded phosphates that contain over 10 ppm uranium and placer deposits that contain twice background thorium or uranium. Placers are prime exploration targets because they often contain multiple mineral values, and modern placers along beaches or rivers provide convenient ground control for navigation purposes. In evaluation placers, a combination of gamma-ray and aeromagnetic techniques is advantageous because many placer deposits contain enough ilmenite and magnetite to give a detectable aeromagnetic anomaly under the conditions of the gamma-ray survey. Furthermore, the aeromagnetic anomaly will arise from minerals at such greater depths than in the case with the gamma-ray anomaly. (auth)

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Albert, R., P. Elvira, J. Franco, J. Harley, S. Harris, and M. Eisenbud, Health and Safety Laboratory, New York, NY. 1955.

Industrial Hygiene and Medical Survey of a Thorium Refinery. American Medical Association Archives of Industrial Health, 11(3), 234-242.

This report describes an environmental and medical study of a refinery engaged for many years in the extraction of thorium and the rare earths from monazite. Approximately 30% of the 84 current employees are exposed to 100 disintegrations per minute per cubic meter or less of thorium and approximately 60% of the thorium exposures of the group ranged between 100 and 1000 disintegrations per minute per cubic meter. Although two of the workers had average exposures of 2000 disintegrations per minute per cubic meter, all thoron concentrations in the work place were below 2 x 10¹⁰ (2-11) curies/liter, and in general, gamma radiation levels in the working environment were not found to be significantly high except where mesothorium extraction takes place. These workers involved in mesothorium extraction during a 40 hour week would be slightly above the tolerance level of 300 millirads per week. In summary, the study of this thorium refinery revealed thorium exposures considerably in excess of currently acceptable standards for uranium; however, there was no evidence of overt industrial disease. (RBF)

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Albert, R.E., New York University Medical Center, Institute of Environmental Medicine, New York, NY. 1966, November.

Measurement of Thorium and Thoron Hazards. Thorium: Its Industrial Hygiene Aspects, Chapter 11. Academic Press, New York, New York, (pp. 171-189), 222 pp.

Methods for air monitoring and bioassay of thorium and thoron are discussed. For dust sampling, filter paper is most commonly used; filter membranes are good for sampling thoron daughters. General methods are breathing zone sampling, which provides estimate of individual exposures, and general air sampling. The hazard to lungs is in part dependent on particle size; thus, respirable and non-respirable fractions are collected. Important thoron decay products and their half lives are Po 216 (T_{1/2} 0.16 sec), Pb 212 (T_{1/2} 10.6 hr), and Bi 212 (T_{1/2} 60.6 min). The equations for determinations in an atmosphere containing thoron decay products are given. Decay chain isotopes from Th 232, each with its own HPC in air, form rapidly. Important isotopes from the standpoint of hazard are Th 232, Th 228, Ra 228, and Ra 224. The relative magnitudes of HPC values for these as insoluble particles are 1.0, 0.6, 4.0, 70.0 respectively. For soluble particles, the ratios are 1.0, 4.5, 35.0, and 2500. Methods for determination are discussed. Bioassays for estimating body burdens of Th are discussed. Three general categories of methods are: analysis of breath, urinalysis, and whole body counting of gamma emissions. (WC)

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Andreyeva, O.S., and G.D. (Translator) Lord, 1976.

Identification of Actinium in the Air in the

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MONITORING, MEASUREMENT AND ANALYSIS

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Presence of Other Emanations. ORNL-tr-450; 4 pp.; Gigiena i Sanitariya, 1, 71-74.

A scintillation method was developed for the detection of actinon (Ac) in the air of working installations. The method is based on the faster decay of Ac (half-life=3.92 sec) in comparison to thoron (half-life=54.5 sec) and radon (half-life=3.82 days). The detection system includes: an air-intake hose with a filter for trapping aerosols in the air; a calcium chloride desiccant; a 1-l buffer vessel designed for the decay of Ac; a spherical scintillation chamber with an industrial "Tiss" device and a "Tl" sensor; a flow meter; a blower for pumping air; and an auxiliary buffer vessel. The total activity due to Ac, Ra and Rn is first measured and then by using a buffer vessel set for the decay of Ac, the activity of Ra and Rn is measured. The difference between the total activity minus the activity of Ra and Rn gives the activity of Ac. (RAP)

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Ipt, K.L., Los Alamos Scientific Laboratory, Los Alamos, N.M. 1977, December.

Uranium Mill Monitoring for Natural Fission Reactors. LA-7062-MS; 29 pp.

Isotopic monitoring of the product stream from operating uranium mills is proposed for discovering other possible natural fission reactors; aspects of their occurrence and discovery are considered. Uranium mill operating characteristics are formulated in terms of the total uranium capacity, the uranium throughput, and the dilution half-time of the mill. The requirements for detection of milled reactor-zone uranium are expressed in terms of the dilution half-time and the sampling frequency. Detection of different amounts of reactor ore with varying degrees of U 235 depletion is considered. For an episodic introduction of reactor ore into a mill, the detection threshold of the isotopic anomaly using "grab" sampling is compared to that using continuous sampling. For a continuous introduction of reactor ore, the detection threshold for a "steady-state" concentration of anomalous uranium is determined, and times required for processing reactor zones are estimated. Mill monitoring schemes which are most sensitive to initial episodes of reactor ore throughput are recommended, but the operating characteristics of a given mill influence the choice of type and frequency of sampling. The effectiveness of monitoring schemes is investigated in terms of the analytical sensitivity of the isotopic analysis and the sampling specifics. Systematic uranium mill monitoring should be effective in discovering other natural fission reactors. (Auth)

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Argonne National Laboratory, Argonne, IL. 1969.

Air and Water Monitoring. Radiological Health and Data Reports, 10, 227-230.

Argonne wastewater is discharged into Savanah Creek, a stream that runs through the Argonne grounds and enters the Des Plaines River about 500-yards downstream from the wastewater discharge. Savanah Creek was sampled above and below the discharge to evaluate the effect of the wastewater on the radioactivity in the creek. The total alpha and beta radioactivities found in the Savanah Creek during January-June 1968 are given in a

table. The alpha-particle emitters most likely to be present in Argonne wastewater are isotopes of U, Pu, and Th. The alpha radioactivity in the creek water due to these elements are summarized in a table. The average U concentrations below the outfall was about 2.4 pCi/liter, while the Pu and Th concentrations averaged less than the minimum detectable amount. Air filter samples were collected continuously from 12 sites. The average alpha activity was 0.005 pCi/m³ and the average beta activity was 0.25 pCi/m³. There was no significant difference between on-site and off-site locations. (Auth) (JNC)

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Argonne National Laboratory, Argonne, IL. 1965; 1968.

Environmental Radioactivity at Argonne National Laboratory, July - December 1968, Annual Summary, 1968. TID-25306; 32 pp.

The radioactivity of the environment was determined by measuring the radioactivity in naturally occurring materials collected both on and off the Argonne site. Since radioactivity is usually spread by air and water, the environmental monitoring program concentrated on these materials. The total alpha and beta activities and the concentrations of several fission products and of Be 7 are summarized in a table. Savanah Creek, a stream in which Argonne waste water is discharged, was sampled above and below the discharge to evaluate the effect of waste water from Argonne on the radioactivity in the creek. In addition to natural and fallout activity, radioactivity from waste water was found in samples of Savanah Creek water collected below the discharge. A comparison of these concentrations with those above the discharge indicated that essentially all of the Cs 137, Co 58, Co 60, N 3, Pu, and Tc 99 and about one-half of the Sr 90, U, Th 234-Pa 234, and total alpha and beta activities originated in Argonne waste water. The concentrations were all small compared to radiation protection standards. (Auth)

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Baker, S.L., National Accelerator Laboratory, Batavia, IL. 1973, August; 1973, March 23.

Environmental Monitoring Report for Calendar Year 1972. WASH-1259; Environmental Monitoring at Major U.S. Atomic Energy Commission Contractor Sites, Calendar Year 1972, (pp. 553-596), 1217 pp. (WASH-1259).

Analyses for residual radioactivity are performed specifically for accelerator-produced nuclides as well as for radium and thorium. Environmental radiation data are collected from radiation detections throughout the accelerator and experimental areas. Except for a minute amount of tritium in the closed loop in the Neutrino Area, no accelerator produced activity other than 53 day half-life beryllium 7 has been found in the water. The concentration of Ra 22 in soil was determined to be 9×10^{-6} pCi/g just outside the Neutrino Area Target Tube. Penetrating radiation is monitored at the Environmental Radiation Monitoring Station located in the National Accelerator Laboratory Village. No evidence of accelerator produced radiation has been seen by any detector in the station during the reporting period. The neutron monitors have indicated an average neutron dose of approximately 0.0005 mrem/hr, which is

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consistent with the expected cosmic-ray neutron background. There were no unusual incidents or releases during the reporting period. In addition, there were no nonradioactive materials produced in quantities which could pollute the environment, and there were no abnormal natural occurrences which could have resulted from or have had some impact upon the facility or its operation. (744)

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Salovey, J.F., and W.A. Hoggan, Battelle-Pacific Northwest Laboratories, Richland, WA. 1977, May.

Nondestructive Analysis for Uranium 232 and Thorium 232 in Animal Tissues. BNWL-2100, Part 1; Annual Report for 1976, (pp. 95-97), 214 pp. (BNWL-2100, Part 1).

Because of possible disequilibrium among daughter products and expense and time needed for wet chemical analysis, a rapid, nondestructive technique is needed to determine sized radionuclides in Th fuel materials. Internal radiation doses are largely from alpha-emitting radionuclides which should be determined for accurate dosimetry. Preliminary results are from two detector systems, an intrinsic Ge detector to detect and differentiate low energy gamma-rays and gamma photons and a NaI(Tl) anticoincidence-shielded Ge diode for gamma photon energies greater than 100 keV. A spectrum for animal tissue analyzed by the Ge(Li) detector is shown. U 232 can be identified and quantified and other energy peaks represent various daughter products. Uranium in excess of 100 keV were detected with the NaI(Tl) Ge diode. Issues containing freshly separated U 232 following aerosol inhalation could be analyzed as accurately by a liquid scintillation system (total alpha) as with the Ge(Li) diode, but with age and ingrowth of daughter activity, the two were significantly different. Most promising is the ability of the Ge(Li) diode to detect and resolve low energy emissions from the U 232 decay series in a fresh tissue matrix. These results will probably be adjusted as the procedure becomes more standardized and data further analyzed. U 232 analyses are now thought valid in the range of 0.03-0.35 aCi, counting time of 300 min. A detection limit for Th 228 of 0.01 aCi should be attainable by analysis after Th 228 decay products have equilibrated (after 30 days in a sealed counting vial). (WC)

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Faltinsen, T., National Radiation Laboratory, Department of Health, Christchurch, New Zealand. 1975, June.

Simple Method for the Determination of Uranium in Soils by Two Stage Ion Exchange. Analytical Chemistry, 47(7), 1187-1189.

A simple method for determining U in soils by a two stage ion exchange separation and alpha counting is described. The procedure gives greater than 95% U recovery, eliminates interference by other natural radionuclides, utilizes ordinary reagents and ion exchange resin, requires no elaborate instrumentation and can be done in a short time. There are no precipitations until the final step; thus loss of U due to solubility or complex ion formation is avoided. Agreement among triplicate analyses of natural U was good for all five soils tested. The Th 226 activity was within approximately plus or minus 50% of

the U 239 activity for all soils and, in one case, was in exact agreement. Reasonable accuracy can be obtained with small samples. The method may be especially suitable in laboratory setting with investigation of environmental radioactivity and not equipped for sophisticated chemical analyses. (Auth) (WC)

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Beck, H.L., W.J. Combs, and W.C. Lowder, Health and Safety Laboratory, New York, NY. 1968, October.

Spectrometric Techniques for Measuring Environmental Gamma Radiation. NASL-159; 72 pp.

Pulse height spectra obtained in the field using a large NaI(Tl) crystal can be analyzed by relatively unsophisticated methods to determine accurately total environmental gamma-ray dose rates, as well as the individual dose rate contributions from K 40, the U 238 series, the Th 232 series, and the principal gamma-ray emitting fission products. The calibration of a 5-in by 3-in detector is described in detail, and the applicability and limitations of the spectral analysis methods are examined. Several problems associated with field measurements are discussed, in particular the effects of radon migration from the soil, soil moisture, and natural fallout. Evidence is presented to demonstrate the validity and utility of dosimetric and related information obtained from field spectra analyzed by these methods. (Auth)

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Becker, K., and D.B. Johnson, Oak Ridge National Laboratory, Health Physics Division, Oak Ridge, TN. 1970.

Some Dosimetric Applications of Nuclear Track Registration in Polymers. Radiation Research, 83(1), 71.

In recent years, the registration of fission fragment tracks in various insulating solids by preferential etching has become a standard technique for integrating thermal and fast neutron dosimetry. It is more difficult to register and to count automatically less densely ionizing particles such as alpha particles. A newly developed technique, based on the counting of electrical discharges occurring through etched tracks in specially prepared thin cellulose nitrate films, permits not only the fast, automatic counting even of extremely low particle densities, but also the immediate imaging of their spatial distribution. This method has, among other applications, been used at ORNL for the reading of a new radon progeny personnel dosimeter for uranium miners; to improve the sensitivity in alpha autoradiography; in an ultrasensitive technique to determine quantity and distribution of fissile elements in different materials such as uranium in drinking water and air and plutonium in bone; and for the sensitive measurement of thermal and fast neutron fluxes using (n, alpha), fission and recoil reactions. Several other possible applications, for example in neutron radiography, and the relative advantages and disadvantages of these techniques are discussed briefly. (Auth)

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Rees, P., and E. Steinsens, Institutt for Atomenergi, Isotope Laboratories, Kjeller,

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MONITORING, MEASUREMENT AND ANALYSIS

<558> CONT.
Norway. 1975, August.

Migration Forms of Trace Elements in Natural Fresh Waters and the Effect of the Water Storage. Water Research, 9(8), 761-779.

The concentration and physico-chemical state of 18 trace and major elements in river and lake waters were studied as a function of time (two hours to 35 days), for which the samples of water were stored in polyethylene bottles. The methods of investigation were dialysis, centrifugation, ion exchange filtration, and electrophoresis, combined with instrumental neutron activation analysis. It was shown that considerable amounts of Na, Co, Al, Sc, La, Ce, Fe, Cr, and Th may be lost by the adsorption to the walls of polyethylene containers and that the ratio of forms of existence of Co, Na, La, Ce, Sc, Fe, and Cr in the solution may be substantially changed during the storage for one week or more. The prevailing forms of trivalent and tetravalent elements (Al, Sc, La, Ce, Sm, Fe, and Th) in the waters studied were colloidal or suspended particles as indicated by their high retention during the dialysis and considerable removal by centrifugation. (BAP)

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Flomqvist, L., Institute of Radiation Physics, Helsinki, Finland. 1975, May.

Germanium-Lithium Gamma Spectrometry in Environmental Monitoring. Health Physics, 28, 639-644.

When using Ge(Li) gamma spectrometry in situ it becomes possible to reach detection limits for gamma-emitting nuclides that are low enough to solve the measurement problem associated with environmental monitoring in the vicinity of nuclear power plants. The very good energy resolution of the Ge(Li) detector makes it possible to distinguish between potential contributions from the nuclear reactor and natural background or other sources of radiation. A Ge(Li) detector with 6% efficiency was used. It was calibrated to determine the relationship between the registered count rate in a photopeak and the corresponding exposure rate in air. Using mathematical solutions of the radiation field in air resulting from various radionuclide depth distributions in the ground, the exposure rate contribution from scattered radiation was included in the calibration. Background spectra were obtained in the surroundings of a nuclear power station construction site. The spectra were processed on a small computer and the exposure rates due to the U and Th series, K 40 and Cs 137 from weapons test fallout were thus obtained. Using these background spectra, the detection limits for some common deposition nuclides were assessed. For I 131 this limit is 0.006 mrad/yr in a 60-min measurement. (Auth)

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Freslin, A.J., and N. Gleiberman, 1970.

Investigation of Radioactive Dust Dispersed from Uranium Tailings Piles. CONF-680108; Environmental Surveillance in the Vicinity of Nuclear Facilities, W.C. Reineig (Ed.), Proceedings of a Symposium held in Augusta, Georgia, January 24-26, 1968. Charles C. Thomas, Publisher, Springfield, Illinois, (pp. 249-253), 465 pp. (CONF-680108).

The concentrations of radioactive dust in the air around three inactive mills typifying different milling processes were measured. Two mills were in town and the third was in a remote desert region. Samplers were distributed around the tailings piles with one or two upwind and the remainder in wide arcs at distances downwind from 100 ft to one-half mile. Sampling periods were 4 to 6 hours with 4 or 5 runs at each site. Samples were analyzed for total alpha, U, Th 230, Ra 226, and Pb 210. The investigations showed that radioactive dusts are dispersed by the wind from exposed tailings piles, that dust concentrations decrease in fairly consistent patterns with distance from the piles, and their magnitude vary with local conditions such as moisture content at different mills. In regard to inhalation exposures, radioactive dust concentrations were trivial at two mills, and, at the third, hypothetical exposures would not exceed appropriate maximum permissible concentrations except, possibly, within the shadow of the tailings piles. (BAP)

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Butler, G.C., National Research Council of Canada, Ottawa, Ontario, Canada. 1972.

Retention and Excretion Equations for Different Patterns of Uptake. CONF-711104; STI/PSB/290; IAEA-SR-150/42; Assessment of Radioactive Organ and Body Burdens, Proceedings of a Symposium held in Stockholm, Sweden, November 22-26, 1971, (pp. 495-508), 698 pp. (STI/PSB/290, IAEA-SR-150/42, CONF-711104).

The general relations between uptake, retention and excretion of a radionuclide as functions of time are given. These are used to derive retention and excretion equations for the following patterns of uptake: single isolated; chronic; irregularly repeated; continued but declining. These are applied to calculations of the body content and excretion of some of the radionuclides most commonly encountered in radiation protection such as tritium, strontium 90, cesium, thorium and plutonium. The differences between the bone-seeking radionuclides and the others are noted. Investigation levels and derived investigation levels (ICRP Publication 10) are defined and the retention and excretion equations used to calculate them. The method of calculating radiation doses to organs and tissues of man is also described. (Auth)

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Caldwell, B.D., Nuclear Materials and Equipment Corporation, Appollo, PA. 1967, June 6.

The Detection of Insoluble Alpha Emitters in the Lung. CONF-661018; Bioassay and Analytical Chemistry, Proceedings of the 12th Annual Meeting held in Gatlinburg, Tennessee, October 13-14, 1966, (pp. 120-133), 238 pp. (CONF-661018).

The pulmonary lung is the critical organ for many industrial exposures to radioaerosols. The method of fecal sampling was used to estimate burdens of insoluble alpha emitters. These insoluble alpha emitters are those actinide compounds classified as Class Y in the new lung model. The most important are plutonium 239 dioxide, americium 241 dioxide, uranium 234 dioxide, and thorium 232 dioxide. The deficiencies of urinalysis and in-vivo counting for monitoring actinide elements were outlined with reference to the ICRP deposition and retention models. The value

TECHNIQUES, MEASUREMENT AND ANALYSIS

<562> CONT.

of fecal sampling was discussed in relation to work involved in a glove box explosion. Urine samples showed negligible quantities of americium 241 while the fecal sample showed more than 16 ac thus prompting chelation therapy. It was pointed out that fecal sampling should be done after a person had been away from exposure for at least two days. Fecal urine ratios for chronic uranium 238 fluoride exposure cases were compared and showed that some uranium dioxide exposures were poorly detected by urinalysis. Whole body counting was effective for enriched uranium lung burdens greater than 7 ac. However fecal sampling was necessary for the estimation of smaller fractions of the permissible lung burden. (PNN)

overburden increases, but not to the same extent. In-situ measurements were made at stations near Mont Laurier and Elliot Lake. These were compared with airborne measurements by averaging values for those ground stations located in the areas between each contour level on airborne maps. Radioelement concentrations in bedrock are higher than corresponding airborne measurements, and this difference increases at higher radioelement concentrations. Radioelement concentrations in glacial drift are slightly higher than airborne contour values for the same area. Airborne contour maps of the radioelement ratios give values similar to the ratios determined by ground measurements on overburden and outcrop. (Auth) (VC)

<563>

Canera, V., G. Sarassi, and J.J. Legros, Commission of the European Communities, Joint Nuclear Research Centre, Ispra Establishment (Italy), Medical Service, Luxembourg, German Federal Republic. 1971.

Rapid and Simple Method for Determination of Total Alpha Radioactivity in Urine. EUR-46751; 18 pp.

A rapid and simple method is described for the total determination of alpha emitters (Pu, Th, Pa and Sp) in urine by means of the extraction, in a beaker, of radionuclides in a solution of triethylphosphine oxide (TOPO) on a base of Nitex 350/90 (polyethylene). The method can be used for the quantitative determination of natural thorium in urine (by means of colorimetry with Arsenazo III) and for the search for one or more alpha emitting radionuclides, always in urine, in case of an accident or of suspected internal contamination. Recoveries of 89 percent-Pa, 86 percent-Th, 89 percent-U, and 89 percent-Pu were obtained. (Auth) (JNC)

<564>

Charbonneau, B.V., P.G. Killeen, J.N. Carson, G.W. Cameron, and K.A. Richardson, Geological Survey of Canada, Ottawa, Ontario, Canada. 1976.

Significance of Radioelement Concentration Measurements Made by Airborne Gamma-Ray Spectrometry over the Canadian Shield. CNRP-760316; IAEA-SM-208/3; Exploration for Uranium Ore Deposits, Proceedings of an International Symposium held in Vienna, Austria, March 29-April 2, 1976 (pp. 35-53) (CNRP-760316, IAEA-SM-208/3).

Results of airborne gamma-ray spectrometer surveys are presented as maps contoured in units of radioelement and concentration ratios. These values represent average surface concentrations of radioelements over areas of several square km. The relationship between "average surface concentration" and radioelement concentration in bedrock underlying the area depends on: % of outcrop; relation between overburden and bedrock radioelement concentration; % of marshland or surface water; soil moisture; and density of vegetation. More than 2500 portable gamma-ray spectrometer analyses of outcrop and overburden have been made in the Bancroft, Elliot Lake and Fort Smith areas of the Canadian Precambrian Shield. The radioelement concentrations in glacial drift reflect concentrations in underlying bedrock. Rocks with near-crustal average contents of Th, U, and K are overlain by glacial drift of similar concentrations. As the concentration in bedrock increases, that in the local

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Clark, D.L., Robert S. Orr, Environmental Research Laboratory, Ala, OK. 1974, June.

Testing and Monitoring Programs. EPA-660/2-74-038; State of the Art: Uranium Mining, Milling, and Refining Industry, (pp. 94-101), 113 pp. (EPA-660/2-74-038).

All companies involved in milling and refining of radioactive materials must meet certain requirements. The companies are licensed by the Atomic Energy Commission or by states designated as agreement states. The Code of Federal Regulations limit for soluble radium 226 that may be discharged to an unrestricted area is 30 pCi/l and for insoluble or suspended Ra 226, 30,000 pCi/l. Both short-term and continuous long-term monitoring activities have been carried out in the Colorado River Basin. Sample analyses for the Colorado River Basin Project consisted of gross alpha, gross beta, gross gamma scans, Ra 226, natural U, Th, Pb 210, Po 210 and Sr 90. To obtain a comprehensive overview of the effects of U milling waste products on the environment, many types of samples other than water were analyzed, including river and reservoir sediments, topsoil, water treatment plant filter sands, aquatic biota, crops and milk. (PNN)

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Clifton, R.J., W. Farrow, and E.I. Hamilton, Radiological Protection Service, Walsort, Sutton, Surrey, England. 1971.

Measurements of Thorium 232 in Normal and Industrially Exposed Humans. Annals of Occupational Hygiene, 14(4), 303-308.

Samples of blood, bone (rib), and urine were obtained from workers not exposed to Th, and urine from workers engaged in the chemical processing of thorium. Air particulate matter, together with drinking water, was sampled at the Radiological Protection Service (RPS) site while representative samples of a United Kingdom (UK) prepared packet basket diet were obtained from a UK Ministry of Agriculture, Fisheries and Food survey. The concentration of thorium in the samples was determined by neutron activation analysis. The chemical procedures adopted for the processing of blood (irradiated), urine, and bone were governed by the chemical composition and size of the sample taken. A mean concentration of 2.42 plus or minus 0.40 ug/l Th 232 in blood was obtained for 30 samples. The concentration of Th in the blood varied by a factor of 80 plus or minus 20 in the different samples. No correlation has been observed between Th content of blood and geographical location, residence, age, or

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MONITORING, MEASUREMENT AND ANALYSIS

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sex; the effect of diet on the blood levels was not assessed. A mean concentration of 28.7 ± 11.1 $\mu\text{g/g}$ Th 232 in ash was obtained for 13 samples of human rib; the concentration of Th varied by a factor of 230 plus or minus 30 for the different samples. Concentration of Th in unexposed people was below the limits of detection of 0.001 $\mu\text{g/g}$ Th 232, while Th was present in some samples of urine from workers exposed to industrial Th processing. It was estimated that a 70 kg man (unexposed) contains 215 μg Th 232 in the total body. Measurements of the concentration of Th 232 in air gave values of between 0.01 and 0.32 $\mu\text{g/m}^3$, while the concentration of Th in 8 samples of diet (dry wt.) and 2 of drinking water was below the limits of detection of the method. (SPS)

<567>

Cohn, S.H., E.A. Gussano, and J.S. Robertson, Brookhaven National Laboratory, Medical Research Center, Upton, Long Island, NY. 1967, December.

Calculation of Radiation Dose from Thorotrast Using Whole-Body Gamma-Ray Spectral Data. Annals of the New York Academy of Sciences, 145(3), 608-622; CONF-660422: Distribution, Retention, and Late Effects of Thorium Dioxide, F.L. Swann (Ed.), Proceedings of a Conference held in New York, New York, April 20-22, 1966, (pp. 608-622), 336 pp. (CONF-660422).

In an epidemiological study of the late effects of Thorotrast in patients, it is necessary to measure the radiation dose to the critical tissues in order to establish a dose-effect relationship. It is thus necessary to measure the concentration of Th 232 and its descendants as a function of time in the critical tissues. The only way that these measurements can be made IN VIVO at late times after administration of Thorotrast is with whole-body gamma spectrometers. From the concentrations of several of the gamma-emitting daughters of Th 232 in the critical tissues, it is possible to calculate the integral radiation dose to the patient from the date of Thorotrast injection. This report describes the technique for obtaining whole-body measurements in patients with Thorotrast burdens, and the computer analyses of their gamma spectral data. By means of a computer program, the theoretical IN VIVO relationships between Th 232 and its descendants were calculated as a function of time. Thus the initial amount of Th 232 could be deduced from the spectroscopic measurements of the Ac 228 and Tl 208 daughters at any given time. Once this determination was made, it was then possible, by referring to the calculated time patterns of the Th 232 decay scheme, to determine the activities of each of the daughters over the time period following administration, and to sum these to obtain an average dose to the liver and spleen. The complex decay scheme of Th 232 and the resultant dynamic relationship involving equilibria, altered by the different metabolic patterns of distribution and excretion of the daughters, introduces a degree of variability into the analysis, but despite this, the method appears most promising and capable of further refinement. (Auth)

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Copp, J.J., U.S. Environmental Protection Agency, Radiation Office, Rockville, MD. 1971, March.

Summary of Environmental Monitoring at Ames Laboratory, 1962-1969. Radiological Health Data and Reports, 12(3), 119-128.

The Ames Laboratory Research Reactor facility (ALRR), operated for the U.S. Atomic Energy Commission by the Iowa State University of Science and Technology, reached full power in July 1965. Research at Ames Laboratory has included methods for separating zirconium and hafnium; methods for separating niobium and tantalum; a technique for separation of Th 233 from thorium; and liquid metal extraction methods for removal of fission products and plutonium from power reactor fuels. The preoperational and present environmental monitoring program consists of gross alpha and gross beta radioactivity determinations in air, soil, vegetation, river water, ALRR outfall, river bottom sediment, precipitation, well water, and pond water samples. The average beta radioactivity levels in air ranged from 3.86 pCi/m³ in 1963 to 0.12 pCi/m³ in 1967. The 1968 average level of beta radioactivity (1.26 pCi/m³) was about one-third of the 1962-1963 average levels. The beta radioactivity in soil increased from 1962 to a peak of 20 pCi/g in 1964, probably due to weapons fallout, then decreased to a plateau of 13-15 pCi/g in 1965 through 1969. The alpha radioactivity increases from 1962 to 1968 and leveled to a plateau (1964-1969) of 0.7-1.0 pCi/g. Vegetation samples show decreasing levels of beta radioactivity to 20-30 pCi/g. The alpha radioactivity in vegetation was variable with a general decrease from 1962 to 1965, leveling to 0.1-0.2 pCi/g in 1966-1968 and showing a rise to 0.31 pCi/g in 1969. The environmental data indicate that any radiation that may have been contributed by the Ames Laboratory Research Reactor facility could not be detected. (Auth) (FHH)

<569>

Cross, P., and G.W. McBeth, Brighton Polytechnic, Applied Physics Department, Brighton, England. 1970, September.

Absolute Determination of Trace Quantities of the Thorium 228 Series. Health Physics, 27, 265-272.

Low activity levels of Th 228 (approximately 7 pCi) have been determined to $\pm$ 4% in 800 min counting time. The theory of the technique has been fully described and its ability to discriminate against other radioactive series has been assessed. There is an indication that under favorable circumstances activities of approximately 10(E-12) Ci of Th 228 could be determined in 800 min counting time. As an example of the system in operation 7 pCi of Th 228 in a sample of Thorium-X (Ra 224) varnish has been determined and a contamination level of 60 nCi Th 228 per ml of varnish and 2.5×10 (E-4) μCi Th 228 per μCi Ra 224 established. (Auth)

<570>

Darley, A.C., Q. Bristow, and D.W. Donhofer, Geological Survey of Canada; Atomic Energy of Canada Limited, Ottawa, Ontario, Canada. 1969.

Airborne Gamma-Ray Spectrometer Experiments over the Canadian Shield. CONF-691229: IAEA-SM-112/11: Nuclear Techniques and Mineral Resources in Developing Countries, Proceedings of a Panel held in Krakow, Poland, December 8-12, 1969, (pp. 163-186) (CONF-691229, IAEA-SM-112/11).

TECHNOLOGY, MEASUREMENT AND ANALYSIS

<571> CCNY.

The Geological Survey of Canada and Atomic Energy of Canada Ltd. have produced a high sensitivity spectrometer for radiometric mapping of the Canadian Shield. During 1967 experiments were undertaken in the Bancroft and Elliot Lake areas of Ontario to determine the system parameters. Ground control was provided by measurements with field gamma-ray spectrometers on a 200-ft grid over 2 square miles. An experimental spectrometer employed three 5 x 5 in. (12.5 x 12.5 cm) diam. NaI(Tl) detectors, in order to record the full gamma-spectrum in real-time on magnetic tape. To provide the highest possible count-rates per unit distance at varying heights the spectrometer was flown in a helicopter at 25 mph (40 kmph). A study of the spectra obtained shows that the optimum spectral window widths for measuring the relative abundance of potassium, uranium and thorium are: potassium, K 40 1.35 - 1.58 m.e.v.; uranium, Bi 214 1.65 - 1.88 m.e.v.; thorium, Th 232 2.42 - 2.62 m.e.v. The recorded data was subsequently processed through a PDP-9 computer to provide corrections for dead-time, Compton scattering and deviations from constant terrain clearance. Based on this work a more sensitive airborne system was constructed in 1968 and installed in a twin-engine STOL aircraft. The system employs twelve 9 x 4 in. (23 x 10 cm) NaI (Tl) crystals. This detector volume provides a 10% (1 standard deviation) precision in corrected accumulated count in any of the three spectral windows when the aircraft measures radiation over an elapsed distance of 350 ft at a ground speed of 120 mph and 400 ft terrain clearance. The airborne system includes Doppler navigation, radar altimeter, and TV tracking camera equipment. (Auth)

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De Brito, J., A.P. Lorfello, and A. Abrao, Instituto de Energia Atomica, Sao Paulo, Brazil. 1976, April.

Spectrographic Determination of Rare Earths in Thorium Compounds. Chromatographic Preconcentration in an Acid-Ether-Cellulose System. IAEA-415; 29 pp.

A method for spectrographic determination of Gd, Sm, Dy, Eu, Y, Th, Pa and La in thorium compounds has been developed. Sensitivities of 0.01 µg rare earths/gran ThO₂ were achieved. The rare earth elements were chromatographically separated in a nitric acid-ether-cellulose system. The solvent mixture was 11% nitric acid in ether. The method is based on absorption of rare earths on activated cellulose, the elements being eluted together with 0.01 N HNO₃. Retention of Eu 152, 154 used as tracer was 99.8%. Recoveries of other elements varied from 95-99% indirect carrier distillation of the elements was used. Several concentrations of silver chloride were used to study the volatility behavior of the rare earths. Two percent AgCl was added to the matrix as definite carrier, and lanthanum was selected as internal standard. The average coefficient for this method was + or - 7%. (Tr)

<572>

Duggan, H.J., National Radiological Protection Board, Belmont, Sutton, Surrey, England. 1973, March.

Some Aspects of the Hazard from Airborne Thoron and its Daughter Products. Health Physics, 24,

321-310.

There are no epidemiological studies to provide evidence for an exposure-risk relationship in respect to the inhalation hazard from thoron, and considerations of lung dosimetry are therefore of prime importance. Such considerations, together with those of the relative concentrations of thoron and its daughter products, suggest that the doses from inhaled thoron, ThB and ThC are comparable in various factories and mines presented. It is concluded that, although a full assessment of the inhalation hazard from thoron and its daughters require the measurement of the concentrations in air of all three nuclides (thoron, ThB and ThC), in many circumstances it is acceptable to assess the hazard from a knowledge of the ThB and ThC concentrations. (Auth)

<573>

Duggan, H.J., and D.W. Howell, Radiological Protection Service, Sutton, Surrey, England. 1968.

A Method for Measuring the Concentrations of the Short-Lived Daughter Products of Radon 222 in the Atmosphere. International Journal of Applied Radiation and Isotopes, 19, 865-870.

A method is described for the simultaneous determination of each of the short-lived daughters of radon 222. The method entails sampling the atmosphere of interest through a filter and carrying out alpha-spectrometry on the activity collected on the filter. The spectrometry measurements must be made both during and after sampling. From a knowledge of the RaA and RaC disintegrations occurring on the filter it is possible to calculate the atmospheric concentrations of RaA, RaB and RaC. The determinations made by the method indicate that its accuracy is sufficient to obtain meaningful results with the smallest daughter product concentrations usually found in the atmosphere. (Auth)

<574>

Duport, P., G. Hadelaine, P. Zetwood, and A. Benoux, Laboratory of Atmospheric Physics, Technical Section for the Study of Air and Mine Pollution, Fontenay-lez-Roses, France; Laboratory of Aerosol and Physics and Atmospheric Radioactivity, Department of Sciences, Brest, France. 1977.

Experimental Study of the Penetration of Radioactive Aerosols into the Respiratory Tract. Chemosphere, 1, 35-40; ORNL-tr-4526; 11 pp.

A new autoradiographic technique allows direct examination of radioactive aerosols deposited in the respiratory tract of rats. The technique uses a cellulose nitrate film and appropriately placed screens to reach the detector. The method of the removal and preparation of the organs can be improved by immediate freezing of the excised organs which would allow a more accurate sectioning of the respiratory tract and prevent loss of body fluids. The quantitative analysis of the radioactivity retained in each section should be done by autoradiography and gamma-counting of the organ segments. The production of marked aerosols of clearly-determined dimensions would allow refinement of such retention studies. The results agree with those of Bargic in an experimental rat study using an Anderson cascade impactor in which the succession of eight stages represents increasingly deep segments of the respiratory airways. The greatest deposit is

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MONITORING, "PASSIVE" AND ANALYSIS

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in the deep lung with progressively less deposit in tracheobronchial and nasopharyngeal regions. (Tr)(VC)

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Radie, G.G., and D.E. Bernhardt, U.S. Environmental Protection Agency, Office of Radiation Programs, Las Vegas Facility, Las Vegas, NV. 1976, December.

Sampling and Data Reporting Considerations for Airborne Particulate Radioactivity. EPA-47-76-9. 30 pp.

Selected air filters were evaluated for their suitability as collection media for the radiological analysis of airborne particulate matter. Standard four-inch diameter filters were analyzed for their natural radioactivity contents. Of the filters tested, glass fiber filters had the highest Ra 226 content (0.35 picocuries per filter) and Microsorban filters contained roughly one-third of this activity. Microsorban filters also had lower U and Th contents than do the glass fiber filters. For the analytical methods used in this study, all filter types tested had undetectable Po 210, Pb 210, and Ra 228 contents. Dust loading characteristics of selected filters were also evaluated. The results indicate that Microsorban filters have higher collection and dust retention efficiencies (ranging from 6 to 26 percent greater) than do glass fiber filters. As a result of these evaluations, Microsorban filters are being used in the routine environmental radiological air quality monitoring networks operated by the Office of Radiation Programs - Las Vegas Facility (ORP-177). (Auth) (RAD)

<576>

Radie, G.G., and R.V. Kaufmann, U.S. Environmental Protection Agency, Office of Radiation Programs, Las Vegas, NV. 1977, April.

Radiological Evaluation of the Effects of Uranium Mining and Milling Operations on Selected Ground Water Supplies in the Grants Mineral Belt, New Mexico. Health Physics, 32, 231-241.

A study was conducted by the U.S. Environmental Protection Agency and the New Mexico Environmental Improvement Agency to evaluate the possible radiological contamination of ground-water supplies in the Grants Mineral Belt area of New Mexico. Ground-water contamination from uranium mining and milling results from the infiltration of mine and mill discharge waters and ion-exchange plant effluents enriched in uranium series decay products. To date, municipal water supplies in the area have not been adversely affected by radionuclides in wastes associated with uranium mining and milling operations. However, ground-water sampling locations show slightly elevated radionuclide concentrations attributable to mining and milling activities. Only seven of the 72 sampling locations of this study had radium 226 concentrations in excess of 3 pCi/l. Two of the seven involved potable water supplies; they contain 3.6 and 3.7 pCi/l. Routine monitoring for U and Ra is recommended for areas where water supply may be affected by mining and milling operations. Thorium isotopes and polonium 210 contents fluctuate about background levels, whereas uranium contents are difficult to distinguish from the naturally elevated concentrations due to

proximity to uranium-bearing formations. (Auth) (VC)

<577>

Enkins, J.D., and P.J. Goss, Atomic Energy Research Establishment, Health Physics and Medical Division, Didcot, Berkshire, England. 1968.

The Determination of Gross Alpha Activity in Trise by Adsorption on Glass Fibre Filter Paper. Health Physics, 10, 461-472.

A description is given of work carried out to determine the optimum conditions for maximum surface adsorption of a number of alpha emitting radionuclides on glass fibre filter paper. The effect of valency, pH and presence of pyrophosphate is discussed and a new technique for the determination of gross alpha activity is given based on surface adsorption. Overall recoveries of thorium, protactinium, neptunium, plutonium, americium and curium are about 80 percent using this procedure. The advantages of surface adsorption over conventional ion exchange are discussed and the development of other procedures based on this principle is suggested. (Auth)

<578>

Evans, R.D., University of California, Physics Department, CA; Massachusetts Institute of Technology, Cambridge, MA. 1935, April.

Apparatus for the Determination of Minute Quantities of Radium, Radon and Thoron in Solids, Liquids and Gases. Review of Scientific Instruments, 6, 99-117.

The radium content of ordinary materials is determined by removing and measuring the radon which is in equilibrium with the radium. 1. Generalization of the direct fusion furnace method now permits the rapid and complete desorption of any solid by direct boiling at 2000 degrees C. 2. Improved boiling apparatus for the removal of radon from liquids avoids loss of traces of radon by absorption. 3. Gaseous samples, at atmospheric pressure, may be examined directly for radon. 4. Double ionization chambers, coupled to a high sensitivity string electrometer, permit observations on very feeble sources. Statistical fluctuations in the emission of contamination alpha-rays from the ionization chamber walls impose a natural observational limit of 7.2×10^{-14} (B) (E-1/2) curies of radon, when the ionization currents are observed for a hour. 5. Photographic recording of the ionization current, with hourly automatic recalibration of the electrometer at three arbitrary potentials, makes possible long runs and higher precision, particularly for weak sources. 6. Induction, null-induction and ionization methods for the measurement of the electrostatic capacity of ionization chamber systems are described. 7. Caution is given against a spurious ionization, of unknown origin, occasionally observed in connection with radon tests. 8. The flow method for the measurement of thoron is shown to be more applicable to liquid samples than to solids. Under normal operating conditions the emanating power of liquid samples is about 0.6. 9. Mean values of the radium content of certain classes of rocks, sea waters and organisms are given. (Auth)

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Evans, R.D., and C. Goodson, Massachusetts

MEASUREMENT, SEPARATION AND ANALYSIS

<579> CCNY.

Institute of Technology, Department of Physics, Cambridge, MA. 1940, March.

Determination of the Thoron Content of Air and Its Bearing on Lung Cancer Hazards in Industry. *Journal of Industrial Hygiene and Toxicology*, 22(3), 85-95.

Portable apparatus is described for collecting reproducible samples of thoron 9, on which alpha or beta ray analysis can be quantitatively interpreted in terms of the thoron concentration of the air originally sampled. The biological effectiveness of alpha radiation on the lungs and bones of man, rats, and mice is considered in terms of the radiation energy dissipated per hour per gram of dry tissue. Consideration of all available quantitative evidence suggests that long-continued breathing of air containing 10 (P-9) curies per liter results in a high incidence of lung cancer, and leads us to recommend 10 microcuries (10(E-11) curies) per liter of air as the safe working concentration of radon or thoron in plants, laboratories, and offices. The results of typical plant air measurements are reported and show thoron concentrations of 23 to 100 times this recommended value. (auth) (VC)

<580>

Fishman, W.J., and D.E. Erdmann, U.S. Geological Survey, Lakewood, CO. 1975, April.

Water Analysis. *Analytical Chemistry*, 47(5), 134-161.

This sixteenth review of the literature of analytical chemistry applied to water analysis covers the period from October 1972 through September 1974. The material used in preparing this review comes mainly from major analytical journals and chemical abstracts. Conference proceedings, obscure foreign journals, and most trade journals are generally excluded. The summary of each article is shorter than in the past and the reader should refer to the specific journal or chemical abstract for the details. Stridlin, Havel, and Sommer described a spectrophotometric method for determining U using chromotropic acid. Absorbance is measured at either 410, 460, or 500 mμ. Most interfering cations are masked. Beer's law is obeyed up to 100 μg per ml of UO₂(+2). Ryabinin and Lazarev modified the colorimetric arsenazo III method for U in sea water. Uranium is separated from iron(III) by 2-stage carbonate leaching and photometry is done from 4-6N hydrochloric acid with preliminary reduction of U (VI) to U(IV) with zinc. Korkisch and Koch concentrated U from sea water on Dowex 1-X8 anion exchange resin prior to fluorometric or spectrophotometric measurement. In an earlier publication Korkisch and Steffan described another anion exchange (Dowex 1-X8) separation of U from water and other geological materials. The eluted U is determined fluorometrically or titrimetrically. Danielsson et al. described a fluorometric determination of U in natural waters. The limit of detection is 0.3 ppm. Ion-exchange is used to preconcentrate the U by a factor of 22 and to separate it from quenching ions in the sample. Horrocks measured U in water in amounts equal to or greater than 0.1 μg/ml by liquid scintillation alpha counting. An emulsifier system is used to incorporate 5 ml of aqueous solution in a 15-ml counting solution with 100% counting efficiency for alpha particles from the U 234 and U 238. A multichannel analyzer allows corrections for the presence

of short-lived beta emitters in the U decay chain. Steinhilber reported that a neutron activation method based on 23.5 minute ²³⁹Pa using solvent extraction with tri-n-butyl phosphate as a selective separation step is sensitive and precise for the determination of U in fresh waters. Korkisch and Dimitriadis used Dowex 1-X8 anion exchange resin to concentrate Th in natural waters. The Th is eluted with 6N hydrochloric acid and determined spectrophotometrically by the arsenazo III method. (auth) (VC)

<581>

Fleischer, R.L., and A.C. Delany, General Electric Research and Development Center, Schenectady, NY; National Center for Atmospheric Research, Boulder, CO. 1976, April.

Determination of Suspended and Dissolved Uranium in Water. *Analytical Chemistry*, 48(3), 642-645.

Measurement of uranium in environmental surface water can be complicated by a variable mass of suspended uranium-bearing particles. The abundance of such particles is in turn affected by many factors, including flow velocities, degree of turbulence, and the local geology and vegetation. A technique for analytically separating the uranium that is located in suspended, particulate matter from that which is present in solution is described. A nuclear track technique outlined for sensitively measuring the uranium content of water droplets and supplying the necessary experimental detail was used. Individual droplets of water can be analyzed for uranium down to less than 0.01 μg/l using readily available neutron doses. By separately counting randomly arrayed and clustered tracks, the dissolved uranium can be separated from that which is suspended in particulate matter. (auth) (VC)

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Footo, W.S., Texas Instruments, Inc., Dallas, TX. 1969.

Improvement in Airborne Gamma-Radiation Data Analyses for Anomalous Radiation by Removal of Environmental and Pedologic Radiation Changes. *CONF-691229: IAEA-SM-112/13; Nuclear Techniques and Mineral Resources in Developing Countries, Proceedings of a Panel held in Krakow, Poland, December 8-12, 1969, (pp. 187-196) (CONF-691229, IAEA-SM-112/13).*

Analysis of airborne gamma-radiation spectral data gathered from an array of 11 1/2-in.-diam. by 4-in.-thick NaI(Tl) detectors provides iso-radiation maps of the average surface concentration of uranium (Bi 214), thorium (Th 232) and potassium (K 40) only if aircraft and atmospheric radiation are properly measured and removed. The atmospheric radiation consists of ambient, mineral and surface pedologic components. Airborne measurements of the average radiation along a flight line indicates Th 232 and K 40 surface intensities to be consistently measured to ± 2%. Airborne measurement of Bi 214 intensities at 400-ft surface altitude indicates that as much as 70% of the data originates in the atmosphere as a result of the decay of atmospheric radon concentrations. These atmospheric Bi 214 intensities are being measured and removed from the data. Such data have been accumulated indicating the specific correlation between the average intensities of radiation from the decay of the natural radionuclides within pedologic environments.

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MONITORING, RECOVERY, AND ANALYSIS

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Thus, digital data gathered from a magnetic tape multichannel analysis system can be reduced by computer operation to give isoradiation maps that indicate regions of anomalous radiation where the effects of surface pedologic changes are minimized or removed. This analysis separates desired anomalies from those created by surface pedologic changes. (Auth)

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Forlyce, J.S., and D.W. Sheibley, National Aeronautics and Space Administration, Lewis Research Center. 1975.

Estimate of Contribution of Jet Operations to Trace Element Concentration at or Near Airports. Journal of Air Pollution Control Association, 25(7), 721-728.

Samples of AST4 type A jet fuel were analyzed for trace element content by instrumental neutron activation techniques. Forty-nine elements, including thorium, were sought. Only ten, aluminum, gold, indium, lanthanum, titanium, vanadium, barium, dysprosium, tellurium, and uranium, were observed at levels above the detection limits encountered; of these only aluminum, titanium, and barium were present at concentrations greater than 0.1 ppm. Estimates of exhaust gas concentrations are made, and the ambient contribution at or near airports is calculated by using the Los Angeles International Airport dispersion model. It is shown that the ambient contribution is about an order of magnitude below typical urban levels for virtually all elements sought. (Auth)

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Fusamura, Y., Y. Kurosawa, and H. Hisaya, Waseda University, Science and Engineering Laboratory, Tokyo, Japan; Atomic Fuel Corporation, Mining Section, Tokyo, Japan. 1964, December.

The Measurement of Radioactive Gas and Dust in Uranium Mines in Japan. Health Physics, 10(12), 509-515.

Measurements and evaluations of radon and radon daughter products in Japanese mines include determinations of Ra free ion in mine air and the age estimate of radon emanated from the ore bodies or mine waters. The steady state of radon emanation will be influenced by the Ra content in the ore body, the radon concentration in mine water, the permeability of the strata, and other mine conditions. The daughter products maintain equilibria with the parents in the sources. An empirical equation was developed to express the age of radon. The natural uranium concentration of airborne dust range from 0.3×10^{13} (E-13) to 4.5×10^{13} (E-13) ac/cm³. In general, if the dust concentration is lower, the uranium content in dust is higher and the concentration of natural airborne uranium is lower. (BAP)

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Gridgeman, H.T., National Research Council of Canada, Division of Biology, Ottawa, Ontario, Canada. 1971.

Methods of Assay of the Relative Toxicity of Certain Bone-Seeking Radionuclides. Radiation Research, 48, 291-302.

Four methods of handling the dose-response relation in the data from the long-term

experiment on the effects of certain radionuclides administered intravenously to dogs at the University of Utah are presented and discussed. The results are cast in terms of the relative biological effectiveness of five radionuclides: Ra 226, Pu 239, Sr 90, Ba 228 and Th 228 for the production of bone cancers. One of the methods is based on quantal response (deaths from osteosarcomas), two are based on survival times, and the fourth is a modification of that proposed by Blair (which takes account of the induction period between dosage and the beginning of oncogenesis). There is evidence that Blair's approach has merit. (Auth)

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Geddes, P.H., Lawrence Radiation Laboratory, Livermore, CA. 1970.

LRL Environmental Surveillance Program. UCRL-50007-70-3; Hazards Control Progress Report No. 38, September through December 1970, (pp. 7-9) (UCRL-50007-70-3).

The Laboratory is significantly upgrading its environmental surveillance capability by means of increased analytical sensitivity in order to better monitor the effect of Laboratory operations on the environment. Initially, the major effort in the program will be toward determining the environmental background levels of radionuclides which could conceivably escape from the Laboratory. These radionuclides include Pu 238, 239, U 233, 235, 238, Th 232, Am 241, Cs 241, and others. (Auth)

<587>

Gwiazdowski, B., J. Pensko, J. Jagielak, H. Siemacka, and K. Pawluc-Ciesla, Central Laboratory for Radiological Protection, Warsaw, Poland. 1973.

Environmental Gamma Radiation Measurements in Nuclear Power Station Siting Studies in Poland. CONF-731117; STI/PUB/353; IAEA-SM-180/22; The Environmental Surveillance Around Nuclear Installations, Proceedings of a Symposium held in Warsaw, Poland, November 5-9, 1973, Vol. 1, (pp. 89-105), 470 pp. (CONF-731117, STI/PUB/353, IAEA-SM-180/22).

A survey of environmental gamma background radiation in a region surrounding one of the proposed nuclear power station sites in Poland, in the vicinity of Iarnowieckie Lake, has been described. Over a three-year period, a program of field measurements using a portable high-pressure ionization chamber and an airborne monitor and with spectrometric evaluation of soil samples has been completed. The program of surface measurements comprised the survey of gamma background exposure dose rate at one meter above the ground at 100 measurement points distributed over a region of 40 km radius. The airborne monitor survey was made by recording the dose rate during flights on parallel paths 2 km apart. The dose rate was determined for ground level over a square net of points spaced at 2 km sides, which was the basis used for drawing up the map of dose-rate distribution. The paper discusses the method used for the survey and the results obtained. (Auth)

Tables 1 and 2 show the results of environmental gamma background radiation measurements in the Iarnowieckie Lake area.

TECHNIQUE, MEASUREMENT AND ANALYSIS

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Peterberger, K., V. Balak, and J. Szanek, J. Heyrovsky Institute of Physical Chemistry and Electrochemistry, Czechoslovak Academy of Sciences, Prague, Czechoslovakia; Institute of Nuclear Research, Rez, Czechoslovakia. 1977, February.

Combination of Evacuation Thermal Analysis with Evolved Gas Analysis and Differential Thermal Analysis. A comparative study of the thermal decomposition of calcium carbonate and calcium oxalate. Radiochemical and Radioanalytical Letters, 28(4), 301-307.

The possibilities of evacuation thermal analysis (ETA) can be enlarged by combining it with other thermal methods such as evolved gas analysis (EGA) and differential thermal analysis (DTA). Calcium carbonate and calcium oxalate samples were used for investigations combining ETA, EGA and DTA. The results are compared with those obtained by ETA alone. Samples were labelled with Th 229 and the daughter, Bi 220 was measured by ETA. Calcium carbonate and calcium oxalate were measured with ETA and EGA. Evacuation thermal analysis has shown the existence of irreversible annealing of surface defects in finely dispersed calcium carbonate, which show no effect on the ETA and EGA curves. In the case of calcium oxalate, the combination of methods permitted explanation of results obtained by ETA both in nitrogen (demonstrating a predecomposition stage in anhydrous calcium oxalate) and in air (showing that oxygen in the reaction atmosphere causes not only the oxidation of its various products but also affects the decomposition process itself). (Auth) (VC)

<589>

Hailton, I.L., Radiological Protection Service, Belmont, Sutton, Surrey, England. 1970, October.

The Concentration of Uranium in Air from Contrasted Natural Environments. Health Physics, 19, 511-520.

The concentration of uranium in the air has been determined by the fission track method, using polycarbonate detectors, from two contrasted natural environments, namely, the Radiological Protection Service site at Sutton, U.K., and during an oceanic cruise from Belgium to Antarctica. A modal concentration of 20×10^{-12} g U/m³ air and 45 eq of dust/m³ air has been obtained for the Sutton site which is equivalent to a modal concentration of 0.4 pCi/m³ in the air particulate matter. A mean concentration of 4.1×10^{-12} g U/m³ air has been obtained for Atlantic ocean air sampled in the Northern Hemisphere; in the Southern Hemisphere, no uranium was detected in any of the samples, but a mean concentration of 3×10^{-12} g U/m³ air was obtained for air sampled on the land mass of Antarctica. Various sources are considered to account for the presence of uranium in the air. A correlation between the periodicity of fission products in the air and the concentration of uranium is noted. It is concluded that uranium present in the air at a particular site consists of local debris, together with distant debris transported as a result of world wide meteorological conditions. (Auth)

<590>

Harley, J.W. (Ed.), New York Operations Office, New York, NY. 1967.

Health and Safety Laboratory Manual of Standard Procedures. HSO-8700 (Rev.) (Suppl. 1).

The information contained in this manual is intended to supplement the standard analytical procedures used by the Health and Safety Laboratory of the USAEC. Included are sections that describe radiation measurements (alpha, beta, and gamma counting); chemical procedures for determination of stable or radioactive nuclides of the elements Fe, Ca, Zn, Pb, Sr., Cr, Sb, Cd, I, Cs, Co, Na, U, Th, Pu, and Pb; methods of fallout collection and analysis; and equipment specifications. (Auth)

<591>

Raywood, P.F., G.D. Kerr, W.A. Goldsmith, P.T. Perdue, and J.N. Thorngate, Oak Ridge National Laboratory, Health Physics Division, Oak Ridge, TN. 1976.

Measurements of Radon Daughter Concentrations in Structures Built on or Near Uranium Mill Tailings. COSF-761071: Personal Dosimetry and Area Monitoring Suitable for Radon and Daughter Products, Proceedings of a Specialist Meeting held in Ontario, Canada, October 4-8, 1976, (pp. 219-229) (COSF-761071).

A technique is discussed that has been used to measure air concentrations of short-lived daughters of Ra 222 in residential and commercial structures built on or near uranium mill tailings in the western parts of the United States. The concentrations of RaA, RaB, and PaC are calculated from one integral count of the RaA and two integral counts of the PaC alpha-particle activity collected on a filter with an air sampling device. A computer program is available to calculate the concentrations of RaA, RaB, and PaC in air and to estimate the accuracy in these calculated concentrations. This program is written in the BASIC language. Also discussed are the alpha-particle spectrometer used to count activity on the air filters and the results of radon daughter measurements in Colorado, Utah, and New Mexico. Results of these and other measurements are now being used in a comprehensive study of potential radiation exposures to the public from uranium mill tailings piles. (Auth)

<592>

Meler, K.S., and J.J.W. Rogers, Rice University, Department of Geology, Houston, TX. 1963.

Radiometric Determination of Thorium, Uranium and Potassium in Basalts and in Two Magmatic Differentiation Series. Geochimica et Cosmochimica Acta, 27(2), 137-156.

Thorium, uranium and potassium contents of basalts and other basic rocks have been measured by gamma-ray spectrometry. The ratios of Th/K, U/K and Th/U are constant within one order of magnitude in a wide variety of rock types. The averages for basalts are Th/K $\times 10^{(E-4)} = 2.8$, U/K $\times 10^{(E-4)} = 0.60$ and Th/U = 0.8. Some tendency exists, however, for increase in these ratios with igneous differentiation, as shown by investigations of the Duluth and Southern California intrusive sequences. The Th/U ratio is particularly low in tholeiites (1.6) from the orogenically active Japanese area and is also lower in the basic rocks of the Duluth and Southern California sequences than in most basalts. Apparently the process which leads to the formation of sags in orogenic areas causes removal of thorium,

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WRITING, MEASUREMENT AND ANALYSIS

<592> CONT.

potassium and to a lesser extent, uranium from source materials before intrusion or eruption. Close relationship between potassium content and Th/U ratio in basic rocks from widely separated areas, however, suggests that the subcrust in which basic magmas originate is compositionally uniform and differences between the compositions of primary basaltic magmas are probably the result of local processes. (Auth)

<593>

Hodge, V.P., F.L. Hoffman, R.L. Foreman, and L.R. Polson, Scripps Institution of Oceanography, La Jolla, CA. 1978, August.

Simple Recovery of Plutonium, Americium, Uranium, and Polonium from Large Volumes of Ocean Water. *Analytical Chemistry*, 46(9), 1330-1332.

Plutonium can be consistently recovered from 50- and 200-liter volumes of sea water in high yields by partial precipitation of magnesium hydroxide and calcium carbonate by addition of small amounts of sodium hydroxide. Similarly, americium, uranium and polonium can be concentrated and then easily purified for alpha spectrometry. The addition of 3.5 mol NaOH/l removed 67-77% of the added Pu 236, Am 243, U 232 and Po 209 tracers. Similar recoveries of plutonium and americium tracers were obtained with 10.5 ml of 50% NaOH in 50 l of sea water or 34 ml in 200 l of sea water. Working recoveries of plutonium (averaging 76% for 50 l of sea water) are significantly better than those obtained with iron hydroxide and bismuth phosphate coprecipitation. Losses due to ion exchange and plating techniques are: Pu-16%, Am-15%, U-25%, Po-33%. When average working recoveries are corrected for these losses, the partial precipitation of alkaline earth hydroxides and carbonates carries these four elements with an efficiency of about 90%. The fact that no iron carrier is used in the technique allows an ion exchange chromatography to be done in HCl media in which many other metals can be selectively eluted (e.g. Pu 55). (VC)

<594>

Hell, A.P. (Comp.), L. Kartsana, D. Henze, E. Miller, J. Schile, J. Phillips, D. Simpson, and J. Steiners, Brookhaven National Laboratory, Upton, Long Island, NY. 1973, August; 1973, May.

1972 Environmental Monitoring Report. EML-17874; HASN-1259; Environmental Monitoring at Major U.S. Atomic Energy Commission Contractor Sites, Calendar Year 1972, (pp. 413-466), 1217 pp. (EML-17874, HASN-1259).

Natural background and radiation levels in the vicinity of Brookhaven National Laboratory attributable to its operations during 1972 are summarized. Among the data reported are external radiation levels; air particulate, tritium and radioiodine concentrations; precipitation and liquid effluent-related concentrations in streams, groundwater and surveillance wells, as well as levels in milk, grass and soil samples. Other than tritium, there was no indication of BNL effluents in environmental air and precipitation samples. In air, the largest BNL effluent-related tritium concentration was 4×10^{10} (B-12) dCi/ml which is 0.002% of the applicable standard. In precipitation it was 2.77×10^{10} (B-4) dCi/ml, which is 0.01% of the standard for drinking water. Quarterly milk samples were obtained from two nearby

dairy farms. No significant differences between Cs 137 levels in these and those generally prevailing in the southeast United States were apparent. Two sets of grass and soil samples were also collected from these and three other farms, as well as from perimeter and onsite locations. There was no significant difference between offsite samples generally downwind and those generally upwind of Brookhaven. (Auth) (PNT)

Table A shows total activities and average concentrations of identifiable nuclides in groundwater, site boundary and former perimeter. Tables 10 and 11 show concentrations of re-emitting nuclides (including Th and U) in Pecenic River, Carman's River sediments and Carman's River vegetation. Table 12 shows concentrations of emitting nuclides in turtles and catfish obtained from the Pecenic River. Other tables show concentrations of nuclides in milk, grass, soil and waste disposal areas.

<595>

Isaich, H., University of Heidelberg, Department of Medical Documentation and Statistics, Heidelberg, German Federal Republic. 1973, June.

Statistical Problems of Thorotrast Studies. CONF-710475; HISO-294; Toxicity of Thorotrast, H. Faber (Ed.), Proceedings of the 3rd International Meeting held in Copenhagen, Denmark, April 25-27, 1973, (pp. 140-150) (CONF-710475, HISO-294).

A cross-section study on the toxicity of Thorotrast requires a control group. The requirements for establishing such a group discussed are: definition of the two groups, comparison of groups with regard to time, compatibility of groups with respect to age and sex, and equality of treatments such as physical, radiological and laboratory examination. Data should be evaluated after collection for the whole study has been completed to insure that true differences between carrier and control groups are being seen. (VC)

<596>

Iyengar, H.A.R., and P.N. Markose, Bhabha Atomic Research Center, Bombay, India. 1970.

An Investigation into the Distribution of Uranium and Daughters in the Environment of a Uranium Ore Processing Facility. CONF-701227; Radiation and Radioisotopes in Soil Studies and Plant Nutrition, Proceedings of a Symposium held in Bangalore, India, December 21, 1970, (pp. 143-153) (CONF-701227).

An environmental survey is given of the uranium mining and processing facility at Jaduguda, Bihar. Radioactive wastes are discharged into a tailings pond; the effluents drain into a river. Results of soil, air, water, vegetation and food monitoring are presented. A concentration of radioactivity in soil patches adjacent to the river banks and nine premises was found. Air activity due to Ra was significantly higher than in Trombay or Alwaye. Water activity varied widely in its radioisotope content. A wide range of concentrations was also found in foods. The hazards of utilizing mine streams for domestic cultivation of vegetables and fishing is demonstrated. Algae were found to be good indicator organisms in water pollution. (BAP)

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Jackson, F.O., and B.O. Steart, Battelle-Pacific

TECHNIQUE, MEASUREMENT AND ANALYSIS

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Northwest Laboratories, Richland, WA. 1969, June.

The Determination of Trace Levels of Uranium, Thorium 230, Lead 210, and Polonium 210 in Soft Tissues. BNWL-1051 (Part 2); Annual Report for 1968, D.W. Pearce (Ed.), (pp. 5-6) (BNWL-1051, Part 2).

A method for the determination of trace concentrations of U, Th 230, Pb 210, and Po 210 in soft tissues of animals exposed to airborne uranium ore dust has been developed. The techniques have been applied to such tissue samples as lung, liver, spleen, kidney, and lymph nodes, as well as bioassay material such as urine. The sample is decomposed to a slurry in HNO₃. Uranium 233, Th 234, and Po 208 tracers are added; the sample is wet ashed with HNO₃, H₂O₂ and HClO₄. It is used to volatilize silicone materials. The salts are dissolved in dilute nitric acid, filtered, and the filters are alpha and beta counted to determine that dissolution is complete. Thorium 230 is calculated by applying usual efficiency, volatility and decay corrections. Th 228 ingrowth is calculated from the time interval between U 233 purification and Th separation using the U 232 content measured alpha energy analysis. The total U mass in the sample is measured fluorimetrically. The Pb 210 is determined from measurements taken on Po 210 separated after a period of ingrowth following lead separation. (BNP)

A flow chart shows the overall separation scheme.

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Jackson, S., and W.A. Taylor, United Kingdom Atomic Energy Authority Radiological Protection Division, Harwell, Berkshire, England. 1968.

A Survey of the Methods Used in the United Kingdom Atomic Energy Authority for the Determination of Radionuclides in Urine. CCR-448; STI/PUB/84; Assessment of Radioactive Body Burdens in Man, Proceedings of a Symposium held in Heidelberg, Germany, May 15-16, 1968, Vol. 1, (pp. 169-194), 1043 pp. (COSP-448, STI/PUB/84).

A survey has been made throughout the United Kingdom Atomic Energy Authority of current practice in urine analysis for radionuclides. The elements which are of greatest importance are plutonium, uranium, tritium and fission products (notably strontium 90 and cesium 137). Other radionuclides dealt with are polonium 210, radium 226, protactinium 231, phosphorus 32, carbon 14, sulphur 35, americium 241 and thorium. In assessing the function and scope of urine analysis, the factors affecting the choice of a suitable analytical method are discussed. The sensitivity and precision of the method must be adequate in relation to the maximum permissible body burden, the excretion rate and the sampling frequency; the method must be sufficiently specific or selective to eliminate the possibility of interference by other radionuclides; and finally, the cost must be assessed in relation to all these factors, and also to the speed and convenience of the method. The sensitivity required for each radionuclide is calculated from the maximum permissible body burden by applying a representative urinary excretion rate, based on the best data available. The methods of urine analysis which are currently used in the United Kingdom Atomic Energy Authority are fully described. According to the calculated requirements for sensitivity,

the best methods in use are capable of quantitatively detecting, from urinary excretion, internal contamination with one-tenth of the maximum permissible body burden of any of the above radionuclides, and with one-hundredth of the maximum permissible body burden in the case of enriched uranium, tritium, polonium 210 or cesium 137. (Auth)

<599>

Jacobi, W., Rahn-Heitner-Institut für Kernforschung, Abteilung Strahlenphysik, Berlin, German Federal Republic. 1972, May.

Activity and Potential Alpha-Energy of Radon 222 and Radon 220-Daughters in Different Air Atmospheres. Health Physics, 22, 441-450.

A simple model is described to estimate the activity balance of Ra- and Th-decay products in a turbulent mixed air volume in the steady-state equilibrium taking into account the attachment to aerosol particles and the removal of activity by ventilation and wall deposition. On the basis of this model the principal relationships between these parameters and the degree of radioactive disequilibrium, the fraction of free atoms or ions and the concentration of potential alpha-energy in the air are calculated and discussed, especially with regard to the conditions in uranium mines. The concept of potential alpha-energy is transferred also to Th-daughters. The results will be a useful guidance to estimate the relation between the inhaled potential alpha-energy and the lung dose of workers in uranium and fluorspar mines. (Auth)

<600>

Jones, Y.R., and T.W. Bessley, Battelle-Pacific Northwest Laboratories, Richland, WA. 1967, December.

Natural and Artificial Radionuclides in Fish Flour. BNWL-481 Part of Annual Report for 1966, (pp. 71-74) (BNWL-481, Part 2).

Fish flour samples received from the U.S. Bureau of Commercial Fisheries and Viebina Corporation, Monticello, IL., were analyzed for measurable levels of various radionuclides. Pb 210, Ra 226, Co 60, Cs 137, Ba 226, Th 228, and Fe 55 were detected and their concentration levels established. Pb 210 and Ra 226 appear to be the only two radionuclides that occur in biologically significant quantities. The concentration levels in fish flour correspond to concentration factors over sea water of 4000 for Pb 210 and 230 for Ra 226. (Auth)

<601>

Joshi, L.G., and A.K. Ganguly, Bhabha Atomic Research Centre, Division of Radiological Protection, Trombay, Bombay, India. 1976.

Studies on Thorium and Uranium Disequilibrium on the Surface Layers of the Coastal Sediments and their Absolute Concentrations in the Sediments. Journal of Radioanalytical Chemistry, 34, 299-308.

Measurements of thorium and uranium isotopic activity ratios were carried out in top layers of the sediments of the west coast of India. The southern part of the west coast contains a large amount of placer deposits while the northern region is free from such deposits. Large variations in the activity ratios of Th 228/Th 232 were observed in sediment samples collected from Bombay to

<601>

ENVIRONMENTAL MONITORING AND ANALYSIS

<602> CONT.

Kottilpadd. In the Bombay and in the monazite regions, the activity ratios were in the range of 0.55 to 0.67, while they ranged from 2.00 to 2.19 in the region between Batajari and Bonavar. The Th 230/Th 232 activity ratio in the Bombay region was found to be 0.13 to 0.15; corresponding activity ratios in samples from Batajari to Hanovar were 0.45 to 1.07, while they ranged from 0.23 to 0.25 in the monazite bearing areas. The Th 230/U 238 and U 235/U 238 activity ratios were in the range of 1.12 to 1.16 from Bombay to Kottilpadd; the U 235/U 238 ratios were 0.48 which is identical to the one found for natural uranium. The U 234/U 238 activity ratios were in the range of 1.15 to 1.16, and 0.946 for Th 230/U 238. (BAP)

Previously environmental radiation levels and concentration reports have reflected air sample results, for both alpha and beta-gamma, taken at twenty-one off-site locations. These samples were taken once per month at each location. In April 1970, the Atomic Energy Commission requested that Goodyear Atomic Corporation report only the results of air samples taken from a minimum of four off-site sampling locations. Sampling at these locations should be at a frequency of at least three, 1000 fcl samples per week. In selecting sample locations, the prevailing wind direction and the locations with the highest concentrations should be considered as indicated in past reports. The air sample results in this report reflect this request. (Auth)

<603>

Wahn, B., Georgia Institute of Technology, Atlanta, GA. 1976.

Background Measurements in Monitoring Radioactive Effluent. CONF-760806; Controlling Airborne Effluents from Fuel Cycle Plants. Proceedings of the ANS-NCHE Topical Meeting held in Sun Valley, Idaho, August 5-6, 1976, (pp. 10-1) - 10-16), 340 pp. (CONF-760806).

The radiation background at nuclear facilities is discussed with regard to the measurement of airborne effluent in the environment. The effluent can be detected by measuring the increase in the external radiation dose rate or by collecting and analyzing airborne radionuclides. The contributions to ambient radiation and radionuclide levels by cosmic rays, cosmogenic radionuclides, terrestrial radionuclides in the ground and air, and human activities are indicated. Typical radiation dose rates in air and concentration ranges of the more important terrestrial and airborne radionuclides are listed. Dose rates of 0.1-10 mrad/year from photon-emitting airborne effluent can be measured, in the order of increasing sensitivity, with passive detectors such as TMs, sensitive continuously recording detectors such as pressurized ionization chambers, and scintillation detectors with spectrometers. Procedures are also available for collecting and measuring airborne radioactive particles and gases in effluent at concentrations corresponding to these low annual doses. (Auth)

<604>

Wahn, B., and S.W. Hulett, Goodyear Atomic Corporation, Industrial Relations Division, Industrial Hygiene and Health Physics Department, Piketon, OH. 1970, September 14.

Environmental Radiation Levels and Concentration, First Half 1970. GAT-628; 10 pp.

The average environmental radiation levels for the Goodyear Atomic Corporation gaseous diffusion plant, for the first half of 1970, are summarized. For the first half of 1970, the water alpha and beta-gamma, and the air alpha decreased when compared with the 1969 calendar year values. For the first half of 1970, the air beta-gamma increased when compared with the 1969 calendar year values. It is assumed that the gross alpha activity is due to highly enriched uranium and the beta-gamma activity is from its daughter product, thorium 234. Penetrating background dose rates for the first half of 1970 remained essentially the same when compared with the 1969 calendar year values.

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Kartashov, V.P., and G.P. Shunkov, 1973, September.

Dynamics of the Changes Taking Place in the Content of Radioactive Emanations in the Air of Mining Installations. Atomnaya Energiya, 35(3), 155-158; Atomnaya Energiya, 35, 791-794.

The concentrations of radioactive aerosols constituting the decay products of emanations are of particular interest in relation to radiation safety. To calculate the decay product concentrations, the concentration of the emanation must be known. This paper attempts to estimate theoretically the content of radon, thoron and actinon in a mining atmosphere under various draught conditions (also without ventilation) and the rate at which the concentration changes when fans are turned on. The following factors are considered: content of emanations in the air of a draughtless (deadend) working area; dynamics of the change taking place in the emanation content when the fans are switched on; relation among the Ra, Th, and Ac concentrations in a mine atmosphere. (Tr) (VC) (BAP)

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Keefer, D.H., and F. Dauer, U.S. Department of Health, Education, and Welfare, Bureau of Radiological Health, Training Manpower Development Program, Washington, DC; University of Miami, Graduate School, Department of Radiology, Miami, FL. 1970, September.

Natural Environmental Radioactivity in South Florida Sands and Soils, February-June 1968. Radiation Data and Reports, 11, 441-448.

An investigation of the naturally occurring gamma-emitting radionuclides present in selected sands and soils of south Florida was conducted. Although the primary interest was in the natural environmental radioactivity from uranium 238, radium 226, thorium 232, and potassium 40, the concentrations of five fission products were also determined to minimize the error in computing the concentrations of the four naturally occurring radionuclides. The determination of these nine radionuclides in 45 environmental samples was performed by the linear least-squares method of analysis utilizing a computer. It was found that the uranium 238 concentration in sands and soils of southern Florida is approximately 0.75 ppm. This level of natural radioactivity is expected because of the higher uranium content of specific limestone formations native to south Florida. (Auth) (PM)

Table 1 shows radionuclide content of southern

MONITORING, MEASUREMENT AND ANALYSIS

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Florida sands and soils. Table 2 shows natural environmental radioactivity in sands and soils of southern Florida.

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Kiefer, H., R. Naushart, R. Ehret, H. Pessier, E. Fiesch, G. Stablein, and W. (Translator) Friese, Karlsruhe Nuclear Research Center, Karlsruhe, German Federal Republic. 1972.

Radiation Protection Measurement. Radiation Protection Measurement. Pergamon Press, Oxford, England: 557 pp.

A comparison is made of present-day knowledge in the methods of radiation protection measurement based on an evaluation of the literature. The main topics covered are dose determination, activity determination, radionuclide determination measurements for the protection of the population, trends in development relating to semiconductor detectors and problems of radiation measurement in space flight. (1,671 references) (PNN)

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Khan, R.A., P. Afzal, P. Chaudhary, S. Rehman, P.I. Nagi, and A. Wahid, Pakistan Institute of Nuclear Science and Technology, Rawalpindi, Pakistan. 1977, August.

Some Characteristic Differences Between the Etch Pits Due to Radon and Thorium Alpha Particles in CA80-15 and LA-115 Cellulose Nitrate Track Detectors. International Journal of Applied Radiation and Isotopes, 28(4), 727-731.

Experiments have been carried out to study the characteristic differences between the etch pits due to radon and thorium alpha particles in CA80-15 and LA-115, cellulose nitrate track detectors. The parameters studied include: (a) the track density, ρ , (b) the average etched track length, l , and (c) the maximum-etched track length, l_{max} . Experiments were also carried out to study the annealing properties of the latent damage trails produced by these two alpha groups. The results seem to be useful in (a) design of radon and thorium dosimeters and (b) exploration of uranium/thorium by using alpha track method. (Auth)

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Kiefer, H., R. Naushart, R. Ehret, H. Pessier, E. Fiesch, G. Stablein, and W. (Translator) Friese, Karlsruhe Nuclear Research Center, Karlsruhe, German Federal Republic. 1972.

Activity Determination. Radiation Protection Measurement, Chapter 3. Pergamon Press, Oxford, England, (pp. 199-320), 557 pp.

Measurement procedures, calibration and accuracy of measurement, measurement of activity in water, air, food and the biological substances with emphasis on sampling and instrumentation, measurement of external contamination of surfaces, clothing and persons and finally measurement of internal contamination with methods of detection of beta radiation, radium 226, uranium, thorium, radium 228, radon 222, and plutonium 239 in man, using whole body or partial body counters are discussed in this chapter. Also given are excretion measurements in relation to techniques for measurement of urine, feces, blood samples, sputum and nasal mucus and respiratory air. (PNN)

Fig. 214 shows excretion of soluble and insoluble uranium from the body. Fig. 215 shows excretion of plutonium after intravenous injection.

<609>

Klecka, J.P., and E.W. Hyde, Lawrence Radiation Laboratory, Berkeley, CA. 1966, October 3.

Quantitative Analysis of Uranium and Thorium Solutions with a Semiconductor Y-Fay Emission Spectrometer. UCRL-17165; 18 pp.

Recent improvements in the energy resolution performance of photon detectors made of Li-drifted Si and Ge semiconductors has made possible the construction of an improved non-dispersive x-ray emission spectrometer. Studies on the feasibility of rapid analysis of U or Th solutions have been carried out using a Si detector and Li x-rays. Measurements were made on U, Th, and mixtures of U and Th in solution. Observed count rates along with L(sub alpha) peaks are tabulated and shown graphically as calibration curves which are linear below 2.6 ug/ml. Analysis of mixed solutions was difficult because of the close energies of the x-rays. The resolution of the detector system was 1.2 keV and the x-rays were separated by approximately 0.6 keV. Possible solutions for this problem are discussed. (VC)

<610>

Kondrat'eva, T.N., Ya.I. Merisov, and E.I. Petrova, State Scientific Research and Project Institute of the Rare Metal Industry, Moscow, USSR. 1975, October.

Spectrometric Determination of Thorium in Technological Solutions of Rare Earth Manufacture. Industrial Laboratory, 3(10), 1859-1861; Zavodskaya Laboratoriya, 41 (10), 1183-1185.

A highly accelerated and sensitive method for spectrophotometric determination of thorium has been developed. The method, which utilizes the arsenazo III technique, analyzes technological solutions of rare earth manufacture having complex chemical composition. The effects of Fe(3), P(-ion) in hydrochloric and nitric acids were studied. Samples of technological solutions of rare earth manufacture were analyzed. Accuracy was controlled by addition of thorium and analysis of various volumes. The sensitivity of analysis was equal to 0.5 lig/l in aqueous solutions and 3 ug/l in tributyl phosphat-. The relative standard deviation of one determination amounted to 0.15-0.20 (n=12) for concentrations exceeding 1.5-3 times the minimum determinable concentrations. (Auth) (VC)

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Kotrappa, P., University of Rochester, School of Dentistry, Rochester, NY. 1977.

Shape Factors for Aerosols of Coal, Uranium Dioxide, and Thorium Dioxide in Respirable Size Range. Assessment of Airborne Particles, T.T. Mercer, T.T. Morrow and S. Stober (Ed.). Charles C. Thomas, Publisher, Springfield, Illinois, (pp. 331-360).

Aerodynamic diameters in the range from 0.3 to 5 um were determined for particles of a low-grade coal, pulverized UO_2 , and ThO_2 , using a recently developed spiral centrifuge aerosol spectrometer. Volume shape factors,

<611>

MONITORING, MEASUREMENT AND ANALYSIS

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dynamic shape factors, ratios of projected area diameter to Stokes' diameter and projected area diameter resistance shape factors were determined and the functional relationships between shape factors and projected area diameter were established. Surface shape factors, averaged over the entire size range, were also determined. The shape factor relating projected area diameter to Stokes' diameter for 802 is shown to be useful in revising calibration curves for respirable mass samples (cyclones) and cascade impactors which were originally calibrated using uranium oxide aerosol. Use of the Hatch and Choate equation for calculating mass median diameters from the mass distribution is examined, as is the procedure of fitting a suitable spheroid model to satisfy the shape factors. (Auth)

<612>

Prishankar, S., and M.S. Sarin, Physical Research Laboratory, Ahmedabad, India. 1976.

The Simultaneous Determination of Thorium, Plutonium, Radium Isotopes, Lead 210, Iron 55, Silicon 32 and Carbon 14 in Marine Suspended Phases. *Analytica Chimica Acta*, 83, 143-156.

An efficient and systematic chemical procedure for the simultaneous measurement of Th, Pu, Ra isotopes, Pb 210, Fe 55, Si 32 and C 14 in the same sample has been developed. This method has been applied successfully to the measurement of these isotopes in oceanic particulate samples collected from several tons of sea water. The procedure should be applicable to analysis of geochemical samples. The description of procedures includes reagents and materials, carriers and tracers, instrumentation, ashing of filters and measurement, separation of isotopes, and radiochemical purification methods. Estimated sensitivities (3000 s - counting period) are tabulated and detection limits given. Average chemical yields for Th and Pb were 70 - 80% and slightly less for plutonium. Recovery of iron was almost quantitative. Concentrations of radioisotopes in surface particulates of the Atlantic Ocean are tabulated. The values in dpm/g ash for Th 232 at 4 locations are less than 0.05, 0.32, 1.64, 0.44; for Th 230: 0.06, 1.1, 1.0, 0.57; for Th 228: 1.4, 36.3, 55.0, 27.2; for Pu 239: 0.7, 7.5, 0.6, 0.08; for Ra 226: 0.25, 16.3, 3.9, 25.6; for 2 Fe 55 samples, less than 1, 4. (Auth) (VC)

<613>

Fu, T., University of Southern California, Department of Geological Sciences, Los Angeles, CA. 1976.

Uranium and Thorium Isotopes: Deep Sea Drilling Project, Leg 23. Initial Reports of the Deep Sea Drilling Project, Vol. 23, (pp. 951-952).

Analysis for U 238, U 234, Th 230 and Th 232 was done on silty calcareous ooze type sediment samples from sites 228 and 229. Measurements were done in order to: delineate sedimentation rates from amounts of excess Th 230; detect from Th 230/U 238 and U 234/U 238 ratios if post-depositional U and Th migration had occurred; assess U and Th concentrations in sediments from a land-locked oceanic basin for comparison with open-ocean pelagic deposits. The consistently low Th/U ratios of the sediments means they represent a redox potential system much lower than open ocean deposits. Their U contents are similar to those of shales and

pelagic clays (2-3 ppm) but Th is lower (5-7 ppm vs 10-12 ppm). Site 229 sediments have abnormally high U, which indicates highly reducing conditions. Sedimentation rate estimation and activity ratios indicate post-depositional migration of U. It is estimated that each square cm of the Red Sea floor receives approximately 2.6 dpm of Th 230/1000 years. The sedimentation rate for Th 230 (sub ex) is calculated to be of the order of 10 cm/yr which is in agreement with radiometric measurements on lutite cores. (VC)

<614>

Kochta, D.B., J. Fend, and D.B. Holtzman, Argonne National Laboratory, Radiological and Environmental Research Division, Argonne, IL. 1976.

Low-Level Determination of Skeletal Radium 228 and Thorium 228 in the Presence of Gross Amounts of Radium 226. CONF-751126: IAEA-SR-202/418: Biological Effects of Low-Level Radiation Pertinent to Protection of Man and his Environment, Proceedings of an International Symposium held in Chicago, Illinois, November 3-7, 1975, (pp. 183-196) (IAEA-SR-202/41, CONF-751126).

A method is described for determining Th 228 (and hence Ra 228 in small samples of human bone when accompanied by very small amounts of Ra 226). Such determinations are needed for the radiation dosimetry of skeletally-deposited radium 30-50 years after intake of mixtures in unknown proportions of the two isotopes of radium. The only preparation of the bone sample is ashing and dissolution in nitric acid. The short-lived radioactive gas, Ra 228 (54.5 seconds), is de-enamated from the solution with nitrogen, which carries it into a 3.8-liter collection chamber. Positively charged ions of Po 216 and Pb 212 produced by the decay of the Ra 228 during its stay in the chamber are collected on a negatively charged electrode in the form of a copper disk, to which is cemented a zinc sulphide phosphor-coated Mylar disk. De-enamiation and ion collection continue for up to 24 hours. The electrode is then removed and presented to a second phosphor disk on the window of a photo-multiplier tube. Alpha particles from the collected radioactivity are thus counted with almost 4 pi geometry, and an initial efficiency is obtained of about 0.3 count per disintegration of Th 228 in the solution. Positively charged ions of Po 218 and Pb 214 from the decay of some Ra 226 in the chamber are also collected. The overall efficiency for this is much lower than for the collection of the daughters of Ra 222 but, because of the much higher activity of the Ra 226, the initial counting rate is primarily due to its daughters. To make maximum use of all the counting data, they are analyzed by a computer method of least squares. In routine use, de-enamiation for 1800 minutes, followed by counting for 1800 minutes, permits the measurement of a few tens of fCi of Th 228. The need for correct weighting of very low counting rates is demonstrated. (Auth)

<615>

Leuchner, A.H., Atomic Energy Board, Pretoria, South Africa. 1977, January.

Uranium Fire Aerosols. *Health Physics*, 32(1), 50.

Uranium metal which can ignite spontaneously in air, produces an aerosol which is

CONTRIBUTING, PRESENTATION AND ANALYSIS

(415) CCNY.

Chemically and radiologically toxic. The uptake of uranium oxide by the respiratory tract is largely determined by the aerosol properties. A study was made of the characteristics of the aerosol which originates when uranium cuttings burn in air. The uranium fire aerosol can be described by a bimodal log-normal or a monomodal log-normal particle size distribution, depending on the way in which the uranium cuttings burn. The activity median-aerodynamic diameter of the two peaks were determined as 0.49 and 6.0 μ m. (Auth)

(416)

Lieberman, R., and A.A. Haghissi, Southeastern Radiological Health Laboratory, Montgomery, AL. 1968.

Co-precipitation Technique for Alpha Spectroscopic Determination of Uranium, Thorium and Plutonium. Health Physics, 15, 359-362.

The co-precipitation technique can be used for analyses of environmental samples including food, vegetation and soil after suitable separation of the actinides. Recoveries of 75-90 percent of uranium, thorium, and plutonium were recorded using anion exchange separation with an average recovery of approximately 80 percent. (RM)

(417)

Lindke, C.L., P.H. Geddes, J.B. Meadows, K.C. Hasty, and L.B. Auspau, Lawrence Livermore Laboratory, Livermore, CA. 1973, April 16.

Environmental Levels of Radioactivity in Livermore Valley Soils. COSP-730603; OCHL-74024; Health Physics Society, Proceedings of the 19th Annual Symposium held in Miami Beach, Florida, June 17-21, 1973, (14 pp.) (COSP-730603, OCHL-74024).

Soil samples collected from areas surrounding the Lawrence Livermore Laboratory in the Livermore Valley were analyzed for Pu 239, Pu 233, Am 241, Sr 90, Cs 137, and naturally occurring gamma emitters as part of a continuing environmental surveillance program. The median Pu 239 activity corresponds to a surface deposition value of 1.1 uCi/km². Activities from Pu 233 and Am 241 were lower than Pu 239 activity by a factor of about 10. Median Sr 90 and Cs 137 deposition values were 13 and 31 uCi/km², respectively. All deposition values appear to be typical of those expected from global fallout in this area. At present, Cs 137 is the principal gamma emitter observed in fallout. The radiation exposure rate at 1 m, calculated from the median Cs 137 soil activity, was about 0.1 uR/hr. Natural terrestrial exposure rates calculated from the K 40, Bi 214, and Pb 212 soil sample activities vary from 3 to 7 uR/hr. These values are in good agreement with measurements made using CaF₂:Dy TLD dosimeters and those obtained with a field-operated Ge(Li) detector. (Auth)

Table 1 shows the comparison of Pu 239 content of soils downwind from LLL with samples from the Livermore Valley. Table 2 shows activity of U 238, Th 232, K 40, Cs 137, Sr 90 and Sb 95 at different stations.

(418)

Lindke, C.L., J.B. White, A.J. Toy, and C.B. Sandbeck, Lawrence Livermore Laboratory,

Livermore, CA. 1975, November 21.

Ambient Environmental Radiation Monitoring at the Lawrence Livermore Laboratory. OCHL-77106; Operational Health Physics, Proceedings of the Health Physics Society 9th Biyear Topical Symposium held in Denver, Colorado, February 9-12, 1976, (6 pp.) (OCHL-77106).

Thermoluminescence dosimetry (TLD) is the principal means of measuring ambient gamma radiation at the Lawrence Livermore Laboratory. These dosimeters are used at 12 perimeter locations and 81 locations in the offsite vicinity of the Laboratory, and are exchanged quarterly. Control dosimeters are stored in a 75-mm-thick lead shield located out-of-doors to duplicate temperature cycling of field dosimeters. Effect of dosimeter response to radiation in the shield is determined each quarter. Calibration irradiations are made midway through the exposure cycle to compensate for signal fading. Terrestrial exposure rates calculated from the activities of naturally occurring uranium, thorium, and potassium in Livermore Valley soils vary from 3 to 7 uR/hr. Local inferred exposure rates from cosmic radiation are approximately 4 uR/hr. TLD measurements are in good agreement with these data. Offsite and site perimeter data are compared, and differences related to Laboratory operations are discussed. (Auth)

(419)

Lomborg, L., and P. Kirkegaard, Danish Atomic Energy Commission, Research Establishment, Riso, Roskilde, Denmark. 1975, February.

Numerical Evaluation of the Natural Gamma Radiation Field at Aerial Survey Heights. NISO-317: 39 pp.

In computational studies of the count rates to be expected in airborne, radiometric surveys of geological formations, knowledge is required of the aerial gamma radiation field produced by the radioactive minerals in the ground. Calculations of the energy and angular distribution of the gamma-ray flux at distances of between 0 and 200 m from a plane, homogeneous ground with known abundances of thorium, uranium, and potassium are given. A tabulation permitting calculation of the gamma dose rate in the air is also given. The data are applicable to any normal ground material (rock or soil) in which uranium and thorium are in secular equilibrium with their respective daughters. In addition, the air density may have an arbitrary variation with the distance to the ground. In calculating the flux of gamma rays that strike an airborne NaI(Tl) detector it is suggested to represent the bottom of the aircraft by an equivalent layer of air. For use in the numerical evaluation of aerial total count rates the angular gamma-ray flux at the point of detection is approximated in accordance with the double-P sub 1 polynomial expansion method. A detailed tabulation of flux expansion coefficients, calculated for 0.05-MeV energy intervals, is presented. To evaluate the differential count rates of high-energy Th-U-K gamma rays, it is convenient to make use of the formulas for a flux of unscattered gamma rays. (Auth) (SAP)

(420)

Harple, R.L., W.L. Clements, and B.A. Perkins, Los Alamos Scientific Laboratory, Health Division, Los Alamos, NM. 1977, July.

Measurements of Radon 222 Flux from Inactive

MONITORING, MEASUREMENT AND ANALYSIS

<620> CONT.

Granite Hill Tailings Piles. LA-6898-PH; Biomedical and Environmental Research Program of the LANS Health Division, January-December 1976, T.P. Petersen and P.N. Sullivan (Comps.), (pp. 73-75) (LA-6898-PH).

The Rn 222 flux from three inactive uranium mill tailings piles near Grants, New Mexico were measured and its attenuation by overburden established for revegetation purposes was evaluated. The Rn flux at the three sites ranged from 65 to 1414 atoms cm²(E-1) under a variety of atmospheric conditions. Soil overburdens of depths of 30 and 40 cm may attenuate the flux by as much as 30%. Thus, unless overburdens are substantially deeper than those in this study, the tailings piles still present a significant local source of Rn 222 to the atmosphere due to their large exhalation compared to background levels. (JAF)

<621>

Rijnbeek, E.J., Commission of the European Communities, Joint Nuclear Research Centre, Geel Establishment, Central Bureau for Nuclear Measurements, Luxembourg, Belgium. 1973, October.

The Performance of a Fission Track Dosimeter for Monitoring the Neutron Radiation from Californium 252 Sources on Hands Inside Glove Boxes. ERM-5041-e; 46 pp.

A description is given of a personnel neutron dosimeter based on fission track registration in a 10 μ m thick Makrofol foil in combination with two thorium discs, for use on the hands of operators during the handling of Cf 252 sources inside glove boxes or during implantation work for therapy purposes. The device contains also a TLD-100 chip for measuring the gamma-dose equivalent on the hand. The angular dependence of the response of the dosimeter with thorium and other fissile materials was measured at different energies. The neutron sensitivity of the dosimeter was determined with a calibrated Cf 252 source and amounts to 14.9 plus or minus 0.7 mrem. (Auth)

<622>

Eyers, W.G., and P.A. White, Department of Nuclear Science, Rensselaer Polytechnic Institute, Troy, NY. 1971.

Mass Spectrometry and Fission Track Analysis in Nuclear Environmental Measurements. Nuclear Methods in Environmental Research, University of Missouri, (pp. 39-41).

With the advent of nuclear power throughout the United States, it is appropriate to monitor those specific environmental contaminants that might arise from this form of energy production. Specifically, it appears that mass spectrometry and fission track techniques can be employed in a complementary fashion for assaying trace quantities of the fissile nuclides, Th, U and Pu. An investigation was made to determine the concentration of uranium in surface air at urban and rural locations within New York State by applying these methods. Average uranium concentrations ranged from 0.10 to 1.47 μ g/m³ (0.035 $\pm$ 0.07 fCi/m³), with each area indicating that a significant correlation exists between the uranium concentration and the density of total suspended particulates. Present levels of uranium in the air environment are attributed primarily to naturally occurring uranium sources and nonnuclear industrial activity.

In the immediate vicinity of a nuclear fuel reprocessing plant, a slight excess of uranium has been detected by observing the degree of U 235 enrichment. The isotopic data obtained via the mass spectrometric analysis points up its potential in such environmental studies. (Auth)

<623>

National Lead Company of Ohio, Health and Safety Division, Cincinnati, OH. 1973, August; 1973, February 16.

Feed Materials Production Center, Environmental Monitoring Annual Report for 1972. NRCO-1998; WASH-1259; Environmental Monitoring at Major U.S. Atomic Energy Commission Contractor Sites, Calendar Year 1972, (pp. 867-987), 1217 pp. (NRCO-1998, WASH-1259).

Environmental monitoring data collected at the Feed Materials Production Center (FMPC) during 1972 are summarized. These data show that the average offsite concentrations of radioactive contaminants from FMPC operations were less than 0.5% of the guide levels published in AEC Manual Chapter 0524. At least once each year, soil samples are collected near the six Boundary Sampling Stations and analyzed for uranium to observe the possible contribution from stack effluents. The average concentrations of uranium, thorium and radium added to the Great Miami river was < 0.001% of the AEC Radiation Protection standards. The average upstream concentrations of radium 226 and radium 228 were 2.8% and 1.4% of the standard for uncontrolled areas. State criteria for gross beta and fissionable alpha radioactivity were not exceeded in the river. The average radionuclide concentrations in air, at the boundary sampling stations, were no greater than 0.4% of their respective standards for offsite areas. It is concluded from these data that any offsite radiation exposure resulting from FMPC airborne contaminants would be a small fraction of the standards. (FMS)

Table 1 shows radioactive contaminants in air. Table 3 shows radioactive contaminants in water. Table 5 shows uranium in soil.

<624>

Nishiwaki, Y., H. Kawai, and H. Morishima, Kyoto University, Research Reactor Institute, Kusatori-cho, Sennan-gun, Osaka-fu, Japan. 1971.

Rapid Method of Confirmation of Fissionable Materials with the Etch-Pit Counting Method. CONF-710735; IAEA-SM-148/48; Rapid Methods for Measurement of Radioactivity in the Environment, Proceedings of an International Symposium held in Neuherberg bei Muenchen, Germany July 5-9, 1971, (pp. 267) (CONF-710705, IAEA-SM-148/48).

Fission fragments leave scars on insulators made of glass, silica and plastic. The scars on the surface of insulator material caused by the fission fragment can be etched by suitable chemical treatment to form etchpits on the surface or etch-holes in the foil. The number of etch-pits may be counted by the ordinary optical microscope and those of etch-holes by the spark counter. This method can be used as a rapid method of estimating the amount of fissionable material. Since the fissionable materials we have tested are alpha emitters, the amount of the alpha-emitting fissionable material may be estimated by measuring alpha rays. However, even if the fraction containing a certain fissionable material is separated by ordinary

SCINTILLATION, MEASUREMENT AND ANALYSIS

<624> CCNT.

Chemical analysis, a number of other interfering non-fissionable alpha, beta and gamma emitters may be included in the fraction. In such cases, the etch-pit or etch-hole counting method may give a more direct and less confusing estimate of fissionable material without interference from contamination by other nonfissionable alpha, beta or gamma emitters. Considering the background, the minimum detectable number of etch-pits or etch-holes may be about $10(2)/\text{cm}^2$. However, the reasonable detectable number of etch-pits or etch-holes per unit area may be estimated at about $10(3)/\text{cm}^2$. Based on these figures, the necessary neutron fluence and the necessary volume of water samples containing maximum permissible concentration of natural Th, natural U or Pu 239 are estimated. (Auth)

materials can be solved given sufficiently accurate, sensitive and specific methods of determination. To measure low amounts of Th in biological materials, the reagent arsenazo III used for determining Th in ores and zircons was utilized. The interaction of Th and arsenazo III is highly sensitive and selective. It forms a green complex with Th; excess reagent produces violet hues. Removal of interfering substance and preparation of samples are detailed. The Th is determined with a photoelectrocolorimeter and comparison with standard solutions. The sensitivity is 0.1 gamma/5 ml and minimum amount of Th which can be assayed is 2 gamma. The error of determination is less than 15%. Determinations of known amounts of Th in muscle, liver, spleen and blood have been done satisfactorily. (VC)

<625> Farr, F.H., 1965, October.

The Radioactivity of Thorotrast and Its In-Vitro Distribution between the Various Physical Phases. CCNP-651069; Dosimetry and Toxicity of Thorotrast, Proceedings of an International Symposium held in Vienna, Austria, October 4-7, 1965, (22 pp.) (CCNP-651069).

Much experimentation is needed before the mechanism of distribution of Th daughter activities among the different physical phases of Thorotrast are understood. Thus, some of the following conclusions are tentative; particularly estimated fractional retentions in the particulate phase are only approximate, and significant differences would not be unexpected. Total IV VITRO Thorotrast activity varies significantly and predictably until 50 years after manufacture. The initial Th 228/Th 232 ratio is important in regard to total activity during the first 7-10 years. The physical phases include particles, solution, container walls and, possibly, particle surfaces. Loss of activity from the particulate phase is probably by high energy recoils or, possibly, in the case of atoms located on particle surfaces by low energy recoil. Both mechanisms are probably strongly influenced by particle size. Approximately 90% of Ra 228 (and Ac 228) activity is outside the particulate phase. Corresponding ratios for Th 228 and daughters increase, reaching a maximum after 10 years. Significant fractions of Ra 224, Ra 220, Po 216, Pb 212 and Tl 208 escape from the particulate phase. Animal experiments suggest that the fractions are about 40-60% for Ra 224 and 35-65% for Ra 220. Variations in distribution of daughter activities in Thorotrast at administration are likely to affect subsequent dosimetry for as long as 10 years. Significant proportions of activities may be bound to the walls of the ampoule. Radium 228 is more strongly absorbed than is Th 228. The principal factors determining absorption are chemical composition of the glass and pH of the solution. (Auth) (VC)

<626> Pavlovskaya, N.A., and T.M. Cherkashina, 1970.

Photometric Determination of Low Amounts of Thorium in Biological Materials. The Toxicology of Radioactive Substances: Thorium 232 and Uranium 238, Vol. 4, A.A. Letavet and E.B. Kurlyandskaya (Eds.). Pergamon Press, New York, New York, (pp. 83-86), 144 pp.

The problem of distribution, accumulation and elimination of thorium in biological

<627>

Piesch, E., Kernforschungszentrum Karlsruhe, Gesellschaft für Kernforschung mbH, Karlsruhe, German Federal Republic. 1976.

Neutron Dosimetry in the Radiation Field of Californium 252 Sources. CCNP-7504102; STI/PUB/418; IAEA-SR-3/5; Some Physical, Dosimetry and Biomedical Aspects of Californium 252, Proceedings of an Educational Seminar on the Uses of Californium 252 in Teaching and Research held in Karlsruhe, Germany, April 14-18, 1975, (pp. 91-122), 274 pp. (STI/PUB/418, IAEA-SR-3/5, CCNP-7504102).

The radiation field of Cf 252 of source in free space is described in terms of kerma, absorbed dose and dose equivalent with respect to dose measurements made for radiation protection purposes. Kerma is defined as the total kinetic energy of directly ionizing particles generated per unit mass of a specified material by the action of indirectly ionizing radiation. The applications of various detectors and the calibration technique are discussed and compared with the ionization chamber method. Results of fluence and dose measurements are presented which were obtained with activation and threshold detectors, and with very sensitive dose-rate meters placed in the radiation field: the source was positioned in free air, behind shielding and in a glove box. The use of track etching detectors and albedo neutron detectors in field and personnel dosimetry, and measurement on Cf 252 sources with low emission rates are also discussed. (Auth)

<628>

Prall, J.B., National Lead Company of Ohio, Technical Division, Cincinnati, OH. 1977, January.

Automated In-Plant Monitoring of Uranyl Nitrate Solutions for Thorium. NLCO-1138; CCNP-770204; Analytical Chemical and Applied Spectroscopy, Proceedings of the 28th Pittsburgh Conference held in Cleveland, Ohio, February 28-March 4, 1977, (19 pp.) (NLCO-1138, CCNP-770204).

An automated continuous flow system has been developed to monitor thorium at four sampling points in uranyl nitrate solution streams of a uranium refinery. The system employs a four channel Technicon AutoAnalyzer II to perform the colorimetric determination in the range of 0 - 100 ug/ml. Arsenazo III in 3M HCl is the chromogenic agent. The absorbance is measured at 660 nm in a 15 mm flowcell. Since uranium is an interference at the concentration present (120 ug/ml), it must be separated from thorium prior to the

MONITORING, MEASUREMENT AND ANALYSIS

<628> CCWT.

colorimetric analysis. Uranium is adsorbed on two Dowex 118 ion exchange resin columns contained in a 4 mm (O.D.) standard wall glass tubing 9 cm in length. Proper acid conditions for adsorption are obtained by injecting the sample stream into 6.7N HCl. The diluted sample stream is 6.0N HCl when introduced into the ion exchange columns. The diluted sample stream is split and a portion is pumped through a prepared ion exchange column. Thorium passes through the column into the Arsenazo III analyzing stream where the analysis is completed. (Auth) (WAF)

<629>

Sangarajan, C., and J.C. Mishra, Atomic Energy Establishment, Health Physics Division, Bombay, India. 1966.

Methods of Fallout Measurements Used in India. CCWT-660341: Radioactivity and Meteorology of Radionuclides, Proceedings of the All India Symposium held in Bombay, India, March 14-18, 1966, (pp. 287-300), (CCWT-660341).

Measurements of environmental radioactivity in India have been made since early 1956. These measurements are useful in estimating the contamination of the environment with the radioactivity released in nuclear tests, in studying atmospheric motions and mixing processes involved, and in obtaining information on types of weapons. Measurements have been made on the radioactivity of ground level air, rainwater and deposited dust, milk and other food stuffs consumed by the population, human bone and surface soil. Ground level air, rainwater and deposited dust have been measured for total beta activity and also for certain long-lived isotopes. Milk is analyzed for Sr 90, Cs 137 and natural activity due to K 40. Bone analyses are confined to Sr 90 measurements. Soil measurements are carried out to estimate the natural activity from uranium, thorium, K 40 and also the fission product activity deposited as a result of nuclear tests. A brief summary of these measurements is given. (LB)

<630>

Lead, J., and J.C. Rottnas, Radium Institute, Mount Vernon Hospital. 1939.

The Tolerance Concentration of Radon in the Atmosphere. British Journal of Radiology, 12(133), 54-60.

Reasons are given for suspecting that radon in the atmosphere may be responsible for leucopenia among radium workers. The radon concentrations measured in air samples taken from several radium laboratories are given. Mice have been kept in very low radon concentrations, and the effects on them are described. It is suggested that 10(R-11) curies/cc may be regarded as a reasonable value for the "tolerance concentration" of radon in the atmosphere. Precautions to minimize the dangers are discussed. (Auth)

<631>

Fitchie, J.C., and J.B. McHenry, U.S. Department of Agriculture, Sedimentation Laboratory, Oxford, MS. 1973.

Determination of Fallout Cesium 137 and Naturally Occurring Gamma-Ray Emitters in Sediments. International Journal of Applied Radiation and Isotopes, 24, 575-578.

Research is being conducted on the movement and redistribution of Cs 137 and the naturally occurring gamma-ray emitting radionuclides, thorium, uranium and potassium, in relation to cultural and erosional processes within water sheds. Methods are described to determine Cs 137 and the naturally occurring gamma-ray emitters in sediments. Selected reservoir and estuary samples (3000-4000 g) are collected, dried and sieved in a number of steps, then put into a Marinelli counting bucket for 4 weeks to allow Th and U to reach equilibrium with their daughter products. The detector is a thallium-activated sodium iodide crystal with matching phototube. Preparation of standards containing Cs 137, Th 232, U 238 and K 40 and reproducibility of measured concentrations is given. The coefficient of variation for Cs 137 is less than 2%, for K 40 less than 3%, for Th 232 less than 4.5% and for U 238 less than 6%. (WAF)

<632>

Rotblat, J., and G. Ward, Medical College of St. Bartholomew's Hospital, London, England. 1958.

Analysis of the Radioactive Content of Tissues by Alpha-Track Autoradiography. Physics in Medicine and Biology, 1, 57-70.

An autoradiographic technique is described based on the measurement of the lengths of tracks of alpha-particles emitted from sections of tissue and recorded in photographic emulsions. The distribution of lengths of these tracks from a section of finite thickness is derived, and it is shown that an analysis of this distribution makes it possible to determine the radioactive content of the tissue. The technique was applied to two practical problems (a) the calculation of tissue dosage from Thorotrast introduced into the body as a radiographical contrast medium, and (b) the measurement of the radon content of the bones of a subject who inhaled radon. In the Thorotrast work the analysis provides a measure of the activity of parent thorium relative to that of its decay products RnTh, etc., the relative content varying according to the age of the Thorotrast and the proportion of soluble products retained in the body. In the radon work the form of the distribution suggested, in addition to radon, the presence of YAP derived from inhaled radon; the resolution was not sufficiently good to measure the relative activities of these elements accurately, but it was possible to give limits for the radon content of the bone. (Auth)

<633>

Sakagishi, S., Japan Atomic Energy Research Institute, Division of Health Physics and Safety, Tokai-mura, Naka-gun, Ibaraki-ken, Japan. 1968, June.

Environmental Survey. JAERI-5017: Activities in the Division of Health Physics and Safety, April 1, 1967-March 31, 1968, (pp. 131-139), 177 pp. (JAERI-5017).

Several technical developments on the analyses of radionuclides in soil were made and applied to the routine monitoring. Relating to the environmental hazard evaluation, wind speed and atmospheric stability were analyzed statistically. Environmental hazard was evaluated for the design of several facilities and the start of operation in the establishment. The analysis of sea current in the coastal area off Tokai,

MONITORING, REPRESENTATION AND ANALYSIS

<632> CCMT.

which was difficult until the preceding year because of insufficient data, was made systematically. (Auth)

Table 2-18 shows the activity of Th 232, U 238, K 40, Pu 239, Sr 90-94, and Cs 137 in soil.

<633>

Founders, D.V., and H.J. Potts, Texas Instruments Incorporated, Dallas, TX. 1976.

Interpretation and Application of High Sensitivity Airborne Gamma-Ray Spectrometer Data. CONF-760316; IAEA-SM-208/45; Exploration of Uranium Ore Deposits, Proceedings of an International Symposium held in Vienna, Austria, March 29-April 2, 1976, (pp. 107-124) (CONF-760316, IAEA-SM-208/45).

Interpretation of high-sensitivity gamma-ray spectrometer reconnaissance data has two major objectives: to define broad uranium provinces in which the rocks and soils are preferentially enriched in uranium; and to evaluate uranium anomalies along the flight lines in order to determine the geological types of deposits that may be found, and to eliminate any false or misleading anomalies. Spectrometer data showing Th, K, U/K, and Th/K that have been statistically corrected for surface geology are examined in conjunction with the geology, topography, and flight logs to identify uranium anomalies which may have been caused by problems in statistical processing; meteorological effects in shielding and on the distribution of radon and its daughters; errors in geological mapping; downstream transport of gamma-ray emitters; and cultural effects. The more significant anomalies are classified according to types of deposits most likely to be found under the local geological conditions. Experience has shown that aeromagnetic data interpretation and geomorphic lineament studies using satellite imagery can be useful in the gamma-ray data interpretation by providing information on basement structure. (Auth)

<635>

Schüttelkopf, H., Gesellschaft für Kernforschung mbH, Abteilung Strahlenschutz und Sicherheit, Karlsruhe, German Federal Republic. 1971.

Determination of Plutonium in Environmental Surveillance Samples. CONF-710705; IAEA-SM-149/61; Rapid Methods for Measurement of Radioactivity in the Environment, Proceedings of an International Symposium held in Neuberberg bei München, Germany, July 5-9, 1971, (pp. 182-197) (CONF-710705, IAEA-SM-149/61).

Because of the large number of samples to be investigated for Pu 239 within the environmental surveillance program, a new analytical procedure was developed. It offers a considerable saving in time. About 5 1/2 h are needed for the working operation from the disintegration solution to the processed sample. Eight to ten analyses can be performed by the operator daily. The analytical procedure consists in the separation of plutonium by co-precipitation with lanthanumfluoride and subsequent extraction by TTA/benzene solution. The reduction of PuO₂(+2) to Pu(+3) by the weak reduction reagent hydroxylamine was substituted by a reduction with Ti(+3). The time requirement of 3-15 h was thus reduced to minutes for the reduction step. The subsequent precipitation by lanthanumfluoride

and the extraction by TTA/benzene were optimized; each single step has important decontamination functions, high yields and can be performed rapidly. The subsequent reextraction yields a nitric acid solution, which, after boiling down, can be used for the gross alpha measurement of Pu 239. So as not to dispense with the advantages of alpha spectrometry, a procedure for the electrolytic deposition and isolation of Pu 239 on special steel planchets was developed. For the purpose of purification, the Pu 239 solution is passed through an anion exchanger before electrolysis. The volumes of the washings and of the eluate were optimized. The electrolytic deposition proceeds quantitatively. The addition of Pu 236 to the samples enables reference analyses to be dispensed with. A considerable improvement in the mean error of the single results was achieved. The analytical procedure described gives a yield of about 80 percent, if all single steps for the samples mentioned are optimized. Interferences by the high potassium content of plant ashes and by the fairly considerable manganese content of air needles were removed. The purification of the lanthanum carrier and the preparation and purification of Pu 236 are described. The decontamination factors for polonium, radon, thorium and americium are reported. After a corresponding disintegration, the procedure can be applied to all environmental surveillance samples (vegetation, soil, plankton samples, evaporated precipitates, dust filters). (Auth)

<636>

Scott, F.M., and C.H. West, 1968.

Health Physics Application of IN VIVO Gamma Spectrometry in a Uranium Processing Plant. CONF-670521; Diagnosis and Treatment of Deposited Radionuclides, H.A. Kornberg and W.D. Norwood (Eds.), Proceedings of a Symposium held in Richmond, Washington, May 15-17, 1967, (pp. 543-552) (CONF-670521).

In vivo spectrometry has been used routinely for the past six and a half years in the health physics monitoring of uranium processing workers. The major problems associated with the technique are: (1) effects of surface contamination, (2) relative insensitiveness of the methods, and (3) the difficulty of predicting the base spectrum in the uranium region. The solutions to the problems at Oak Ridge's 12 plant have been to: (a) use the back detector data when contamination is indicated, (b) increase the number of detectors, and (c) derive a prediction equation and count a control population to assure continued reliability of the equation. Experience has shown that urinalysis will not point out all exposure cases and that generally once a person has been removed from uranium exposure, the urine level will return to acceptable levels long before in vivo measurements do. Consequently, it has been concluded that in vivo spectrometry is superior to urinalysis as a monitor for insoluble uranium. However, for soluble uranium and areas of low exposure potential, urinalysis is of real value. (Auth)

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Sedlet, J., H.W. Golchert, and T.L. Duffy, Argonne National Laboratory, Occupational Health and Safety Division, Argonne, IL. 1973, August; 1973, March.

Environmental Monitoring at Argonne National

<617>

MONITORING, MEASUREMENT AND ANALYSIS

<617> CCST.

Laboratory, Annual Report for 1972. ARL-8007; HASR-1259; Environmental Monitoring at Major U.S. Atomic Energy Commission Contractor Sites, Calendar Year 1972, (pp. 331-400), 1217 pp. (ARL-8007, HASR-1259).

The environmental monitoring program at Argonne National Laboratory for 1972 is described and the results are presented. To evaluate the effect of Argonne operations on the environment, measurements were made for a variety of radionuclides in air, surface water, soil, grass, benthos, and silt; for a variety of chemical constituents in surface and Argonne effluent water; and for the environmental penetrating radiation dose. Sample collections and measurements were made both on and off the Argonne site for comparison purposes. Air sampling for Po was conducted on the Argonne site beginning in March. The Po 239 and Po 238 concentrations in monthly samples varied from 1 to 45 x 10(E-10) uCi, well within the range reported by the AEC Health and Safety Laboratory for fallout Po in air samples collected away from nuclear installations. The average concentration was 27 x 10(E-10) uCi/ml for Po 239 and 2.2 x 10(E-10) uCi/ml for Po 238. Po concentrations in soil showed the same general range and average concentrations on and off the site. The average Po 239 concentration was 1.83 plus or minus 0.24 10(E-3) uCi/m² and 1.63 plus or minus 0.29 x 10(E-3) uCi/m² offsite. The Po 239 content of grass was similar both on and off the site and ranged from 0.17 to 0.67 x 10(E-6) uCi/m², a factor of two thousand to five thousand lower than in soil from the same location. The results of the program are interpreted in terms of the sources and origin of the radioactive and chemical substances (natural, fallout, Argonne, and other) and are compared with accepted environmental quality standards. (Auth)(PNN)

Table 8 shows Pu, Th and U concentrations in air-filter samples on the Argonne National Laboratory site, 1972. Table 15 shows Pu concentrations in onsite soil, 1972. Table 16 shows Pu concentration in offsite soil, 1972. Table 17 shows Po 239 concentrations in grass, 1972. Table 18 shows Pu concentrations in benthic material. Tables 12, 13 and 14 show radioactivity in Sawmill Creek water, Des Moines River water, and Illinois River water, 1972.

<639>

Sellet, J., and P.S. Ivami, Argonne National Laboratory, Argonne, IL. 1965, January.

Environmental Radioactivity at Argonne National Laboratory Report for 1962 and 1963. ARL-6945; 62 pp.

This report presents the results of the environmental monitoring program at Argonne National Laboratory during 1962 and 1963. The purposes of the program are to measure the natural radioactive content of the ARL site and its surroundings, and to determine the origin, identity, and magnitude of any radioactivity not naturally present. Of primary interest is the detection of radioactive materials released to the environment as a result of Argonne operations. (Auth)

<639>

Shreve, J.C., Jr., and J.E. Cleveland, Kerr-McCoy Corporation, Oklahoma City, OK. 1972.

Effects of Depressing Attachment Ratio of Radon Daughters in Uranium Mine Atmosphere. American Industrial Hygiene Association Journal, 33(5), 304-314.

The diffusion coefficient of particles 5 to 6 A in diameter-primary radon daughters, for instance-is roughly 100 times that for condensation nuclei (200 to 1000 A in diameter) to which radon daughters normally attach. This difference should manifest itself as a measurable increase in daughter deposition on uranium mine walls were condensation nuclei previously removed by air filtration. This report is an account of experiments done to quantify the degree to which this simple air treatment might make a mine atmosphere self-cleaning of radon daughters. Experimental results indicate that airborne Pa can be kept to less than 50% and RaC taken to less than 30% of concentrations they would grow to otherwise. Practical applications are not immediately obvious. However, in time and with engineering ingenuity the power of the filtration technique may be brought to bear on secondary ventilation problems. (Auth)

<643>

Sill, C.W., Health Services Laboratory, Idaho Falls, ID. 1969.

Separation and Radiochemical Determination of Uranium and the Transuranic Elements Using Barium Sulfate. Health Physics, 17, 99-107.

By a proper sequence of oxidation-reduction reactions, ions of uranium, neptunium, plutonium, americium, curium, and californium can be coprecipitated with barium sulfate, either together or individually. Recovery of 99 percent or better can be achieved. The sulfate precipitate may be counted directly for alpha activity with a loss of about 6 percent in efficiency. The total amount of ions carried should not exceed 0.3 mg. The procedure is not applicable to samples containing large amounts of lanthanides, bismuth, zirconium, or calcium. (JCL)

This is a long, complex procedure, not suitable for glovebox use. (JHC)

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Sill, C.W., U.S. Energy Research and Development Administration, Health Services Laboratory, Idaho Falls, ID. 1977, November.

Simultaneous Determination of Uranium 238, Uranium 235, Thorium 230, Radium 226, and Lead 210 in Uranium Ores, Dusts, and Mill Tailings. Health Physics, 33, 393-404.

A procedure is described for determining the five most important radionuclides of the U 238 series in the same sample. This procedure helps eliminate apparent changes in isotopic composition caused by sample inhomogeneity and to maximize sensitivity and precision on air dusts when only small samples are available. The sample is decomposed with hydrofluoric acid and pyrosulfate fusion to guarantee complete conversion of refractory compounds to the ionic state before chemical separation. Thorium and radium are separated from the hydrochloric acid solution of the pyrosulfate cake by precipitation on barium sulfate. Thorium is then extracted into bis(2-ethylhexyl)phosphoric acid, electrodeposited, and analyzed by alpha spectrometry. Radium is determined by the emanation procedure. Lead and bismuth are

"SITTING, MEASUREMENT AND ANALYSIS

<641> CCYT.

extracted into diethyldithiocarbamate from the filtrate of the barium sulfate separation, and Pb 210 is determined by beta counting its Bi 210 daughter. Uranium is extracted into Aliquat-336, after prior concentration on barium sulfate when the quantity of uranium present is small, electrodeposited, and analyzed by alpha spectrometry. Isotopic tracers for thorium and uranium are used and chemical yields for all four elements are higher than 85 %. On the ores and tests analyzed, uranium was generally depleted in ^{234}Th by as much as 15-20 % compared to the ^{238}U parent, although one sample was depleted by 50 %. Thorium 230 varied from slight depletion to substantial enrichment up to 75 %. Radium 226 varied from such lower to such higher than its ^{230}Th precursor, depending on the particular ore. Lead 210 was depleted significantly compared to its ^{226}Ra precursor in every case except a single pitchblende standard known to be in equilibrium. No great differences in the isotopic composition were observed either among ores and dusts from the same mill or as a function of particle size. (Auth)

<642>

Snyder, W.S., Oak Ridge National Laboratory, Health Physics Division, Oak Ridge, TN. 1968.

Revision of the ICRP and ICRP Recommendations on Internal Dose. ICRP-4060 (1st Ed.); Research and Development in Progress, Biology and Medicine, (pp. 287), 323 pp. (IIC-4060, 1st Ed.).

The metabolic models for estimating maximum permissible concentration (MPC) values and permissible body burden values as given in the reports of the ICRP and ICRP Committees on internal dose are being systematically reviewed and updated. The revision uses the data and models for lung, gastrointestinal tract, and standard man as recommended by the ICRP Task Groups on (1) lung dynamics, P.E. Morrow, chairman, (2) physiology of the gastrointestinal tract, I.S. Eise, and (3) standard man, W.S. Snyder, chairman. Also more explicit attention is being given to the chemical forms in which the radionuclide might occur, and data on excretion which would be useful for the interpretation of bioassay data are being included. To date, preliminary formats based on the new concepts for isotopes of H, C, Sr, I, Ba, Th, and Pu have been reviewed by the Committees, and the changes they suggested are presently being incorporated into revised drafts for further consideration. (Auth)

<643>

Staatliche Zentrale fuer Strahlenschutz, Berlin, German Democratic Republic. 1973, March.

German-Soviet Working Meeting on the Question of Radiation Protection held in Berlin, Germany, June 8-9, 1972. 525-148; 146 pp.

Seventeen papers were presented at the conference and four have been abstracted separately for the Data Base. The topics discussed include the metabolism of Pu 147 and Pu 237 in animals, effects of DTPA on excretion of Pu 239, determination of deoxyribosides in urine and blood of rat and man and metabolism of coffee isotopes in man. Several papers dealt with monitoring such as monitoring radioactive aerosols in working areas, environmental monitoring, including contamination of rivers with long lived natural radionuclides, detectors for

monitoring in radiation protection and biomedical examinations, determination of ^{232}Th and ^{235}U in dusts and ores, models for evaluation of internal exposure, monitoring radionuclides emitting low energy radiation (such as ^3H , ^6Li , ^7Li , ^{239}Pu and ^{241}Am) and detection of low energy photon emitters. Also discussed were chromosome analysis after radiotherapy of tumor patients and geohydrological requirements for storage of radioactive wastes. (PWR)

<644>

Stahlhofen, W., and A. Kaul, Max Planck Institute for Biophysics, Frankfurt, German Federal Republic. 1968.

Measurement of Radium 226, Thorium 232 and Daughter Products in Biological Samples. COSP-104: Radiological Health and Safety in Nuclear Materials Mining and Milling, Vol. 2, Proceedings of a Symposium held in Vienna, Austria, August, 1963, (pp. 475-487) (COSP-104).

A detailed description of the mixing method for measuring low-level alpha activities is given. The samples to be measured and the scintillator $2\text{NaS}(\text{Ag})$ are mixed in calculated proportions. The efficiency of the method depends on the mixing proportion between zinc sulfide and ash and the sample thickness, on the particle size of zinc sulfide and ash, on the luminescence coefficient of the mixture, and on the chemical composition of the sample. The lower limit of detection depends on the contamination of the scintillator, the multiplier noise, and the stability of the electronic equipment. The ^{232}Th content of tissue samples of Thorotrast patients was determined by this method. By measuring the total alpha activity it was possible to estimate the ^{232}Th content of the samples. The ^{226}Ra content was determined by the emanation method. In addition, all samples was measured alpha-spectrometrically for ^{228}Th and ^{228}Ac . Comparison of results agree within the limits of both methods. For ^{226}Ra measurements of the amount of incorporated ^{226}Ra an alpha scintillation counter was developed for measuring the exhaled radon by electrostatic separation of the ^{222}Rn -daughters on a zinc sulfide layer. (RAF)

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Stuckless, J.S., H.T. Millard, Jr., C.V. Fuaker, I.T. Khono, J.N. Fosholt, C.A. Bush, C. Huffman, Jr., and R.L. Keil, Natural Resources Laboratory, Inc., Gestabs Division, Golden, CO. 1977, January.

A Comparison of Some Analytical Techniques for Determining Uranium, Thorium, and Potassium in Granitic Rocks. Journal of Research of the U.S. Geological Survey, 5(1), 83-91.

Geochemical exploration for uranium requires accurate and precise determinations of low-level concentrations. We have used seven different techniques and four different treatments of the fluorometric method to analyze for uranium in granitic rocks. In addition we have used four analytical techniques for thorium and three analytical techniques for potassium, two elements that are commonly present in anomalous amounts within uranium provinces. Our results show that commonly used techniques for thorium and potassium determinations are both adequately precise and accurate, but that many techniques used for uranium determinations lack the necessary precision or accuracy for complete geochemical prospecting. We suggest

MONITORING, MEASUREMENT AND ANALYSIS

<485> CCNY.

that a combination of delayed-neutron determinations for uranium and gamma-ray spectrometric analyses for radium equivalent uranium, thorium, and potassium provides the best data base for geochemical exploration for uranium. If more detailed interpretations are desired, the combination of gamma-ray spectrometry and alpha-spectrometry may be best. Carefully done electrostatic analyses should be adequate for water, ore, mineralized rock, and other applications where high precision and accuracy are not required. (Auth)

<486>

Trumbo, B.J., U.S. Geological Survey, Denver, CO. 1972.

Uranium-Series Systematics in Natural Materials from the Newport Area, Oregon. U.S. Geological Survey Professional Paper, 800-C, (pp. 199-201).

Analyses of uranium, thorium, and protactinium isotopes in recent and fossil wood and kelp samples from the Newport area, Oregon, indicate that migration of these radioelements has been extensive. Thus, this type of material at this location is unsuitable for uranium-series dating. The analytical data from a shell sample from the same area showed evidence of recent uranium assimilation, which contributed to a serious age estimate only. (Auth)

<487>

U.S. Department of Health, Education, and Welfare, Washington, DC. 1963, May.

Radiological Health Data and Reports Station. Radiological Health Data and Reports, 4(5), 225-278.

Data are presented on the radioactivity in samples by airborne particulates, precipitation, and surface waters collected throughout the U.S. and other locations during 1962 and 1963. Data are included on the content of Sr 89, Sr 90, and I 131 in milk samples from various locations, the environmental levels of radioactivity at Argonne National Laboratory and the Portsmouth Area Gaseous Diffusion Plant during 1962, and the Shippingport Atomic Power Station during the second half of 1961 and the first half of 1962. Results are reported from a survey of radioactivity emitted by luminous dial watches. Only one nuclear detonation was announced during April 1963. Characteristics of the detonation are summarized. (Auth)

<488>

U.S. Department of Health, Education, and Welfare, Washington, DC. 1964, August.

Radiological Health Data and Reports. Radiological Health Data and Reports, 5(8), 351-409.

Data are presented on the radioactivity from fallout in samples of air, precipitation, milk, foods, and surface waters collected during April 1964 at various locations throughout North and South America. Environmental levels of radioactivity during the calendar year 1963 are reported for Argonne National Laboratory and the Savannah River Plant and from October, 1962 to March 1964 for the Nevada Test Site. Data are presented on Sr 90 in surface waters of the United States during 1959-1963, on

radioisotopes detected in the Columbia River during January 1962-July 1963, and on cross-check analyses of radioisotopes in milk. Two low-yield underground nuclear tests at the Nevada Test Site during July 1964 were announced by the Atomic Energy Commission. (Auth)

<489>

U.S. Environmental Protection Agency, Colorado River Basin Water Quality Control Project. 1972, March.

Radioactivity in Surface Waters of the Colorado River Basin, Radium Monitoring Network, 1968. Radiation Data and Reports, 13(3), 184-187.

Sampling stations located throughout the Colorado River Basin provide a continuous assay of basin river water radioactivity that results primarily from uranium milling and milling industry waste discharge. Radium 226 concentrations measured in 1968 at all of the twenty stations except one, averaged well below maximum concentrations. Lead 210, Po 210, and thorium concentrations were detectable but were not of significance as health hazards. Higher concentrations were generally observed below the uranium mill at Grand, Colorado than at other stations. Gross alpha and gross beta radioactivity concentrations also were generally higher there. (PHE)

<490>

U.S. Environmental Protection Agency, Office of Water Programs, Pollution Source Control Program, Division of Applied Technology, Engineering and Sciences Branch, Cincinnati, OH. 1972, April.

Radioactivity Levels in Selected Ohio Streams, the Great Miami River, the Little Miami River, and Mill Creek, June-August 1968. Radiation Data and Reports, 13(4), 189-194.

A water quality study of the Little Miami River, Great Miami River, and Mill Creek was conducted by the Office of Water Programs, U.S. Environmental Protection Agency. Analyses were performed for uranium, radium 226, lead 210, thorium and strontium 90. Uranium concentrations in the Little Miami River, Great Miami River, and Mill Creek averaged 0.4, 0.9, and 0.3 ug/liter, respectively. Radium 226 concentrations averaged 0.08, 0.11, and 0.04 uCi/liter, respectively. Strontium 90 concentrations averaged 0.7, 0.4, and 1.1 pCi/liter, respectively. The average thorium concentration was less than 3 ug/liter in all three streams. Lead 210 averaged less than 0.2 pCi/liter in the Little and Great Miami Rivers and 0.7 pCi/liter in Mill Creek. The concentrations of all the natural radioisotopes measured were well below the concentration limits for drinking water. The use of the Great Miami River for the ultimate disposal of liquid radioactive wastes from two nuclear installations has not produced any changes in water quality which are of public health significance. (Auth) (EAP)

<491>

U.S. Environmental Protection Agency, Region 8, Technical Investigation Branch and Surveillance and Analysis Division, Denver, CO. 1973, July.

Radium 226, Uranium and Other Radiological Data from Water Quality Surveillance Stations Located in the Colorado River Basin of Colorado, Utah, New Mexico and Arizona - January, 1961 through

MONITORING, MEASUREMENT AND ANALYSIS

<651> CCST.

June, 1972. EPA/TIR-26: 226 pp.

The Radiological Monitoring Network has collected Ra 226 and total α (both as dissolved solids) data along with less frequent measurements of Pb 210, Po 210, Th, Sr, total alpha and total beta activities from surface waters of the Colorado River Basin. This report presents all of the available data supplied by the RNN System to date. Certain of these data are also examined in terms of their long- and short-term trends. In excess of 3000 measurements of Ra 226 and α in the dissolved state are presented as are many measurements of other radioactivity parameters. The report concentrates on total α and Ra 226 data for surface waters and compares the mean background concentration of 0.00 pCi Ra 226/l and 2.1 ug α tot/l with concentrations downstream of uranium mills and uranium tailings piles, which have been as high as 26 pCi Ra 226/l and 260 α tot/l. Due in part to a decrease in the number of uranium mills and in part to an improvement in the caretaking of uranium tailings piles, concentrations of Ra 226 and α tot have generally decreased throughout the basin with the notable exceptions within the Dolores-San Miguel Rivers System. Statistical analysis of radium 226 concentrations in the Dolores-San Miguel Rivers System clearly show the water quality degradation caused by uranium extraction activities. This straight forward statistical analysis also serves as a basis for evaluating the radium content of other river systems. The RNN sampling and analysis system has operated for about ten years and despite recent reductions in stations, sampling frequencies, and radioassay capability, continues to provide the essential element of water quality analyses—long-term measurements of ambient and "contaminated" conditions. (RNP)

<652>

Union Carbide Corporation, Paducah, KY. 1972.

Paducah Plant, July-December 1970. Radiation Data and Reports, 13(4), 238-240.

The Paducah Gaseous Diffusion Plant processes large quantities of relatively pure uranium compounds. Environmental concentrations of radioactive materials in air and water and gamma radiation levels in the plant vicinity are summarized. The average α concentration in air at the perimeter fence was 1% of the AEC standards for people residing in the vicinity of a controlled area. The average air concentration at the 1-mile stations was 0.5% of the AEC standard. The concentrations of gross beta radioactivity was 0.005 and 0.02% of the AEC standard at the 1-mile stations, respectively. Analysis of nine grab samples taken at the mouth of creeks averaged 0.01% of the AEC standard. Uranium in the Ohio River was not significantly above the detection limit. Beta activity in the drainage streams was less than 0.5% of the AEC standard in Big Bayou, less than 5% in Little Bayou, and averaged below the detection limit at the mouths of the creeks and in the Ohio River samples. External gamma radiation in the vicinity of the plant averaged 0.02 mR/h at all sampling stations except for the east plant perimeter which had an average of 0.03 mR/h. (RNP)

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Bry, W.D., Massachusetts Institute of Technology, Cambridge, MA. 1936, January.

Determination of the Thorium Content of Rocks. Journal of Chemical Physics, 6, 38-40.

A new method for the determination of thorium in quantities of the order of 10 (E-5) to 10 (E-6)g is employed to complete the data necessary for the calculation of the age of geological material. The alpha-particle activity of thorium in a streaming gas is measured with a counter, a procedure which is shown to be superior to the usual ionization measurements on the thoron deposit. Simultaneously, the Pa/Pa ratio in common rocks can be determined. (Auth)

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Vitez, B., Not given. 1976, January.

Trace Elements in Flue Gases and Air Quality Criteria. Power Engineering, 80, 56-60.

Over 60 elements in trace quantities are found in coal and fuel oil. Two-thirds of them already have been found as airborne trace pollutants in rural as well as industrial areas. Over a number of years, regulators set emission standards for some or all of the trace elements, but at present energy system designers are faced with unknown future abatement requirements. A method is presented in this article by which the relative environmental impacts of trace element pollutants may be estimated quite rapidly. Thorium appears in one table showing the makeup of particulate air pollution over metropolitan land use areas of New England showing element concentration and relative potential for having harmful effects; the mean thorium concentration is 0.8 ug/cu m and it is not even included in the toxicity order column. (Auth) (VC)

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Malton, R.B., R.H. Augustson, L.V. East, A.E. Evans, J.E. Foley, S.A. Forster, G.P. Keppin, J.J. Kusanffy, R.O. Menlove, J.S. Menzel, J.L. Parker, T.D. Peilly, D.B. Smith, W.N. Thorpe, and C.W. Weisbin, Los Alamos Scientific Laboratory, Los Alamos, NM. 1971.

Nondestructive Analytical Techniques for Materials in the Nuclear Fuel Cycle. LA-DC-12801; 25 pp.

Nuclear nondestructive assay (NDA) techniques have been shown to be especially valuable in the nuclear fuel cycle for scrap and waste materials. The three most useful methods are active neutron assay, passive gamma-ray assay, and passive neutron assay. The details of these methods which are used for analysis of the various isotopes of thorium, uranium, and plutonium are described. The limits of detection are given for plutonium scrap and waste, uranium scrap, feed materials, fuel rod assay, small sample assay, and process line survey. Two tables are given, comparing NDA values with traditional chemical analyses on a number of samples. (JNC)

<656>

Welford, G.A., D.C. Sutton, P.S. Morse, and S. Tarras, Health and Safety Laboratory, New York, NY. 1958, December.

Determination of Thorium in Urine. American Industrial Hygiene Association Journal, 19, 464-468.

There is some evidence that Th content of

<656>

MONITORING, MEASUREMENT AND ANALYSIS

<656> CCNY.

urine is not a reasonable estimate of exposure level, although it is used to indicate that exposure has occurred. A method for isolation and determination of Th is described. The quadrivalent Th is absorbed by a cation exchange resin and is not eluted by HCl. Oxalate precipitation prior to ion exchange reduces concentrations of SO₄ and PO₄ ions. Details about apparatus, reagents, and resin preparation are given. The solution containing Th isolated from wet ashed samples is transferred to the Dowex 50 1-8 column and eluted with 92% HCl. The eluent was then prepared and treated by one of three determinative procedures; transmission was read in a Beckman DU spectrophotometer at 510 millimicrons for the chrome azurol S procedure, 545 millimicrons for the thorin procedure and 410 millimicrons for the morin procedure. Detection of microgram quantities of Th in order of decreasing sensitivity, was: morin, chrome azurol S, and thorin. The percents Th determined for added amounts of 1, 3, 5, and 10 micrograms were generally greater than 90%. The percents for all levels added were: chrome azurol S, 95.9, thorin, 98.6; morin, 94.2. (VC)

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Seltz, C.G., Jr., and H.W. Tiernan, U.S. Atomic Energy Commission, Division of Operational Safety, Washington, DC. 1974, October.

Assessment of Public Radiation Exposure in the Vicinity of U.S. Atomic Energy Commission Sites. *CCNY-741218: Population Exposures*, J.C. Bert, et al (Eds.), Proceedings of the 8th Biyear Topical Symposium of the Health Physics Society held in Knoxville, Tennessee, October, 21-24, 1974, (pp. 421-426), 434 pp. (CCNY-741218).

There are 27 major AEC sites in the United States which handle or process radioactive materials in quantities to warrant the maintenance of a routine environmental monitoring and reporting program. In 1972 as part of this routine program, these sites made an annual assessment of the radiation dose to the public which could have resulted from operations conducted at the site. Actual measurements of radioactivity in the pathways of exposure close to man are used whenever possible, although for certain nuclides, like noble gases, estimates of dose are normally made using effluent and meteorological data, and appropriate dispersion equations. Estimates include (1) site boundary dose rates, (2) population dose, and (3) the whole-body 30 kilometer man-rem population dose. In 1973 estimated whole-body dose rates near the boundary of AEC sites ranged from less than 1 to about 30 mrem per year, or from less than 1 to about 6 percent of the radiation protection standard for an individual. The doses are dependent on the types of operations conducted at the particular site and often on the size of the site itself. The 30 kilometer man-rem estimates for all AEC sites ranged from less than 1 to about 195 man-rem per year, the

maximen for primarily to tritium. (Auth)

Table 5 shows estimated maximum dose from Pu to individuals in the population near AEC sites. Table 6 shows estimated maximum dose from J and Th to individuals in the population near AEC sites, critical organs are also shown. Table 7 shows estimated maximum dose from tritium to individuals in the population near AEC sites, including the Nevada Test Site.

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Whitnack, G.C., Naval Weapons Center, China Lake, CA. 1975, April.

Single-Sweep Polarographic Techniques Useful in Micropollution Studies of Ground and Surface Waters. *Analytical Chemistry*, 47(4), 619-621.

Single-sweep polarography offers many advantages to the chemist who is faced with the control and analysis of water quality today. Advantages include the following: a technique that can characterize soluble species; a highly sensitive (parts-per-billion) method suitable for field operation, automation, and continuous monitoring; and direct analyses, with preconcentration or separation of the micropollutant from the water sample many times unnecessary, and matrix problems of interference minimized. Single-sweep polarographic procedures have been developed in these laboratories that have proved useful in detecting and analyzing a number of micropollutants of river water, well and spring water, tap water, sea water, and effluent waters from many sources. *Potential methods of analysis are discussed* for chromium (Cr III and Cr VI), arsenic (As III and As V) and iodine (I and IO₃) soluble ionic species. Some uranium, selenium, lead, cadmium, tellurium, thallium, manganese, copper, nickel, and zinc ionic species were also studied and techniques are presented for their analysis. Techniques for the single-sweep polarographic analysis of traces of explosives and plasticizers in water, such as nitroglycerine, 1,2-propylene glycol dinitrate, 2,4,6-trinitrotoluene (TNT), 1,1,5-trinitro-1,3,5-hexamethyltriazine (RDX), diethyl phthalate, and dibutyl sebacate are also presented and discussed. (Auth)

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Zhuikov, B.I., 1971, January.

Photometric Determination of Thorium in Soils. *Soviet Soil Science*, 1(1), 126.

A photometric method of determining thorium in soils with arsenazo III after decomposition of the sample by sintering with sodium peroxide and precipitation on calcium oxalate is described. The sensitivity of this method is 0.04 µg/ml, permitting determination of 1 x 10⁻⁶ g/g of soil. The analysis does not require platinum ware and fluoric acid. (Auth)

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Fein, Y., S.S. Cline, and J. Kastner, Argonne National Laboratory, Radiological Physics Division, Argonne, IL. 1969, May 15.

Production Rates of Neutrons in Soils Due to Natural Radioactivity. Journal of Geophysical Research, 73(10), 3131-3142.

The relative neutron yield of several targets of light elements exposed to monoenergetic incident helium beams from the Argonne tandem accelerator was determined for alpha energies ranging from 4.8 to 8.8 MeV. Our ratio of the neutron yields for 5.3 MeV are in agreement with published data on thick target yields obtained with Po 210 alpha particles. The average (alpha, neutron) yield per alpha particle of the natural radioactive series for some elements and for different soil compositions was calculated from our results assuming an (alpha, neutron) yield of 75 neutrons per 10^{10} alpha particles of Po 210 alpha for aluminum. If 3 cps J 238 and 11 cps Th 232 are assumed as representative of the earth's upper crust, a production rate of approximately 6.7 neutrons/g/yr in sand and approximately 13.5 neutrons/g/yr in granite is obtained. Additional 1.4 neutrons/g/yr will be generated because of the spontaneous fission of U 238. As the production rate of neutrons through interactions of cosmic rays with the earth's surface at sea level is of the order of 400 neutrons/g/yr, these (alpha, neutron) reactions cannot be of any significance to exposure rates of human populations. They may be of some interest to geologists, however, and may be the main contributors to neutron fluxes in tunnels, deep caves, or mines, where cosmic-ray background is very low. (Auth)

<661>

Kigoshi, K., Gakushuin University, Department of Chemistry, Meiji, Tokyo, Japan. 1971, July 2.

Alpha-Recoil Thorium 234: Dissolution Into Water and the Uranium 234/Uranium 238 Disequilibrium in Nature. Science, 173(3991), 47-48.

A radioactive disequilibrium state between U 238 and Th 234 has been observed in natural waters. The probability of dissolution of Th 234 atoms produced by the alpha decay of U 238 located near the surface of solid silicate particles contributing to the disequilibrium state was investigated. The amount of Th 234 in the aqueous phase of a system consisting of fine zircon powder and diluted nitric acid or sodium carbonate solution was observed to increase with time. The rate of ejection of alpha-recoil Th 234 into solution gave an alpha-recoil range of 550 angstroms. Ejected alpha-recoil Th 234 atoms may supply excess U 238 in groundwater and contribute to the supply of U 238 in the sedimentary column of pelagic sediments. (ST)

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Kovarik, A.P., and H.I. Adams, Jr., Yale University, Sloane Physics Laboratory, New Haven, CT. 1938, September 15.

The Disintegration Constant of Thorium and the Branching Ratios of Thorium C. Physical Review, 54, 413-421.

In age determinations of minerals in which thorium predominates, some inconsistencies have appeared when the value used for the disintegration constant of thorium is that adopted by the International Radium-Standards Commission (1930). This value differs from the original Geiger-Rutherford value by 30 percent. The present research was undertaken to determine the disintegration constant of thorium by the method of counting alpha-particles. Easily weighed sources were used. The material was obtained from a thorite from the same lot that was used by Geiger and Rutherford. The thorite contained only a small amount of uranium and correction for the ionium present was made. Various checks on the counting are given. The half-value period of thorium was found to be $1.39 \times 10^{10} (\pm 10)$ years and the branching ratio, thorium C' to thorium (C + C'), is 0.663. A method of impounding the thorium, yet permitting alpha-particles to escape, is described. (Auth)

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Yaron, F., Israel Atomic Energy Commission, Beer Sheva, Israel. 1976.

Comment on "Excess Uranium 234: An Aging Effect in Confined Waters", by J. Kronfeld, 21 Al. Earth and Planetary Science Letters, 33(1), 176.

A 10-fold excess of U 234 reported by Kronfeld et al. has been attributed to eject Th 234. The ejection model has been postulated by Kigoshi who found considerable quantities of Th 234 in the aqueous phase in his experiments. The amount of ejected Th 234 grew toward an "equilibrium" state and he suggested a numerical expression for the ejection phenomenon. Insofar as ejected Th 234 is not removed from solution, one should find in solution U 238 generated through decay of ejected Th 234. The amount of U 238 from this source can become significant only after thousands of years; however, Kigoshi found a 10-20% excess of U 238 after a few days' leaching. This excess cannot be due to ejected Th 234 and some other model must have been operative. The body of water described by Kronfeld et al. is supposed to have been stagnant for more than five half-lives of U 238 and therefore results do not disagree with Kigoshi's ejection concept. However, the absolute absence of Th isotopes, particularly Th 230 requires explanation. The relationship between Th 230 and U 238 should be the same as between Th 234 and U 238 and Kigoshi's equation should apply to the former after appropriate changes in the relevant parameters are made. One can then show that in the water described by Kronfeld the activities of Th 234 and Th 230 should be nearly equal, unless some removal mechanism is invoked. One could argue that ejection of both nuclides occurred, ejected Th 234 bred U 234 and then the Th isotopes were removed (leaving the U 238 unsupported). One may regret only that Kronfeld et al. did not analyze their samples for Th 234, which could perhaps clarify the matter. One can hardly deny the possibility of ejection; however, to make it quantitatively responsible for the excess of U 238 one must explain a few incompatibilities which so far have not been dealt with. (Auth) (VC)

DISCUSSION

<664>

Albert, R.P., New York University Medical Center, Institute of Environmental Medicine, New York, NY. 1966, November.

Industrial Processing of Thorium. Thorium: Its Industrial Systems Aspects, Chapter 3. Academic Press, New York, New York, (pp. 27-45), 222 pp.

The chapter on industrial processing of Th includes sections on resources and minerals, mining and ore concentration, treatment of ores, purification of concentrates, reduction to metal, melting and casting, metal fabrication, Th-Mg alloys thoriated tungsten electrodes, thorium refractories, and fabrication of mantles. Average Th content of the earth's crust is 13 ppm, three times that of U. High levels are in thorite, thorite and the commercially significant monazite which contains 18% Th. Major Th-bearing minerals, their formulae and Th content are tabulated. Monazite composition is variable and different extraction methods are used. Sulfuric acid or caustic soda digestions are examples. Process diagrams are given and nitric acid digestion described. Concentrations of contaminants in commercial mantle and reactor grade Th are compared. The method used for producing Th metal involving ThF₄ reduction by Ca is described. Other methods not used commercially are outlined. Thorium metal is produced as a sponge or powder and then consolidated by melting or powder metallurgy methods; generally, melting in vacuum or an inert atmosphere. High purity Th metal can be fabricated by conventional methods. Thorium is extruded at 500 to 1000 deg C by Cu-cladding techniques. Thorium is readily forged and easily swaged by conventional equipment. Rods and wires are made by drawing. Powder metallurgy techniques for Th permit fabrication of high reactivity metals and alloys of different densities. Thorium-magnesium alloys, because of desirable heat characteristics, are used in aircraft. Thoriated tungsten alloy is advantageous for arc welding electrodes. Thorium oxide is used where temperatures exceed melting points of more common refractories. The hand fabrication of Th mantles is described. (VC)

<665>

Arnold, R.C., 1966.

Radiation Hazards of Recycled Uranium 233-Thorium Fuels. Nuclear Safety, 5(4), 382-389.

Using U 233 fuel would require semi-remote or remote handling. If U contained more than 200 ppm U 232 or fabrication time was more than 2 weeks, a shielded refabrication facility would be needed. U would have to be free of light-elements to reduce the alpha-produced neutron background. Freshly recovered power-reactor Th would have radiations intensities greater than 10 times that of natural Th and would have to be refabricated in a shielded facility. In many cases it might be justifiable to handle natural Th during the refabrication of reactor fuel elements and to hold back the irradiated Th for 12 years to allow decay of Th 228 to natural-Th backgrounds. The practicality of this procedure would depend on the actual cost of Th and the inventory charge. If a shielded fuel-handling facility were used, it might not be necessary to use purified Th for fabrication of sintered oxide fuel elements because the shield thickness would need to be increased by only 20 to 30

cm of concrete for recycling the Th. Those conversion and refabrication operations that used only Th might be handled more economically by using low-activity Th without shielding. This would be especially true if the reactor used separate fuel elements of U 233 and Th. A thorough economic study would be necessary before a firm statement could be made about the relative merits of complete Th recycle (no excessive decay period) compared with a refabrication operation that used purified Th, with spent Th being allowed to decay for 12 years. In fuel-cycle-operations analysis, in addition to the activity that builds in from U 233 decay, it would be necessary to consider the following: residual Th 228 or daughter activity or both in the recycled U; residual Th 228 activity in the Th; fission-product contamination in both recycled U and Th; equipment and cells contaminated by a small amount of longer aged U or Th. (Auth) (VC)

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Carrigan, R.E., Fellows Medical Manufacturing Company, Fellows-Testagar Division, Inc., Detroit, MI. 1967, December.

Manufacture of Thorium Dioxide Suspension (Thorotrast). Annals of the New York Academy of Sciences, 145(3), 530-532; CONF-660422; Distribution, Retention, and Late Effects of Thorium Dioxide, R.L. Swann (Ed.), Proceedings of a Conference held in New York, New York, April 20-22, 1966, (pp. 530-532), 336 pp. (CONF-660422).

Fellows-Testagar first manufactured and marketed its thorium dioxide suspension in 1955. The manufacturing method was composed of five steps. 1) Oxidation of Th oxalate to Th dioxide was done at 550 degrees C with O₂ and Pt catalyst. The hot ThO₂ was added to dilute HCl, sized under specified conditions and stored for six months. 2) The colloid was decanted, centrifuged and assayed for concentration of ThO₂ which, in the final product is 25%. 3) A purified, pyrogen-free tapioca dextrine to be used as vehicle for the ThO₂ was prepared. 4) ThO₂ was suspended with purified dextrine, methyl paraben, and water for injection. Trial tests for standardization and pH stability were carried out. 5) After going through a series of filtrations, Thorotrast was put into vials and autoclaved. Quality control measures involved the following determinations: particle size, sterility testing, pyrogen testing, safety assay for ThO₂, methyl paraben assay, pH stability control, ThO₂ assay, and checks of purity and identity of all raw materials. The company adhered to all precautions regarding radioactivity required by the AEC. (WC)

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Dean, O.C., Oak Ridge National Laboratory, Chemical Technology Division, Oak Ridge, TN. 1957.

Methods for the Production of Thorium Metal. Advances in Nuclear Engineering, Vol 1, J.R. Dunning and R.R. Prentice (Eds.), Proceedings of the 2nd Nuclear Engineering and Science Conference held in Philadelphia, Pennsylvania, 1957. Pergamon Press, New York, New York, (pp. 66-73).

The high degree of stability of Th oxide, fluoride, the high melting point, and reactivity of Th metal to a variety of materials rigidly limits reductants, contaminants, materials of apparatus

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PRODUCTION

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construction, and procedures. Thorium metal has been successfully prepared only from the oxide and the halides. The reductions with the best chances for success are: oxide with calcium; fluoride and chloride with calcium, magnesium or sodium; electrolysis of chloride, fluoride or iodide; thermal decomposition of iodide. Thorium is extremely reactive at high temperatures with oxygen, nitrogen, carbon, and many of the metals. Thus, conditions of the experiment (vacuum or purified inert atmosphere) are dictated and materials used for crucibles are limited. The general methods used in preparation of pure Th on a commercial scale are: thermal reduction of Th oxide with carbon or active metals; thermal decomposition of the halides; metallothermic reduction of the halides; electrolysis of various compounds in water, organic or fused salt solution. This paper surveys early and modern investigations published in open and classified literature. The discussion includes the following topics: preparation of Th source materials; reduction of Th oxide; metallothermic reduction of Th fluoride; decomposition of Th iodide; metallothermic reduction of Th chloride; electrolytic reduction of Th compounds and fused chlorides. The text is supplemented with numerous diagrams concerning specific processes. Included are: Sylvania oxide reduction; Ames fluoride reduction; Kroll Th reduction; Metallix Analysis reduction; Horizons electrolysis. (Auth) (VC)

<669>

Enterlin, W.L., Battelle-Pacific Northwest Laboratories, Richland, WA. 1973, February.

In Assessment of U.S. Domestic Capacity for Producing Reactor-Grade Thorium Dioxide and Controlling Associated Wastes and Effluents. EML-25691: 49 pp.

This study assesses U.S. capacity for producing reactor-grade ThO₂ and controlling the wastes and effluents. A 24,000 MWe Th-U fuel cycle can be sustained using domestic ThO₂ byproduct if purification capacity is expanded, the market for rare-earth products remains stable, and sufficient imported monazite remains available. Analysis of the information obtained in this investigation gave the results that follow. Waste water, tailings, dust, smoke and gas, and radionuclides (primarily Th 232, Ra 226) associated with ThO₂ production are quantified. There are 1,500 short tons of crude Th hydroxide, readily convertible to reactor-grade ThO₂ that is surrounded with rare-earth wastes at Chattanooga, TN. Crude byproduct is produced at 250 ton/year of equivalent ThO₂. Eighty one percent is produced from imported monazite and 19% from domestic monazite. The maximum domestic capacity for producing reactor-grade ThO₂ is about 65 to 100 ton/year. This capacity can sustain a Th fuel cycle up to 11,000 MWe without recycling Th depending on the reactor types. This range can be increased to 28,000 MWe by expanding ThO₂ purification capacity. Constraints which could affect domestic ThO₂ production are: uncertainty in the marketplace; limited Th for production of ThO₂; limited production capacity; mounting concern over radioactivity in production. If tests for domestic ThO₂ exceeds 250 ton/year, expanded research on costs, reserves, extraction, impact, and production constraints will be required. (Auth) (VC)

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Government of India, Department of Atomic Energy, Bombay, India. 1969, April.

Atomic Materials in India. Nuclear News, 12(4), 27-28.

The Indian Atomic Energy Commission surveys and develops the atomic materials of India. Patterns of distribution and development are given for U, Th, Be, Li, Tr and the rare earths. Bihar, in NE India, is the richest mineral state and first in U production. Here, the Singhbhum Thrust Belt has the highest potential for U deposits associated primarily with Cu. The richest deposit in the belt is in Jajjala. Mining has been undertaken there and a nearby mill extracts U by acid leaching. A deposit at Yaruapahar, in the middle of the belt is the largest known in the country. Another location, Bhatin, near Jaduguda has a deposit. Promising areas are Kersaungri, Fanyalaka, Parandungri and Pajjata. Deposits of consequence are confined to the Singhbhum Thrust Belt Area. Even though the U mineralization is low grade, this is the most important and richest U region in the country. In Rajasthan, deposits have been explored and developed at Tara and Udaisar. U has been found in some parts of the Himalayas and minor deposits in other areas. India has the largest established Th reserves in the world. Monazite is found in granites, meta-sediments, and sediments of Peninsular India and along river and stream courses. It is transported to the sea and finally redeposited on the beaches. Rich deposits are in parts of Kerala and South Madras coasts. Inland deposits occur in the Raichur district of Bihar and in the Paralia district of West Bengal. Major mineral assets are deposits on the seacoast of Kerala and Madras States. The major deposits are at Chavara in Kerala and Manavalakurichi in Madras State. Plants processing minerals and producing nuclear-grade materials are detailed. (VC)

<77>

Garris, W.B., Health and Safety Laboratory, New York, NY. 1959, October.

Health and Safety in Handling the Newer Metals. American Journal of Public Health, 49(10), 1339-1342.

Safety aspects of handling thorium, uranium, zirconium, titanium, beryllium, and plutonium powders are discussed. The ignition and explosion properties of dust clouds are discussed as well as maximum permissible levels for 8 hours exposure (for 1959). Some suggestions for handling safety are mentioned (i.e. glove boxes) but no details are given. Both Th and U are pyrophoric, U being less stable than Th. A dust cloud of U will ignite at room temperature, while one of Th requires 270 deg C. Handling of powders requires some degree of isolation to ensure safety. Th may react with explosive violence, while U powder burns more passively. Conversion of powder to oxide is difficult to stop. The oxide fume, composed of small particles, become easily airborne, with the resultant possibility of inhalation exposure to U. Samples from a 30 cu m room, following burning of 100 g U gave average dust concentrations below permissible levels. The maximum permissible concentration for U (MCP and CPM) is 5 x 10⁻¹¹ uc/ml (occupational, 40 hrs/week), equivalent to 80 ug/Cu m. The ACGIH level is 250 ug/cu m/8 hr day. U and Th have similar health hazards. CPM lists the maximum permissible value for

PROTECTION

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TR AT 912 wj/cn a. (GAD)

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Leut, H.O., and P.G. (Translator) Silver,
Institut fuer Reine Chemie,
Forschungszentrum, Karlsruhe, German Federal
Republic. 1975.

Protection, Disposal, and Relative Toxicity of
Long-Lived Fission Products and Actinides in the
Radioactive Wastes from Nuclear Fuel Cycles.
COST-ER-4302; 190 pp.; CERN-2322; 190 pp.

This report concerns long-term problems
related to radioactive wastes in the German
Federal Republic and Western Europe. Future
development of nuclear energy, specifically,
contributions of nuclear power plants,
various types of reactors and fuel
fabrication and reprocessing, is discussed.
Fuel cycle variations and production of
fission products and actinides in waste from
reprocessed nuclear fuels is the subject of
one chapter. The discussion includes U-Pu
cycles and Th-U cycles. Other chapters cover
the following subjects: long-lived fission
products and actinides in the waste streams
from the reprocessing of nuclear fuels;
relative toxicity index; presently preferred
waste-management concepts; alternative
concepts for the elimination of high-level
wastes. Appendices include: A prognosis of
the development of nuclear power plants in
the German Federal Republic and Western
Europe; build-up of the transuranium elements
in the U-Pu fuel cycle; notes on the Th-U
fuel cycle with coated-particle fuel. The
report does not include discussion of the
hazards associated with radioactive wastes
during production, temporary storage,
treatment, transportation, or placement into
their final resting place. (VC)

(672)

International Atomic Energy Agency, Vienna,
Austria. 1976.

Manual on Radiological Safety in Uranium and
Thorium Mines and Mills. Safety Series No. 63;
82 pp.

Uranium mining and milling industries are
growing and this trend may continue with the
increasing demand for nuclear fuel. A
similar trend is noted in Th mining and
milling, although these do not represent a
significant part of nuclear industry. The
problems of radiological hazards in this
component of the nuclear fuel cycle have
received considerable attention because
radioactivity is present in mines and mill.
Such problems can also be significant in
non-radioactive metal mining, because of the
pervasive distribution of U and Th in the
earth's crust. Radiological hazards result
primarily from exposure to airborne
radioactivity and, to a lesser degree,
external radiation. The inhalation hazard is
of more concern in underground and deep-pit
mining than in open-pit mining. It is
particularly significant in U mining
operations, which are mostly underground, and
less significant in Th mining, generally a
surface operation. Inhalation hazard in
mills is of concern at the concentrate areas.
For radiological protection in mining and
milling adequate monitoring and control
should be provided, particularly as there has
been some evidence of occupational illness in
U mining. The introduction of efficient
control measures depends primarily on
knowledge of the radiation situation,

especially on accurate determination of
airborne radioactivity. Efficient control of
Th and its daughters in the mine atmosphere
is a somewhat difficult task. This
publication is intended as an operating
manual with emphasis on implementation
methods. It is anticipated that the manual
will have application at non-nuclear sites
and mills since radiological hazards can
exist there also. The scope of this manual
is limited to occupational hazards in mining
and milling; liquid, solid and gaseous wastes
produced are identified but not treated in
detail. (Auth) (VC)

The following areas are discussed:
administrative responsibilities, radiation
hazards, standards, monitoring program,
monitoring methods, control measures, and
medical control. Appendices include information
about physical properties of relevant
radioisotopes, equations for radon daughter
concentration, factors for use in the two-filter
method, precautions in air sample collection,
medical contraindications for employment in
U and Th mining and milling. Also included are
references, recommended bibliography and a
lossary.

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Kotrappa, P., D.P. Shanti, V.S. Venoe, R.
Dhandayathan, C.C. Gohel, and P. Nambiar, Shabha
Atomic Research Center, Health Physics Division,
Bombay, India. 1976, November.

Assessment of Airborne Hazards in the Thorium
Processing Industry. American Industrial
Hygiene Association Journal, 37(11), 613-616.

Airborne thorium, thoron and its decay
products contribute significantly to the
hazards in the thorium industry. These
hazards were measured and compared to
standards in the Trombay Thorium Plant. This
facility processes thorium hydroxide into
high purity nitrates, oxides, and other
compounds of thorium. Inhalation has been the
main source of hazard in this and any other
thorium processing plant. The inhalation
hazard varies according to the concentration
and aerodynamic particle size parameter,
activity median aerodynamic diameter (AMAD).
Air samples were collected over a period of 6
to 20 hours, and filters were assayed for
alpha activity. Results showed that thorium
concentrations vary widely within the plant
and can vary in even the same area when
different handling techniques are being used.
Airborne thorium concentrations in different
areas of the thorium plant varied from 0.121 ± 11 (E-12) $\mu\text{Ci}/\text{cu cm}$ to 52.020 ± 10 (E-12)
 $\mu\text{Ci}/\text{cu cm}$. Recommended value for this plant
is 2.5 ± 11 (E-11) $\mu\text{Ci}/\text{cu cm}$. Based on
particle size distribution studies on the
aerosols, the MPC for Th was safe by a factor
of 2. Measurement of thoron decay products,
the MPC for thoron was also safe by a factor
of 2. Measured equivalent radon working
levels were 2-3 times lower than MPC units of
thoron. (Auth) (GAD)

(674)

Lotts, A.L., and P.R. Easton, Oak Ridge National
Laboratory, Oak Ridge, TN. 1977, July.

Gas-Cooled Reactor Programs: Thorium
Utilization Program Progress Report. ONSI-5266;
Thorium Utilization Program Progress Report for
July 1, 1975 through September 30, 1976; 320 pp.

The Thorium Utilization Program is intended
to extend nuclear fuel resources through
application of fuel cycles which utilize

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REPRODUCTION

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conversion of Th 232 to U 233. Its most promising application is in the high-temperature gas-cooled reactor. The goal of the program is to provide a demonstration plant for the recycle of RTGS fuels. The plant will demonstrate facility and equipment design and operating procedures that are licensable and commercially feasible from spent fuel treatment. The facility will provide interim recycle services for RTGS spent fuel in support of private commitments. Aspects of the program included in the report are: program management and analysis; reprocessing development (task management, cold and hot laboratories development, cold engineering development); refabrication development (general development, uranium feed preparation, resin loading, resin carbonization, microsphere coating, fuel rod fabrication, fuel element assembly, sample inspection, plant management, waste and scrap, material handling); waste treatment development (reprocessing wastes, refabrication wastes); fuels irradiation and examination; RTGS fuel recycle demonstration facility; hot engineering test project; cold prototype refabrication development. The author of the program management and analysis section recommends strong support be given to RTGS as the best contingency in the event of delay in introduction of LWRs. Emphasis should be on commercialization and scheduling such that RTGS could have a large share of the nuclear power market by the year 2000. If there are limitations on fuel recycle, thorium-uranium mixed cycles may be necessary in a breeder economy and could have implications for thermal reactor fuel cycles; this is an area requiring detailed study. (VC)

<675>

MacDonald, R.P., Berkeley Nuclear Laboratories, Central Electricity Generating Board, Berkeley, England. 1976.

Radiological Implications of Plutonium Recycle and the Use of Thorium Fuels in Power Reactor Operations. BN/B/W-3523; 26 pp.

As economically attractive sources of natural uranium are gradually depleted attention will turn to recycling plutonium or the use of thorium fuels. In this study the radiological implications of these fuel cycles in terms of fuel handling and radioactive waste disposal are investigated in relation to a conventional U 235 enriched oxide fuel. It is suggested that a comparative study of this nature may be an important aspect of the overall optimization of future fuel cycle strategies. It is shown that the use of thorium based fuels has distinct advantages in terms of neutron dose rates from irradiated fuels and long term alpha decay heating commitment compared with conventional uranium/plutonium fuels. However, this introduces a gamma dose rate problem in the fabrication and handling of unirradiated U 233 fuels. For both plutonium and thorium fuels these radiological problems increase during storage of the fuel prior to reactor irradiation. Finally, the novel health physics problems which arise in the handling and processing of thorium fuels are reviewed in an appendix. (Auth)

<676>

Marshall, P., 1977, March.

Cost Saving Techniques Developed for Lower Grade Uranium Ores. Nuclear Engineering

174

International, 22(254), 66-68.

Cheaper techniques of coping with lower grade uranium ores took prominent place at the International Symposium on Geology, Mining and Extractive Processing of Uranium in London. Cost savings of around \$2/kg (1971 prices) might be obtainable over conventional acid slurry leaching processes with an in-plant method of bacterial leaching developed by Warren Spring Laboratory and the Atomic Energy Authority in the UK. Technical and economic advantages/disadvantages of dilute acid slurry leaching and strong acid leaching (SAL) of low grade uranium-bearing ores were debated extensively at the symposium. A static heap-leaching process developed by Empresa Nacional del Uranio (ENUSA) offered a cheap and efficient technological solution for the mining and processing of small uranium ore bodies. With increasing costs of both open pit and underground mining in the '70s, such effort has been invested in developing more economical methods. There were 15 or more ISMIR leaching test programs and 2 production units in operation. Hydraulic mining is a way of recovering from sandstone areas; its disadvantages were lack of selectivity, incomplete recovery, and blockages through hard ribs in the ore. Resonance mining with a high-pressure water jet at the bottom of cased drill-holes has been tested. The resulting slurry was then pumped to the surface for normal leaching. (VC)

<677>

Morris, J.P., University of Missouri, Department of Chemistry, Columbia, MO. 1938.

Hazards in the Radium and Mesothorium Refining Plant at the University of Missouri. Journal of Industrial Hygiene and Toxicology, 20(1), 36-45.

A study of the hazards involved in the refining of radium and mesothorium was conducted at the refining plant at the University of Missouri-Columbia. Danger to workers from alpha and beta rays was found to be small as these rays are absorbed by safety mediums. Gamma rays are emitted by transformation products, radium B and radium C, and may be at an appreciable level by the last stages of the crystallizing process. Worker exposure to radiation intensity was measured by x-ray film exposure, blood counts, and alpha activity in expired air from workers. Average alpha particle measurement in worker expelled air was 70. Gamma ray irradiation was shown to be considerable by the x-ray film exposures. Gamma ray exposure was the greatest in the final stages of refining. The films also showed that greater gamma ray exposure was encountered when working with mesothorium than radium in the refining plant. (GAD)

A description of radiation hazards which commonly occurred on survey subjects is given in the text.

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Murray, D., and D. Hoffert, Canada Center for Mineral and Energy Technology, Elliot Lake Laboratory, Mining Research Laboratories, Elliot Lake, Ontario, Canada. 1977, July.

Vegetating the Uranium Mine Tailings at Elliot Lake, Ontario. Journal of Soil and Water Conservation, 32(4), 171-174.

Canada is the world's second largest uranium producer; about 85% of this production is from mines near Elliot Lake, Ontario. The

REPRODUCTION

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mining in the last 20 years has left abandoned tailings in sites occupying more than 320 hectares. For each metric ton, 0.5-1.25 kg of uranium oxide are obtained and 999 kg of solid wastes or tailings are left. About three million metric tons of wastes are added to these tailings. Adverse environmental effects include dusting, water pollution and barrenness. Because Elliot Lake is a wet, temperate region, vegetation of the tailings is feasible. Pyritic uranium tailings near Elliot Lake was revegetated with a surface application of limestone [2.24 kilograms/square meter (10 tons/acre)] to neutralize acidity and fertilizers to compensate for the lack of nutrients and a very low cation exchange capacity. The study involved an supplemental organic matter or topsoil. He seeded 24 grasses, legumes, and annuals in field plots, 3 meters x 6 meters (10 feet x 20 feet). Six grasses and three legumes persisted over four growing seasons. Species selection was based on herbage yield, percent groundcover and field observations. Feed canarygrass proved to be the most successful species, but a mixture of creeping red fescue with redtop or Kentucky bluegrass seemed preferable because of its superior soil-foraging abilities. Legumes performed so poorly that we do not recommend their incorporation in seed mixtures. (Auth) (VC)

<475>

Fearson, J.S., University of Denver, Denver, CO. 1975, April.

A Sociological Analysis of the Reduction of Hazardous Radiation in Uranium Mines. NIOSH-75-171; 137 pp.

This report describes the responses of companies, unions and government enforcement agencies to the problem of excessive radiation in mines resulting in respiratory cancer in Colorado chiefly between the years 1950 and 1969. It focuses on the organizational actions which ultimately solved the hazard as well as the non-technological factors that prevented an earlier solution of the problem. Information was assembled from mining archives on more than 500 Colorado uranium mines. This permitted a statistical analysis of the relationships between and among the scale and stability of the industry over time, the history of government enforcement activities and the changing levels of radiation in mines. Such analysis revealed that the greatest reduction in hazardous radiation in mines followed inspection and sanction activities by an enforcement agency. From an extensive historical analysis and a series of interviews, it was also shown that the demand for uranium ore for defense purposes, the invisibility of the radiation hazard to the naked senses, and the transient and speculative nature of the early uranium mining industry prevented an earlier solution of the problem. These results argue for policies related to health and job safety that emphasize periodic inspections which carry a threat of punishment for employers who knowingly violate standards. (Auth)

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Roberts, J.T., L.M. Ferris, E.L. Nicholson, R.E. Sainey, and C.D. Watson, Oak Ridge National Laboratory, Oak Ridge, TN. 1966.

Reprocessing Methods and Costs for Selected Thorium-Bearing Reactor Fuel Types. Technical Reports Series No. 52; Utilization of Thorium in

Power Reactors, (pp. 343-352).

Developments in the chemical reprocessing of Th fuels from the most promising reactor types in the advanced converter reactor program are reviewed. Emphasis is on differences in methods and costs between Th fuels and low-enrichment U metal or oxide fuels clad in Al, Zr, or stainless steel alloys. The relationship between reprocessing and the rest of the fuel cycle for proposed recycle schemes is discussed. Primary consideration is given to pyrolytic C-coated Th-U oxide or carbide microspheres contained in graphite fuel elements, i.e. fuels for high-temperature, gas cooled reactors and Th-U metal, oxide, or carbide clad with Zr or Al alloys, including fuels for heavy-water-cooled and moderated reactors, heavy-water-moderated, organic-cooled reactors, and also spectral shift control reactors and light-water-cooled and moderated sand-blanket reactors. Some aspects in which Th fuels are non-standard are given. Some differences can increase cost by 2 or more on a weight basis, or prevent processing of certain fuels in plants used for standard ones. Because of higher burn-up and/or thermal efficiency, some Th fuels can stand the cost, while others cannot. On the other hand, plant handling Th fuels with processes described in this paper, could have only slightly higher cost, allowing the Th-fueled converters to take advantage of higher burn-up and/or thermal efficiency in achieving lower power costs. Thus, Th reprocessing problems are seen as temporary initial economic disadvantages for the early advanced converters; these problems will fade as the industry reaches a reasonable size. (Auth) (VC)

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Schlundt, H., University of Missouri, Columbia, MO. 1931.

The Refining of Mesothorium. Journal of Chemical Education, 8(7), 1267-1287.

Mesothorium, an isotope of radium, is of fundamental interest for its radioactive properties. Its limited occurrence in nature, and its extraction and recovery from monazite sand are first discussed; then the process of refining the previous element is described in some detail. Incident to the handling of highly active radioactive substances, certain hazards to the workers have been studied. The precautions taken to protect workers engaged in refining operations against the radiations have been extended so as to render the occupation safe. Since, weight for weight, mesothorium is about two hundred fifty times as active as radium, the actual quantity of mesothorium in commercial samples is extremely small. The methods used in measuring the mesothorium in concentrates and keeping track of its distribution in separations from other elements constitute another section of this report. (Auth)

<482>

Sears, H.B., Oak Ridge National Laboratory, Oak Ridge, TN. 1976.

Airborne Effluent Control at Uranium Mills. CONF-760806; Controlling Airborne Effluents from Fuel Cycle Plants, Proceedings of the AWS-AICME Topical Meeting held in Sun Valley, Idaho, August 5-6, 1976, (pp. 17-11 - 17-13), 340 pp. (CONF-760806).

<#2>

DISCUSSION

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This paper summarizes the results of a survey by Oak Ridge National Laboratory relating to control of airborne radioactivity at uranium processing mills in the U.S. Steps common to all mills, irrespective of particular chemical processes, are crushing, grinding, leaching and recovery of uranium. The dust producing activities are virtually the same at all mills. Sources and control methods for ore dusts are discussed. Crushing, screening, conveyor belt transfer points, all activities generating dust, are usually enclosed in buildings which are generally appropriately ventilated. Dust levels in crushing rooms are generally 10 % of the 10 CFR 20 radiation concentration guide for occupational exposure. Dust is collected before air is released; concentrations vary from about 5 x 10⁻⁴ (E-4) (of the 4) from ore with 4% moisture and a wet scrubber to 7 x 10⁻⁴ (E-5) for ore of 9-10% moisture and no scrubber. Dust generation can be reduced by use of a wet autogenous grinding circuit. Dust control practices for the sample tower are similar to those used for crushing. Exact ore losses from the ore dryer are not known, but mills using a wet dynamic precipitator or a venturi scrubber had approximately 99% removal efficiency. Sources and control of yellow cake dusts are discussed. All drying operations are done under negative pressure; packaging systems are enclosed or hooded and generally separated from the rest of the plant. The yellow cake areas are ventilated. Dust levels range from 10-70% of the concentration guide. Dust is removed from dryer off-gases before their release. The 50-year dose commitment is discussed as a way of expressing effectiveness of waste treatment. The calculations of total body dose from a model plant processing 2000 tons of ore/day indicate that achievement of low dose levels with conventional dust collectors is possible. Reasons for differences between doses estimated by EPA and ORNL are presented. (VC)

Includes numerous tables and figures.

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Shook, D.A., 1977, February.

Solution Mining. Mining Engineering, 46-48.

Solution mining seems particularly well-suited for marginal uranium deposits and is promising for deposits below the marginal level at current prices. Deposits in porous formations, primarily sands with controllable permeability are most amenable to solution mining. Economic evaluation at sites in Texas and Wyoming show that solution mining should be profitable at \$20-25/lb U₃O₈. Costs associated with environmental protection were not included in the estimates. Wyoming Minerals feels that economic U₃O₈ recovery is possible from ore grades of 0.05% or less. Atlantic Richfield in its uranium complex in Texas has shown that solution mining has fewer environmental problems than does surface mining; in particular this company has taken extensive measures to protect ground water formations, dispose of wastes and restore the ore-body after completion of mining. Developments in copper leaching are outlined. A special problem for solution mining may come from future regulations concerning ground water contamination and disturbance of nearby formations. (VC)

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Steen, C.A., G.R. Pitt, Jr., G.R. Baren, Jr., and E.P. McEllean, Ute Exploration Company, Utah, 70; U.S. Bureau of Mines, Mineral Resources Branch, Denver, CO. 1953, October.

Uranium-Mining Operations of the Ute Exploration Co in the Big Indian District, San Juan County, Utah. MS-IC-7667; 13 pp.

The ore deposit in the Ute Mine, San Juan County, Utah was discovered in 1952 while drilling a diamond-core borehole. High-grade ore was penetrated. Sinking of a shaft, from which to develop the ore body, was begun in October; the first shipment of ore left the property in December. Ore production, as recorded on ore-settlement sheets up to July 15, 1953, totaled 16,001 tons averaging 0.61 percent U₃O₈ and 1.26 percent V₂O₅. Discovery of the ore and the large production were achieved without financial assistance from the government. The Big Indian mining district is on the southwest flank of the Lisbon Valley anticline, which plunges to the northwest; the ore-bearing horizon is overlain by a considerable thickness of Jurassic and Cretaceous sediments. In the area the Chinle formation consists of variegated mudstones and siltstones, intraformational conglomerates, and fine- to medium-grained cross-bedded sandstones. The ore-bearing unit, in the Chinle formation, contains fossil flora replaced by pyrite or uraninite or preserved as carbon. Throughout the region carbon has been important in concentrating uranium. Two theories about ore deposition have been expressed, the channel theory and the anticlinal theory. Because of the large size of the ore body, an inclined shaft to permit mechanical haulage underground was driven to the ore body from about 400 feet southeast of the shaft. The shaft was completed in May 1953 and is used jointly by the Ute Exploration Co. and the G. G. Mining Co., which holds a lease on a 200-foot segment across the 600-foot width of the El Vida claim. The ore is 10 to 23 feet thick, and a modified room-and-pillar method of mining is employed. Ore is loaded underground with shovel loaders into a diesel truck by the Ute Co. and into a trailer by the lessee company for transport to a stockpile on the surface. From the stockpile the ore is moved by trucks to ore-bayging stations at Monticello and Thompson, Utah, and Grand Junction, Colo. (Auth) (VC)

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Watrous, J.D., McDonnell Douglas Astronautics Company, Donald W. Douglas Laboratories, Richland, WA. 1972, July.

Plutonia/Ceria Compatibility Testing, April-June 1972, Quarterly Report No. 15. NDC-G3153; 81 pp.

Compatibility tests with plutonia 238 in refractory metal capsules have shown that Mo-86 Re is the best container material in exposures at 1800 degrees centigrade for 15,000 to 18,000 hours. Phenix is also adequate but results in greater transport of plutonia within the container. Compatibility tests of plutonia-molybdenum ceramets (PMC) and plutonia-thoria-molybdenum ceramets (SSC) in double layer refractory containers at 1500 degrees, 1800 degrees, and 2000 degrees centigrade resulted in complex interactions. The SSC fuel form was equivalent to the PMC fuel form in helium release, degraded more structurally, but indicated less aggressive attack on the container materials. TZM and Mo-86 Re appeared to provide the best structural containment at 1500 degrees and

PRODUCTION

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1800 degrees centigrade. T-111 appeared inadequate in all tests conducted at these temperatures. Plutonia and PuC fuel aging specimens with various 242 afflictions to accelerate helium generation will complete exposure and be examined during the next quarter. (Auth) (P74)

<686>

Wittmann, G.T.W., and M. Foerstner, University of Pretoria, Pretoria, South Africa; University of Heidelberg, Department of Chemistry, Laboratory for Sediment Research, Heidelberg, German Federal Republic. 1977, February.

Heavy Metal Enrichment in Mine Drainage: 3. The Ficksburg, West Vits and Evander Goldfields. South African Journal of Science, 73, 53-57.

Mine drainage from gold and uranium recovery is characterized by low pH and high metal values. The treatment of Witwatersrand ores from uranium is discussed; the process involves acid leaching and recovery by anion exchange resins. Samples from various sites were taken for determination of metal concentrations and hydrochemistry. The uranium-producing mines studied had drainage of low pH and high levels of sulfate, zinc, and, in some, lead. The environmental impact from uranium recovery is related primarily to the radiation hazards. In the case of gold mines, sludge dams may contain high levels of toxic metals (e.g. Pb, Hg, Zn, As). Sediments from sludge residues of the major uranium producers studied are less enriched with trace metals. Low pH, high conductivity and elevated Fe are found in most uranium-producing mines in the goldfields studied. Mine drainage from the gold mines in South Africa, along the edge of Witwatersrand Basin has a marked effect on the environment. Further studies are being done to show the interrelated effects of gold and uranium recovery, sulfuric acid production as well as acid leaching from hydro-metallurgical procedures. (TC)

<697>

Bright, W.J., Australian Atomic Energy Commission, Fuel Element Development Section, Lucas Heights, Australia. 1966, December.

The Machining of Nuclear Materials. Australian Machinery and Production Engineering, 19, 21-35.

The machining of "nuclear materials" such as U, Th, Pu, Be and Zr is influenced by their

radioactive, toxic or pyrophoric nature. The hazards involved are described briefly and examples are given of techniques and equipment which have been found satisfactory within the Australian Atomic Energy Commission's laboratories. The machining characteristics of these materials are reviewed and some examples are given of the consequences of surface deformation or failure which occurs in machining. Very little work has been done in the large-scale machining of Pu, and conditions are tentatively established by consideration of the hazards involved, rather than the characteristics of the metal. In general, Pu machines in a manner similar to U. (Auth)

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Tourt, G.P., 1975.

Environmental Aspects of the Canadian Mining Industry. Canadian Nuclear Association, Proceedings of an International Conference held in Ottawa, Ontario, Canada, June, 1975, (pp. 19-23).

This paper covers a brief history of uranium mining in Canada, environmental problems, control measures, monitoring of the various contaminants in air and water, information on standards, cancer incidence and effects of smoking. The environmental problems discussed include: emanation of radon gas and its decay products into the atmosphere of the mine; Radium 226 in mine water and mill solutions; ingestion and inhalation of uranium concentrates by operators in the precipitation, filtering, drying and packaging areas in the mill; thorium as a by-product; external radiation; tailings disposal; smoking. Control measures include suppression, confinement, dilution with ventilation, cleaning, air, respirators, and job rotation. Control measures for radium and thorium concentrates are discussed. It is concluded that uranium mining companies could have done better in controlling harmful air contaminants, such as radon daughters, if information and experience now available had been available during planning. Conditions were improved in most cases when the necessary knowledge was acquired. Lack of awareness of the effects of smoking on the health of miners is still hampering the prevention of lung cancer and other diseases. There is need for epidemiological study of the incidence of lung cancer among uranium miners including not only their exposure but smoking habits. (Auth) (TC)

RADIATION SAFETY AND CONTROL

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Albert, R.E., New York University Medical Center, Institute of Environmental Medicine, New York, NY. 1966, November.

Control of Thorium Hazards. Thorium: Its Industrial Hygiene Aspects, Chapter 12. Academic Press, New York, New York, (pp. 190-212), 222 pp.

The control of thorium hazards is discussed in detail. Aspects of control included were: atmospheric contamination, particularly 1) local ventilation (hoods, drum dumping, packaging, grinding and screening, boat refueling, machining operations, downdraft enclosures, glove boxes), dust collection, and respirators; 2) shielding from external radiation; 3) classification of radiation areas; 4) surface contamination, particularly standards and control measures (house keeping, protective clothing, change rooms and laundry); 5) disposal of radioactive wastes; 6) shipping regulations; 7) aspects of industrial medical program relevant to radiation hazards including management of accidents and decontamination methods. Numerous tabular, graphic, and pictorial data are included. (VC)

<690>

Albert, R.E., New York University Medical Center, Institute of Environmental Medicine, New York, NY. 1966, November.

The Nature of Thorium Hazards in Industry. Thorium: Its Industrial Hygiene Aspects, Chapter 10. Academic Press, New York, New York, (pp. 189-190), 222 pp.

The health problems common to most industrial uses of thorium include (1) the inhalation of Th dust and thoron gas and its decay products and (2) external beta and gamma radiation. The relative importance of each of these hazards varies with the nature of the industrial process. The inhalation hazard from Th is greatest in dusty operations, such as the grinding of metals and ceramics or the handling of thorium powders. The release of thoron gas depends on the physical state of Th since the short half-life of thoron permits significant emanation only from porous or finely powdered materials. The beta-gamma radiation hazard is a function of the isotopic composition of the Th. The gamma-ray activity and thoron emanation build up rapidly after chemical processing (unlike radon), but the equilibrium levels are reduced in proportion to the reduction in the ratio of Th 228 to Th 232. The melting of Th metal or sintering of Th ceramics volatilizes Ra 228 and Ra 224. These concentrate on the cooler portions of the furnace or migrate to the surface of the molten Th and produce excessive beta-gamma radiation levels. The handling of neutron-irradiated Th presents a major gamma-ray hazard, because of the formation of Th 228 and its decay products from the decay of neutron-produced U 232. Potential hazards in the following areas are discussed: Th fires; smelting; refining in India and U.S.; production of Th metal; rolling, forging and machining; Th-Hg alloys; thoriated tungsten; handling neutron-irradiated Th and U 233 feed material; welding with thoriated tungsten electrodes; Th oxide optical glass. Graphic and tabular data are included on airborne radioactivity, daughter activity, isotopic activity ratios, breathing zone samples, and radiation from Th-Hg alloy and electrostatic precipitators. (Auth) (VC)

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Albert, R.E., New York University Medical Center, Institute of Environmental Medicine, New York, NY. 1966.

Thorium. Its Industrial Hygiene Aspects. Academic Press, New York, New York.

The major areas discussed in the book are as follows (in parentheses are the specific subjects: physical, chemical, and radioactive properties of thorium and thoron (properties of Th metal, compounds of Th, Th complexes and solvent extraction, ion exchange, coprecipitation and colloid formation, radioactive properties, compounds of thoron, thoron emanation); industrial processing of Th (resources and minerals, mining and ore concentration, treatment of ores, purification of concentrates, reduction, melting and casting, fabrication, Th-Hg alloys, thoriated tungsten electrodes, thorium refractories, fabrication of castles); Th and nuclear power (reactors, fuel elements, fuel reprocessing); chemical and radiological effects of Th (chemical toxicity, biological effects of ionizing radiation, radiological toxicity); metabolism of principal isotopes in the Th 232 decay chain (Th, Pa, thoron, Pb 212); inhalation hazards (structure, deposition of particles, clearance, fate of thoron and radon decay products, lung dose, bronchial dose, lung cancer in animals, lung fibrosis and cancer in man); skeletal hazards (history, structure, metabolism of isotopes, dosimetry, radiation injury, cancer, bone cancer risks); hygienic guides (evolution of regulations, maximum permissible concentrations and calculations, uncertainties in standards); the nature of Th hazards in industry (general principles, Th fires, smelting, refining, production of metal, rolling, forging, machining, alloys with Hg, thoriated tungsten, neutron-irradiated Th and U 233 feed material, welding, optical glass); measurement of Th and thoron hazards (air monitoring, bioassay); control of Th hazards (atmospheric contamination, shielding from external radiation, classification of radiation areas, surface contamination, disposal of radioactive wastes, shipping regulations, industrial medical program). Each chapter was separately entered into the data base.

<692>

Albert, R.E., New York University Medical Center, Institute of Environmental Medicine, New York, NY. 1966, November.

Hygiene Guides. Thorium: Its Industrial Hygiene Aspects, Chapter 9. Academic Press, New York, New York, (pp. 136-148), 222 pp.

Current radiation protection standards for thorium are described and evaluated. These standards involve the control of hazards from whole-body gamma radiation, beta radiation of the skin, soluble and insoluble thorium dust, and thoron and its decay products. The standards used for thorium, in the absence of such direct experience with thorium toxicity, are derived mainly from the basic radiation protection regulations used for other forms of ionizing radiation and radioactive materials. The permissible limits for exposure to external beta and gamma radiation and the permissible dose to the lung, which is used for calculating the maximum permissible concentration in air for insoluble thorium, are standards that evolved from the control of x-ray hazards. The maximum permissible concentration in air

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<692>

RADIATION SAFETY AND CONTROL

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(WFC) for soluble thorium (which is a bone-seeking isotope) depends on the maximum permissible 3a 224 dose burden. The WFC for thoron is derived from the WFC for radon. The discussion concerns (1) the evolution of the basic radiation protection standards, (2) the calculated maximum permissible concentrations of inhaled or ingested soluble and insoluble thorium, and (3) the range of uncertainty in the current thorium standards. (Auth)

<693>

Angleton, G.W., Colorado State University, Department of Mathematics and Statistics, Fort Collins, CO; Colorado State University, Department of Radiology and Radiation Biology, Fort Collins, CO. 1967.

A Mathematical Model for the Biological Effectiveness of Radiations. Health Physics, 13, 45-50.

Cosmic, electromagnetic and other radiations in their passage through matter produce modifications of molecular structures proportional to their energy loss per unit length (LET). When the structure is an integral part of a functioning biological system, the degree of modification of biological responses depending on the integrity of this structure is a function of the LETs of the radiations. A mathematical model describing this dependency is presented. It is based on the primary postulate that there exists a critical value of the density of the energy deposition for which the contributions to the biological response is a maximum; higher values of energy density deposition correspond to the over-kill concept. An interpretation is given to the parameters of the proposed model along with the discussion as to how they may be estimated. The agreement of this model with existing data is reasonable. The model serves as a basis for extrapolation of these existing data to obtain estimates of the biological effectiveness of the cosmic rays which are characterized by extremely high values of the LETs. (Auth)

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Atherton, D.P., B.D. Lloyd, C.W. Nays, and D.H. Taysen, University of Utah, College of Medicine, Division of Radiobiology, Department of Anatomy, Salt Lake City, UT. 1971, 74p.

Radiobiology Safety Manual. CO-119-245; 33 pp.

This safety manual for a radiation laboratory studying the effect of radioactivity in logs, covers the properties of toxicity in radionuclides, maximum permissible dose-rates, permissible burdens and detection limits, and fire and explosion potential. The main kinds of radiation are defined, and procedures are outlined. (HP)

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Ausler, J.A., D.J. Christian, T.D. Jones, G.D. Kerr, F.T. Perdue, W.W. Shimpugh, and J.W. Therngate, Oak Ridge National Laboratory, Health Physics Division, Oak Ridge, TN. 1973, September.

Contribution of Natural Terrestrial Sources to the Total Radiation Dose to Man. ORNL-TN-4323; Ph.D. Thesis, Georgia Institute of Technology; 160 pp.

Investigations were done to determine the

important parameters affecting radon emanation from radionuclides for typical concentrations in soil, to determine the possibility and practicability of using high resolution spectrometers to measure low levels of radioactive contamination due to human activities, and to evaluate major sources of external and internal human exposure due to the natural radiation environment. It was demonstrated that the most important parameter in controlling the emanation of radon from concrete is the free moisture content of the concrete. Radon concentrations in dwellings constructed of uranium bearing materials are often in the range 1-5 pCi/l of air. These concentrations result in the irradiation of the basal cells of the lung bronchial epithelium near the first five bifurcations by the alpha emitting daughters of radon that often exceeds, sometimes by a large factor, the average whole body absorbed dose due to the gamma rays from the natural radiation environment. Further, the doses to these basal cells over a 50-year span may approach the levels at which the incidence of lung cancer in uranium miners is increased by a factor of two over the normal incidence in men of the same age. (Auth) (P.M.)

Table 3 shows average concentration of Th and Th in geologic formations. Table 4 shows geographical areas having soil concentrations of Th and/or Th to produce the dose increments indicated.

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Blanchard, V.L., and D.A. Holaday, U.S. Public Health Service, Occupational Health Program, Salt Lake City, UT. 1969, June.

Evaluation of Radiation Hazards Created by Thoron and Thoron Daughters. American Industrial Hygiene Association Journal, 21, 201-206.

A theoretical evaluation is given of thoron and its daughters as sources for lung radiation doses. Methods for measuring atmospheric concentrations of thoron daughters were developed. Ventilation is much more effective in reducing atmospheric concentrations of thoron daughters than it is for radon daughters. Conversely, practical rates of ventilation will not appreciably lower atmospheric concentrations of thoron. In comparison with radon daughters much longer sampling times are feasible. The calculations indicate that a concentration of only eight microcuries per liter is equivalent in potential alpha energy to a concentration of 100 microcuries of radon per liter at equilibrium (1.3×10^{10} Mev/l). At equilibrium the calculated lung radiation dose from thoron is insignificant compared to the calculated lung radiation dose from thoron daughters. On an activity basis, the permissible atmospheric concentration of thoron daughters should be much less than the level of radon daughters. (HAF)

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Breslin, A.J., and W.B. Harris, New York Operations Office, Health and Safety Division, Industrial Hygiene Branch, New York, NY. 1952, December.

Use of Thoriated Tungsten Electrodes in Inert Gas Shielded Arc Welding-- Investigation of Potential Hazard. Industrial Hygiene Association Quarterly, 13(4), 191-195.

When thoriated tungsten electrodes are used

BIOLOGICAL SAFETY AND CONTROL

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To generate an arc, radioactive thorium oxide is released from the arc and becomes airborne as a fume. The rate of release is a direct function of the rate of electrode consumption, which in turn depends on such factors as current flow, electrode diameter, and welding technique. The activity released is sufficient to exceed the maximum permissible concentration at a distance of 4" from the arc. However, the activity which is released is sufficiently diluted by normal ventilation currents that the concentration at the breathing zone of the operator is well below the maximum allowable. A variety of commercial welding techniques were tested. It is concluded that within the limits of the test inert gas welding using thoriated tungsten electrodes may be employed with no significant hazard to the operator or to other room occupants. (PAP)

(498)

Salpeter, L.A., E.P. Lyubchanskii, Yu.I. Postaler, A.F. Vifator, A.A. (Trans.) Horvath, and R.C. (Ed.) Thomas, Lovelace Foundation for Medical Education and Research, Fission Product Inhalation Laboratory, Albuquerque, NM. 1970, June.

Basis for Setting the Maximum Permissible Limits of Plutonium 239 in the Human Body, Air and Water. LP-tr-81; Problems of Plutonium Toxicology, (pp. 199-225), 225 pp. (LP-tr-41).

Problems dealing with the basis for the maximum permissible burdens (MPB) of Pu 239 in the human body and the maximum permissible concentration (MPC) in the air and water are discussed. Interest in this highly important problem of radiation hygiene is stimulated by the large biological effectiveness of Pu 239 compared with other alpha and beta emitters. This peculiarity in the biological effect of Pu 239 is reflected in the existing standards for the MPB in the human body and for the MPC for water and air - the MPE for Pu 239 (0.34 uCi) is either equal to that of the Th 232 or is 1.25-2.5 times lower than for Am 241, Sp 237, and Pa 234. Compared with the beta emitters Sr 90 and Co 60, the MPE for Pu 239 proved to be 50-125 times lower. The same trend was observed in considering the standards for the MPC of these emitters in the air, but the ratios between the MPB's of these isotopes and their MPE's are not proportional. Thus, the MPC for Pu 239 in the air surrounding industrial premises is 2.5-15 times lower than with the earlier named alpha emitters, and 150-2000 times lower than with the beta emitters. This disparity is still more pronounced between the MPE's and MPC's in comparing the MPC's of the emitters in water. The MPC of Pa 234, Ba 226, and Sr 90 have a ratio of 1:1:0.6 and their MPE's have a ratio of 1:2.5:50. The differences cited were derived using many parameters which are specific for every radionuclide. 181 references are given. (Auth)

(499)

Cofield, R.E., Union Carbide Corporation, T-12 Plant, Oak Ridge, TN. 1962.

Radioactivity Distributions in the Metallurgical Processing of Thorium. Health Physics, 7, 191-208.

The radioactivity distribution patterns produced in the metallurgical processing (particularly casting by consumable arc melting) of thorium metal have been studied.

Samples from various locations in the metal, from material deposited on process equipment, and from process area environmental sampling were subjected to gross counting, alpha- and gamma-spectrometry, and growth-decay studies. Separation of thorium and radium and the release of thoron gas are the two important effects observed. A simple gamma-spectrometry photopoint ratio method for determining the enrichment or depletion of radium in thorium samples, along with its calibration, is described. The data indicate extensive removal of the radium daughters from thorium in arc-melting, two successive arc-meltings removing essentially all of the Pa 234. The radiological hazard and analysis implications of these radioactivity distribution patterns are discussed. (Auth)

(500)

Callego, T.L., Pontificia Universidade Catolica, Rio De Janeiro, Instituto De Fisica, Brazil. 1967.

A Study of Natural Radioactivity in Brazil. STC-2577-8; 69 pp.

Results of studies of natural background radiation in some areas; radon 220 in the atmosphere; thoron body burden; thorium activity in the atmosphere and a lamp factory; thorium detection and measurement in lamp factory personnel; gamma ray activity in sears; and radiochemical assay of Pb 210, Pa 226, and Th 228 in plants in Brazil are reported. Instruments used were thermoluminescent dosimeters, scintillation flasks, whole body counters, and Casella cascade impactors. (ST)

(501)

Fry, S.M., Australian Atomic Energy Commission, Lucas Heights, Australia. 1977, October.

Radiation Hazards in Uranium Mining and Milling. Atomic Energy in Australia, 10(4), 12-31.

As well as the need to control the more conventional hazards associated with mining and milling, special care must be exercised in the mining and milling of uranium because of the radioactivity of the ore. Uranium ore, though only mildly radioactive, contains a complex mixture of radioactive isotopes, behavior of which during each phase of the mining and milling process, determines controls that must be established to ensure safe working conditions. This paper examines the radiological problems that arise in these processes and explains their scientific background. The radiation standards that should be applied and the procedures that should be adopted to minimize radiation exposure to all persons are set down in the Australian "Code of Practice on Radiation Protection in the Mining and Milling of Radioactive Ores 1975". If the requirements of this code are adhered to, the radiological safety of miners, mill workers and members of the public can be assured. The major operational requirement is to ensure that exposure of miners over their working lives to radon and its daughter products does not lead to an unacceptable increase in the chance of contracting lung cancer. Studies on the incidence of lung cancer amongst underground uranium miners indicate that this risk will be small if lifetime exposures are kept below about 120 "Working Level Months", even among underground miners who smoke cigarettes. The risk is much smaller again for miners who do not smoke. Other hazards that must be controlled are exposure of

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RADIATION SAFETY AND CONTROL

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miners and mill workers to external radiation and to dusts containing long-lived radioactive alpha emitting isotopes. Finally, the solid waste products from the mill (the tailings) which contain most of the naturally occurring radioactivity, must be properly impounded and, after closure of the mill, stabilized to ensure long-term containment. Access by the public to the stabilized tailings must be controlled and habitation within the controlled area prohibited. (Auth)

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George, A.C., L. Hinchcliffe, and B. Siodowski, Health and Safety Laboratory, New York, NY. 1974, January.

Size Distribution of Radon Daughter Particles in Uranium Mine Atmospheres. American Industrial Hygiene Association Journal, 36(1), 488-490.

The size distribution of radon daughters was measured in several uranium mines using four compact diffusion batteries and a round jet cascade impactor. Simultaneously, measurements were made of uncombined fractions of radon daughters, radon concentration, working level and particle concentrations. The size distributions found for radon daughters were log normal. The activity median diameters ranged from 0.09 μ m to 0.3 μ m with a mean value of 0.17 μ m. Geometric standard deviations were in the range from 1.3 to 4 with a mean value of 2.7. Uncombined fractions expressed in accordance with the ICRP definition ranged from 0.008 to 0.16 with a mean value of 0.04. The radon daughter sizes in these mines are greater than the sizes assumed by various authors in calculating respiratory tract dose. The disparity may reflect the widespread use of diesel-powered equipment in large uranium mines. (Auth)

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McKinn, D.J., J.S. Pollock, and P.V. Sutcliffe, Harwell Industrial Research, Chemistry Division, Atomic Energy Research Establishment, Harwell, Oxfordshire, England. 1976.

Harding, Characterization, and Monitoring of Condensates Produced by Atomization from the Molten State. Powder Metallurgy, 1, 12-16.

In any process of atomization from the molten state it is inevitable that vapor species are produced. It has been found that these vapors condense to extremely small particles of the order of 0.01 μ m diameter and larger. When such particles are produced under high-purity inert atmospheres, they are extremely pure, remain in suspension, and are therefore intensely pyrophoric when introduced to oxidizing atmospheres. In addition such particles are often toxic. The dusts resulting from the processing of ferrous, nickel, and titanium alloys have been characterized by electron microscopy in order to assess the problem of safe removal. The procedures developed to minimize the handling risks of such condensates are described in the context of operation of an arc-melting centrifugal atomizer. Sensitive monitoring techniques are available for specialized materials such as beryllium and uranium as well as the more common metals, and these can be utilized to assess the levels of both airborne and surface contamination that are likely to arise in the laboratory or plant environment from powder

atomization. (Auth)

<704>

Inq, H., and W.G. Cross, Atomic Energy of Canada Limited, Chalk River Nuclear Laboratories, Health Physics Branch, Chalk River, Ontario, Canada. 1975, December.

Spectra and Dosimetry of Neutrons from Moderation of Uranium 235 and Californium 252 Fission Sources in Water. Health Physics, 29(6), 839-851.

Spectra from Monte Carlo calculations are presented for neutrons from fission of ^{235}U and spontaneous fission of ^{252}Cf after moderation by various thicknesses of water up to 50 cm. For ^{235}U the source was located at the center of spheres, distributed uniformly throughout spheres and in the form of a collimated beam incident on water slabs. Changes in spectral shape with water thickness, source geometry and detector location are discussed with reference to spectral models used for determining neutron dose from readings of neutron detectors. For ^{252}Cf spectra were computed only with the source at the center of water spheres. These calculations provide standard fluxes of different average energies for calibration of neutron dosimeters and for checking cross-sections of various nuclear reactions. Effective cross-sections (sigma) for threshold detectors ^{10}B , ^{115}In , ^{32}S , ^{237}Th and ^{238}U were obtained by averaging the cross-sections over the calculated spectra. Average keta (K), dose equivalent and maximum dose per neutron/cm² were also calculated. Curves of sigma, K and K/sigma show the sensitivity of these detectors to changes in the fission spectrum from water moderation and also permit the computation of correction factors to dosimeter readings. Of the detectors studied, the dose responses of ^{32}S and ^{10}B were most nearly independent (± 10 percent) of spectral changes. (Auth)

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Jack, G.C., Department of National Health and Welfare, Canada. 1970.

The Radiation Protection Division's Whole Body Counter--Its Use and Calibration. Physics in Medicine and Biology, 15, 767.

The Radiation Protection Division of the Department of National Health and Welfare has two permanently-installed whole-body counters, plus auxiliary detectors and equipment including a portable whole-body counter. These systems have been used for a wide range of investigations, including studies of fallout ^{137}Cs in the Estrie population and in Ottawa school children, studies of uranium lung burdens in industrial workers, investigation of incidents involving exposure of personnel to iodine radioisotopes, and studies on the metabolism of sodium and cobalt in humans. The detectors used varied from a single 3 in. x 3 in. crystal to four large blocks of scintillator. The variety of detectors and purpose of measurement raised many different problems of calibration and the advantages of each counting system are discussed with respect to the particular application for which it was used. (Auth)

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Janusz, H., D. Mechali, and J. Lafuze.

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Problems Involved in the Practical Application of Health Regulations in Uranium Mines.
CNSL-tr-57: 3 pp.

There are three types of radiation hazards in uranium mines: external gamma radiation, internal radiation produced by long-lived dust particles, and internal radiation produced by radon and its active deposits. While gamma radiation penetrates the entire human organism, mineral dust and the active radon daughters irradiate the respiratory tract. Various methods have been suggested to eliminate the hazards. The most effective method of lowering the internal and external radiation levels of mine personnel is the organization of personnel rotations. On the public level, the main practical problem is the eventual contamination of water and food. Of the radioactive nuclides ejected with the water from the mines and mineral processing plants Pa 226 constitutes the biggest problem. Wastes occasionally produce localized contamination of water, and the use of this water, either by irrigation or for the watering of animals, can contaminate certain food chain elements such as vegetables and milk. (RNF)

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Sehestedt, P.L., J.W. Bartley, and D.K. Davis, Battelle-Pacific Northwest Laboratories, Richland, WA. 1977, January.

Use of Asphalt Emulsion Sealants to Contain Radon and Radon in Uranium Tailings.
EHWL-2190: 67 pp.

The results of a study evaluating asphalt emulsions as a sealant to contain radon in 7 mill tailings led to the following conclusions: A 3-2 mm Arak E-63 or Arak 17 59 cationic asphalt seal prevented radon diffusion to the environment. Radon diffusion rates through such a seal were calculated to be about 9×10^{-10} (E-63) pCi/sq cm sec . A 6-8 mm thick Arak E-63 seal prevented radon, radon, and nitrogen permeation under 3.5 kg/sq cm (50 psi) overpressure for 17 days. The physico-chemical properties of the tailings surface must be detailed in order to identify asphalt emulsion and/or additive requirements for good seals. The moisture content of the tailings surface must be controlled to facilitate the good penetration of emulsion required for good sealing. The integrity of the seal was not affected when asphalt emulsion tailings seal was exposed to 19 freeze/thaw (0 to 72 degrees F) cycles. The seal integrity was not affected by exposure to 100,000 R gamma radiation. UV radiation and O₂ exposure could cause deterioration of the emulsion. A layer of soil would prevent UV deterioration and anaerobic burial would prevent O₂ exposure. Microorganisms can attack asphalt, but degradation is very slow. Airless spray application of asphalt emulsion is less likely to cause bubble formation than is conventional air pressure spray equipment. It appears that such cationic asphalt emulsion applied to 6 tailings can be cost-effective. Additional studies are suggested before widespread use is made of such emulsions. The areas of study involve primarily the properties of tailings, their interactions with the sealant, technology of emulsion application, and cost estimation. (Auth) (NC)

Appendices include: Radon-radon transport through asphalt emulsion and typical data taken during laboratory experiments.

<709>

Little, J.C., Union Carbide Corporation, Nuclear Division, Y-12 Plant, Oak Ridge, TN. 1968.

Air Cleaning at the Y-12 Plant.
STI/P99/195; CONF-680311; Developmental Experience in the Treatment of Airborne Radioactive Wastes, Proceedings of a Symposium held in New York, New York, August 26-30, 1968, (pp. 695-724). 310 pp. (CONF-680311, STI/P99/195).

This paper describes some of the air-cleaning requirements of production, research, development, and biological facilities in the Y-12 area. Problems and their solutions in hazardous-material containment, air cleaning, contamination control, and air pollution control are enumerated. Bioclean and laminarflow clean rooms, germ-free supply air systems, exhaust systems for handling toxic and radioactive materials, virus containment and exhaust facilities are described. The Plant's practices regarding air cleaning are discussed including standardization of specifications for high-efficiency particulate air filters and mounting frames, DOP testing of air filter systems, and the replacement of sub-standard filter installations. Some of the radioactive materials processed in the Y-12 Plant are: ²³³U, ²³⁵U, ²³⁸U, Pa 239, Th, Ac 231. (Auth)

32 Figures are given

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Lyashkiy, P.F., V.A. Pavlovskaya, and Yu.T. Kapitanov, USSR Academy of Medical Sciences, Institute of Labor Hygiene and Occupational Diseases, Moscow, USSR. 1972.

Justification of Permissible Standards of Soluble Compounds of Thorium 232, Natural Thorium, Radium 226 and Thorium 228 in the Air of Factories. Gidreza i Sanitariya, 17(8), 53-57; TB-490-75; 6 pp.

Maximum permissible concentrations (MPC) of soluble Th 232 compounds as recommended by ICRP-59 and average annual permissible concentrations (APC) adopted by SES-69 are 2×10^{-10} (E-15) and 1.9×10^{-10} (E-15) curie/respectively. MPC of soluble compounds of Ra 226 and Th 228 are 7×10^{-14} and 9×10^{-15} respectively. Both MPC and APC values are calculated without considering the metabolism of either the parent or its daughter radionuclides nor did calculations include data concerning retention of Th in lungs or its absorption into blood. The work reported here was done to justify parameters needed to calculate standards of soluble Th compounds in factory air and to calculate maximum permissible intake (MPI) and APC of Th 232 and natural Th. On the basis of analysis of available literature as well as experimental data, a number of parameters used to calculate APC and MPI were more accurately defined. The data indicate that APC and MPI for soluble compounds of natural Th correspond to the recommendations of SES-69 and at the present time do not require revision. Standards of soluble compounds of Th 232 and Th 228 can be increased 4.7 and 6.7 times respectively and for Ra 226 reduced 40 times. In addition, it must also be taken into consideration that standards depend on the dispersity of particles. Therefore, in standardizing radioactive substances in factory air it is necessary either to indicate APC and MPI of aerosols of various dispersity or give corresponding coefficients

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RADIATION SAFETY AND CONTROL

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for conversion. (Tr) (WC)

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Iyarsky, P.F., L.Y. Elvovskaya, Ya.T. Kapitanov, and A.Y. Denisov, 1970, September.

Reglamentation of Radiation Safety Extent in Work with Natural Radioactive Substances at Enterprises of Rare Metals Production. Gigiena i Sanitariya, 9, 30-38.

Work with substances having specific activity below $1 \cdot 10^5$ (E-9) curie/g presents no radiation hazard. Changes of permissible levels and total amount of dust of loparitium and zirconium concentrate within 2 mg/cu a allow work with them to be regarded as "A" category (for personnel) and "B" category (for population) judging by the extent of radiation hazard respectively. (Tr)

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Fays, C.S., C.F. Taysun, H.D. Lloyd, and D.B. Atherton, University of Utah, College of Medicine, Salt Lake City, UT. 1966, July.

Safety Manual. CCG-119-230; 31 pp.

Safe procedures for handling radioactive materials and toxic chemicals are described. Of special interest is a section detailing appropriate measures to take following a radiation accident to decrease the body burden of internal radioactivity. (Auth)

<712>

Petta, S.K., and L.V. Krishnan, Bhabha Atomic Research Center, Health Physics Division, Trombay, Bombay, India. 1969.

Safety Features in the Design of Radiological Laboratories, Trombay. CONF-691008; 58-125/1; Radiation Safety Problems in the Design and Operation of "Hot" Facilities, Proceedings of a Symposium held in Saclay, France, October 13-17, 1969, (9 pp.) (CCNY-691008, 58-125/1).

India's nuclear program of development and fabrication of U and Pu oxide fuels for fast breeder reactors, investigations of compounds of uranium, thorium, plutonium, transuranic elements and fission products and increased isotope production necessitated new laboratories and handling facilities for multi-kilocurie activities. The radiological laboratories were designed as a single facility to cater to the above diverse functions carried out by the Metallurgy, Radiochemistry and Isotope Divisions of the Bhabha Atomic Research Centre (B.A.R.C.) at Trombay. A description is given of the safety features in the laboratory design and operation, and of the hot cells, the glove boxes and shielded boxes, the ventilation system, the radiation monitoring and fire protection system. (PAM)

<713>

Porgan, J.W., and L.G. Faust, Hanford Atomic Products Operation, Richland, WA. 1966, July 15.

A Comparison of Theoretical and Measured Dose Rates of Thorium and Thorium Oxide. HS-83206; 17 pp.

The surface dose rate due to each isotope in the thorium chain was calculated by means of currently accepted formulas. After corrections were made for the rate of equilibrium of the material, good agreement

was found between theoretical and experimental values of surface dose rates. The thorium being produced at H.A.P. should not present a serious problem with respect to external personnel exposure. Formulas are presented which give an approximate value for the time lapse since the most recent purification. Gamma and alpha energy spectra measurements for the metal and the oxide of thorium are presented, and are in full agreement with those given in the literature. (Auth)

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Morsy, S.W., E. Jahas, and A.A. Aloush, Atomic Energy Establishment, Radiation Protection Department, Cairo, Egypt. 1970.

In Vivo Gamma-Spectrometric Investigation of Thorium Body Burden in the Egyptian Monazite Area. Health Physics, 10, 263-266.

Thorium body burdens in the Egyptian monazite area have been investigated using a whole body counter provided by a 6 in. X 8 in. NaI(Tl) crystal. In the course of analyzing the results, it was assumed that Th 232 which is initially 100% in equilibrium with its daughters reaches a steady state of 40-50% equilibrium in the body due to the metabolic effects. The measurements have been performed for the inhabitants of Rosetta as well as workers of the Egyptian Black sand refinery plant. The detection sensitivity for a single individual worker or inhabitant was 3.04 nCi and 3.01 nCi respectively. Treating each group as statistically equivalent, the minimum detectable activity was 0.8 nCi and 0.93 nCi respectively. Activity was found in either group. (Auth) (PAP)

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National Council on Radiation Protection and Measurements, Washington, DC. 1970.

Specification of Units for Natural Uranium and Natural Thorium. Medical Physics, 1(1), 35.

Maximum permissible body burdens (MPBB) and maximum permissible concentration (MPC) in air and water for natural U were originally expressed in units of mass and mass per unit volume, respectively. Later, the ICRP recognized a special curie for natural U and Th. For U, this corresponded to the sum of 3.7×10^{10} (E+10) dis/sec from U 238, the same for U 235, and 1.7×10^{10} (E+9) from U 234. This unit has been confusing and compromises the integrity of the curie. Thus, ICRP recommends that the special curie not be used and that mass units be used for natural U. Thus, MPBB and MPC values in the ICRP Report No. 22 may be multiplied by 3×10^{10} (E+6) ug per special curie; the MPC for air for a 40-hr/wk exposure to soluble natural U compounds with the kidney as reference organ becomes a 210 ug/cu m and for insoluble compounds with lung as the critical organ, 180 ug/cu m. Such a conversion connotes no specific endorsement of the values or any implication regarding whether the primary mechanism of damage is irradiation or chemical toxicity, subjects which are currently being studied. The special curie for natural Th corresponded to the sum of 3.7×10^{10} (E+10) dis/sec from Th 232 and the same for Th 230. The ICRP also recommends that this definition be discontinued. Since the isotopic composition is not constant, use of a limiting concentration for natural Th as an entity should be discontinued and established values for the individual Th isotopes should

RADIATION SAFETY AND CONTROL

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Re: U.S. (Auth) (VC)

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Seufert, J., and M. Wright, Oak Ridge National Laboratory, Health Physics Division, Oak Ridge, TN. 1972, August.

Radiation Levels and Fluence Conversion Factors. Health Physics, 23, 183-186.

The Code of Federal Regulations defines a radiation area and high radiation area in terms of dose equivalent rate, but the manner in which dose equivalent rate is to be determined from measurements of the field has not been prescribed. It is suggested in this investigation that radiation area and high radiation area be defined in terms of effective radiation level which is the rate of change of the maximum dose equivalent in an anthropomorphic phantom placed in the radiation field. A discussion is given on the conversion of physical data describing radiation into the effective radiation level, and the significance of normal station based on fluence and incident fluence is pointed out. (Auth)

(717)
Valley, D.T., U.S. Environmental Protection Agency, Office of Radiation Programs, Surveillance and Inspection Division, Washington, DC. 1977, June.

Natural Radiation Exposure in the United States. (EPA-510-72-1; 68 pp.

The exposure of man to natural radiation sources in the United States was estimated by considering the distribution of the population with respect to certain factors, principally geology and elevation, which influence exposure to terrestrial and cosmic radiation. Data obtained by aerial surveys in the United States were used to calculate an average dose equivalent (DE) estimate of 40 mrem/yr to the population. The results also indicate three distinct areas of terrestrial radioactivity in the United States: 1) the Coastal Plain, which consists of all or portions of states from Texas to New Jersey (23 mrem/yr); 2) a portion of the Colorado Front Range (90 mrem/yr); and 3) the rest of the United States, i.e., portions of the United States not included in "1" or "2" (86 mrem/yr). Since elevation is the primary determinant of cosmic ray DE in the United States, the population distribution with respect to elevation was determined. The average population elevation of the United States was determined to be approximately 700 feet, and the average cosmic ray DE was estimated to be 48 mrem/yr. To arrive at an estimate of the gonadal DE, the influence of housing, biological shielding, and the DE contribution from internal emitters was also considered. The first two factors serve to attenuate man's gonadal DE due to terrestrial radiation by about the same amount that is contributed by internal emitters. The average gonadal DE to the United States population was calculated to be 48 mrem/yr and the average bone marrow DE was 87 mrem/yr. (Auth)

Table 9 shows radionuclide content and dose equivalent rates (of uranium, thorium and K 40) from common rocks and soil. Table 10 shows ground surveys of background radiation in the United States. Table 11 shows dose equivalent measurements in the United States. Figure 11 shows dose equivalent rate due to fallout in the

United States, 1950-1971. Table 17 shows the gonadal dose equivalent to the United States population from natural radiation.

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Owen, F.E., Hanford Atomic Products Operation, Irradiation Processing Department, Process and Reactor Development Research and Engineering, Richland, WA. 1968, April.

Beta-Gamma Dose Rates from Uranium 232 in Uranium 233. HW-81964; 23 pp.

The significant external dose rate from ^{233}U comes from the daughters of the ^{232}U that is present as an impurity. For this reason, the dose rates increase with time as the daughter activity increases. The rate of increase is governed by the 1.9-yr half-life of ^{228}Th . The radiation consists primarily of very penetrating gamma (2.6 Mev) from ^{208}Tl and energetic beta from both ^{212}Bi (2.26 Mev) and ^{212}Po (1.8 Mev). At 1 ppm ^{232}U , the dose rate starts well below that of ^{239}Pu but is equal to it within a month or two and reaches a level an order of magnitude higher within a year. The dose rates will be in direct proportion to the amount of ^{232}U present, increased amounts of which will significantly reduce the age at which ^{233}U can be handled at a reasonable dose rate. For example, at 10 ppm ^{232}U , the ^{233}U dose rate exceeds that of ^{239}Pu in 10 days and is two orders of magnitude higher in a year. (Auth)

(719)
Owen, F.E., Hanford Atomic Products Operation, Irradiation Processing Department, Research and Engineering Section, Richland, WA. 1968, May 15.

Recycled Thorium Dose Rates. HW-81933; 11 pp.

The dose rates which one can expect to encounter in handling recycled thorium target elements from the production of ^{233}U are described, along with the activities of the various dose contributors and how they change with time after processing. The two important sources of radiation dose in thorium are ^{228}Ac and the ^{228}Th daughters. The concentrations of ^{228}Ac and daughters of ^{228}Th in natural thorium are reduced by the recycle process. In recycling thorium, ^{228}Th builds in during the cooling period from the ^{232}U created during irradiation increasing the concentration of ^{228}Th daughters. In producing ^{233}U with 5 ppm ^{232}U from thorium which cools for 270 days and is recycled annually, the thorium will maintain a dose rate very close to that of natural thorium at secular equilibrium. Production of ^{233}U with 1 ppm ^{232}U will reduce the dose rate from thorium by a factor of eight which makes it about equal to natural uranium. At 10 ppm ^{232}U , the dose rate is increased by a factor of three. Thorium 230 would materially increase the dose rate but because of its short half-life (28.1 days), it decays to insignificance within the cooling period. Exceptions to this occur when high fluxes are used greater than 5×10^{13} n/cm²/sec, or when the cooling period is sufficiently less than 270 days. (Auth) (PAF)

(720)
Reynolds Electrical and Engineering Company, Inc., Nevada Test Site, Mercury, NV. 1968, July.

Radiological Emergency Operations, Student's Manual. TID-24919; 425 pp.

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RADIATION SAFETY AND CONTROL

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The Student's Manual provides guidance and information for the student attending the ten-day Radiological Emergency Operations course. The manual includes: the schedule of classes, a list of publications recommended as texts for the course, information as to where to obtain the recommended texts, a bibliography of references, movie films used in this course, a brief outline of the subject matter covered in each lesson, study questions and answers on the main points in each lesson, and technical reference information pertinent to the subjects covered. Section 4 of the manual contains a chapter on each of the twenty-two subjects covered in the lessons. Among these topics are: radiation detection instruments, air sampling techniques, radioactive materials (including U, Pu, Th, I, Cs, Tritium and Sr), radiological accidents, biological effects of radiation, emergency team operating procedures, safe handling of radionuclides, decontamination, and legal and press responsibilities. (Auth) (FNN)

See also Instructor's Manual, TID-20918.

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Schubert, J., Argonne National Laboratory, Chicago, IL. 1951, March.

Estimating Radioelements in Exposed Individuals.
2. Radiations Dose and Permissible Levels.
Nucleonics, 8(3), 66-78.

The practical side of judging the amounts and fate of radioactive substances that enter a worker's body involves consideration of arbitrary standards. These standards interrelate physiological data on "standard man" and the properties of the radioelements most harmful to him. Statistics and physiological data for the standard man are given. Permissible body content values for the metal radioisotopes and the fraction retained in the body after different routes of exposure are tabulated. (BBN)

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Schubert, J., Argonne National Laboratory, Chicago, IL. 1951, April.

Estimating Radioelements in Exposed Individuals.
1. Bioassay Operations and Procedures.
Nucleonics, 8(4), 59-67.

Based on established practices at Argonne, recommendations are outlined for administrative and analytical procedures designed to protect personnel from overexposure to radioactive elements. Four requirements must be met for results of bioassay work to be reliable. The bioassay laboratory should be isolated and have equipment, atmosphere, and fixtures as free as possible from contamination. Analytical methods should be capable of isolating carrier-free amounts of a radioelement from large amounts of urine and feces. The alpha-counting instruments used should have a maximum background of 5 counts an hour for a sample counted at 50% efficiency. Strict regulations for collecting and handling specimens from personnel should be put into effect. Analytical radiochemical procedures for routine bioassay operations are detailed for Pa 226, Pu 239, Am and Cm, Po, Ac 227, Th 230, Th 232, and rare earths, alkaline earths, Tl, S 35, C 14, and radioisotope mixtures. (BBN)

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Smith, C.F., T.W.T. Barrett, and S.Z. Eastenberg, University of California, School of Engineering and Applied Science, Los Angeles, CA. 1975.

A New Relative Hazard Index. CONF-751126: Biological Effects of Low-Level Radiation Pertinent to Protection of Man and his Environment, Proceedings of an International Symposium held in Chicago, Illinois, November 3-7, 1975, (pp. 225-237) (CONF-751126, IAEA-SM-202/536).

A new relative hazard index is derived for use in the assessment of the future burden to mankind from the presence of radionuclides in the environment. Multiple decay schemes, non-equilibrium conditions, and finite time periods are taken into account. As an application of this hazard index, a comparison is made between thermal reactor radioactive waste and the uranium required as fuel with the following conclusions: 1) For short time intervals ($\delta < \text{or} = 5000$ years), the waste hazard index equals the uranium ore hazard index for a release time of 2000 years or less. 2) For short time intervals of concern, the waste hazard index equals the consumed uranium index at a release time of approximately 20,000 years. An important factor is the consumption of U 238 breaking the uranium decay chain. 3) For long time intervals of concern ($\delta > \text{or} = 500,000$ years), the reactor waste and consumed uranium indexes are equal after a such shorter decay time (about 10 years). (Auth) (BAF)

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U.S. Environmental Protection Agency, Field Operations Division, Office of Radiation Programs, Washington, DC. 1973, October.

Exposure Pathway, Radiation Dose and Health Effect Parameters. EPA-520/9-73-003-B; Environmental Analysis of the Uranium Fuel Cycle, Part 1, Fuel Supply, Appendix, (pp. A-10 - A-30), 189 pp. (EPA-520/9-73-003-B).

This appendix to a report on the environmental analysis of the U fuel cycle explains the assumptions and parameters used in (1) calculating how radiation effluents discharged from fuel supply operations are transported through the environment, (2) calculating the doses resulting from the interaction of radiation with man, and (3) converting radiation doses to health effects. The effluents include U and associated daughter products both as aerosols and liquid soluble effluents. Tables are provided of dose conversion factors for the airborne soluble and insoluble particulates of U 238, U 235, Th 230 and Pa 226. Also in tabular form are airborne and waterborne dose calculations and health effects for model facilities, including health effects resulting from the 100-year dose commitment from U, doses to critical organs from naturally occurring U and air releases of one curie from a model plant. (BAF)

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Voigt, A.P., Iowa State College, Institute for Atomic Research, Department of Chemistry, Ames, IA. 1956.

Hazards Associated with Thorium Metallurgy. The Metal Thorium, H.A. Wilhelm (Ed.), Chapter 19, Proceedings of a Symposium held in Cleveland, Ohio, October 11, 1956. American Society for

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Metals, Cleveland, Ohio, (pp. 296-315).

Sources of danger to personnel in the metallurgical operations are chemical and radiological toxicity, fire, and explosion hazards. Thorium salts are not excessively toxic; acute reactions would be produced in man by ingestion of 100 g. Soluble salts in the blood cause damage such as hemolysis, necrosis, and irritation. At appreciable concentrations, inhaled dusts of compounds produced only minor toxicity; major effects were changes in white blood cells and bone marrow. Radiological toxicity is primarily from high energy gamma radiation. Radiation levels in work areas must be held within acceptable limits. Storage for excess material as well as protective measures for personnel should be provided. Effects from decay products must be considered along with those of Th itself. Like Pa, Th is deposited in bone near blood-forming areas. The energy from bone Th is two to five times as damaging as an equivalent amount of Pa which is deposited in the crystalline portion of bone. A large part of Pa 228 daughter activity (from Th 228) is released from the bone; part is excreted and part relocates in less sensitive bone areas thereby reducing the toxicity of the chain. Thorium actions of other members of the decay series are discussed. Thorium and Th daughter concentrations considered as reasonable permissible levels in air are tabulated. In a Th refinery in operation 30 years, there have been no cases of radiation injury even though air Th levels are higher than reasonable permissible values; thus, standards appear adequate. Hazards in the Ames process of Th production are discussed. Powdered Th and ThO₂ are pyrophoric and explosive as powders and should be handled with caution. Hazards to possible dangers, along with adequate safeguards is necessary in work with Th. A program should include radiation health supervision and equipment as well as a good physical safety program. (VC)

usefulness is dependent on the Th 232/Th 228 ratio of exposure materials and on the relative amount of thorium as related to its daughters. Pa 228 has to be considered as an internal hazard which must be evaluated independently. The lung burden of Pa 228 and thorium are additive. In operations involving high temperatures, the radium isotopes may be a much greater hazard potential than thorium. The direct exposure potential from thorium appears to be no greater than that from normal uranium. (RAF)

(727)
West, C.N., Union Carbide Corporation, Y-12 Plant, Oak Ridge, TN. 1965, March 10.

Health Physics Considerations Associated with Thorium Processing. Y-KF-53: 30 pp.

Approaches to the health physics problems of thorium area and personnel monitoring are presented with emphasis on the techniques used in the Y-12 plant, a thorium metallurgical processing facility. A system has been developed for area monitoring and data interpretation to avoid the complications caused by the many short-lived thorium daughters and at the same time insure adequate information at reasonable cost. It is difficult to evaluate internal exposures to thorium because fecal, urine, and breath thoron analysis provide very doubtful data. Additional human and/or animal data relative to the excretion of thorium and/or daughters by urine, feces, and particularly breath are needed before thorium lung burdens are to be satisfactorily evaluated by bioassay methods. However, exposure estimates by IN VIVO monitoring are practicable. The potential internal hazard from thorium is shown to be greater than that of uranium but many times less than that from plutonium. (Auth) (RAF)

(728)
Wrenn, R.E., U.S. Atomic Energy Commission. 1974.

An Examination of the Potential Relative Toxicity of Uranium and Plutonium in LWR and HTGR Fuel. Transactions of the American Nuclear Society, 18, 392-393.

The U nuclides for high-temperature gas-cooled reactors (HTGR) and plutonium nuclides from light-water reactors (LWR) are examined with respect to relative toxicity. Typical isotopic compositions of U and Pu in fuels are tabulated. The specific alpha activity of Pu in LWR fuel varies from 0.7 Ci/g in recycle mode to 0.8 Ci/g without recycle. Most of the activity is due to Pu 238 and is in excess of that of low burnup material, primarily Pu 239, SA of 0.06 Ci/g. LWR Pu has a SA 1/30 that of Pu 238. With regard to distribution and toxicity, the Pu of LWR fuel might behave in an intermediate manner between Pu 239 and Pu 238. In HTGR fuel, high SA is associated with U 233 which contains abundant 232 with respect to activity; U 232 is also associated with buildup of high-energy gamma emitters. The specific alpha activity of this U is less than that of Pu in LWR recycle fuel although this SA is only four times less than that of Pu 239. The SA of the U 235 is two orders of magnitude less than U 233 which in turn is two orders higher than that of natural U. Uranium 233 has SA of five orders of magnitude greater than natural U. Thus, the U 233 fraction represents a toxicologically new type of U because of its high SA. After attempting to evaluate relative toxicities of

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West, C.N., Union Carbide Corporation, Y-12 Plant, Oak Ridge, TN. 1962.

An Evaluation of the Health Physics Problems from Thorium and Its Daughters in a Thorium Purification and Fabrication Process. Health Physics, 8, 279-297; CONF-610601; Health Physics Society, Proceedings of a Symposium held in Las Vegas, Nevada, June 12-16, 1961, (19 pp.) (CONF-610601).

Evaluation of the health physics problems associated with thorium processing is complicated by the presence of the short-lived daughters of the decay chain. Measurements made during exploratory thorium purification and fabrication processes included direct counting, alpha- and gamma-spectrometry, and IN VIVO counting. Data, illustrating and defining the daughter complications, are reported. In many cases over 90% of the alpha activity noted by conventional counting techniques is due to the daughter elements. It is concluded that a realistic evaluation of radiological hazards associated with thorium processing should include isotope identification techniques as well as screening by direct radiological counting. Beta and alpha-counts should be made on air and sweat samples for the purpose of screening and further action. The IN VIVO counting offers a feasible method of evaluating the degree of internal personnel exposure from thorium. Its ultimate

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RESEARCH, SUPPLY AND CONTROL

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the two materials, one can conclude that the
Pu nuclides are more potentially toxic than
U. However, this estimate is not adjusted
for relative amounts of materials available

in the two cycles and is developed on a per
gram basis. (Auth) (UC)

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Fasen, S., Oak Ridge National Laboratory, Oak Ridge, TN. 1975.

Some Activities in the United States Concerning the Physics Aspects of Actinide Waste Recycling. (ORNL-751178; Transactional Isotope Nuclear Data, Proceedings of the IAEA Advisory Group Meeting held in Karlsruhe, Germany, November 2-7, 1974, (15 pp.) (ORNL-751178).

The reactor types which are considered for the purpose of actinide waste recycling include thermal reactors operating on the 1.1 percent ^{235}U and the $\text{U}^{233}\text{-Th}^{232}$ fuel cycles, liquid metal fast breeder reactors, reactors fueled entirely by actinide wastes,

gaseous fuel reactors, and fusion reactors. Quantitative predictions of the various nuclei produced, transmuted and fissioned in reactors are necessary for systematic actinide management. These quantitative predictions are made with special computer programs which require relevant cross sections of all the nuclides in the region of interest. Deficiencies in many areas of neutron section measurements are noted. Cross section measurement programs in progress or planned toward providing basic data for testing the recycle concept are briefly discussed. (14p)

WASTE DISPOSAL AND MANAGEMENT

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Pell, E.J., and E.S. Dillon, Oak Ridge National Laboratory, Oak Ridge, TN. 1971, November.

Long-term Hazard of Radioactive Wastes Produced by the Enriched Uranium, Plutonium-Uranium 238, and Uranium 233-Thorium Fuel Cycles. ORNL-TN-3548; 23 pp.

An evaluation was made of the long-term hazards of high-level and alpha radioactive wastes generated by irradiation of three fuels representative of those that will be used to generate electrical power in the next several decades. In this evaluation, the composition and radioactivity of the wastes generated by typical LWR, LMFBR, and molten-salt breeder reactors utilizing enriched uranium, Pu-U 238, and U 233-Th fuel cycles, respectively, have been computed for times up to 10 billion years after discharge. The volumes of water necessary to dilute the various types of high-level waste to the radiation concentration guides (RCG) for ingestion in unrestricted areas were computed as a function of age of the waste. It was found that the volumes required to dilute the three types of waste were similar when evaluated at the same age and exposure. The volume of water necessary to dilute any of the three wastes aged 1000 yrs and the associated salt in the proposed Federal Repository to the RCG for unrestricted areas is less than that required to dilute the same amount of uranium ore tailings to the RCG. The high-level waste deposited in the Federal Repository will result in an alpha activity of less than 10 micro Ci/kg at 10,000 yrs after burial when averaged over the total mass of the repository. The hazard of a number of types of waste contaminated to 10 micro Ci/kg (the upper limit assumed for surface burial) of initial parent alpha activity was also calculated as a function of time, and the time of maximum relative hazard was determined. Transuranium or alpha wastes contaminated to this level will present a serious ingestion hazard similar to naturally occurring uranium ores. (Auth)

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Pohach, R.W., J.C. Davis, R.W. Ross, and J.B. Stevenson, National Lead Company of Ohio, Cincinnati, OH. 1971, April.

Disposal of Low-Level Radioactive Wastes from Pilot Plants. Chemical Engineering Progress, 67(4), 81-86.

The National Lead Company of Ohio produces uranium and thorium materials for the Atomic Energy Commission. Activities in the pilot plant have included experimental operations and tonnage quantity production of Th and U materials. The paper deals with handling of wastes from this and other plant operations. Major equipment in the pilot plant complex includes a solvent extraction system, a "wet area" for aqueous feed dissolution and precipitation, and a "dry area" containing furnaces, heat treating systems and other equipment for metal production. These operations produce several waste streams, all of which contain low levels of radioactivity. Aqueous effluents are the major type of contaminated waste. Their treatment is required because they may contain enough Th for ecological recovery, radioactive decay products of Th may be high enough to require removal for release into the Great Miami River, or acid solutions must be neutralized before final treatment and disposal. The extraction process produces as much as 1500 gal/day of acidic waste. Treatment processes

are described. The effluent is first neutralized, precipitated and filtered. The solids from the precipitation are sent away for burial. The treatment of other liquid and solid wastes is described. Procedures for handling wastes include daily sampling and analysis to ensure that the river maintains drinking water standards. (VC)

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Claiborne, H.C., Oak Ridge National Laboratory, Chemical Technology Division, Oak Ridge, TN. 1975, January.

Effect of Actinide Removal on the Long-Term Hazard of High-Level Waste. ORNL-TN-6724; 40 pp.

A possible method for improving the management of high-level radioactive waste involves the removal of actinides to a very high degree to reduce the long-term hazard potential of wastes stored in geological formations. In this method, actinides are removed to levels where their contribution to the hazard potential is comparable to that from the long-lived fission products. Removal of actinides to this extent reduces the long-term (>1000 years) hazard potential of high-level waste to about 5% of that for pitchblende mineral on the basis of the hazard index. Calculations show removals of 99.9% plutonium, 99.9% uranium, americium, and curium, and 95% neptunium from spent uranium-plutonium fuels accomplish this result. High Temperature Gas-Cooled Reactor fuel will also require removal of 99.5% thorium and 95% protactinium, and increasing the uranium removal to 99.9%. Attaining these actinide removal percentages will require removal factors that are 10 to 100 times greater than have been achieved with existing high-radiation-level processing technology. Consideration of removal of long-lived fission products and additional actinides does not appear to be warranted until it has been demonstrated that actinides can be removed to levels approaching the present calculated values. These values of actinide removals serve as a desirable goal in process development studies of the waste fractionation program at Oak Ridge National Laboratory. (Auth)

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Clark, D.A., Robert S. Kerr Environmental Research Laboratory, Ada, OK. 1974, June.

Waste Treatment and Disposal. EPA-660/2-74-038; State-of-the-Art: Uranium Mining, Milling, and Refining Industry, Section 10, D.A. Clark (pp. 63-74), 113 pp. (EPA-660/2-74-038).

The maximum permissible concentration in water, (MPC(w)), for uranium is 13,300 picocuries/l. which is equivalent to 40 milligrams of U/l. The MPC(w) values for several other radionuclides are given in tabular form. Waste treatment systems have been designed with the major objective to remove extremely hazardous radionuclide 226 from the effluent. Various types of waste treatment and disposal practices are discussed. Environmental surveys have been made of several U mill tailings piles to evaluate potential radiation hazards. Some of the conclusions are that the radiation levels on the tailings were of such levels as to preclude the release of the tailings area in public use; wind environment spread tailings area for material to distances of 1,000 feet from the tailing area to the extent that radiation levels exceeded recommended standards; Ra 226 and Th 230

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WASTE DISPOSAL AND MANAGEMENT

<732> CONT.

concentrations in art exceeded recommended concentrations downward from the pile of left uncovered and unstabilized. Remedial measures have been taken by members of the industry. Other waste disposal methods discussed are chemical treatment and dilution, underground disposal such as by deep well injection, recycling of discharges and offsite disposal such as in abandoned mines. (PHE)

<734>

Clarke, R.H., and H.V. MacDonald, Berkeley Nuclear Laboratories, Central Electricity Generating Board, Berkeley, England; Imperial College of Science and Technology, Department of Mechanical Engineering, Nuclear Power Section, London, England. 1975, July.

Waste Disposal Aspects of the Long Term Cooling Characteristics of Irradiated Nuclear Fuels. *Annals of Nuclear Energy*, 2, 851-866.

A study has been made of the long term cooling characteristics of nuclear fuels irradiated in commercial reactor designs of interest within the United Kingdom. In the case of thermal reactors, Magnox, AGR, SGWR, LWR and HTGR systems fuelled with either natural or enriched uranium are reviewed, together with a fast reactor fuelled with plutonium derived either from the Magnox or the AGR programs. Alternative uses for Magnox plutonium are discussed by simulating a plutonium fuelled HTGR thermal system and the development of a Th/U 233 fuel cycle has been anticipated for both a fast reactor and an HTGR. For each system the activities as a function of cooling time are given on the assumption of 100% recovery from the fuel during reprocessing, within a year of discharge from the reactor and for the alternative case of 50 U/Pu extraction. The reprocessing waste products associated with the various fuel cycles have then been compared both on the basis of decay heating and radiological hazard per GW(e) yr. The thorium fuel cycles considered show reduced radiological hazards, negligible neutron dose rates and improved long term cooling characteristics compared with the conventional uranium or plutonium systems. Finally, recycling of transplutonium elements is also considered with a view to reducing the long term heating commitment from the higher actinides. (PAP)

<735>

Lavis, W., Jr., R.E. Blanco, B.C. Finney, G.S. Hill, R.E. Moore, and J.P. Witherspoon, Oak Ridge National Laboratory, Chemical Technology Division, Oak Ridge, TN. 1976, May.

Correlation of Radioactive Waste Treatment Costs and the Environmental Impact of Waste Effluents in the Nuclear Fuel Cycle - Reprocessing of High-Temperature Gas-Cooled Reactor Fuel Containing Uranium 233 and Thorium. ORNL/WDREG/TN-4; 182 pp.

A cost/benefit study was made to determine the cost and effectiveness of various radioactive waste (radwaste) treatment systems for decreasing the release of radioactive materials from a model high-temperature gas-cooled reactor (HTGR) fuel reprocessing plant and to determine the radiological impact (dose commitment) of the released materials on the environment. The study is designed to assist the U.S. Nuclear Regulatory Commission in defining the terms "as low as reasonable achievable" as it

applies to this nuclear facility. The base case is representative of conceptual, developing technology of head-end graphite-burning operations and of extensions of solvent-extraction technology of current design for light-water-reactor (LWR) fuel reprocessing plants. The model plant has an annual capacity of 450 metric tons of heavy metal (HTM), where heavy metal is uranium plus thorium, as charged to about fifty 1000-MW(e) HTGRs. Additional radwaste treatment systems are added to the base-case plant in a series of case studies to decrease the amounts of radioactive materials released and to reduce the radiological dose commitment to the population in the surrounding area. The capital and annual costs for the added waste treatment operations and the corresponding reductions in dose commitments are calculated for each case. In the final analysis, the cost/benefit of each case, calculated as additional cost of radwaste system divided by the reduction in dose commitment, is tabulated or the dose commitment is plotted with cost as the variable. The status of each of the radwaste treatment methods used in the case studies is discussed. Much of the technology used in the advanced cases is in an early stage of development and is not suitable for immediate use in detailed designs of an HTGR fuel reprocessing plant. However, the radwaste treatment methods are believed to be reducible to practice. The methodology used in estimating the costs is presented in Appendix A. (Auth)

See also ORNL/WDREG/TN-5 and ORNL/WDREG/TN-7.

<736>

Molovay, C.F., W.A. Goldsmith, and V.H. Elfridge, Oak Ridge National Laboratory, Health Physics Division, Health Physics Information System, Oak Ridge, TN; Oak Ridge National Laboratory, Health Physics Division, Assessment Technology Section, Oak Ridge, TN. 1975, December.

Uranium Tailings Bibliography. ORNL-5109; 97 pp.

In the bibliography 1,212 references are listed based upon the general problem of reducing human exposure to tailings pile radionuclides from uranium mills. The references are divided into 7 broad categories: Uranium tailings pile, standards and philosophy, Etiology of radiation effects; internal dosimetry and metabolism, environmental transport; background sources of tailings radionuclides, and large-area decontamination. (JTE)

<737>

Lewis, W.B., Atomic Energy of Canada Limited, Chalk River Nuclear Laboratories, Chalk River, Ontario, Canada. 1972, October.

Radioactive Waste Management in the Long Term. OR-123; 11 pp.

A future is envisaged in which a world of 15,000 million people is supplied with energy from nuclear fission at an average of 50 thermal kilowatts per capita. The resulting radioactive wastes are managed permanently within the boundaries of plants that recover fuel for recycle and fabricate the new nuclear fuel. It is foreseen that a single plant would manage the fuel and wastes for 250 to 300 million kilowatts electric generating capacity. By the year 2000 about four such plants may be seeded in North

WASTE DISPOSAL AND MANAGEMENT

<737> CCST.

America. In the long-term future about 1,000 such plants would meet the envisaged world demand. An outline is sketched of the operations in such a plant on a near-breeding thorium-uranium fuel cycle. The operations are characterized by multiple parallel cycles for all materials and retrievable storage of radioactive wastes. (Auth)

<738>

Oak Ridge National Laboratory, Chemical Technology Division, Oak Ridge, TN. 1975, January.

Program for Improved Waste Management in Commercial Nuclear Fuel Reprocessing Facilities. ORNL-TM-4722; 24 pp.

The principal objective of the program proposed in the report is to decrease the long-term (more than 1000 years) hazards of radioactive wastes from commercial nuclear fuel reprocessing facilities. This is to be accomplished by modifying reprocessing methods currently in use to increase actinide recoveries and to produce waste streams that are amenable to recycle or further treatment; all wastes should be treated so as to achieve separation into a solid, fission-product-containing fraction with low concentrations of long-lived actinides and a separate concentrated fraction containing the actinides. After sufficient information has been accumulated from laboratory-scale studies to allow preparation of overall, detailed flowcharts and to permit making a technical evaluation, a detailed review will be made to determine if the program should be continued through construction and operation of a large-scale demonstration plant that will satisfactorily treat all waste streams from a scaled nuclear fuel reprocessing facility. There is a listing and brief summary of the tasks required to carry out this program. Also included are estimates of the manpower, costs, and time required to complete the program. (Auth)

<739>

Boddy, J.W., R.E. Blanco, G.S. Hill, R.E. Moore, W.D. Seagren, and J.P. Witherspoon, Oak Ridge National Laboratory, Chemical Technology Division, Oak Ridge, TN. 1976, September.

Correlation of Radioactive Waste Treatment Costs and the Environmental Impact of Waste Effluents in the Nuclear Fuel Cycle - Fabrication of High-Temperature Gas-Cooled Reactor Fuel Containing Uranium 233 and Thorium. ORNL/NUREG/TR-5; 217 pp.

A cost/benefit study was made to determine the cost and effectiveness of various radioactive waste (radwaste) treatment systems for decreasing the release of radioactive materials from model High-Temperature Gas-Cooled (HTGR) fuel fabrication plants and to determine the radiological impact (dose commitment) of the released materials on the environment. The study is designed to assist the U.S. Nuclear Regulatory Commission in defining the term "as low as is reasonably achievable" as it applies to these nuclear facilities. The base cases of the two model plants, a fresh fuel fabrication plant and a refabrication plant, are representative of current proposed commercial designs or are based on technology that is being developed to fabricate uranium, thorium, and graphite into fuel elements. The annual capacities of the fresh fuel plant and the refabrication plant are 450 and 245

metric tons of heavy metal (where heavy metal is uranium plus thorium), as charged to about fifty 1000-MW(e) HTGRs. Additional radwaste treatment systems are added to the base case plants in a series of case studies to decrease the amounts of radioactive materials released and to reduce the radiological dose commitment to the population in the surrounding area. The capital and annual costs for the added waste treatment operations and the corresponding reductions in dose commitments are calculated for each case. In the final analysis, the cost/benefit of each case, calculated as additional cost of radwaste system divided by the reduction in dose commitment, is calculated or the dose commitment is plotted with cost as the variable. The status of each of the radwaste treatment methods used in the case studies is discussed. Each of the technology included in the advanced case studies has been utilized in either pilot-plant or industrial-scale operations, although no existing fabrication plant has used all of the treatment methods. The methodology used in estimating the costs is presented in Appendix A. (Auth)

See also ORNL/NUREG/TR-4 and ORNL/NUREG/TR-7.

<740>

Sears, R.E., R.E. Blanco, R.C. Finney, G.S. Hill, R.E. Moore, and J.P. Witherspoon, Oak Ridge National Laboratory, Chemical Technology Division, Oak Ridge, TN. 1977, September.

Correlation of Radioactive Waste Treatment Costs and the Environmental Impact of Waste Effluents in the Nuclear Fuel Cycle - Conversion of Yellow Cake to Uranium Hexafluoride. Part I. The Fluorination-Fractionation Process. ORNL/NUREG/TR-7; 305 pp.

A cost/benefit study was made to determine the cost and effectiveness of radioactive waste (radwaste) treatment systems for decreasing the release of radioactive materials and chemicals from a model uranium hexafluoride (UF₆) production plant using the fluorination-fractionation (dry hydrofluor) process, and to evaluate the radiological impact (dose commitment) of the released materials on the environment. This study is designed to assist in defining the term "as low as is reasonably achievable" (ALARA) in relation to limiting the release of radioactive materials from nuclear facilities. The model plant processes 10,000 metric tons of uranium per year. Base-case waste treatment is the minimum necessary to operate the process. Effluents meet the radiological requirements listed in the Code of Federal Regulations, Title 40, Part 20 (10 CFR 20), Appendix B, Table II, but may not be acceptable chemically at all sites. Additional radwaste treatment techniques are applied to the base-case plant in a series of case studies to decrease the amounts of radioactive materials released and to reduce the radiological dose commitment to the population in the surrounding area. The costs for the added waste treatment operations and the corresponding dose commitment are calculated for each case. In the final analysis, radiological dose is plotted vs the annual cost for treatment of the radwastes. The status of the radwaste treatment methods used in the case studies is discussed. Each of the technology used in the advanced cases will require development and demonstration or else is proprietary and unavailable for immediate use. The methodology and assumptions for the radiological doses are found in ORNL-4992.

<740>

WASTE DISPOSAL AND MANAGEMENT

<740> CONT.
(Auth)

See also OHL/WHDC/TR-5 and OHL/WHDC/TR-6.

AUTHOR

AUTHOR INDEX

- Abbott, J.D. 381, 382
 Abmayr, W. 455
 Abreo, A. 571
 Ackerman, T.L. 291
 Adachuk, I.P. 545
 Adams, J.A.S. 546
 Adams, W. 382
 Adams, W.L., Jr. 662
 Adee, E.P. 145
 Adrikova, J. 490
 Afzal, M. 607
 Albert, P. 547
 Albert, P.E. 1, 2, 217, 292, 294, 384, 385, 546, 664, 689, 690, 691, 692
 Alekshin, B.P. 282
 Alexander, B. 36
 Alexander, G.V. 291
 Allen, E.J. 309
 Allred, V.D. 245
 Almgren, E. 295
 Almodovar, L.B. 203
 Aloush, A.A. 714
 Altshuler, E. 396
 Ananyan, V.L. 330
 Anis, B.S. 350
 Anory, B.L. 387
 Andreeva, C.S. 288
 Andreyeva, C.S. 549
 Ariflikova, J. 539
 Asgleton, G.M. 592
 Angus, W. 178
 Arspaugh, J. S. 617
 Appich, T.W., Jr. (Translator) 122, 310
 Apt, K.E. 550
 Archer, V.P. 389, 511
 Arnold, E.D. 665
 Arnold, J.S. 3, 4, 35, 96, 97, 98, 99, 100, 450, 460
 Arthur, W.H. 296
 Atherton, D.B. 5, 6, 26, 124, 126, 150, 151, 152, 153, 154, 175, 218, 694, 711
 Aub, J.C. 390
 Augustson, R.H. 655
 Aulenbach, D. 468
 Austin, S.P. 337
 Auxier, J.A. 695
 Axelrod, D.J. 37
 Ayres, W.W. 500
 Baker, S.L. 553
 Bakharov, V.G. 207, 275
 Balek, V. 588
 Ballos, J.E. 7, 8, 9, 10, 11, 554
 Baltakness, T. 331, 555
 Banerjee, S. 126
 Baptista, A.S. 435
 Barassi, G. 563
 Barciński, H.L. 400
 Barnett, H.J.H. 479
 Barros, F.B. 512
 Bartine, D.E. 309, 320, 321
 Bartley, H.H. 101, 103
 Bauman, H.P. 315
 Beasley, T.H. 12, 157, 158, 161, 600
 Beck, H.L. 554
 Becker, K. 372, 557
 Beckler, P.A. 511
 Behari, J.R. 170
 Bell, H.J. 298, 730
 Beloborodova, Y.L. 13
 Bennett, L.L. 315
 Benes, P. 558
 Bennett, B.G. 14
 Bennett, S. 79, 80
 Bensted, J.P.H. 15
 Bertalis, C.C. (Ed.) 16
 Berke, H.L. 17
 Berliner, D.L. 18, 19, 64, 65, 144, 149
 Berliner, H.L. 18
 Bernhardt, D.E. 575
 Bhandari, M.C. 201
 Bhatti, D.P. 376, 673
 Bhat, I.S. 239
 Bierbach, H. 587
 Billings, M.H. 246
 Blair, H.A. 20
 Blanchard, R.L. 391, 696
 Bianco, B.E. 735, 737, 740
 Blaylock, B.G. 267, 268
 Blomberg, R. 392
 Blomqvist, L. 559
 Bloomfield, C. 332
 Boback, W.W. 731
 Bochvar, I.I. 21
 Boecker, B.E. 22, 23, 24
 Bondietti, E.A. 219, 322
 Bonner, J.P. 147
 Book, S.A. 77
 Boone, I.V. 25
 Borckenhagen, J. 456
 Breslin, A.J. 420, 560, 697
 Brewer, P. 393
 Brewer, L.W. (Ed.) 220
 Brinton, H.P. 389
 Bristow, C. 579
 Brito, S.S. 316
 Brits, B.J.W. 221
 Brogden, I. 244
 Brogli, R.H. 299
 Brown, J.A. 538
 Brown, M. 513
 Bruegger, P.W. 5, 26, 150
 Brychtova, V. 536
 Buckton, K.E. 394
 Budin, E. 395
 Budy, A.M. 128
 Buldakov, L.A. 628
 Bunch, R.P. 387
 Bunker, C.H. 645
 Burnett, T.W.T. 723
 Burnett, W.C. 333
 Burns, T.J. 321
 Burton, C.A. 299
 Bush, C.A. 645
 Boster, D.S. 150, 151
 Butler, G.C. 561
 Caldwell, R.D. 562
 Camera, V. 563
 Cameron, G.W. 564
 Canner, P. 27
 Canlon, P. 470
 Carlsmith, R.S. 715
 Carlson, R.E. 503
 Carpenter, B.S. 222
 Carrigan, R.H. 666

BLANK PAGE

AUTHOR INDEX

- Carson, J.N. 564
 Carter, W.L. 309
 Casper, J. 396, 397
 Catsch, A. 28, 29, 30
 Cayolla Da Rotta, L. 403, 434
 Chamberlain, A.C. 398
 Chandra, S.V. 170
 Chang, J.P. 179
 Charbonneau, E.W. 564
 Chaudhry, P. 607
 Chaudhry, A. 469
 Cherdynatsev, V.V. 269
 Cherkashina, T.N. 626
 Cherry, W.H. 544
 Cherry, R.D. 270, 271, 283, 428
 Chhabra, A.S. 399
 Childress, J.E. 291
 Chipperfield, A.W. 31, 32, 172
 Chow, T. 340
 Christensen, W.H. 33, 60, 124, 475
 Christian, D.J. 695
 Claiborne, H.C. 732
 Clark, C.A. 565, 733
 Clarke, P.H. 734
 Clary, P.L. 164
 Clements, V.P. 620
 Cleveland, J.C. 321
 Cleveland, J.P. 639
 Clifton, R.J. 566
 Cloutier, R.J. 419
 Coats, G.I. 422
 Cochran, T.R. 34, 35, 99, 102
 Coffield, B.E. 699
 Cohen, G. 503
 Cohn, S.N. 56
 Colby, P.J. 118
 Cole, G. 63
 Cohen, D.G. 223, 352
 Collinson, A.J.L. 427
 Collins, B. 36
 Colodzin, H. 440, 461
 Condon, W.J. 554
 Copp, D.W. 37
 Copp, J.J. 568
 Corcoran, J.R. 572
 Costa-Ribeiro, C. 400, 497
 Craig, D.E. 164
 Cristina, H.L. 435
 Crook, K. 176
 Cross, P. 569
 Cross, W.G. 704
 Crozy, A. (Translator) 115
 Cullen, T.L. 700
 Curry, J.L. 401
 D'Souza, T.J. 202
 Da Rotta, L.A.C.-R.C. 402
 Da Rotta, L.C. 404
 Da Silva Rotta, J. 403, 404, 512
 Dahlgren, S. 405, 406
 Dahlman, B.C. 323
 Danielson, A. 224
 Daraley, A.G. 570
 Das, B.A. 264
 Daser, K. 605
 Davies, C.W. 38
 Davis, D.K. 707
 Davis, J.O. 731
 Davis, W., Jr. 735
 Davis, W.D. 225
 De Bortoli, R.C. 226
 De Brito, J. 571
 De Silva Rotta, J. 407, 408
 Dean, O.C. 667
 Delany, A.C. 581
 Deleaux, H.H. 334
 Della Site, A. 227, 228
 Denimov, A.P. 710
 Denton, C.A. 120
 Dhandayathasan, R. 376, 673
 Dilley, J.V. 135
 Dillon, H.S. 298, 730
 Dimitriadis, D. 241
 Dix, G.P., Jr. 684
 Dobbs, J.R. 335
 Dockes, W.L. 101, 103, 450
 Doe, B.R. 334
 Dolphin, G.W. (Translator Ed.) 115
 Donhoff, D.K. 570
 Dougherty, J.H. 39, 40, 41, 42, 43, 44, 60, 124, 174, 475
 Dougherty, T.P. 18, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 59, 60, 123, 124, 173, 174, 187, 475
 Dougherty, T.P. (Ed.) 57, 58
 Drichko, V.P. 353
 Drings, I. 533
 Drusillard, R.P. 337
 Dudley, J.A. 409, 410
 Duffy, T.L. 637
 Duggan, H.J. 411, 572, 573
 Dupont, P. 574
 Durbin, P. 61
 Durbin, P.W. 62
 Dvorak, V. 446
 Dyson, E.D. 398
 Eddie, G.G. 575, 576
 Eakins, J.D. 577
 East, L.V. 655
 Edgington, D.W. 110, 203, 463
 Edsall, J.T. 300
 Egorova, H.S. 388
 Ekret, R. 606, 608
 Eisenbud, H. 547
 Ekpechi, O.L.V. 63
 El Shazly, E.M. 336
 El-Petey, S.A. 234
 El-Hamoon Yehia, K. 234
 Eldridge, V.V. 736
 Ellis, J.R. 337
 Ellis, L.C. 64, 65
 Elvskaya, L.T. 66, 710
 Enderlin, W.I. 668
 Eranetsaie, O. 204
 Erdmann, D.E. 580
 Erffle, V. 67
 Evans, A.E. 655
 Evans, R.D. 390, 412, 467, 578, 579
 Exner, H.E. 365
 Eyma, L.D. 322
 Eyring, H. 153
 Faber, R. 68, 69, 413, 414
 Faber, R. (Ed.) 415
 Fakar, H. 416
 Faraglan, W.G. 110
 Farshan, J.E. 142

AUTHOR INDEX

- Yarcok, D.T. 246
 Yarrow, H. 566
 Faust, L.G. 713
 Paige, Y. 660
 Feinberg, D.H. 401
 Feldman, I. 229
 Ferris, L.H. 607
 Fessler, E. 606, 608
 Fetter, W. 232
 Figueiredo, W. 400
 Finch, S.C. 417
 Finkel, H.P. 70, 71
 Finney, B.C. 735, 740
 Fischer, P. 418
 Fisher, D.E. 230
 Fishman, H.J. 580
 Fiszman, H. 497
 Fleischner, P.L. 581
 Fleischman, R.B. 301
 Fletcher, W. 338
 Flynn, H.J. 449
 Forstner, U. 686
 Foley, J.P. 655
 Foley, L.H. (Ed.) 379
 Folsom, T.H. 593
 Fote, E.S. 582
 Fordyce, J.S. 583
 Freeman, P.L. 593
 Fergac, J. 339
 Fetscher, R.A. 655
 Forster, W.C. 109
 Fraghan, W.G. 111
 Francis, C.W. 231, 322
 Fraumeni, J.P., Jr. 471
 Fresco, J. 232, 547
 Fried, J.P. 72
 Friedman, G.H. 382
 Frieser, R. (Translator) 606, 608
 Fritz, J.S. 249
 Fry, B.H. 701
 Fuqua, P.A. 429
 Furumura, H. 584
 Fushbaugh, C.C. 419
 Galikis, G.P. 73
 Gallon, W. 503
 Gansage, R.D. 373
 Ganguly, A.R. 346, 347, 348, 601
 Gardes, H.S. 86
 Garten, C.T., Jr. 322
 Gaur, J.S. 259
 Geale, D.C. 479
 Geiger, F. 421
 Gessicke, P. 74
 Genz, O. 457
 George, A.C. 420, 702
 Gericke, I.H. 270
 Gerrard, R. (Translator) 494
 Gershon-Cohen, J. 395
 Gies, R.A. 8, 9, 10, 11
 Gift, E.H. 304, 309
 Girardi, P. 75
 Glad, S.W. 126
 Gladney, E.S. 233
 Glauberman, M. 563
 Goessner, W. 67, 119
 Cohel, C.O. 673
 Goldova, E.S. 76
 Golchert, H.W. 637
 Goldberg, E.D. 276, 340
 Goldin, A.S. 421, 422
 Goldman, R. 77
 Goldsmith, W.A. 591, 736
 Goldthorpe, H.C. 60, 78, 79, 80
 Golob, E. 418
 Gonn, P.J. 577
 Gorncharova, A.A. 251
 Goussan, C. 579
 Gordon, S.A. 203
 Gotlieb, A.I. 423
 Graetzer, H.C. 341
 Grappa, G. 81, 82, 424
 Grazybowska, D. 285
 Green, J.H. 491
 Gridgean, W.T. 585
 Grien, H.L. 493
 Griffin, J.J. 276
 Grillmaier, E. 425, 489
 Grudov, B.I. 205, 287
 Gudiksen, P.H. 586, 617
 Gurek, H.P. 305
 Gerney, H.E. 235, 375
 Gussano, E.A. 467
 Gustafson, P.P. 426, 407
 Guzak, S. 419
 Gvirtzman, G. 342
 Gwiazdowski, B. 587
 Habersberger, R. 588
 Haggag, A. 234
 Haidis, P. 476
 Hale, V.Q. 291
 Hall, R.H. 83, 84
 Halsall, H.J. 305
 Hamby, H.C. 617
 Hamilton, E.I. 546, 589
 Hamilton, J.G. 77, 85, 86
 Hampton, J.C. 47
 Harlick, F.E. 197
 Hansen, P.O. 343, 344
 Haque, A.K.H.M. 427
 Harley, J. 232, 547
 Harley, J.H. (Ed.) 590
 Harris, J.L. (Ed.) 379
 Harris, P.S. 25
 Harris, W. 547
 Harris, W.B. 670, 697
 Harrison, J.E. 129, 479, 481
 Hartley, J.W. 707
 Hartmann, E. 594
 Hasson, V. 428
 Hatcher, S.R. 306
 Hathaway, E.A. 426
 Haug, H.O. 471
 Haywood, P.P. 591
 Hazen, S.W., Jr. 634
 Reid, K.R. 429
 Heier, K.S. 592
 Hellstrom, P.A. 27
 Heloke, P.A. 345
 Hempelmann, L.H. 390
 Henze, D. 594
 Herzfeld, U. 485
 Higashi, S. 272
 Hill, C.W. 284
 Hill, G.S. 735, 739, 740
 Miller, C.W. 374

APPENDIX

- Hinchliffe, L. 702
 Hirdman, F.D. 253, 254
 Hirschinger, P. 455
 Hirsch, G.W. 77
 Hodge, R.C. 40, 114
 Hodge, W.P. 235, 375, 593
 Holberg, D.P. 707
 Hoelgerman, S.P. 470
 Hoffman, F.L. 593
 Hoffman, H.P. 439
 Holgren, V. 431
 Holclay, D.A. 696
 Holoway, C.P. 776
 Holt, P. 150
 Holtzman, P.E. 674
 Holtzman, S.W. 517
 Hovan, F.J. 709
 Honda, Y. 356
 Hornath, A.A. (Translator) 74
 Hrovitz-Rimacva, L.A. 206
 Hrovitz, C.T. 206
 Hocrath, A.P. (Trans.) 694
 Horta de Silva, J. 432
 Horta, J.S. 433, 434, 435, 525
 Hout, J. 377
 Howard, W.E. 135, 162, 163, 164
 Howe, J.P. 207
 Howell, D.W. 573
 Huffman, C., Jr. 645
 Hogg, O. 47
 Hogg, W. 179
 Hulett, S.R. 603
 Huil, A.P. (Ccap.) 594
 Humason, G. 419
 Hunt, V.R. 436
 Hursh, J.B. 437, 438, 439, 440
 Huskey, I. 373
 Hutchinson, J.L. 423
 Hyde, P.R. 609
 Hyman, C. 89
 Imai, T. 274
 Iwachi, R. 441
 Ing, H. 794
 Irqman, P. 224
 Innich, H. 595
 Ishihara, S. 234
 Iskra, A.A. 237, 275
 Iwami, F.S. 678
 Iyengar, N.A.R. 218, 596
 Izawa, H. 116
 Jaafola, T. 446
 Jack, J.C. 705
 Jackson, H.L. 345
 Jackson, P.C. 159, 165, 597
 Jackson, S. 598
 Jacobi, W. 447, 599
 Jagielak, J. 587
 Jahas, P. 77
 Jaicaj Behari, A.K. 259
 James, A.C. 172
 James, L.A. 511
 Jamet, H. 736
 Janover, H.L. 421, 448, 449
 Jaworski, D. 285
 Jew, W.S.S. 35, 63, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 124, 457, 460, 475
 Jenkins, J.D. 309
 Jensen, P.G. 510
 Johansen, C. 49, 105
 Johnson, D.W. 557
 Johnson, H.A. 177
 Johnson, W.G. 401
 Jones, E.V. 245
 Jones, T.D. 495
 Jones, T.H. 12, 160, 600
 Joshi, L.N. 346, 347, 348, 601
 Jun, J.S. 372
 Justya, J. 174
 Kaaz, H. 291
 Kabisch, W.T. 107
 Kahn, B. 402
 Kahn, H.L. 451
 Kalani, D.K. 237
 Kalson, R. 601
 Kalugina, V.A. 368
 Kamath, P.R. 238
 Kamath, V.A. 239
 Kampesann, H. 452
 Kampmann, H. 540, 542
 Kapitanov, Ya.T. 66, 729, 710
 Karbe, L. 174
 Kartashov, V.P. 634
 Karsten, P.E. 709, 707, 474
 Kastenbergt, W.E. 723
 Kastner, J. 180, 660
 Katsurayama, K. 344
 Kauffman, P.E. 422
 Kaufmann, E.P. 576
 Kaul, A. 135, 453, 454, 455, 64
 Kawai, H. 354, 424
 Keane, A.T. 467, 517
 Keefer, D.H. 635
 Keopio, G.P. 645
 Keifer, H. 406
 Keil, B.L. 545
 Keirra-Harkus, Y.P. 21
 Keller, E. 151
 Kelso, W.L. 332
 Kemmer, W. 456
 Kenner, G.A. 173
 Kenner, G.H. 101
 Kerr, G.D. 373, 591, 495
 Khan, H.A. 607
 Khanolkar, V.S. 234
 Kharkar, D.P. 179
 Kiefer, H. 408
 Kigoshi, K. 461
 Killeen, P.G. 544
 Kimura, Y. 758
 Kinnear, J.E. 201
 Kirk, H.E. 423
 Kirkegaard, P. 419
 Kisielecki, W.E. 110, 111
 Kispert, R.C. 240
 Kjellstrom, L.E. 224
 Klecka, J.P. 609
 Klein, D.H. 324
 Klement, A. 325
 Klevin, P. 547
 Koef, J.P. 470
 Knoop, H. 457
 Kohnstedt, P.L. 707
 Koga, T. 358
 Koide, H. 276

Author Index

- Acliar, C. 156
 Aceto, T. 258
 Aclrat'eva, T.V. 610
 Aclrisch, J. 241, 242, 351
 Aclshy, P. 238
 Acltrappa, P. 376, 459, 611, 671
 Aclvalovich, A.I. 200
 Aclvarik, A.P. 662
 Aclvetner, H.F. 288
 Aclvieger, H. 400
 Aclvishnan, L.V. 712
 Aclvishnaswami, S. 350, 612
 Aclvivanec, M. 242
 Aclv, T. 611
 Aclvhta, D.P. 614
 Aclvikhov, H.V. 237, 209, 275
 Aclvibel, B. 405
 Aclvize-Nohl, F. 419
 Aclvrat, G. 351
 Aclvriyand'skaya, E.B. 112, 113, 115
 Aclvrosawa, R. 594
 Aclvrschuet, M. 286
 Aclvsuma, J. 116, 706
 Aclv, D. 350
 Aclvne, A.D. 306
 Aclvne, J.A. 310
 Aclvngill, J. 419
 Aclvnglands, A.C. 394
 Aclvrsen, P.P. 242
 Aclvrsen, L.P. 392
 Aclvrence, J.P. 86
 Aclvach, L.J. 114
 Aclv, S.T. 345
 Aclvros, J.J. 563
 Aclvst, K.W. 240
 Aclvlsure, G.W. 341
 Aclvtavet, A.A. 115
 Aclvtschner, A.H. 615
 Aclvvi, M. 460
 Aclvvis, B.B. 737
 Aclv, R. 185
 Aclvberman, P. 616
 Aclvika, P.C. 301
 Aclvkhachev, Yu.P. 66
 Aclvdeken, C.L. 223, 352, 617, 618
 Aclvelli, E. 392
 Aclvlenbaum, A. 116, 117
 Aclvlgren, E. 392
 Aclvsachenko, P.P. 351
 Aclvllie, J.C. 739
 Aclvlyd, P.D. 124, 175, 477, 694, 711
 Aclvloao, H. 433, 497
 Aclvlborg, L. 619
 Aclvlooney, W.C. 440, 453, 455, 460, 461
 Aclvori, G.D. (Translator) 251, 492, 549
 Aclvordello, A.R. 571
 Aclvlorenz, D. 462, 511
 Aclvlorenz, W.J. 462
 Aclvlots, A.L. 309, 574
 Aclvlrborg, L. 367
 Aclvlo-Beer, B.V.A. 36
 Aclvlvier, W.V. 556
 Aclvlve, M. 100, 104
 Aclvlucas, H.P. 118, 463, 464
 Aclvlucas, H.P., Jr. 465, 493
 Aclvlumborg, V. 27
 Aclvlurdgard, T. 367
 Aclvlunz, O.R. 291
 Aclvlusk, S. 106
 Aclvluz, A. 67, 119
 Aclvlyarskii, P.P. 66
 Aclvlyarskiy, P.P. 251, 709
 Aclvlyarskiy, P.P. 710
 Aclvlyubchanskii, E.B. 698
 Aclvlyon, W.S. (Ed.) 114
 AclvlyDonald, H.P. 675, 734
 AclvlyDonald, W.S. 465
 Aclvlychlin, L.J. 120
 Aclvlydelaine, G. 574
 Aclvlyagno, P.J. 421, 422
 Aclvlyakeeva, L.G. 121
 Aclvlyakeyeva, L.G. 122
 Aclvlyal'tseva, H.H. 251
 Aclvlyalanify, J.J. 655
 Aclvlyalatova, I. 466
 Aclvlyaletskos, C.J. 467
 Aclvlyasont-Ciesla, K. 587
 Aclvlyauero, T. 241, 350
 Aclvbanin, J.E. 271
 Aclvbaly, P.J. 464
 Aclvbann, W.S. 444
 Aclvbaricelli, L.D. 426, 472, 502
 Aclvbarkose, P.W. 496
 Aclvbarkun, P. 443, 464, 465
 Aclvbarkle, M.I. 629
 Aclvbarggart, W.H. 47
 Aclvbarkson, E. 286
 Aclvbarkshall, J.H. 517
 Aclvbarkshall, P. 674
 Aclvbartin, D.D. 252
 Aclvbartland, H.S. 150, 470
 Aclvbaslov, V.I. 297, 292
 Aclvbaslava, K.I. 247
 Aclvbason, T.J. 471
 Aclvbassie, S. 264
 Aclvbathur, A.K. 170, 259
 Aclvbatsuda, H. 257
 Aclvbatsunoto, E. 277
 Aclvbathews, K.V. 335
 Aclvbauhart, R. 606, 608
 Aclvbaxwell, W.E. 10
 Aclvay, M. 465, 472
 Aclvayneort, W.V. 210, 215, 530, 531
 Aclvays, C.W. 59, 60, 123, 124, 125, 126, 127, 152, 175, 178, 187, 473, 474, 475, 476, 477, 478, 518, 694, 711
 AclvMcBeth, G.W. 564
 AclvMcBride, J.P. 245
 AclvMcDowell, W.I. 246
 AclvMcFarland, S. 178
 AclvMcGenock, W., Jr. 513
 AclvMcHenry, J.P. 631
 AclvMcKay, P.W. 471
 AclvMcLean, P.C. 128
 AclvMcLellan, B.P. 684
 AclvMcNeill, K.G. 129, 479, 481
 AclvMeadors, J.W. 352, 617
 AclvMeadors, J.W.T. 223
 AclvMechall, D. 706
 AclvMedvedovsky, A.P. 137
 AclvMegusi, K. 247, 354
 AclvMehta, S.K. 712
 AclvMel'nikova, H.D. 545

AUTHOR INDEX

- Vello, J.C. 316
 Venlove, R.C. 655
 Venon, V.B. 673
 Verzel, J.W. 655
 Verzel, W.C. 355
 Verinsov, Ye.I. 610
 Verlini, R. 75
 Vetroper, R.V. 170
 Vical, P. 100, 102, 104
 Vical, P.S. 99, 450
 Widdlesworth, V. 63
 Wijnheer, E.J. 621
 Wikhailova, C.A. 248
 Willerf, R.T., Jr. 645
 Willer, W.S. 342
 Willer, R. 594
 Willer, E.B. 66
 Wirta, R.P. 479
 Wicawa, W. 564
 Wiskra, T.C. 629
 Wistry, R.E. 202
 Wiyaguchi, Y. 358
 Wiyake, Y. 277, 356
 Wiyazi, T. 483
 Yatsukanyan, E.E. 370
 Ye, T. 365
 Yechizuki, T. 236
 Yeffete, D. 678
 Yeghissi, A.A. 616
 Yehr, B. 377
 Yole, R.H. 480
 Yolla, R.A.P. 481
 Yocoe, J.B. 391
 Yocoe, P.E. 735, 739, 740
 Yordberg, Ye.L. 482
 Yorgin, J.W. 713
 Yoti, T. 121, 483
 Yotishima, H. 358, 624
 Yorris, J.P. 677
 Yorse, R.S. 656
 Yorny, S.H. 714
 Yoskaler, Ye.I. 698
 Yozilev, Yu.I. 116
 Yottram, J.C. 630
 Yoyer, B. 86
 Zoyers, E.V. 249
 Zabarokhan, S. 607
 Zeller, S. 103
 Zeller, J.H. 240
 Zeller, W.A. 67, 119
 Zeller, B. 139
 Zeller, W.A. 132
 Zallner, T. 418
 Zalty, W.C. 500
 Zarray, D. 678
 Zeth, H. 425, 456, 484, 465, 489
 Zeyer, W.G. 622
 Zebors, C.J. 149
 Zebors, C.J., Jr. 19, 475
 Zeele, P. 311
 Zagi, P.I. 607
 Zashlag, P. 673
 Zazarov, A.B. 281
 Zelson, B. 386
 Zoufeld, J. 716
 Zouuan, W.P. 147
 Zevill, V.A. 312
 Zq, Y.C. 288
 Zicholson, E.L. 690
 Zielemayr, G. 351
 Zilsen, B.L. 367
 Zifator, A.P. 698
 Zikiforov, V.S. 287
 Zikiforova, Ye.H. 357
 Zikolaeva, A.V. 211
 Zishivaki, Y. 358, 624
 Zitschke, H.W. 74
 Zkono, I.T. 645
 Zobile, J. 594
 Zordin, W.A. 527
 Zorris, W.P. 110, 111
 Zoten, A. 487
 Zots, K.J. 309
 Zovak, L. 488
 Zovak, Lj. 196
 Zovikov, Yu.V. 113
 Zovosad, P. 536
 Zovue, Y. 483
 Zumes, J.H. 432
 Zokley, D.T. 717
 Zoberhausen, E. 425, 484, 485, 489
 Zkanoto, T. 131
 Zkazzina, H. 131
 Zkavara, S. 134
 Zlsen, A.V. 304
 Zlsen, E.A. 79
 Zltman, B.G. 667
 Zosenigo, G. 313
 Zabeta, W.S. 289
 Zatenberg, C.L. 12
 Zttosen, P. 124
 Zven, P.E. 718, 719
 Zvons, J.W. 233
 Zchadzhanov, D.W. 545
 Palazzolo, H.J. 17
 Paldino, W.L. 49
 Palek, V. 497
 Pallister, E.T. 491
 Panov, D. 196, 488
 Paranjpe, S.B. 314
 Parekh, P.P. 239
 Park, J.P. 135
 Parker, J.L. 655
 Parkinson, J. 136
 Farr, R.H. 492, 493, 625
 Patterson, C. 340
 Pavlovalaya, H.Q. 250
 Pavlovskaya, H.A. 121, 122, 137, 251, 494, 626, 709
 Pearson, J.S. 679
 Pearson, P.R. 120
 Penna-Franca, E. 490, 495, 496, 497
 Pensko, J. 587
 Pepper, R.G. 359
 Percival, D.P. 252
 Perdue, P.T. 591, 695
 Perkins, B.A. 620
 Perkins, R.W. 161, 498, 501
 Petermann, P. 176
 Petrova, E.I. 610
 Petrich, I.V. 73
 Phillips, J. 594
 Ples, E. 606, 627
 Pinter, T. 214
 Pittman, D.C. (Ed.) 379

AUTHOR INDEX

- Planer, H.P. 498
 Pohl, P.C. 499
 Pollock, J.S. 703
 Pechikareva, T.E. 353
 Popov, D.H. 288, 353
 Potts, P.J. 638
 Prall, J.P. 628
 Pratt, P.W. 288
 Pravdina, E.I. 368
 Presyna, A.P. 530
 Pupal, W.W. 258
 Quan, W. 377
 Quirk, J.P. 359
 Rab Hille, R.A. 129
 Radford, E.P., Jr. 436
 Radley, J.N. 210, 215, 530, 531
 Rainey, W.H. 309, 680
 Raman, S. 729
 Rancitelli, L.A. 501
 Rancon, D. 290
 Rangarajan, C. 629
 Ranzetti, A.L., Jr. 501
 Read, J. 630
 Rector, J.W. 280
 Reffeld, C.E. 33, 60, 138, 176, 177
 Reilly, T.D. 655
 Renoux, A. 578
 Reynolds, J.C. 502
 Reynolds, S.A. 219
 Richardson, R.A. 568
 Riedel, W. 139
 Riesch, E. 608
 Rigbi, P. 393
 Risik, B.S. 180
 Ritchie, J.C. 671
 Roberts, J.C., Jr. 503
 Roberts, J.T. 680
 Robertson, J.S. 567
 Reddy, J.W. 739
 Rogers, E.A. 265
 Rogers, B.S. 25
 Rogers, J.J.W. 592
 Rojkovic, I. 360
 Rooney, E.H. 291
 Ronholm, E. 228
 Root, E.E. 84
 Rosario, E. 87
 Rose-Cannan, J. 367
 Rosenblatt, L.S. 41, 42, 43, 77
 Rosenthal, H.H. 116, 141, 315
 Rotholt, J.E. 645
 Rowe, A.S. 212
 Rows, K.W. 731
 Rothlat, J. 504, 632
 Rowland, R.E. 182, 505, 506
 Rubanovskaya, A.A. 187
 Rubtsov, D.H. 205, 361, 362, 363, 368
 Rudras, K. 234
 Rueb, D.L. 538
 Ruheann, A.G. 188
 Rundo, J. 505, 507, 508, 509, 510, 618
 Rushton, J.E. 309
 Ryan, J.L. 9
 Ryan, R.H. 469
 Sacconanno, G. 511
 Sachdev, A. 469
 Sackett, W.N. 365
 Sah, Y. 103
 Saito, K. 131
 Sakagishi, S. 633
 Sakanoue, Y. 278
 Sanad, Y. 238
 Sanders, C.L. 145
 Santori, G. 228, 260
 Santos, J.C. 316
 Santos, P.L. 497
 Saragoca, A. 512, 525
 Sarin, H.N. 612
 Saroniok, J. 213
 Sattler, E.L. 439
 Saunders, D.P. 634
 Saun/era, E.P. 511
 Scheer, K.E. 538
 Scheffrahn, K. 103
 Schiager, K.J. 378
 Schilling, C.E. 245
 Schlundt, H. 513, 681
 Schmidlin, P. 518
 Schmit, J. 458
 Schmorak, J. (Translator) 269
 Schneebeli, L. 177
 Schaler, C. 108
 Schock, H.H. 206
 Schow, E. 539
 Schraub, A. 439
 Schubert, J. 117, 198, 515, 721, 722
 Schultz, W.P. 299
 Schultz, V. 324
 Schuttkopf, H. 615
 Schwartz, S. 186
 Scott, P.H. 634
 Scott, J.E. 28, 84, 147, 145
 Scott, L.W. 516
 Seagren, R.D. 739
 Seaton, A. 125
 Seaton, B. 682, 780
 Sedlet, J. 637, 618
 Seemann, W. 351
 Segal, Y. 487
 Segall, A. 436
 Sen, D.W. 291
 Seymour, K. 88
 Shabestari, L. 173, 174, 175, 178
 Shalayev, I.L. 882
 Shanks, H.H. 219
 Shannon, L.V. 271, 279
 Sheibley, D.W. 583
 Shelly, W.J. 266
 Shiapough, W.H. 695
 Shock, D.A. 681
 Shreve, J.D., Jr. 639
 Shunkov, G.P. 608
 Shvydko, W.S. 288
 Sidel, V.W. 889
 Sievers, H.C. 108
 Sill, C.W. 253, 254, 255, 640, 641
 Silver, E.G. (Translator) 671
 Simons, D.J. 517
 Simpson, D. 598
 Singh, G.B. 259
 Sinha, A.T. 366
 Sisselman, P. 317

AUTHOR INDEX

- Chiaroff, D.W. 544
 Chikowski, N. 702
 Chir, M.C.P. 221
 Clith, A.P. 349
 Clith, P. 81
 Clith, C.C. 33
 Clith, C.P. 723
 Clith, P.P. 455
 Clith, M.W. (Ed.) 319
 Clith, M.S. 116, 442
 Clithner, R.V. 315
 Clithner, R. 367
 Clithner, R. 367
 Clithner, A. 350
 Clithner, P.P. 365
 Clithner, M. 478, 518
 Clithner, I. 320, 321
 Clithner, W.L. 383
 Clithner, J. 456
 Clithner, G. 606, 608
 Clithner, B. 519, 644
 Clithner, J.S. 144, 520
 Clithner, J.W. 231
 Clithner, L.T. 94, 440
 Clithner, C.A. 644
 Clithner, A.P. 526, 521
 Clithners, J. 594
 Clithners, E. 554
 Clithness, E. 256
 Clithness, B. 19, 26, 149, 475
 Clithness, J.E. 731
 Clithner, R.E. 84
 Clithner, E.S. 86
 Clithner, P.P. 344
 Clithner, P.J. 5, 6, 26, 60, 124, 126, 150, 151, 152, 153, 154, 475
 Clithner, C.W., Jr. 155
 Clithner, P. 156, 214
 Clithner, C.A. 84
 Clithner, B.C. 135, 157, 158, 159, 160, 161, 162, 163, 164, 498, 537
 Clithner, O. 165
 Clithner, J.E. 645
 Clithner, Y. 277, 356
 Clithner, C.W. 614
 Clithner, F.W. 703
 Clithner, D.C. 454
 Clithner, M. 522
 Clithner, P.L. (Ed.) 523
 Clithner, J. 445
 Clithner-Shan, Y. 76, 156, 167, 169, 169
 Clithner, G.E. 114
 Clithner, B.J. 646
 Clithner, J. 479
 Clithner, S. 483
 Clithner, Y. 257
 Clithner, H. 306
 Clithner, T. 258
 Clithner, S.K. 170, 259
 Clithner, P.K. 298
 Clithner, W.L. 524
 Clithner, S. 656
 Clithner, M.R. 493, 494, 512, 525
 Clithner, D.W. 31, 32, 116, 171, 172
 Clithner, J.Y. 33, 124, 154, 173, 174, 175, 176, 177, 178, 187, 475
 Clithner, M.A. 596
 Clithner, D.H. 494, 711
 Clithner, M.C. 526
 Clithner, M.C. 467
 Clithner, H. 527
 Clithner, C.P. 179
 Clithner, C. 223, 263, 524
 Clithner, B.V. 21
 Clithner, S. 469
 Clithner, C.W. 261
 Clithner, R.J. 24, 49, 140, 151, 182, 183, 194, 195
 Clithner, R.T. (Ed.) 498
 Clithner, W.E. 321
 Clithner, H.H. 201
 Clithner, D.L. 529
 Clithner, R.C. 116
 Clithner, S.E. 289
 Clithner, B.J. 327
 Clithner, J. 109
 Clithner, J.H. 591, 695
 Clithner, M.H. 655
 Clithner, G.H. 186, 187
 Clithner, H.W. 657
 Clithner, C.A. 86
 Clithner, M.L. 306
 Clithner, M.S. 194
 Clithner, W.P. 240
 Clithner, R.J. 614
 Clithner, M. 189
 Clithner, P. 454
 Clithner, M. 447
 Clithner, C. 190
 Clithner, A.B. 427
 Clithner, F.V. 104
 Clithner, P.C. 210, 215, 530, 531
 Clithner, J. 154
 Clithner, J. 190
 Clithner, J.A. 99
 Clithner, E.B. 368
 Clithner, P.C. 385
 Clithner, M.A. 19
 Clithner, R. 131
 Clithner, S. 257
 Clithner, J.M. 401
 Clithner, C.W. 314
 Clithner, P.W. 243
 Clithner, W.D. 653
 Clithner, V.I. 545
 Clithner, E. 532
 Clithner, D. 517
 Clithner, C.D. 194
 Clithner, M.A. 264
 Clithner, M.A. 6, 476
 Clithner, G. 442
 Clithner, G. 533, 534
 Clithner, D.H. 315
 Clithner, L. 195, 535
 Clithner, J. 114
 Clithner, P.P. 292
 Clithner, J.I. 306
 Clithner, I.V. 287, 292
 Clithner, I. 536
 Clithner, B. 654
 Clithner, V. 196
 Clithner, C.H. 537
 Clithner, A.P. 725
 Clithner, C.C. 518
 Clithner, G. 514
 Clithner, V. 490, 539

LETTER INDEX

Vachonova, W. 539
 Vaccmer, J. F. 399
 Vahid, A. 607
 Vaincarter, T. S. 238
 Wallace, A. 291
 Walsh, F. L. 157
 Walton, L. 222
 Walton, P. E. 455
 Ward, A. H. 510
 Ward, G. 506, 632
 Watrous, J. E. 485
 Watson, C. D. 680
 Wegener, E. 452, 540, 542
 Wehner, A. P. 135
 Weisbin, C. W. 655
 Welford, C. A. 656
 Welty, C. G., Jr. 657
 Weng, W. 541
 Wesch, E. 452, 540, 542
 West, C. W. 634, 726, 727
 Weyneth, P. 26
 White, E. C. 25
 White, F. A. 622
 White, J. H. 618
 White, J. P. 221
 White, W. W. 198
 Whitnack, G. C. 658
 Wilhelm, H. A. 265
 Willard, C. B. 162, 163, 164
 Williams, J. 175, 178
 Willis, C. P. 255
 Wilson, P. D. 77
 Wilson, R. E. 114
 Winster, S. 544
 Witherspoon, J. P. 267, 268, 735, 739, 740
 Wittmann, G. T. B. 684
 Wagon, B. A. 11, 554
 Wollenberg, R. A. 369
 Woodhead, D. S. 199, 280
 Woodliff, H. J. 543
 Wrenn, H. E. 446, 728
 Wright, H. 716
 Wright, W. J. 687
 Yakovleva, V. E. 200
 Yanakawa, W. 328
 Yamamoto, T. 328
 Yaron, E. 663
 Yastrebcev, N. T. 372, 371
 Yasujima, T. 356
 Yee, J. 101
 Ylirookanen, I. 204, 216
 Young, I. 544
 Yount, G. R. 648
 Yulina, T. V. 133
 Yule, C. L. 114
 Yonoki, E. 329
 Zahner, E. 540
 Zargaria, B. 146
 Zeltser, H. B. 137
 Zelenko, A. Ya. 231
 Zetwood, P. 571
 Zhukov, B. I. 659
 Zimmer, E. 311

GEOGRAPHIC LOCATION

BLANK PAGE

GEOGRAPHIC LOCATION INDEX

- Adriatic Sea 140
 Adriatic Sea (B) 156, 214
 Africa 606
 Africa (C) 216
 Africa (S). Republic of South Africa (S), Cape of Good Hope 283
 Alaska 233
 Amazon River 365
 Antarctica 585
 Antarctica, Victoria Land (S), Wright Valley 345
 Arizona 651
 Atlantic Ocean 269, 280, 281, 612
 Atlantic Ocean (B) 589
 Atlantic Ocean (S) 270, 589
 Atlantic Ocean (S), Walvis Ridge 270
 Australia 284
 Australia (SE), New South Wales 491
 Australia (SW), Wongan Hills 359
 Austria (S), Carinthia, Drauzog 351
 Baltic Sea 280
 Black Sea 280, 281
 Brazil 400, 780
 Brazil (E), Espírito Santo 495
 Brazil (E), Pinar Gatais 495
 Brazil (SC) 316
 Brazil, Aroze 496
 Brazil, Guarapary-Mesipe 496
 Brazil, Torric de Perro 496
 California (C), Sacramento-San Joaquin Delta Area 352
 California (C), Stanislaus County 343
 California (E), Sierra Nevada 369
 California (E), Sierra Nevada Foot Hills 369
 California (NW), La Jolla, Scripps Institution of Oceanography 593
 California (SW), Santa Barbara Basin 350
 California (W), Livermore Valley 617
 California (WC), San Francisco Bay 369
 California, La Jolla, Scripps Pier 375
 California, San Andreas Fault Zone 369
 California, Santa Barbara Basin 276
 California, Soledad Basin (SW), California, Soledad Basin 276
 Canada 305, 648, 688
 Canada (EC), Catario (SE), Bancroft Lake 573
 Canada (EC), Catario (SE), Elliot Lake 570, 678
 Canada (S), Saint Lawrence River 365
 Canada (W), Mackenzie River 365
 Canada, Bancroft 568
 Canada, Canadian Precambrian Shield 568
 Canada, Elliot Lake 568
 Canada, Fort Smith 568
 Canada, Hout Laurier 568
 Caribbean Sea 109
 Caribbean Sea, Bahamas 382
 China, Yangtze River 365
 Colorado 651, 679
 Colorado (W) 471
 Colorado (W), Grand Junction 378
 Colorado Plateau 511
 Colorado River 546, 565
 Colorado River Basin 649
 Colorado, Grand Junction 591
 Columbia River 648
 Congo River 365
 Czechoslovakia (C), Ostrava 516
 Czechoslovakia (WE), Jachymov 536
 Czechoslovakia (NW), Kladno 539
 Czechoslovakia (W), Bohemia 539
 Czechoslovakia (W), Bohemia (W) 106
 Czechoslovakia (W), Pribran 536, 539
 Czechoslovakia, (NW), Prague 466
 Czechoslovakia, Haer 539
 Czechoslovakia, West Carpathians, Vikartovsky Chrbat Area 360
 Denmark 416
 East China Sea 278, 356
 Egypt (SE), Dausletta 714
 Egypt (SW), Rosetta 714
 England, Surrey, Sutton, Belmont 589
 Europe (W) 671
 Florida 319
 Florida (S) 605
 Germany 538, 671
 Germany, Baltic Sea 108
 Germany, Elbe Estuary 108
 Germany, Elbe River 108
 Germany, Ems Estuary 108
 Germany, Helgoland 108
 Germany, Jade Bay 108
 Germany, Nordfriesland 106
 Germany, North Sea 108

BLANK PAGE

GEOGRAPHIC LOCATION INDEX

213

- Germany, Lower Saxony 100
- Great Basin, Western 369
- Great Britain 210
- Greenland (S), Illinaussaq Intrusion, Kvanefjeld 367
- Gulf of Mexico 365
- Hawaii 340
- Illinois (DE), Bataria, National Accelerator Laboratory 553
- Illinois (DE), Des Plaines River 637
- Illinois (DE), Illinois River 637
- Illinois, Argonne, Argonne National Laboratory, Savanill Creek 551
- Illinois, Argonne, Argonne National Laboratory 552, 637, 638, 647, 648
- Illinois, Argonne, Savanill Creek 637
- India 295, 314, 629, 690
- India (DE), Bihar, Jaduguda 596
- India (DE), Bihar, Ranchi 669
- India (DE), Bihar, Singbhum Thrust Belt, Jaduguda 669
- India (DE), Bihar, Singbhum Thrust Belt, Warvapur 669
- India (S), Alleppey 347
- India (S), Chevaca 347
- India (S), Korumagoppally 347
- India (S), Kayankulam 347
- India (S), Shertallay 347
- India (S), Thettapolly 347
- India (SE), Kerala 347, 399
- India (W) 348
- India (W), Pondy 399, 673
- India (W), Pondy, Dangri 347
- India (W), Pondy, Kalyan 347
- India (W), Pondy, Kambelli 347
- India (W), Pondy, Mora 347
- India (W), Pondy, Panje 347
- India (W), Pondy, Uran 347
- India (W), Dakhoi 347
- India (W), Deogad 347
- India (W), Gca 347
- India (W), Honavar 347
- India (W), Jaygad 347
- India (W), Karwar 347
- India (W), Balvan 347
- India (W), Batnagiri 347
- India (W), Trenchay 712
- India (W), Vengurla 347
- India, Bagjata 669
- India, Bhatia 669
- India, Ganges-Brahma-Putra River 365
- India, Kanyakulka 669
- India, Kerala, Chavara 669
- India, Kervadungri 669
- India, Madras, Manvalakurichi 669
- India, Parandungri 669
- India, Rajasthan, Udaipur 669
- India, Rajasthan, Umer 669
- India, West Bengal, Perulia 669
- India, West Coast 346, 601
- Indian Ocean 269, 280
- Indian Ocean, Agulhas Current 279
- Iowa, Ames, Ames Laboratory Research Reactor 554
- Irish Sea 199
- Italy 313
- Italy (C), Rome 528
- Italy (W) 351
- Japan 356, 613
- Japan (C), Shimane Prefecture 236
- Japan (SE), Tokai 633
- Japan Sea 274, 356
- Japan, Okayama Prefecture, Kasaisabara Village, Wakatsugo, Ten-Bo 328
- Japan, Okayama Prefecture, Mitsu Town, Uraishiki 328
- Japan, Okayama Prefecture, Tsutsuka Town, Tomiyoshi 328
- Japan, Osaka Bay 358
- Japan, Yoron Island 274
- Kentucky (DE), Paducah 652
- Kuroshio 356
- La Plata-Parana River 365
- Lake Erie 118
- Lake Michigan 118, 324
- Lake Superior 118
- London 427
- Malaysia 319
- Massachusetts 526
- Massachusetts (W), Boston 449
- Mediterranean Sea 269, 280
- Mediterranean Sea (W) 214
- Hohong River 365
- Mexico 648
- Mexico (DE), Coastal Rivers 273
- Michigan 526
- Minnesota (SE), Big Stone Power Plant 341

GEOGRAPHIC LOCATION INDEX

- Mississippi River 365
 Missouri River 365
 Missouri, Columbia 677
 Nevada, Nevada Test Site 291, 648, 657
 Nevada, Nevada Test Site, Mojave Desert (N) 291
 New Hampshire, Concord 436
 New Hampshire, Conway 436
 New Hampshire, Franklin 436
 New Hampshire, Manchester 436
 New Mexico 223, 651, 682
 New Mexico (N), Grants 620, 702
 New Mexico, McKinley County (SE), Grants Mineral Belt 576
 New Mexico, Shiprock 591
 New Mexico, Valencia County (WC), Grants Mineral Belt 576
 New York 622
 New York (SE), New York City 620
 New York, Long Island, Carmans River 590
 New York, Long Island, Peconic River 590
 New York, Long Island, Upton, Brookhaven National Laboratory 590
 New Zealand 286, 331, 335
 Nigeria 63
 Nile River 365
 North Atlantic Ocean, Bermuda 302
 North Sea 280
 Norway (E), Glomma River 558
 Norway, Lake Treboingen 558
 Norway, Nitelva River 558
 Ohio (SW), Cincinnati, Feed Materials Production Center 623
 Ohio (SW), Mill Creek 650
 Ohio (N), Great Miami River 623
 Ohio, Great Miami River 650
 Ohio, Little Miami River 650
 Ohio, Portsmouth, Goodyear Atomic Corporation Gaseous Diffusion Plant 603
 Ohio, Portsmouth, Portsmouth Area Gaseous Diffusion Plant 607
 Oregon (WC), Newport 646
 Pacific Ocean 269, 280
 Pacific Ocean (N) 270, 333
 Pacific Ocean (SC), Line Island 286
 Pacific Ocean, 120 and 180 degrees West Longitude from 40 degrees N to 20 degrees S 380
 Pennsylvania, Shippingport, Shippingport Atomic Power 647
 Poland 284
 Poland (N), Gdansk, Zarnowieckie Lake Area 597
 Portugal 302, 302, 400, 433, 430, 512
 Puerto Rico 233
 Red Sea 269, 334
 Red Sea, Sinai Peninsula (S), Sharm-e-Sheikh area 302
 Scotland (SE), Edinburgh 394
 Sea of Japan 277
 South Africa, Coast 270
 South Atlantic Ocean, Benguela Current 279
 South Atlantic Ocean, Subtropical Convergence 279
 South Atlantic Ocean, Walvis Ridge 279
 South Carolina, Aiken, Savannah River Plant 641
 South Dakota (NE), Big Stone Power Plant 641
 Sweden 255, 405, 406
 Tennessee (E), Oak Ridge, Y-12 Plant 636
 Tennessee (SE) Chattanooga 644
 Tennessee, Oak Ridge, Y-12 Plant 708
 Texas 365
 Texas (N) 582
 Texas, Coastal Rivers 273
 Texas, Corpus Christi, Texas (SW) 546
 Texas, George West 683
 Texas, McAllen Beach 546
 United Arab Republic (E), Eastern Desert 336
 United Arab Republic (N), Mediterranean Coast 336
 United Arab Republic (NE), Sinai 336
 United Kingdom 286, 491, 734
 United States 315, 491, 682, 690, 717
 USSR 211, 287, 353
 USSR (SW), Armenia 330
 USSR (N) 371
 USSR, Tashov Region, Kolochnaya Forest-Steppe 370
 USSR, Transbaikal (SE) 357
 Utah 651
 Utah (E), Moab, Mivida Claim, Big Indian Mining District 680
 Utah (SE), San Juan County, Salt Lake Meridian, Sec 11, T. 30S., R 24E 684
 Utah, Salt Lake City 476, 591
 Vermont, Bennington 436
 Vermont, Burlington 436
 Vermont, Middlebury 436
 Vermont, Rutland 436
 Wales (N), Lake Trausfynydd 199
 Wyoming 506, 682
 Wyoming, Bruni Field 683

GEOGRAPHIC LOCATION INDEX**Yugoslavia, Gorenja Vas 488****Yugoslavia, Kalna 488**

KEYWORDS

KEYWORD INDEX

AECOMER 166, 167
 AERODERIVATIONS 394, 400, 417, 418, 424, 430, 442, 456, 496, 501
 AEROSOLIZATION 1, 6, 22, 24, 37, 61, 85, 115, 116, 181, 238, 371, 412, 419, 447, 467, 524, 535, 625
 ACCELERATORS 553
 ACCIDENTS 424, 542, 689, 711, 720
 ACCIDENTS, POTENTIAL 694
 ACCUMULATION 19, 35, 72, 85, 100, 140, 157, 158, 187, 194, 202, 205, 207, 208, 209, 211, 267, 274, 278, 281, 287, 292, 322, 361, 364, 444, 505, 522
 ACIDS 219
 ACTINIDES 5, 26, 36, 61, 62, 92, 116, 152, 220, 228, 244, 271, 524, 562, 675, 729, 732, 734, 738
 ACTINIUM 288, 325, 482
 ACTINIUM 227 5, 61, 171, 252, 271, 721, 722
 ACTINIUM 228 238, 261, 271, 322, 465, 466, 492, 493, 625, 719
 ACTINIUM 41 486
 ACTINON 549, 604
 ACTIVATION ANALYSIS 75, 326
 AERIAL GLANCES 18, 44, 89, 191, 440, 452, 459, 460, 524
 AEROSOLIZATION 198, 208, 229, 264, 349, 558, 577
 AEROSOLS 8, 5, 10, 11, 22, 24, 27, 30, 66, 85, 135, 157, 160, 180, 182, 197, 267, 276, 324, 383, 400, 427, 435, 447, 458, 491, 520, 524, 554, 574, 599, 604, 611, 615, 643, 702, 703, 724
 AGE 61, 92, 106, 119, 153, 178, 187, 290, 327, 344, 345, 350, 389, 403, 480, 511, 519, 530, 539, 584, 646, 662
 AGING 70, 79, 194
 AGRICULTURE 325, 495, 497
 AIR 14, 76, 88, 165, 225, 255, 289, 291, 294, 312, 337, 363, 373, 376, 378, 383, 386, 389, 389, 400, 412, 447, 470, 494, 486, 488, 498, 513, 524, 548, 549, 557, 559, 560, 566, 568, 572, 573, 575, 579, 582, 583, 584, 587, 585, 591, 593, 596, 599, 602, 603, 604, 608, 615, 619, 622, 623, 629, 630, 633, 637, 638, 639, 641, 647, 648, 652, 654, 673, 688, 689, 690, 691, 692, 696, 697, 698, 699, 700, 702, 708, 709, 715, 720, 724, 727, 733
 AIRCRAFT 546, 564, 570, 583, 619, 634
 ALUMINUM 19, 89, 149, 393, 403, 512
 ALKALI 203, 209, 214, 219, 261, 278, 281, 326, 342, 596
 ALKALINE EARTHS 30, 95, 128, 152,

ALKALINE EARTHS 409, 722
 ALLOYS 265, 644, 690, 691
 ALPHA PARTICLES 2, 41, 43, 59, 63, 67, 70, 90, 94, 96, 99, 109, 104, 111, 119, 124, 125, 127, 129, 132, 138, 140, 145, 159, 208, 210, 213, 215, 217, 230, 232, 235, 246, 254, 261, 262, 271, 279, 283, 284, 286, 335, 359, 373, 374, 375, 383, 386, 390, 428, 432, 436, 447, 455, 474, 475, 477, 487, 491, 497, 500, 504, 508, 509, 510, 513, 519, 523, 524, 528, 530, 531, 532, 541, 551, 552, 554, 557, 560, 563, 565, 568, 577, 591, 594, 598, 599, 602, 603, 608, 623, 624, 632, 644, 649, 651, 652, 653, 661, 662, 665, 677, 681, 698, 702, 713, 726, 730, 731
 ALTITUDE 717
 ALUMINUM 27, 190, 261, 324, 546, 558
 AMAD 615, 702
 AMERICIUM 32, 85, 85, 86, 141, 228, 260, 375, 532, 577, 635, 640, 722, 732, 738
 AMERICIUM 241 5, 26, 30, 40, 45, 51, 61, 91, 92, 123, 148, 171, 172, 220, 227, 235, 248, 254, 261, 271, 486, 528, 562, 586, 598, 617, 643, 694, 698, 708, 721
 AMERICIUM 243 261, 593
 AMINO ACIDS 92, 332
 ANIONISM 231
 ANDROGENS 51, 64, 65
 ANEMIA 13, 15, 44, 136, 138, 381, 392, 403, 417, 459, 470, 500, 524, 534, 535
 ANIMALS 1, 2, 5, 10, 11, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 27, 28, 29, 30, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 107, 110, 111, 112, 113, 114, 118, 115, 116, 117, 118, 119, 121, 122, 123, 124, 126, 129, 130, 131, 132, 133, 134, 135, 136, 137, 138, 139, 140, 141, 142, 143, 144, 145, 147, 148, 149, 150, 151, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164, 165, 166, 167, 168, 170, 172, 173, 175, 176, 177, 178, 179, 180, 181, 182, 183, 184, 185, 186, 187, 188, 189, 190, 191, 192, 193, 194, 195, 196, 198, 200, 259, 262, 278, 281, 283, 284, 286, 287, 288, 289, 292, 326, 385, 386, 393, 410, 413, 415, 442, 455, 475, 476, 477, 481, 485, 492, 493, 504, 506, 515, 522, 524, 528, 531, 535, 542, 543, 579, 594, 597, 625, 630, 643, 709, 725, 736, 574

ANTIMONY 114, 124, 141, 634
 AQUATIC ORGANISMS 104, 154, 247, 248, 545
 ARCHEOLOGY 324
 ARSENIC 119, 146, 124, 141, 654
 ARSENIC 76 496
 ASHING 213, 214, 255
 ASPHALT 707
 ASTATINE 211 496
 ATOMOSPHERES 403, 409, 421, 422, 433, 440, 451, 452, 470, 483, 503, 527, 542
 BACKGROUND 290, 399, 436, 504, 587, 598, 602, 603, 634, 651, 717
 BAL 28, 86
 BARIUM 85, 86, 349, 638, 647, 648
 BARIUM SULFATES 255
 BARIUM 137 486, 695
 BARIUM 140 496
 BEACHES 315, 546
 BEANS 202
 BEDROCK 564
 BENZENE 637
 BENZENE 249 58, 506
 BERYLLIUM 27, 146, 265, 590, 638, 669, 670, 687
 BERYLLIUM OXIDES 373
 BERYLLIUM 7 486, 537, 552, 553, 602
 BETA PARTICLES 2, 20, 21, 41, 43, 59, 94, 124, 138, 208, 213, 217, 232, 238, 255, 262, 326, 468, 475, 487, 495, 509, 508, 524, 528, 552, 565, 568, 594, 598, 602, 603, 608, 623, 624, 629, 649, 651, 652, 665, 677, 681, 690, 692, 694, 698, 718, 509
 BIBLIOGRAPHY 326, 442, 736
 BILE 62, 435
 BILE DUCT 131, 174, 407, 408, 451
 BINDING 5, 26, 29, 31, 32, 61, 62, 92, 212, 494
 BIOASSAY 548, 597, 722, 727
 BIOCHEMISTRY 19, 79, 128, 146, 155, 259, 322, 512, 536
 BIOLOGICAL FLUIDS 251
 BIOLOGICAL HALF-LIFE 37, 70, 85, 184, 422, 446
 BIOLOGICAL MATERIALS 75, 218, 222, 243, 244, 244, 325, 390, 524, 532, 644
 BIOLOGICAL STRESS 191
 BIOLOGICAL TRANSPORT 61, 212, 322,

BLANK PAGE

KEYWORD INDEX

- BIOLOGICAL TRANSPORT 447, 736
- BICHAS 104
- BICRYSTALLINITY 10, 51, 64, 65
- BICRY 545
- BISPHENOL 265
- BISPHENOL 210 255, 431, 641
- BISPHENOL 211 271
- BISPHENOL 212 172, 271, 271, 422, 439, 479, 486, 492, 493, 540, 550, 625, 718
- BISPHENOL 214 459, 570, 573, 582, 617
- BIABENZ 111, 422
- BLOOD 5, 7, 13, 17, 19, 22, 26, 26, 41, 43, 44, 51, 58, 61, 69, 77, 78, 85, 89, 101, 112, 117, 122, 123, 131, 141, 147, 149, 160, 183, 189, 190, 222, 302, 391, 392, 394, 400, 401, 403, 410, 412, 421, 422, 423, 425, 428, 430, 439, 442, 446, 450, 461, 464, 470, 476, 483, 484, 486, 488, 494, 506, 509, 513, 524, 530, 535, 538, 543, 546, 600, 626, 643, 677, 681, 709, 725
- BLOOD CELLS 17, 40, 60, 454, 492
- BLOOD CELLS, RED 13, 34, 39, 42, 44, 65, 83, 136, 146, 160, 420, 439, 470, 485, 536, 538
- BLOOD CELLS, WHITE 2, 13, 39, 41, 42, 44, 112, 130, 135, 140, 418, 470, 483, 620, 725
- BLOOD PLASMA 5, 26, 36, 40, 92, 117, 136, 152, 420, 439, 535
- BLOOD PLATELETS 36, 44, 160
- BLOOD PRESSURE 112, 169
- BLOOD SUGAR 19, 36, 40, 51, 54, 78, 79, 80, 84, 144, 149, 200, 403, 525
- BLOOD VESSELS 34, 49, 96, 98, 101, 102, 103, 105, 143, 188, 419, 434, 452, 524
- BOBY 141, 445, 515, 521, 561, 657
- BOBY BURDEN 23, 50, 72, 80, 94, 171, 176, 180, 182, 322, 385, 391, 395, 403, 409, 418, 425, 426, 430, 437, 439, 443, 446, 454, 479, 481, 484, 485, 486, 491, 492, 495, 496, 497, 506, 519, 540, 548, 567, 642, 700, 711, 714, 726, 736
- BOBY FRACTURES 33, 48, 95, 96, 98, 104, 194, 390
- BOBY HADRON 2, 4, 16, 25, 35, 39, 44, 51, 61, 69, 84, 104, 107, 107, 103, 129, 262, 403, 421, 424, 433, 436, 438, 440, 452, 453, 454, 455, 459, 460, 461, 470, 474, 485, 493, 504, 507, 509, 510, 522, 524, 527, 530, 580, 717, 725
- BOBY REMODELING 48, 98
- BOBBS 1, 2, 3, 4, 5, 7, 8, 9, 10, 11, 16, 20, 22, 23, 24, 25, 28, 29, 30, 31, 32, 33, 35, 37, 40, 4085, 42, 43, 44, 49, 50, 51, 52, 53, 54, 55, 57, 59, 60, 61, 62, 67, 70, 71, 72, 74, 77, 84, 85, 86, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 106, 110, 111, 112, 117, 120, 122, 124, 125, 126, 127, 128, 129, 132, 132, 134, 138, 142, 143, 144, 150, 151, 152, 155, 157, 158, 164, 167, 171, 172, 178, 183, 185, 186, 189, 191, 192, 194, 195, 198, 199, 243, 271, 284, 286, 322, 393, 385, 390, 391, 399, 404, 409, 410, 412, 421, 422, 424, 434, 436, 444, 445, 446, 450, 453, 459, 464, 467, 463, 467, 470, 474, 479, 478, 477, 478, 482, 485, 486, 491, 492, 493, 502, 505, 506, 507, 517, 518, 519, 520, 521, 524, 530, 531, 542, 543, 557, 561, 564, 579, 585, 614, 625, 629, 632, 691, 692, 709, 724, 725, 735, 739, 740
- BORON 222, 627
- BRAIN 112, 180, 391, 399, 452, 524, 582, 583
- BROSINE 110, 324, 326, 341
- BROUCHI 150, 145, 386, 398, 447, 510
- BUILDINGS 370, 471, 591, 695
- BURDEN 1, 8, 9, 21, 22, 23, 24, 132, 135, 450, 562, 636, 705
- BURNING 337, 491, 615
- BURROWS 287
- CADMIUM 75, 110, 393, 590, 627, 658
- CADMIUM 109 486
- CALCIFICATION 187
- CALCIUM 37, 78, 80, 83, 120, 130, 142, 203, 229, 231, 238, 324, 342, 349, 497, 529, 590, 647
- CALCIUM CARBONATE 61, 500
- CALCIUM OTTA 72
- CALCIUM EDTA 426, 544
- CALCIUM OXALATE 508
- CALCIUM PROSPHATES 32, 61
- CALCIUM 45 58, 195, 326, 444, 486, 721
- CALCULATIONS 7, 9, 21, 93, 122, 132, 153, 197, 230, 232, 242, 250, 280, 295, 296, 304, 320, 346, 366, 383, 384, 409, 412, 413, 427, 431, 437, 445, 447, 450, 454, 458, 465, 466, 468, 481, 502, 505, 508, 515, 518, 530, 567, 569, 573, 584, 591, 599, 601, 604, 611, 613, 619, 632, 636, 653, 665, 696, 704, 709, 713, 716, 718, 724, 735, 740
- CALIBRATION 377, 378, 466, 529, 544, 559, 614, 627, 699, 704, 705, 714
- CALIPORNIUM 61, 640
- CALIPORNIUM 249 26, 45, 58, 92, 123, 506, 694
- CALIPORNIUM 252 45, 58, 92, 123, 254, 326, 621, 627, 655, 494, 704
- CALORIMETRY 659
- CARBOHYDRATES 55, 90, 209, 212
- CARBON 27, 130, 245, 340, 642
- CARBON DIOXIDE 326
- CARBON TETRACHLORIDE 258
- CARBON 14 65, 199, 325, 326, 444, 486, 529, 537, 590, 602, 612, 643, 721, 722
- CARCINOGENESIS 15, 16, 67, 68, 69, 76, 131, 135, 140, 266, 382, 386, 395, 396, 404, 408, 413, 415, 416, 444, 461, 471, 473, 480, 510, 520, 585, 736
- CARCINOGENS 68
- CARCINOMAS 15, 76, 82, 95, 123, 131, 174, 395, 403, 404, 405, 407, 408, 409, 412, 414, 424, 451, 452, 489, 503, 512, 525, 540, 547
- CARCINOMAS, IDIOPATHIC 81, 405, 451, 525
- CARFOTITE 159, 164, 165
- CARRIERS 141, 183, 248
- CARTILAGE 102
- CASE HISTORIES 69, 387, 394, 395, 401, 402, 404, 409, 412, 416, 418, 421, 422, 429, 451, 460, 464, 469, 470, 500, 503, 506, 514, 517, 523, 524, 526, 527, 533, 538, 544, 547
- CASTRATION 82
- CATTLE 32, 63, 172, 230, 288, 531
- CELL ULTRASTRUCTURE 435, 145
- CELLS, ALVEOLAR 197, 254, 432, 447
- CELLS, BIOLOGICAL 4, 5, 16, 26, 54, 61, 65, 87, 90, 92, 95, 96, 98, 100, 145, 179, 197, 212, 432, 469, 511, 518, 522, 527, 535
- CELLS, CULTURED 131, 543
- CELLS, EPITHELIAL 81, 87, 131, 386, 447
- CEREALS 215, 399, 531
- CERIUM 36, 37, 85, 141, 156, 216, 237, 403, 558, 590, 638, 647, 648
- CERIUM 144 28, 29, 605, 698, 721
- CESIUM 85, 128, 156, 182, 206, 225, 349, 443, 590, 638, 647, 688, 720
- CESIUM 134 267
- CESIUM 135 738
- CESIUM 137 12, 14, 30, 34, 209, 226, 238, 267, 291, 377, 445, 486, 491, 552, 559, 590, 600, 602, 605, 617, 629, 631, 633, 705
- CESIUM 144 358, 486

ALPHABET INDEX

217

APPARATUS 28, 29, 30, 36, 72, 92,
117, 120, 141, 217, 515, 544, 562

APPARATUS 36, 249, 544

APPARATUS ANALYSIS 100, 210, 220,
227, 236, 237, 238, 239, 241,
242, 260, 264, 323, 334, 422,
501, 520, 543, 580, 588, 598,
658, 655

APPARATUS FORM 102, 207, 265

APPARATUS PROPERTIES 146, 152, 166,
250, 265, 390, 490, 524, 550,
667, 707

APPARATUS TOXICITY 2, 17, 115, 303,
522, 711, 725

APPARATUS 36, 217, 234, 535, 580,
625, 641, 681, 733

APPARATUS 490

APPARATUS 120, 206

APPARATUS 457, 510, 530, 705

APPARATUS 53

APPARATUS 122, 182

APPARATUS 324

APPARATUS 36 486

APPARATUSOGRAPHY 65, 227, 228, 249,
571

APPARATUS 27, 28, 110, 206, 225,
265, 324, 341, 550, 640, 658

APPARATUS 51 486

APPARATUS 394, 400, 403, 417,
418, 424, 430, 440, 456, 496,
506, 543, 643

APPARATUS SYSTEM 16, 89, 90, 140

APPARATUS 405, 533, 534

APPARATUS 149, 198, 242

APPARATUS 411

APPARATUS 360, 613

APPARATUS 7, 22, 27, 89, 122, 128,
143, 147, 157, 172, 181, 199,
197, 250, 304, 427, 439, 447, 520

APPARATUS 539

APPARATUS STUDIES 30, 390, 401,
402, 403, 404, 408, 415, 423,
426, 428, 435, 437, 439, 440,
455, 457, 459, 461, 462, 470,
479, 483, 489, 503, 506, 512,
514, 518, 522, 525, 527, 533,
534, 538, 541, 542, 543, 544, 566

APPARATUS 36

APPARATUS 285, 300, 312, 499, 536, 654

APPARATUS 20, 75, 107, 110, 156, 206,
212, 341, 349, 550, 630, 647,
648, 705

APPARATUS 50 552

APPARATUS 60 12, 234, 486, 552, 600

APPARATUS 10, 65

APPARATUS 196, 400, 419

APPARATUS 72, 89, 116, 139, 190,
217, 269, 332, 397, 507, 510,
523, 666

APPARATUS 203, 229, 494

APPARATUS PROGRAMS 337, 410, 545,
567, 570, 582, 591, 614, 729

APPARATUS 130, 264, 274, 296,
331, 356, 421, 436, 566, 576, 703

APPARATUS FACTOR 109, 140,
156, 207, 274, 279, 281, 283, 600

APPARATUS 695

APPARATUS 139

APPARATUS TISSUE 4, 23, 81, 195,
396

APPARATUS 255, 550, 625, 685

APPARATUS 280, 290, 350, 393,
443, 495, 497, 551, 576, 604,
608, 624, 629, 643, 672, 689,
691, 695, 699, 706, 708, 731

APPARATUS 12, 20, 63, 66, 75, 80,
106, 109, 110, 155, 156, 160,
164, 181, 202, 203, 204, 206,
207, 209, 210, 214, 215, 216,
225, 226, 233, 235, 246, 253,
255, 256, 257, 270, 271, 272,
273, 275, 277, 281, 283, 284,
285, 286, 287, 290, 292, 325,
327, 330, 336, 342, 343, 344,
345, 349, 353, 355, 361, 362,
363, 364, 369, 371, 445, 446,
463, 464, 506, 510, 519, 530,
531, 532, 549, 551, 552, 553,
558, 560, 561, 568, 572, 573,
584, 589, 594, 596, 600, 605,
623, 632, 637, 646, 649, 50,
651, 652, 696, 700, 717, 71

APPARATUS MEDIA 302, 424, 440, 510,
535

APPARATUS 312, 595, 666, 672, 679,
689, 708

APPARATUS 110, 212, 225, 249, 249,
265, 324, 324, 501, 658

APPARATUS 64 486

APPARATUS 269, 271, 272, 274, 342

APPARATUS 320, 321, 329, 379,
380, 735, 739, 740

APPARATUS 133, 446

APPARATUS 265

APPARATUS ORGANS 105, 303, 445,
482, 724, 727

APPARATUS 355, 545

APPARATUS 280

APPARATUS 32, 85, 86, 220, 260, 267,
577, 627, 640, 722, 732, 738

APPARATUS 241 546

APPARATUS 242 61, 271, 298, 486, 685,
721

APPARATUS 243 45, 92

APPARATUS 244 45, 92, 171, 220, 254,
271, 298

APPARATUS 269, 326, 333, 345, 350,
646

APPARATUS 537

APPARATUS PRODUCTS 1, 9, 11, 25, 122,
132, 140, 141, 196, 197, 246,
294, 335, 376, 384, 410, 420,
422, 427, 447, 450, 492, 493,
494, 499, 509, 524, 548, 554,
555, 567, 576, 582, 595, 604,
614, 634, 661, 665, 672, 679,
681, 688, 690, 691, 692, 701,
709, 725, 731

APPARATUS, RADIOACTIVE 151, 223, 232,
251, 294, 327, 344, 398, 549

APPARATUS 588

APPARATUS 29, 86, 92, 141,
260, 275, 426, 524, 669, 711,
720, 732, 736

APPARATUS 54, 144, 259

APPARATUS 231

APPARATUS 265

APPARATUS 1, 3, 4, 7, 8, 11, 23,
28, 30, 35, 37, 51, 62, 64, 65,
74, 77, 86, 87, 95, 96, 98, 100,
102, 105, 106, 110, 111, 116,
117, 123, 131, 134, 135, 142,
143, 150, 161, 172, 179, 183,
185, 190, 197, 198, 269, 277,
324, 333, 350, 359, 384, 386,
390, 392, 398, 401, 402, 405,
406, 409, 410, 419, 420, 424,
425, 439, 445, 446, 447, 452,
459, 460, 461, 474, 484, 489,
492, 498, 504, 507, 509, 516,
520, 523, 541, 546, 559, 574,
599, 617, 639, 709, 725

APPARATUS 277, 350

APPARATUS 291, 336

APPARATUS 246, 247, 302, 303, 315,
338, 376, 378, 674, 712

APPARATUS 375, 438, 516, 524, 554,
554, 574, 580, 608, 656

APPARATUS 381, 387, 395, 397, 442,
449, 523, 533, 537, 542, 543

APPARATUS 37, 328, 383, 497, 529

APPARATUS 290, 176, 639

APPARATUS 2, 13, 15, 33, 64, 67,
69, 71, 71, 74, 76, 82, 105, 112,
114, 119, 132, 136, 140, 162,
163, 195, 381, 382, 384, 385,
390, 392, 393, 395, 396, 397,
401, 402, 403, 404, 404, 405,
406, 407, 408, 412, 414, 416,
417, 418, 419, 423, 424, 432,
434, 440, 451, 452, 459, 474,
478, 480, 499, 500, 512, 520,
522, 523, 524, 525, 526, 527,
533, 534, 535, 538, 540, 541,
679, 688, 691, 701, 701, 724

APPARATUS 7, 11, 30, 40, 49,
61, 62, 92, 97, 99, 102, 111,
116, 128, 152, 159, 180, 182,
198, 205, 209, 250, 271, 278,
282, 287, 289, 290, 292, 325,
344, 349, 357, 360, 361, 362,
364, 386, 412, 421, 422, 492,
494, 535, 567, 699, 702

APPARATUS, BIOLOGICAL 9, 22,
24, 82, 84, 87, 93, 110, 115,
129, 132, 142, 158, 167, 179,
183, 189, 263, 304, 385, 391,

KEYWORD INDEX

DISTRIBUTION, BIOLOGICAL 415, 439, 440, 447, 453, 454, 455, 481, 493, 498, 505, 507, 510, 519, 520, 542, 426

DISTRIBUTION, GEOGRAPHICAL 336, 401

DISTRIBUTION, GEOLOGICAL 335, 342, 349

DOGS 1, 2, 3, 4, 5, 7, 13, 18, 20, 34, 38, 40, 51, 52, 56, 57, 74, 79, 80, 83, 84, 88, 104, 112, 113, 114, 142, 143, 148, 155, 162, 163, 166, 180, 181, 182, 184, 188, 192, 450, 465, 476, 477, 493, 425, 736

DOGS, PEARLE 3, 19, 33, 34, 35, 39, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 54, 55, 59, 69, 64, 65, 77, 78, 90, 91, 92, 93, 94, 95, 96, 57, 98, 99, 103, 101, 102, 103, 104, 123, 124, 126, 129, 135, 136, 138, 144, 149, 150, 151, 152, 153, 154, 159, 160, 164, 165, 173, 174, 175, 176, 177, 178, 186, 187, 191, 194, 195, 245, 475, 476, 481, 545

DOSE COMMITMENT 537, 735, 739, 740

DOSE DEPENDENCE 33, 39, 46, 90, 107, 119, 413

DOSE RATE 14, 29, 30, 35, 45, 60, 93, 95, 119, 125, 127, 132, 199, 232, 246, 280, 369, 391, 410, 421, 454, 455, 458, 474, 477, 480, 485, 491, 493, 505, 510, 519, 529, 529, 556, 602, 619, 627, 657, 665, 675, 713, 716, 718, 719, 734

DOSE/STEP 326, 372, 373, 529, 617, 618, 621, 627, 700, 704

DOSE/STBY 394, 424

DRINKING WATER 204, 325, 482, 557, 566, 736

DRUGS 172

DTPA 28, 25, 30, 92, 117, 141, 171, 228, 515, 643

DUST 66, 48, 135, 157, 159, 160, 161, 162, 162, 164, 196, 252, 255, 259, 262, 266, 276, 374, 411, 498, 547, 548, 560, 575, 584, 589, 597, 641, 643, 668, 670, 676, 682, 692, 701, 703, 706, 710

DUST STORMS 560

EARS 16

ECONOMICS 297, 299, 302, 304, 305, 306, 308, 309, 310, 313, 315, 317, 319, 324, 330, 379, 380, 546, 599, 668, 676, 690, 682, 683, 707, 727, 738

ECOSYSTEM ANALYSIS 291, 326

ECRA 188

EETA 28, 29, 30, 117, 141, 346, 515

EFFICIENCY 299

EFFLUENTS 199, 252, 267, 290, 375, 380, 576, 594, 596, 602, 637, 657, 668, 686, 724, 731, 733, 739, 740

EGGS 120, 294

EINSTABILITY 253 92

ELECTROCARDIOGRAPHY 176

EL DEPOSITION 235, 252, 254, 263, 532, 598, 641

ELECTRON MICROSCOPY 82, 97, 145, 179, 413, 435, 733

ELECTROPHORESIS 44, 393, 403, 450

ELEMENT 61 85

ELEMENTS 291, 351

EMBRYOS 120

EMERGENCIES 720

EMISSIONS 205

ENDOCRINE GLANDS 16, 54, 65, 148

ENRICHMENT 139, 247, 351, 354

ENRICHMENT, URANIUM 268, 301, 323, 351, 379, 652, 734

ENVIRONMENT 144, 244, 278, 285, 290, 291, 301, 322, 323, 495, 506, 552, 553, 556, 559, 565, 568, 586, 599, 594, 603, 635, 617, 622, 623, 629, 635, 637, 638, 643, 648, 683, 723

ENZYMES 19, 51, 54, 79, 133, 144, 149, 170, 212, 259, 417, 448, 525

EPIDEMIOLOGY 135, 307, 344, 403, 404, 414, 415, 434, 436, 441, 478, 679

EQUATIONS 20, 126, 127, 152, 231, 232, 289, 445, 502, 527, 510, 530, 561, 584, 614, 636, 663, 693, 713, 716, 723

EQUATIONS, DERIVED 125, 230, 402

EQUILIBRIUM 9, 331, 335, 347, 348, 453, 465, 554, 631, 663, 690

EQUIPMENT 302, 303, 339, 524, 633

EROSION 359, 631

ERRORS 182, 372, 631

ESTROGENS 82

ESTUARIES 358, 631

EUTHION 156

EUTHION 154 486

EVALUATION 22, 40, 81, 117, 151, 183, 222, 231, 298, 302, 303, 304, 305, 308, 309, 310, 311, 313, 314, 318, 329, 337, 365, 372, 386, 391, 393, 413, 502, 511, 575, 624, 633, 635, 644, 707, 713, 723, 726, 727, 728, 734, 738

EVAPORATION 27

EXCRETION 1, 6, 7, 8, 22, 23, 24, 25, 28, 30, 37, 44, 61, 62, 72, 74, 110, 111, 112, 115, 117, 129, 132, 134, 137, 141, 146, 147, 151, 152, 160, 167, 180, 182, 183, 189, 190, 198, 263, 410, 412, 421, 426, 431, 437, 438

EXCRETION 439, 440, 445, 446, 446, 453, 455, 464, 467, 481, 484, 498, 489, 492, 494, 522, 506, 515, 521, 524, 531, 532, 544, 541, 542, 563, 564, 567, 497, 598, 606, 636, 642, 643, 456, 725, 727

EXHALATION 190, 389, 390, 425, 437, 479, 494, 485, 444

EXHAUST GASES 162, 163, 543

EXPERIMENTAL STUDIES 220, 222, 237, 281, 661

EXPLOSIONS, NON-NUCLEAR 725

EXPLOSIONS, NUCLEAR 291, 537, 647, 648

EXPOSURE, ACUTE 154

EXPOSURE, CHRONIC 73, 113, 114, 133, 154, 159, 162, 163, 194, 188, 249, 243, 399, 429, 479, 531

EXPOSURE, EXTERNAL 245, 471, 483, 495, 496, 537, 713, 727

EXPOSURE, INTERNAL 81, 134, 174, 191, 265, 268, 391, 461, 495, 537, 727, 736

EXPOSURE, OCCUPATIONAL 2, 7, 135, 260, 262, 294, 383, 384, 355, 388, 389, 400, 427, 429, 410, 431, 446, 461, 467, 470, 475, 488, 490, 498, 511, 513, 524, 529, 530, 536, 539, 547, 562, 566, 549, 630, 636, 670, 672, 677, 679, 681, 682, 688, 691, 697, 701, 702, 705, 710, 713, 714, 721, 722, 725, 736

EXPOSURE, POPULATION 14, 380, 382, 391, 427, 471, 478, 524, 537, 657, 698

EXTRACTION METHODS 221, 227, 229, 234, 239, 240, 246, 248, 252, 254, 256, 259, 260, 266, 302, 303, 346, 464, 674, 686, 731

EYES 16, 91, 152, 174, 175, 177, 486, 487

FABRICATION PLANTS, NUCLEAR 726, 739, 740

FABRICATION, FUEL ELEMENT 231, 267, 268, 303, 313, 665, 675, 733, 102

FALLOTT 14, 128, 140, 276, 280, 284, 288, 491, 529, 552, 556, 559, 590, 602, 617, 629, 637, 638, 647, 648, 705, 717

FATS 486

FECES 8, 22, 23, 24, 25, 28, 62, 74, 129, 143, 146, 147, 151, 160, 167, 162, 183, 189, 198, 412, 412, 437, 439, 440, 445, 446, 467, 484, 494, 528, 531, 532, 562, 508, 636, 727

FERRITIN 61

FERTILITY 199

FERTILIZERS 273, 335, 352, 353, 355, 365, 678

FETUSES 113

FIELD STUDIES 211, 276, 337, 369, 520, 546, 556

REFINED INDEX

FILICES 255, 548, 549, 573, 575,
 577, 594, 635, 708
 FINGER 426, 627
 FIRE 262, 615, 670, 690, 694, 725
 FISH 12, 196, 118, 199, 267, 271,
 274, 280, 298, 326, 554
 FISSION 627, 704, 729
 FISSION PRODUCTS 181, 239, 290,
 311, 523, 552, 589, 605, 639,
 706, 712, 732, 734, 739
 FISSION TRACER ANALYSIS 230, 257,
 342, 345, 372, 504, 557, 595, 621
 FICUS 235, 208
 FIDUCIOSITY 545, 599
 FIDUCIARY 18 486
 FIFE 106, 215, 294, 297, 298, 322,
 325, 345, 482, 495, 497, 531,
 546, 548, 606, 678, 614, 629,
 646, 682, 706
 FIFE CHAINS 271, 287, 325, 495,
 672
 FIFTHS 261, 262, 368
 FIFTHS 646
 FIFTHS 598
 FIFTHS SYSTEMS 199, 297, 209,
 268, 273, 275, 278, 322, 324,
 342, 558, 650, 651, 658
 FIFTH 210, 215, 399
 FIFTH CYCLE 268, 293, 295, 296,
 297, 298, 299, 301, 302, 303,
 304, 305, 306, 307, 308, 309,
 310, 311, 313, 314, 315, 316,
 318, 319, 320, 321, 322, 323,
 324, 326, 665, 668, 671, 672,
 674, 675, 686, 723, 724, 728,
 729, 730, 734, 735, 739
 FIFTH ELEMENTS 297, 301, 568, 655,
 671, 680, 685, 712, 732, 734,
 737, 739
 FIFTH, POSSIL 285, 300, 312, 491,
 499, 654
 FIFTH 206, 212
 FIFTH 152 271
 FIFTH BLADE 432, 452
 FIFTH 72 486
 FIFTHS 303, 330, 380, 578, 584, 697
 FIFTH JUICE 251
 FIFTH INTERSTIAL TRACT 1, 2, 6,
 16, 22, 61, 85, 112, 116, 143,
 147, 167, 183, 322, 403, 412,
 452, 467, 482, 493, 494, 512,
 520, 524, 525, 642, 735, 739, 740
 FIFTH 2, 147, 183
 FIFTH-RUELLER COUNTERS 598
 FIFTHS 2, 16, 148, 199, 267,
 286, 300, 394, 400, 417, 430, 506
 FIFTHS 236, 337, 342, 346,
 351, 356, 357, 358, 365, 369,
 412, 605

GEOGRAPHIC VARIATION 328
 GEOGRAPHY 684, 695
 GEOLOGIC STRUCTURES 333, 334, 351,
 366, 367, 373, 553, 592, 694, 712
 GEOLOGIC TIME 550, 657
 GEOLOGY 333, 334, 339, 340, 345,
 351, 357, 364, 369, 370, 546,
 570, 581, 592, 613, 634, 645,
 633, 694, 695, 717, 718
 GERANIUM 71 496
 GLASS 222, 255, 575
 GLOBULINS 19, 30, 149, 393, 403,
 490, 512, 539
 GLOBE BONES 621, 627, 712
 GLOBULE 536
 GLYCOGEN 259
 GOLD 75, 118, 265, 324, 535, 627
 GOLD 198 486
 GOLD 199 486
 GONADS 14, 524, 717, 724
 GRANITES 216, 236, 649
 GRANULOMAS 404, 406, 407, 408,
 419, 451, 541
 GRASSES 210, 211, 294, 326, 292,
 326, 368, 594, 637, 638, 678
 GROUNDWATER 290, 576, 594, 658,
 641, 683
 GROWTH 292
 GROWTH 3, 35, 44, 187, 213, 333
 GUINEA PIGS 6, 84, 116, 147, 166
 HABITATS 213
 HAPTIUM 204, 341, 545, 568
 HAPTIUM OXIDES 139
 HAPTIUM 174 271
 HAIR 111
 HANSTERS 94, 131, 135, 159, 162,
 163, 165
 HANDLING 712
 HANDS 426, 448, 621
 HAZARD ANALYSIS 12, 83, 88, 119,
 159, 182, 262, 265, 266, 294,
 300, 312, 355, 376, 381, 382,
 384, 386, 389, 443, 470, 478,
 485, 491, 499, 509, 513, 520,
 529, 547, 560, 572, 633, 649,
 654, 665, 670, 671, 672, 673,
 677, 679, 681, 686, 687, 690,
 691, 694, 696, 697, 699, 706,
 710, 711, 723, 724, 725, 726,
 727, 739, 732, 733, 734, 736, 738
 HEAD 174, 446, 490
 HEALTH PHYSICS 374, 618, 706, 726,
 727

HEART 176, 189, 230, 357, 199,
 422, 440, 452, 493, 524, 547
 HEAT 253, 714
 HELIUM 695
 HEMATOLOGY 44, 401
 HEMATOLOGY 17, 30, 40, 42, 43, 44,
 69, 94, 97, 116, 164, 341, 417,
 459, 535, 538
 HEMATOPOIETIC SYSTEM 16, 34, 39,
 41, 42, 44, 77, 148, 164, 174,
 513, 524, 641
 HEMOGLOBINS 43, 200, 401, 470, 447
 HISTOLOGY 15, 25, 34, 49, 60, 76,
 81, 82, 83, 84, 93, 95, 104, 105,
 114, 124, 129, 131, 143, 155,
 167, 173, 189, 194, 259, 184,
 406, 407, 408, 419, 432, 433,
 449, 451, 453, 455, 460, 149,
 449, 512, 522, 540
 HOLMITE 166 486
 HORMONES 44, 55, 82, 89, 119
 HOT CELLS 712
 HUMIC ACIDS 201, 332
 HUMIDITY 702
 HYDROCHLORIC ACID 257, 610
 HYDROGEN 349, 552, 642
 HYDROLOGY 643
 HYDROLYSIS 116, 149, 229
 HYDROXYPROLINE 196
 IMMUNE RESPONSE 135, 443, 499,
 539, 539
 INDION 115 704
 INFORMATION 441
 INGESTION 2, 85, 113, 116, 147,
 183, 188, 262, 265, 266, 284,
 288, 299, 322, 383, 399, 412,
 445, 461, 467, 482, 491, 494,
 497, 529, 488, 725, 730, 736
 INHALATION 1, 2, 8, 9, 10, 11, 22,
 23, 24, 27, 30, 61, 73, 74, 83,
 84, 85, 88, 112, 114, 116, 135,
 148, 157, 158, 159, 160, 161,
 162, 163, 165, 180, 181, 182,
 184, 196, 197, 262, 265, 266,
 294, 298, 384, 386, 398, 411,
 420, 429, 439, 443, 445, 447,
 458, 461, 476, 491, 494, 495,
 498, 520, 524, 529, 554, 572,
 579, 599, 630, 632, 670, 672,
 673, 673, 677, 679, 688, 690,
 725, 736
 INHIBITION 36, 212, 231
 INJECTION 19, 20, 28, 40, 42, 44,
 50, 51, 52, 53, 54, 55, 61, 64,
 80, 85, 87, 92, 101, 117, 120,
 126, 131, 136, 150, 166, 174,
 194, 262, 382, 387, 392, 394,
 401, 414, 423, 433, 435, 440,
 459, 462, 474, 476, 478, 503,
 510, 512, 514, 515, 518, 523,
 524, 533, 534
 INJECTION, INTRAMUSCULAR 492

SYNONYM INDEX

INJECTION, INTERARTICULAR 62, 96,
107, 171, 172, 183, 185, 193

INJECTION, INTEREPIDURAL 2, 17,
67, 72, 95, 117, 119, 132, 185,
164, 188, 189, 177, 184, 189, 198

INJECTION, INTERFASCIAL 129, 481

INJECTION, INTERNEURAL 2, 13,
64, 74, 117, 121, 122, 137, 183,
187, 187, 188, 189, 189, 195,
199, 209, 494

INJECTION, INTRAVASCULAR 445

INJECTION, INTRAVENOUS 1, 2, 25,
33, 38, 75, 79, 81, 83, 88, 85,
86, 87, 88, 89, 90, 95, 70, 71,
12, 28, 79, 81, 92, 87, 90, 91,
92, 95, 96, 97, 96, 100, 102,
97, 105, 107, 112, 111, 117,
123, 128, 129, 130, 134, 181,
182, 184, 187, 189, 151, 152,
143, 154, 171, 173, 176, 177,
179, 181, 185, 186, 187, 190,
193, 195, 202, 812, 826, 834,
837, 854, 855, 861, 867, 881,
892, 893, 895, 517, 509, 543, 595

INJECTION, SPECULANT 183, 199

INJURIES 17, 77, 57, 99, 129, 435,
479, 480, 483, 529

INJURIES 286, 326, 375, 376,
567, 590, 655, 702

INJURIES 8, 34, 104, 132, 191,
404, 432, 440, 471

INJURIES 267, 171, 288

INJURY 85, 56, 590, 606, 638, 642,
643, 647, 648, 648, 705, 723

INJURY 129 701, 602, 602, 738

INJURY 131 238, 445, 473, 494,
527, 594

INJURY 137 559

ION EXCHANGE 273, 217, 224, 233,
238, 241, 242, 243, 331, 349,
555, 558, 571, 590, 593, 616,
628, 656, 686

ION EXCHANGE RESINS 221, 249, 555,
656

IONIC 269

IONIZATION CHAMBERS 374, 578

IONS 62, 72, 133, 225, 229, 249,
322, 337, 454, 584, 559, 613

IODINE 114 30

IODINE 190 486

IODINE 192 30, 486

IRON 28, 61, 75, 136, 156, 198,
200, 206, 242, 246, 257, 324,
331, 333, 337, 341, 535, 546,
558, 590, 610, 627

IRON 55 12, 350, 486, 593, 600,
612

IRON 59 486

IRRIGATION 349, 706

ISOTOPE RATIO 157, 161, 164, 223,
265, 274, 276, 277, 279, 327,
336, 340, 346, 347, 356, 376,

ISOTOPE RATIO 113, 497, 508, 510,
531, 637, 651, 661, 690, 695, 726,

JITTERS 514

KELP 444

KIDNEYS 4, 9, 10, 16, 23, 25, 28,
34, 51, 62, 73, 76, 80, 81, 85,
102, 115, 111, 112, 118, 122,
132, 133, 138, 143, 147, 148,
151, 157, 158, 163, 164, 165,
167, 171, 183, 188, 189, 198,
259, 266, 284, 303, 391, 393,
399, 410, 422, 440, 454, 460,
462, 464, 489, 492, 493, 519,
522, 524, 541, 547, 597, 630,
715, 719, 749

KINETICS 9, 9, 36, 250, 627

KRYPTON 43 633

KRYPTON 85 326, 499, 602

LABORATORY STUDIES 1, 2, 6, 7, 8,
9, 10, 11, 11, 15, 17, 18, 21,
22, 23, 24, 25, 27, 31, 32, 33,
34, 36, 38, 39, 40, 42, 43, 44,
45, 46, 47, 48, 49, 50, 51, 52,
53, 54, 55, 56, 59, 60, 64, 65,
67, 68, 69, 70, 71, 72, 73, 74,
76, 77, 78, 79, 80, 81, 82, 83,
84, 85, 87, 88, 89, 90, 91, 92,
93, 96, 97, 98, 99, 100, 102,
103, 104, 105, 107, 108, 111,
111, 114, 116, 117, 119, 120,
121, 122, 123, 129, 131, 132,
133, 134, 135, 136, 137, 138,
140, 142, 143, 144, 145, 147,
149, 150, 151, 152, 157, 158,
159, 160, 162, 163, 165, 166,
167, 169, 169, 170, 172, 176,
179, 179, 181, 185, 187, 188,
190, 191, 196, 198, 200, 201,
202, 207, 211, 219, 224, 227,
234, 240, 250, 259, 264, 274,
275, 294, 296, 331, 333, 334,
335, 337, 347, 348, 351, 356,
365, 369, 385, 399, 407, 409,
412, 415, 418, 420, 422, 428,
430, 438, 449, 450, 451, 455,
465, 467, 472, 476, 488, 493,
515, 520, 529, 539, 545, 554,
555, 567, 571, 574, 576, 578,
579, 581, 582, 583, 588, 592,
593, 607, 609, 610, 612, 613,
614, 625, 626, 627, 630, 631,
636, 639, 641, 656, 658, 660,
678, 707, 709

LAKES 199, 324, 325, 558

LANTHANIDES 36, 61, 62, 216

LANTHANUM 36, 85, 118, 146, 156,
216, 248, 324, 341, 349, 487, 558

LANTHANUM CHLORIDES 120

LANTHANUM 100 86, 486

LATEX EFFECTS 55, 68, 70, 71,
385, 390, 401, 405, 413, 414,
418, 459, 469, 500, 527

LATEX BEADS 145

LEACHING 251, 251, 253, 327, 338,
342, 343, 344, 346, 359, 366,
601, 676, 683, 686

LEAD 27, 146, 212, 216, 225, 265,
273, 286, 325, 334, 340, 590,
658, 686, 719

LEAD 203 486

LEAD 204 554

LEAD 210 12, 54, 52, 105, 164,
199, 202, 209, 255, 275, 276,
288, 285, 326, 350, 354, 367,
431, 436, 446, 506, 514, 521,
524, 567, 565, 575, 597, 630,
602, 612, 641, 649, 650, 651, 700

LEAD 211 271

LEAD 212 1, 7, 11, 122, 197, 251,
271, 403, 421, 422, 437, 438,
439, 454, 465, 476, 482, 493,
494, 544, 548, 554, 602, 614,
617, 625, 641

LEAD 214 497, 573, 602

LEAVES 295, 294, 217, 222, 284,
289, 291

LEGAL ASPECTS 720

LEP 30, 529, 697

LETHAL DOSE 112, 166

LETHAL DOSE 50 2, 24, 70, 112,
120, 166

LEUKEMIA 15, 84, 69, 381, 382,
392, 403, 404, 413, 414, 416,
417, 444, 448, 459, 461, 471,
480, 483, 485, 518, 524, 537,
534, 535, 538

LEUKOPHORIA 13, 43, 344, 630

LICHENS 204, 216, 364

LIFE-SPAN 2, 33, 70, 117, 149, 165

LIGHT 201

LIGHT MICROSCOPY 179, 410

LIPIDS 290

LIQUIDS 574

LITHIUM 222, 225, 349, 649

LITTER 205, 361, 362, 368

LIVER 6, 7, 8, 15, 16, 22, 23, 28,
29, 30, 34, 51, 55, 62, 68, 72,
73, 74, 76, 80, 82, 83, 84, 85,
86, 87, 89, 91, 92, 95, 102, 105,
107, 112, 117, 118, 122, 127,
129, 131, 132, 133, 134, 138,
146, 147, 148, 149, 151, 158,
160, 164, 165, 167, 171, 178,
179, 183, 188, 189, 190, 198,
199, 200, 222, 259, 262, 284,
382, 385, 391, 392, 396, 399,
401, 403, 404, 405, 407, 408,
409, 410, 413, 414, 416, 421,
422, 424, 432, 432, 433, 434,
435, 438, 440, 442, 444, 451,
452, 453, 454, 455, 459, 460,
461, 469, 470, 482, 483, 485,
486, 492, 493, 503, 504, 507,
509, 510, 512, 514, 519, 523,
524, 525, 527, 533, 534, 538,
540, 542, 543, 544, 567, 597,
625, 626, 630, 739, 740

LOBSTERS 279

LUMINOUS PAINT 390

LUNGS 2, 7, 8, 9, 10, 11, 15, 22,
23, 24, 27, 38, 61, 66, 73, 74,
76, 81, 83, 88, 85, 88, 102, 105,
107, 112, 114, 121, 122, 130,
131, 132, 135, 137, 143, 147,
148, 157, 158, 160, 161, 162,
163, 164, 165, 167, 180, 181,

KEYWORD INDEX

LYNGS 144, 185, 190, 190, 190,
197, 197, 255, 294, 302, 303,
390, 396, 395, 391, 398, 399,
432, 436, 442, 425, 427, 429,
432, 434, 437, 439, 440, 445,
445, 452, 454, 457, 459, 459,
467, 471, 474, 485, 486, 491,
492, 493, 499, 501, 507, 511,
511, 516, 522, 522, 524, 524,
525, 554, 572, 574, 579, 597,
599, 636, 642, 679, 699, 692,
695, 696, 701, 705, 709, 715,
724, 727, 735, 739, 740

LYNCHING 177 484

LYNCH MOORS 34, 74, 83, 88, 112,
114, 135, 143, 149, 157, 159,
162, 164, 165, 167, 181, 184,
190, 196, 198, 391, 401, 407,
412, 421, 422, 424, 429, 432,
445, 452, 458, 460, 492, 533,
545, 552, 552, 524, 527, 540,
542, 597, 630

LYNCH SYSTEM 16, 51, 529

LYNCH SYSTEMS 13, 17, 34, 40, 69,
112, 135, 140, 390, 400, 417, 430

LYNCHING 417

LYNCHINGENIA 13, 34, 40, 135

LYSOSOMES 145

MACROPHAGES 27, 432, 441, 500, 527

MAGNETISM 120, 324, 342, 349, 691

MAGNETISM 245, 337

MAGNETUS 116, 141, 140, 326

MARRALS, MARINE 271

MARSHY GLAVES 44, 42, 174

MAR 1, 2, 5, 10, 16, 30, 36, 38,
55, 59, 61, 69, 69, 74, 81, 85,
88, 93, 95, 116, 135, 141, 149,
190, 195, 197, 240, 242, 244,
246, 248, 312, 322, 322, 324,
345, 378, 381, 382, 383, 384,
385, 386, 387, 389, 399, 390,
393, 394, 395, 396, 397, 399,
401, 402, 403, 404, 405, 406,
407, 408, 409, 410, 411, 412,
413, 414, 415, 416, 417, 418,
419, 420, 421, 424, 425, 426,
427, 428, 429, 430, 431, 432,
433, 434, 435, 436, 437, 438,
439, 440, 441, 442, 443, 445,
446, 447, 448, 449, 450, 451,
452, 453, 454, 455, 456, 457,
459, 461, 462, 463, 464, 465,
466, 467, 468, 469, 471,
472, 473, 474, 475, 477, 478,
479, 480, 481, 482, 483, 484,
485, 486, 487, 489, 490, 491,
492, 493, 494, 495, 496, 497,
498, 499, 500, 501, 502, 504,
505, 506, 509, 510, 511, 512,
513, 514, 516, 517, 518, 519,
521, 522, 523, 524, 525, 526,
527, 529, 530, 531, 532, 533,
535, 536, 537, 538, 539, 540,
541, 542, 543, 544, 547, 557,
561, 562, 562, 566, 567, 576,
579, 594, 602, 606, 609, 621,
625, 630, 636, 642, 643, 644,
657, 670, 672, 677, 679, 681,
682, 688, 691, 695, 697, 698,
705, 706, 711, 714, 717, 721,
722, 724, 725, 726, 727, 736

MARGARESE 27, 28, 190, 212, 320,
333, 337, 554, 590, 638, 648, 658

MARGARESE 54 12, 600, 625, 631

MARGARESE 56 484

MARS 544, 573, 634

MARINE COGNACIS 140, 271, 279

MARINE SEDIMENTS 274, 356

MARINE SYSTEMS 130, 194, 274, 280,
322, 324, 333, 334, 340, 347,
354, 359, 374, 612, 654

MARTIN PERMISSIBLE BODY STRESS
94, 351, 474, 594, 698, 714

MARTIN DEPRESSIBLE CONCENTRATION
24, 35, 66, 93, 165, 183, 184,
394, 393, 411, 444, 447, 442,
446, 502, 524, 529, 540, 550,
642, 643, 673, 691, 692, 697,
698, 715, 725, 726, 733

MARTIN PERMISSIBLE DOSE 73, 440,
721

MARTIN PERMISSIBLE VALUE 74, 290,
390, 590, 673, 739, 710, 715

MARTINMENT 12, 14, 63, 75, 104,
108, 109, 119, 124, 154, 154,
202, 203, 204, 206, 209, 210,
210, 215, 216, 221, 223, 224,
225, 230, 231, 235, 238, 240,
246, 247, 254, 255, 258, 258,
257, 261, 273, 272, 273, 281,
293, 294, 295, 296, 297, 292,
294, 325, 327, 330, 334, 341,
344, 345, 349, 352, 353, 355,
357, 361, 362, 363, 364, 369,
371, 375, 376, 390, 420, 422,
425, 428, 429, 444, 450, 452,
463, 464, 464, 472, 484, 485,
488, 489, 490, 507, 509, 510,
513, 519, 530, 531, 532, 544,
545, 549, 550, 555, 557, 558,
560, 564, 569, 570, 571, 572,
573, 574, 579, 579, 580, 581,
592, 594, 594, 591, 592, 593,
596, 597, 598, 602, 601, 602,
602, 607, 609, 610, 612, 613,
614, 615, 619, 619, 620, 621,
625, 626, 627, 630, 631, 632,
634, 635, 636, 639, 641, 644,
646, 650, 651, 652, 653, 655,
656, 658, 659, 662, 672, 681,
684, 695, 696, 730, 713, 716, 729

MEAT 249, 399

MECHANICAL PROPERTIES 265

MEDICAL MANAGEMENT 294, 472, 725

MEDICINE 449, 500, 501, 509, 524,
542, 543

MELANOMAS 174, 175

MENSTRUATES 87, 212

MERCURY 75, 212, 324, 341

MESOTROPION 390, 470, 513, 524,
547, 677, 681

METABOLISM 9, 39, 44, 51, 60, 80,
104, 110, 116, 121, 128, 133,
141, 146, 151, 152, 183, 198,
200, 250, 294, 326, 383, 383,
410, 417, 476, 483, 492, 493,
494, 502, 536, 598, 643, 691,
705, 714, 734

METALLURGY 265, 644, 699, 725

METALS 66, 104, 130, 212, 229,
265, 297, 311, 340, 501, 615,

METALS 644, 647, 647, 670, 696,
699

METAMORPHOSIS 164

METAPLASIA 135

METROLOGY 549

METROIDS 14, 54, 154, 214, 220,
221, 222, 223, 224, 224, 224,
238, 242, 243, 244, 244, 251,
254, 257, 265, 261, 264, 277,
326, 345, 352, 375, 410, 412,
443, 444, 472, 524, 533, 545,
548, 550, 554, 554, 557, 567,
564, 570, 571, 572, 573, 577,
578, 579, 582, 581, 582, 587,
589, 593, 597, 598, 607, 629,
632, 632, 634, 634, 631, 632,
635, 636, 641, 644, 645, 651,
654, 655, 656, 659, 662, 664,
667, 672, 672, 681, 681, 684,
691, 694, 723, 720, 722, 731

MICAS 144

MICE 15, 24, 31, 47, 74, 71, 72,
74, 84, 84, 87, 95, 117, 117,
112, 119, 132, 134, 144, 151,
475, 477, 504, 422, 574, 410

MICE, FIELD 292

MICROORGANISMS 231, 707

MILK 113, 215, 280, 349, 545, 594,
594, 629, 637, 638, 647, 648

MILLING 44, 104, 159, 239, 254,
264, 267, 268, 301, 334, 374,
378, 379, 380, 400, 471, 499,
550, 567, 565, 576, 591, 594,
629, 641, 647, 651, 664, 672,
682, 684, 690, 731, 734

MISCELLANEOUS 124, 290, 211, 216, 222,
223, 227, 251, 251, 290, 322,
333, 346, 332, 334, 339, 340,
346, 352, 347, 462, 644, 736, 737

MIXES 373, 472, 544, 702, 711

MIXING 174, 135, 144, 159, 167,
274, 246, 247, 249, 300, 301,
317, 319, 318, 351, 374, 374,
379, 389, 391, 431, 444, 471,
480, 484, 490, 491, 494, 501,
511, 520, 514, 539, 557, 574,
594, 599, 604, 639, 644, 644,
672, 674, 676, 679, 681, 694,
694, 698, 697, 697, 721, 704

MITOCHONDRIA 415

MITOSIS 170, 417

MODELS 41, 115, 141, 197, 199,
207, 294, 343, 400, 412, 427,
492, 520, 542, 543, 545, 642,
643, 647, 679, 724

MODELS, MATHEMATICAL 194, 247,
599, 691

MOISTURE 291, 310, 495

MOLES 292

MOLASSES 249, 271, 279, 240

MOLYBDENUM 204, 216, 332, 341, 445

MOLYBDENUM 97 444

MORAZITE 217, 259, 317, 319, 334,
344, 400, 497, 547, 644, 644, 700

MONITORING 44, 294, 374, 471, 544,

 

RECYCLING 507, 550, 551, 552, 557, 559, 565, 575, 586, 590, 596, 602, 623, 628, 629, 630, 637, 643, 648, 651, 657, 658, 672, 690, 691, 703, 712, 726, 727, 731

RECYCLES 6, 70, 80, 110

RECYCLES 123

RECYCLOGY 17, 160, 211, 250, 407, 417

RECYCLITY 77, 80, 130, 166, 390, 410, 416, 430, 440, 449, 471, 480, 512, 520

RECYCLES 200, 206, 216, 292, 360

RECYC 3, 529

RECYC 306, 407

RECYCLES 7, 23, 85, 106, 132, 169, 183, 185, 189, 271, 391, 452, 486, 493, 500, 519, 626, 739, 740

RECYCATIONS 152, 267, 300

RECYCATION 30

RECYCATION 100 271

RECYCLAS 2, 4, 15, 20, 42, 49, 50, 51, 59, 61, 60, 79, 91, 93, 103, 110, 120, 135, 138, 173, 178, 192, 194, 197, 262, 300, 305, 397, 432, 442, 451, 520, 521, 522, 526, 579, 603, 679

RECYCLAS, HAIGHAWT 50, 69, 70, 71, 70, 76, 77, 81, 92, 94, 95, 105, 112, 119, 124, 132, 140, 175, 178, 187, 195, 300, 301, 302, 390, 392, 394, 395, 396, 471, 482, 483, 484, 485, 486, 487, 488, 489, 493, 494, 495, 496, 497, 498, 499, 501, 502, 503, 504, 505, 506, 507, 508, 509, 510, 511, 512, 513, 514, 515, 516, 517, 518, 519, 520, 521, 522, 523, 524, 525, 526, 527, 528, 529, 530, 531, 532, 533, 534, 535, 536, 537, 538, 539, 540, 541, 542, 543, 544, 545, 546, 547, 548, 549, 550, 551, 552, 553, 554, 555, 556, 557, 558, 559, 560, 561, 562, 563, 564, 565, 566, 567, 568, 569, 570, 571, 572, 573, 574, 575, 576, 577, 578, 579, 580, 581, 582, 583, 584, 585, 586, 587, 588, 589, 590, 591, 592, 593, 594, 595, 596, 597, 598, 599, 600, 601, 602, 603, 604, 605, 606, 607, 608, 609, 610, 611, 612, 613, 614, 615, 616, 617, 618, 619, 620, 621, 622, 623, 624, 625, 626, 627, 628, 629, 630, 631, 632, 633, 634, 635, 636, 637, 638, 639, 640, 641, 642, 643, 644, 645, 646, 647, 648, 649, 650, 651, 652, 653, 654, 655, 656, 657, 658, 659, 660, 661, 662, 663, 664, 665, 666, 667, 668, 669, 670, 671, 672, 673, 674, 675, 676, 677, 678, 679, 680, 681, 682, 683, 684, 685, 686, 687, 688, 689, 690, 691, 692, 693, 694, 695, 696, 697, 698, 699, 700, 701, 702, 703, 704, 705, 706, 707, 708, 709, 710, 711, 712, 713, 714, 715, 716, 717, 718, 719, 720, 721, 722, 723, 724, 725, 726, 727, 728, 729, 730, 731, 732, 733, 734, 735, 736, 737, 738, 739, 740, 741, 742, 743, 744, 745, 746, 747, 748, 749, 750, 751, 752, 753, 754, 755, 756, 757, 758, 759, 760, 761, 762, 763, 764, 765, 766, 767, 768, 769, 770, 771, 772, 773, 774, 775, 776, 777, 778, 779, 780, 781, 782, 783, 784, 785, 786, 787, 788, 789, 790, 791, 792, 793, 794, 795, 796, 797, 798, 799, 800, 801, 802, 803, 804, 805, 806, 807, 808, 809, 810, 811, 812, 813, 814, 815, 816, 817, 818, 819, 820, 821, 822, 823, 824, 825, 826, 827, 828, 829, 830, 831, 832, 833, 834, 835, 836, 837, 838, 839, 840, 841, 842, 843, 844, 845, 846, 847, 848, 849, 850, 851, 852, 853, 854, 855, 856, 857, 858, 859, 860, 861, 862, 863, 864, 865, 866, 867, 868, 869, 870, 871, 872, 873, 874, 875, 876, 877, 878, 879, 880, 881, 882, 883, 884, 885, 886, 887, 888, 889, 890, 891, 892, 893, 894, 895, 896, 897, 898, 899, 900, 901, 902, 903, 904, 905, 906, 907, 908, 909, 910, 911, 912, 913, 914, 915, 916, 917, 918, 919, 920, 921, 922, 923, 924, 925, 926, 927, 928, 929, 930, 931, 932, 933, 934, 935, 936, 937, 938, 939, 940, 941, 942, 943, 944, 945, 946, 947, 948, 949, 950, 951, 952, 953, 954, 955, 956, 957, 958, 959, 960, 961, 962, 963, 964, 965, 966, 967, 968, 969, 970, 971, 972, 973, 974, 975, 976, 977, 978, 979, 980, 981, 982, 983, 984, 985, 986, 987, 988, 989, 990, 991, 992, 993, 994, 995, 996, 997, 998, 999, 1000

RECYCLAS, SANCORAS 407

RECYCLING 85, 220, 260, 563, 577, 600, 640, 732, 730

RECYCLING 235 86

RECYCLING 237 5, 26, 61, 220, 227, 254, 271, 301, 627, 637, 643, 690, 700

RECYCLES SYSTEM 16, 129, 169, 180, 266, 479, 481

RECYCLING ACTIVITIES 100, 233, 256, 260, 452, 501, 502, 550, 566, 583

RECYCLES 221, 222, 230, 292, 553, 557, 581, 621, 627, 660, 690, 700, 730

RECYCLES, PAST 372

NICKEL 212, 265, 450

NICKEL 59 416

NICKEL 30, 180, 200, 265, 267, 560, 590, 607

NICKEL OXALATES 182

RECYCLING 95 406, 605, 617, 633

RECYCLES 231

RECYCLIC ACID 250, 610

RECYCLES 70, 90, 203, 222

RECYC 370

RECYC 16, 520, 600

RECYCLIC FACILITIES 100, 267, 200, 290, 290, 305, 310, 310, 393, 602, 610, 633, 657, 671, 717

RECYCLIC POWER 300, 310, 310, 310, 319, 526, 671, 691

RECYCLIC ACIDS 133

RECYCLES 202

RECYCLIC 100, 100, 199, 269, 270, 276, 326, 327, 333, 336, 300, 347, 340, 305, 612, 613

OILS 312

RECYCLES 64, 135, 157, 159, 160, 161, 162, 163, 164, 165, 196, 209, 251, 252, 255, 290, 299, 316, 321, 333, 337, 338, 360, 367, 501, 506, 547, 560, 597, 601, 603, 605, 640, 660, 669, 670, 670, 682, 680, 686, 691, 701, 723

RECYCLIC ACIDS 227

RECYCLIC COMPOUNDS 225, 220, 250

RECYCLIC BATTERY 203, 220, 337, 362

RECYCLIC 0, 29, 73, 116, 121, 122, 147, 160, 190, 259, 497, 410, 421, 422, 432, 442, 445, 452, 460, 470, 485, 492, 490, 509, 522, 570, 630, 657

RECYCLES 292

RECYCLIC 89, 170, 396, 630, 739, 740

RECYCLIC 219, 230, 666

RECYCLIC 130, 229, 311

RECYCLIC 225, 269, 707

RECYCLIC 627

RECYCLIC 666

RECYCLIC 103 406

RECYCLIC 190, 391, 399, 405, 432, 471, 493

RECYCLIC SIZE 30, 30, 70, 89, 107, 110, 139, 141, 145, 182, 190, 205, 276, 350, 380, 386, 407, 499, 520, 500, 500, 615, 639, 641, 670, 673, 682, 702, 703, 709

RECYCLIC 27, 61, 60, 87, 116, 130, 145, 181, 225, 269, 322, 340, 492, 599, 611, 612, 625, 702, 703, 706

RECYCLIC, AIRBORNE 312, 427, 490, 572, 580, 589, 597, 650, 673, 682, 697, 719, 740

RECYCLIC 25, 30, 40, 49, 51, 52, 53, 54, 80, 90, 100, 100, 112, 120, 135, 143, 155, 170, 195, 196, 385, 387, 390, 401, 403, 404, 406, 408, 417, 419, 435,

RECYCLIC 449, 451, 460, 469, 500, 525, 540

RECYCLIC 303, 390, 403, 410, 433, 430, 435, 437, 441, 440, 450, 455, 461, 462, 470, 470, 479, 485, 489, 500, 505, 510, 510, 525, 530, 540, 640

RECYC 360

RECYCLIC TABLE 62

RECYCLIC 130, 145, 396

RECYCLIC 500

RECYCLIC 269, 379, 411, 426, 431, 440, 506, 557, 621, 672, 679, 697, 700, 705, 706, 721, 722, 726, 727

RECYC 32, 62, 227, 231, 236, 242, 249, 260, 332, 350, 577, 625, 666, 686

RECYCLOSIS 27, 82, 107, 130, 145, 435, 523

RECYCLIC 10, 403, 446, 472, 507, 627, 716

RECYCLIC 392, 406, 570

RECYCLIC 19, 70, 133, 149, 170, 259, 403, 440, 512, 525

RECYCLIC 230, 273, 355, 546

RECYCLIC 259

RECYCLIC 37, 70, 80, 133, 215, 236, 337, 453

RECYCLIC 32 86, 230, 473, 486, 590

RECYCLIC POP 72, 102, 207, 265

RECYCLIC PROPERTIES 29, 116, 146, 195, 245, 265, 271, 337, 390, 412, 509, 520, 550, 662, 681, 691, 707, 729

RECYCLIC 315, 660

RECYCLIC 16, 120, 141

RECYCLIC 200, 527

RECYCLIC 150, 159, 160, 165, 732

RECYCLIC 452

RECYCLIC 112, 113, 495, 519

RECYCLIC 199

RECYCLIC 109, 270, 271, 279, 279, 280, 281, 283, 635

RECYCLIC 291, 360

RECYCLIC 201, 202, 203, 204, 205, 206, 207, 208, 209, 210, 211, 213, 214, 216, 244, 267, 272, 273, 275, 278, 281, 282, 283, 284, 286, 287, 288, 289, 291, 292, 322, 326, 332, 349, 351, 355, 363, 368, 371, 377, 440, 481, 500, 506, 616, 620, 635, 670, 700

RECYCLIC, INDUSTRIAL 239, 265, 572, 579, 620, 652, 660, 677, 710, 731

RECYCLIC 230

ALPHABETIC INDEX

RADIATION SICKNESS 200

RADIATION, COSMIC 521, 537, 602, 610, 693

RADIATION, GAMMA 1, 2, 10, 21, 120, 213, 214, 261, 335, 363, 385, 373, 377, 390, 437, 460, 479, 487, 489, 495, 500, 507, 509, 513, 520, 510, 529, 507, 540, 556, 565, 587, 587, 590, 602, 603, 605, 617, 610, 619, 621, 620, 627, 631, 652, 655, 665, 675, 677, 681, 688, 690, 692, 693, 690, 695, 704, 706, 707, 713, 710, 725

RADIATION, ION LEVEL 119, 260, 529

RADIATION, SYNCHRO 301, 455, 675

RADIATION, THERMION 222, 373, 487, 550, 551

RADIATION, X-RAY 519, 550, 600, 650

RADIATION EFFECTS, LATENT 501

RADIOACTIVITY 62, 107, 120, 103, 211, 263, 283, 335, 303, 401, 450, 503, 521, 552, 553, 565, 566, 590, 617, 610, 623, 629, 637, 640, 657, 679, 693, 699

RADIOACTIVITY, NATURAL 10, 61, 66, 120, 213, 214, 270, 280, 203, 205, 206, 207, 208, 209, 325, 330, 306, 355, 367, 405, 406, 407, 521, 529, 575, 602, 605, 617, 601, 660, 693, 700, 717

RADIOAUTOGRAPHY 3, 4, 25, 30, 80, 80, 81, 82, 85, 96, 93, 97, 99, 100, 102, 104, 105, 167, 172, 109, 432, 450, 452, 453, 460, 500, 500, 500, 557, 570, 632

RADIOBIOLOGY 120

RADIOCHEMISTRY 91, 160, 232, 230, 200, 252, 255, 260, 375, 436, 465, 465, 520, 627, 700

RADIOCHEMISTRY 213

RADIOGRAPHY 23, 100, 106, 302, 400, 432, 401, 600

RADIOISOTOPE RATIO 11, 165, 269, 277, 311, 339, 303, 300, 357, 366, 366, 502, 519, 560, 592, 612, 610

RADIOISOTOPES 3, 4, 7, 8, 9, 10, 10, 10, 10, 25, 29, 30, 33, 36, 43, 45, 47, 49, 50, 60, 62, 60, 70, 77, 85, 90, 93, 95, 106, 117, 122, 120, 101, 102, 100, 172, 192, 193, 209, 213, 229, 210, 250, 261, 262, 267, 200, 290, 300, 320, 320, 325, 339, 350, 360, 393, 409, 410, 421, 422, 436, 440, 443, 453, 459, 461, 465, 466, 476, 486, 500, 535, 537, 553, 554, 555, 556, 559, 561, 560, 569, 576, 579, 590, 590, 590, 600, 602, 610, 605, 606, 623, 625, 633, 635, 637, 601, 665, 673, 675, 695, 590, 715, 717, 720, 721, 722, 723, 733, 736

RADIOSENSITIVITY 100, 105, 205

RADIOTHERAPY 16, 290, 401, 450, 520, 500, 603, 600

RADIOTHERAPY 470, 500, 520

RADIUM 120, 136, 191, 192, 193, 203, 205, 200, 213, 215, 260, 260, 273, 283, 200, 205, 200, 209, 292, 327, 350, 355, 357, 361, 362, 360, 390, 403, 459, 461, 470, 482, 502, 506, 513, 530, 531, 535, 507, 553, 570, 590, 600, 612, 632, 635, 640, 602, 602, 677, 601, 691, 707, 711

RADIUM DAUGHTERS 502, 519

RADIUM 222 150

RADIUM 223 132, 271, 426

RADIUM 220 1, 7, 11, 21, 51, 50, 50, 67, 109, 122, 132, 100, 100, 100, 107, 190, 230, 239, 251, 271, 412, 421, 422, 436, 437, 430, 400, 402, 450, 467, 473, 470, 475, 470, 492, 493, 490, 505, 510, 520, 500, 550, 569, 600, 625, 699, 709, 725

RADIUM 226 6, 12, 16, 10, 19, 20, 21, 33, 30, 35, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 63, 64, 65, 70, 71, 77, 78, 79, 80, 90, 91, 92, 93, 90, 95, 97, 98, 99, 103, 101, 103, 100, 106, 109, 123, 120, 125, 127, 130, 100, 100, 109, 152, 153, 150, 155, 173, 170, 175, 176, 177, 170, 106, 107, 190, 195, 199, 207, 209, 210, 226, 229, 230, 252, 250, 261, 266, 267, 260, 271, 275, 270, 282, 200, 205, 301, 325, 331, 335, 303, 307, 350, 352, 353, 370, 371, 385, 399, 409, 421, 436, 440, 445, 473, 475, 476, 477, 480, 486, 491, 495, 496, 497, 517, 519, 521, 520, 520, 529, 560, 565, 575, 576, 585, 596, 590, 600, 605, 600, 610, 623, 641, 640, 609, 650, 660, 692, 690, 690, 700, 721, 722, 720, 733, 740

RADIUM 220 1, 16, 19, 19, 20, 33, 30, 35, 39, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 52, 54, 55, 56, 57, 58, 59, 60, 60, 65, 70, 79, 90, 90, 91, 92, 90, 95, 97, 99, 100, 101, 103, 100, 109, 120, 129, 130, 100, 100, 109, 152, 153, 154, 155, 173, 170, 175, 176, 177, 170, 106, 107, 190, 190, 195, 199, 202, 235, 239, 252, 280, 335, 409, 412, 421, 422, 436, 437, 430, 440, 442, 450, 453, 450, 465, 470, 475, 476, 477, 481, 480, 492, 493, 496, 497, 517, 521, 520, 500, 575, 585, 600, 610, 623, 625, 600, 690, 690, 699, 700, 709, 725, 726

RADON 135, 196, 206, 330, 376, 380, 386, 390, 412, 420, 427, 431, 403, 400, 513, 520, 509, 556, 570, 570, 582, 580, 596, 600, 606, 607, 630, 632, 630, 639, 672, 679, 682, 680, 695, 701, 706, 707, 736

RADON DAUGHTERS 135, 162, 163, 160, 165, 209, 373, 370, 306, 305, 431, 439, 446, 447, 491, 490, 557, 573, 580, 591, 599, 611, 639, 696, 702

RADON 220 1, 11, 190, 370, 422, 430, 407, 450, 400, 506, 521, 550, 500, 599, 610, 662, 700, 725

RADON 222 1, 197, 239, 271, 209,

RADON 222 301, 326, 370, 399, 407, 473, 400, 496, 491, 499, 521, 573, 599, 602, 610, 620, 725

RADON 226 555

RARE EARTHS 30, 101, 211, 203, 350, 403, 571, 660, 669, 722

RAYS 1, 2, 6, 9, 10, 11, 17, 20, 22, 23, 20, 25, 20, 29, 37, 30, 62, 66, 73, 70, 76, 81, 92, 93, 80, 85, 86, 89, 92, 107, 112, 110, 115, 116, 117, 121, 122, 130, 132, 133, 137, 101, 105, 107, 157, 150, 159, 161, 165, 166, 167, 160, 169, 170, 171, 172, 179, 100, 101, 102, 103, 100, 105, 109, 192, 196, 190, 259, 207, 465, 475, 477, 493, 515, 520, 550, 570, 579, 625, 603, 736

REACTIONS 293, 299, 303, 300, 310, 311, 313, 310, 320, 300, 520, 550, 640, 600, 729

REACTIONS, BOILING-WATER 295

REACTIONS, BREEDER 293, 296, 299, 300, 300, 310, 310, 315, 317, 320, 675, 729, 730

REACTIONS, CANDU 309, 310, 317, 310

REACTIONS, FAST BREEDER 309

REACTIONS, GCFR 303

REACTIONS, HEAVY-WATER 300, 306

REACTIONS, HIGH TEMPERATURE 671

REACTIONS, HIGH-TEMPERATURE GAS-COOLED 299, 301, 302, 300, 309, 315, 317, 310, 319, 320, 321, 670, 720, 732, 730, 735, 739, 701

REACTIONS, HWR 303, 309, 315, 310

REACTIONS, LIGHT-WATER 290, 301, 300, 309, 310, 671, 723, 720, 727, 730, 730

REACTIONS, LIQUID METAL FAST BREEDER 290, 301, 307, 310, 320, 671, 670, 729, 730

REACTIONS, MOLTEN SALT 730

REACTIONS, MOLTER SALT BREEDER 290, 315, 310

REACTIONS, NSCR 315

REACTIONS, POWER 260, 293, 295, 297, 299, 310, 315, 316, 520, 675

REACTIONS, PRESSURIZED WATER 296, 315

REACTIONS, PRESSURIZED-WATER 320

REACTIONS, PWR 319

REACTIONS, RESEARCH 560

REACTIONS, SWR 315

REACTIONS, SSCR 315

RECOMMENDATIONS 290, 299, 395, 477, 500, 579, 595, 670, 670, 715, 736

RECOVERY 40

REDISTRIBUTION 209, 276, 201, 202, 207, 209, 292, 363, 360, 631, 606

ALPHABETIC INDEX

- BRIDGE 613
 REGULATIONS, FEDERAL LEVEL 312, 565, 679, 683, 691, 716
 REGULATIONS, STATE LEVEL 679
 RELATIVE BIOLOGICAL EFFECTIVENESS 40, 41, 59, 77, 124
 REPROCESSING 293, 303, 311, 313, 316, 318, 671, 690, 691, 734, 735, 737
 REPROCESSING PLANTS, NUCLEAR 267, 268, 318, 375, 390, 622, 640, 730
 REPRODUCTION 14
 REPRODUCTIVE SYSTEM 16
 RESPIRATION 137, 140, 476, 600, 611
 RESPIRATORY SYSTEM 8, 16, 23, 76, 95, 135, 142, 181, 188, 197, 420, 427, 447, 452, 459, 499, 498, 524, 574, 615, 679, 691, 706
 RETENTION 1, 7, 8, 9, 10, 23, 25, 28, 29, 35, 35, 47, 53, 56, 57, 61, 74, 77, 85, 88, 91, 93, 111, 116, 122, 126, 128, 132, 134, 135, 151, 152, 158, 165, 167, 171, 172, 181, 190, 290, 332, 383, 384, 410, 412, 415, 421, 426, 440, 445, 452, 459, 467, 492, 493, 522, 503, 504, 509, 520, 523, 524, 531, 538, 541, 561, 574, 625, 709, 721
 RETICULATORS 13
 RETICULOENDOTHELIAL SYSTEM 7, 15, 18, 34, 47, 49, 102, 135, 139, 147, 181, 185, 401, 403, 407, 423, 425, 435, 438, 454, 455, 461, 470, 492, 493, 500, 504, 509, 522, 540, 542, 625
 RHEGOTACTIC 678
 REVIEW 1, 2, 16, 30, 62, 74, 95, 112, 116, 125, 139, 140, 166, 183, 195, 197, 209, 217, 229, 265, 269, 271, 280, 289, 293, 308, 313, 315, 322, 325, 327, 338, 365, 381, 385, 393, 397, 417, 417, 438, 451, 473, 475, 492, 500, 517, 523, 524, 535, 537, 548, 579, 580, 590, 606, 625, 664, 667, 676, 679, 680, 688, 690, 691, 692, 701, 709, 725
 RHENIUM 118, 225, 685
 RHENIUM 103 704
 RHENIUM 103 416
 RHODIUM 103 416
 RHODIUM 105 416
 RHODIUM 106 486, 605
 RICE 349, 596
 RIVERS 199, 234, 264, 713, 336, 354, 365, 546, 551, 553, 568, 594, 622, 637, 643, 650, 651, 652, 658, 721
 ROCKS 216, 223, 234, 289, 331, 336, 339, 345, 355, 357, 361, 366, 369, 371, 545, 546, 548, 570, 592, 602, 619, 634, 645, 653, 717
 ROBERTS 21, 100, 207
 ROOTS 202, 209, 349, 371, 497
 RYBIDION 118, 154, 206, 225, 247, 326, 349
 RYBIDION 86 486
 RYBIDION 87 199, 325
 RYHOFF 267
 RURAL AREAS 295
 RUTHENIUM 85, 630, 647, 648
 RUTHENIUM 106 30, 486, 605
 SAFEGUARDS 333, 673, 673, 707
 SALINITY 358
 SALIVARY GLANDS 16
 SAMARIUM 558
 SAMARIUM 147 271
 SAMARIUM 151 486
 SAMPLES 6, 213, 237, 247, 244, 323, 335, 354, 355, 356, 377, 422, 529, 542, 550, 560, 566, 578, 579, 613, 626, 630, 631, 632, 654, 673, 697
 SAMPLING 17, 223, 341, 369, 373, 374, 376, 379, 422, 548, 550, 560, 562, 573, 589, 591, 598, 603, 605, 608, 630, 637, 649, 651, 652, 688, 696, 699, 702, 720, 731
 SANDS 237, 334, 340, 545, 605, 660, 681, 714
 SANDSTONE 379
 SARCONAS 76, 81, 100, 155, 392, 404, 408
 SARCONAS, PEROX 105, 131, 406, 448
 SARCONAS, HEMANGIO 433
 SARCONAS, LYMPHO 44
 SARCONAS, OSTEO 33, 35, 44, 46, 54, 59, 60, 67, 74, 77, 78, 92, 92, 94, 97, 104, 119, 123, 124, 132, 148, 149, 153, 154, 184, 187, 194, 195, 302, 385, 433, 473, 474, 477, 478, 505, 506, 518, 526, 535, 585
 SCANDIUM 75, 156, 204, 324, 341, 558
 SCANDIUM 46 486
 SCANNING 535
 SCINTILLATION COUNTERS 218, 246, 399, 476, 484, 519, 543, 549, 598, 614, 627, 644, 705
 SEALS 707
 SEAS 336
 SEASONS 100, 211, 207, 328
 SEAWATER 109, 156, 199, 203, 214, 221, 229, 230, 235, 249, 264, 269, 270, 271, 274, 279, 280, 281, 288, 325, 326, 340, 342, 346, 354, 358, 375, 500, 593, 600, 601, 612, 633, 658
 SEAWEEDS 272, 279
 SEDIMENTATION 44, 245, 324, 348, 613
 SEDIMENTS 134, 199, 230, 234, 269, 277, 281, 325, 326, 327, 330, 340, 346, 347, 348, 350, 351, 358, 365, 545, 548, 594, 601, 613, 631, 641, 646
 SEEDLINGS 201
 SELENIUM 118, 324, 324, 341, 659
 SEPARATION PROCESSES 65, 224, 247, 233, 234, 238, 240, 241, 242, 243, 246, 249, 249, 252, 254, 255, 256, 257, 260, 261, 321, 330, 520, 532, 548, 580, 581, 593, 601, 603, 614, 624, 628, 635, 642, 641, 662, 668, 671, 681, 699, 738
 SERIES 379
 SEX 119, 187, 401, 519, 529
 SHAPE 611
 SHIELDING 46, 627, 645, 409, 712, 717, 718
 SHOOTS 202, 208
 SHROPS 211, 216, 291, 292
 SILICON 324, 349
 SILICON 32 412
 SILT 334, 613, 678
 SILVER 27, 75, 206, 212, 265, 324
 SILVER 105 486
 SILVER 109 486
 SILVER 111 486
 SIMULATION 249, 251, 323, 507
 SIMOSES 402, 412
 SITE EVALUATION 507, 638
 SIZE 24, 187, 627
 SKIN 2, 16, 20, 23, 61, 116, 143, 193, 419, 468, 486, 524
 SMOKE 668
 SMOKE, CIGARETTE 135, 162, 163, 164, 389, 464, 480, 511, 516, 688, 701
 SNAILS 267
 SODIUM 200, 225, 324, 341, 349, 705
 SODIUM CHLORIDE 27
 SODIUM HYDROXIDE 593
 SODIUM 22 553
 SODIUM 24 486
 SOIL PROFILE 282, 287, 290, 291, 292, 330, 343, 345, 354, 361, 362, 363, 364, 371
 SOIL TRANSPORT 290, 322

KEYWORD INDEX

224

SCILS 14, 21, 205, 206, 207, 210,
213, 219, 222, 223, 226, 240,
246, 247, 252, 253, 254, 261,
275, 276, 282, 285, 286, 287,
288, 289, 290, 291, 292, 322,
324, 325, 326, 330, 331, 332,
335, 337, 341, 343, 344, 345,
349, 352, 353, 354, 357, 359,
361, 362, 363, 364, 365, 368,
369, 370, 370, 371, 377, 495,
496, 497, 531, 546, 553, 555,
556, 565, 566, 567, 594, 596,
602, 605, 606, 617, 619, 620,
623, 629, 625, 626, 635, 637,
638, 659, 660, 670, 695, 707,
714, 717

SCILS, CLAY 219, 478

SCILS, SIET ICAH 219

SCILDS 578

SCIENCE 24, 62, 112, 115, 144,
187, 183, 184, 185, 189, 229,
251, 354, 494, 625, 724

SCIENTISTS 290, 509, 581, 625, 683

SCIENTISTS 233, 240, 246, 251, 254,
256, 258

SCIENTIST 219, 322

SEACE FLIGHT 406

SEAFH CCNTEPS 216

SEAFICIP ACTIVITY 10, 40, 625, 728

SEAFICIP ACTIVITY 211, 216, 220, 230,
241, 242, 343, 460, 465, 500,
503, 556, 571, 580, 587, 590,
608, 610, 611, 617, 626, 656,
659, 695

SEAFICIP ACTIVITY, ALFA 81, 220, 254,
260, 274, 279, 354, 412, 421,
555, 573, 591, 593, 616, 635,
641, 644, 645, 726, 699

SEAFICIP ACTIVITY, GAMMA 122, 223, 239,
247, 326, 331, 337, 353, 354,
369, 370, 422, 426, 453, 465,
493, 546, 559, 546, 567, 570,
592, 634, 636, 645, 659, 714, 726

SEAFICIP ACTIVITY, INFRARED 253

SEAFICIP ACTIVITY, PASS 225, 352, 622

SEAFICIP ACTIVITY, X 243, 545, 609

SEAFICIP 6, 15, 25, 51, 83, 86, 86,
87, 105, 107, 122, 132, 133, 134,
147, 160, 164, 171, 183, 188,
189, 190, 198, 262, 284, 382,
391, 396, 395, 401, 407, 410,
421, 422, 424, 432, 432, 438,
440, 442, 451, 452, 453, 454,
455, 459, 460, 461, 465, 469,
470, 482, 483, 485, 486, 492,
493, 503, 504, 507, 509, 510,
514, 519, 525, 528, 527, 530,
540, 544, 567, 597, 626, 630,
739, 740

SEAFICIP 62, 229, 494

SEAFICIP 380, 602, 623, 682

SEAFICIP, FEDERAL LEVEL 380, 385,
486, 529, 565, 652, 654, 657,
679, 682, 692, 736

SEAFICIP, INTERNATIONAL LEVEL
529, 662, 688, 701

SEAFICIP, INTERNATIONAL LEVEL 709

SEAFICIP 19, 23, 40, 100, 370,
337, 394, 400, 403, 415, 418,
441, 456, 471, 511, 514, 514,
517, 545, 595, 631, 633, 651, 679

SEAFICIP 291

SEAFICIP 18, 44, 64, 65

SEAFICIP 8, 199, 391, 432, 471

SEAFICIP 643

SEAFICIP 196, 650

SEAFICIP 1, 20, 37, 75, 85, 120,
156, 191, 192, 193, 225, 326,
349, 443, 590, 634, 642, 647,
648, 651, 711, 720

SEAFICIP 89 202, 226, 326, 406,
520, 721

SEAFICIP 90 16, 18, 19, 34, 35,
39, 41, 42, 43, 44, 45, 46, 47,
48, 49, 50, 51, 52, 53, 54, 55,
56, 57, 58, 59, 60, 65, 77, 79,
80, 91, 92, 93, 94, 95, 97, 100,
101, 103, 104, 123, 124, 126,
130, 144, 148, 152, 153, 154,
155, 173, 174, 175, 176, 177,
178, 184, 187, 194, 195, 209,
210, 226, 276, 444, 445, 475,
484, 491, 515, 520, 528, 529,
552, 561, 565, 585, 598, 602,
617, 629, 650, 694, 698, 721

SEAFICIP 201, 709

SULFATES 236

SULFUR 324, 326

SULFUR 32 627, 704

SULFUR 35 406, 590, 643, 721, 722

SURFACE WATERS 264, 491, 591, 607,
648, 658

SURGERY 20, 89, 107, 141, 173, 465

SURVEYS 370, 410, 415, 471, 480,
483, 534, 546, 547, 564, 570, 682

SURVIVAL TIME 20, 46, 59, 124,
153, 154, 194, 511

SYNTHESIS 162, 163, 400

TAILINGS 252, 255, 370, 379, 471,
499, 560, 591, 596, 620, 641,
651, 660, 670, 701, 707, 733, 736

TANTALUM 341, 568

TANTALUM HYDROXIDES 120

TEA 491

TECHNETIUM 404

TECHNETIUM 96 406

TECHNETIUM 99 552, 738

TECH 3, 49, 91, 95, 97, 99, 100,
102, 104, 120, 130, 286, 436,
486, 491, 495, 529, 530

TELLURIUM 85, 326, 658

TELLURIUM 127 406

TELLURIUM 127 404

TEMPERATURE 245, 291, 627, 645,
794, 792

TERRAIN 546, 582

TERRESTRIAL SYSTEMS 322, 349

TESTES 51, 64, 89, 132, 179, 391,
452, 630, 739, 740

TRILLIUM 659

TRILLIUM 20 554

TRILLIUM 207 271

TRILLIUM 208 271, 422, 570, 625,
718

THEORETICAL STUDIES 14, 20, 232,
299, 315, 482, 544, 604, 633,
661, 663, 665, 713, 735, 739, 740

THERAPY 16, 79, 30, 37, 72, 141,
457, 515, 517, 544, 562, 621, 711

THERMOLUMINESCENT DOSIMETERS 14,
370, 460, 709

THICKNESS 384, 704

TINCPAY 165

TINCPAY 2, 3, 4, 21, 24, 30, 31,
32, 34, 37, 39, 62, 66, 74, 75,
76, 85, 86, 100, 116, 117, 118,
128, 141, 146, 147, 156, 166,
180, 184, 189, 191, 192, 193,
198, 203, 204, 205, 206, 208,
211, 213, 214, 215, 216, 222,
228, 230, 237, 239, 240, 241,
242, 243, 247, 248, 249, 250,
253, 259, 260, 261, 262, 269,
272, 282, 284, 285, 286, 287,
288, 289, 290, 291, 292, 293,
297, 298, 302, 303, 304, 306,
307, 308, 309, 310, 311, 313,
314, 315, 316, 317, 318, 319,
320, 321, 323, 324, 325, 329,
330, 334, 336, 339, 340, 341,
344, 349, 355, 356, 357, 359,
359, 360, 361, 362, 363, 364,
364, 367, 368, 369, 375, 376,
377, 379, 384, 387, 394, 410,
411, 429, 430, 443, 444, 452,
457, 459, 460, 464, 469, 475,
479, 482, 487, 491, 494, 500,
501, 507, 509, 515, 516, 522,
528, 529, 530, 531, 532, 535,
543, 545, 546, 547, 551, 553,
558, 559, 561, 563, 564, 565,
566, 569, 570, 571, 575, 577,
578, 579, 580, 582, 583, 587,
590, 592, 594, 598, 604, 607,
608, 609, 610, 614, 618, 619,
621, 622, 623, 624, 626, 628,
629, 634, 635, 637, 639, 640,
642, 643, 645, 646, 647, 648,
649, 650, 651, 653, 654, 655,
656, 657, 659, 662, 664, 667,
669, 670, 672, 673, 674, 675,
677, 680, 681, 682, 685, 687,
688, 689, 692, 695, 700, 704,
709, 711, 712, 713, 717, 720,
727, 730, 731, 732, 735, 736,
737, 738, 739

TINCPAY CARBIDE 297, 320

TINCPAY CHLORIDES 2, 22, 23, 74,
112, 120, 122, 137, 166, 182,
217, 426

TINCPAY CITRATES 22, 23, 102, 112,
132

TINCPAY DAUGHTERS 129, 190, 230,

KEYWORD INDEX

TRICHLIN DAUGHTERS 232, 359, 415,
437, 454, 455, 481, 493, 504,
505, 516, 519, 537, 632, 713,
719, 726, 727

TRICHLIN DECEASE 74, 81, 92, 97,
98, 107, 147, 168, 169, 179, 251,
397, 402, 403, 404, 405, 406,
423, 438, 449, 450, 523, 526,
539, 541, 544, 644

TRICHLIN FLUORIDES 84, 217, 524,
667

TRICHLIN GLUCOSE 130

TRICHLIN HALIDES 234

TRICHLIN HYDROGENS 217, 524, 725

TRICHLIN HYDROCHLORIDES 217, 524, 644,
673

TRICHLIN NITRATES 2, 74, 84, 112,
144, 170, 189, 217, 240, 250,
524, 673

TRICHLIN OXALATES 83, 84, 217, 524

TRICHLIN OXIDES 7, 74, 84, 88, 112,
115, 137, 145, 164, 181, 189,
245, 267, 293, 297, 299, 302,
313, 317, 326, 321, 334, 394,
400, 401, 411, 422, 452, 453,
460, 469, 500, 503, 507, 508,
510, 524, 527, 611, 665, 667,
668, 673, 697, 713

TRICHLIN PEROXYCHLORATES 217

TRICHLIN SULFATES 147, 217, 234,
524

TRICHLIN 223 648

TRICHLIN 227 61, 199, 132, 252,
271, 426, 502

TRICHLIN 228 6, 7, 9, 11, 12, 15,
16, 18, 19, 20, 26, 23, 34, 35,
39, 40, 41, 42, 43, 44, 45, 46,
47, 48, 49, 50, 51, 52, 53, 54,
55, 56, 57, 58, 59, 60, 63, 64,
65, 70, 77, 78, 79, 80, 90, 91,
92, 93, 94, 95, 96, 97, 98, 99,
100, 101, 102, 103, 104, 109,
121, 122, 123, 124, 125, 126,
127, 129, 132, 133, 134, 137,
138, 140, 148, 149, 150, 151,
152, 153, 154, 155, 171, 172,
173, 174, 175, 176, 177, 178,
186, 187, 190, 194, 195, 199,
230, 217, 218, 224, 235, 238,
251, 252, 276, 271, 274, 276,
277, 279, 282, 326, 335, 346,
347, 348, 350, 353, 354, 412,
421, 422, 425, 437, 438, 450,
453, 467, 474, 475, 476, 477,
481, 484, 493, 495, 497, 502,
504, 508, 515, 524, 544, 548,
554, 565, 585, 588, 600, 601,
614, 625, 644, 665, 690, 694,
699, 700, 709, 714, 715, 718,
719, 719, 725, 726

TRICHLIN 229 301, 444

TRICHLIN 230 15, 25, 40, 139, 157,
158, 159, 160, 161, 164, 165,
183, 199, 202, 217, 220, 229,
252, 254, 267, 268, 269, 271,
274, 277, 294, 327, 333, 340,
343, 346, 354, 356, 421, 499,
502, 521, 544, 574, 596, 597,
607, 612, 613, 641, 663, 721,
722, 724, 732, 740

TRICHLIN 232 1, 14, 15, 23, 25, 68,
109, 112, 115, 122, 137, 150,

TRICHLIN 232 183, 185, 199, 199,
237, 249, 250, 257, 258, 259,
251, 252, 265, 271, 274, 275,
276, 277, 278, 279, 283, 294,
295, 296, 299, 305, 326, 327,
331, 333, 335, 337, 343, 346,
347, 348, 350, 354, 374, 371,
372, 385, 420, 409, 415, 421,
422, 437, 438, 440, 454, 453,
454, 455, 467, 465, 466, 473,
474, 481, 492, 493, 494, 502,
505, 508, 521, 524, 529, 537,
539, 542, 544, 546, 547, 547,
574, 584, 601, 602, 605, 612,
613, 617, 625, 627, 631, 633,
644, 644, 645, 671, 694, 691,
698, 699, 704, 725, 714, 715,
725, 726, 729

TRICHLIN 233 5, 265

TRICHLIN 234 22, 28, 29, 72, 109,
117, 163, 185, 217, 219, 223,
227, 244, 249, 343, 352, 354,
412, 467, 486, 547, 552, 603,
641, 643, 719

TRICHLIN 237 61

TRICHLIN 238 492

TRICHLIN 217, 374, 376, 384, 390,
425, 438, 476, 479, 485, 489,
510, 513, 524, 547, 548, 549,
572, 599, 604, 627, 625, 653,
672, 673, 697, 691, 692, 696,
699, 725

TRICHLIN DAUGHTERS 572, 696, 699

TRICHLIN 220 137

TRICHLIN 221 2, 15, 16, 68, 69, 74,
87, 85, 105, 107, 129, 131, 134,
139, 141, 144, 179, 189, 242,
243, 301, 302, 345, 347, 392,
394, 395, 394, 397, 401, 422,
437, 434, 435, 446, 447, 448,
449, 450, 451, 454, 455, 456,
457, 458, 459, 462, 465, 466,
469, 472, 473, 474, 478, 479,
481, 483, 484, 485, 489, 492,
493, 500, 502, 504, 505, 508,
509, 512, 514, 523, 524, 525,
526, 527, 533, 534, 538, 540,
541, 542, 543, 547, 595, 625,
632, 644, 646

TRICHLIN 170 446, 524

TRICHLIN 16

TRICHLIN 61, 85, 92, 108, 200, 391,
422, 452, 457, 460, 484, 493,
735, 739, 740

TRICHLIN FACTOR 29, 24, 67, 90, 103,
171, 187, 232, 254, 264, 502,
543, 723, 730, 738

TRICHLIN 113 406

TRICHLIN 3, 10, 11, 16, 25, 50,
53, 55, 62, 73, 81, 91, 97, 99,
102, 110, 111, 116, 117, 122,
125, 127, 150, 151, 152, 157,
160, 174, 178, 190, 198, 199,
271, 280, 306, 307, 410, 422,
424, 428, 439, 440, 452, 467,
481, 492, 494, 500, 502, 504,
509, 515, 519, 530, 535, 554,
567, 597, 632, 724

TITANIUM 192, 251, 265, 470

TRICHLIN 491

TRICHLIN 1, 4, 15, 14, 20, 26, 39,
43, 41, 42, 45, 48, 49, 53, 51,
52, 54, 55, 57, 69, 71, 74, 83,
88, 100, 112, 123, 144, 154, 166,
189, 193, 194, 231, 242, 263,
264, 301, 393, 411, 413, 415,
502, 654, 691, 694, 707

TRICHLIN 143

TRICHLIN ELEMENTS 75, 100, 118, 154,
206, 249, 324, 341, 554, 543,
597, 644

TRICHLIN STUDIES 86, 120, 238, 251

TRICHLIN 183, 227, 235, 252, 323,
350, 5

TRICHLIN 8, 112, 145, 147, 197,
390, 447, 510

TRICHLIN 19, 144

TRICHLIN 31, 41

TRICHLIN 11, 116, 135, 181,
182, 184, 202, 409, 410, 422,
436, 485, 490, 494, 496, 498,
492, 493, 498, 505

TRICHLIN 140

TRICHLIN 16, 55

TRICHLIN 302, 475, 699, 691

TRICHLIN ELEMENTS 30, 40, 92,
220, 240, 712

TRICHLIN 235, 210, 292

TRICHLIN 50, 65, 144, 199, 325,
326, 443, 445, 446, 537, 553,
561, 544, 546, 602, 643, 647,
657, 729, 721, 722

TRICHLIN 106, 326

TRICHLIN, 1904, 106, 199

TRICHLIN 28, 29

TRICHLIN 77, 81, 104, 194,
302, 433

TRICHLIN 204, 691, 697

TRICHLIN 594

TRICHLIN 117, 132

TRICHLIN 22, 24, 61, 87, 107, 130,
211, 273, 244, 248, 249, 292,
322, 324, 342, 355, 445, 461

TRICHLIN 21, 27, 24, 36, 38, 46,
75, 106, 111, 118, 133, 135, 142,
146, 148, 150, 159, 160, 161,
162, 163, 164, 180, 184, 194,
197, 201, 203, 204, 205, 208,
210, 213, 216, 221, 222, 224,
225, 226, 228, 229, 230, 233,
235, 236, 237, 240, 242, 244,
247, 248, 249, 253, 255, 257,
260, 261, 262, 265, 266, 267,
267, 268, 269, 271, 282, 283,
284, 285, 287, 288, 289, 290,
291, 292, 297, 300, 301, 302,
308, 309, 319, 312, 313, 314,
319, 321, 325, 326, 328, 330,
332, 333, 334, 335, 336, 338,
339, 342, 344, 345, 347, 351,
355, 357, 360, 361, 364, 365,
366, 367, 369, 373, 375, 377,
378, 379, 380, 383, 384, 391,
393, 411, 429, 431, 443, 445,

REVERSED INDEX

URANIUM 445, 446, 446, 460, 471, 473, 480, 482, 488, 490, 491, 497, 498, 501, 511, 520, 522, 528, 529, 530, 532, 536, 539, 545, 546, 547, 547, 551, 552, 557, 559, 560, 561, 564, 570, 575, 576, 580, 581, 582, 583, 587, 589, 590, 591, 592, 594, 596, 597, 598, 599, 603, 604, 607, 608, 609, 615, 616, 618, 619, 620, 622, 623, 624, 628, 629, 634, 637, 638, 639, 640, 643, 645, 646, 647, 648, 649, 650, 651, 652, 657, 658, 662, 668, 669, 670, 672, 674, 676, 678, 679, 680, 682, 683, 684, 686, 687, 688, 689, 701, 702, 703, 705, 706, 707, 712, 717, 720, 727, 731, 732, 733, 736, 737, 738, 744

URANIUM CARBONATES 365

URANIUM CHLORIDES 74, 112

URANIUM DAUGHTERS 710

URANIUM FLUORIDES 73, 301, 740

URANIUM NITRATES 8, 9, 10, 11, 74, 112, 142, 554

URANIUM OXIDES 13, 74, 88, 112, 113, 114, 115, 143, 145, 181, 188, 212, 231, 245, 293, 299, 304, 309, 313, 320, 336, 337, 400, 550, 611, 678, 683, 684

URANIUM 223 86

URANIUM 226 688

URANIUM 230 61

URANIUM 232 8, 9, 10, 11, 70, 71, 142, 296, 301, 322, 343, 554, 593, 665, 718, 719

URANIUM 233 5, 8, 9, 26, 70, 71, 110, 111, 142, 220, 254, 293, 295, 296, 298, 299, 301, 305, 308, 314, 315, 321, 322, 444, 568, 586, 665, 671, 675, 691, 708, 718, 719, 728, 729, 730, 735, 739

URANIUM 234 74, 109, 164, 165, 199, 267, 269, 271, 277, 296, 301, 321, 343, 346, 348, 555, 562, 601, 612, 636, 641, 661, 663, 715, 723, 724

URANIUM 235 74, 199, 200, 217, 223, 256, 267, 271, 286, 296, 299, 301, 304, 305, 310, 314, 327, 346, 352, 379, 393, 550, 555, 584, 601, 622, 636, 655, 671, 675, 704, 708, 715, 724, 726, 729

URANIUM 236 296, 301

URANIUM 238 14, 71, 74, 109, 112, 115, 157, 160, 161, 165, 199, 207, 209, 223, 255, 267, 269, 271, 275, 277, 278, 286, 296, 298, 299, 305, 318, 327, 331, 337, 343, 346, 348, 352, 354, 370, 371, 383, 393, 521, 537, 555, 556, 586, 601, 602, 605, 613, 617, 627, 631, 633, 641, 655, 660, 661, 663, 671, 704, 708, 715, 724, 728, 729, 730

URANIUM 239 74, 264, 550

URANIUM, ENRICHED 730

URANIUM, NATURAL 74, 133, 238,

URANIUM, NATURAL 264, 383, 406, 565, 584, 720, 734

URANIUM 231 227

URANYL ACETATES 201

URANYL CARBONATES 322

URANYL IONS 130, 221, 224

URANYL NITRATES 17, 20, 628

URSA 78, 80, 133

URSE 8, 22, 23, 24, 25, 28, 44, 62, 74, 94, 111, 129, 141, 146, 147, 151, 160, 167, 182, 183, 189, 198, 220, 227, 228, 238, 248, 260, 329, 393, 400, 412, 412, 426, 431, 439, 440, 443, 445, 446, 446, 467, 484, 488, 489, 494, 515, 528, 544, 547, 548, 562, 563, 566, 577, 597, 598, 608, 636, 643, 656, 727

UTERUS 68, 89, 170

VALENCIA 5, 32, 54, 61, 62, 203, 212, 219, 227, 249, 290, 322, 515, 522, 577

VANADIUM 265, 324, 332, 337

VANADIUM 40 486

VEGETABLES 215, 349, 497, 596, 629

VENTILATION 520, 524, 572, 599, 604, 639, 674, 682, 689, 696

VIRUSES 326

VOLATILITY 255

VOLCANOES 497

VOLES 287

WASTE DISPOSAL 326, 552, 668, 671, 675, 682, 683, 688, 689, 691, 733

WASTE DISPOSAL, EXTRATERRESTRIAL 671

WASTE REPOSITORIES 671

WASTE "BREATH" 668, 671, 682, 731, 733, 735, 738, 739, 740

WASTE WATER 231, 648

WASTES, HIGH-LEVEL 732

WASTES, RADIOACTIVE 199, 275, 280, 298, 300, 301, 311, 326, 551, 565, 576, 596, 643, 649, 655, 671, 672, 675, 678, 682, 688, 691, 701, 704, 723, 730, 731, 733, 736, 737, 738

WASTES, RECYCLING 729

WATER 199, 207, 209, 219, 221, 224, 233, 241, 242, 244, 245, 246, 252, 256, 256, 257, 258, 266, 269, 279, 278, 287, 288, 292, 298, 324, 325, 326, 334, 340, 349, 354, 399, 494, 531, 552, 552, 553, 568, 576, 580, 584, 594, 596, 603, 608, 623, 629, 637, 645, 649, 650, 651, 652, 658, 661, 663, 688, 698, 704, 706, 715, 730, 731, 733

WATER, DISTILLED 251

WEAPONS, NUCLEAR 537, 559

WEATHER 620

WEATHERING 354, 359, 363, 366

WEIGHT 73, 114, 527

WELLS 733

WHEAT 286

WHOLE BODY COUNTS 446, 479, 484, 498, 562, 608, 700, 705, 714

WHOLE BODY COUNTING 22, 410, 425, 437, 439, 440, 443, 465, 466, 485, 489, 548, 567

WHOLE BODY IRRADIATION 480

WIND 276, 560, 603, 633, 733

WORKING LEVEL MONTH 391, 702

WOUNDS 445, 528, 529

WOUNDS, PUNCTURE 426

YENON 85, 647, 657

YENON 133 486

YENON 135 486

YEASTS 212

YELLOW CAKE 740

YTIUM 30, 85, 128, 141, 198, 216, 267, 722

YTIUM 90 195, 444, 528

YTIUM 91 28, 29, 358, 486, 721

ZINC 28, 75, 118, 156, 204, 212, 324, 648, 658, 686

ZINC SULFIDES 644

ZINC 65 30, 486

ZIRCONIUM 15, 42, 45, 45, 46, 141, 146, 198, 248, 249, 251, 265, 545, 568, 590, 638, 647, 648, 669, 670, 687, 710

ZIRCONIUM OXIDES 139

ZIRCONIUM 93 738

ZIRCONIUM 95 602, 605, 617, 633, 721

TITLE

Workers with Low Body Burdens of Bisanta 2120Chromosome	Aberrations in the Peripheral Lymphocytes of Thorium	027430
Thorium Dioxide*	Aberrations in Lymphocytes from Patients Exposed to	027543
Chromosome	Aberrations in Thorium Dioxide Patients*	027619
Chromosome	Aberrations Caused by Thorotrast*	027655
Chromosome	Absolute Concentrations in the Sediments*	027661
The Surface Layers of the Coastal Sediments and their	Absolute Determination of Trace Quantities of the	027665
Thorium 228 Series*	Absorbed Dose in the Human Organism*	027668
Thorotrast and its Daughter Nuclides and Estimation of	Absorbed Dose Due to Environmental Gamma Radiation*	027674
Estimation of Total	Absorbed Dose* the Analysis of Microscopic Distribution	027691
of Some Bone-Seeking Radionuclides and Assessment of	Absorption and Methods of Elimination: Factors	027741
Influencing Elimination from the Body*	Absorption of Radium and Thorium through the Gut as a	027806
Function of Chemical Form. B.*	Absorption of Radium 226 and Thorium 230 and Source	027867
Genetic Considerations of Radium 226	Absorption, Distribution and Excretions of Certain	027889
Soluble Compounds of Natural Thorium*	Accidental Puncture Contaminated with Thorium 232.	027926
Studies on Elimination and Residual Body	Accumulation by Marine Organisms*	027941
Case of	Accumulation of Radioactivity in Pine Fields*	027945
232 Thorium 232	Accumulation of Thorium, Uranium, and Radium by Plants	027955
and Organogypsum Accretions of Soils*	Accumulation of Uranium and Thorium in Pats After	027961
Inhalation of Uranium Ore Dust*	Acetate on Seedling Growth, Excise? Cotyledones,	027961
Chlorophylls, Proteins Effect of Hemic Acid and Granyl	Acid and Granyl Acetate on Seedling Growth, Excise?	027961
Cotyledones, Chlorophylls, Proteins Effect of Hemic	Acid as Stationary Phase in Extraction Chromatography*	027961
Analytical Applications of Neotritecanohydroxamic	Acid by Tributyl Phosphate-Carbon Tetrachloride Solution	027961
Solvent Extraction of Thorium Nitrate and Nitric	Acid Resin*	027961
Analytical Applications of a Propyleneiminecarboxylic	Acid-Ether-Cellulose System* of Rare Earths in Thorium	027961
Compounds. Chromatographic Preconcentration in an	Actinide Elements in the Yate*	027961
Effect of Desferrioxamine on the Retention of	Actinide Elements with Blood Constituents*	027961
The Interaction of some	Actinide Removal on the Long-Term Hazard of High-Level	027961
Waste*	Actinide Waste Recycling*	027961
in the United States Concerning the Physics Aspects of	Activities in the Radioactive Wastes from Nuclear Fuel	027961
Relative Toxicity of Long-Lived Fission Products and	Actinides in Urine*	027961
The Determination of	Actinides on Blood Coagulation. I. Evidence for and	027961
Properties of a New	Actinides*	027961
The Effect of Lanthanides and	Actinium 227, and Thorium Isotopes in Environmental and	027961
Interaction between Blood Constituents and some	Actinism in the Air in the Presence of Other Emanations*	027961
The Metabolism of Compounds of Plutonium and other	Activation Analysis after Adsorption on Charcoal*	027961
Sequential Determination of Radium 226, Radium 228,	Activation Analysis*	027961
Identification of	Activation Analysis*	027961
of Uranium in Sea and Surface Waters by Neutron	Activation Analysis* on the Distribution of Trace	027961
Determination of Uranium in Natural Waters by Neutron	Activation Analysis* of the North Sea and the Baltic.	027961
Assessment of Organ Distribution of Thorium by Neutron	Activation Method for Uranium in Water*	027961
Elements in a Hollock from a Freshwater Environment by	Activities in the United States Concerning the Physics	027961
Multielement Analyses Using Instrumental Neutron	Activities of Humans and their Environment*	027961
A Rapid and Sensitive Neutron	Activity and Potential Alpha-Energy of Radon 222 and	027961
Aspects of Actinide Waste Recycling*	Activity in Urine by Adsorption on Glass Fibre Filter	027961
Some	Activity of the Pentose phosphate Pathway*	027961
Alpha-Ray	Activity of Certain Botanical Materials*	027961
Radon 220-Daughters in Different Air Atmospheres*	Activity of Food*	027961
The Determination of Gross Alpha	Activity of Human Tissues*	027961
Red Blood Cells of Uranium Miners: the	Activity of Soils in Relation to Landscape Development*	027961
Alpha	Activity Determination*	027961
The Naturally Occurring Alpha-Ray	Activity Ratios in Backwater Sediments along the West	027961
The Alpha	Activity Ratios of Thorium 232 and Daughters in Sea	027961
Thorium 228/Thorium 232 and Thorium 230/Thorium 232	Activity Ratios Thorium 230/Thorium 232 and Thorium 228/	027961
Following	Activity* Case of Accidental Puncture Contaminated with	027961
Thorium 232 in Sea Water	Actual Status of the German Thorotrast Study*	027961
Thorium 227. Studies on Elimination and Residual Body	Acute and Chronic Poisoning with 230Th	027961
Pathomorphological Changes in Animals Following	Acute Poisoning with 230Th	027961
Changes in the Peripheral Blood Following Chronic and	Acute Toxicity of Inhaled Thorium Compounds*	027961
of Mononuclear Phagocytes Following Intraperitoneal	Administration of Plutonium 239 PuO2*The Ultrastructure	027961
in the Lungs and Other Organs in Rats on Intratracheal	Administration of Thorium Dioxide* Morphological Changes	027961
230) of the Air Inspired by Rats After Intratracheal	Administration of Thoron Compounds* Content (Thoron	027961
Skeletal Dose from Radium 226 Following Intravascular	Administration of Thorotrast*	027961
in Man and Other Animals Following Intravascular	Administration of Thorotrast*Decay Series Radionuclides	027961
Lung Tumors in Rats after Thorium Dioxide	Administration*	027961
Two Cases of Carcinoma after Thorotrast	Administration*	027961
Hemangioendotheliomas of Liver Following Thorium Dioxide	Administration*	027961
of Thorium and Thorium Daughters after Thorotrast	Administration*	027961
and Excretion Studies. I. Patterns Following Parenteral	Administration*	027961
Dioxide in Rats after Intratracheal and Intraperitoneal	Administration*	027961
Dissemination (Disease) Occurrence Twenty-Eight Years after Thorium	Administration*	027961
Uranium in Organisms of Animals from the	Administration*	027961
Thorium in Water and Algae from the	Administration*	027961
and Surface Waters by Neutron Activation Analysis after	Administration*	027961
The Determination of Gross Alpha Activity in Urine by	Administration*	027961
Metabolism of the Th 228 Decay Series in	Administration*	027961
Serum Lactic Dehydrogenase Levels in	Administration*	027961
Long Term Biological Effects of Internal Irradiation in	Administration*	027961
239 and Related Radionuclides on Survival of the	Administration*	027961
I) Thorium 228 (Radiothorium) and Strontium 90 in	Administration*	027961
Cancers Induced by Radium 224 (Th X) in Children and	Administration*	027961
Evaluation of the Natural Gamma Radiation Field at	Administration*	027961
Hazards Evaluation Following Inhalation	Administration*	027961
Influence of	Administration*	027961
Experimental Study of the Penetration of Radioactive	Administration*	027961
in Respirable Size Range*	Administration*	027961
Shape Factors for	Administration*	027961
Products Following Inhalation of Uranium 232 972 (90)2	Administration*	027961

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TITLE INDEX

Trace from Continuous Inhalation of Radioactive #Radio Alpha-Radioactivity off Southern and Thorium 228 in Thyroids of Cattle from Nigeria, U. by the Fission Particle Track Replica Method*	Aerosols* of the Surface and Close to the Respiratory Africa. 2. Thorium in Marine Life*	000450
#The Effects of #Comment on "Excess Uranium 238: An #Determination of the Thorium Content of	Aging and Transm Content of Soil Phases from Antarctica Aging and Internal Emitters on Blood Chemistry* Aging Effect in Confined Waters", by J. Kronfeld, Et Al*	000451 000452 000453
Permissible Limits of Plutonium 239 in the Human Body, Human Body and Maximum Permissible Concentrations in of Concentrations of Particulate Impurities in #The Concentration of Uranium in #Identification of Actinon in the 222, Natural Thorium, Radium 226 and Thorium 228 in the Place in the Context of Radioactive Emissions in the of Radon 222 and Radon 220-Daughters in Different	Air and Water Monitoring* Air and Water* Air and Water* Air by Use of Surface Ionization* Air from Contrasted Natural Environments* Air in the Presence of Other Emanations* Air of Factories* of Soil... Compounds of Thorium Air of Mining Installations* of the Changes Taking Air Atmospheres* Activity and Potential Alpha-Energy Air Cleaning at the TSEEC Y-12 Plant* Air Contaminants in Dogs and Mammals* Air Dusts* Air Expired by Pets After Intratracheal Administration Air Quality Criteria* Air Sampler* Air*	000454 000455 000456 000457 000458 000459 000460 000461 000462 000463 000464 000465 000466 000467 000468 000469 000470 000471 000472 000473 000474 000475 000476 000477 000478 000479 000480 000481 000482 000483 000484 000485 000486 000487 000488 000489 000490 000491 000492 000493 000494 000495 000496 000497 000498 000499 000500 000501 000502 000503 000504 000505 000506 000507 000508 000509 000510 000511 000512 000513 000514 000515 000516 000517 000518 000519 000520 000521 000522 000523 000524 000525 000526 000527 000528 000529 000530 000531 000532 000533 000534 000535 000536 000537 000538 000539 000540 000541 000542 000543 000544 000545 000546 000547 000548 000549 000550 000551 000552 000553 000554 000555 000556 000557 000558 000559 000560 000561 000562 000563 000564 000565 000566 000567 000568 000569 000570 000571 000572 000573 000574 000575 000576 000577 000578 000579 000580 000581 000582 000583 000584 000585 000586 000587 000588 000589 000590 000591 000592 000593 000594 000595 000596 000597 000598 000599 000600 000601 000602 000603 000604 000605 000606 000607 000608 000609 000610 000611 000612 000613 000614 000615 000616 000617 000618 000619 000620 000621 000622 000623 000624 000625 000626 000627 000628 000629 000630 000631 000632 000633 000634 000635 000636 000637 000638 000639 000640 000641 000642 000643 000644 000645 000646 000647 000648 000649 000650 000651 000652 000653 000654 000655 000656 000657 000658 000659 000660 000661 000662 000663 000664 000665 000666 000667 000668 000669 000670 000671 000672 000673 000674 000675 000676 000677 000678 000679 000680 000681 000682 000683 000684 000685 000686 000687 000688 000689 000690 000691 000692 000693 000694 000695 000696 000697 000698 000699 000700 000701 000702 000703 000704 000705 000706 000707 000708 000709 000710 000711 000712 000713 000714 000715 000716 000717 000718 000719 000720 000721 000722 000723 000724 000725 000726 000727 000728 000729 000730 000731 000732 000733 000734 000735 000736 000737 000738 000739 000740 000741 000742 000743 000744 000745 000746 000747 000748 000749 000750 000751 000752 000753 000754 000755 000756 000757 000758 000759 000760 000761 000762 000763 000764 000765 000766 000767 000768 000769 000770 000771 000772 000773 000774 000775 000776 000777 000778 000779 000780 000781 000782 000783 000784 000785 000786 000787 000788 000789 000790 000791 000792 000793 000794 000795 000796 000797 000798 000799 000800 000801 000802 000803 000804 000805 000806 000807 000808 000809 000810 000811 000812 000813 000814 000815 000816 000817 000818 000819 000820 000821 000822 000823 000824 000825 000826 000827 000828 000829 000830 000831 000832 000833 000834 000835 000836 000837 000838 000839 000840 000841 000842 000843 000844 000845 000846 000847 000848 000849 000850 000851 000852 000853 000854 000855 000856 000857 000858 000859 000860 000861 000862 000863 000864 000865 000866 000867 000868 000869 000870 000871 000872 000873 000874 000875 000876 000877 000878 000879 000880 000881 000882 000883 000884 000885 000886 000887 000888 000889 000890 000891 000892 000893 000894 000895 000896 000897 000898 000899 000900 000901 000902 000903 000904 000905 000906 000907 000908 000909 000910 000911 000912 000913 000914 000915 000916 000917 000918 000919 000920 000921 000922 000923 000924 000925 000926 000927 000928 000929 000930 000931 000932 000933 000934 000935 000936 000937 000938 000939 000940 000941 000942 000943 000944 000945 000946 000947 000948 000949 000950 000951 000952 000953 000954 000955 000956 000957 000958 000959 000960 000961 000962 000963 000964 000965 000966 000967 000968 000969 000970 000971 000972 000973 000974 000975 000976 000977 000978 000979 000980 000981 000982 000983 000984 000985 000986 000987 000988 000989 000990 000991 000992 000993 000994 000995 000996 000997 000998 000999 001000

TITLE INDEX

Track Autoradiography*	Analysis of the Radioactive Content of Tissues by Alpha-	272832
Transmutation*	Analysis of the Radioactivity in the Soil*	000226
Transmutation*	Analysis of the Production of Hazardous Radiation in	000679
Transmutation*	Analysis of the Transmutation of Thorium Families*	002322
Structure of Thorium	Analysis of Biological Material for Small Quantities of	002219
Structure of Thorium	Analysis of Human Lung Tissue*	002501
Part 2*	Analysis of Indian Monazite Sand in Animal Tissues,	000237
Seeking Radioisotopes and	Analysis of Isotopic Ratios in Thorium Mill Effluents*	000239
Alpha Emitters*	Analysis of Microscopic Distribution of Some Bone-	000293
Thorium, Uranium, Radium, and	Analysis of Bone Flow Samples for the Detection of	000512
on Thorotrast Dosimetry Supplied by the Radiochemical	Analysis of Powdered Rock Samples. Determination of	000545
Semiconductor X-ray Emission Spectrometer*	Analysis of Tissue Specimens*	000442
Thermal Analysis. A	Analysis of Uranium and Thorium Solutions with a	000409
with Evolved Gas Analysis and Differential Thermal	Analysis with Evolved Gas Analysis and Differential	000589
Analysis*	Analysis. A Comparative Study of the Thermal	000580
of Organ Distribution of Thorium by Neutron Activation	Analysis*	000540
of Uranium in Natural Waters by Neutron Activation	Analysis*	000502
a Polluted Area in Freshwater Environment by Activation	Analysis*	000233
Analyses Using Instrumental Neutron Activation	Analysis* on the Distribution of Trace Elements in	000676
Acid Resin*	Analysis* of the North Sea and the Baltic. Multielement	000704
as Stationary Phase in Extraction Chromatography*	Analytical Applications of a Propylenebisacetic	000249
and Potassium in Granitic Rocks*	Analytical Applications of Neotridecanohydroxyacetic Acid	000227
Cycle*	Analytical Techniques for Determining Uranium, Thorium,	000445
Radiations on Endocrine Cells. 6. Alterations in	Analytical Techniques for Materials in the Nuclear Fuel	000655
Radioisotopes and the Subsequent Alteration of	Androgen Biosynthesis by Canine Testicular Tissue after	000605
Thorium Induced Septic Hemangioendothelioma. Neutrogen-	Androgen Biosynthesis by Canine Testicular Tissue*	000664
State Effects of Thorotrast in Cerebral	angiographic Findings in Two Additional Cases with	000401
Endocrine Disease Following Thorium Dioxide	Angiography*	000392
Analysis of Indian Monazite Sand in	Angiography*	000423
Behavior of Plutonium in	Animal Tissues, Part 2*	000237
Uranium in Organisms of	Animals and Man*	000661
Following Repeated Inhalation Exposures of Laboratory	Animals from the Adriatic Sea*	000180
Long-Lived Uranium Chain Alpha-Emitters in Experimental	Animals to Uranium Ore*	000159
Pathomorphological Changes in	Animals During and After Chronic Inhalation of Uranium	000165
Thorium 232 Decay Series Radioisotopes in Man and Other	Animals Following Acute and Chronic Poisoning with ²³⁰ Th	000194
Analysis for Uranium 232 and Decay Progress in	Animals Following Intravascular Administration of	000441
Some Tumors Induced in	Animals Tissues*	000554
Radioecology of Freshwater Plants and	Animals*	000194
of the Daughters of Thorium 232 in the Soft Tissue in	Animals*	000274
of Uranium in Natural Water by Preconcentration on	Animals*	000190
of Thorotrast Patients from Boston, Massachusetts and	Antion-Exchange Resin and Delayed-Neutron Counting*	000221
	Ann Arbor, Michigan, USA*	000448
	Annual Progress Report, March 31, 1959*	000155
	Annual Report for 1972*	000423
	Annual Report for 1972*	000677
	Annual Report of Work in Progress in the Internal	000051
	Annual Report of Work in Progress in the Internal	000092
	Annual Report of Work in Progress on the Chronic	000048
	Annual Report of Work in Progress on the Chronic	000049
	Annual Report of Work in Progress on the Chronic	000052
	Annual Report of Work in Progress on the Chronic	000054
	Annual Report, July 1972 through June 1973*	000564
	Annual Summary, 1968*	000552
	Annulus (Revised)*	000377
	Anticoincidence Behavior of Thorium and Uranium Isotopes in	000346
	Anticoincidence Radiation by Removal of Environmental and	000582
	Anticoincidence Thorium 228/Thorium 232 and Thorium 230/*	000347
	Anticoincidence of Silver Water in the Eastern Part of Shimane	000236
	Anticoincidence by the Fission Particle Track Replicas Method*	000345
	Anticoincidence Wall Annulus (Revised)*	000377
	Apatite-Derived Fertilizers* Spectrometric Measurements	000352
	Apparatus for the Determination of Minute Quantities of	000578
	Apparatus in Rats* Thorium Dioxide on Arterial Pressure	000169
	Applicable to the Thorium Fuel Cycle*	000322
	April-June 1972, Quarterly Report No. 15*	000685
	April-June, 1966*	000297
	Aquatic Biota Exposed to Radioactive Releases from LWR	000268
	Aquatic Biota Resulting from Radioactive Releases from	000267
	Aqueous Thorium-Uranium Oxide Slurries*	000245
	Arab Republic and their Possible Utilization*	000336
	Arbor, Michigan, USA*	000448
	Arc Welding-- Investigation of Potential Hazard*	000497
	Archaeo-Basalts*	000346
	Arms (The West Carpathians)*	000360
	Arms*	000714
	Arms, Oregon*	000646
	Arms of the Nevada Test Site* Some Characteristics of	000291
	Arms of the North Sea and the Baltic. Multielement	000108
	Arms of the USSR*	000371
	Arms of Brazil*	000497
	Arms of High Fetal Radiation*	000496
	Argonne National Laboratory Report for 1962 and 1963*	000638
	Argonne National Laboratory, Annual Report for 1972*	000637
	Argonne National Laboratory, July - December 1968,	000552
	Arizona - January, 1961 through June, 1972*	000651
	Arterial Pressure and Threshold of Stimulation of the	000169
	Artificial Radioisotopes in Fish Flour*	000600
	Artificial Radioisotopes in Seafoods and Marine Proteins	000012

TITLE INDEX

in Uranium Tailings*	Use of	Asphalt Emulsion Sealants to Contain Radon and Radium	009707
Radionuclides*	Methods of	Assay of the Relative Toxicity of Certain Bone-Seeking	003585
Uranium in the Body and Critical Organs*	Assessment of the	Content of Concentrated and Natural	007389
Routes to Fish in Contaminated Environments, and the	Assessment of the	Possible Consequences* Radiation Dose	007195
	Assessment of the	Thorium Fuel Cycle in Power Reactors*	000109
Distribution of Some Bone-Seeking Radionuclides and	Assessment of Absorbed Dose*the Analysis of Microscopic		000053
Processing Industry*	Assessment of Airborne Hazards in the Thorium		007171
Recurrent or Prolonged Uptakes*	Assessment of Internal Contamination Resulting from		007445
Activation Analysis*	Assessment of Organ Distribution of Thorium by Neutron		000542
of U.S. Atomic Energy Commission Sites*	Assessment of Public Radiation Exposure in the Vicinity		009657
for Uniformly Distributed Uranium 239, Thorium 232,	Assessment of Radioactivity in "van Gasey-Ray Spectra		009447
Reactor-Grade Thorium Dioxide and Controlling*	Assessment of Thorium as a Fuel for Thermal Reactors*		007375
United States and the Effect of Policy Alternatives*	Assessment of U.S. Domestic Capacity for Protecting		007460
Resulting from Thorium Fuel Cycle in SWRs (CAPSUs)*	Assessment of Uranium and Thorium Resources in the		007179
Quarter Fiscal 1977*	Assessment of U308 Requirements and Fuel Cycle Costs		009334
Quarter Fiscal 1977*	Assessment Study Quarterly Progress Report for Second		003321
	Assessment Study Quarterly Progress Report for Third		003320
Radiochemical Aspects and Radiation Levels	Associated with the Filling of Monazite Sand*		007400
	Associated with Thorium Metallurgy*		007325
	Associated with Thorium Processing*		007227
Protecting Reactor-Grade Thorium Dioxide and Controlling	Associated Wastes and Effluents* Domestic Capacity for		007448
	Atmosphere*		006435
the Tolerance Concentration of Radon in the	Atmosphere*		006439
Attachment Ratio of Radon Daughters in Uranium Mine	Atmosphere* Daughters Attached to Dust Particles in the		009498
Respiratory System of Humans Exposed to Uranium Mine	Atmosphere* A Method for Measuring the Concentrations of		009571
the Short-Lived Daughter Products of Radon 222 in the	Atmosphere*		009164
Chronic Exposure of Dogs to Simulated Uranium Mine	Atmosphere*		007702
of Radon Daughter Particles in Uranium Mine	Atmosphere*		007599
of Radon 222 and Radon 220-Daughters in Different Air	Atmosphere*		007598
91 Survey of the Methods Used in the United Kingdom	Atomic Energy Authority for the Determination of		009657
of Public Radiation Exposure in the Vicinity of U.S.	Atomic Energy Commission Sites*		009669
	Atomic Materials in India*		000701
and Monitoring of Condensates Produced by	Atmospheric from the Molten State* Characterization,		009155
Injection*	Atoms on Thorium Distribution Following Intravenous		009498
Preliminary Report on the Effect of Number of	Attached to Dust Particles in the Respiratory System of		006435
the Distribution and Deposition of Radon Daughters	Attachment Ratio of Radon Daughters in Uranium Mine		009650
Atmosphere*	August 1968* in Selected Ohio Streams, the Great Miami		007351
River, the Little Miami River, and Mill Creek, June-	Austria* Uranium-Thorium Geochemistry of German		007398
and Triassic Sediments of the Drauzog, Carinthia,	Authority for the Determination of Radionuclides in		009629
of the Methods Used in the United Kingdom Atomic Energy	Automated In-Plant Monitoring of Uranyl Nitrate		009421
Scientists for Thorium*	Autopsy Samples from Thorotrast Patients*		009460
	Autoradiographic and Histopathological Studies of		009104
Thorium Dioxide Patients*	Autoradiographic Findings*		009453
	Autoradiographic Investigations of the Distribution and		009540
Excretion of Thorium and Gamma-Spectrometric and Histo-	Autoradiographic Investigations* Spleen, Lymph Nodes,		009122
Some Tissues) of Thorotrast Patients (Histological and	Autoradiographies from Pieces of Organs of People*		009632
Injected Systemically with	Autoradiography*		000497
of the Radioactive Content of Tissues by Alpha-Track	Background Areas of Brazil*		009177
Radioactivity in the Diet in High	Background Germanium-Lithium Detector with		000602
Anticoincidence NaI Annulus (Revised)*	Background Measurements in Monitoring Radioactive		009347
Effluents*	Background Measurements in Monitoring Radioactive		009108
232 and Thorium 230/Thorium 232 Activity Ratios in	Background Measurements in Monitoring Radioactive		009350
ED7115) from Coastal Areas of the North Sea and the	Background Measurements in Monitoring Radioactive		009444
Particulate Settling*	Background Measurements in Monitoring Radioactive		009592
Geochronological Studies in Santa	Background Measurements in Monitoring Radioactive		009366
or Uranium and the Transuranic Elements Using	Background Measurements in Monitoring Radioactive		009498
Determination of Thorium, Uranium and Potassium in	Background Measurements in Monitoring Radioactive		009651
Significance of Thorium/Uranium Ratios from Archean	Background Measurements in Monitoring Radioactive		009649
Dissociation Products in the Body*	Background Measurements in Monitoring Radioactive		009350
	Background Measurements in Monitoring Radioactive		009178
Completion of the Injection Phase of the	Background Measurements in Monitoring Radioactive		009019
Surveillance Stations Located in the Colorado River	Background Measurements in Monitoring Radioactive		009151
Radioactivity in Surface Waters of the Colorado River	Background Measurements in Monitoring Radioactive		009188
Settling*	Background Measurements in Monitoring Radioactive		009123
Geochronological Studies in Santa Barbara	Background Measurements in Monitoring Radioactive		009039
Manary Neoplasia in a Closed	Background Measurements in Monitoring Radioactive		009129
Induced by Internally Deposited Radionuclides in	Background Measurements in Monitoring Radioactive		009187
Metabolism of the Th 229 Decay Series in Adult	Background Measurements in Monitoring Radioactive		009041
Serum Lactic Dehydrogenase Levels in Adult	Background Measurements in Monitoring Radioactive		009173
	Background Measurements in Monitoring Radioactive		009176
Physiological Responses to Internal Irradiation in the	Background Measurements in Monitoring Radioactive		009124
Distribution of Thorium Series Nuclides in	Background Measurements in Monitoring Radioactive		009178
Growth Dynamics of Osteosarcomas Induced in	Background Measurements in Monitoring Radioactive		009186
228 and Strontium 90 to the Hematopoietic System of	Background Measurements in Monitoring Radioactive		009076
228, Thorium	Background Measurements in Monitoring Radioactive		009082
Non-Skeletal Tumor Incidence Observed in	Background Measurements in Monitoring Radioactive		009059
Electrocardiogram Evaluation of	Background Measurements in Monitoring Radioactive		009102
Radiation-Induced Bone Cancer in	Background Measurements in Monitoring Radioactive		009153
Skeletal Dosimetry in Utah	Background Measurements in Monitoring Radioactive		009160
Soft-Tissue Tumors in Internally Irradiated	Background Measurements in Monitoring Radioactive		009047
Growth Dynamics of Osteosarcomas in	Background Measurements in Monitoring Radioactive		009152
Thoron Inhalation in Radiothorium-Burdened	Background Measurements in Monitoring Radioactive		009043
Long-Term Hematological Effects of Internal Emitters in	Background Measurements in Monitoring Radioactive		009579
Bone Cancer Induced by Internally-Deposited Emitters in	Background Measurements in Monitoring Radioactive		009680
Distribution of Plutonium 239 and Thorium 230 in	Background Measurements in Monitoring Radioactive		009358
239 and Related Radionuclides on Survival of the Adult	Background Measurements in Monitoring Radioactive		009290
Uranium and Thorium After Inhalation of Uranium	Background Measurements in Monitoring Radioactive		
Biological Effects of Internal Irradiation in Adult	Background Measurements in Monitoring Radioactive		
1) Thorium 228 (Radiothorium) and Strontium 90 in Adult	Background Measurements in Monitoring Radioactive		
228, Radium 228, and Strontium 90 to Leukocytes of	Background Measurements in Monitoring Radioactive		
Determination of the Thoron Content of Air and Its	Background Measurements in Monitoring Radioactive		
Processing Methods and Costs for Selected Thorium	Background Measurements in Monitoring Radioactive		
Coastal and Estuarine Waters*	Background Measurements in Monitoring Radioactive		
Thorium Discharged by the Nuclear Industry*	Background Measurements in Monitoring Radioactive		

TITLE INDEX

Reservoirs. Communication 1*	Behavior of Natural Radioactive Elements in Standing	000275
Environment of the West Coast of India*	Behavior of Plutonium in Animals and Man*	000281
and Intraperitoneal Administration*	Behavior of Thorium and Uranium Isotopes in the Marine	000386
and Thorium in the Biosphere: A Review Emphasizing	Behavior of Thorium in Soils*	000389
Source Dosimetric Considerations of Polonium 210 in Human	Behavior of Thorium Dioxide in Rats after Intratracheal	000397
or Selected Ground Water Supplies in the Grants Mineral	Behavior Applicable to the Thorium Fuel Cycle* Uranium	000467
Meeting on the Protection of Radiation Protection held in	Behavior and Absorption of Radium 226 and Thorium 230 and	000576
Increased Content of Nuclides of the Uranium	Belt, New Mexico* Uranium Status and Milling Operations	000683
Effects*	Berlin, Germany, June 8-9, 1972* German-Soviet Working	000714
Radioclasts and Ionizing Radiation: A Selected	Beta-Gamma Dose Rates from Uranium 232 in Uranium 233*	000721
mining Operations of the West Exploration Co in the	Beta-Irradiation of Mouse-like Rodents in Soil with an	000882
III) and Cerium (III) to the Constituents of	Bibliography of Its Diagnostic Use and Biological	000736
Estimating Radioelements in Exposed Individuals. 1.	Bibliography*	000736
Percent Radiochemical Procedures for	Biological Techniques Utilizing	000736
Radioclasts in Beagle Dog Bl. 3. A Statistical Study*	Big Indian District, San Juan County, Utah* Uranium-	000736
Effect of Fallout Products on	Binding of Plutonium to Glycoproteins in Vitro*	000736
Different	Binding of Thorium (IV), Plutonium (IV), Americium (	000736
Natural Radioelements and Their Effects in Terrestrial	Biosay Operations and Procedures*	000736
of Uranium, Radium, and Thorium in Natural	Biochemical Changes Induced by Internally Deposited	000736
Uranium Dioxide (UO ₂) Dust. Postexposure Potentiation and	Biochemical Indices of Blood Serum in Cows*	000736
Intake of Polonium*	Biochemical Reports*	000736
in Water*	Biogenic Migration of Uranium, Radium and Thorium under	000736
EA Mathematical Model for the	Bioprocesses*	000736
Emitters in C. Sc. 1 Female Mice (2019)*	Bioprocesses*	000736
Emitters*	Bioprocesses*	000736
216 (Neutronium II), Thorium 226 (	Bioprocesses*	000736
Thorotrast: A Bibliography of Its Diagnostic Use and	Bioprocesses*	000736
EA Scintillation Method for the Analysis of	Bioprocesses*	000736
Identification of Alpha-Emitters in Normal	Bioprocesses*	000736
Estimation of Low Amounts of Thorium in	Bioprocesses*	000736
Determination of Thorium in Bone and Other	Bioprocesses*	000736
of Radium 226, Thorium 232 and Daughter Products in	Bioprocesses*	000736
the Thorium Fuel Cycle*	Bioprocesses*	000736
EA Thorium and Thorium in the	Bioprocesses*	000736
EA Endocrine Cells. 4. Alterations in Adrenocortical	Bioprocesses*	000736
Radioelements and the Subsequent Alteration of Adrenocortical	Bioprocesses*	000736
by Internally Deposited Radioelements on Corticosteroid	Bioprocesses*	000736
Radioelements and Effects Estimated for Aquatic	Bioprocesses*	000736
EA Protection of Radiation Effects on Aquatic	Bioprocesses*	000736
Lymphocytes of Thorium Workers with Low Body Burdens of	Bioprocesses*	000736
Lymphocyte of the Rat*	Bioprocesses*	000736
EA Polonium 210 in	Bioprocesses*	000736
EA Early Radiation Effects on Bone and	Bioprocesses*	000736
EA The Effect of Thorium Dioxide on the Peripheral	Bioprocesses*	000736
Transuranic Nuclides*	Bioprocesses*	000736
EA Thorium	Bioprocesses*	000736
EA The Effects of Aging and Internal Emitters on	Bioprocesses*	000736
New Serum	Bioprocesses*	000736
EA The Effect of Lanthanides and Actinides on	Bioprocesses*	000736
EA Interaction of some Actinide Elements with	Bioprocesses*	000736
EA Leukemia and Other Fatal	Bioprocesses*	000736
EA Changes in the Peripheral	Bioprocesses*	000736
EA Effect of Fallout Products on Biochemical Indices of	Bioprocesses*	000736
EA Effect of Internally Deposited Radioisotopes Upon	Bioprocesses*	000736
EA Effect of Internally Deposited Radioisotopes Upon the	Bioprocesses*	000736
EA by Internally Deposited Radioisotopes in Beagle Dog	Bioprocesses*	000736
EA Alpha-Radioactivity of Human	Bioprocesses*	000736
EA Thorium and Uranium in	Bioprocesses*	000736
EA Analysis of Bone	Bioprocesses*	000736
EA the Content of Concentrated and Natural Uranium in the	Bioprocesses*	000736
EA Permissible Amounts of Radioisotopes in the Human	Bioprocesses*	000736
EA The Effect of 2308 on the	Bioprocesses*	000736
EA Soluble Metabolism of Thorium and Radioisotopes in the	Bioprocesses*	000736
EA with Thorium 227. Studies on Elongation and Residual	Bioprocesses*	000736
EA and Polonium 210 in a Uranium Mining Population*	Bioprocesses*	000736
EA In Vivo Gamma-Spectrometric Investigation of Thorium	Bioprocesses*	000736
EA and the Incidence of Myelopathy*	Bioprocesses*	000736
EA the Peripheral Lymphocytes of Thorium Workers with Low	Bioprocesses*	000736
EA Infection*	Bioprocesses*	000736
EA The Radiation Protection Division's Whole	Bioprocesses*	000736
EA Thorotrast*	Bioprocesses*	000736
EA Results of the Whole	Bioprocesses*	000736
EA of Radiation Dose from Thorotrast Using Whole	Bioprocesses*	000736
EA Effect of Thorotrast on	Bioprocesses*	000736
EA of Thorium 232 and Its Dissociation Products in the	Bioprocesses*	000736
EA Elimination: Factors Influencing Elimination from the	Bioprocesses*	000736
EA 232 and that of its Dissociation Products in the	Bioprocesses*	000736
EA 226, Radium 226 and their Daughters in the Human	Bioprocesses*	000736
EA Produced by the Decay of Thorium Parents within the	Bioprocesses*	000736
EA Permissible Limits of Plutonium 239 in the Human	Bioprocesses*	000736
EA Radium 226 in Food and Man in	Bioprocesses*	000736
EA Effect*	Bioprocesses*	000736
EA Early Radiation Effects on	Bioprocesses*	000736

Stead 210 Concentrations Measured in the Or-Way Spectrometric Determination of Thorium in The Deposition of Radioactive Metal in and Cesium (III) to the Constituents of Bovine Cortical 1974a	Thorium Series Radionuclides in Compact Incidence of Dogs Case and Adults	012410 012411 012412 012413 012414 012415 012416 012417 012418 012419 012420 012421 012422 012423 012424 012425 012426 012427 012428 012429 012430 012431 012432 012433 012434 012435 012436 012437 012438 012439 012440 012441 012442 012443 012444 012445 012446 012447 012448 012449 012450 012451 012452 012453 012454 012455 012456 012457 012458 012459 012460 012461 012462 012463 012464 012465 012466 012467 012468 012469 012470 012471 012472 012473 012474 012475 012476 012477 012478 012479 012480 012481 012482 012483 012484 012485 012486 012487 012488 012489 012490 012491 012492 012493 012494 012495 012496 012497 012498 012499 012500 012501 012502 012503 012504 012505 012506 012507 012508 012509 012510 012511 012512 012513 012514 012515 012516 012517 012518 012519 012520 012521 012522 012523 012524 012525 012526 012527 012528 012529 012530 012531 012532 012533 012534 012535 012536 012537 012538 012539 012540 012541 012542 012543 012544 012545 012546 012547 012548 012549 012550 012551 012552 012553 012554 012555 012556 012557 012558 012559 012560 012561 012562 012563 012564 012565 012566 012567 012568 012569 012570 012571 012572 012573 012574 012575 012576 012577 012578 012579 012580 012581 012582 012583 012584 012585 012586 012587 012588 012589 012590 012591 012592 012593 012594 012595 012596 012597 012598 012599 012600 012601 012602 012603 012604 012605 012606 012607 012608 012609 012610 012611 012612 012613 012614 012615 012616 012617 012618 012619 012620 012621 012622 012623 012624 012625 012626 012627 012628 012629 012630 012631 012632 012633 012634 012635 012636 012637 012638 012639 012640 012641 012642 012643 012644 012645 012646 012647 012648 012649 012650 012651 012652 012653 012654 012655 012656 012657 012658 012659 012660 012661 012662 012663 012664 012665 012666 012667 012668 012669 012670 012671 012672 012673 012674 012675 012676 012677 012678 012679 012680 012681 012682 012683 012684 012685 012686 012687 012688 012689 012690 012691 012692 012693 012694 012695 012696 012697 012698 012699 012700 012701 012702 012703 012704 012705 012706 012707 012708 012709 012710 012711 012712 012713 012714 012715 012716 012717 012718 012719 012720 012721 012722 012723 012724 012725 012726 012727 012728 012729 012730 012731 012732 012733 012734 012735 012736 012737 012738 012739 012740 012741 012742 012743 012744 012745 012746 012747 012748 012749 012750 012751 012752 012753 012754 012755 012756 012757 012758 012759 012760 012761 012762 012763 012764 012765 012766 012767 012768 012769 012770 012771 012772 012773 012774 012775 012776 012777 012778 012779 012780 012781 012782 012783 012784 012785 012786 012787 012788 012789 012790 012791 012792 012793 012794 012795 012796 012797 012798 012799 012800 012801 012802 012803 012804 012805 012806 012807 012808 012809 012810 012811 012812 012813 012814 012815 012816 012817 012818 012819 012820 012821 012822 012823 012824 012825 012826 012827 012828 012829 012830 012831 012832 012833 012834 012835 012836 012837 012838 012839 012840 012841 012842 012843 012844 012845 012846 012847 012848 012849 012850 012851 012852 012853 012854 012855 012856 012857 012858 012859 012860 012861 012862 012863 012864 012865 012866 012867 012868 012869 012870 012871 012872 012873 012874 012875 012876 012877 012878 012879 012880 012881 012882 012883 012884 012885 012886 012887 012888 012889 012890 012891 012892 012893 012894 012895 012896 012897 012898 012899 012900 012901 012902 012903 012904 012905 012906 012907 01
--	---	--

of the Thorium Content of Air and Its Bearing on Lung
Cancers*
Uranium Mill Tailings and
Thorium Cycle in Heavy Water: Moderated Pressure Tube
Cycle Costs Resulting from Thorium Fuel Cycle in HWTR's
Cells. 6. Alterations in Androgen Biosynthesis by
the Subsequent Alteration of Androgen Biosynthesis by
Coating Five Sacro Particles with
Thorium Nitrate and Nitric Acid by Triethyl Phosphate-
Radium Isotopes, Lead 210, Iron 55, Silicon 32 and
Study of the Thermal Decomposition of Calcium
Cocarcinogenic Studies in Pulmonary
Effect Relations in Hepatic
Pneumonia Metastases from a Thyroid
and Thorium Decay Series Nuclides in Plantton from the
of Persian and Trianic Sediments of the Brouage,
of Radioactive Elements in Rhyolites in the West
the Choc Vapors in the Vihartovsky Chrbat Area (The West
with Enthusiasm upon the Route of Injection and Amount of
Series Radionuclides in Compact Bone of Thorotrast

Bentzen-Angelographic Findings in Two Additional
A Survey of Radiation Dosimetry in Thorium Dioxide
Follow-Up of Danish Thorotrast
Plugged Reversion Canals and Skeletal Bone in Radium
Laboratory and Clinical Findings (Study of 175
Material Radium 226 and Thorium 232 in Thyroids of
to the
Etch Pits Due to Radium and Thoron Alpha Particles in
Hamsters*
Nuclides*
Canine Effects of Ionizing Radiations or Endocrine
Effects of Heavy Metals on Fungal
Radium and Thoron Alpha Particles in C80-15 and LR-115
Chromatographic Preconcentration in an Acid-Ether
Wood Materials Production
Medical Problems Concerning the
Late Effects of Thorotrast in
Dioxine Extravasates in the Subcutaneous Tissues of the
in Sediments*
Distribution of Palladium
Distributed Uranium 238, Thorium 232, Potassium 40, and
Effectiveness of Radium and Other Alpha Emitters in
Exposures of
Disposition of Long-Lived Transur
After Chronic In Vivo Separation of Long-Lived Transur
of the Principal Isotopes in the Thorium 232 Decay
in the Persian of the Choc Vapors in the Geochemical
Produced by Attenuation from the Nolten Sandhandling,
by Neutron Activation Analysis after Adsorption on
Sustained Action of Injected
State on the Penetration of Hydrolyzable Radioelements by
of Thorium*

A Summary of the
Part of Shikane Prefecture -- with Special Emphasis on
Metabolic Characteristics Within a
of Radium and Thorium through the Gut as a Function of
Thores*
Physical,
The Terminal Blood
Effects of Aging and Internal Emitters on Blood
Tissues, and Thorium Compounds in the Developing
Pulmonary Metastases from a Thyroid Carcinoma in
Ofcose Cancers Induced by Radium 226 (Th II) in
Complex and Multiple Inhalation Exposures to the
Transyl Acetate on Seedling Growth, Unfixed Cotyledones,
Copper-Lead Mineralization in the Persian of the
Hazards of Nuclear Fusion Power and the
Health Effects and Energy
Thorotrast-Induced Spindle Cell Sarcoma and Hepatic
in the Persian of the Choc Vapors in the Vihartovsky
Detritation of Bare Earths in Thorium Compounds
of the Transuranium Elements by Extraction
Acid as Stationary Phase in Extraction

Thorium Workers with Low Body Burdens of Bismuth 212*
Exposed to Thorium Dioxide*

Changes in the Peripheral Blood Following
Atmospheres*
Alpha-Emitters in Experimental Animals During and After
The Biocyclical Action of Uranium Tetrafluoride in
Radionuclides in Corticosteroid
Effects of
Changes in Animals Following Acute and
Radiobiology, Annual Report of Work in Progress on the
Radiobiology, Annual Report of Work in Progress on the

Cancer Hazards in Industry
Cancer Induced by Internally-Deposited Emitters in
Cancer Induction by Radionuclides: Incidence vs. Dose*
Cancer Induction in Man from Internal Radioactivity*
Cancer Mortality in Colorado
Cancers Induced by Radium 226 (Th II) in Children and
CAH97) Reactors*
CHADUS)* On Assessment of 3398 Requirements and Fuel
Canine Testicular Tissue after the Internal Deposition
Canine Testicular Issues* Deposited Radionuclides and
Carbon and Metals for Long Clearance Studies*
Carbon Tetrachloride Solution* Solvent Extraction of
Carbon 14 in Marine Suspended Phases* Plutonium,
Carbonate and Calcium Oxalate* Analysis. A comparative
Carcinogenesis*
Carcinogenesis*
Carcinoma after Thorotrast Administration*
Carcinoma in Childhood after Thorium-X Treatment*
Carcinoma Seventeen Years after Injection of Thorium
Caribole* Uranium
Carinthia, Austria* Uranium-Thorium-Geochemistry
Carpathians* Geochemistry
Carpathians)* Lead Mineralization in the Persian of
Carrier Present* Distribution and Excretion of Thorium
Cases - Results of Measurements at IAEA* Thorium
Cases of Carcinoma after Thorotrast Administration*
Cases with Clinical Inform and Consent Problems*
Cases*
Cases*
Cases*
Liver Studies in the Thorotrast Patients-
Cattle from Nigeria, W. Africa*
Cauda Equina Due to Thorotrast Pellography*
C80-15 and LR-115 Cellulose Nitrate Track Detectors*
Cell Sarcoma and Hepatic Cholangiocarcinoma in Syrian
Cells of American 201 Compared to Other Transuranium
Cells. 6. Alterations in Androgen Biosynthesis by
Cells*
Cellulose Nitrate Track Detectors* The Etch Pits Due to
Cellulose System* of Bare Earths in Thorium Compounds.
Center, Environmental Monitoring Annual Report for 1972
Central Group*
Coronal angiography*
Cervical Region in Man* Effects of Colloidal Thorium
Cesium 137 and Naturally Occurring Gamma-Ray Emitters
Cosmic 137* in Man Gamma-Ray Spectra for Uniformly
CP No. 1 Female Mice (20394)* Relative Biological
Chain Alpha Emitters Following repeated Inhalation
Chain Alpha-Emitters in Experimental Animals During and
Chain* Metabolism
Characterization of Uranium-Copper-Lead Mineralization
Characterization, and Monitoring of Condensates
Charcoal* of Uranium in Sea and Surface Waters
Chelating Agents*
Chelation* Influence of Physical
Chelation-Enhanced Excretion of Radioactive Daughters
Chemical and Radiological Effects of Thorium*
Chemical Characteristics of River Water in the Eastern
Chemical Family*
Chemical Para. 4.* Absorption
Chemical, and Radioactive Properties of Thorium and
Chemistry of Radioisotope Injected Dogs*
Chemistry*
Chick Embryo* Relative Toxicity of Lanthanum,
Childhood after Thorium-X Treatment*
Children and Adults*
Chloride* 3. Single Inhalation Exposure to the Citrate
Chlorophylls, Proteins and Sugar Contents in CIT701175
Choc Vapors in the Vihartovsky Chrbat Area (The Best
Choice of Alternatives*
Choices*
Cholangiocarcinoma in Syrian Hamsters*
Chrbat Area (The West Carpathians)* Lead Mineralization
Chromatographic Preconcentration in an Acid-Ether-
Chromatography in Urines Containing DTPA* Determination
Chromatography* Applications of Neutron-absorbing
Chromosomal Aberrations in Thorium Dioxide Patients*
Chromosome Aberrations in the Peripheral Lymphocytes of
Chromosome Aberrations in Lymphocytes from Patients
Chromosome Aberrations Caused by Thorotrast*
Chronic and Acute Poisoning with U308*
Chronic Exposure of Dogs to Simulated Uranium Mine
Chronic Inhalation of Uranium Ores* Liver Uranium Chain
Chronic Inhalation Poisoning*
Chronic Irradiation by Internally Deposited
Chronic Poisoning with U308* Pathomorphological
Chronic Toxicity Program* Research in
Chronic Toxicity Program* Research in

TITLE INDEX

Radiochemistry, Annual Report of Work in Progress on the	Chronic Toxicity Program*	*Research in	000044
As Annual Report of Work in Progress on the	Chronic Toxicity Program*	*Research in Radiochemistry,	000045
Semiannual Report of Work in Progress on the	Chronic Toxicity Program*	*Research in Pathology,	000046
Semiannual Report of Work in Progress on the	Chronic Toxicity Program*	*Research in Pathology,	000047
Atom-Thorium	Chronic Toxicity Program*	Chronic Toxicity Program*	000048
From Daughters, Uranium Ore Dust, Diesel Exhaust, and	Chronic Toxicity Program*	Chronic Toxicity Program*	000049
Thorium and Uranium in Blood, Tissue, and	Chronic Toxicity Program*	Chronic Toxicity Program*	000050
Excretion Studies. 1. Single Inhalation Exposure to the	Chronic Toxicity Program*	Chronic Toxicity Program*	000051
Chlorophylls, Proteins and Sugar Contents in	Chronic Toxicity Program*	Chronic Toxicity Program*	000052
The Toxicity	Chronic Toxicity Program*	Chronic Toxicity Program*	000053
Five Micron Particles with Carbon and Metals for Lung	Chronic Toxicity Program*	Chronic Toxicity Program*	000054
with Thorium Dioxide*	Chronic Toxicity Program*	Chronic Toxicity Program*	000055
Radioactive Materials*	Chronic Toxicity Program*	Chronic Toxicity Program*	000056
Studies in the Thorotrast Patients--Laboratory and	Chronic Toxicity Program*	Chronic Toxicity Program*	000057
Measurements and	Chronic Toxicity Program*	Chronic Toxicity Program*	000058
Special	Chronic Toxicity Program*	Chronic Toxicity Program*	000059
Angiographic Findings in Two Additional Cases with	Chronic Toxicity Program*	Chronic Toxicity Program*	000060
Thorium Dioxide Effects in Man. Epidemiological,	Chronic Toxicity Program*	Chronic Toxicity Program*	000061
Primary Neoplasia in a	Chronic Toxicity Program*	Chronic Toxicity Program*	000062
Indirect Methods Used at	Chronic Toxicity Program*	Chronic Toxicity Program*	000063
Genus The Effect of Lanthanides and Actinides on Blood	Chronic Toxicity Program*	Chronic Toxicity Program*	000064
Respirable Size Range*	Chronic Toxicity Program*	Chronic Toxicity Program*	000065
Shape Factors for Aerosols of	Chronic Toxicity Program*	Chronic Toxicity Program*	000066
Crystalline Isotopes in the Marine Environment of the West	Chronic Toxicity Program*	Chronic Toxicity Program*	000067
Processes in the Marine Environment of the West	Chronic Toxicity Program*	Chronic Toxicity Program*	000068
Activity Patterns in Backwater Sediments along the West	Chronic Toxicity Program*	Chronic Toxicity Program*	000069
Coast of India* Thorium 232 and Thorium 230/Thorium 232	Chronic Toxicity Program*	Chronic Toxicity Program*	000070
Behavior and Distribution of Radioactive Substances in	Chronic Toxicity Program*	Chronic Toxicity Program*	000071
Trace Elements in Mussels (MYTILUS EDULIS) from	Chronic Toxicity Program*	Chronic Toxicity Program*	000072
and Uranium Disequilibrium on the Surface Layers of the	Chronic Toxicity Program*	Chronic Toxicity Program*	000073
for Lung Clearance Studies*	Chronic Toxicity Program*	Chronic Toxicity Program*	000074
Rate*	Chronic Toxicity Program*	Chronic Toxicity Program*	000075
Phagocytosis of Colloidal Thorium Dioxide and	Chronic Toxicity Program*	Chronic Toxicity Program*	000076
Diffusion Sampler Useful for Measuring Diffusion	Chronic Toxicity Program*	Chronic Toxicity Program*	000077
Aspects of	Chronic Toxicity Program*	Chronic Toxicity Program*	000078
Non-Radiation Effects of Thorotrast and Other	Chronic Toxicity Program*	Chronic Toxicity Program*	000079
Reticuloendothelial System of the Rat Phagocytosis of	Chronic Toxicity Program*	Chronic Toxicity Program*	000080
Epithelial Tumors in Rats*	Chronic Toxicity Program*	Chronic Toxicity Program*	000081
Intravenous Injection*	Chronic Toxicity Program*	Chronic Toxicity Program*	000082
Substitutes*	Chronic Toxicity Program*	Chronic Toxicity Program*	000083
Influence of Sex Hormones and Tissues on	Chronic Toxicity Program*	Chronic Toxicity Program*	000084
Subcutaneous Tissues*	Chronic Toxicity Program*	Chronic Toxicity Program*	000085
Effects of Locally Deposited	Chronic Toxicity Program*	Chronic Toxicity Program*	000086
of the Kidney Following Retrograde Pyelography with	Chronic Toxicity Program*	Chronic Toxicity Program*	000087
Primary Neoplasia in a Closed Beagle	Chronic Toxicity Program*	Chronic Toxicity Program*	000088
From Water Quality Surveillance Stations Located in the	Chronic Toxicity Program*	Chronic Toxicity Program*	000089
Radioactivity in Surface Waters of the	Chronic Toxicity Program*	Chronic Toxicity Program*	000090
Uranium Mill Tailings and Cancer Mortality in	Chronic Toxicity Program*	Chronic Toxicity Program*	000091
Stations Located in the Colorado River Basin of	Chronic Toxicity Program*	Chronic Toxicity Program*	000092
Program for Improved Waste Management in	Chronic Toxicity Program*	Chronic Toxicity Program*	000093
Exposure in the Vicinity of U.S. Atomic Energy	Chronic Toxicity Program*	Chronic Toxicity Program*	000094
of Radioactivity in the Marine Environment and the Dose	Chronic Toxicity Program*	Chronic Toxicity Program*	000095
of Natural Radioactive Elements in Standing Reservoirs.	Chronic Toxicity Program*	Chronic Toxicity Program*	000096
Measurements at IAEA*	Chronic Toxicity Program*	Chronic Toxicity Program*	000097
Thorium Series Radionuclides in	Chronic Toxicity Program*	Chronic Toxicity Program*	000098
Whistopathological Endpoints in	Chronic Toxicity Program*	Chronic Toxicity Program*	000099
Gas Analysis and Differential Thermal Analysis. A	Chronic Toxicity Program*	Chronic Toxicity Program*	000100
Thorium 228, Radium 228 and Strontium 90 to the	Chronic Toxicity Program*	Chronic Toxicity Program*	000101
Thorium 228, Radium 228, and Strontium 90 to	Chronic Toxicity Program*	Chronic Toxicity Program*	000102
of Thorium 232*	Chronic Toxicity Program*	Chronic Toxicity Program*	000103
210, and Polonium 210 by Plants*	Chronic Toxicity Program*	Chronic Toxicity Program*	000104
Report No. 15*	Chronic Toxicity Program*	Chronic Toxicity Program*	000105
Experiments*	Chronic Toxicity Program*	Chronic Toxicity Program*	000106
Studies. 1. Single Inhalation Exposure to the Citrate	Chronic Toxicity Program*	Chronic Toxicity Program*	000107
Interaction of Plutonium with	Chronic Toxicity Program*	Chronic Toxicity Program*	000108
Selected Fuel Cycles*	Chronic Toxicity Program*	Chronic Toxicity Program*	000109
Uranium, Thorium, and Lead Contents and Lead Isotopic	Chronic Toxicity Program*	Chronic Toxicity Program*	000110
Open Intratracheal Introduction of a Dissolved Thorium	Chronic Toxicity Program*	Chronic Toxicity Program*	000111
after Intratracheal Introduction of Soluble Thorium	Chronic Toxicity Program*	Chronic Toxicity Program*	000112
Relative Toxicity of Lanthanum, Tantalum, and Thorium	Chronic Toxicity Program*	Chronic Toxicity Program*	000113
Distribution and Excretions of Certain Soluble	Chronic Toxicity Program*	Chronic Toxicity Program*	000114
The Metabolism of	Chronic Toxicity Program*	Chronic Toxicity Program*	000115
Certain Aspects of the Toxicology of Insoluble	Chronic Toxicity Program*	Chronic Toxicity Program*	000116
Comparative Toxicity of Soluble and Insoluble	Chronic Toxicity Program*	Chronic Toxicity Program*	000117
and Justification of Permissible Standards of Soluble	Chronic Toxicity Program*	Chronic Toxicity Program*	000118
Spectrographic Determination of Rare Earths in Thorium	Chronic Toxicity Program*	Chronic Toxicity Program*	000119
Acute Toxicity of Inhaled Thorium	Chronic Toxicity Program*	Chronic Toxicity Program*	000120
Thorium and Its	Chronic Toxicity Program*	Chronic Toxicity Program*	000121
by Rats After Intratracheal Administration of Thoron	Chronic Toxicity Program*	Chronic Toxicity Program*	000122
Radioactive Materials (Thorium, Uranium) in Ore,	Chronic Toxicity Program*	Chronic Toxicity Program*	000123
Artificial Radionuclides in Seafoods and Marine Protein	Chronic Toxicity Program*	Chronic Toxicity Program*	000124
Thorium 232 and Thorium 228/Thorium 232 in Sea	Chronic Toxicity Program*	Chronic Toxicity Program*	000125
of Contribution of Jet Operations to Trace Element	Chronic Toxicity Program*	Chronic Toxicity Program*	000126
of Continuous Mass Spectrometric Determination of	Chronic Toxicity Program*	Chronic Toxicity Program*	000127
Made Phosphorus Fertilizers*	Chronic Toxicity Program*	Chronic Toxicity Program*	000128
Tropical Algae*	Chronic Toxicity Program*	Chronic Toxicity Program*	000129
The Tolerance	Chronic Toxicity Program*	Chronic Toxicity Program*	000130
The	Chronic Toxicity Program*	Chronic Toxicity Program*	000131
Different Times during Vegetation*	Chronic Toxicity Program*	Chronic Toxicity Program*	000132
The	Chronic Toxicity Program*	Chronic Toxicity Program*	000133
The	Chronic Toxicity Program*	Chronic Toxicity Program*	000134
The	Chronic Toxicity Program*	Chronic Toxicity Program*	000135
The	Chronic Toxicity Program*	Chronic Toxicity Program*	000136
The	Chronic Toxicity Program*	Chronic Toxicity Program*	000137
The	Chronic Toxicity Program*	Chronic Toxicity Program*	000138
The	Chronic Toxicity Program*	Chronic Toxicity Program*	000139
The	Chronic Toxicity Program*	Chronic Toxicity Program*	000140
The	Chronic Toxicity Program*	Chronic Toxicity Program*	000141
The	Chronic Toxicity Program*	Chronic Toxicity Program*	000142
The	Chronic Toxicity Program*	Chronic Toxicity Program*	000143
The	Chronic Toxicity Program*	Chronic Toxicity Program*	000144
The	Chronic Toxicity Program*	Chronic Toxicity Program*	000145
The	Chronic Toxicity Program*	Chronic Toxicity Program*	000146
The	Chronic Toxicity Program*	Chronic Toxicity Program*	000147
The	Chronic Toxicity Program*	Chronic Toxicity Program*	000148
The	Chronic Toxicity Program*	Chronic Toxicity Program*	000149
The	Chronic Toxicity Program*	Chronic Toxicity Program*	000150
The	Chronic Toxicity Program*	Chronic Toxicity Program*	000151
The	Chronic Toxicity Program*	Chronic Toxicity Program*	000152
The	Chronic Toxicity Program*	Chronic Toxicity Program*	000153
The	Chronic Toxicity Program*	Chronic Toxicity Program*	000154
The	Chronic Toxicity Program*	Chronic Toxicity Program*	000155
The	Chronic Toxicity Program*	Chronic Toxicity Program*	000156
The	Chronic Toxicity Program*	Chronic Toxicity Program*	000157
The	Chronic Toxicity Program*	Chronic Toxicity Program*	000158
The	Chronic Toxicity Program*	Chronic Toxicity Program*	000159
The	Chronic Toxicity Program*	Chronic Toxicity Program*	000160
The	Chronic Toxicity Program*	Chronic Toxicity Program*	000161
The	Chronic Toxicity Program*	Chronic Toxicity Program*	000162
The	Chronic Toxicity Program*	Chronic Toxicity Program*	000163
The	Chronic Toxicity Program*	Chronic Toxicity Program*	000164
The	Chronic Toxicity Program*	Chronic Toxicity Program*	000165
The	Chronic Toxicity Program*	Chronic Toxicity Program*	000166
The	Chronic Toxicity Program*	Chronic Toxicity Program*	000167
The	Chronic Toxicity Program*	Chronic Toxicity Program*	000168
The	Chronic Toxicity Program*	Chronic Toxicity Program*	000169
The	Chronic Toxicity Program*	Chronic Toxicity Program*	000170
The	Chronic Toxicity Program*	Chronic Toxicity Program*	000171
The	Chronic Toxicity Program*	Chronic Toxicity Program*	000172
The	Chronic Toxicity Program*	Chronic Toxicity Program*	000173
The	Chronic Toxicity Program*	Chronic Toxicity Program*	000174
The	Chronic Toxicity Program*	Chronic Toxicity Program*	000175
The	Chronic Toxicity Program*	Chronic Toxicity Program*	000176
The	Chronic Toxicity Program*	Chronic Toxicity Program*	000177
The	Chronic Toxicity Program*	Chronic Toxicity Program*	000178
The	Chronic Toxicity Program*	Chronic Toxicity Program*	000179
 

•

Transmutations
 Spectrometry over the
 Significance of Radioelement
 Environmental Radiation Levels and
 Layers of the Coastal Sediments and their Absolute
 Radiocarbon in the Human Fetus and Marine Permissible
 Survey of Naturally Occurring Radioisotopes
 Measurements of Polonium Daughter
 Radon 222 in the Atmosphere
 Method for Measuring the
 Indian Population
 Naturally Occurring
 Maximum Permissible
 Particles in Relation to their Sizes
 Thorium Series
 Their Consequences for Fuel Recycling
 Environmental
 Sampling, Characterization, and Monitoring of
 Comment on "Excess Uranium 235: An Aging Effect in
 Counting Method"
 Rapid Method of
 Study of Intracellular Fluorine Tissue Deposits: Their
 in Two Affiliated Cases with Clinical Inform and
 Disintegration
 Interaction between Blood
 Comparison of Serum Transaminase Levels and Other Serum
 Plutonium (IV), Americium (III) and Curium (III) to the
 The Interaction of some Actinide Elements with Blood
 Uranium Hexafluoride
 and a-Signal Body
 A Case of Accidental Penetration
 The Estimation of Radiation Dose Rates to Fish in
 Internal
 Detection of Environmental
 Variations of Uranium Content
 Studies on Environmental
 Ore Mining and
 Evaluation of Natural Radioisotopes
 The Assessment of Internal
 Methods Used at CERN for the Evaluation of Internal
 Preliminary Report on Uranium, Thorium, and Lead
 Enclosed Cysteines, Chlorophylls, Proteins and Sugar
 on the Late Effects of Radioactive and Nonradioactive
 The Concentration of Uranium in Air from
 Mining Diagenesis
 Airborne Effluent
 for Producing Reactor-Grade Thorium Dioxide and
 Geologic Factors
 Impact of Waste Effluents in the Nuclear Fuel Cycle -
 Radiation Levels and Plutonium
 Environmental Concerns in Uranium Mining, Milling, and
 Fuel Cycle - Postprocessing of High-Temperature Gas
 Fuel Cycle - Fabrication of High-Temperature Gas
 Progress Report
 Gas
 Thorium Fuel Cycle for Heavy Water Moderated Organic
 Waste Disposal Aspects of the Long Term
 Vapors in the
 Geochemical Characterization of Uranium-
 of Porphyrin Metabolism: The Effect of Metals on
 Thorium and Plutonium in Sea Water and Recreant
 Control and Distribution of Uranium in
 the Microgram Amount of Thorium in Plants, Shells, and
 Monium-Thorium Chronology of the Japan Sea
 The Environmental Impact of Waste Effluents in the
 The Environmental Impact of Waste Effluents in the
 The Environmental Impact of Waste Effluents in the
 (III) and Curium (III) to the Constituents of Bovine
 Deposited Radioisotopes Upon the Blood Vessels of
 Preliminary Report: Changes in Vascularity of
 Deposited Radioisotopes Upon Blood Vessels of
 Irradiated by Internally Deposited Radionuclides on
 Uranium Ores
 Correlation of Radioactive Waste Treatment
 in the
 Correlation of Radioactive Waste Treatment
 in the
 Correlation of Radioactive Waste Treatment
 in the
 Postprocessing Methods and
 An Assessment of U108 Requirements and Fuel Cycle
 Acid and Uranyl Acetate on Seedling Growth, Exposed
 The Radiation Protection Division's Whole Body
 Thorotrast
 Results of the Whole-Body
 Techniques and Preliminary Results
 In Vivo
 Confirmation of Fissionable Materials with the Etch-Pit
 on Anion-Exchange Resin and Delayed-Neutron
 Exploration Co in the Big Indian District, San Juan
 Products on Biochemical Indices of Blood Serum in
 Evaluation of Radiation Hazards
 Trace Elements in Flue Gases and Air Quality
 Toxicology of Transportable Uranium: A
 of Concentrated and Natural Uranium in the Body and
 Distribution of Some Bone-Seeking Radionuclides and A
 Report No. 15
 Plutonium/
 of Thorium (IV), Plutonium (IV), Americium (III) and
 Radiation Effects in Man:
 Evaluation of Thorium Fuel
 and Radiological Properties of Uranium in Selected Fuel
 Concentration Measurements Made by Airborne Gamma-Ray
 Concentration, First Half 1970
 Concentrations in the Sediments
 on the Surface
 Concentrations in Air and Water: Permissible Amounts of
 Concentrations in New Zealand Soils
 Concentrations in Structures Built on or Near Uranium
 Concentrations of the Short-Lived Daughter Products of
 Concentrations of Alpha-Emitting Isotopes in a New
 Concentrations of Natural Radioactive Materials in
 Concentrations of Uranium Series Nuclides in Soil
 Concentrations Measured in the Bone and Excreta of a
 Concepts for the High Temperature Thorium Reactor and
 Concerns in Uranium Mining, Milling, and Conversion
 Condensates Produced by Atomization from the Volcan
 Confined Waters, by J. Cronwell, p. 310
 Confirmation of Fissionable Materials with the Etch-Pit
 Conjectured Path
 Histopathologic
 Consent Problems
 Biostereographic Findings
 Constant of Thorium and the Branching Ratios of Thorium
 Constituents and some Actinides
 Constituents in Dogs Buried with Plutonium 239,
 Constituents of Bovine Cortical Bone in Vitro (IV),
 Constituents
 Contaminants in Dogs and Monkeys
 Contaminated with Thorium 227. Studies on Elimination
 Contaminated Environments, and the Assessment of the
 Contamination and its Treatment
 Contamination by Uranium. Part 1
 Contamination by Uranium. Seasonal and Regional
 Contamination of Fishes in Streams Affected by Uranium
 Contamination Resulting from Recurrent or Prolonged
 Contamination
 Indirect
 Contents and Leaf Isotopic Compositions in Sediment
 Contents in CIPOLLINO Species
 on Seedling Growth,
 Contrast Media
 Experimental Studies in Mice
 Contrasted Natural Environments
 Control and Distribution of Uranium in Coral Reefs
 Control at Uranium Mills
 Control of Thorium Hexafluoride
 Controlling Associated Wastes and Effluents
 Capacity
 Controlling Terrestrial Gamma-Ray Dose Rates
 Conversion of Yellow Cake to Uranium Hexafluoride. Part
 Conversion Factors
 Conversion
 Cooled Reactor Fuel Containing Uranium 235 and Thorium
 Cooled Reactor Fuel Containing Uranium 235 and Thorium
 Cooled Reactor Progress: Thorium Utilization Program
 Cooled Reactors, Technical Progress Report No. 5, April
 Cooling Characteristics of Irradiated Nuclear Fuels
 Copper-Lead Mineralization in the Perianth of the Choc
 Coproporphyrin Excretion
 Studies
 Coral in the North Pacific
 Content of Plutonium,
 Coral Reefs during Diagenesis
 Estimation of
 Corals
 Corals
 Correlation of Radioactive Waste Treatment Costs and
 Correlation of Radioactive Waste Treatment Costs and
 Correlation of Radioactive Waste Treatment Costs and
 Cortical Bone in Vitro (IV), Plutonium (IV), Americium
 Cortical Bone
 The Effect of Internally
 Cortical Bones Induced by Bone Seeking Radionuclides
 Cortical Bones
 Effect of Internally
 Corticosteroid Biosynthesis
 The Effects of Chronic
 Cost Saving Techniques Developed for Lower Grade
 Costs and the Environmental Impact of Waste Effluents
 Costs and the Environmental Impact of Waste Effluents
 Costs and the Environmental Impact of Waste Effluents
 Costs for Selected Thorium-Bearing Reactor Fuel Types
 Costs Resulting from Thorium Fuel Cycle in HWRS (CANDUs)
 Cysteolones, Chlorophylls, Proteins and Sugar Contents
 Counter-Its Use and Calibration
 Counting of Patients with Known Amount of Injected
 Counting of Thorium Dioxide Patients: Special
 Counting Methods
 Rapid Method of
 Counting
 Uranium in Natural Water by Preconcentration
 County, Utah
 Uranium-Mining Operations of the Utah
 Cows
 Effect of Fallout
 Created by Thoron and Thoron Daughters
 Criteria
 Critical Contribution to Health Protection of Workers
 Critical Organs
 Assessment of the Content
 Critical Survey of the Analysis of Microscopic
 Critical Compatibility Testing, April-June 1972, Quarterly
 Curium (III) to the Constituents of Bovine Cortical
 Current Views and Prospects
 Cycles
 Cycles
 Isotopic Composition

•

Plutonium-Uranium 239, and Uranium 233-Thorium Pacl	Cycles*	Waste Produced by the Enriched Uranium,	930299
Plutonium-Uranium 238, and Uranium 233-Thorium Pacl	Cycles*	Wastes Produced by the Enriched Uranium,	930730
Activities in the Radioactive Wastes from Nuclear Fuel	Cycles*	Toxicity of Long-Lived Fission Products and	930671
The Pittsburgh Thorotrast Series--Report of a	Cytogenetic Study*	Cytogenetic Study*	930394
Primary Excretion of Radioactive Polonium 210 by	Czechoslovakian "Uranium Timers"	Czechoslovakian "Uranium Timers"	930631
Seasonal and Regional Variations of Uranium Content in	Daily Diet and Urine*	Contamination by Uranium,	930325
Relationship of Microdistribution of Alpha Particles to	Damages*	Damages*	930395
Substances*	Some Unrecognized	Danger of Cancer from Thorotrast as a Diagnostic Medium	930745
		Dangers in the Use and Handling of Radioactive	930770
		Dangers in Refining Radioactive Substances*	930713
		Danish Thorotrast Cases*	930314
		Dated Results*	930314
		Dating Techniques*	930333
		Danger by Thorium Dioxide Patients*	930630
		Daughter Concentrations in Structures Built on or Near	930556
		Daughter Nuclides and Estimation of Absorbed Dose in	930313
		Daughter Particles in Uranium Mine Atmospheres*	930702
		Daughter Products in Biological Samples*	930484
		Daughter Products in Tissue: Effect of Time on the	930722
		Daughter Products of Radon 222 in the Atmosphere*Method	930573
		Daughter Products*	930572
		Daughter Products*	930572
		Daughters after Thorotrast Administration*	930449
		Daughters in a Thorium Purification and Fabrication	930774
		Daughters in the Environment of a Uranium Ore	930544
		Daughters in the Human Body*	930519
		Daughters in the Spleen of a Thorotrast Case*	930485
		Daughters in Bone*	930485
		Daughters in Different Air Atmospheres*	930599
		Daughters in Human Subjects*	930820
		Daughters in Man Following Intravascular Injection of	930454
		Daughters in Thorotrast Patients*	930453
		Daughters in Uranium Mine Atmosphere*	930649
		Daughters of Thorium 232 in the Soft Tissue in Animals*	930449
		Daughters of Thorium*	930584
		Daughters After Thorotrast Injection*	930437
		Daughters Attached to Dust Particles in the Respiratory	930649
		Daughters*	930386
		Daughters*	930649
		Daughters, Uranium Ore Dust, Diesel Exhaust, and	930712
		Decay in the Lungs of Rats*	930649
		Decay of Thorium Parent within the Body-Calculations	930502
		Decay Chain*	930399
		Decay Products of Radon and Thoron*	930399
		Decay Products Following Inhalation of Uranium 232 232 (	930311
		Decay Products* for Measuring Diffusion Coefficients	930376
		Decay Products*The Dose to the Human Respiratory Tract	930485
		Decay Property in Animals Tissues*	930554
		Decay Series in Adult Beagle Dogs. I. Thorium 229 (84th)	930351
		Decay Series Elements in the Oceans and Sediments*	930327
		Decay Series Nuclides in Plankton from the Caribbean*	930309
		Decay Series Radionuclides in Fish and Other Animals	930493
		December 1969, Annual Summary, 1969*	930552
		December 1970*	930652
		Decomposing Plant Matter*	930332
		Decomposition of Calcium Carbonate and Calcium Oxalate*	930588
		Deduced by Uranium-Series and Pyritation-Pint Dating	930337
		Deep Sea Drilling Project, Leg 2*	930413
		Dehydrogenase Levels in Adult Beagle Dogs*	930184
		Delayed-Neutron Counting*	930221
		Dematured Thorium Cycle*	930314
		Dematured Uranium Peeled PUPS*	930294
		Denitrification in Continuous Flow-Stirred Reactors*	930231
		Denmark*	930416
		Dental Porcelain*	930529
		Depleted Uranium Operation*The "Use of Thermoluminescent	930448
		Deposit at Wasefield*, the Illaustaq Intrusion, South	930367
		Deposited Colloidal Thorium Dioxide*	930406
		Deposited Emitters in Beagles*	930359
		Deposited Radioactive Materials in Man*	930390
		Deposited Radioisotopes Upon the Blood Vessels of	930390
		Deposited Radioisotopes Upon Blood Vessels of Cortical	930496
		Deposited Radionuclides and the Subsequent Alteration	930604
		Deposited Radionuclides in Beagle Dog Blood. A	930618
		Deposited Radionuclides on Corticosteroid Biosynthesis*	930618
		Deposited Radionuclides*	930629
		Deposited Thorium by Means of Studies with a Pealistic	930507
		Deposition of Inhaled Uranyl Nitrate (Uranium 232 and	930508
		Deposition of Natural Radon Daughters in Human Subjects*	930420
		Deposition of Plutonium and Related Elements, in Rat	930172
		Deposition of Radioactive Materials*	930459
		Deposition of Radioactive Materials*	930461
		Deposition of Radioactive Metal in Bone as a Potential	930037
		Deposition of Radon Daughters Attached to Dust	930498
		Deposition of Some Radionuclides* Androgen Biosynthesis	930065
		Deposition of Uranium in Bone*	930162
		Deposits in the Kidney*	930499
		Deposits of Plutonium 239, Thorium 228, and Radon 226*	930125

TITLE INDEX

On the Follow-up of Patients with Thorium Dioxide	237444
Histopathologic Study of Intratracheal Plutonium Dioxide	237445
Transuranic Waste Storage	237446
Effects of	237447
of Soil and Perennial Vegetation in Northern Bohemia	237448
is the Part	237449
Safety Features in the	237450
Analysis of Bore Flow Samples for the	237451
Part 1.	237452
Other	237453
Slow Background Germanium-Lithium	237454
Particles in C102-15 and L9-115 Cellulose Nitrate Track	237455
Radioactive Materials--	237456
Cost Saving Techniques	237457
Therotrast (Portuguese Experience)	237458
Tumors	237459
of Lanthanum, Tantalum, and Thorium Compounds in the	237460
the Maxillary Sinus to Man from the Fallout of Nuclear	237461
and Distribution of Thorium in Cerebral Neurons During	237462
the Danger of Cancer from Therotrast as a	237463
the Introduction in 1920-1929 of Thorium Dioxide in	237464
Therotrast: A Bibliography of Its	237465
Studies of Inhaled Radon Daughters, Uranium Ore Dust,	237466
and Regional Variations of Uranium Content in Daily	237467
Stationarity in the	237468
Elevated Natural Radiation	237469
Thorium Alpha Particles in C100-15	237470
Some Characteristic	237471
Thermal Analysis with Evolved Gas Analysis and	237472
Uranium and Potassium in Fossils and in Two Neogenic	237473
and Thorium	237474
Diffusion Sampler Useful for Measuring	237475
Coefficients and Unattached Fraction of Radon and	237476
Tumors Developed in People Injected with Thorium	237477
A Five Year Inhalation Study with Natural Uranium	237478
System of the Fat	237479
Phagocytosis of Colloidal Thorium	237480
Domestic Capacity for Producing Reactor-Grade Thorium	237481
Rats	237482
Oliver Distribution of Colloidal Thorium	237483
with Radiothorium (Thorium 230) Enriched Thorium	237484
Follow-Up Study of Portuguese Patients Given Thorium	237485
the Introduction in 1920-1929 of Thorium	237486
the Distribution of Colloidal Thorium	237487
Administration	237488
the Behavior of Thorium	237489
for Aerosols of Coal, Uranium Dioxide, and Thorium	237490
Plate Effects of Thorium	237491
the Effect of Thorium	237492
Stimulation of the Nerve-Fascicle	237493
the Effect of Thorium	237494
Along Tumors in Rats after Thorium	237495
Hemangioendothelioma of Liver Following Thorium	237496
Wheeler's Disease Following Thorium	237497
a Survey of Radiation Dosimetry in Thorium	237498
from Boston on the Follow-up of Patients with Thorium	237499
of Sex Hormones and Tissues on Colloidal Thorium	237500
Pathological Studies (Experience in Portugal) Thorium	237501
Cervical Pexia in Man	237502
Effects of Colloidal Thorium	237503
Follow-Up of Thorium	237504
Follow-Up Study of Thorium	237505
Stenosis and Other Fatal Blood Dyscrasias in Thorium	237506
Chromosomal Aberrations in Thorium	237507
Gloss of Thorium Daughter by Thorium	237508
and Histopathological Studies of Thorium	237509
Results	237510
In Vivo Counting of Thorium	237511
Manufacture of Thorium	237512
Effects of Locally Deposited Colloidal Thorium	237513
Objections Induced by Thorium	237514
Distribution, Retention, and Late Effects of Thorium	237515
Rabbits after Injection of Various Amounts of Thorium	237516
Carcinoma Seventeen Years after Injection of Thorium	237517
Laboratory Findings in Patients Injected with Thorium	237518
Following Retrograde Pyelography with Colloidal Thorium	237519
in Lymphocytes from Patients Exposed to Thorium	237520
in Rats on Intratracheal Administration of Thorium	237521
Shape Factors for Aerosols of Coal, Uranium	237522
is Underground Environments of Uranium and Thorium	237523
Wheeler's	237524
Administration	237525
Erythrocytosis (Di Guglielmo's)	237526
Stenosis and Other Hematological	237527
Dissolution Into Water and the Uranium 230/Uranium 238	237528
Sediments and their	237529
Studies on Thorium and Uranium	237530
Series of Thorium C	237531
Investigation of Radioactive Dust	237532
Plants	237533
Characteristics of Irradiated Nuclear Fuels	237534
Waste Treatment and	237535
Products and Actinides in the Radioactive Production,	237536
Featuring Repeated Inhalation Exposures of Laboratory	237537
Inhalation of Uranium 232 UO ₂ (BO) 2 Aerosols	237538
Basic Patterns of Metabolism of Thorium 232 and its	237539
Effect of the Metabolism of Thorium 232 and that of its	237540
Deposits	237541
Preliminary Report from Boston	237542
Deposits: Their Conjectured Fate	237543
Depositing Attachment Station of Fat in Neutrophils in	237544
Beatty Areas of the Nevada Test Site	237545
Characteristics	237546
De-Iodination on the Detection of Actinide Elements	237547
Design of Radiological Laboratories, Trombay	237548
Detection of Alpha Emitters	237549
Detection of Environmental Contamination by Thorium	237550
Detection of Insoluble Alpha Emitters in the Lung	237551
Detector with Anticoincidence Hal Annodes (Device)	237552
Detectors	237553
the Rich Pits Due to Polonium and Thorium Alpha	237554
Determination of Thorium in Urine	237555
Determinants of Dose of the Respiratory Tract	237556
Developed for Lower Grade Uranium Ores	237557
Developed in People Infected with Thorium Dioxide	237558
Developing Chick Embryo	237559
Relative Toxicity	237560
Devices	237561
a Handbook for Estimating the Maximum	237562
Diagnosis	237563
Diagnostic Medium	237564
Diagnostic Radiology	237565
Diagnostic Use and Biological Effects	237566
Diesel Exhaust, and Cigarette Smoke in Dogs and Humans	237567
Diet and Urine	237568
Contamination by Uranium, Cerebral	237569
Diet in High Background Areas of Brazil	237570
Diet of the Inhabitants of the Brazilian District of	237571
Differences Between the Rich Pits Due to Polonium and	237572
Differential Thermal Analysis: A Comparative Study of	237573
Differentiation Series	237574
Determination of Thorium	237575
Diffusion Coefficients and Unattached Fraction of Radon	237576
Diffusion Sampler Useful for Measuring Diffusion	237577
Dioxide (Therotrast) (Portuguese Experience)	237578
Dioxide (Th ²³⁰) Dust: Postexposure Retention and Biologic	237579
Dioxide and Cobaltic Oxide by the Volcanic-ethanol	237580
Dioxide and Controlling Associated Noses and Effluents	237581
Dioxide and Development of Liver Endothelial Tumors in	237582
Dioxide and Its Radioactive Properties	237583
Dioxide in the Peritoneal Sinus	237584
Dioxide in Diagnostic Radiology	237585
Dioxide in Bone: Liver after intravenous injections	237586
Dioxide in Rats after Intratracheal and Intraperitoneal	237587
Dioxide in Respirable Size Range	237588
Shape Factors	237589
Dioxide on the Liver of Patients in Portugal	237590
Dioxide on the Peripheral Blood of Rats	237591
Dioxide on Arterial Pressure and Threshold of	237592
Dioxide Administration	237593
Dioxide Administration	237594
Dioxide Angiography	237595
Dioxin Cases	237596
Dioxide Deposits	237597
Preliminary Report	237598
Distribution and Effects in Rabbits	237599
Dioxide Effects in Man: Epidemiological, Clinical, and	237600
Dioxide Extravasates in the Subcutaneous Tissues of the	237601
Dioxide Patients in the United States	237602
Dioxide Patients in Denmark	237603
Dioxide Patients in Portugal	237604
Dioxide Patients	237605
Dioxide Patients	237606
Dioxide Patients	237607
Dioxide Patients	237608
Dioxide Patients: Special Techniques and Preliminary	237609
Dioxide Suspension (Therotrast)	237610
Dioxide	237611
Dioxide	237612
Dioxide	237613
Dioxide	237614
Dioxide	237615
Dioxide	237616
Dioxide	237617
Dioxide	237618
Dioxide	237619
Dioxide	237620
Dioxide	237621
Dioxide	237622
Dioxide	237623
Dioxide	237624
Dioxide	237625
Dioxide	237626
Dioxide	237627
Dioxide	237628
Dioxide	237629
Dioxide	237630
Dioxide	237631
Dioxide	237632
Dioxide	237633
Dioxide	237634
Dioxide	237635
Dioxide	237636
Dioxide	237637
Dioxide	237638
Dioxide	237639
Dioxide	237640
Dioxide	237641
Dioxide	237642
Dioxide	237643
Dioxide	237644
Dioxide	237645
Dioxide	237646
Dioxide	237647
Dioxide	237648
Dioxide	237649
Dioxide	237650
Dioxide	237651
Dioxide	237652
Dioxide	237653
Dioxide	237654
Dioxide	237655
Dioxide	237656
Dioxide	237657
Dioxide	237658
Dioxide	237659
Dioxide	237660
Dioxide	237661
Dioxide	237662
Dioxide	237663
Dioxide	237664
Dioxide	237665
Dioxide	237666
Dioxide	237667
Dioxide	237668
Dioxide	237669
Dioxide	237670
Dioxide	237671
Dioxide	237672
Dioxide	237673
Dioxide	237674
Dioxide	237675
Dioxide	237676
Dioxide	237677
Dioxide	237678
Dioxide	237679
Dioxide	237680
Dioxide	237681
Dioxide	237682
Dioxide	237683
Dioxide	237684
Dioxide	237685
Dioxide	237686
Dioxide	237687
Dioxide	237688
Dioxide	237689
Dioxide	237690
Dioxide	237691
Dioxide	237692
Dioxide	237693
Dioxide	237694
Dioxide	237695
Dioxide	237696
Dioxide	237697
Dioxide	237698
Dioxide	237699
Dioxide	237700

TITLE INDEX

- Disequilibrium in Nature* α Alpha-Recoil Thorium 230: 022661
 in Organs of Rat upon Intratracheal Introduction of a 022122
 Determination of Suspended and 022581
 of Radioactivity in Man Gamma-Ray Spectra for Uniformly 022883
 to Dust Particles in the Respiratory System of 022898
 Ser Mammals and Tissues on Colloidal Thorium Dioxide 022089
 and Histo-Radiographic Investigations of the 022453
 upon the Route of Injection and Amount of Carrier 022183
 022187
 Following Parenteral Administration* 022185
 Following Inhalation and the Effect of the 022024
 Inhalation Exposure to the Citrate Complex and Thorium 022023
 Influence of Aerosol Properties upon Gross 022180
 of Bismuth and Other Metals on Plutonium and Thorium 022158
 Compounds of Thorium 022189
 210 in a Uranium Miner Population* 022191
 Thorium in Natural Biogeochemicals* 022252
 Thorium 232 and Carcinogens in Man Following 022858
 022625
 The Radioactivity of Thorotrast and Its In-Vitro 022982
 Development of Liver Epithelial Tumors in Rats* 022507
 Liver after Intravenous Injection* 022025
 of Studies with a Realistic 022207
 Toxicity, Excretion and Tissue 022102
 of Freshwater Vegetation in Processes of Migration and 022097
 022100
 Radioisotopes in the Teeth of Dogs. 1. The 022355
 Mesothorium and Radioisotopes in Teeth. 1. The 022152
 Estuarine Waters* 022702
 Mesothorium II Thorium 022067
 and Vine Mesophytes* 022093
 The Dependence of Late Effects in Mice on the Temporal 022582
 A Critical Survey of the Analysis of Microscopic 022363
 Assessment of Organ 022450
 after Intraspinal Thorotrast Injection* 022129
 and Estimation of Absorbed Dose in the Human Organs* 022118
 Freshwater Environment by Activation 022075
 the Environment of a Uranium Ore 022596
 the Investigation into the 022361
 Mountain Soils of Thin Forests* 022382
 022110
 022111
 022364
 022150
 022289
 022523
 022699
 022384
 022158
 022684
 022506
 022705
 022118
 022020
 022019
 022100
 022163
 022162
 022164
 022189
 022151
 022097
 022033
 022035
 022086
 022080
 022184
 022668
 022721
 022508
 022288
 022724
 022386
 022119
 022288
 022505
 022067
 022038
 022117
 022197
 022391
 022047
 022047
 022050
 022390
 022695
 022078
- Dissolution into Water and the Uranium 230/Thorium 230 022661
 Dissolved Thorium Compound (ThCl₄)* the Thorium Family 022122
 Dissolved Uranium in Water* 022581
 Distributed Uranium 238, Thorium 232, Potassium ⁴⁰K, and 022883
 Distribution and Deposition of Radon Daughters Attached 022898
 Distribution and Effects in Rabbits* 022089
 Distribution and Excretion of Thorium and Its Daughters 022453
 Distribution and Excretion of Thorium with Emphasis 022183
 Distribution and Excretion of Thorium Sulphate* 022187
 Distribution and Excretion Studies. 1. Patterns 022185
 Distribution and Excretion Studies. 2. General Patterns 022024
 Distribution and Excretion Studies. 3. Single 022023
 Distribution and Excretion* 022180
 Distribution and Excretion* 022158
 Distribution and Excretions of Certain Soluble 022189
 Internal Dose of Lead 212 and Polonium 210 022191
 Distribution and Redistribution of Uranium, Radium, and 022252
 Distribution and Steady State Activity Ratios of 022858
 Distribution between the Various Physical Phases* 022625
 Distribution of Colloidal Thorium Dioxide and 022982
 Distribution of Colloidal Thorium Dioxide in Mouse 022507
 Distribution of Internally Deposited Thorium by Years 022025
 Distribution of Ionium (Thorium 230) in Rats* 022207
 Distribution of Natural Radioactive Elements in the 022102
 Distribution of Plutonium 239 and Thorium 230 in Beagles 022097
 Distribution of Plutonium, Radium, Radiothorium, 022100
 Distribution of 022355
 Distribution of Radioactive Substances in Coastal and 022152
 Distribution of Radium 226, Plutonium 239, Radium 228 (022702
 Distribution of Radon Daughter Particles in Uranium 022067
 Distribution of Skeletal Alpha-Doses from Radium 228 022093
 Distribution of Some Bone-Seeking Radionuclides: and 022582
 Distribution of Thorium by Electron Activation Analysis* 022363
 Distribution of Thorium in Various Soils* 022450
 Distribution of Thorium Daughters in Bone* 022129
 Distribution of Thorium Series Nuclides in Beagles 022118
 Distribution of Thorotrast and Its Daughter Nuclides 022075
 Distribution of Trace Elements in a Mollusk from a 022596
 Distribution of Uranium and Daughters in the 022361
 Distribution of Uranium and Radium in the Podzolic 022382
 Distribution of Uranium 233 in Mice* 022110
 Distribution of Uranium 233 in Rats* 022111
 Distribution of Uranium, Radium, and Thorium in 022364
 Distribution Following Intravenous Injection* 022150
 Distribution, Movement, and Possible Effect within 022289
 Distribution, Retention, and Late Effects of Thorium 022523
 Distributions in the Metallurgical Processing of Thorium 022699
 Distributions of Uranium and Thorium in Soils* 022384
 Distributions of Uranium and Thorium Following: 022158
 District, San Juan County, Utah* 022684
 Division Annual Report, July 1972 through June 1973* 022506
 Division's Whole Body Counter--Its Use and Calibration* 022705
 Dog and Rat* 022118
 Dog and Skin Tumors in the Rat* 022020
 Dog Blood. A Statistical Study* 022019
 Dog Teeth. 1. The Distribution of Plutonium, Radium, 022100
 Dogs and Humans* 022163
 Dogs and Mammals* of Inhaled Radon Daughters, Uranium 022162
 Dogs to Simulated Uranium Mine Atmospheres* 022164
 Dogs Burdened with Plutonium 239, Thorium 228, Radium 022189
 Dogs. 1. Thorium 228 (RdTh)* 022151
 Dogs. 1. The Distribution of Plutonium, Radium, 022097
 Dogs* 022033
 Dogs* 022035
 Dogs* 022086
 Dogs* 022080
 Dogs* 022184
 Domestic Capacity for Producing Reactor-Grade Thorium 022668
 Dosage and Permissible Levels* 022721
 Dosage from Thorotrast* 022508
 Dosage to Man from the Fallout of Nuclear Devices. 1. 022288
 Dose and Health Effect Parameters* 022724
 Dose from the Inhalation of Radon and Daughters* 022386
 Dose from Experimental Results after Incorporation of 022119
 Dose from Radionuclides Released to the Biosphere* 022288
 Dose from Radium 228 Following Intravascular 022505
 Dose from Thorotrast Using Whole-Body Gamma-Ray 022067
 Dose in the Human Organs* 022038
 Dose in Radium Cases* 022117
 Dose of the Respiratory Tract* 022197
 Dose of Lead 212 and Polonium 210 in a Uranium Miner 022391
 Dose to the Human Respiratory Tract by Inhalation of 022047
 Dose to the Respiratory System Due to Radon and its 022047
 Dose to the Respiratory Tract from Continuous 022050
 Dose to the Trachea and Bronchi from the Decay Products 022390
 Dose to Man* 022695
 Dose to Thorotrast Patients* 022078
- 022089
 022453
 022183
 022187
 022185
 022024
 022023
 022180
 022158
 022189
 022191
 022252
 022858
 022625
 022982
 022507
 022025
 022207
 022102
 022097
 022100
 022355
 022152
 022702
 022067
 022093
 022582
 022363
 022450
 022129
 022118
 022075
 022596
 022361
 022382
 022110
 022111
 022364
 022150
 022289
 022523
 022699
 022384
 022158
 022684
 022506
 022705
 022118
 022020
 022019
 022100
 022163
 022162
 022164
 022189
 022151
 022097
 022033
 022035
 022086
 022080
 022184
 022668
 022721
 022508
 022288
 022724
 022386
 022119
 022288
 022505
 022067
 022038
 022117
 022197
 022391
 022047
 022047
 022050
 022390
 022695
 022078

TITLE INDEX

of Radioactivity in the Marine Environment and the Estimation of Total Absorbed	Dose Commitment to Marine Organisms*	Levels	000280
Aquatic Biota Resulting from Radioactive Releases from 235, Thorium 232, and Determination of Localized Alpha Determination of Localized Alpha	Dose Due to Environmental Gamma Radiation*		000281
Thorotrast*	Dose Effect Relations in Hepatic Carcinogenesis*		000282
the Assessment of the Estimation of Radiation Ecologic Factors Controlling Terrestrial Gamma-Ray Recycled Thorium	Dose Estimation and Prediction of Radiation Effects on Dose III from Surface and Volume Deposits of Plutonium Dose IV in Soft Tissue Near Radioactive Bone*		000283
Some Cancer Induction by Radionuclides: Incidence vs. of the Sarcoma Incidence vs. Alpha Particle	Dose Rates from Uranium 232 in Uranium 233*		000284
Poke-Smoking Radionuclides and Assessment of Absorbed Inhalation and the Effect of the Size of the Inhaled Dog and Skin Tumors in the Rat*	Dose Rates in Man Following Intramuscular Injection of Dose Rates of Thorium and Thorium Oxide*		000285
Radioactive Released from the Fuel Cycle	Dose Rates to Fish in Contaminated Environments, and Dose Rates*		000286
in Nice on the Temporal Distribution of Skeletal Alpha-Californium 252	Dose Rates*		000287
Transuranic Operations*	Dose*		000288
in Polymers*	Dose*		000289
and Absorption of Radium 226 and Thorium 230 and Source Radioactivity*	Dose*		000290
the Use of Thermoluminescent Dosimeters (TLD) for Hand Sources*	Dose*		000291
	Dose*		000292
and Californium 252 Fission Sources in Tissue Specimens*	Dose*		000293
Goldfields*	Dose*		000294
Geochemistry of Permian and Triassic Sediments of the Uranium and Thorium Isotopes: Deep Sea Isotopes of the Uranium and Thorium Family in by Extraction Chromatography in Urines Containing Thorium Dioxide*	Dose*		000295
	Dose*		000296
	Dose*		000297
	Dose*		000298
	Dose*		000299
	Dose*		000300
	Dose*		000301
	Dose*		000302
	Dose*		000303
	Dose*		000304
	Dose*		000305
	Dose*		000306
	Dose*		000307
	Dose*		000308
	Dose*		000309
	Dose*		000310
	Dose*		000311
	Dose*		000312
	Dose*		000313
	Dose*		000314
	Dose*		000315
	Dose*		000316
	Dose*		000317
	Dose*		000318
	Dose*		000319
	Dose*		000320
	Dose*		000321
	Dose*		000322
	Dose*		000323
	Dose*		000324
	Dose*		000325
	Dose*		000326
	Dose*		000327
	Dose*		000328
	Dose*		000329
	Dose*		000330
	Dose*		000331
	Dose*		000332
	Dose*		000333
	Dose*		000334
	Dose*		000335
	Dose*		000336
	Dose*		000337
	Dose*		000338
	Dose*		000339
	Dose*		000340
	Dose*		000341
	Dose*		000342
	Dose*		000343
	Dose*		000344
	Dose*		000345
	Dose*		000346
	Dose*		000347
	Dose*		000348
	Dose*		000349
	Dose*		000350
	Dose*		000351
	Dose*		000352
	Dose*		000353
	Dose*		000354
	Dose*		000355
	Dose*		000356
	Dose*		000357
	Dose*		000358
	Dose*		000359
	Dose*		000360
	Dose*		000361
	Dose*		000362
	Dose*		000363
	Dose*		000364
	Dose*		000365
	Dose*		000366
	Dose*		000367
	Dose*		000368
	Dose*		000369
	Dose*		000370
	Dose*		000371
	Dose*		000372
	Dose*		000373
	Dose*		000374
	Dose*		000375
	Dose*		000376
	Dose*		000377
	Dose*		000378
	Dose*		000379
	Dose*		000380
	Dose*		000381
	Dose*		000382
	Dose*		000383
	Dose*		000384
	Dose*		000385
	Dose*		000386
	Dose*		000387
	Dose*		000388
	Dose*		000389
	Dose*		000390
	Dose*		000391
	Dose*		000392
	Dose*		000393
	Dose*		000394
	Dose*		000395
	Dose*		000396
	Dose*		000397
	Dose*		000398
	Dose*		000399
	Dose*		000400

TITLE INDEX

0 Vegetating the Graniter Mine Tailings at and Differential Thermal Analysis. A the Changes Taking Place in the Content of Radioactive of Actinium in the Air in the Presence of Other Materials, and Thorium Compounds in the Developing Chick 0 Radiological and Thorium Solutions with a Semiconductor V-Ray 0 The Detection of Insoluble Alpha Short-Term Radiological Effects of Internal Dose Cancer Induced by Internally-Deposited Biological Effectiveness of Radium and Other Alpha- 0 In Vivo Separation of Long-Lived Uranium Chain Alpha- 0 Studies on Short-Lived Internal Alpha- 0 Identification of Alpha- of Palladium Cesium 137 and Naturally Occurring Gamma-Ray 0 The Effects of Aging and Internal 0 Disposition of Long-Lived Uranium Chain Alpha after Incorporation of Short-Lived Bone-Seeking Alpha Seaboard Long-Term Experiments with Short-Lived Alpha- of Bone Flow Samples for the Detection of Alpha 0 Naturally Occurring Concentrations of Alpha- 0 Simultaneous Determinations of Alpha- the Eastern Part of Shimane Prefecture -- with Special Carrier 0 Distribution and Excretion of Thorium with Cycle* 0 Uranium and Thorium in the Biosphere: A Review Tracer Tailings* 0 Use of Asphalt Biosynthesis by 0 The Effects of Ionizing Radiations on	Elliot Lake, Ontario* Emission Thermal Analysis with Evolved Gas Analysis Emissions in the Air of Mining Installations* of Emanations* 0 Identification Embryos* 0 Relative Toxicity of Isthmus, Emergency Operations, Student's Manual Emission Spectrometer* 0 Quantitative Analysis of Uranium Emitters in the Lung* Emitters in Beagles* Emitters in Beagles* Emitters in CF No. 1 Female Mice (20394)* 0 Relative Emitters in Experimental Animals During and After Emitters in Mice and Rats. Part 2. Thorium 227* Emitters in Normal Biological Materials* Emitters in Sediments* 0 Determination Emitters on Blood Chemistry* Emitters Following Repeated Inhalation Exposures of Emitters Radium 224 and Thorium 227 in Mice* Results Emitters. Part 1. The Dependence of Late Effects in Emitters* 0 Analysis Emitting Isotopes in a New England Population* Emitting Nuclides of Radium through California in Soil* Emphasis on Cause of Uranium Anomaly* of River Water in Emphasis upon the Route of Injection and Amount of Emphasizing Behavior Applicable to the Thorium Fuel Emulsion Sealants to Contain Radium and Radium in Endocrine Cells. 6. Alterations in Androgen Endocrine Dose to Thorotrast Patients* Endpoints in Compact Bones Receiving Alpha Irradiation* Energy of Radon 222 and Radon 220-Daughters in Energy Authority for the Determination of Radionuclides Energy Choices* 0 Assessment of Public Energy Commission Sites* 0 Energy Industry* England Population* 0 Naturally Occurring Enhanced Excretion of Radioactive Daughters of Thorium* Enriched with Thorium 230* Enriched Thorium Dioxide and Its Radioactive Progeny* Enriched Uranium, Plutonium-Uranium 238, and Uranium Enriched Uranium, Plutonium-Uranium 238, and Uranium Enrichment in Mine Drainage: 1. The Hertsford, West Enterprises of Rare Metals Production* Radiation Safety Environment and the Dose Commitment to Marine Organisms* Environment by Activation Analysis* on the Distribution Environment of a Uranium Ore Processing Facility* Environment of the West Coast of India* 0 Natural Environment of the West Coast of India* 0 Anomalous Environment* Environmental and Pedologic Radiation Changes* Radiation Environmental and Process Waste Samples* of Radon 0 Environmental Aspects of the Canadian Mining Industry* 0 Environmental Concerns in Uranium Mining, Milling, and 0 Environmental Contamination by Uranium. Part 1.* 0 Environmental Contamination by Uranium. Seasonal and 0 Environmental Factors Influencing the In Vitro 0 Environmental Gamma Radiation Measurements in Nuclear 0 Environmental Gamma Radiation* 0 Environmental Gamma Radiation* 0 Environmental Impact of Waste Effluents in the Nuclear 0 Environmental Impact of Waste Effluents in the Nuclear 0 Environmental Impact of Waste Effluents in the Nuclear 0 Environmental Levels of Radioactivity in Livermore 0 Environmental Materials* 0 Environmental Measurements* 0 Environmental Monitoring at Ames Laboratory, 1962-1969* 0 Environmental Monitoring at Argonne National 0 Environmental Monitoring Annual Report for 1972* 0 Environmental Monitoring Report for Calendar Year 1972* 0 Environmental Monitoring Reports* 0 Environmental Monitoring* 0 Environmental Radiation Levels and Concentration, First 0 Environmental Radiation Monitoring at the Lawrence 0 Environmental Radioactivity at Argonne National 0 Environmental Radioactivity at Argonne National 0 Environmental Radioactivity in New South Wales* 0 Environmental Radioactivity in South Florida Sands and 0 Environmental Research Division Annual Report, July 0 Environmental Samples: Combined Solvent Extraction- 0 Environmental Surveillance Program* 0 Environmental Surveillance Samples* 0 Environmental Survey* 0 Environments of Uranium and Thorium Discharged by the 0 Environments* 0 The 0 Environments, and the Assessment of the Possible 0 Epidemiological Follow-Up Studies of the Portuguese 0 Epidemiological, Clinical, and Pathological Studies (I 0 Epithelial Tumors in Rats* 0 Liver Distribution 0 Equations for Different Patterns of Uptake* 0	002678 000580 000604 000589 000127 000720 000405 000562 000062 000259 000707 000164 000132 000288 000631 000070 000159 000119 000067 000532 000436 000254 000234 000163 000372 000707 000065 000478 000090 000599 000590 000317 000457 000520 000436 000584 000068 000007 000298 000730 000686 000717 000280 000074 000594 000388 000384 000531 000582 000252 000680 000266 000267 000378 000130 000587 000014 000556 000735 000739 000740 000617 000288 000622 000568 000637 000623 000553 000594 000559 000603 000616 000552 000638 000491 000605 000506 000286 000586 000635 000633 000290 000599 000199 000434 000403 000082 000561
 

Skills-their Relationship	07ranium 239 and Radium 226	Equilibrium and Thorium: Uranium Ratio in New Zealand	000131
Following Inhalation of Uranium Ore by Rats	0930-	Equilibrium Tissue Distributions of Uranium and Thorium	000132
	000000 to the Canada	Equilibrium Due to Thorotrast Hysteresis	000133
Pentose Phosphate Pathway		Erythrocytes of Uranium Miners: the Activity of the	000134
Twenty-Eight Years after Thorium Administration		Erythrocytes (Di Guelletto's Disease) Occurrence	000135
Element Concentration at or Near Airports		Estimate of Contribution of Jet Operations to Trace	000136
Releases from LWR Fuel	000000 Doses and Effects	Estimated for Aquatic Biota Exposed to Radioactive	000137
from the Failure of Nuclear Devices. 4. Handbook for		Estimating the Maximum Internal Dose from Radionuclides	000138
Radiation Dosage and Permissible Levels		Estimating Radioelements in Exposed Individuals. 2.	000139
Biomass Operations and Procedures		Estimating Radioelements in Exposed Individuals. 3.	000140
Aquatic Biota Resulting from Radioactive Releases	000000	Estimation and Prediction of Radiation Effects on	000141
Plants, Shells, and Corals		Estimation of the Microgram Amount of Thorium in	000142
of Thorotrast and Its Daughter Products and		Estimation of Absorbed Dose in the Human Organism	000143
Environmental Gamma Radiation		Estimation of Gonadal Absorbed Dose Due to	000144
Radon and Daughters		Estimation of Lung Tissue Dose from the Inhalation of	000145
Contaminated Environments, and the Assessment of	000000	Estimation of Radiation Dose Rates to Fish in	000146
Results after Incorporation of Short-Lived Bone-		Estimation of Tumor Risk at Low Dose from Experimental	000147
Distribution of Radioactive Substances in Coastal and		Estuarine Waters	000148
An Aging Effect in Confined Waters, by J. Kronfeld,		Et Al	000149
CNO-15	000000 Characteristic Differences between the	Etch Pits Due to Radon and Thoron Alpha Particles in	000150
of Configuration of Fissionable Materials with the		Etch-Pit Counting Methods	000151
Centroids. Chromatographic Preconcentration in an Acid-		Ether-Cellulose System	000152
Organic Solubility of Some Black-Partha in the		of Rare Earths in Thorium	000153
in Mine Drainage: 3. The Hlerkshoff, West Bits and		European Areas of the USSR	000154
000000 of Uranium Thorium Analysis with		Evaporator Gelfield	000155
by J. Kronfeld, Et Al	000000	Evolved Gas Analysis and Differential Thermal Analysis.	000156
of Hemic Acid and Triethyl Acetate on Seedling Growth,		Excess Uranium 238: An Aging Effect in Confined Waters	000157
Lead 210 Concentrations Measured in the Bone and		Excess: Cytodermis, Chlorophylls, Proteins and Sugar	000158
220 in Rats	000000	Excretion and Tissue Distribution of Iodine (Thorium	000159
	000000	Excretion of Radioactive Daughters of Thorium	000160
Czechoslovakian Uranium Miners		Excretion of Radioactive Polonium 210 by	000161
Autodiagnostic Investigations of the Distribution and	000000	Excretion of Thorium and Its Daughters in Thorotrast	000162
Thorotrast Administration		Excretion of Thorium and Thorium Daughters after	000163
Injection and Amount of Carrier	000000	Excretion of Thorium with Emphasis upon the Route of	000164
	000000	Excretion of Thorium Sulphate	000165
	000000	Excretion Equations for Different Patterns of Uptake	000166
Administration	000000	Excretion Studies. 1. Patterns Following Parenteral	000167
Inhalation and the Effect of	000000	Excretion Studies. 2. General Patterns Following	000168
Citrate Complex and Multiple	000000	Excretion Studies. 3. Single Inhalation Exposure to the	000169
of Aerosol Properties upon Gross Distribution and		Excretion	000170
Metabolism: The Effect of Metals on Coproporphyrin		Excretion	000171
Other Metals on Plutonium and Uranium Distribution and		Excretion	000172
Thorium	000000	Excretions of Certain Soluble Compounds of Natural	000173
	000000	Excretion of Radiothorium-Purified Beagles	000174
of Inhaled Radon Daughters, Uranium Ore Dust, Diesel		Excretion, and Cigarette Smoke in Dogs and Humans	000175
	000000	Expected Late Effects in Thorotrast Patients	000176
Epidemiological, Clinical, and Pathological Studies		Experience in Portugal) Thorium Dioxide Effects in Man.	000177
Leukemic Risk Data Derived from Portuguese Thorotrast		Experience	000178
Injected with Thorium Dioxide (Thorotrast) (Portuguese		Experience)	000179
Thoron	000000	Exposure by Rats After Intratracheal Administration of	000180
County, Utah	000000	Exposure to the Chloride Complexes of Thorium 230	000181
Radon Scattering	000000	Exposure to Thorium 230: Uranium-Mining Operations of the West	000182
Radiation Doses and Effects Estimated for Aquatic Biota		Exposure to Thorium Dioxide	000183
Chromosome Aberrations in Lymphocytes from Patients		Exposure to Uranium Mine Atmosphere: Daughters Attached	000184
to Dust Particles in the Respiratory System of Humans		Exposure to Thorium Dioxide	000185
Measurements of Thorium 232 in Normal and Industrially		Exposure to Thorium Dioxide	000186
Permissible Levels	000000	Exposure to Thorium Dioxide	000187
Procedures	000000	Exposure to Thorium Dioxide	000188
	000000	Exposure to Thorium Dioxide	000189
	000000	Exposure to Thorium Dioxide	000190
	000000	Exposure to Thorium Dioxide	000191
	 		

22

in Cows*	Methods of Effect of	Fallout Measurements Use in India*	004229
Efficiency/Alpha Analysis of the Uranium, Thorium	Effect of	Fallout Products on Biochemical Indices of Blood Serum	005209
of Isotopes of the Uranium and Thorium Radioactive	Effect of	Families*	005230
Natural Radioactive Isotopes of the Uranium and Thorium	Effect of	Families* Rodents in Soil with an Increased Content	005231
The Metabolism of Radionuclides of the Thorium	Effect of	Family in Drinking Water and Food* the Content of	005232
Metabolic Characteristics Within a Chemical	Effect of	Family in Organs of Rats upon Intratracheal	005233
Neutrons and Other	Effect of	Family*	005234
Interannual Plutonium Metal Deposits: Their Conjectured	Effect of	Fetal Blood Dyscrasias in Thorium Dioxide Patients*	005235
Thorium Utilization in an	Effect of	Fate of Lead 212 Inhaled by Human Subjects*	005236
Quarterly Progress Report for the Period Ending	Effect of	Fate*	005237
Radioactivity in South Florida Sands and Soils,	Effect of	FBR/RTM Power System*	005238
Monitoring Annual Report for 1972*	Effect of	February 29, 1970*	005239
The Effect of U-238 on the Body of the Pregnant	Effect of	February-June 1968*	005240
of Uranium and Other Alpha Emitters in CP No. 1	Effect of	Female and the Fetus*	005241
High Uranium Content in Rivers Due to	Effect of	Female Mice (20374)* Relative Biological Effectiveness	005242
of Radon 226 and Thorium 230 in Soviet-Rade Phosphorus	Effect of	Fertilizers*	005243
Uranium Series in Soils Treated with Apatite-Derived	Effect of	Fertilizers* Spectrometric Measurements of Isotopic	005244
of U-238 on the Body of the Pregnant Female and the	Effect of	Fertilizers* The Effect	005245
of Cross Alpha Activity in Urine by Adsorption on Glass	Effect of	Fibre Filter Paper*	005246
Statistical Evaluation of the Natural Gamma Radiation	Effect of	Field at Aerial Survey Heights*	005247
Neutron Dosimetry in the Radiation	Effect of	Field of Californium 252 Sources*	005248
The Role of Thorium Metal in the Nuclear	Effect of	Fields*	005249
Accumulation of Radioactivity in Visc	Effect of	Filter Paper*	005250
Alpha Activity in Urine by Adsorption on Glass Fibre	Effect of	Findings (Study of 175 Cases)*	005251
in the Thorotrast Patients--Laboratory and Clinical	Effect of	Findings in the Peticuloendothelial System (Liver,	005252
Spleen, Lymph Nodes, Bone Marrow) of	Effect of	Findings in Patients Injected with Thorium Dioxide*	005253
Some Clinical and Laboratory	Effect of	Findings in Patients Injected with Thorotrast*	005254
Hepatic Mesangiocapillary Nephropathy--Angiographic	Effect of	Findings in Two Additional Cases with Clinical Inform	005255
Measurements and Clinical	Effect of	Findings on Thorotrast Deposits in the Kidney*	005256
Special Clinical	Effect of	Findings Among Thorotrast Patients*	005257
Histopathologic and Autoradiographic	Effect of	Findings*	005258
the Poly-Calculations and Comparison with Experimental	Effect of	Findings* by the Decay of Thorium Parents within	005259
Uranium	Effect of	Fire Aerosols*	005260
Study Quarterly Progress Report for Third Quarter	Effect of	Fiscal 1977*	005261
Study Quarterly Progress Report for Second Quarter	Effect of	Fiscal 1977*	005262
of the	Effect of	Fish in Contaminated Environments, and the Assessment	005263
The Estimation of Radiation Dose Rates to	Effect of	Fish Flour*	005264
Natural and Artificial Radionuclides in	Effect of	Fishes in Streams Affected by Uranium Ore Mining and	005265
Evaluation of Natural Radionuclide Contamination of	Effect of	Fishes*	005266
Concentration of Trace Elements in Great Lakes	Effect of	Fission Particle Track Replica Method*	005267
Uranium Content of Soil Nicas from Antarctica by the	Effect of	Fission Power and the Choice of Alternatives*	005268
Retards of Fission	Effect of	Fission Products and the Heaviest Elements*	005269
The Metabolism of the	Effect of	Fission Products and Actinides in the Radioactive	005270
Disposal, and Relative Toxicity of Long-Lived	Effect of	Fission Reactors*	005271
Uranium Will Monitoring for Natural	Effect of	Fission Sources in Water* and Dosimetry of Neutrons	005272
from Moderation of Uranium 235 and Californium 252	Effect of	Fission Track Analysis in Nuclear Environmental	005273
Measurements*	Effect of	Fission Track Dosimeter for Monitoring the Neutron	005274
Radiation from Californium 252	Effect of	Fission Track Technique for the Determination of Uranium	005275
in Natural Waters*	Effect of	Fission/Alpha Analysis of the Uranium, Thorium Families	005276
	Effect of	Fissionable Materials with the Etch-Pit Counting Method*	005277
	Effect of	Fixation of Polybromine, Vanadium, and Uranium by	005278
	Effect of	Florida Sands and Soils, February-June 1968*	005279
	Effect of	Flour*	005280
	Effect of	Flow-Stirred Reactors*	005281
	Effect of	Flue Gases and Air Quality Criteria*	005282
	Effect of	Fluence Conversion Factors*	005283
	Effect of	Fluids*	005284
	Effect of	Fluorescence Analysis of Powdered Rock Samples.	005285
	Effect of	Fluorimetric Method for the Determination of Uranium in	005286
	Effect of	Fluorination-Fractionation Process* Cycle - Conversion	005287
	Effect of	Flux from Inactive Uranium Mill Tailings Piles*	005288
	Effect of	Fluxes, Residence Times, and Sources of Some Elements	005289
	Effect of	Follow-up of Patients with Thorium Dioxide Deposits*	005290
	Effect of	Follow-Up of Danish Thorotrast Cases*	005291
	Effect of	Follow-Up of Thorium Dioxide Patients in the United	005292
	Effect of	Follow-Up of Thorotrast Patients from Boston,	005293
	Effect of	Follow-Up Studies of the Portuguese Thorotrast Series (	005294
	Effect of	Follow-Up Study of Portuguese Patients Given Thorium	005295
	Effect of	Follow-Up Study of Thorium Dioxide Patients in Portugal	005296
	Effect of	Follow-Up Studies*	005297
	Effect of	Followup Studies After Internal Deposition of	005298
	Effect of	Food and Man in Bombay and Kerala State (India)*	005299
	Effect of	Food Source Materials*	005300
	Effect of	Food* the Content of Natural Radioactive Isotopes	005301
	Effect of	Food* and Food Source Materials*	005302
	Effect of	Food*	005303
	Effect of	Forest-Steppe of the Tannu Region*	005304
	Effect of	Forests*	005305
	Effect of	Forests*	005306
	Effect of	Forests* Thorium and Radium Content in the	005307
	Effect of	Fore. S.* Absorption of Radium	005308
	Effect of	Former Uranium Miner*	005309
	Effect of	Forms of Trace Elements in Natural Fresh Waters and the	005310
	Effect of	Fraction of the Podzolic Mountain Soils of Thin Forests*	005311
	Effect of	Fraction of Radon and Thoron Decay Products*	005312
	Effect of	Useful	005313

TITLE INDEX

Take to Uranium Hexafluoride, Part 1. The Fluorination- Oxidation Forces of Trace Elements in Natural the Distribution of Trace Elements in a Soilless from a Radioecology of Distribution of Natural Radioactive Elements Role of A Preliminary Assessment of Thorium as a and Their Consequences for Fuel Recycling Reprocessing of High-Temperature Gas-Cooled Reactor Fabrication of High-Temperature Gas-Cooled Reactor Environmental Impact of Waste Effluents in the Nuclear Environmental Impact of Waste Effluents in the Nuclear Environmental Impact of Waste Effluents in the Nuclear Reactors, Technical Progress Report No. 5, Thorium and Fuel Cycle Costs Resulting from Thorium Thorium-Uranium Assessment of the Thorium Units (CANDU)* An Assessment of "120 Requirements and Useful Work on the Thorium 232-Uranium 233 for Implementation of ALARA for the Nuclear Analytical Techniques for Materials in the Nuclear Resulting from Radioactive Releases from the Nuclear A Review Emphasizing Behavior Applicable to the Thorium Evaluation of Thorium and Radiological Properties of Thorium in Selected and Activities in the Radioactive Wastes from Nuclear Reactors, Plutonium-Uranium 235, and Uranium 233-Thorium Uranium, Plutonium-Uranium 235, and Uranium 233-Thorium Temperature Thorium Reactor and Their Consequences for for Improved Waste Management in Commercial Nuclear Methods and Costs for Selected Thorium-Bearing Reactor Toxicity of Uranium and Plutonium in LRP and HTR Aquatic Biota Exposed to Radioactive Releases from LWR Uranium Production in Thorium/Breeder Thorium of Plutonium Recycle and the Use of Thorium Radiation Hazards of Recycled Uranium 233-Thorium Long Term Cooling Characteristics of Irradiated Nuclear Absorption of Sodium and Thorium through the Gut as a Pulmonary Kidney and Bone Retention Stone Effects of Heavy Metals on Immunoglobulin (Ig G) Chemical Evaluation of the Natural Siting Studies in Poland Spectroscopic Techniques for Measuring Environmental of General Absorbed Dose Due to Environmental Comparison of Thorium Health Physics Application of IN VIVO Germanium-Lithium by Removal of Environmental Improvement in Airborne Ecologic Factors Controlling Terrestrial of Fallout Cesium 137 and Naturally Occurring 238, Thorium 232, Assessment of Radioactivity in Man of Radiation Dose from Thorium Using Whole-Body and Application of High Sensitivity Airborne Shield Concentration Measurements Made by Airborne in Soils Using High-Resolution Germanium-Lithium Total and Spectrometric Investigations of the Distribution and Excretion of Sulfates in the Egyptian Nubia Area In Vivo The Measurement of Radioactive Combination of Resonance Thermal Analysis with Evolved Gases Use of Thoriated Tungsten Electrodes in Inert Nuclear Fuel Cycle - Reprocessing of High-Temperature Nuclear Fuel Cycle - Fabrication of High-Temperature Program Progress Report Trace Elements in Flye of Radium, Polonium and Thoron in Solids, Liquids and Mineralization in the Persian of the Choc Nappe in the West Coast of India Natural Radioactivity and Geologic Susceptibility and Dreuzug, Carinthia, Austria the West Carpathians Reevaluation of the Marine as a "Unique Tracer for Particulate Settling" Notes Actual Status of the Radiation Protection held in Berlin, Germany, June 4- Isotopic Uranium Ratios in Soils Treated with Apatite- Amelior (Provided) Flow Background Monitoring of ppm Levels of Uranium in Soils Using High-Resolution on the Question of Radiation Protection held in Berlin, of Gross Alpha Activity in Urine by Adsorption on Radiation from Californium 252 Sources on Hands Inside Fractionation Process*Fuel Cycle - Conversion of Yellow Fresh Waters and the Effect of the Water Storage Freshwater Environment by Activation Analysis on Freshwater Plants and Animals Freshwater Plants Freshwater Vegetation in Processes of Migration and Fuel for Thermal Reactors Fuel Concepts for the High Temperature Thorium Reactor Fuel Containing Uranium 233 and Thorium Fuel Cycle Fuel Containing Uranium 233 and Thorium Fuel Cycle Fuel Cycle - Conversion of Yellow Cake to Uranium Fuel Cycle - Fabrication of High-Temperature Gas-Cooled Fuel Cycle - Reprocessing of High-Temperature Gas- Fuel Cycle for Heavy Water Moderated Organic Cooled Fuel Cycle in HWRs (CANDUs) of 1300 Requirements Fuel Cycle in Italy Fuel Cycle in Power Reactors Fuel Cycle Costs Resulting from Thorium Fuel Cycle in Fuel Cycle Fuel Cycle The Rationale Nondestructive of Radiation Effects on Aquatic Biota Uranium and Thorium in the Biosphere Fuel Cycles Isotopic Composition Fuel Cycles Toxicity of Long-Lived Fission Products Fuel Cycles Radioactive Waste Produced by the Enriched Fuel Cycles*Radioactive Wastes Produced by the Enriched Fuel Recycling Fuel Concepts for the High Fuel Reprocessing Facilities Program Fuel Types Reprocessing Fuel An Examination of the Potential Relative Fuel-Cycle Facilities Doses and Effects Estimated for Fueled PWRs Fuels in Power Reactor Operations Implications Fuels Waste Disposal Aspects of the Function of Chemical Form. 4. Function of Uranium Miners Functions in the Human Metabolism of Uranium Fungal Cells G, Ig A, Ig M Values in a Few Population Groups Gamma Dose Rates from Uranium 232 in Uranium 233 Gamma Radiation Field at Aerial Survey Heights Gamma Radiation Measurements in Nuclear Power Station Gamma Radiation Gamma Radiation Estimation Gamma Spectra in Smokers and Nonsmokers Gamma Spectrometry in a Uranium Processing Plant Gamma Spectrometry in Environmental Monitoring Gamma-Radiation Data Analyses for Anomalous Radiation Gamma-Ray Dose Rates Gamma-Ray Detectors in Sediments Determination Gamma-Ray Spectra for Uniformly Distributed Uranium Gamma-Ray Spectral Data Calculation Gamma-Ray Spectrometer Data Interpretation Gamma-Ray Spectrometer Experiments over the Canadian Gamma-Ray Spectrometry over the Canadian Shield Gamma-Ray Spectroscopy of ppm Levels of Uranium Gamma-Ray Surveys from Helicopters and Vehicles Gamma-Spectrometric and Histo-Autoradiographic Gamma-Spectrometric Investigation of Thorium Body Gas and Dust in Uranium Mines in Japan Gas Analysis and Differential Thermal Analysis. A Gas Shielded Arc Welding-- Investigation of Potential Gas-Cooled Reactor Fuel Containing Uranium 233 and Gas-Cooled Reactor Fuel Containing Uranium 233 and Gas-Cooled Reactor Programs: Thorium Utilization Gases and Air Quality Criteria Gases Gases for the Determination of Windy Quantities Geochemical Characterization of Uranium-Copper-Lead Geochemical Processes in the Marine Environment of the Geochemical Relationships as Uranium Prospecting Guides Geochemistry of Permian and Triassic Sediments of the Geochemistry of Radioactive Elements in Shyolites in Geochemistry of Uranium Geochronological Studies in Santa Barbara Basin: Iron Geologic Factors Controlling Terrestrial Gamma-Ray Dose German Thorium Study German-Soviet Working Meeting on the Question of Germanium Lithium Spectrometric Measurements of Germanium-Lithium Detector with Anticoincidence GAI Germanium-Lithium Gamma Spectroscopy in Environmental Germanium-Lithium Gamma-Ray Spectroscopy Measurement Germany, June 8-9, 1972 German-Soviet Working Meeting Glass Fibre Filter Paper The Determination Glove Boxes Track Dosimeter for Monitoring the Neutron	000740 000558 000075 000278 000209 000207 000305 000311 000735 000739 000740 000739 000735 000297 000304 000311 000309 000304 000295 000780 000655 000267 000322 000359 000301 000671 000299 000730 000311 000738 000630 000728 000269 000294 000675 000645 000734 000606 000389 000783 000212 000539 000718 000619 000587 000556 000018 000536 000636 000559 000582 000369 000631 000681 000647 000638 000570 000548 000227 000544 000657 000718 000588 000588 000697 000735 000739 000678 000654 000078 000579 000360 000388 000337 000351 000339 000365 000350 000369 000538 000681 000352 000377 000459 000227 000681 000577 000621
---	--

TITLE INDEX

- Binding of Plutonium to
 Reference to Plutonium, Thorium, Radium, Iron and
 Nine Drainage: J. The Klerksdorp, West Wits and Vander
 Radiation*
 Estimation of
 of U.S. Domestic Capacity for Producing Radium-226
 Cost Saving Techniques Developed for Lower
 Lead, Lanthanides and Yttrium in Some Plants Growing on
 for Determining Thorium, Thorium, and Potassium in
 Operations on Selected Ground Water Supplies in the
 the Great Miami River, the Little Miami River, and Mill
 Deposit at Wasefield, the Hiramburg Intrusion, South
 Filter Filter Paper*
 The Determination of
 Skeletal Radium 226 and Thorium 232 in the Presence of
 Influence of Aerosol Properties upon
 Techniques Useful in Micropollution Studies of
 of Thorium Mining and Milling Operations on Selected
 Thorium, Lead, Lanthanides and Yttrium in Some Plants
- Bone-Seeking Radionuclides*
 Thorium-Series and Uranium-Series Dating Techniques*
 Thorium-232 Setback Status
 Effect of Hemic Acid and Triethyl Acetate on Solubility
 after Thorium Administration*
 Erythrocytosis (Di
 Guides*
 and Geophysical Relationships as Thorium Prospecting
 Absorption of Radium and Thorium through the
 Incorporation with Particular Reference to Plutonium,
 Determination of Thorium, Uranium, Zirconium, and
 Manganese*
 Environmental Radiation Levels and Concentration, First
 Solvent Extraction Studies on Thorium Sulphate and
 Uranium Nitrate Air Concentrations in Dogs and
 Cell Sarcoma and Hepatic Cholangiocarcinoma in Syrian
 Dust, Diesel Exhaust, and Cigarette Smoke in Dogs and
 The Use of Thermoluminescent Dosimeters (TLD) for
 Dosage to Man from the Fallout of Nuclear Devices. A
 the Neutron Radiation from Californium 252 Sources on
- Plutonium
 Some Aspects of the
 Effect of Actinide Removal on the Long-Term
 Thorium, Plutonium-Uranium 238, and
 The Long-Term
 Thorium, Plutonium-Uranium 238, and Thorium
 Long-Term
 A New Relative
 of Radioactive Metal in Bone as a Potential Health
 Content in Phosphate Rocks and Their Possible Radiation
 Gas Shielded Arc Welding-- Investigation of Potential
 A Sociological Analysis of the Reduction of
 Thorium Risks*
 Health
 An Evaluation of Inhalation
 the University of Missouri*
 Assessment of Airborne
 The Nature of Thorium
 Thoron Content of Air and Its Bearing on Lung Cancer
 Radiation
 Alternatives*
 Radiation
 Evaluation of Radiation
 of Aerosol Properties and the Respiratory Pattern from
 Inhalation
 Skeletal
 Measurement of Thorium and Thoron
 Control of Thorium
- Procedures*
 Industrial
 Radiological
 Radiological
 Exposure Pathway, Radiation Dose and
 Deposition of Radioactive Metal in Bone as a Potential
 and Thorium Risks*
 Spectrometry in a Uranium Processing Plant*
 Processing*
 in a Thorium Purification and
 An Evaluation of the
 Medical and
 of Transportable Uranium: A Critical Contribution to
 Problems Involved in the Practical Application of
 The Metabolism of the Fission Products and the
 Klerksdorp, West Wits and Vander Goldfields*
 Some Effects of
 Technical Progress Report No. Thorium Fuel Cycle for
 Thorium Cycle in
 of the Natural Gamma Radiation Field at Aerial Survey
 Total and Spectrometric Gamma-Ray Surveys from
 Administration*
 in Two Artificial Cases with Thorium Induced Hepatic
- Glycyl-L-histidine in Vitro*
 Gold*
 of Radioisotope Incorporation with Particular
 Goldfields*
 Heavy Metal Enrichment in
 Canada Absorbed Dose Due to Environmental Gamma
 Grade Thorium Dioxide and Controlling Associated Wastes
 Grade Uranium Ores*
 Thorium, Thorium,
 Granitic and Radioactive Rocks*
 Granitic Rocks*Comparison of Some Analytical Techniques
 Grants Mineral Belt, New Mexico*
 Mining and Milling
 Creek, June-August 1968*
 in Selected Ohio Streams,
 Greenland*
 The Thorium
 Gross Alpha Activity in Urine by Adsorption on Glass
 Gross Amounts of Radium 226*Low-Level Determination of
 Gross Distribution and Excretion*
 Ground and Surface Waters*
 Single-Sweep Polarographic
 Ground Water Supplies in the Grants Mineral Belt, New
 Growing on Granitic and Radioactive Rocks*
 Thorium,
 Growth Dynamics of Osteosarcomas in Beagles*
 Growth Dynamics of Osteosarcomas Induced in Beagles by
 Growth Rates of Pacific Nanyangese Rodules as Deduced by
 Growth*
 Growth, Excised Cotyledones, Chlorophylls, Proteins and
 Gagliardi's Disease) Occurrence Twenty-Eight Years
 Guides*
 Genetic Susceptibility
 Gut as a Function of Chemical Form. A.*
 Radiological Consequences of Radioisotope
 Hafnium*Fluorescence Analysis of Powdered Rock Samples.
 Hafnium, Tungsten, Thorium, and Uranium in Lichens and
 Half 1970*
 Halides*
 Hamsters*
 Hamsters*
 of Inhaled Radium Daughters, Uranium Ore
 and Dosimetry in a Depleted Uranium Operation*
 Handbook for Estimating the Maximum Internal Dose from
 Hands Inside Glove Boxes*Track Dosimeter for Monitoring
 Navigation Canals and Skeletal Dose in Radium Cases*
 Hazard from Airborne Thoron and Its Daughter Products*
 Hazard of High-Level Waste*
 Hazard of Radioactive Waste Produced by the Enriched
 Hazard of Radioactive Wastes Produced by the Enriched
 Hazard Index*
 The Deposition
 Thorium, Radium, and Thorium
 Hazard*
 Use of Thoriated Tungsten Electrodes in Inert
 Hazardous Radiation in Uranium Mines*
 Hazards from the Inhalation of Insoluble Thorium and
 Hazards in the Nuclear Energy Industry*
 Hazards in the Radium and Mesothorium Refining Plant at
 Hazards in the Thorium Processing Industry*
 Hazards in Industry*
 Hazards in Industry*
 Determination of the
 Hazards in Uranium Mining and Milling*
 Hazards of Nuclear Fission Power and the Choice of
 Hazards of Recycled Thorium 233-Thorium Fuels*
 Hazards Associated with Thorium Metallurgy*
 Hazards Created by Thoron and Thoron Daughters*
 Hazards Evaluation Following Inhalation Exposure*
 Hazards*
 Hazards*
 Hazards*
 Hazards*
 Health and Safety in Handling the Newer Metals*
 Health and Safety Laboratory Manual of Standard
 Health in Handling Thorium*
 Health Data and Reports Station*
 Health Data and Reports*
 Health Effect Parameters*
 Health Effects and Energy Choices*
 Health Effects of Radon 222 from Thorium Mining*
 Health Hazards*
 The
 Health Hazards from the Inhalation of Insoluble Thorium
 Health Physics Application of In Vivo Gamma
 Health Physics Considerations Associated with Thorium
 Health Physics Problems from Thorium and Its Daughters
 Health Physics Section, Progress Report for May 1967*
 Health Protection of Workers*
 Health Regulations in Uranium Mines*
 Toxicology
 Heaviest Elements*
 Heavy Metal Enrichment in Mine Drainage: J. The
 Heavy Metals on Fungal Cells*
 Heavy Water Moderated Organic Cooled Reactors,
 Heavy Water Moderated Pressure Tube (CANDU) Reactors*
 Heights*
 Numerical Evaluation
 Helicopters and Vehicles*
 Mesangioendothelioma of Liver Following Thorium Dioxide
 Mesangioendothelioma. Roentgen-angiographic Findings

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[illegible]

0Radiation and Mesothorium Poisoning and Dosimetry and Instrumentation Techniques in Applied Radioactivity	300412
0Actinides	000370
0Constituents	000370
0Soils and Natural Waters	000005
0Therium 232	000219
0Studies on Short-Lived	000132
0The Assessment of	000515
0Indirect Methods Used at CNRS for the Evaluation of	000005
0Late Clinical Changes Following the	000528
0Late Followup Studies After	000059
0Biogenesis by Canine Testicular Tissue after the	000065
0Nuclear Devices. A Handbook for Estimating the Various	000200
0Inert Populations	000319
0Physics of the WSP and ICRP Recommendations on	000642
0Long-Term Hematological Effects of	000002
0The Effects of Aging and	000070
0Some Hematological Responses to	000309
0Study of the Long Term Biological Effects of	000007
0in Radiobiology, Semiannual Report of Progress in the	000053
0Radiobiology, Annual Report of Work in Progress in the	000051
0Radiobiology, Annual Report of Work in Progress in the	000092
0Eye Changes Induced by	000177
0Cancer Induction in Man from	000473
0The Effect of	000099
0Effect of	000094
0Alteration of Androgen Biosynthesis by Canine	000019
0A Statistical Study	000018
0Biochemical Changes Induced by	000029
0The Effects of Chronic Irradiation by	000507
0Principles and Trends in Therapeutic Removal of	000174
0The Determination of the Distribution of	000033
0Soft-Tissue Tumors in	000004
0Radiographic Changes in	000059
0Incidence of Bone Cancer in Internally	000290
0Bone Cancer Induced by	000015
0The Late Effects of	000046
0Proceedings of the Third	000099
0Airborne Gamma-Ray Spectrometer Data	000167
0An	000181
0Histopathologic Study of	000019
0Mean Organ Dose Rates in Man Following	000055
0Radiation Induced	000175
0The Ultrastructure of Mononuclear Phagocytes Following	000105
0of Thorium Dioxide in Rats after Intratracheal and	000167
0of Thorium Series Nuclides in Beagles after	000129
0The Behavior of Thorium Dioxide in Rats after	000076
0Changes in the Lungs and Other Organs in Rats on	000137
0Content (Therium 230) of the Air Expired by Rats after	000122
0of the Thorium Family in Organs of Rats upon	000121
0of Thorium and Radium in the Pools of Rats after	000595
0The Skeletal Dose from Radium 226 Following	000009
0Series Radionuclides in Man and Other Animals Following	000054
0Ratios of Thorium 232 and Daughters in Man Following	000007
0of Colloidal Thorium Dioxide in Mouse Liver after	000150
0of Number of Atoms in Thorium Distribution Following	000007
0The Uranium Deposit at Kvanefjeld, the Ilmussaq	000150
0Elements in Natural Waters Thorium	000007
0for the Determination of Uranium in Soils by Two Stage	000150
0Elements in Natural Waters. 9.	000007
0Application of	000150
0Toxicity, Excretion and Tissue Distribution of	000007
0Oceanic Water Masses	000150
0of Particulate Impurities in Air by Use of Surface	000007
0Ecological Aspects of	000150
0Ecological Techniques Utilizing Radionuclides and	000007
0in Androgen Biosynthesis by Canine	000150
0The Effects of	000007
0Particular Reference to Plutonium, Thorium, Radium,	000150
0Ratio in New Zealand Soils--their Relation to	000007
0Plasma	000150
0Geochronological Studies in Santa Barbara Basin:	000007
0of Thorium, Plutonium, Radium Isotopes, Lead 210,	000150
0Soft-Tissue Tumors in Internally	000007
0Radiographic Changes in Internally	000150
0Incidence of Bone Cancer in Internally	000007
0Aspects of the Lung Tumor Coking Characteristics of	000150
0Corticosteroid Biosynthesis	000007
0The Effects of Chronic	000150
0Some Hematological Responses to Internal	000007
0Study of the Long Term Biological Effects of Internal	000150
0Increased Content of Nuclides of the	000007
0External Beta-	000150
0Annual Report of Work in Progress in the Internal	000007
0Semiannual Report of Progress in the Internal	000150
0Annual Report of Work in Progress in the Internal	000007
0Pathology of	000150
0Eye Changes Induced by Internal	000007
0of Trace Elements in Soil Samples. / Neutron	000150
0Endpoints in Compact Bones Receiving Alpha	000007
0Plutonium-Thorium and Lead	000150
0Naturally Occurring Concentrations of Alpha-Emitting	000007
0Isotopes in a New England Population	000150
0Isotope Ratios as Indicators of Oceanic Water Masses	000007
0Integrating Rader Property Air Sampler	000150
0Interaction between Blood Constituents and some	000007
0Interaction of some Actinide Elements with Blood	000150
0Interaction of Plutonium with Complexing Substances in	000007
0Internal Alpha-Emitters in Rats and Mice. Part 2.	000150
0Internal Contamination and its Treatment	000007
0Internal Contamination Resulting from Decarboxylate or	000150
0Internal Contamination	000007
0Internal Deposition of Radioactive Materials	000150
0Internal Deposition of Radioactive Materials	000007
0Internal Deposition of Some Radionuclides in Androgen	000150
0Internal Dose from Radionuclides Released to the	000007
0Internal Dose of Lead 212 and Polonium 210 in a Uranium	000150
0Internal Dose	000007
0Internal Emitters in Beagles	000150
0Internal Emitters on Blood Chemistry	000007
0Internal Irradiation in the Beagle	000150
0Internal Irradiation in Adult Beagles	000007
0Internal Irradiation Program	000150
0Internal Irradiation Program	000007
0Internal Irradiation Program	000150
0Internal Irradiation	000007
0Internally Deposited Radionuclides Upon the Blood	000150
0Internally Deposited Radionuclides Upon Blood Vessels	000007
0Internally Deposited Radionuclides and the Subsequent	000150
0Internally Deposited Radionuclides in Beagle Dog Blood.	000007
0Internally Deposited Radionuclides on Corticosteroid	000150
0Internally Deposited Radionuclides	000007
0Internally Deposited Thorium by Means of Studies with a	000150
0Internally Irradiated Beagles	000007
0Internally Irradiated Dogs	000150
0Internally Irradiated Dogs	000007
0Internally-Deposited Emitters in Beagles	000150
0Internally-Deposited Radioactive Materials in Man	000007
0International Meeting on the Toxicity of Thorotrast	000150
0Interpretation and Application of High Sensitivity	000007
0Interspecies Model for Retention of Inhaled Particles	0

TITLE INDEX

- India*
 Anomalous Behavior of Thorium and Uranium
 Radioactive
 Metabolism of the Principal
 of Radium 226, Radium 228, Actinium 227, and Thorium
 Method of Evaluating the Content of Natural Radioactive
 within the Body*
 Retention and Elimination of Radium
 Radiation,
 Determination of Thorium, Plutonium, Radium
 Uranium and Thorium
 Uranium in Selected Fuel Cycles*
 Report on Uranium, Thorium, and Lead Contents and Lead
 Analysis of
 Germanium Lithium Spectrometric Measurements of
 Thorium-Uranium Fuel Cycle in
 Uranium 238: An Aging Effect in Confined Waters*, by
 River Basin of Colorado, Utah, New Mexico and Arizona -
 Uranium-Thorium Chronology of the
 Thorotrast Injury in
 of Radioactive Gas and Dust in Uranium Mines in
 Near Airports*
 Estimate of Contribution of
 the Texas Exploration Co. in the Big Indian District, San
 Radioactivity at Argonne National Laboratory,
 and Environmental Research Division Annual Report,
 Paducah Plant,
 in South Florida Sands and Soils, February-
 Plutonium/Ceria Compatibility Testing, April-
 Research Division Annual Report, July 1972 through
 of Radiological Protection held in Berlin, Germany,
 Miami River, the Little Miami River, and Mill Creek,
 Coal Pools, Technical Progress Report No. 5, April-
 Utah, New Mexico and Arizona - January, 1961 through
 Compounds of Thorium 232, Natural Thorium, Radium 226*
 Radium 226 in Food and Man in Bombay and
 Metabolism of Uranium*
 Thorium Dioxide*
 Tumors of the
 and Clinical Findings on Thorotrast Deposits in the
 of
 A Survey of the Methods Used in the United
 Heavy Metal Enrichment in Mine Drainage: 3. The
 Radioactivity of Some Soils in Landscapes of the
 Uranium 238: An Aging Effect in Confined Waters*, by J.
 The Uranium Deposit at
 Studies on the Radioecology of NARCHEPTIA POLYMERPHA
 Safety Features in the Design of Radiological
 Silver Studies in the Thorotrast Patients--
 Sitters Following Repeated Inhalation Exposures of
 Dioxide*
 Some Clinical and
 Health and Safety
 Environmental Radioactivity at Argonne National
 Radiation Monitoring at the Lawrence Livermore
 Environmental Monitoring at Argonne National
 Environmental Radioactivity at Argonne National
 Summary of Environmental Monitoring at Ames
 Serum
 Residence Times, and Sources of Some Elements to
 Vegetating the Uranium Mine Tailings at Elliot
 Concentration of Trace Elements in Great
 The Alpha Activity of Soils in Relation to
 Regions*
 Natural Radioactivity of Some Soils in
 Evidence for and Properties of a New
 The Effect of
 Granitic and Radioclastic Rocks*
 Uranium, Thorium, Lead,
 Developing Chick Embryo*
 Relative Toxicity of
 Recognition of Radiation-Induced
 of Radioactive Materials*
 on Bone and Blood as Predictors of Osteosarcoma: A
 Short-Lived Alpha-Emitters. Part 1. The Dependence of
 Expected
 Materials in Man*
 The
 Media*
 Experimental Studies in Mice on the
 Patients in Sweden*
 Distribution, Retention, and
 their Efferent Lymph Nodes*
 Radioactive Materials*
 Ambient Environmental Radiation Monitoring at the
 on Thorium and Uranium Disequilibrium on the Surface
 Sediment
 Preliminary Report on Uranium, Thorium, and
 Radium*
 Uranium-Thorium and
 Report on Uranium, Thorium, and Lead Contents and
 the
 Geochemical Characterization of Uranium-Copper-
 Radiochemical Determination of
 Uranium 238, Uranium 235, Thorium 230, Radium 226, and
 Excreta of a Former Uranium Miner*
 Cooperative Uptake of Thorium 230, Radium 226,
 Determination of Trace Levels of Uranium, Thorium 230,
 Determination of Thorium, Plutonium, Radium Isotopes,
 Body Burden, Distribution and Internal Dose of
 Isotopes in the Marine Environment of the West Coast of
 Isotopes in the System Water-Freshwater Plants*
 Isotopes in the Thorium 232 Decay Chain*
 Isotopes in Environmental and Process Waste Samples*
 Isotopes of the Uranium and Thorium Family in Drinking
 Isotopes Produced by the Decay of Thorium Parents
 Isotopes, and Bone*
 Isotopes, Lead 210, Iron 55, Silicon 32 and Carbon 14
 Isotopes: Deep Sea Drilling Project, Leg 23*
 Isotopic Composition and Radiological Properties of
 Isotopic Compositions in Sediment Samples from the Red
 Isotopic Distributions of Uranium and Thorium in Soils*
 Isotopic Radium in Thorium Mill Effluents*
 Isotopic Uranium Ratios in Soils Treated with Apatite-
 Italy*
 J. Kromfeld, Et Al*
 Comment on "Excess
 in the Colorado
 Japan Sea Core*
 Japan*
 The Measurement
 Jet Operations to Trace Element Concentration at or
 Jean County, Utah*
 Uranium-Mining Operations of
 July - December 1968, Annual Summary, 1969*
 July 1972 through June 1973*
 Radiological
 July-December 1970*
 Natural Environmental Radioactivity
 June 1968*
 Quarterly Report No. 15*
 June 1973*
 Radiological and Environmental
 June 8-9, 1972*
 Soviet Working Meeting on the Question
 June-August 1968*
 in Selected Ohio Streams, the Great
 June, 1964*
 Fuel Cycle for Heavy Water Moderated Organic
 June, 1972*
 in the Colorado River Basin of Colorado,
 Justification of Permissible Standards of Soluble
 Kerala State (India)*
 Kidney and Bone Retention Functions in the Human
 Kidney Following Retrograde Pyelography with Colloidal
 Kidney*
 Measurements
 Kingdom Atomic Energy Authority for the Determination
 Klerksborg, West Vits and Vander Goldfields*
 Kolchanka Forest-Steppe of the Tanbov Region*
 Natural
 Kromfeld, Et Al*
 Comment on "Excess
 Kromfeld, the Ilmaussag Intrusion, South Greenland*
 L. in the Sudetes*
 Laboratories, Tromsø*
 Laboratory and Clinical Findings (Study of 175 Cases)*
 Laboratory Animals to Uranium Ore*
 Uranium Chain Alpha
 Laboratory Findings in Patients Injected with Thorium
 Laboratory Manual of Standard Procedures*
 Laboratory Report for 1962 and 1963*
 Laboratory*
 Ambient Environmental
 Laboratory, Annual Report for 1972*
 Laboratory, July - December 1964, Annual Summary, 1968*
 Laboratory, 1962-1969*
 Lactic Dehydrogenase Levels in Adult Beagle Dogs*
 Lake Michigan*
 Places,
 Lake, Ontario*
 Lakes Fishes*
 Landscape Development*
 Landscapes of the Kolchanka Forest-Steppe of the Tanbov
 Lanthanides and Actinides on Blood Coagulation. I.
 Lanthanoids and Yttrium in Some Plants Growing on
 Lanthanum, Tantalum, and Thorium Compounds in the
 Late Bone Marrow Changes*
 Late Clinical Changes Following the Internal Deposition
 Late Effect*
 Early Radiation Effects
 Late Effects in Mice on the Temporal Distribution of
 Late Effects in Thorotrast Patients*
 Late Effects of Internally-Deposited Radioactive
 Late Effects of Radioactive and Nonradioactive Contrast
 Late Effects of Thorium Dioxide on the Liver of
 Late Effects of Thorium Dioxide*
 Late Effects of Thorotrast in Cerebral Angiography*
 Late Effects of Thorotrast in Tissues*
 Late Effects of Thorotrast on the Liver and Spleen, and
 Late Followup Studies After Internal Deposition of
 Lawrence Livermore Laboratory*
 Layers of the Coastal Sediments and their Absolute
 Lead Contents and Lead Isotopic Compositions in
 Lead Isotopic Ratios as Indicators of Oceanic Water
 Lead Isotopic Compositions in Sediment Samples from the
 Lead Mineralization in the Permian of the Choc Mague in
 Lead 210 in Uranium Ores and Air Ousts*
 Lead 210 in Uranium Ores, Dents, and Mill Tailings*
 of
 Lead 210 Concentrations Measured in the Bone and
 Lead 210, and Polonium 210 by Plants*
 Lead 210, and Polonium 210 in Soft Tissues*
 The
 Lead 210, Iron 55, Silicon 32 and Carbon 14 in Marine
 Lead 212 and Polonium 210 in a Uranium Miner Population*
 002386
 002209
 002001
 002552
 002482
 002527
 002128
 002612
 002113
 002361
 002334
 002744
 002279
 002352
 002313
 002643
 002651
 002277
 002483
 002584
 002583
 002684
 002598
 002686
 002370
 002663
 002367
 002213
 002712
 002525
 002159
 002512
 002599
 002632
 002618
 002637
 002552
 002568
 002184
 002324
 002678
 002118
 002359
 002370
 002076
 002216
 002120
 002497
 002459
 002077
 002087
 002085
 002390
 002075
 002405
 002523
 002392
 002500
 002407
 002461
 002618
 002601
 002334
 002380
 002334
 002360
 002255
 002641
 002486
 002202
 002597
 002612
 002391

Granitic and Radioactive Rocks*	*Uranium, Thorium, and Thorium Isotopes: Deep Sea Drilling Project, Type Exposure by Thorium Contained	*State of Lead 212 Inhaled by Human Subjects*	39439
		Lead, Lanthanoids and Yttrium in Some Plants Growing on Leads Toward Depleted Thorium Cycle*	39216
		Lead 210	39319
		Lead 210	39313
Dioxin Patients*		Lead 210	39497
Thorotrast*		Lead 210 and Other Fatal Blood Dyscrasias in Thorium	39381
Experience*		Lead 210 and Other Hematological Diseases after	39389
		Lead 210 Risk Data Derived from Portuguese Thorotrast	39382
		Leukocytes of Beagles* Toxicity of Radium 226, Plutonium	39383
		Lichens and Mosses*	39384
		Life*	39385
		Life*	39386
		Life*	39387
		Life*	39388
		Life*	39389
		Life*	39390
		Life*	39391
		Life*	39392
		Life*	39393
		Life*	39394
		Life*	39395
		Life*	39396
		Life*	39397
		Life*	39398
		Life*	39399
		Life*	39400
		Life*	39401
		Life*	39402
		Life*	39403
		Life*	39404
		Life*	39405
		Life*	39406
		Life*	39407
		Life*	39408
		Life*	39409
		Life*	39410
		Life*	39411
		Life*	39412
		Life*	39413
		Life*	39414
		Life*	39415
		Life*	39416
		Life*	39417
		Life*	39418
		Life*	39419
		Life*	39420
		Life*	39421
		Life*	39422
		Life*	39423
		Life*	39424
		Life*	39425
		Life*	39426
		Life*	39427
		Life*	39428
		Life*	39429
		Life*	39430
		Life*	39431
		Life*	39432
		Life*	39433
		Life*	39434
		Life*	39435
		Life*	39436
		Life*	39437
		Life*	39438
		Life*	39439
		Life*	39440
		Life*	39441
		Life*	39442
		Life*	39443
		Life*	39444
		Life*	39445
		Life*	39446
		Life*	39447
		Life*	39448
		Life*	39449
		Life*	39450
		Life*	39451
		Life*	39452
		Life*	39453
		Life*	39454
		Life*	39455
		Life*	39456
		Life*	39457
		Life*	39458
		Life*	39459
		Life*	39460
		Life*	39461
		Life*	39462
		Life*	39463
		Life*	39464
		Life*	39465
		Life*	39466
		Life*	39467
		Life*	39468
		Life*	39469
		Life*	39470
		Life*	39471
		Life*	39472
		Life*	39473
		Life*	39474
		Life*	39475
		Life*	39476
		Life*	39477
		Life*	39478
		Life*	39479
		Life*	39480
		Life*	39481
		Life*	39482
		Life*	39483
		Life*	39484
		Life*	39485
		Life*	39486
		Life*	39487
		Life*	39488
		Life*	39489
		Life*	39490
		Life*	39491
		Life*	39492
		Life*	39493
		Life*	39494
		Life*	39495
		Life*	39496
		Life*	39497
		Life*	39498
		Life*	39499
		Life*	39500

229, Thorium 232, Studies (Experience in	Assessment of Radioactivity in Thorium Dioxide Effects in Behavior of Plutonium in Animals and in the Skeleton: Naturally Occurring Radioisotopes in of Internally-Deposited Radioactive Materials in Terrestrial Sources to the Total Radiation Dose to in the Subcutaneous Tissues of the Cervical Region in Radiation Effects in Radioactive Waste	Man Gamma-Ray Spectra for Uniformly Distributed Thorium Nan. Epidemiological, Clinical, and Pathological	709441 000403 000404 000405 000406 000407 000408 000409 000410 000411 000412 000413 000414 000415 000416 000417 000418 000419 000420 000421 000422 000423 000424 000425 000426 000427 000428 000429 000430 000431 000432 000433 000434 000435 000436 000437 000438 000439 000440 000441 000442 000443 000444 000445 000446 000447 000448 000449 000450 000451 000452 000453 000454 000455 000456 000457 000458 000459 000460 000461 000462 000463 000464 000465 000466 000467 000468 000469 000470 000471 000472 000473 000474 000475 000476 000477 000478 000479 000480 000481 000482 000483 000484 000485 000486 000487 000488 000489 000490 000491 000492 000493 000494 000495 000496 000497 000498 000499 000500 000501 000502 000503 000504 000505 000506 000507 000508 000509 000510 000511 000512 000513 000514 000515 000516 000517 000518 000519 000520 000521 000522 000523 000524 000525 000526 000527 000528 000529 000530 000531 000532 000533 000534 000535 000536 000537 000538 000539 000540 000541 000542 000543 000544 000545 000546 000547 000548 000549 000550 000551 000552 000553 000554 000555 000556 000557 000558 000559 000560 000561 000562 000563 000564 000565 000566 000567 000568 000569 000570 000571 000572 000573 000574 000575 000576 000577 000578 000579 000580 000581 000582 000583 000584 000585 000586 000587 000588 000589 000590 000591 000592 000593 000594 000595 000596 000597 000598 000599 000600 000601 000602 000603 000604 000605 000606 000607 000608 000609 000610 000611 000612 000613 000614 000615 000616 000617 000618 000619 000620 000621 000622 000623 000624 000625 000626 000627 000628 000629 000630 000631 000632 000633 000634 000635 000636 000637 000638 000639 000640 000641 000642 000643 000644 000645 000646 000647 000648 000649 000650 000651 000652 000653 000654 000655 000656 000657 000658 000659 000660 000661 000662 000663 000664 000665 000666 000667 000668 000669 000670 000671 000672 000673 000674 000675 000676 000677 000678 000679 000680 000681 000682 000683 000684 000685 000686 000687 000688 000689 000690 000691 000692 000693 000694 000695 000696 000697 000698 000699 000700 000701 000702 000703 000704 000705 000706 000707 000708 000709 000710 000711 000712 000713 000714 000715 000716 000717 000718 000719 000720 000721 000722 000723 000724 000725 000726 000727 000728 000729 000730 000731 000732 000733 000734 000735 000736 000737 000738 000739 000740 000741 000742 000743 000744 000745 000746 000747 000748 000749 000750 000751 000752 000753 000754 000755 000756 000757 000758 000759 000760 000761 000762 000763 000764 000765 000766 000767 000768 000769 000770 000771 000772 000773 000774 000775 000776 000777 000778 000779 000780 000781 000782 000783 000784 000785 000786 000787 000788 000789 000790 000791 000792 000793 000794 000795 000796 000797 000798 000799 000800 000801 000802 000803 000804 000805 000806 000807 000808 000809 000810 000811 000812 000813 000814 000815 000816 000817 000818 000819 000820 000821 000822 000823 000824 000825 000826 000827 000828 000829 000830 000831 000832 000833 000834 000835 000836 000837 000838 000839 000840 000841 000842 000843 000844 000845 000846 000847 000848 000849 000850 000851 000852 000853 000854 000855 000856 000857 000858 000859 000860 000861 000862 000863 000864 000865 000866 000867 000868 000869 000870 000871 000872 000873 000874 000875 000876 000877 000878 000879 000880 000881 000882 000883 000884 000885 000886 000887 000888 000889 000890 000891 000892 000893 000894 000895 000896 00
--	---	--	--

TITLE INDEX

over the	Significance of Radioelement Concentration	Measurements Made by Airborne Gamma-Ray Spectrometry	077504
	Methods of Fallout	Measurements of ^{238}Pu in India	002629
	and Fission Track Analysis in Nuclear Environmental	Measurements	037627
	Daughter Products of Radon 222 in the	Mass Spectrometry	037671
	Practice of Radon and	Measuring the Concentrations of the Short-Lived	037674
	Diffusion Sampler Useful for	Measuring Diffusion Coefficients and Viscosity	000554
	Spectrometric Analysis for	Measuring Environmental Gamma Radiation	037681
	Activities in Soil Samples	Measuring Uranium, Thorium, Radium, Plutonium, and	000551
	Procedure for	Media Resolving Physiologic Fluids	037684
	Reliability of Certain Thorium-Containing Substances in	Medical and Health Physics Section, Progress Report for	000550
	Late Effects of Radioactive and Nonradioactive Contrast	Medical Problems Concerning the Central Group	037687
	May 1967	Medical Survey of a Thorium Refinery	000555
		Refining	037691
	Industrial Systems and	Meeting on the Question of Radiation Protection Held at	000556
	The Danger of Cancer from Thorotrast as a Diagnostic	Meeting on the Toxicity of Thorotrast	037694
	Reagent, June 6-9, 1972	Nelema	000557
	Proceedings of the Third International	Nelema	037697
	Radiation Induced Intracellular	Nelema	000558
	The Distribution of Plutonium, Radium, Radiothorium,	Nelema	037698
	Distribution of Radium 226, Plutonium 239, Radium 226	Nelema	000559
	Effects of Radium 226, Plutonium 239, Radium 226	Nelema	037699
	Techniques in Applied Radioactivity	Nelema	000560
	in the Radium and	Nelema	037700
	Characteristics in the Radium and	Nelema	000561
	The Refining of	Nelema	037701
	The Distribution of Plutonium, Radium, Radiothorium,	Nelema	000562
	Elements	Nelema	037702
	Decay Chain	Nelema	000563
	Decay, I. Thorium 232 (97th)	Nelema	037703
		Nelema	000564
	Organs of Mice upon Intratracheal Introduction of	Nelema	037704
	Mice after Intratracheal Introduction of Soluble	Nelema	000565
	Products in the Body	Nelema	037705
	Basic Patterns of the	Nelema	000566
	Man and Other Animals Following Intravascular	Nelema	037706
	Excretion and Some Potential Functions in the Human	Nelema	000567
	Excretion	Nelema	037707
	Studies of Porphyria	Nelema	000568
	The Role of Thorium	Nelema	037708
	The Deposition of Radioactive	Nelema	000569
	Histopathologic Study of Intratracheal Plutonium	Nelema	037709
	West Vets and Evander Goldfields	Nelema	000570
		Nelema	037710
	Methods for the Production of Thorium	Nelema	000571
	Radioactivity Distributions in the	Nelema	037711
	The Physical	Nelema	000572
	Hazards Associated with Thorium	Nelema	037712
	Measuring Five Micron Particles with Carbon and	Nelema	000573
	Studies of Porphyria Metabolism. The Effect of	Nelema	037713
	Some Effects of Heavy	Nelema	000574
	Excretion	Nelema	037714
	The Action of Salts of Zirconium and Other	Nelema	000575
	Natural Radioactive Substances at Enterprises of Pure	Nelema	037715
	Toxicology: Radioactive	Nelema	000576
	Health and Safety in Handling the New	Nelema	037716
	Tranion in Ore, Concentrate, and Milling Dusts of Rare	Nelema	000577
	Thorium-1 Treatment	Nelema	037717
	Pulmonary	Nelema	000578
	in the Colorado River Basin of Colorado, Utah, New	Nelema	037718
	Ground Water Supplies in the Grants Mineral Belt, New	Nelema	000579
	Ohio Streams, the Great Miami River, the Little	Nelema	037719
	Levels in Selected Ohio Streams, the Great	Nelema	000580
	Replica Method	Nelema	037720
	Age and Uranium Content of Soil	Nelema	000581
	of Radium and Other Alpha Emitters in CP No. 1 Female	Nelema	037721
	Studies in Short-Lived Internal Alpha-Emitters in	Nelema	000582
	Nonradioactive Contrast Media	Nelema	037722
	Experimental Studies in	Nelema	000583
	Emitters. Part 1. The Dependence of Late Effects in	Nelema	037723
	The Retention and Distribution of Uranium 231 in	Nelema	000584
	The Retention and Distribution of Uranium 231 in	Nelema	037724
	Soaking Alpha Emitters Radium 226 and Thorium 227 in	Nelema	000585
	Residence Times, and Sources of Some Elements to Lake	Nelema	037725
	Patients from Boston, Massachusetts and Ann Arbor,	Nelema	000586
	Investigations of Certain	Nelema	037726
	Relationship of	Nelema	000587
	Estimation of the	Nelema	037727
	Coating Five	Nelema	000588
	Single-Sweep Polarographic Techniques Useful in	Nelema	037728
	228 in Beagles	Nelema	000589
	Radionuclides and a Critical Survey of the Analysis of	Nelema	037729
	Thorotrast Localization by Light and Electron	Nelema	000590
	Elements of Freshwater Vegetation in Processes of	Nelema	037730
	Terrestrial Filicercosities	Nelema	000591
	Different	Nelema	037731
	The Role of Nutrient Rodents in the Biogenic	Nelema	000592
	Waters and the Effect of the Water Storage	Nelema	037732
	Analysis of Isotopic Radium in Thorium	Nelema	000593
	the Great Miami River, the Little Miami River, and	Nelema	037733
	Uranium	Nelema	000594
	Uranium	Nelema	037734
	Measurements of Radon 222 Plus from Inactive Uranium	Nelema	000595
	Concentrations in Structures Built on or Near Uranium	Nelema	037735
	Radon 222, and Lead 210 in Uranium Ores, Dusts, and	Nelema	000596
	Aspects and Radiation Levels Associated with the	Nelema	037736
	Materials (Thorium, Uranium) in Ore, Concentrate, and	Nelema	000597

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Pressure and Threshold of Stimulation of the Nervous System in the Baltic.	Trace Elements in the Baltic.	003160
Thyroid Disorders in Humans Following Thyrotoxicosis in the Caspian Sea Due to Thyrotoxicosis Following Thyrotoxic Syphilography and the Incidence of the Baltic. Multielement	Trace Elements in the Baltic.	003161
Germanium-Lithium Detector with Anticoincidence	Trace Elements in the Baltic.	003162
Copper-Lead Mineralization in the Permian of the Chocoma	Trace Elements in the Baltic.	003163
The Toxicity Classification of Thorium-232	Trace Elements in the Baltic.	003164
The Toxicity Classification of Thorium-232 and Uranium-238	Trace Elements in the Baltic.	003165
Environmental Radioactivity at Argonne	Trace Elements in the Baltic.	003166
Environmental Monitoring at Argonne	Trace Elements in the Baltic.	003167
Environmental Radioactivity at Argonne	Trace Elements in the Baltic.	003168
Marine Protein Concentrates	Trace Elements in the Baltic.	003169
and Distribution of Uranium, Radium, and Thorium in the Human Body	Trace Elements in the Baltic.	003170
Sands and Soils, February-June 1968	Trace Elements in the Baltic.	003171
The Concentration of Uranium in Air from Contrasted	Trace Elements in the Baltic.	003172
Uranium Mill Monitoring for	Trace Elements in the Baltic.	003173
Migration Forms of Trace Elements in	Trace Elements in the Baltic.	003174
Chemical Evaluation of the	Trace Elements in the Baltic.	003175
Uranium-Series Systematics in	Trace Elements in the Baltic.	003176
and Radioecological Studies on Brazilian Areas of High of the Inhabitants of the Brazilian Regions of Elevated and Sediments	Trace Elements in the Baltic.	003177
in Processes of Migration and Distribution of	Trace Elements in the Baltic.	003178
Communications	Trace Elements in the Baltic.	003179
Family in Drinking	Trace Elements in the Baltic.	003180
Method of Evaluating the Content of	Trace Elements in the Baltic.	003181
Ornithine Permissible Concentrations of	Trace Elements in the Baltic.	003182
Regimentation of Radiation Safety Extent in Work with	Trace Elements in the Baltic.	003183
Nature Environment of the West Coast of India	Trace Elements in the Baltic.	003184
European Areas of the USSR	Trace Elements in the Baltic.	003185
the Kolchyna Forest-Steppe of the Tashkent Region	Trace Elements in the Baltic.	003186
Production Rates of Neutrons in Soils Due to	Trace Elements in the Baltic.	003187
Affected by Uranium Ore Mining and	Trace Elements in the Baltic.	003188
Biogeochemistry	Trace Elements in the Baltic.	003189
Cattle from Nigeria, N. Africa	Trace Elements in the Baltic.	003190
to Man	Trace Elements in the Baltic.	003191
Specification of Units for Natural Uranium and	Trace Elements in the Baltic.	003192
and Excretions of Certain Soluble Compounds of	Trace Elements in the Baltic.	003193
Standards of Soluble Compounds of Thorium 232.	Trace Elements in the Baltic.	003194
Assessment of the Content of Concentrated and	Trace Elements in the Baltic.	003195
Data on the Biological Effect of Small Amounts of	Trace Elements in the Baltic.	003196
Retention and	Trace Elements in the Baltic.	003197
Resin and Delayed-Neutron	Trace Elements in the Baltic.	003198
Determination of Uranium in	Trace Elements in the Baltic.	003199
Methods for the Determination of Trace Elements in	Trace Elements in the Baltic.	003200
Separations to Determination of Trace Elements in	Trace Elements in the Baltic.	003201
Fluorimetric Method for the Determination of Uranium in	Trace Elements in the Baltic.	003202
of Plutonium with Complexing Substances in Soils and	Trace Elements in the Baltic.	003203
Track Technique to the Determination of Uranium in	Trace Elements in the Baltic.	003204
Isotopes in a New England Population	Trace Elements in the Baltic.	003205
Determination of Fissionable Cesium 137 and	Trace Elements in the Baltic.	003206
Zealand Soils	Trace Elements in the Baltic.	003207
The Colloidal	Trace Elements in the Baltic.	003208
Water and the Uranium 236/Uranium 238 Disequilibrium in	Trace Elements in the Baltic.	003209
Extraction Chromatography	Trace Elements in the Baltic.	003210
Analytical Applications of	Trace Elements in the Baltic.	003211
Arterial Pressure and Threshold of Stimulation of the	Trace Elements in the Baltic.	003212
Waters of the Colorado River Basin, Radium Monitoring	Trace Elements in the Baltic.	003213
Emitters. Part 1. The Dependence of	Trace Elements in the Baltic.	003214
Determination of Uranium in Sea and Surface Waters by	Trace Elements in the Baltic.	003215
Determination of Uranium in Natural Waters by	Trace Elements in the Baltic.	003216
Assessment of Organ Distribution of Thorium by	Trace Elements in the Baltic.	003217
the Baltic. Multielement Analyses Using Instrumental	Trace Elements in the Baltic.	003218
by Preconcentration on Anion-Exchange Resin and Delayed-	Trace Elements in the Baltic.	003219
232 Sources	Trace Elements in the Baltic.	003220
Determination of Trace Elements in Soil Samples by	Trace Elements in the Baltic.	003221
of a Fission Track Dosimeter for Monitoring the	Trace Elements in the Baltic.	003222
Transfer Dosimeters for Fast	Trace Elements in the Baltic.	003223
232 Fission Sources in Water	Trace Elements in the Baltic.	003224
Spectra and Dosimetry of	Trace Elements in the Baltic.	003225
Vegetation in Northern Mojave Desert Areas of the	Trace Elements in the Baltic.	003226
Health and Safety in Handling the	Trace Elements in the Baltic.	003227
Newer Metals	Trace Elements in the Baltic.	003228
Muscle Apparatus in Rats of Thorium Dioxide on Arterial	Trace Elements in the Baltic.	003229
Mussels (MYTILUS EDULIS) from Coastal Areas of the	Trace Elements in the Baltic.	003230
Hydrography and the Incidence of Hydrography	Trace Elements in the Baltic.	003231
Hydrography	Trace Elements in the Baltic.	003232
Hydrography	Trace Elements in the Baltic.	003233
Hydrography	Trace Elements in the Baltic.	003234
Hydrography	Trace Elements in the Baltic.	003235
Hydrography	Trace Elements in the Baltic.	003236
Hydrography	Trace Elements in the Baltic.	003237
Hydrography	Trace Elements in the Baltic.	003238
Hydrography	Trace Elements in the Baltic.	003239
Hydrography	Trace Elements in the Baltic.	003240
Hydrography	Trace Elements in the Baltic.	003241
Hydrography	Trace Elements in the Baltic.	003242
Hydrography	Trace Elements in the Baltic.	003243
Hydrography	Trace Elements in the Baltic.	003244
Hydrography	Trace Elements in the Baltic.	003245
Hydrography	Trace Elements in the Baltic.	003246
Hydrography	Trace Elements in the Baltic.	003247
Hydrography	Trace Elements in the Baltic.	003248
Hydrography	Trace Elements in the Baltic.	003249
Hydrography	Trace Elements in the Baltic.	003250
Hydrography	Trace Elements in the Baltic.	003251
Hydrography	Trace Elements in the Baltic.	003252

TITLE INDEX

Series Systematics in Natural Materials from the Saturn 226 and Thorium 232 in Thyroids of Cattle from Tanzania in Lichens and Mosses*	Newport Area, Oregon*	Uranium-235	002644
Early Deposition of Inhaled Uranyl Tetrachloride Solutions*	Nigeria, W. Africa*	Natural	002645
Retention and Translocation of Inhaled Uranyl Tetrachloride Solutions*	Niobium, Molybdenum, Hafnium, Tantalum, Thorium, and Vanadium (Uranium 232 and Uranium 233) in Rats*		002646
Long-Term Effects of Inhaled Uranyl Tetrachloride Solutions*	Nitrate (Uranium 232 and Uranium 233) in Rats*		002647
The Biogenic Effect of Uranyl Tetrachloride Solutions*	Nitrate and Nitric Acid by Tributyl Phosphate-Carbon Solutions in Rats*		002648
High	Nitrate on the Peripheral Lymphocyte of the Rat*		002649
Automated In-Plant Monitoring of Uranyl Thorium Alpha Particles in C-90-15 and LB-115 Cellulose Solutions*	Nitrate Desulfurization in Continuous Flow-Stirred Reactor Solutions for Thorium*		002650
Effectiveness of Radium and Other Alpha Emitters in CF Testing, April-June 1972, Quarterly Report	Nitrate Track Detectors: the Rich Pits Due to Radon and Nitric Acid by Tributyl Phosphate-Carbon Tetrachloride No. 1 Female Mice (20394)*		002651
Organic Coiled Reactors, Technical Progress Report of Relatively Insoluble Materials from Lung to Lymph or the Liver and Spleen, and their Effluent Lymph in the Pericardioendothelial System (Liver, Spleen, Lymph Ducting Techniques)*	No. 15*	Plutonium/Ceria Compatibility	002652
Growth Rates of Pacific Manganese Thoria Following Inhalation of Uranium Ore by Rats*	No. 5, April-June, 1966*Cycle for Heavy Water Moderated Reactor*	Transport	002653
Retention Burden of Radium 226, Radium 228, Thorium 232 in Animals*	Nodes*	Late Effects of Thorotrast	002654
Properties of Atomic Tissues*	Nodes, Bone Marrow of Thorotrast Patients (		002655
The Nuclear Fuel Cycle*	Nodes as Deduced by Uranium-Series and Pyrolysis-Ind uced Equilibrium Tissue Distributions of Uranium and Thorium*		002656
Studies in Rats on the Late Effects of Radioactive and Chemical Thorium Gamma Spectra in Smokers and Non-Smokers*	Non-Radiation Effects of Thorotrast and Other Colloidal Non-Skeletal Tumor Incidence Observed in Beagles with Thorotrast*		002657
Measurements of Thorium 232 in Identifications of Alpha-Emitters in and Protactinium in Sea Water and Recent Coral in the and Thorium 232/Thorium 233 in Sea Water in the Western Mediterranean (MUTILUS EOLIS) from Coastal Areas of the Characteristics of Soil and Perennial Vegetation in Analysis of	Non-Structural Analysis for Uranium 232 and Decay Non-Structural Analytical Techniques for Materials in Non-Radiation Contrast Media*	Experimental	002658
Decay Products Following Inhalation of Uranium 232 702 of the Maximum Dosage to Man from the Fallout of the Evaluation of Inhalation Hazards in the Mass Spectrometry and Fission Track Analysis in The Role of Thorium Metal in the Hazards of	Normal and Industrially Exposed Humans*		002659
and the Environmental Impact of Waste Effluents in the and the Environmental Impact of Waste Effluents in the and the Environmental Impact of Waste Effluents in the The National for and Implementation of ALARA for the Analytical Techniques for Materials in the Biota Resulting from Radioactive Releases from the Projects and Activities in the Radioactive Wastes from Program for Improved Waste Management in Commercial of the Long Term Cooling Characteristics of Irradiated Environments of Uranium and Thorium Discharged by the	Normal Biological Materials*		002660
	North Pacific*	Content of Plutonium, Thorium Thorium 232/Thorium 233	002661
	North Pacific* Activity Ratios Thorium 232/Thorium 233 North Sea and the Baltic. Multielement Analyses Using Northern Mojave Desert Areas of the Nevada Test Site*		002662
	Soil Blow Samples for the Detection of Alpha Emitters*		002663
	Soil 2 Aerosols*	Disposition of Uranium 232 Nuclear Devices. 4. Handbook for Estimating the Maximum Nuclear Energy Industry*	002664
	Nuclear Environmental Measurements*		002665
	Nuclear Field*		002666
	Nuclear Fission Power and the Choice of Alternatives*		002667
	Nuclear Fuel Cycle - Conversion of Yellow Cake to Nuclear Fuel Cycle - Fabrication of High-Temperature Nuclear Fuel Cycle - Reprocessing of High-Temperature Nuclear Fuel Cycle*		002668
	Nuclear Fuel Cycle*	Nondestructive	002669
	Nuclear Fuel Cycle* of Radiation Effects on Aquatic Nuclear Fuel Cycles* Toxicity of Long-Lived Fission Nuclear Fuel Reprocessing Facilities*		002670
	Nuclear Fuels*	Waste Disposal Aspects	002671
	Nuclear Industry*	The Behavior in Underground*	002672
	Nuclear Materials Transport*		002673
	Nuclear Materials*		002674
	Nuclear Power Program*		002675
	Nuclear Power Program*		002676
	Nuclear Power Station Siting Studies in Poland*		002677
	Nuclear Power*		002678
	Nuclear Track Registration in Polymers*		002679
	Nuclear Track Techniques*		002680
	Nuclides and Estimation of Absorbed Dose in the Human Nuclides in Beagles after Intraspinal Thorotrast Nuclides in Plankton from the Caribbean*		002681
	Nuclides in Soil Particles in Relation to their Sizes*		002682
	Nuclides of the Uranium and Thorium Radioactive Families Nuclides of Radium through Californium in Soil*		002683
	Nuclides*	Toxicity to Blood	002684
	Numerical Evaluation of the Natural Gamma Radiation Occupationally Exposed Workers*	Sensitive Method for Ocean Water*	002685
	Ocean*	Simple Recovery of Plutonium, Oceans*	002686
	Oceanic Water Masses*		002687
	Oceans and Sediments*		002688
	Ohio Streams, the Great Mississippi River, the Little Miami Ontario*		002689
	Operations*	The Use of Thermoluminescent Dosimeters Operations and Procedures*	002690
	Operations*	Estimating Operations of the Uter Exploration Co in the Big Indian Operations on Selected Ground Water Supplies in the Operations to Trace Element Concentration at or Near Operations*	002691
	Operations*	Radiological Implications of Plutonium Operations, Student's Manual*	002692
	Order of the Metabolism of Thorium 232 and that of its Ore by Beagles*	In Vivo Separation	002693
	Ore by Rats*	Non-Equilibrium Tissue Distributions	002694
	Ore Dust*	Selective Tissue Accumulation of Ore Dust, Diesel Exhaust, and Cigarette Smoke in Dogs Ore Dust, Radon and Products of its Decay in the Lungs Ore Mining and Milling*	002695
	Ore Processing Facility*	of Natural Radionuclides into the Distribution of Ore*	002696

Inhalation Exposures of Laboratory Animals to Uranium	000150
of Natural Radioactive Materials (Thorium, Uranium) in	000160
Systematics in Natural Materials from the Newport Area,	000165
Radiochemical Determination of Lead 210 in Uranium	000170
Saving Techniques Developed for Lower Grade Uranium	000175
Animals During and After Chronic Inhalation of Uranium	000180
226, Thorium 230, Radium 226, and Lead 210 in Uranium	000185
Analysis*	000190
Injection of Thorotrast*	000195
5, April- Thorium Fuel Cycle for Heavy Water Moderated	000200
Thorium in	000205
The Alpha Radioactivity of Marine	000210
On Thorium 230 Accumulation by Marine	000215
Marine Environment and the Dose Commitment to Marine	000220
of Thorium, Uranium, and Radium by Plants and	000225
Thorium*	000230
Morphological Changes in the Lungs and Other	000235
Histopathological and Autoradiographic Studies of Pieces of	000240
Metabolism of Radioisotopes of the Thorium Family in	000245
Effect of Monazite on Body	000250
Quantitative Thorium Determination in Thirty	000255
and Natural Uranium in the Body and Critical	000260
Solubility and Estimation of Absorbed Dose in the Human	000265
Radiation Induced	000270
Beta Effects on Bone and Blood as Predictors of	000275
Growth Dynamics of	000280
Growth Dynamics of	000285
Inhalation Toxicity of Thorium	000290
Thermal Decomposition of Calcium Carbonate and Calcium	000295
The Effect of Transuranic	000300
Phagocytosis of Colloidal Thorium Dioxide and Cobaltic	000305
Preparation and Properties of Aqueous Thorium-Uranium	000310
and Measured Dose Rates of Thorium and Thorium	000315
from the Inhalation of Insoluble Uranium and Thorium	000320
and Hydraulic-Head Dating Techniques*	000325
Growth Rates of	000330
Protactinium in Sea Water and Recent Coral in the North	000335
228/Thorium 232 in Sea Water in the Western North	000340
Activity in Urine by Adsorption on Glass Fibre Filter	000345
Exposure Pathway, Radiation Dose and Health Effect	000350
and Excretion Studies. I. Patterns Following	000355
of Radium Isotopes Produced by the Decay of Thorium	000360
Some Sarcoma Incidence vs. Alpha	000365
Content of Soil Ricas from Antarctica by the Passive	000370
Inhaled Radioactive	000375
and Deposition of Radon Daughters Attached to Dust	000380
between the Pitc Pits Due to Radon and Thoron Alpha	000385
Concentrations of Uranium Series Nuclides in Soil	000390
Size Distribution of Radon Daughter	000395
Relationship of Microdistribution of Alpha	000400
Studies*	000405
An Interspecies Model for Retention of Inhaled	000410
Influencing the In Vitro Phagocytosis of Inert Test	000415
Mass Spectrometric Determination of Concentration of	000420
Sampling and Data Reporting Considerations for Airborne	000425
in Santa Barbara Basin: Iron 55 as a Unique Tracer for	000430
(Liver, Spleen, Lymph Nodes, Bone Marrow) of	000435
Cicicde Effects in Man. Epidemiological, Clinical, and	000440
and Chronic Poisoning with U3O8*	000445
Uranium Miners: the Activity of the Pentose Phosphate	000450
Exposure	000455
(Liver, Spleen, Lymph Nodes, Bone Marrow) of Thorotrast	000460
Measurement of Thoron in the Breath of Thorotrast	000465
Michigan, USA*	000470
Follow-Up of Thorotrast	000475
Follow-Up of Thorium Dioxide	000480
Thorium Dioxide	000485
Follow-Up Study of Thorium Dioxide	000490
State Effects of Thorium Dioxide on the Liver of	000495
Results of the Whole-Body Counting of	000500
Preliminary Report from Boston on the Follow-up of	000505
Chromosome Aberrations in Lymphocytes from	000510
Follow-Up Study of Portuguese	000515
Some Clinical and Laboratory Findings in	000520
Liver Ultrastructural Findings in	000525
Chromosomal Aberrations in Thorium Dioxide	000530
Radionuclides in Autopsy Samples from Thorotrast	000535
Dose of Thorium Daughter by Thorium Dioxide	000540
Endosteal Dose to Thorotrast	000545
Some Tumors in Thorotrast	000550
Expected Late Effects in Thorotrast	000555
Special Clinical Findings Among Thorotrast	000560
and Other Fatal Blood Dyscrasias in Thorium Dioxide	000565
Histopathological Studies of Thorium Dioxide	000570
Excretion of Thorium and Its Daughters in Thorotrast	000575
175 Cases)*	000580
Liver Studies in the Thorotrast	000585
In Vivo Counting of Thorium Dioxide	000590
Influence of Aerosol Properties and the Respiratory	000595
Cross	000600
Uranium Chain Alpha Emitters Following Repeated	000605
Ore, Concentrate, and Milling Dusts of Rare Metals*	000610
Oregon*	000615
Ores and Air Dusts*	000620
Ores*	000625
Cost	000630
Ors/Plived Uranium Chain Alpha Emitters in Experimental	000635
Ores, Dusts, and Mill Tailings* of Uranium 238, Uranium	000640
Organ Distribution of Thorium by Neutron Activation	000645
Organ Dose Rates in Man Following Intramuscular	000650
Organic Coated Reactors, Technical Progress Report No.	000655
Organism of Animals from the Adriatic Sea*	000660
Organisms*	000665
Organisms*	000670
Organisms*	000675
Levels of Radioactivity in the	000680
Organogenesis Horizons of Soils*	000685
Accumulation	000690
Organs in Rats on Intratracheal Administration of	000695
Organs of People Injected Systemically with Thorotrast*	000700
Organs of Rats upon Intratracheal Introduction of a	000705
Organs of Rats*	000710
Organs During Human Thorotrastosis*	000715
Organs*	000720
Assessment of the Content of Concentrated	000725
Organs*	000730
Distribution of Thorotrast and Its Daughter	000735
Osteogenic Sarcoma in Dogs*	000740
Osteosarcoma: A Late Effect*	000745
Early	000750
Osteosarcomas in Beagles*	000755
Osteosarcomas Induced in Beagles by Bone-Seeking	000760
Oxalate*	000765
Oxalate* Thermal Analysis. A Comparative Study of the	000770
Oxide (U3O8) in Experimental Work*	000775
Oxide by the Reticuloendothelial System of the Rat*	000780
Oxide Slurries*	000785
Oxide*	000790
PA Comparison of Theoretical	000795
Oxides*	000800
Health Hazards*	000805
Pacific Neoplasms Modules as Detected by Uranium-Series	000810
Pacific*	000815
Content of Plutonium, Thorium and	000820
Pacific*	000825
Ratios Thorium 230/Thorium 232 and Thorium	000830
Paluch Plant, July-December 1979*	000835
Paper*	000840
The Determination of Gross Alpha	000845
Parameters*	000850
Parenteral Administration*	000855
Thorium Distribution	000860
Parents within the Body-Calculations and Comparison	000865
Particle Dose*	000870
Particle Track Replica Method*	000875
Size and Uranium	000880
Particles and Gases*	000885
Particles in the Respiratory System of Humans Exposed	000890
Particles in CA90-15 and LA-115 Cellulose Nitrate Track	000895
Particles in Relation to their Sizes*	000900
Particles in Uranium Mine Atmospheres*	000905
Particles to Damage*	000910
Particles with Carbon and Metals for Lung Clearance	000915
Particles*	000920
Some Environmental Factors	000925
Particulate Impurities in Air by Use of Surface	000930
Particulate Radioactivity*	000935
Particulate Settling*	000940
Geochronological Studies	000945
Pathological Findings in the Reticuloendothelial System	000950
Pathological Studies (Experience in Portugal)* Thorium	000955
Pathology and Detailed Radioautography Report*	000960
Pathology of Irradiation*	000965
Pathomorphological Changes in Animals Following Acute	000970
Pathway*	000975
Erythrocytes of	000980
Pathway, Radiation Dose and Health Effect Parameters*	000985
Patients (Histological and Autoradiographic	000990
Patients and Evaluation of the Results*	000995
Patients from Poston, Massachusetts and Ann Arbor,	001000
Patients in the United States*	001005
Patients in Denmark*	001010
Patients in Portugal*	001015
Patients in Sweden*	001020
Patients with Known Amount of Injected Thorotrast*	001025
Patients with Thorium Dioxide Deposits*	001030
Patients Exposed to Thorium Dioxide*	001035
Patients Given Thorium Dioxide in the Perinatal Sinuses*	001040
Patients Injected with Thorium Dioxide*	001045
Patients Injected with Thorotrast*	001050
Patients*	001055
Patients*	001060
Patients*	001065
Patients*	001070
Patients*	001075
Patients*	001080
Patients*	001085
Patients*	001090
Patients*	001095
Patients*	001100
Patients*	001105
Patients*	001110
Patients*	001115
Patients*	001120
Patients*	001125
Patients*	001130
Patients*	001135
Patients*	001140
Patients*	001145
Patients*	001150
Patients*	001155
Patients*	001160
Patients*	001165
Patients*	001170
Patients*	001175
Patients*	001180
Patients*	001185
Patients*	001190
Patients*	001195
Patients*	001200
Patients*	001205
Patients*	001210
Patients*	001215
Patients*	001220
Patients*	001225
Patients*	001230
Patients*	001235
Patients*	001240
Patients*	001245
Patients*	001250
Patients*	001255
Patients*	001260
Patients*	001265
Patients*	001270
Patients*	001275
Patients*	001280
Patients*	001285
Patients*	001290
Patients*	001295
Patients*	001300
Patients*	001305
Patients*	001310
Patients*	001315
Patients*	001320
Patients*	001325
Patients*	001330
Patients*	001335
Patients*	001340
Patients*	001345
Patients*	001350
Patients*	001355
Patients*	001360
Patients*	001365
Patients*	001370
Patients*	001375
Patients*	001380
Patients*	001385
Patients*	001390
Patients*	001395
Patients*	001400
Patients*	001405
Patients*	001410
Patients*	001415
Patients*	001420
Patients*	001425
Patients*	001430
Patients*	001435
Patients*	001440
Patients*	001445
Patients*	001450
Patients*	001455
Patients*	001460
Patients*	001465
Patients*	001470
Patients*	001475
Patients*	001480
Patients*	001485
Patients*	001490
Patients*	001495
Patients*	001500
Patients*	001505
Patients*	001510
Patients*	001515
Patients*	001520
Patients*	001525
Patients*	001530
Patients*	001535
Patients*	001540
Patients*	001545
Patients*	001550
Patients*	001555
Patients*	001560
Patients*	001565
Patients*	001570
Patients*	001575
Patients*	001580
Patients*	001585
Patients*	001590
Patients*	001595
Patients*	001600
Patients*	001605
Patients*	001610
Patients*	001615
Patients*	001620
Patients*	001625
Patients*	001630
Patients*	001635
Patients*	001640
Patients*	001645
Patients*	001650
Patients*	001655
Patients*	001660
Patients*	001665
Patients*	001670
Patients*	001675
Patients*	001680
Patients*	001685
Patients*	001690
Patients*	001695
Patients*	001700
Patients*	001705
Patients*	001710
Patients*	001715
Patients*	001720
Patients*	001725
Patients*	001730
Patients*	001735
Patients*	001740
Patients*	001745
Patients*	001750
Patients*	001755
Patients*	001760
Patients*	001765
Patients*	001770
Patients*	001775
Patients*	001780
Patients*	001785
Patients*	001790
Patients*	001795
Patients*	001800
Patients*	001805
Patients*	001810
Patients*	001815
Patients*	001820
Patients*	001825
Patients*	001830
Patients*	001835
Patients*	001840
Patients*	001845
Patients*	001850
Patients*	001855
Patients*	001860
Patients*	001865
Patients*	001870
Patients*	001875
Patients*	001880
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Patients*	001915
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Patients*	001940
Patients*	001945
Patients*	001950
Patients*	001955
Patients*	001960
Patients*	001965
Patients*	001970
Patients*	001975
Patients*	001980
Patients*	001985
Patients*	001990
Patients*	001995
Patients*	002000
Patients*	002005
Patients*	002010
Patients*	002015
Patients*	002020
Patients*	002025
Patients*	002030
Patients*	002035
Patients*	002040
Patients*	002045
Patients*	002050
Patients*	002055
Patients*	002060
Patients*	002065
Patients*	002070
Patients*	002075
Patients*	002080
Patients*	002085
Patients*	002090
Patients*	002095
Patients*	002100
Patients*	002105
Patients*	002110
Patients*	002115
Patients*	002120
Patients*	002125
Patients*	002130
Patients*	002135
Patients*	002140
Patients*	002145
Patients*	002150
Patients*	002155
Patients*	002160
Patients*	002165
Patients*	002170
Patients*	002175
Patients*	002180
Patients*	002185
Patients*	002190
Patients*	002195
Patients*	002200
Patients*	002205
Patients*	002210
Patients*	002215
Patients*	002220
Patients*	002225
Patients*	002230
Patients*	002235
Patients*	002240
Patients*	002245
Patients*	002250
Patients*	002255
Patients*	002260
Patients*	002265
Patients*	002270
Patients*	002275
Patients*	002280
Patients*	002285
Patients*	002290
Patients*	002295
Patients*	002300
Patients*	002305
Patients*	002310
Patients*	002315
Patients*	002320
Patients*	002325
Patients*	002330
Patients*	002335
Patients*	002340
Patients*	002345
Patients*	002350
Patients*	002355
Patients*	002360
Patients*	002365
Patients*	002370
Patients*	002375
Patients*	002380
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Patients*	002585
Patients*	002590
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Patients*	002605
Patients*	002610
Patients*	002615
Patients*	002620
Patients*	002625
Patients*	002630
Patients*	002635
Patients*	002640
Patients*	002645
Patients*	002650
Patients*	002655
Patients*	002660
Patients*	002665
Patients*	002670
Patients*	002675
Patients*	002680
Patients*	002685
Patients*	002690
Patients*	002695
Patients*	002700
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Patients*	002710
Patients*	002715
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Patients*	002740
Patients*	002745
Patients*	002750
Patients*	002755
Patients*	002760
Patients*	002765
Patients*	002770
Patients*	002775
Patients*	002780
Patients*	002785
Patients*	002790
Patients*	002795</

TITLE INDEX

Discretion Projects in the Poly*	Basic	Patterns of Metabolism of Thorium 232 and Its	000494
Retention and Excretion Equations for Different		Patterns of Uptake*	000561
Thorium Distribution and Excretion Studies. 2. General		Patterns Following Inhalation and the Effect of the	000674
Thorium Distribution and Excretion Studies. 1.		Patterns Following Parenteral Administration*	000705
for Inhalation: Radiation by Removal of Environmental and		Podologic Radiation Changes* Radiation Data Analyses	000782
Respiratory Tract*		Penetration of Radioactive Aerosols into the	000774
Erythrocytes of Uranium Miners: the Activity of the		Pentose Phosphate Pathway*	000536
Portuguese Experience*		People Injected with Thorium Dioxide (Thorotrast) (	000637
and Autoradiographies from Pieces of Organs of		People Injected Systemically with Thorotrast*	000672
the Nevada Test Site* Some Characteristics of Soil and		Perennial Vegetation in Northern Mojave Desert Areas of	000291
of Portuguese Patients Given Thorium Dioxide in the		Perinatal Diseases*	000202
The Effect of Thorium Dioxide on the		Peripheral Blood of Rats*	000164
with Th. 232*		Peripheral Blood Following Chronic and Acute Poisoning	000077
The Plutogenic Effect of Uranyl Nitrate on the		Peripheral Lymphocyte of the Rat*	000577
Barium of Bismuth 212*		Peripheral Lymphocytes of Thorium Workers with Low Body	000630
Chromatography with Thorotrast*		Peritoneal Hemangioendotheliomatosis after	000394
Carinthia, Austria*		Perivascular Injection of Thorotrast and Its Sequelae*	000347
of Uranium-Thorium-Geochronology of		Persian and Triassic Sediments of the Dniepr, U.S.S.R.	000351
and Uranium Concentrations in Air*		Perruian of the Choc Yappe in the Vitarovsky Chrbat	000765
Amounts of Radioisotopes in the Human Body and Maxima		Permissible Amounts of Radioisotopes in the Human Body	000694
Materials (Thorium, Uranium) in Ore,		Permissible Concentrations in Air and Water*	000604
in Exposed Individuals. 2. Radiation Dosage and		Permissible Concentrations of Natural Radioactive	000744
air and water*		Permissible Levels*	000721
Basic for Setting the Ratios		Permissible Limits of Plutonium 239 in the Human Body,	000690
232, Natural Thorium, Radium 226 and		Permissible Standards of Soluble Compounds of Thorium	000704
Plutonium 239*		Phagocytes Following Intraperitoneal Administration of	000785
The Ultrastructure of Mononuclear		Phagocytosis of Colloidal Thorium Dioxide and Cobaltic	000707
Oxide by the Endothelial System of the Rat*		Phagocytosis of Inert Test Particles*	000730
Some Environmental Factors Influencing the In Vitro		Phantom*	000507
Deposited Thorium by Means of Studies with a Realistic		Phase in Extraction Chromatography*	000727
of Neutrocanohydroxylic Acid as Stationary		Phase of the Pestic Toxicity Experiment*	000754
Completion of the Injection		Phases*	000625
Its In-Vitro Distribution between the Various Physical		Phases* Thorium, Plutonium, Radium Isotopes, Lead 210,	000672
from 55, Silicon 32 and Carbon 14 in Serum Suspended		Phosphate Pathways*	000534
of Uranium Miners: the Activity of the Pentose		Phosphate Pools and Their Possible Radiation Hazards*	000355
of Uranium, Radium, and Thorium Content in		Phosphate-Carbon Tetrachloride Solution*	000254
of Thorium Nitrate and Nitric Acid by Tributyl		Phosphorus Fertilizers*	000357
of Radium 226 and Thorium 232 in Soviet-Rede		Photometric Determination of Low Amounts of Thorium in	000424
Biological Materials*		Photometric Determination of Thorium in Soils*	000559
		Physical Metallurgy of Thorium*	000245
		Physical Phases*	000425
and Its In-Vitro Distribution between the Various		Physical State on the Removal of Hydrolyzable	000672
Radionuclides by Chelation*		Physical, Chemical, and Radioactive Properties of	000217
Thorium and Thoron*		Physics Application of IN VIVO Gamma Spectrometry in a	000646
Tracing Processing Plants*		Physics Aspects of Waste Recycling*	000729
Some Activities in the United States Concerning the		Physics Considerations Associated with Thorium	000727
Processing*		Physics Problems from Thorium and Its Daughters in a	000726
Thorium Purification and		Physics Section, Progress Report for May 1967*	000086
Thorium-Containing Substances in Media Resembling		Physiologic Fluids*	000251
Autoradiographies and Autoradiographies from		Pieces of Organs of People Injected Systemically with	000632
of Radon 222 Flux from Inactive Uranium Mill Tailings		Piles*	000620
of Radioactive Dust Dispersed from Uranium Tailings		Piles*	000560
Disposal of Low-Level Radioactive Wastes from		Pilot Plants*	000731
of Combination of Fissionable Materials with the Thor-		Pit Counting Method*	000624
on*		Pits Due to Radon and Thoron Alpha Particles in CA80-15	000637
Some Characteristic Differences between the Thor-		Plankton and Sea-Water*	000270
on*		Plankton from the Caribbean*	000709
Uranium and Thorium Decay Series Nuclides in		Plankton*	000281
Alpha-Radioactivity of		Plant at the University of Missouri*	000677
Hazards in the Radium and Mesothorium Refining		Plant Matter*	000332
of Polytene, Venation, and Uranium by Decomposing		Plant Monitoring of Uranyl Nitrate Solutions for Thorium	000628
Automated In-		Plant Species*	000204
Thorium, Silver, and Other Trace Elements in Different		Plant*	000704
Air Cleaning at the ASAC T-12		Plant*	000636
of IN VIVO Gamma Spectrometry in a Uranium Processing		Plant, July-December 1970*	000652
Plant*		Plants and Animals*	000278
Radioecology of Freshwater		Plants and Bones*	000286
Radioactivity of Soils,		Plants and Organogenic Horizons of Soils*	000205
Accumulation of Thorium, Uranium, and Radium by		Plants at Different Times during Vegetation*	000211
The Concentration of Thorium and Rare Earths by		Plants Growing on Granitic and Radioactive Rocks*	000216
Uranium, Thorium, Lead, Lanthanoids and Yttrium in Some		Plants*	000208
Natural Radioactive Elements in		Plants*	000209
Radioactive Isotopes in the System Water-Freshwater		Plants*	000731
Disposal of Low-Level Radioactive Wastes from Pilot		Plants*	000202
Thorium 230, Radium 226, Lead 210, and Polonium 210 by		Plants, Shells, and Corals*	000272
Estimation of the Microgram Amount of Thorium in		Plasma Iron Study*	000136
		Plateau*	000511
Blind Cancer of Uranium Miners on the Colorado		Plugged Inversion Canals and Skeletal Dose in Radium	000517
Cases*		Plutonia/Curia Compatibility Testing, April-June 1972,	000685
Quarterly Report No. 15*		Plutonium (IV), Americium (III) and Curium (III) to the	000032
Constituents of Bovine		Plutonium and other Actinides*	000116
The Binding of Thorium (IV),		Plutonium and Radiothorium in Teeth*	000003
The Metabolism of Compounds of		Plutonium and Related Elements, in Rat Bone*	000172
Radioautographic Studies of		Plutonium and Uranium Determination in Environmental	000246
The Effects of Tetracycline in the Deposition of		Plutonium and Yttrium Distribution and Excretion*	000198
Samples: Combined Solvent Extraction-Liquid		Plutonium in Animals and Man*	000061
The Action of Salts of Zirconium and Other Metals on		Plutonium in Environmental Surveillance Samples*	000635
Behavior of		Plutonium in LWR and RTG Fuel*	000728
Determination of			
of the Potential Relative Toxicity of Uranium and			

Natural Waters*

Sensitive Method for the Determination of Low Trisium
Histopathologic Study of Intradermal
Factor Operations* Radiological Implications of
the Beagles* Effects of

Microprecipitation Distribution of
Oasis "or Setting the Maximum Permissible Limits of
Method of Determining

Burdens of Radium 226, Radium 228, Thorium 230,
Shapovitsky Following Intraoperative Administration of
for Small Quantities of Strontium 90, Thorium 230 and
of the Retention and Distribution of Radioactive
Studies of the Biological Effects of Radium 226,
Alpha Dose III from Surface and Volume Deposits of
and Other Secretory Constituents in Dogs Burdened with
to the Comparative Toxicity of Radium 226,
9C to the Comparative Toxicity of Radium 226,

Sequence of Histopathologic Changes in Teeth Containing
Sequence of Microbiologic Changes in Teeth Containing
Spectroscopic Determination of Uranium, Thorium and
of Radioactive Waste Produced by the Enriched Uranium.
of Radioactive Wastes Produced by the Enriched Uranium.

Semi-Quantitative Determination of Uranium,
Semiquantitative Determination of Uranium,
Procedure for Measuring Uranium, Thorium, Radium,
in the Long-Term Toxicity Experiments with Uranium,
Volumes of Ocean Water* Simple Recovery of

7) and The Simultaneous Determination of Thorium,
Radioisotopes; in Dog Teeth. I. The Distribution of
in the Teeth of Dogs. II. The Distribution of
Percent Coral in the North Pacific* Content of

Radiocesium Incorporation with Particular Reference to
Distribution of Uranium and Radium in the
Thorium and Radium Content in the Silt Fraction of the
ie Appl? Radioactivity* Radius and Mesothorium

Changes in Animals Following Acute and Chronic
in the Peripheral Blood Following Chronic and Acute
Action of "Radium Tetrafluoride in Chronic Inhalation
Measurements in Nuclear Power Station Siting Studies in
Studies of Ground and Surface Waters* Single-Sweep

Resources in the United States and the Effect of
Simple Recovery of Plutonium, Americium, Uranium, and
Ordinary Excretion of Radioactive
Uptake of Thorium 230, Radium 226, Lead 210, and
Lithium, Distribution and Internal Dose of Lead 210 and
in Yugoslavia* Trace Levels of Uranium, Thorium 230, Lead 210, and

Applications of Nuclear Track Registration in
Studies on the Radiobiology of NARXASTIA
Innuciglobulin (Ig G, Ig A, Ig M) Values in a Few
General Radiation Exposure of the
of Alpha-Emitting Isotopes in a New England
Dose of Lead 210 and Polonium 210 in a Uranium Miner
Uranium in Dental

Ceoporphyrin Excretion* Studies of
Follow-Up Study of Thorium Dioxide Patients in
Clinical, and Pathological Studies (Experience in
in People Injected with Thorium Dioxide (Thorostrast)
Peculiar Sinuses* Follow-Up Study of

Human Leukemic Risk Data Derived from
Epidemiological Follow-Up Studies of the
Thorium-Cycle
Study with Natural Uranium Dioxide (MO₂) Dust.
Radiometric Determination of Thorium, Uranium and
Techniques for Determining Uranium, Thorium, and
in New Zealand Soils--their Relationship to Iron and
for Uniformly Distributed Uranium 238, Thorium 232,
Daughters in Different Air Atmospheres* Activity and
in Inert Gas Shielded Arc Welding--Investigation of
The Deposition of Radioactive Metal in Bone as a
LBB and MTG Fuel* BAA Examination of the

Uranium, Zirconium, and H-Hay-Fluorescence Analysis of
Hazards of Nuclear Fusion
Role of Thorium in a Nuclear
Thorium-Cycle Possibilities in the Brazilian Nuclear
of Plutonium Recycle and the Use of Thorium Fuels in
Assessment of the Thorium Fuel Cycle in
Environmental Gamma Radiation Measurements in Nuclear
Thorium Utilization in an FBR/MTR
Thorium and Nuclear

Gernamium-Lithium Gamma-Ray The Direct Measurement of
Determinations of Uranium, Thorium and Plutonium Co-
of Rare Earths in Thorium Compounds. Chromatographic
Neutron Determination of Uranium in Natural Water by
Fallout of Nuclear Devices. A Handbook for Estimating
Resulting from Radioactive Dose Estimation and

Poisoning to Glycoproteins in Tissue*

Plutonium with Complexing Substances in Soils and
Plutonium Fallout in Marine and Terrestrial Samples*

Plutonium Levels in Occupationally Exposed Workers*

Plutonium Metal Deposits: Their Concentrated Fate*

Plutonium Recycle and the Use of Thorium Fuels in Power
Plutonium 239 and Related Radionuclides on Survival of
Plutonium 239 and Thorium 232 in Beagles*

Plutonium 239 in the Human Body, Air and Water*

Plutonium 239 in Brine*

Plutonium 239 or Strontium 90 in Beagles with Retained
Plutonium 239 PuO₂* The Ultrastructure of Neoplastic
Plutonium 239* for the Analysis of Biological Material

Plutonium 239, Radium 224 (Mesothorium I), Thorium 230
Plutonium 239, Radium 228 (Mesothorium II), Thorium 232
Plutonium 239, Thorium 228, and Radium 226 of Localized
Plutonium 239, Thorium 228, Radium 226 and Radium 224
Plutonium 239, Thorium 228, Radium 226 and Strontium 90
Plutonium 239, Thorium 228, Radium 226, and Strontium 90
Plutonium* Mesothorium and Strontium and the
Plutonium* Mesothorium, and Strontium and the
Plutonium* Coprecipitation Technique for Alpha
Plutonium-Uranium 238, and Uranium 233-Thorium Fuel
Plutonium-Uranium 238, and Uranium 233-Thorium Fuel
Plutonium, and American in Sea Water*

Plutonium, and American in Seawater*

Plutonium, and American in Soil Samples*

Plutonium, and Sodium* of Malignant Bone Tumors

Plutonium, Americium, Uranium, and Polonium from Large
Plutonium, Radium Isotopes, Lead 210, Iron 55, Silicon
Plutonium, Radium, Radiothorium, Mesothorium, and
Plutonium, Radium, Radiothorium, Mesothorium, and
Plutonium, Thorium and Protactinium in Sea Water and
Plutonium, Thorium, Radium, Iron and Gold* of

Podzolic Mountain Soils of Thin Forests*

Podzolic Mountain Soils of Thin Forests*

Poisoning and Poisoning and Instrumentation Techniques
Poisoning with *CO* Pathomorphological
Poisoning with *SO*

Poisoning* The Biological
Poland* Environmental Gamma Radiation
Polarographic Techniques Useful in Micropollution
Policy Alternatives* Assessment of Uranium and Thorium
Polonium from Large Volumes of Ocean Water*

Polonium 210 by Czechoslovakian Uranium Miners*

Polonium 210 by Plants* Comparative
Polonium 210 in a Uranium Miner Population* Body
Polonium 210 in Blood and Urine of Uranium Mine Workers
Polonium 210 in Soft Tissues* The Determination
Polymer* Some Positron

POLYMER L. in the Sudetes*

Population Groups*

Population*

Population*

Population* Naturally Occurring Concentrations
Porcelain* Body Surface, Distribution and Internal

Porphyria Metabolism. The Effect of Metals on
Portugal*

Portuguese)* Dioxido Effects in Man. Epidemiological,
Portuguese Experience*) Tumors Developed

Portuguese Patients Given Thorium Dioxide in the
Portuguese Throatrast Experience*

Portuguese Throatrast Series (Up-Dated Results)*

Possibilities in the Brazilian Nuclear Power Programme*

Postexposure Retention and Biologic Effects in the
Potassium in Basalts and in Two Magmatic
Potassium in Granitic Rocks* of Some Analytical
Potassium Content* and Thorium: Uranium Ratio
Potassium 40, and Cesium 137 in Nan Guanba-Bay Spectra
Potential Alpha-Energy of RaFm 222 and RaFm 220-
Potential Hazard?* Use of Thoriated Tungsten Electrodes
Potential Health Hazards*

Potential Relative Toxicity of Uranium and Plutonium in
Powdered Rock Samples. Determination of Thorium,
Power and the Choice of Alternatives*

Power Programme*

Power Programme*

Power Reactor Operations* Radiological Implications
Power Reactors*

Power Station Siting Studies in Poland*

Power System*

Power*

p.p.s levels of Uranium in Soils Using High-Resolution
precipitation technique for alpha spectroscopy
Preconcentration in an Acid-Ether-Cellulose System*

Preconcentration on Anion-Exchange Resin and Delayed-

Prediction of the Marissa Dosage to Man from the
Prediction of Radiation Effects on Aquatic Biota

TITLE INDEX

- Early Radiation Effects on Bone and Blood as
of River Water in the Eastern Part of Shima
The Effect of U308 on the Body of the
Reactors* 01
Patients with Thorium Dioxide Deposits*
Thorium Distribution Following Intravenous Injection*
Contents and Lead Isotopic Compositions in Sediment
Bones Induced by Bone Seeking Radionuclides*
of Thorium Dioxide Patients: Special Techniques and
muscle 0The Effect of Thorium Dioxide on Arterial
The Thorium Cycle in Heavy Water Moderated
and Possible Effect within Terrestrial Ecosystems*
toxicity of Thorotrast*
0The Metabolism of the Fission
Disposal, and Relative Toxicity of Long-Lived Fission
of Metabolism of Thorium 232 and Its Dissociation
Metabolism of Thorium 232 and that of its Dissociation
0Measurement of Radium 226, Thorium 232 and Daughter
0Measurement of Thorium and Daughter
Effects of Uranium Ore Dust, Radon and
The Dose to the Trachea and Bronchi from the Decay
the Concentrations of the Short-Lived Daughter
the Concentrations of the Short-Lived Daughter
tetrazole* 0Disposition of Uranium 232 Decay
of the Hazard from Airborne Thorium and Its Daughter
to the Respiratory System Due to Radon and its Daughter
Inhalation of Short-Lived Radon 222 and Radon 220 Decay
as a Fractured Fraction of Radon and Thorium Decay
Nondestructive Analysis for Uranium 232 and Decay
0Integrating Radon
226) Enriched Thorium Dioxide and Its Radioactive
Role of Thorium in a Nuclear Power
Cycle Feasibilities in the Brazilian Nuclear Power
0Testing and Monitoring
0Gas-Cooled Reactor
Research in Radiobiology, Annual Report of Work in
0Research in Radiobiology, Semiannual Report of
0Research in Radiobiology, Annual Report of Work in
0Research in Radiobiology, Annual Report of Work in
0Research in Radiobiology, Annual Report of Work in
0Research in Radiobiology, Semiannual Report of Work in
0Research in Radiobiology, Annual Report of Work in
0Research in Radiobiology, Annual Report of Work in
0Research in Radiobiology, Semiannual Report of Work in
0Thorium Utilization Program, Quarterly
0Thorium Utilization Program, Quarterly
0Medical and Health Physics Section,
0Thorium Assessment Study Quarterly
0Thorium Assessment Study Quarterly
Water Moderated Organic Cooled Reactors, Technical
0Semiannual
Cooler Reactor Programs: Thorium Utilization Program
Annual
in the Long-Term Toxicity Experiments with Uranium,
Uranium 233 in Rats*
0Uranium and Thorium Isotopes: Deep Sea Drilling
of Internal Contamination Resulting from Recurrent or
0Preparation and Analytical Applications of a
Susceptibility and Geochemical Relationships as Uranium
0Radiation Effects in Man: Current Views and
Pacific* 0Content of Plutonium, Thorium and
Soviet Working Meeting on the Question of Radiation
Uranium: A Critical Contribution to Health
Calibration* 0The Radiation
and Artificial Radionuclides in Seafoods and Marine
on Seedling Growth, Excised Cotyledones, Chlorophylls,
Atomic Energy Commission Sites* 0Assessment of
0Carcinogenic Studies in
Childhood after Thorium-X Treatment*
Elimination and Residual Body 0A Case of Accidental
Intraperitoneal Administration of Plutonium 239
Problems from Thorium and its Daughters in a Thorium
0Development of a Thorium
Uranium Production in Thorium/Denatured Uranium Pooled
Tumors of the Kidney Following Retrograde
0Trace Elements in Fine Gases and Air
226, Uranium and Other Radiological Data from Water
with a Semiconductor X-Ray Emission Spectrometer*
Americium in Sea Water* 0Semi-
During Human Thorotrastosis*
Assessment Study Quarterly Progress Report for Third
Assessment Study Quarterly Progress Report for Second
February 28, 1977* 0Thorium Utilization Program,
Predictors of Osteosarcoma: A Late Effect* 000277
Prefecture -- with Special Emphasis on Cause of Uranium
Pregnant Female and the Fetus* 002234
Preliminary Assessment of Thorium as a Fuel for Thermal
0 Preliminary Report from Boston on the Follow-up of
0 Preliminary Report on the Effect of Number of Atoms on
0 Preliminary Report on Uranium, Thorium, and Lead
0 Preliminary Report: Changes in Vascularity of Cortical
Preliminary Results* 0In Vivo Counting
0 Preliminary Studies of Inhaled Uranium Ore* 002161
Pressure and Threshold of Stimulation of the Nerve-
Pressure Tube (CATU) Reactors* 002164
Primordial Radionuclides: Their Distribution, Movement,
0 Proceedings of the Third International Meeting on the
Products and the Heaviest Elements* 002294
Products and Actinides in the Radioactive Wastes from
Products in the Body* 0Basic Patterns
Products in the Body* 0The Main Order of the
Products in Biological Samples* 002444
Products in Tissue: Effect of Time on the Results* 000422
Products of its Decay in the Lungs of Rats* 002194
Products of Radon and Thoron* 002198
Products of Radon 222 in the Atmosphere* for Measuring
Products on Biochemical Indices of Blood Serum in Rats* 002263
Products Following Inhalation of Uranium 232 UO2 /CH2
Products* 0Some Aspects
Products* 0Radiation Dose
Products* 0The Dose to the Human Respiratory Tract by
Products* 0Useful for Measuring Diffusion Coefficients
Property in Animals Tissues* 002254
Propagator Air Sampler* 002378
Propagator* 0Studies with Radiothorium (Thorium
Program* 002007
Program* 0Thorium-
Program* 002314
Program* 000465
Program: Thorium Utilization Program Progress Report* 000474
Progress in the Beagle Studies at the University of Utah
Progress in the Internal Irradiation Program* 000123
Progress in the Internal Irradiation Program* 000951
Progress in the Internal Irradiation Program* 002053
Progress in the Internal Irradiation Program* 000092
Progress on the Chronic Toxicity Program* 000049
Progress on the Chronic Toxicity Program* 002049
Progress on the Chronic Toxicity Program* 002050
Progress on the Chronic Toxicity Program* 002052
Progress on the Chronic Toxicity Program* 002054
Progress on the Chronic Toxicity Program* 002055
Progress Report for the Period Ending February 28, 1977* 002302
Progress Report for the Period Ending May 31, 1977* 000301
Progress Report for May 1967* 002064
Progress Report for Second Quarter Fiscal 1977* 002321
Progress Report for Third Quarter Fiscal 1977* 002320
Progress Report No. 5, April-June, 1966* Cycle for Heavy
Progress Report* 000192
Progress Report* 0Gas-
Progress Report* 002674
Progress Report, March 31, 1959* 002155
Progress Report: The Incidence of Malignant Bone Tumors
Progress Report: The Retention and Distribution of
Project, Leg 23* 002613
Prolonged Uptakes* 0The Assessment
Propyleneimine-tetracarboxylic Acid Resin* 002249
Prospecting Guides* 0Magnetic
Prospects* 000480
Protectant in Sea Water and Percent Coral in the North
Protection held in Berlin, Germany, June 8-9, 1972* 000463
Protection of Workers* 0Toxicology of Transportable
Protection Division's Whole Body Counter--Its Use and
Protection Measurement* 000606
Protein Concentrations* 0Natural
Proteins and Sugar Contents in CITRILLUS Species* 002201
Public Radiation Exposure in the Vicinity of U.S.
Pulmonary Carcinogenesis* 002135
Pulmonary Function of Uranium Miners* 000389
Pulmonary Metastases from a Thyroid Carcinoma in
Puncture Contaminated with Thorium 227. Studies on
PuO2* Ultrastructure of Mononuclear Phagocytes Following
Purification and Fabrication Process* the Health Physics
Purification System* 002240
PWB* 002296
Pyelography with Colloidal Thorium Dioxide* 000541
Quality Criteria* 000654
Quality Surveillance Stations Located in the Colorado
Quantitative Analysis of Uranium and Thorium Solutions
Quantitative Applications of the Nuclear Track Technique
Quantitative Determination of Uranium, Plutonium, and
Quantitative Thorium Determination in Thirty Organs
Quarter Fiscal 1977* 0Thorium
Quarter Fiscal 1977* 0Thorium
Quarterly Progress Report for the Period Ending
000302

TITLE INDEX

1977*	Thorium Utilization Program,	Quarterly Progress Report for the Period Ending May 31,	000307
"	Thorium Assessment Study	Quarterly Progress Report for Second Quarter Fiscal 1977	000321
"	Thorium Assessment Study	Quarterly Progress Report for Third Quarter Fiscal 1977	000322
Polonium/Ceria Compatibility Testing, April-June 1972,		Quarterly Report No. 15*	000365
Germany, June 8-9	German-Soviet Working Meeting on the	Question of Radiation Protection held in Berlin,	000443
	Development and Improvement of the	Questionnaires*	000444
Dioxides*	Factors in	Rabbits after Injection of Various Amounts of Thorium	000455
Colloidal Thorium Dioxide Distribution and Effects in		Rabbits*	000456
in Airborne Gamma-Radiation Data Analyses for Anomalous		Influence of Sex Hormones and Tissues on	000457
of a Passive Track Dosimeter for Monitoring the Neutron		Radiation by Removal of Environmental and Pathologic	000458
of Sociological Analysis of the Reduction of Hazardous		Radiation from Californium 252 Sources on Bands Inside	000459
	The Effects of	Radiation in Uranium Mines*	000460
Radiation by Removal of Environmental and Pathologic		Radiation on Bone*	000461
Removal of Environmental Dispersions in Airborne Gamma		Changes*	000462
Estimating Radioelements in Exposed Individuals. 2.		Radiation Data Analyses for Anomalous	000463
Considerations of the Limits of		Data Analyses for Anomalous Radiation by	000464
Exposure Pathway,		Dosage and Permissible Levels*	000465
Calculation of		Radiation Dosage from Thorotrast*	000466
of Natural Terrestrial Sources to the Total		Radiation Dose and Health Effect Parameters*	000467
Environment, and the Assessment of		Radiation Dose from Thorotrast Using Whole-Body Gamma-	000468
Tumors in the Lung and Skin Tumors in the Rat*		Dose to the Respiratory System Due to Balon	000469
Exposure to Radioactive Releases from LBN Fuel-Cycle		Radiation Dose to Man*	000470
	A Survey of	Radiation Dose Rates to Fish in Contaminated*	000471
Toxicological Aspects of Ionizing		Radiation Dose-Time Relations for Induction of Bone	000472
Substances*	Non-	Doses and Effects Estimated for Aquatic Biota	000473
Radioactive Releases: Dose Estimation and Prediction of		Radiation Dosimetry in Thorium Dioxide Cases*	000474
Carcinogenesis: A Late Effect*		Radiation Due to Bone-Seeking Radioisotopes*	000475
	Statistical	Radiation Effects in Man: Current Views and Prospects*	000476
Energy Commission Sites*	Assessment of Public	Radiation Effects of Thorotrast and Other Colloidal	000477
	General	Radiation Effects on Aquatic Biota Resulting from	000478
	Operational Evaluation of the Natural Gamma	Radiation Effects on Bone and Blood as Predictors of	000479
	Neutron Dosimetry in the	Radiation Exposure in the United States*	000480
Thorium Content in Phosphate Rocks and Their Possible		Radiation Exposure in the Vicinity of U.S. Atomic	000481
		Radiation Exposure of the Population*	000482
		Radiation Field at Aerial Survey Heights*	000483
		Radiation Field of Californium 252 Sources*	000484
		Radiation Hazards*	000485
		Uranium, Radium, and	000486
		Hazards in Uranium Mining and Milling*	000487
		Hazards of Radium and Thorium 230-Thorium Decay*	000488
		Hazards Created by Thoron and Thoron Daughters	000489
		Radiation Induced Intraocular Neoplasms*	000490
		Radiation Induced Osteopetrous Sarcoma in Dogs*	000491
		Radiation Injury with Particular Reference to Thorotrast	000492
		Levels and Concentration, First Half 1970*	000493
		Levels and Fluence Conversion Factors*	000494
		Levels Associated with the Milling of	000495
		Radiation Measurements in Nuclear Power Station Siting	000496
		Monitoring at the Lawrence Livermore	000497
		Radiation Protection held in Berlin, Germany, June 8-9,	000498
		Radiation Protection Division's Whole Body Counter--Its	000499
		Radiation Protection Measurements*	000500
		Radiation Safety Extent in Work with Natural	000501
		Radiation*	000502
		Radiation*	000503
		Radiation*	000504
		Radiation*	000505
		Radiation*	000506
		Radiation*	000507
		Radiation*	000508
		Radiation*	000509
		Radiation*	000510
		Radiation*	000511
		Radiation*	000512
		Radiation*	000513
		Radiation*	000514
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		Radiation*	000600
		Radiation*	000601
		Radiation*	000602
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		Radiation*	000675
		Radiation*	000676
		Radiation*	000677
		Radiation*	000678
		Radiation*	000679
		Radiation*	000680
		Radiation*	000681
		Radiation*	000682
		Radiation*	000683
		Radiation*	000684
		Radiation*	000685
		Radiation*	000686
		Radiation*	000687
		Radiation*	000688
		Radiation*	000689
		Radiation*	000690
		Radiation*	000691
		Radiation*	000692
		Radiation*	000693
		Radiation*	000694
		Radiation*	000695
		Radiation*	000696
		Radiation*	000697
		Radiation*	000698
		Radiation*	000699
		Radiation*	000700

2

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35 Plutonium, Radium, Radiothorium, Mesothorium, and	0 Radioisotopes in the Teeth of Dogs. 1. The Distribution	030697
Plutonium, Radium, Radiothorium, Mesothorium and	0 Radioisotopes in Dog Teeth. 1. The Distribution of	000100
Radioisotopes in the Skeleton: Naturally Occurring	Radioisotopes in Man*	000521
0The Effect of Internally Deposited	Radioisotopes Upon the Blood Vessels of Cortical Bone*	000088
0Effect of Internally Deposited	Radioisotopes Upon Blood Vessels of Cortical Bone*	000054
Aspects of Ionizing Radiation Due to Bone-Seeking	Radioisotopes*	000138
Report, July 1972 through June 1973*	0 Radiological and Environmental Research Division Annual	000505
Stations Located in the 0Radon 226, Uranium and Other	0Radiological Data from Water Quality Surveillance	000651
0A Summary of the Chemical and	0Radiological Effects of Thorium*	000082
Mining and Milling Operations on Selected Ground Water	0Radiological Emergency Operations, Student's Manual*	000720
Use of Thorium Poels in Power Reactor Operations*	0Radiological Evaluation of the Effects of Uranium	000576
0Safety Features in the Design of	0Radiological Health Data and Reports Station*	000647
0Isotopic Composition and	0Radiological Health Data and Reports*	000644
0Manual on	0Radiological Implications of Plutonium Recycle and the	000675
in 1926-1929 of Thorium Dioxide in Diagnostic	0Radiological Laboratories, Trebbay*	000730
Potassium in Basalts and in Two Magmatic	0Radiological Properties of Uranium in Selected Fuel	000672
0Electrocardiogram Evaluation of Beagles with Retained	0Radiological Safety in Uranium and Thorium Mines and	000397
0A Survey of Naturally Occurring	0Radiology*	000342
Affected by Uranium Ore Mining	0Radiometric Determination of Thorium, Uranium and	000232
Biosynthesis by Canine Testicular Internally Deposited	0Radiometric Properties of the Thorium Series*	000176
0Microscopic Distribution of Some Bone-Seeking	0Radionuclide Burdens*	000135
0Bone-Seeking	0Radionuclide Concentrations in New Zealand Soils*	000106
Bibliography*	0Radionuclide Contamination of Fishes in Streams	000064
0Biocoenoses*	0Radionuclides and the Subsequent Alteration of Androgen	000022
Introduction of Soluble	0Radionuclides and Assessment of Absorbed Dose* Analysis	000191
Patients*	0Radionuclides and Bone*	000305
0Biochemical Changes Induced by Internally Deposited	0Radionuclides and Ionizing Radiation: A Selected	000726
Results of Measurements at IAEA*	0Radionuclides and Their Effects in Terrestrial	000721
0Natural and Artificial	0Radionuclides in the Body of Rats after Intratracheal	000021
0Natural	0Radionuclides in Autopsy Samples from Thorotrast	000019
0Metabolism of Thorium 232 Decay Series	0Radionuclides in Beagle Dog Blood. A Statistical Study*	000019
0Natural and Artificial	0Radionuclides in Compact Bone of Thorotrast Cases -	000000
0The Colloidal Nature of	0Radionuclides in Fish Plank*	000325
Extravascular	0Radionuclides in Foods and Food Source Materials*	000285
Concentrates*	0Radionuclides in Industrial and Rural Soils*	000012
Atomic Energy Authority for the Determination of	0Radionuclides in Man and Other Animals Following	000025
upon Intratracheal Introduction or a 0The Metabolism of	0Radionuclides in Seafoods and Marine Protein	000012
Effects of Chronic Irradiation by Internally Deposited	0Radionuclides in Seawater*	000025
0Effects of Plutonium 239 and Related	0Radionuclides in Urine*	000598
Handbook for Estimating the Various Internal Dose from	0Radionuclides of the Thorium Family in Organs of Rats	000018
0Vascular Changes in Bones Following Bone-Seeking	0Radionuclides on Corticosteroid Biosynthesis*	000153
0Toxicology of	0Radionuclides on Survival of the Adult Beagles*	000288
Assay of the Relative Toxicity of Certain Bone-Seeking	0Radionuclides Released to the Biosphere*	000101
Trends in Therapeutic Removal of Internally Deposited	0Radionuclides*	000187
of Osteosarcomas Induced in Beagles by Bone-Seeking	0Radionuclides*	000029
of Standard Soils Containing Known Quantities of	0Radionuclides*	000029
Vascularity of Cortical Bones Induced by Bone Seeking	0Radionuclides*	000193
Testicular Tissue after the Internal Deposition of Some	0Radionuclides*	000045
0Bone Cancer Induction by	0Radionuclides: Incidence vs. Dose*	000289
Possible Effect within Terrestrial	0Radionuclides: Their Distribution, Movement, and	000044
Its Radioactive Property*	0Radionuclides: Their Distribution, Movement, and	000007
0Radioautographic Studies of Plutonium and	0Radiothorium (Thorium 228) Enriched Thorium Dioxide and	000003
Plutonium 239, Radium 226 (Mesothorium I) Thorium 228	0Radiothorium and Strontium 90 in Adult Beagles* 226,	000052
Plutonium 239, Radium 228 (Mesothorium I), Thorium 228	0Radiothorium), and Strontium 90* Effects of Radium 226,	000060
0Thorium 232 in	0Radiothorium-Enriched Beagles*	000076
in Dog Teeth. 1. The Distribution of Plutonium, Radium,	0Radiothorium, Mesothorium and Strontium and the	000100
of Dogs. 1. The Distribution of Plutonium, Radium,	0Radiothorium, Mesothorium, and Strontium and the	000097
Instrumentation Techniques in Applied Radioactivity*	0Radium and Mesothorium Poisoning and Dosimetry and	000012
0Hazard in the	0Radium and Mesothorium Refining Plant at the University	000077
0Relative Biological Effectiveness of	0Radium and Other Alpha Emitters in CF No. 1 Female Mice	000070
Chemical Form. 8.*	0Radium and Thorium through the Gut as a Function of	000006
Puriform Rodents in the Biogenic Migration of Uranium,	0Radium and Thorium under Different Radioecological	000287
0Measurement of	0Radium and Thorium Burdens*	000084
0Accumulation of Thorium, Uranium, and	0Radium by Plants and Organisms in Horizons of Soils*	000205
0Distribution of Uranium and	0Radium in the Podzolic Mountain Soils of This Forest*	000341
0Analysis of Isotopic	0Radium in Thorium Mill Effluents*	000219
Use of Asphalt Emulsion Sealants to Contain Radon and	0Radium in Uranium Tailings*	000707
Determination of Alpha-Emitting Nuclides of	0Radium through Californium in Soil*	000254
0Pledged Reversion Canals and Skeletal Dose in	0Radium Cases*	000517
Mountain Soils of This Forest*	0Radium Content in the Silt Fraction of the Podzolic	000362
Parents within the Body* 0Retention and Elimination of	0Radium Isotopes Produced by the Decay of Thorium	000502
0The Simultaneous Determination of Thorium, Plutonium,	0Radium Isotopes, Lead 210, Iron 55, Silicon 32 and	000012
in Surface Waters of the Colorado River Basin,	0Radium Monitoring Network, 1968*	000049
0Bone Cancers Induced by	0Radium 224 (Th X) in Children and Adults*	000518
of Short-Lived Bone-Seeking Alpha Emitters	0Radium 224 and Thorium 227 in Mice* after Incorporation	000119
the Temporal Distribution of Skeletal Alpha-Doses from	0Radium 224 and Thorium 227* of Late Effects in Mice on	000067
Considerations of Radium	0Radium 224 and Thorium 226 and Source Dosimetric	000067
and Thorium 226 and Source Dosimetric Considerations of	0Radium 224 in Human Beings* and Absorption of Radium 224	000067
Thorotrast*	0Radium 224 Following Intravascular Administration of	000505
0The Skeletal Dose from	0Radium 226 and their Daughters in the Human Body*	000519
0Measurement of the Natural Content of Thorium 226,	0Radium 226 and Thorium 228 in Soviet-Made Phosphorus	000351
Fertilizers*	0Radium 226 and Thorium 228 in Thyroids of Cattle from	000063
Nigeria, W. Africa*	0Radium 226 in Food and Man in Bombay and Kerala State	000399
India*		

TITLE INDEX

- New Zealand Seals--their Relationship 0Uranium 238 and 002331
and Volume Deposits of Plutonium 239, Thorium 228, and 000125
with Plutonium 239, Thorium 228, Radium 226 and 000165
228 and Thorium 228 in the Presence of Gross Amounts of 023618
0Comparative Uptake of Thorium 230, 020202
Thorium 230 Studies of the Retention and Distribution of 000152
Thorium 228 0Studies of the Biological Effects of 000060
Strontium 90 to the 0The Comparative Toxicity of 000041
Strontium 90 to Leukocytes 0Sequential Determination of 000083
Isotopes in Environmental 0The Cooperative Toxicity of 002252
Incidence Observed in Beagles with Retained Burdens of 000173
Biological Samples 0Measurement of 000644
Water Quality Surveillance Stations Located in the 003651
and Distribution of Radium 226, Plutonium 239, 001152
of the Biological Effects of Radium 226, Plutonium 239, 000060
in Dogs Fed with Plutonium 239, Thorium 228, 002169
Toxicity of Radium 226, Plutonium 239, Thorium 228, 000061
Ascents of Radium 0Low-Level Determination of Skeletal 000618
Toxicity of Radium 226, Plutonium 239, Thorium 228, 000083
Environmental 0Sequential Determination of Radium 226, 000252
in Beagles with Retained Burdens of Radium 226, 000173
of Soluble Compounds of Thorium 232, Natural Thorium, 000709
Total Toxicity Experiments with Uranium, Plutonium, and 005071
0Content and Distribution of Uranium, 002364
0Distribution and Redistribution of Uranium, 002292
Their Possible Radiation Hazards 0Uranium, 001355
with Particular Reference to Plutonium, Thorium, 000535
0Procedure for Measuring Uranium, Thorium, 000261
in Dog Teeth. 1. The Distribution of Plutonium, 000190
in the Teeth of Dogs. 1. The Distribution of Plutonium, 000097
Apparatus for the Determination of Minute Quantities of 000578
0The Concentration of 000203
0Radiation Dose to the Respiratory System Due to 000427
0Estimation of Lung Tissue Dose from the Inhalation of 002386
0Effects of Uranium Ore Dust, 002196
0Use of Asphalt Emulsion Sealants to Contain 000707
for the Determination of Minute Quantities of Radium, 000578
Characteristic Differences Between the Etch Pits Due to 000607
Diffusion Coefficients and Attachment Fraction of 000376
to the Trachea and Bronchi from the Decay Products of 000398
0The Tolerance Concentration of 000630
Near Uranium Mill Tailings 0Measurements of 000591
0Size Distribution of 002702
0Deposition of Natural 000420
0Effects of Depressing Attachment of 000619
Respiratory System 0The Distribution and Deposition of 000498
Cigarette Smoke in Dogs and Monkeys 0Studies of Inhaled 000162
0Exploratory Study of the Use of TSC Dosimeters in 000373
0Integrating 000378
0Activity and Potential Alpha-Energy of Radium 222 and 000599
Tract by Inhalation of Short-Lived Radium 222 and 000447
Atmospheres 0Activity and Potential Alpha-Energy of 000599
Human Respiratory Tract by Inhalation of Short-Lived 000447
0Health Effects of 000499
Concentrations of the Short-Lived Daughter Products of 000573
0Measurements of 000620
Uranium in Water 0A 000256
Alpha Radioactivity in Urine 0 000563
Extraction Chromatography in Urines Containing DTPA 000228
with the Etch-Pit Counting Method 000624
Determinations of Thorium in Technological Solutions of 000610
Vegetation 0The Concentration of Thorium and 000211
Preconcentration in an 0Spectrographic Determination of 000571
with Natural Radioactive Substances a. Enterprises of 000710
Uranium in Ore, Concentrate, and Milling Dusts of 000066
is the Deposition of Plutonium and Related Elements, in 000172
of Transyl Nitrate on the Peripheral Lymphocyte of the 0The Effects of Tetracycline
on the Retention of Actinide Elements in the 0The Elastogenic Effect
of Bone Tumors in the Dog and Skin Tumors in the 000171
Cebaitic Crabs by the Pericardioendothelial System of the 000202
Retention and Biologic Effects in the Monkey, Dog and 000197
0Beta-Gamma Dose 000114
Thorostrast 0Mean Org. Dose 000718
0Production 000455
Uranium-Series and Hydration-Pind Dating 0Growth 000660
0A Comparison of Theoretical and Measured Dose 000333
Assessment of the 0The Estimation of Radiation Dose 000713
0Recycled Thorium Dose 000199
Geologic Factors Controlling Terrestrial Gamma-Ray Dose 000719
0Effects of Depressing Attachment 000369
Nuclear Fuel Cycle 0The 000630
0Uranium-Thorium and Lead Isotope 000380
228/Thorium 232 and Thorium 230/Thorium 232 Activity 000366
Lithium Spectrometric Measurements of Isotopic Uranium 000347
Disintegration Constant of Thorium and the Branching 000352
0Tissue Distribution and Steady State Activity 000662
222 in Sea 0Thorium Concentration and the Activity 000454
Radium 226 Equilibrium and Thorium: Uranium Ratio in 000331
Radium 226 of Localized Alpha Dose III from Surface 000125
Radium 226 Other Serum Constituents in Dogs Burdened 000165
Radium 226 0Low-Level Determination of Skeletal Radium 023618
Radium 226, Lead 210, and Polonium 210 by Plants 020202
Radium 226, Plutonium 239, Radium 228 (Mesothorium I) 000152
Radium 226, Plutonium 239, Radium 228 (Mesothorium I), 000060
Radium 226, Plutonium 239, Thorium 228, Radium 228 and 000041
Radium 226, Plutonium 239, Thorium 228, Radium 228, and 000083
Radium 226, Radium 228, Actinium 227, and Thorium 002252
Radium 226, Radium 228, Thorium 228, Plutonium 239 or 000173
Radium 226, Thorium 232 and Daughter Products in 000644
Radium 226, Uranium and Other Radiological Data from 003651
Radium 228 (Mesothorium I) Thorium 228 (Radiothorium), 001152
Radium 228 (Mesothorium I), Thorium 229 (Radiothorium), 000060
Radium 228 and Radium 226 and Other Serum Constituents 002169
Radium 228 and Strontium 90 to the Hematopoietic System 000061
Radium 228 and Thorium 228 in the Presence of Gross 000618
Radium 228 and Strontium 90 to Leukocytes of Beagles 000083
Radium 228, Actinium 227, and Thorium Isotopes in 000252
Radium 228, Thorium 228, Plutonium 239 or Strontium 90 000173
Radium 232 and Thorium 228 in the Air of Factories 000709
Radium 0Incidence of Malignant Bone Tumors in the Long 005071
Radium, and Thorium in Mountain Tundra Soils 002364
Radium, and Thorium in Natural Biogeochemical 002292
Radium, and Thorium Content in Phosphate Rocks and 001355
Radium, Iron and Gold 0of Radioisotope Incorporation 000535
Radium, Plutonium, and Americium in Soil Samples 000261
Radium, Radiothorium, Mesothorium and Strontium and the 000190
Radium, Radiothorium, Mesothorium, and Strontium and the 000097
Radium, Radium and Thorium in Solids, Liquids and Gases 000578
Radium, Thorium, and Uranium by Tropical Algae 000203
Radon and its Daughter Products 000427
Radon and Daughters 002386
Radon and Products of its Decay in the Lungs of Rats 002196
Radon and Radium in Uranium Tailings 000707
Radon and Thoron in Solids, Liquids and Gases 000578
Radon and Thoron Alpha Particles in CA90-15 and LF-115 000607
Radon and Thoron Decay Products 0Useful for Measuring 000376
Radon and Thoron 0The Dose 000398
Radon in the Atmosphere 000630
Radon Daughter Concentrations in Structures Built on or 000591
Radon Daughter Particles in Uranium Mine Atmospheres 002702
Radon Daughters in Human Subjects 000420
Radon Daughters in Uranium Mine Atmosphere 000619
Radon Daughters Attached to Dust Particles in the 000498
Radon Daughters, Uranium Ore Dust, Diesel Exhaust, and 000162
Radon Monitoring 000373
Radon Progeny Air Sampler 000378
Radon 220-Daughters in Different Air Atmospheres 000599
Radon 220-Decay Products Dose to the Human Respiratory 000447
Radon 222 and Radon 220-Daughters in Different Air 000599
Radon 222 and Radon 220-Decay Products 0The Dose to the 000447
Radon 222 from Uranium Mining 000499
Radon 222 in the Atmosphere 0A Method for Measuring the 000573
Radon 222 Flux from Inactive Uranium Mill Tailings Piles 000620
Rapid and Sensitive Neutron Activation Method for 000256
Rapid and Simple Method for Determination of Total 000563
Rapid Determination of the Transuranium Elements by 000228
Rapid Method of Confirmation of Fissionable Materials 000624
Rare Earth Manufacture 0Spectrometric 000610
Rare Earths by Plants at Different Times during 000211
Rare Earths in Thorium Compounds. Chromatographic 000571
Rare Metals Production 0Radiation Safety Extent in Work 000710
Rare Metals of Natural Radioactive Materials (Thorium, 000066
Rat Bone 0The Effects of Tetracycline 000172
Rat 0The Elastogenic Effect 000017
Rat 0The Effects of Desferrioxamine 000171
Rat 0Radiation Dose-Time Relations for Irradiation 000202
Rat 0Phagocytosis of Colloidal Thorium Dioxide and 000197
Rat 0Natural Uranium Dioxide (UO₂) Dust. Postexposure 000114
Rates from Uranium 232 in Uranium 233 000718
Rates in Man Following Intramuscular Injection of 000455
Rates of Neutrons in Soils Due to Natural Radioactivity 000660
Rates of Pacific Manganese Nodules as Defused by 000333
Rates of Thorium and Thorium Oxide 000713
Rates to Fish in Contaminated Environments, and the 000199
Rates 000719
Rates 000369
Ratios of Radon Daughters in Uranium Mine Atmosphere 000630
Ratios for and Implementation of ALARA for the 000380
Ratios as Indicators of Oceanic Water Masses 000366
Ratios from Archean Basalts 000347
Ratios in Backwater Sediments along the West Coast of 000352
Ratios in Soils Treated with Apatite-Derived Fertilizers 000662
Ratios of Thorium C 0The 000454
Ratios of Thorium 232 and Daughters in Man Following 000356
Ratios Thorium 230/Thorium 232 and Thorium 228/Thorium

TITLE INDEX

Administration*	The Behavior of Thorium Dioxide in	Rats after Intratracheal and Intraperitoneal	000167
Metabolism of Thorium Saw Radioisotopes in the Body of		Rats after Intratracheal Introduction of Soluble	000121
	Long Tumors in	Rats after Thorium Dioxide Administration*	000081
Morphological Changes in the Lungs and Other Organs in		Rats on Intratracheal Administration of Thorium Dioxide*	000076
of Radioisotopes of the Thorium Family in Organs of		Rats upon Intratracheal Introduction of a Dissolved	000122
Selective Tissue Accumulation of Uranium and Thorium in		Rats After Inhalation of Uranium Ore Dust*	000157
The Thoron Content (Thoron 220) of the Air Expired by		Rats After Intratracheal Administration of Thoron	000137
on Short-lived Internal Alpha-Emitters in Mice and		Rats, Part 2. Thorium 227*	000132
Long-Term Effects of Inhaled Triethyl Nitrate in		Rats*	000009
Thorium Induced Testicular Changes in		Rats*	000170
Effect of Monazite on Early Organs of		Rats*	000259
Effect of Thorium Dioxide on the Peripheral Blood of		Rats*	000166
Inhaled Triethyl Nitrate (Uranium 232 and Uranium 233) in		Rats*	000008
and Tissue Distribution of Ions (Thorium 230) in		Rats*	000225
Dust, Water and Products of its Decay in the Lungs of		Rats*	000196
Inhaled Triethyl Nitrate (Uranium 233) and Uranium 232 in		Rats*	000010
Dioxide and Development of Liver Epithelial Tumors in		Rats*	000082
and Thorium Following Inhalation of Uranium Ore by		Rats*	000158
of Stimulation of the Nerve-Muscle Apparatus in		Rats*Thorium Dioxide on Arterial Pressure and Threshold	000169
Intratracheal Introduction of		Rat Radioisotopes in the Body of Rats after	000121
	Alpha-	Rat Activities of Humans and their Environment*	000531
	The Naturally Occurring Alpha-	Rat Activity of Foods*	000215
	The Alpha-	Rat Activity of Human Tissues*	000530
	Geologic Factors Controlling Terrestrial Gamma-	Rat Dose Rates*	000369
of Uranium and Thorium Solutions with a Semiconductor X-		Rat Emission Spectrometry*	000609
of Fallout Cesium 137 and Naturally Occurring Gamma-		Rat Emission Spectrometry*	000631
Thorium 232. Assessment of Radioactivity in San Gamma-		Rat Spectra for Uniformly Distributed Uranium 238,	000443
Radiation Dose from Thorotrast Using Whole-Body Gamma-		Rat Spectral Data*	000567
and Application of High Sensitivity Airborne Gamma-		Rat Spectrometer Data*	000638
Barium Gamma-		Rat Spectrometer Experiments over the Canadian Shield*	000570
Other Biological Materials*		Rat Spectrometric Determination of Thorium in Bone and	000283
Concentration Measurements Made by Airborne Gamma-		Rat Spectrometry over the Canadian Shield* Radioelement	000564
in Soils Using High-Resolution Germanium-Lithium Gamma-		Rat Spectrometry* Measurement of ppm Levels of Uranium	000223
Total and Spectrometric Gamma-		Rat Surveys from Helicopters and Vehicles*	000546
Determination of Thorium, Uranium, Zirconium, and		Rat-Fluorescence Analysis of Powdered Rock Samples.	000545
226 Decay Series in Adult Beagle Dogs. I. Thorium 228 (		228Th)*	000151
Fuel Concepts for the High Temperature Thorium		Reactor and Their Consequences for Fuel Recycling*	000311
Economic Incentive for Thorium		Reactor Development*	000310
Cycle - Reprocessing of High-Temperature Gas-Cooled		Reactor Fuel Containing Uranium 233 and Thorium*	000735
Fuel Cycle - Fabrication of High-Temperature Gas-Cooled		Reactor Fuel Containing Uranium 233 and Thorium* Nuclear	000739
Methods and Costs for Selected Thorium-Bearing		Reactor Fuel Types*	000680
Plutonium Recycle and the Use of Thorium Fuels in Power		Reactor Operations*	000675
Report*		Reactor Programs: Thorium Utilization Program Progress	000674
An Assessment of U.S. Domestic Capacity for Producing		Reactor-Grade Thorium Dioxide and Controlling	000669
Assessment of the Thorium Fuel Cycle in Power		Reactors*	000309
Technical and Economic Characteristics of Thorium		Reactors*	000315
Uranium Mill Monitoring for Natural Fission		Reactors*	000550
High Nitrate Denitrification in Continuous Flow-Stirred		Reactors*	000231
Preliminary Assessment of Thorium as a Fuel for Thermal		Reactors*	000305
Cycle in Heavy Water Moderated Pressure Tube (CANDU)		Reactors*	000306
Fuel Cycle for Heavy Water Moderated Organic Cooled		Reactors, Technical Progress Report No. 5, April-June,	000297
Internally Deposited Thorium by Means of Studies with a		Realistic Phantom* Determination of the Distribution of	000507
Histopathological Endpoints in Compact Bones		Receiving Alpha Irradiation*	000090
Changes*		Recognition of Radiation-Induced Late Bone Marrow	000617
Uranium 234/Uranium 238 Disequilibrium in Nature*		Recall Thorium 234: Dissolution Into Water and the	000661
Revision of the NCRP and ICRP		Recommendations on Internal Dose*	000662
Samples*		Records of Plutonium Fallout in Marine and Terrestrial	000276
The Assessment of Internal Contamination Resulting from		Recurrent or Prolonged Uptakes*	000445
Operations*		Recycle and the Use of Thorium Fuels in Power Reactor	000475
		Recycled Thorium Dose Rates*	000719
		Recycled Uranium 233-Thorium Fuels*	000665
		Recycling*	000729
States Concerning the Physics Aspects of Actinide Waste		Recycling*	000311
Thorium Reactor and Their Consequences for Fuel		Recycling*	000338
Lead Isotopic Compositions in Sediment Samples from the		Red Sea* on Uranium, Thorium, and Lead Contents and	000292
Natural Biogeochemistry*		Distribution of Uranium, Radium, and Thorium in	000679
		Reduction of Hazardous Radiation in Uranium Mines*	000382
		Beefs during Diagenesis*	000365
		Reevaluation of the Marine Geochemistry of Uranium*	000587
		Refinery*	000681
Industrial Hygiene and Medical Survey of a Thorium		Refining of Mesothorium*	000677
		Refining Plant at the University of Missouri*	000513
		Refining Radioactive Substances*	000408
		Region in Man*of Colloidal Thorium Dioxide Extravasates	000370
		Regions*	000328
		Regional Variations of Uranium Content in Daily Diet	000495
		Regions of Elevated Natural Radiation*	000557
		Registration in Polymers*	000710
		Regulation of Radiation Safety Extent in Work with	000706
		Regulations in Uranium Mines*	000337
		Relationships as Uranium Prospecting Guides*	000184
		Relatively Insoluble Materials from Lung to Lymph Nodes*	000288
		Released to the Biosphere* Devices. 4. Handbook for	000267
		Releases from the Nuclear Fuel Cycle*	000268
		Releases from LWR Fuel-Cycle Facilities* and Effects	000159
		Repeated Inhalation Exposures of Laboratory Animals to	000365
		Replica Method*	000575
		Reporting Considerations for Airborne Particulate	000735
		Reprocessing of High-Temperature Gas-Cooled Reactor	

TITLE INDEX

- Improved Waste Management in Commercial Nuclear Fuel
Bearing Reactor Fuel Types* 000480
- Thorium Resources in the United Arab
Reprocessing Facilities* 000480
- Reprocessing Methods and Costs for Selected Thorium-
Republic and their Possible Utilization* 000480
- Research in Radiobiology* 000480
- Research in Radiobiology, An Annual Report of Work in
Research in Radiobiology, Annual Report of Work in
Research in Radiobiology, Annual Report of Work in
Research in Radiobiology, Annual Report of Work in
Research in Radiobiology, Annual Report of Work in
Research in Radiobiology, Annual Report of Work in
Research in Radiobiology, Semiannual Report of Progress
Research in Radiobiology, Semiannual Report of Work in
Research in Radiobiology, Semiannual Report of Work in
Research Division Annual Report, July 1972 through June
Researching Physiologic Fluids* 000480
- Reservoir* Vegetation in Processes of "Iteration
Reservoirs, Communication to 000480
- Residence Times, and Sources of Some Elements to Lake
Residual Body Activity*Accidental Reactor Contaminated
Resin and Delayed-Neutron Counting* 000480
- Resin* 000480
- Resolution Germanium-Lithium Gamma-Ray Spectroscopy* 000480
- Resources in the United Arab Republic and their
Resources in the United States and the Effect of Policy
Respirable Size Range* 000480
- Respiratory Pattern Upon Hazards Evaluation Following
Respiratory System of Human Exposed to Uranium Fine
Respiratory System Due to Radon and its Daughter
Respiratory Tract by Inhalation of Short-lived Radon
Respiratory Tract from Continuous Inhalation of
Respiratory Tract* 000480
- Respiratory Tract* 000480
- Responses to Internal Irradiation in the Beagle* 000480
- Retained Burden of Radium 226, Radium 228, Thorium
Retained Radioisotope Burden* 000480
- Retention and Absorption of Radium 226 and Thorium 232
Retention and Biologic Effects in the Monkey, Dog and
Retention and Distribution of Radium 226, Plutonium
Retention and Distribution of Uranium 233 in Mice* 000480
- Retention and Distribution of Uranium 233 in Mice* 000480
- Retention and Elimination of Radium Isotopes Produced
Retention and Excretion Equations for Different
Retention and Translocation of Inhaled Uranyl Nitrate
Retention in Tissues* 000480
- Retention of the Daughters of Thorium 232 in the Soft
Retention of Actinide Elements in the Fat* 000480
- Retention of Inhaled Particles* 000480
- Retention Functions in the Human Metabolism of Uranium
Retention, and Late Effects of Thorium Dioxide* 000480
- Reticuloendothelial System (Liver, Spleen, Lymph Nodes,
Reticuloendothelial System of the Fat* 000480
- Retrograde Pyelography with Colloidal Thorium Dioxide* 000480
- Review of the Radiosensitivity of the Tissues in Bone* 000480
- Review of Uranium Inhalation Case* 000480
- Review Emphasizing Behavior Applicable to the Thorium
Review* 000480
- Revision of the WCRP and ICRP Recommendations on
Rhyolites in the West Carpathians* 000480
- Rice Fields* 000480
- Risk Dating Techniques* Rates of Pacific Manganese
Risk at Low Dose from Experimental Results after
Risk Data Derived from Portuguese Thorotrast Experience* 000480
- River Basin of Colorado, Utah, New Mexico and Arizona -
River Basin, Radium Monitoring Network, 1968* 000480
- River Water in the Eastern Part of Shikane Prefecture -
River, and Hill Creek, June-August 1968* in Selected
River, the Little Miami River, and Hill Creek, June-
Rivers Due to Fertilizers* 000480
- Rock Samples, Determination of Thorium, Uranium,
Rocks and their Possible Radiation Hazards* 000480
- Rocks* 000480
- Rocks* A Comparison of Some Analytical Techniques for
Rocks* Uranium, Thorium, Lead, Lanthanoids and Yttrium
Rocks in the Biogenic Migration of Uranium, Radium
Rocks in Soil with an Increased Content of Neutrons
Röntgen-angiographic Findings in Two Additional Cases
Route of Injection and Amount of Carrier Present* 000480
- Rural Soils* 000480
- S Disease Following Thorium Dioxide Angiography* 000480
- S Disease) Occurrence Twenty-Eight Years after Thorium
S Manual* 000480
- S Whole Body Counter--Its Use and Calibration* 000480
- S. Atomic Energy Commission Sites* 000480
- S. Domestic Capacity for Producing Reactor-Grade
S. Leads Toward Denatured Thorium Cycle* 000480
- S. Safety in Handling the Heavy Metals* 000480
- Safety in Uranium and Thorium Mines and Mills* 000480
- Safety Extent in Work with Natural Radioactive
Substances at Enterprises 000480
- Rehabilitation of Radiation 000480
- Progress on the Chronic Toxicity Program* 000480
- Progress on the Chronic Toxicity Program* 000480
- Progress in the Internal Irradiation Program* 000480
- Progress on the Chronic Toxicity Program* 000480
- Progress on the Chronic Toxicity Program* 000480
- Progress in the Internal Irradiation Program* 000480
- Progress on the Chronic Toxicity Program* 000480
- Progress on the Chronic Toxicity Program* 000480
- 1573* 000480
- Radiological and Environmental
of Certain Thorium-Containing Substances in Media
and Distribution of Natural Radioactive Elements in the
Behavior of Natural Radioactive Elements in Standing
Michigan* 000480
- Plumes,
with Thorium 227. Studies on Elimination and
in Natural Water by Preconcentration on Anion-Exchange
Applications of a Propyleneimineacetic Acid
of ppm Levels of Uranium in Soils Using High-
Possible Utilization* 000480
- Thorium
Alternatives* 000480
- Assessment of Uranium and Thorium
of Coal, Uranium Dioxide, and Thorium Dioxide in
Inhalation 000480
- Influence of Aerosol Properties and the
of Radon Daughters Attached to Dust Particles in the
Products* 000480
- Radiation Dose to the
222 and Rader 222-Decay Products*The Dose to the Human
Radioactive 000480
- Calculation of the Burden and Dose to the
Radioactive Materials--Determinants of Dose of the
of the Penetration of Radioactive Aerosols into the
Some Hematological
Non-Skeletal Tumor Incidence Observed in Beagles with
Electrocardiogram Evaluation of Radium 224 in
and Source Dosimetric Considerations of Radium 224 in
with Natural Uranium Dioxide (UO2) Dust. Postexposure
239, Radium 228 (Radium 228) Thorium 232*Studies of the
The
Progress Report: The
by the Decay of Thorium Parents within the Body-
Patterns of Uptake* 000480
- Uranium 233 and Uranium 232) in Rats* 000480
- The Radioactivity from Thorotrast and Its
Tissue in Animals* 000480
- The Effects of Desferrioxamine on the
An Interspecies Model for
Kidney and Bone
Distribution,
Some Aspects of
Pathological Findings in the
of Colloidal Thorium Dioxide and Colloidal Oxide by the
Tumors of the Kidney Following
The
Fuel Cycle* 000480
- Uranium and Thorium in the Biosphere: A
Substances, Part 3. Uranium and Thorium (A Literature
Internal Dose* 000480
- Geochemistry of Radioactive Elements in
Accumulation of Radioactivity in
Nodules as Deduced by Uranium-Series and Hydration
Incorporation of Short-Lived Bone- 000480
- Estimation of Tumor
Human Leukemic
Quality Surveillance Stations Located in the Colorado
Specificity in Surface Waters of the Colorado
with Special Emphasis on Chemical Characteristics of
Ohio Streams, the Great Miami River, the Little Miami
Levels in Selected Ohio Streams, the Great Miami
High Uranium Content in
Zirconium, and X-Ray-Fluorescence Analysis of Powdered
Uranium, Radium, and Thorium Content in Phosphate
Determination of the Thorium Content of
Determining Uranium, Thorium, and Potassium in Granitic
in Some Plants Growing on Granitic and Radioactive
and Thorium under Different 000480
- The Role of Urifur
of the Uranium 000480
- External Beta-Irradiation of Mouselike
with 000480
- Thorium Induced Hepatic Reticuloendotheliosis
and Excretion of Thorium with Emphasis upon the
Natural Radionuclides in Industrial and
Hodgkin's
Administrative* 000480
- Erythroleukemia (D. Gagliardo)
Radiological Emergency Operations, Student* 000480
- The Radiation Protection Division* 000480
- of Public Radiation Exposure in the Vicinity of U.
Thorium Dioxide and Controlling 000480
- An Assessment of U.
Health and
Manual on Radiological
Substances at Enterprises 000480
- Rehabilitation of Radiation 000480

Health and
Spaciobiology

- 0 Safety Features in the Design of Radiobiological
- 1 Safety Laboratory Manual of Standard Procedures
- 2 Safety Manual
- 3 Safety Manual
- 4 Radiography with Thorotrast
- 5 Salts of Strontium and Other Metals on Plutonium and
- 6 Sampler Useful for Measuring Diffusion Coefficients of
- 7 Samples
- 8 Sampling and Data Reporting Considerations for Airborne
- 9 San Juan County, Utah
- 0 Strontium-90 Operations
- 1 Sand in Animal Tissues, Part 2
- 2 Sem
- 3 Radiobiological Aspects and Radiation
- 4 Sands and Soils, February-June 1969
- 5 Santa Barbara Basin: Iron 55 as a "Unique Tracer for
- 6 Sarcoma and Hepatic Cholangiocarcinoma in Syrian
- 7 Serum in Dogs

Sarcosa Incidence vs. Alpha Particle Dose*
 Saving Techniques Developed for Lower Grade Uranium Ores
 Scandium, Thorium, Salter, and Other Trace Elements in
 Scintillation Methods* Determination in Environmental
 Scintillator Method for the Analysis of Biological
 Sea and the Baltic. Multielement Analyses Using
 Sea and Surface Waters by Neutron Activation Analysis
 Sea Cores*
 Sea Drilling Project, Leg 23*
 Sea Water and Beccat Coral in the North Pacific*
 Sea Water in the Western North Pacific* Activity Ratios
 Sea Water* #Semi-Quantitative
 Sea*
 Sea* on Uranium, Thorium, and Lead Contents and Lead
 Sea-Water*
 Seaweeds and Marine Protein Concentrates*
 Sealants to Contain Radon and Arsenic in Uranium Tailings
 Seasonal and Regional Variations of Uranium Content in
 Seawater*
 Seawater* #Semi-quantitative
 Sediment Samples from the Red Sea* on Uranium, Thorium,
 Sediments along the West Coast of India*Thorium 232 and
 Sediments and their Absolute Concentrations in the
 Sediments of the Drauzog, Carinthia, Austria*
 Sediments* #Natural
 Sediments* #Determination of Palladium in
 Sediments* on the Surface Layers of the Coastal
 Seeding Growth, Excised Cetylones, Chlorophylls,
 Seeking Alpha Emitters Radium 226 and Thorium 227 in
 Seeking Radioisotopes*
 Seeking Radionuclides and Assessment of Absorbed Dose*
 #

- o Seeking Radionuclides and Zones*
- o Seeking Radionuclides*
- o Seeking Radionuclides*
- o Seeking Radionuclides*
- o Seeking Radionuclides*
- o Selected Bibliography*
- o Selected Fuel Cycles*
- o Selected Ground Water Supplies in the Grants Mineral
- o Selected Rio Arriba, the Great Miami River, the
- o Selected Thorium-Bearing Reactor Fuel Types*
- o Selective Tissue Accumulation of Uranium and Thorium in
- o Semi-Quantitative Determination of Uranium, Plutonium,
- o Semiannual Progress Report*
- o Semiannual Report of Progress in the Internal
- o Semiannual Report of Work in Progress on the Chronic
- o Semiannual Report of Work in Progress on the Chronic
- o Semiconductor X-Ray Emission Spectrometer*
- o Semi-quantitative Determination of Uranium, Plutonium,
- o Sensitive Method for the Determination of Low Uranium

- 4 Sensitive Neutron Activation Method for Uranium in Water
- 8 Sensitivity Airborne Gamma-Ray Spectrometer Data*
- 9 Separation and Radiochemical Determination of Uranium
- 0 Separation of Long-Lived Uranium Chain Alpha-Emitters
- 1 Separation of Uranium and Thorium After Inhalation of
- 5 Preparations to Determination of Trace Elements in

- Sequence of Histopathologic Changes in Teeth Containing
- Sequence of Histopathologic Changes in Teeth Containing
- Sequential Determination of Radii 226, Radii 229,
- Series (77-Grated Results) • Epidemiological
- Series and Hydration-Pair Dating Techniques • Dates
- Series and Hydration-Pair Dating Techniques • Dates

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TITLE INDEX

Determination of Trace Quantities of the Thorium 232 in Plants and in Two Magnesian Differentiation	Series*	Absolute	001569
of the Pittsburgh Thorotrast	Series* Determination of Thorium, Uranium and Potassium		001592
of Fallout Products on Biochemical Indices of Blood	Series--Report of a Cytogenetic Study*		001594
of Comparison of Serum Transaminase Levels and Other	Serum in Cows*	Effect	001597
	Serum Constituents in Dogs Fed with Plutonium 239,		001598
Coagulation, 1. Evidence for and Properties of a New	Serum Immunoglobulins in Translating Winers after a Workload		001599
in Dogs Fed with Plutonium 239, 2. A Comparison of	Serum Lactic Dehydrogenase Levels in Adult Beagle Dogs*		001600
in the Human Body, Air and Water*	Serum Thromboplastin Factor*	and Actinides in Blood	001601
Basin: Iron 55 as a Unique Tracer for Particulate	Serum Transaminase Levels and Other Serum Constituents		001602
Hepatic Duct Carcinoma	Setback Stents Growth*		001603
Distribution and Effects in Rabbits*	Setting the Various Permissible Limits of Plutonium 239		001604
of the Microgram Amount of Thorium in Plants,	Settling*	Geochronological Studies in Santa Barbara	001605
Gamma-Ray Spectrometer Experiments over the Canadian	Seventeen Years after Injection of Thorium Dioxide*		001606
By Airborne Gamma-Ray Spectrometry over the Canadian	Sex Hormones and Tissues on Colloidal Thorium Dioxide		001607
Use of Thoriated Tungsten Electrodes in Inert Gas	Shells, and Corals*	Respiration	001608
Characteristics of River Water in the Eastern Part of	Shield*	Airborne	001609
Thorium, Plutonium, Radium Isotopes, Lead 210, Iron 55,	Shield* of - Bioelement Concentration Measurements Made		001610
Plutonium*	Shield* and Welding-- Investigation of Potential Hazard		001611
Species*	Shimane Prefecture -- with Special Emphasis on Cause of		001612
	Silicon 32 and Carbon 14 in Marine Suspended Phases*		001613
	Silt Fraction of the Podzolic Mountain Soils of Thin		001614
	Silver, and Other Trace Elements in Different Plant		001615
	Simulated Uranium Mine Atmospheres*		001616
	Simultaneous Determination of Alpha-Emitting Nuclides		001617
	Simultaneous Determination of Thorium, Plutonium,		001618
	Simultaneous Determination of Uranium and Thorium*		001619
	Simultaneous Determination of Uranium 235, Uranium 238,		001620
	Single Inhalation Exposure to the Citrate Complex and		001621
	Single-Sweep Polarographic Techniques Useful in		001622
	Sinusitis*	Follow-Up Study of Portuguese	001623
	Site* Characteristics of Soil and Perennial Vegetation		001624
	Sites*	Assessment of Public Radiation Exposure	001625
	Siting Studies in Poland*	Environmental	001626
	Sizes*	Concentrations of Uranium	001627
	Skeletal Alpha-Doses from Radium 226 and Thorium 232*		001628
	Skeletal Dose from Radium 226 Following Intravascular		001629
	Skeletal Dose in Radium Cases*		001630
	Skeletal Dosimetry in Utah Beagles*		001631
	Skeletal Hazards*		001632
	Skeletal Radium 226 and Thorium 232 in the Presence of		001633
	Skeletal Tumor Incidence Observed in Beagles with		001634
	Skeleton: Naturally Occurring Radioisotopes in Man*		001635
	Skin Tumors in the Fat*	Radiation Dose-Time	001636
	Slurries*	Preparation	001637
	Smoke in Dogs and Mice*	Inhaled Radon Daughters,	001638
	Smokers and Nonsmokers*		001639
	Sociological Analysis of the Perception of Hazardous		001640
	Soft Tissue in Animals*		001641
	Soft Tissue Year Radioactive Bone*		001642
	Soft Tissues*	The Determination of Trace Levels	001643
	Soft-Tissue Tumors in Internally Irradiated Beagles*		001644
	Soil and Perennial Vegetation in Northern Mojave Desert		001645
	Soil with an Increased Content of Nuclides of the		001646
	Soil Picas from Antarctica by the Fission Particle		001647
	Soil Particles in Relation to their Sizes*		001648
	Soil Samples by Neutron Irradiation*		001649
	Soil Samples*	Procedure for Measuring	001650
	Soil*		001651
	Soil*	Simultaneous Determination of Alpha-	001652
	Soils and Natural Waters*		001653
	Soils by Two Stage Ion Exchange*		001654
	Soils in Landscapes of the Volchynsky Forest-Steppe of		001655
	Soils in Relation to Landscape Development*		001656
	Soils of Thin Forests*	Distribution	001657
	Soils of Thin Forests*	Thorium and Radium	001658
	Soils Containing Known Quantities of Radioisotopes*		001659
	Soils Due to Natural Radioactivity*		001660
	Soils Treated with Apatite-Derived Fertilizers*		001661
	Soils Using High-Resolution Germanium-Lithium Gamma-Ray		001662
	Soils*		001663
	Soils*		001664
	Soils*		001665
	Soils*		001666
	Soils*		001667
	Soils*		001668
	Soils*		001669
	Soils*		001670
	Soils*		001671
	Soils*		001672
	Soils*		001673
	Soils*		001674
	Soils*		001675
	Soils*		001676
	Soils*		001677
	Soils*		001678
	Soils*		001679
	Soils*		001680
	Soils*		001681
	Soils*		001682
	Soils*		001683
	Soils*		001684
	Soils*		001685
	Soils*		001686
	Soils*		001687
	Soils*		001688
	Soils*		001689
	Soils*		001690
	Soils*		001691
	Soils*		001692
	Soils*		001693
	Soils*		001694
	Soils*		001695
	Soils*		001696
	Soils*		001697
	Soils*		001698
	Soils*		001699
	Soils*		001700
	Soils*		001701
	Soils*		001702
	Soils*		001703
	Soils*		001704
	Soils*		001705
	Soils*		001706
	Soils*		001707
	Soils*		001708
	Soils*		001709
	Soils*		001710
	Soils*		001711
	Soils*		001712
	Soils*		001713
	Soils*		001714
	Soils*		001715
	Soils*		001716
	Soils*		001717
	Soils*		001718
	Soils*		001719
	Soils*		001720
	Soils*		001721
	Soils*		001722
	Soils*		001723
	Soils*		001724
	Soils*		001725
	Soils*		001726
	Soils*		001727
	Soils*		001728
	Soils*		001729
	Soils*		001730
	Soils*		001731
	Soils*		001732
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	Soils*		001948
	Soils*		001949
	Soils*		001950
	Soils*		001951
	Soils*		001952
	Soils*		001953

TITLE INDEX

Nitric Acid by Tributyl Phosphate-Carbon Tetrachloride Sulphate: In-Plant Monitoring of Transyl Nitrate Spectroscopic Determination of Thorium in Technological Quantitative Analysis of Uranium and Thorium by Tributyl Phosphate-Carbon Tetrachloride Solution*	Solvent Extraction of Thorium Nitrate and Solutions for Thorium* Solutions of Rare Earth Manufacture* Solutions with a Semiconductor X-Ray Emission Solvent Extraction of Thorium Nitrate and Nitric Acid Solvent Extraction Studies on Thorium Sulphate and Solvent Extraction-Liquid Scintillation Methods* Uranium Source Dosimetric Considerations of Radium 226 in Human Source Materials* Sources in Water* Spectra and Dosimetry of Neutrons from Sources of Space Elements to Lake Michigan* Sources on Roads Inside Above* Track Dosimeter for Sources to the Total Radiation Dose to Man* Sources* South Florida Sands and Soils, February-June 1965* South Greenland* South Wales* Southern Africa. 2. Thorium in Marine Life* Soviet Working Meeting on the Question of Radiation Soviet-Rate Phosphorus Fertilizers* Species* Species* on Seedling Growth, Excised Cotyledons, Specification of Units for Natural Uranium and Natural Species* Spectra and Dosimetry of Neutrons from Polarization of Spectra for Uniformly Distributed* Uranium 238, Thorium Spectra in Smokers and Nonsmokers* Spectral Data* Spectrographic Determination of Rare Earths in Thorium Spectrometer Data* Spectrometer Experiments over the Canadian Shield* Spectrometer* Spectrometric and Histo-Autographic Investigations Spectrometric Determination of Concentration of Spectrometric Determination of Thorium in Bone and Spectrometric Determination of Thorium in Technological Spectrometric Gamma-Ray Surveys from Helicopters and Spectrometric Investigation of Thorium Body Burdens in Spectrometric Measurements of Isotopic Uranium Ratios Spectrometric Techniques for Measuring Environmental Spectrometry and Fission Track Analysis in Nuclear Spectrometry in a Uranium Processing Plant* Spectrometry over the Canadian Shield* of Radioelement Spectroscopic Determination of Uranium, Thorium and Spectroscopy in Environmental Monitoring* Spectroscopy* Spindle Cell Sarcoma and Hepatic Cholangiocarcinoma in Spleen of a Thorotrast Case* Spleen, and their Efferent Lymph Nodes* Spleen, Lymph Nodes, Bone Marrow of Thorotrast Stage Ion Exchange* Standard Procedures* Standard Soils Containing Known Quantities of Standards of Soluble Compounds of Thorium 232, Natural Standing Reservoirs, Communication 1* Station Siting Studies in Poland* Station* Stationary Phase in Extraction Chromatography* Stations Located in the Colorado River Basin of Statistical Problems of Thorotrast Studies* Statistical Study* Status of the German Thorotrast Study* Steady State Activity Ratios of Thorium 232 and Steppe of the Tazov Region* Stimulation of the Nerve-Muscle Apparatus in Rats* of Stirred Reactors* Storage* Stresses Affected by Uranium Ore Mining and Milling* Streams, the Great Hural River, the Little Hural River, Strength* Strontium and the Sequence of Histopathologic Changes Strontium and the Sequence of Histopathologic Changes Strontium 90 in Adult Beagles* Strontium 90 to the Hematopoietic System of Beagles for Strontium 90 to Leukocytes of Beagles* Strontium 90* Strontium 90* Strontium 90* Strontium 90, Thorium 232 and Plutonium 239* Structures Built on or Near Uranium Mill Tailings* Student's Manual* Stucta Growth* Subcutaneous Tissues of the Cervical Region in Man* Subjects* Subjects* Substances at Enterprises of Rare Metals Production* Substances in Coastal and Estuarine Waters*	000481 000482 000483 000484 000485 000486 000487 000488 000489 000490 000491 000492 000493 000494 000495 000496 000497 000498 000499 000500 000501 000502 000503 000504 000505 000506 000507 000508 000509 000510 000511 000512 000513 000514 000515 000516 000517 000518 000519 000520 000521 000522 000523 000524 000525 000526 000527 000528 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001244 001245 001246 001247 001248 001249 001250 001251 001252 001253 001254 001255 001256 001257 001258 001259 001260 001261 001262 001263 001264 001265 001266 001267 001268 001269 001270 001271 001272 001273 001274 001275 001276 001277 001278 001279 001280 001281 001282 001283 001284 001285 001286 001287 001288 001289 001290 001291 001292 001293 001294 001295 001296 001297 001298 001299 001300 001301 001302 001303 001304 001305 001306 001307 001308 001309 001310 001311 001312 001313 001314 001315 001316 001317 001318 001319 001320 001321 001322 001323 001324 001325 001326 001327 001328 001329 001330 001331 001332 001333 001334 001335 001336 001337 001338 001339 001340 001341 001342 001343 001344 001345 001346 001347 001348 001349 001350 001351 001352 001353 001354 001355 001356 001357 001358 001359 001360 001361 001362 001363 001364 001365 001366 001367 001368 001369 001370 001371 001372 001373 001374 001375 001376 001377 001378 001379 001380 001381 001382 001383 001384 001385 001386 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001816 001817 001818 001819 001820 001821 001822 001823 001824 001825 001826 001827 001828 001829 001830 001831 001832 001833 001834 001835 001836 001837 001838 001839 001840 001841 001842 001843 001844 001845 001846 001847 001848 001849 001850 001851 001852 001853 001854 001855 001856 001857 001858 001859 001860 001861 001862 001863 001864 001865 001866 001867 001868 001869 001870 001871 001872 001873 001874 001875 00187
---	---	---

Probability of Certain Thorium-Containing Interaction of Plutonium with Complexing Agents	Substances in Media Resembling Physiological Plastics	000101
Other Inhalation of Radioactive Compounds in Defining Radioactive Non-Hazardous Effects of Thorotrast and Other Colloidal Compounds in the Tissue and Handling of Radioactive Compounds	Substances, Part 1. Thorium and Thorium (A) Interactions	000102
Other Toxicology of Radioactive Compounds	Substances, Volume 2, Thorium 232 and Thorium 230	000103
of the Radioecology of THORANTHUS POLYTHESIA L. in the Coastal, Marine, and Estuarine Environments, Protein and Other Elements and the Transuranium Elements Using Barium Solvent Extraction Studies on Thorium the Distribution and Excretion of Thorium	Sugar Contents in CITHARIDUS Species: Acetate on Seeding Sulfate Separation and Radiochemical Determination Sulphate and Halides	000104
Summary of the Chemical and Pathological Effects of Summary of Environmental Monitoring at Ames Laboratory, Summary, 1969	Environmental Radioactivity at Arizono Supplied by the Radiochemical Analysis of Tissue Supplies in the Grants Mineral Belt, New Mexico	000105
Information on Thorotrast Dosimetry Studies and Milling Operations on Selected Ground Water Dose, Determination of Localized Alpha Dose III from of Particulate Deposition in Air by Use of Studies of Thorium and Uranium Disequilibrium on the Excretion of Thorium	Surface Ionization Determination of Concentration Salt and Layers of the Coastal Sediments and their Surface Waters by Neutron Activation Analysis after Surface Waters of the Colorado River Basin, Reklam Surface Waters Single-Sweep Polarographic Techniques Surveillance Program	000106
Estimation of Thorium in Sea and Monitoring Network, 1969	Surveillance Stations Located in the Colorado River Survey of a Thorium Refinery	000107
Useful in Micropollution Studies of Ground and Environmental Determination of Plutonium in Environmental Thorium and Other Radioisotopes Data from Water Quality Industrial Hygiene and Medical	Survey of the Analysis of Microscopic Distribution of Survey of the Methods Used in the United Kingdom Atomic Survey of Naturally Occurring Radioactivity Survey of Radiation Dosimetry in Thorium Dioxide Cases	000108
of Thorium-230 and Thorium-232	Survey Heights Numerical Evaluation Survey	000109
of the Natural Gamma Radiation Field at Aerial Environmental Total and Spectrometric Gamma-Ray Effects of Plutonium 239 and Related Radioisotopes on Protection Units	Survival of the Adult Beagles Susceptibility and Geochemical Relationships as Uranium Suspended and Dissolved: Uranium in Water Suspended Phases Thorium, Plutonium, Radium Isotopes, Suspension (Thorotrast)	000110
Effect of Thorium Dioxide on the Liver of Patients in Studies of Ground and Surface Waters	Sustained Action of Infected Chelating Agents Sweden	000111
of the Cell Carcinoma and Hepatic Cholangiocarcinoma in Cytological Findings in the Peticuloendothelial Tissue and Cellular Galls by the Peticuloendothelial 239, Radium 226 and Strontium 90 to the Mesotheliotic Diseases Attached to Dust Particles in the Respiratory Exhalation Dose to the Respiratory Radioactive Isotopes in the Development of a Thorium Purification Thorium Utilization in an FFR/HTB Power Concentration in an Acid-Ether-Cellulose	Swedish Work on the Thorium 232-Uranium 233 Fuel Cycle Sweep Polarographic Techniques Useful in Micropollution Syringic Acids Thorotrast-Induced System (Liver, Spleen, Lymph Nodes, Bone Marrow) of System of the Rat Phagocytosis of Colloidal Thorium System of Beagles for the First Year Following Injection System of Humans Exposed to Uranium Fine Atmosphere System Due to Radon and its Daughter Products System Water-Freshwater Plants	000112
from Pieces of Organs of People Injected Injection Injection Injection Injection Injection	System Earths in Thorium Compounds. Chromatographic Systematics in Natural Materials from the Swamp Area, Systematically with Thorotrast and Autoradiographies Tables Tables Tables Tables Tables	000113
of Radium 222 Flux from Inactive Uranium Mill of Radioactive Dust Dispersed from Uranium Residues to Certain Radium and Radium in Uranium 226, and Lead 210 in Uranium Ores, Dusts, and Mill in Structures Built on or Near Uranium Mill in Landscapes of the Poichaya Forest-Steppe of the Bryzys Relative Toxicity of Lanthanum, Radium	Tailings and Lander Mortality in Colorado Tailings at Elliot Lake, Ontario Tailings Bibliography Tailings Piles Tailings Piles Tailings Tailings Uranium 238, Uranium 235, Thorium 230, Radium Tailings Measurements of Radium Daughter Concentrations Tabor Region Natural Radioactivity of Some Soils Tantalum and Thorium Compounds in the Developing Chick Technical and Economic Characteristics of Thorium Technical Progress Report No. 5, April-June, 1966 Cycle Technological Solutions of Pure Earth Manufacture Tectonic Significance of Thorium/Uranium Ratios from Teeth of Dogs. 1. The Distribution of Plutonium, Teeth Containing Plutonium Mesothorium and Strontium Teeth Containing Plutonium Mesothorium, and Strontium Teeth. 1. The Distribution of Plutonium, Radium, Teeth	000114
in the Nuclear Fuel Cycle - Reprocessing of High- in the Nuclear Fuel Cycle - Fabrication of High- Fuel Recycling Part 1. The Dependence of Late Effects in Mice on the Enriched Uranium, Plutonium-Uranium 238, and Adult Beagles Study of the Long Waste Disposal Aspects of the Long Long	Measurements Investigation Use of Asphalt Emulsion Measurements of Radium Daughter Concentrations Natural Radioactivity of Some Soils Tantalum and Thorium Compounds in the Developing Chick Technical and Economic Characteristics of Thorium Technical Progress Report No. 5, April-June, 1966 Cycle Technological Solutions of Pure Earth Manufacture Tectonic Significance of Thorium/Uranium Ratios from Teeth of Dogs. 1. The Distribution of Plutonium, Teeth Containing Plutonium Mesothorium and Strontium Teeth Containing Plutonium Mesothorium, and Strontium Teeth. 1. The Distribution of Plutonium, Radium, Teeth	000115
1. The Dependence of Reports on the Neuberberg Long-	Temperature Gas-Cooled Reactor Fuel Containing Uranium Temperature Gas-Cooled Reactor Fuel Containing Uranium Temperature Thorium Reactor and Their Consequences for Temporal Distribution of Skeletal Alpha-Doses from Tern Hazard of Radioactive Wastes Produced by the Tern Biological Effects of Internal Irradiation in Tern Cooling Characteristics of Irradiated Nuclear Fuels Tern Effects of Inhaled Trivalent Nitrate in Rats Tern Experiments with Short-Lived Alpha-Emitters. Part	000116

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Enhanced Secretion of Radioactive Daughters of Thorium
Distributions in the Metallurgical Processing of
and Secretion of Certain Soluble Compounds of Natural
the Determination of Trace Elements in Natural Waters
Gas-Cooled Reactor Fuel Containing Uranium 233 and
Waters. 5. Simultaneous Determination of Uranium and
Gas-Cooled Reactor Fuel Containing Uranium 233 and
Processing Methods and Costs for Selected
Physiology: Plants* Solubility of Certain
Power Programs*
of the Country, Carinthia, Austria* Uranium
The Toxicity Classification of
Preparation and Properties of Aqueous
Extracts from a Thymus Catechu in Childhood After
Uranium Poisoning in
Etiologic Significance of
Exposition in Preliminary Report on Uranium,
of Case Analytical Techniques for Determining Uranium,
The Concentration of Radium,
Bismuth, Polonium, Radium, Thorium,
Strontium, Barium and Radioactive Rocks* Uranium,
Silicon 32 and The Simultaneous Determination of
Isotopes of Soluble Compounds of Thorium 232, Natural
Incorporation with Particular Reference to Plutonium,
Complex* Procedure for Measuring Uranium,
Plant Species* The Content of Scandium,
Isotopic Differentiation Radiometric Determination of
Concentrations of Natural Radioactive Materials (I)
Organogenesis Horizons of Soils* Accumulation of
Analysis of Powdered Rock Samples. Determination of
Uranium 234 and Radium 226 Equilibrium and
Some Aspects of the Hazard from Airborne
Evaluation of Radiation Hazards Created by
Evaluation of the Results* Measurement of
Measurement of
Determination of Minute Quantities of Radium, Barium and
Differences Between the Eth Plates Due to Radium and
Exposed by Rats After Intratracheal Administration of
After Intratracheal Administration of Thoron The
hazards in Industry* Determination of the
Evaluation of Radiation Hazards Created by Thoron and
Coefficients and Unattached Fraction of Radium and
Measurement of Thorium and
Intratracheal Administration of The Thoron Content (I)
Chemical, and Radioactive Properties of Thorium and
and Prochi from the Decay Products of Radium and
Absorbed Dose in the Human Organs* Distribution of
Various Physical Phases* The Radioactivity of
The Radioactivity from
Perivascular Injection of
Non-Radiation Effects of
The Danger of Cancer from
Late Effects of
Late Effects of
Lymph Nodes* Late Effects of
The Secretion of Thorium and Thorium Daughters after
Two Cases of Carcinoma after
Thorium Daughters in the Spleen of a
Thorium Series Radionuclides in Compact Bone of
Follow-Up of Danish
Measurements and Clinical Findings on
Analysis of Tissue Specimens* Information on
The Effect of
Human Leukemic Risk Data Derived from Portuguese
Body Content of Thorium 232 Daughters After
of Thorium Series Nuclides in Beagles after Intraspinal
Thorium Body Burden in Humans Following
Doses to the Cauda Equina Due to
System (Liver, Spleen, Lymph Nodes, Bone Marrow) of
Measurement of Thoron in the Breath of
Arbor, Michigan, USA* Follow-Up of
Radionuclides in Autopsy Samples from
Endosteal Dose to
Bone Tumors in
Expected Late Effects in
Special Clinical Findings Among
and Secretion of Thorium and Its Daughters in
Study of 175 Cases* Liver Studies in the
Epidemiological Follow-Up Studies of the Portuguese
The Edinburgh
Statistical Problems of

Radiocactivity
Absorption, Distribution
Application of Ion Exchange Methods for
Fuel Cycle - Fabrication of High-Temperature
to Determination of Trace Elements in Natural
Fuel Cycle - Reprocessing of High-Temperature
Thorium-Bearing Reactor Fuel Types*
Thorium-Containing Substances in Radio Remediating
Thorium-Cycle Possibilities in the Brazilian Nuclear
Thorium-Geochronology of Permian and Triassic Sediments
Thorium-ATG Setback Stents Growth*
Thorium-WAF and Uranium-WAF*
Thorium-Uranium Fuel Cycle in Italy*
Thorium-Uranium Oxide Slurries*
Thorium-T Treatment* Pulmonary
Thorium/Depleted Uranium Fuel: PWR*
Thorium/Uranium Ratio from Ancient Fossils*
Thorium, and Lead Contents and Leaf Isotopes
Thorium, and Potassium in Granitic Rocks* A Comparison
Thorium, and Uranium by Tropical Algae*
Thorium, and Uranium in Lichens and Mosses*
Thorium, Lead, Lanthanoids and Yttrium in Some Plants
Thorium, Plutonium, Radium Isotopes, Lead 210, Iron 55,
Thorium, Radium 232 and Thorium 230 in the Air of
Thorium, Radium, Iron and Gold* of Radioisotope
Thorium, Radium, Plutonium, and Americium in Soil
Thorium, Silver, and Other Trace Elements in Different
Thorium, Uranium and Potassium in Basalts and in Two
Thorium, Uranium in Ore, Concentrate, and Milling
Thorium, Uranium, and Radium by Plants and
Thorium, Uranium, Zirconium, and Hafnium* Fluorescence
Thorium: Its Industrial Hygiene Aspects*
Thorium: Uranium Ratio in New Zealand Soils-their
Thoron and Its Daughter Products*
Thoron and Thoron Daughters*
Thoron in the Breath of Thorotrast Patients and
Thoron in the Breath*
Thoron in Solids, Liquids and Gases* Apparatus for the
Thoron Alpha Particles in C180-15 and L9-115 Cellulose
Thoron Compounds* Thoron Content (Thoron 230) of the Air
Thoron Content (Thoron 230) of the Air Expired by Rats
Thoron Content of Air and Its Bearing on Lung Cancer
Thoron Daughters*
Thoron Decay Products* Useful for Measuring Diffusion
Thoron Inhalation in Radiothorium-Breathed Beagles*
Thoron Hazards*
Thoron Monitors*
Thoron 230 of the Air Expired by Rats After
Thoron* Physical,
Thoron* The Dose to the Trachea
Thorotrast and Its Daughter Nuclides and Estimation of
Thorotrast and Its In-Vitro Distribution Between the
Thorotrast and Its Retention in Tissues*
Thorotrast and Its Sequelae*
Thorotrast and Other Colloidal Substances*
Thorotrast as a Diagnostic Medium*
Thorotrast in Cerebral Angiography*
Thorotrast in Tissues*
Thorotrast on the Liver and Spleen, and their Effluent
Thorotrast Administration*
Thorotrast Administration*
Thorotrast Case*
Thorotrast Cases - Results of Measurements at IAEA*
Thorotrast Cases*
Thorotrast Deposits in the Kidney*
Thorotrast Dosimetry Supplied by the Radiochemical
Thorotrast Enriched with Thorium 230*
Thorotrast Experience*
Thorotrast Injection*
Thorotrast Injection* Distribution
Thorotrast Injury in Japan*
Thorotrast Localization by Light and Electron Microscopy
Thorotrast Hystelography and the Incidence of Hystelopathy*
Thorotrast Hystelography*
Thorotrast Patients (Histological and Autoradiographic
Thorotrast Patients and Evaluation of the Results*
Thorotrast Patients from Boston, Massachusetts and Ann
Thorotrast Patients*
Thorotrast Patients*
Thorotrast Patients*
Thorotrast Patients*
Thorotrast Patients*
Thorotrast Patients* Investigations of the Distribution
Thorotrast Patients-Laboratory and Clinical Findings (I)
Thorotrast Series (Up-Dated Results)*
Thorotrast Series-Report of a Cytogenetic Study*
Thorotrast Studies*

[illegible]

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Searches	0In Vivo Separation of	Uranium and Thorium After Inhalation of Uranium Ore by	000160
in the Caribbean	0Uranium and Thorium Decay Series Nuclides in Plankton	Uranium and Thorium Discharged by the Nuclear Industry	030109
0The Behavior in Terrestrial Environments of	Uranium and Thorium Family in Drinking Water and Food	Uranium and Thorium Following Inhalation of Uranium Ore	030280
the Content of Natural Radioactive Isotopes of the	Uranium and Thorium Isotopes: Deep Sea Drilling	Uranium and Thorium Mines and Mills	030318
by Bats	Uranium and Thorium Cnides	Uranium and Thorium Radioactive Families	030372
Project, Vol 23	Uranium and Thorium Resources in the United States and	Uranium and Thorium Solutions with a Sequestration Factor	030379
0Annual on Radiological Safety in	Uranium and Thorium: Determination of Trace Elements	Uranium by Decomposing Plant Matter	030382
0Health Hazards from the Inhalation of Insoluble	Uranium by Tropical Algae	Uranium in the Body and Critical Organs	030383
in Soil with an Increased Content of Nuclides of the	Uranium in Air from Contrasted Natural Environments	Uranium in Blood, Urine, and Cigarettes	030384
Effect of Policy Alternatives	Uranium is Bone	Uranium in Coral Seeks during Diagenesis	030385
0Assessment of	Uranium is Dental Porcelain	Uranium in Lichens and Mosses	030386
0Bay Mass Spectrometer	Uranium is Natural Water by Preconcentration on Anion-	Uranium in Natural Waters by Neutron Activation Analysis	030387
0Quantitative Analysis of	Uranium in Natural Waters	Uranium in Natural Waters	030388
in Natural Waters. 9. Simultaneous Determination of	Uranium in Natural Waters	Uranium in Natural Waters	030389
0Polonium and 210Pb	Uranium in Natural Waters	Uranium in Natural Waters	030390
0The Concentration of Radium, Thorium, and	Uranium in Natural Waters	Uranium in Natural Waters	030391
0Assessment of the Content of Concentrated and Natural	Uranium in Natural Waters	Uranium in Natural Waters	030392
0The Concentration of	Uranium in Natural Waters	Uranium in Natural Waters	030393
0The Deposition of	Uranium in Natural Waters	Uranium in Natural Waters	030394
0Control and Distribution of	Uranium in Natural Waters	Uranium in Natural Waters	030395
0Uranium, Polonium, Radium, Thorium, and	Uranium in Natural Waters	Uranium in Natural Waters	030396
Exchange Resin and Delayed-Neutron	Uranium in Natural Waters	Uranium in Natural Waters	030397
0Determination of	Uranium in Natural Waters	Uranium in Natural Waters	030398
0The Determination of	Uranium in Natural Waters	Uranium in Natural Waters	030399
of the Fission Track Technique to the Determination of	Uranium in Natural Waters	Uranium in Natural Waters	030400
Analysis after Adsorption on Charcoal	Uranium in Natural Waters	Uranium in Natural Waters	030401
0Determination of	Uranium in Natural Waters	Uranium in Natural Waters	030402
0Isotopic Composition and Radiological Properties of	Uranium in Natural Waters	Uranium in Natural Waters	030403
0Simple Method for the Determination of	Uranium in Natural Waters	Uranium in Natural Waters	030404
Lichens Canada	Uranium in Natural Waters	Uranium in Natural Waters	030405
0The Direct Measurement of ppm Levels of	Uranium in Natural Waters	Uranium in Natural Waters	030406
0A Paper and Sensitive Neutron Activation Method for	Uranium in Natural Waters	Uranium in Natural Waters	030407
0Determination of Suspended and Dissolved	Uranium in Natural Waters	Uranium in Natural Waters	030408
on the Biological Effect of Small Amounts of Natural	Uranium in Natural Waters	Uranium in Natural Waters	030409
0Chemical Prefecture -- with Special Emphasis on Cause of	Uranium in Natural Waters	Uranium in Natural Waters	030410
Inhalation Exposures of	Uranium in Natural Waters	Uranium in Natural Waters	030411
Before and After	Uranium in Natural Waters	Uranium in Natural Waters	030412
0In Vivo Separation of Long-Lived	Uranium in Natural Waters	Uranium in Natural Waters	030413
by Uranium. Seasonal and Regional Variations of	Uranium in Natural Waters	Uranium in Natural Waters	030414
0High	Uranium in Natural Waters	Uranium in Natural Waters	030415
Fission Particle Track Replica Method	Uranium in Natural Waters	Uranium in Natural Waters	030416
0Age and	Uranium in Natural Waters	Uranium in Natural Waters	030417
Intrusion, South Greenland	Uranium in Natural Waters	Uranium in Natural Waters	030418
0The	Uranium in Natural Waters	Uranium in Natural Waters	030419
Combined Solvent Extraction-Liquid	Uranium in Natural Waters	Uranium in Natural Waters	030420
0Plutonium and	Uranium in Natural Waters	Uranium in Natural Waters	030421
Biologic	Uranium in Natural Waters	Uranium in Natural Waters	030422
0A Five Year Inhalation Study with Natural	Uranium in Natural Waters	Uranium in Natural Waters	030423
0Shape Factors for Aerosols of Coal,	Uranium in Natural Waters	Uranium in Natural Waters	030424
Coastal Sediments and their	Uranium in Natural Waters	Uranium in Natural Waters	030425
0Studies on Thorium and	Uranium in Natural Waters	Uranium in Natural Waters	030426
0Thorium-	Uranium in Natural Waters	Uranium in Natural Waters	030427
Uranium Production in Thorium-Denatured	Uranium in Natural Waters	Uranium in Natural Waters	030428
the Nuclear Fuel Cycle - Conversion of Yellow Cake to	Uranium in Natural Waters	Uranium in Natural Waters	030429
0Review of	Uranium in Natural Waters	Uranium in Natural Waters	030430
Coast of India	Uranium in Natural Waters	Uranium in Natural Waters	030431
0Anomalous Behavior of Thorium and	Uranium in Natural Waters	Uranium in Natural Waters	030432
0Measurements of Radon 222 Flux from Inactive	Uranium in Natural Waters	Uranium in Natural Waters	030433
Daughter Concentrations in Structures Built on or Near	Uranium in Natural Waters	Uranium in Natural Waters	030434
0Airborne Effluent Control at	Uranium in Natural Waters	Uranium in Natural Waters	030435
of Depressing Attachment Ratio of Radon Daughters in	Uranium in Natural Waters	Uranium in Natural Waters	030436
in the Respiratory System of Humans Exposed to	Uranium in Natural Waters	Uranium in Natural Waters	030437
0Chronic Exposure of Dogs to Simulated	Uranium in Natural Waters	Uranium in Natural Waters	030438
0Size Distribution of Radon Daughter Particles in	Uranium in Natural Waters	Uranium in Natural Waters	030439
0Vegetating the	Uranium in Natural Waters	Uranium in Natural Waters	030440
0Polonium 210 in Blood and Urine of	Uranium in Natural Waters	Uranium in Natural Waters	030441
and Internal Dose of Lead 210 and Polonium 210 in a	Uranium in Natural Waters	Uranium in Natural Waters	030442
Measure of the Power and Excreta of a Pomer	Uranium in Natural Waters	Uranium in Natural Waters	030443
0Serum Immunoglobulins in	Uranium in Natural Waters	Uranium in Natural Waters	030444
0Lung Cancer of	Uranium in Natural Waters	Uranium in Natural Waters	030445
0Pulmonary Function of	Uranium in Natural Waters	Uranium in Natural Waters	030446
of Radioactive Polonium 210 by Czechoslovakian	Uranium in Natural Waters	Uranium in Natural Waters	030447
Pathway	Uranium in Natural Waters	Uranium in Natural Waters	030448
0Erythrocytes of	Uranium in Natural Waters	Uranium in Natural Waters	030449
0The Measurement of Radioactive Gas and Dust in	Uranium in Natural Waters	Uranium in Natural Waters	030450
Analysis of the Reduction of Hazardous Radiation in	Uranium in Natural Waters	Uranium in Natural Waters	030451
in the Practical Application of Health Regulations in	Uranium in Natural Waters	Uranium in Natural Waters	030452

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1

07The Determination of Actinides in
 08Method of Determining Plutonium 239 in
 09Determination of Thorium in
 10for Determination of Total Alpha Radioactivity in
 11Variation of Uranium Content in Daily Diet and
 12Authority of the Determination of Radioisotopes in
 13Thorium and Uranium in Food,
 14Transuranic Elements by Extraction Chromatography in
 15Free Porten, Massachusetts and Ann Arbor, Michigan,
 16Air Cleaning at the
 17Unaffected Fraction of Radon and
 18Single-Sweep Polarographic Techniques
 19of Some Black-earths in the European Areas of the
 20Skeletal Dosimetry in
 21Progress in the Peagle Studies at the University of
 22Co in the Big Indian District, San Juan County,
 23located in the Colorado River basin of Colorado,
 24Juan County, Utah. Uranium-Mining Operations of the
 25232 Radium Products Following Inhalation of Uranium 232
 26The Effect of
 27in Animals Following Acute and Chronic Poisoning with
 28Thorium Fuel Cycle in HPA (CNS) 0999. An Assessment of
 29Blood Following Chronic and Acute Poisoning with
 30The Effect of Uranous-Thorium Oxide
 31Environmental Levels of Radioactivity in Livestock
 32Immunoglobulin (Ig G, Ig M, Ig A)
 33The Mobilization and Fixation of Nucleonides,
 34Radioisotopes
 35Radioisotopes
 36Oxide
 37Nevada Test Some Characteristics of Soil and Perennial
 38of Natural Radioactive Elements in the Case of Freshwater
 39and Bare Earths by Plants at Different Times during
 40Spectrometric Gamma-Ray Surveys from Helicopters and
 41Effect of Internally Deposited Radioisotopes Upon Blood
 42of Internally Deposited Radioisotopes Upon the Blood
 43Radiation Effects in the Current
 44Mineralization in the Persian of the Choc Nappe in the
 45The Radioactivity of Thororast and Its In-
 46Some Environmental Factors Influencing the In-
 47Binding of Plutonium to Glycoproteins in
 48(III) to the Constituent of Bovine Cortical Bone in
 49Techniques and Preliminary Results
 50Acidosis in the Egyptian Limestone Area
 51Eutectics in Experimental Animals During and After
 52of Uranium Ore by Beagles
 53Health Physics Application of the
 54of Localized Alpha Dose III from Surface and
 55The Toxicology of Radioactive Substances,
 56Plutonium, Americium, Uranium, and Polonium from Large
 57226 and Thorium 228 in Thyroids of Cattle from Nigeria,
 58Environmental Radioactivity in New South
 59Characteristics of Irradiated Nuclear Fuels
 60Waste Treatment Costs and the Environmental Impact of
 61Waste Treatment Costs and the Environmental Impact of
 62Waste Treatment Costs and the Environmental Impact of
 63Radioactive
 64Reprocessing Facilities
 65Program for Improved
 66Uranium 238, and The Long-Term Hazard of Radioactive
 67States Concerning the Physics Aspects of Actinide
 68227, and Thorium Isotopes in Environmental and Process
 69Waste Effluents in the
 70Correlation of Radioactive
 71Waste Effluents in the
 72Correlation of Radioactive
 73Waste Effluents in the
 74Correlation of Radioactive
 75Actinide Rescues on the Long-Term Hazard of High-Level
 76Grade Thorium Dioxide and Controlling Associated
 77Lived Fission Products and Actinides in the Radioactive
 78Disposal of Low-Level Radioactive
 79Uranium 238, and
 80Long-term Hazard of Radioactive
 81Waste
 82Alpha-Recoil Thorium 238: Dissolution into
 83Thorium in
 84Isotopes of the Uranium and Thorium Family in Drinking
 85Content of Plutonium, Thorium and Protactinium in Sea
 86Delayed-Neutrons
 87Determination of Uranium in Natural
 88Special Emphasis on
 89Chemical Characteristics of Silver
 90230/Thorium 232 and Thorium 228/Thorium 232 in Sea
 91and Lead Isotope Ratios as Indicators of Oceanic
 92Progress Report No. 5, Thorium Fuel Cycle for Heavy
 93Thorium Cycle in Heavy
 94Oil and
 95Uranium 226, Uranium and Other Radiological Data from
 96Elements: 1. Natural Fresh Waters and the Effect of the
 97Mining and Milling Operations on Selected Ground
 98Thorium 228 in Marine Plankton and Sea-
 99Determination of Suspended and Dissolved Uranium in
 100and Sensitive Neutron Activation Method for Uranium in
 101Urine
 102Urine
 103Urine
 104Urine
 105Urine
 106Urine
 107Urine
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 199Urine
 200Urine

Effect of "Real" Absorbers of Natural Uranium in	Water*	Data on the Biological	309183
of Uranium, Plutonium, and Americium in Sea	Water*	85 Semi-Quantitative Determination	309186
Uranium, and Polonium from Latex Volcanics of Ocean	Water*	85 Simple Recovery of Plutonium, Americium,	309187
Limits of Plutonium 239 in the Human Body, Air and	Water*	Basis for Setting the Maximum Permissible	309188
Soil and "Maximum Permissible Concentrations in Air and	Water*	Amounts of Radioisotopes in the Human	309189
of Uranium 238 and Californium 252 Fission Sources in	Water*	Spectra and Cosimetry of Neutrons from Moderation	309190
Radioactive Isotopes in the System	Water-Freshwater Plants*		309195
Moderation Pores of Trace Elements in Natural Fresh	Waters and the Effect of the Water Storage*		309196
in Characterization of Uranium in Sea and Surface	Waters by Neutron Activation Analysis after Adsorption		309198
Determination of Uranium in Natural	Waters by Neutron Activation Analysis*		309203
Concentration	Waters of the Colorado River Basin, Patina Monitoring		309204
Radioactivity in Surface	Waters Thorium*	Application of Ion Exchange Methods	309207
for the Determination of Trace Elements in Natural	Waters. 3. Simultaneous Determination of Uranium and		309210
to Determination of Trace Elements in Natural	Waters*	Plasma-Metric	309216
Method for the Determination of Uranium in Natural	Waters*	Interaction of Plutonium	309218
with Complexing Substances in Soils and Natural	Waters*	Behavior and Distribution	309219
of Radioactive Substances in Coastal and Estuarine	Waters*	Application of the Fission Track	309227
Techniques to the Determination of Uranium in Natural	Waters*	Single-Sweep Polarographic Techniques	309230
Useful in Micropollution Studies of Ground and Surface	Waters*, by J. Kronfeld, Et Al*	Occurrence	309231
Water "Excess Uranium 238: An Aging Effect in Confined	Wellings - Investigation of Potential Hazards*	Use of	309237
Thermostated Tungsten Electrodes in Inert Gas Shielded Arc	West Carpathians*	Geochemistry	309238
of Radioactive Elements in Shyllites in the	West Carpathians*	Least Mineralization in the Permian	309240
of the Choc Bayge in the Viharkovsky Christ Area (The	West Coast of India*	Natural Radioactivity and	309241
Geochemical Processes in the Marine Environment of the	West Coast of India*	Anomalous Behavior of Thorium	309242
and Uranium Isotopes in the Marine Environment of the	West Coast of India*Thorium 232 and Thorium 230/Thorium		309247
232 Activity Ratios in Backwater Sediments along the	West Wits and Evander Goldfields*	Heavy Metal	309248
Vital Enrichment in Mine Drainage: 1. The Klertsford,	Western North Pacific*	Potassium Thorium 232/Thorium	309249
232 and Thorium 229/Thorium 232 in Sea Water in the	Wits and Evander Goldfields*	Heavy Metal	309251
Environment in Mine Drainage: 1. The Klertsford, West	Work in Progress in the Internal Irradiation Program*		309252
Research in Radiobiology, Annual Report of	Work in Progress in the Internal Irradiation Program*		309253
Research in Radiobiology, Annual Report of	Work in Progress on the Chronic Toxicity Program*		309254
Research in Radiobiology, Annual Report of	Work in Progress on the Chronic Toxicity Program*		309255
Research in Radiobiology, Annual Report of	Work in Progress on the Chronic Toxicity Program*		309256
Research in Radiobiology, Annual Report of	Work in Progress on the Chronic Toxicity Program*		309257
Research in Radiobiology, Annual Report of	Work in Progress on the Chronic Toxicity Program*		309258
Research in Radiobiology, Annual Report of	Work in Progress on the Chronic Toxicity Program*		309259
Research in Radiobiology, Annual Report of	Work in Progress on the Chronic Toxicity Program*		309260
Research in Radiobiology, Annual Report of	Work with Natural Radioactive Substances at Enterprises		309270
of Rare	Work*	85th	309283
Effect of Uranium-Uranic Oxide (U3O8) in Experimental	Workers in Yugoslavia*		309286
Potassium 210 in Blood and Urine of Uranium Mine	Workers with Low Pcdy Burdens of Bismuth 212*Chromosome		309290
Aberrations in the Peripheral Lymphocytes of Thorium	Workers*	Toxicology of Transportable Uranium:	309295
A Critical Contribution to Health Protection of	Workers*	Sensitive Method for the Determination of	309296
the Urinary Plutonium Levels in Occupationally Exposed	Working Meeting on the Question of Radiation Protection		309298
held in Berlin, January, June 8-9, 1972* German-Soviet	Workload*		309299
Corus Immunoglobulins in Uranium Miners after a	X Treatment*	Pulmonary Metastases	309307
from a Thyroid Carcinoma in Childhood after Thorium-	Y in "Children and Adults"		309310
Bone Cancers Induced by Radium 226 (Th	Y-Ray Emission Spectrometer*	Quantitative Analysis	309314
of Uranium and Thorium Solutions with a Semiconductor	Y-Ray Spectrometric Determination of Thorium in Bone		309323
and Other Biological Materials*	Y-Ray-Fluorescence Analysis of Powde of Rock Samples.		309325
Determinations of Thorium, Uranium, and	Y-12 Plant*		309328
Air Cleaning at the 9542C	Years after Injection of Thorium Dioxide*		309330
Hepatic Duct Carcinoma Seventeen	Years after Thorium Administration*	Erythroleukemia	309332
(Mc Gilliemo's Disease) Occurrence Twenty-Eight	Yellow Cake to Uranium Hexafluoride. Part I. The		309340
Effluents in the Nuclear Fuel Cycle - Conversion of	Yttrium in Some Plants Growing on Granitic and		309216
Radioactive	Yttrium Distribution and Excretion*	The Action	309199
of Salts of Zirconium and Other Metals on Plutonium and	Yugoslavia*	Polonium	309208
210 in Blood and Urine of Uranium Mine Workers in	Zealand Soils*	A Survey of	309235
Naturally Occurring Radionuclide Concentrations in New	Zealand Soils--their Relationship to Iron and Potassium		309331
224 Equilibrium and Thorium: Uranium Ratio in Vein	Zirconium and Other Metals on Plutonium and Yttrium		309199
Distribution and Excretion*	Zirconium, and Radium*	Analysis of Powdered	309254
Rock Samples. Determination of Thorium, Uranium,			

PUBLICATION DESCRIPTION

PUBLICATION DESCRIPTION INDEX

- A/COSP-75/P-738 520
- Academic Press, New York, New York 128, 296, 691
- Acta Biologica et Medica Germanica, 38, 1875-1882 170
- Acta Radiologica, 47, 887-898 440
- Acta Radiologica, 47, 65-78 507
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- Advances in Nuclear Engineering, Vol 1, J.B. Dunning and E.B. Prentice (Eds.), Proceedings of the 2nd Nuclear Engineering and Science Conference held in Philadelphia, Pennsylvania, 1957. Pergamon Press, New York, New York, (pp. 66-73) 667
- AEC-STD-8 377
- AEC-tr-6536 (Rev.) 524
- AEC-tr-7666 209, 281
- AEC-5398 306
- AEC-3057 110
- AEC-1109 3, 4, 136, 192, 193
- AEC-7522 38, 44, 75, 194
- AEC-3583 6
- AEC-COSP-76-430-005 67
- AEC-COSP-76-666-029 330
- Akademiya nauk Armianskoy SSR, Bioloicheskii Zhurnal, 26(11), 66-70 330
- American Industrial Hygiene Association Journal, 35(2), 207-217 17
- American Industrial Hygiene Association Journal, 35(3), 165-174 378
- American Industrial Hygiene Association Journal, 33(3), 152-156 498
- American Industrial Hygiene Association Journal, 33(5), 104-114 639
- American Industrial Hygiene Association Journal, 19, 444-468 674
- American Industrial Hygiene Association Journal, 37(11), 613-616 673
- American Industrial Hygiene Association Journal, 21, 201-206 696
- American Industrial Hygiene Association Journal, 36(1), 444-490 702
- American Industrial Hygiene Association Journal, 19, 285-295 25
- American Journal of Gastroenterology, 57, 301-310 512
- American Journal of Public Health, 49(10), 1336-1342 670
- American Journal of Roentgenology, Radium Therapy and Nuclear Medicine, 58, 10-16 37
- American Journal of Roentgenology, Radium Therapy and Nuclear Medicine, 75, 1188-1193 395
- American Journal of Roentgenology, Radium Therapy and Nuclear Medicine, 125(3), 671-677 401
- American Medical Association Archives of Pathology, 60, 173-178 460
- American Medical Association Archives of Industrial Health, 11(3), 234-242 547
- American Medical Association Journal, 92(26), 2183-2185 263
- American Nuclear Society and the Atomic Industrial Forum Joint Meeting held in San Francisco, California, November 16-21, 1975, (28 pp.) (AEC-5398, COSP-751101) 306
- American Power, Proceedings of a Conference held in Chicago, Illinois, April 29-May 1, 1974, Vol. 36, (pp. 247-154) (COSP-760400) 299
- Analytica Chimica Acta, 83, 143-156 612
- Analytical Chemical and Applied Spectroscopy, Proceedings of the 28th Pittsburgh Conference held in Cleveland, Ohio, February 28-March 4, 1977, (15 pp.) (NLC-1138, COSP-770204) 618
- Analytical Chemistry Division Annual Progress Report for Period Ending September 30, 1971, (pp. 39-40), 97 pp. (OESL-4930) 288
- Analytical Chemistry, 46(11), 113-118 253
- Analytical Chemistry, 46(12), 1742-1749 252
- Analytical Chemistry, 46(12), 1725-1737 254
- Analytical Chemistry, 46(9), 1338-1336 593
- Analytical Chemistry, 47(11), 1866-1868 235, 375
- Analytical Chemistry, 47(8), 619-621 658
- Analytical Chemistry, 47(5), 338-361 580
- Analytical Chemistry, 47(7), 1147-1149 555
- Analytical Chemistry, 49(4), 642-645 581
- Analytical Chemistry, 43(7), 973-975 233
- Analytical Chemistry, 49(1), 67-69 221
- Analytical Chemistry, 49(2), 302-306 255
- Analytical Chemistry, 49(3), 419-423 249
- Analytical Procedures for the Environmental Health Laboratory, (pp. 3-1 - 3-2), 147 pp. (SC-N-67-1044) 220
- ATL-TRANS-347 431
- ATL-4531 110, 111
- ATL-4794 71
- ATL-5689 502
- ATL-6637 72
- ATL-6945 638
- ATL-76-88 (Part 2) 243
- ATL-74-88 (Part 20) 430
- ATL-7615 203, 463, 493
- ATL-7760 (Part 2) 444
- ATL-8007 637
- ATL-8060 (Part 2) 506
- Annals of Internal Medicine, 42, 378-387 459
- Annals of Nuclear Energy, 2, 451-466 734
- Annals of Occupational Hygiene, 14(4), 303-308 546

BLANK PAGE

PUBLICATION DESCRIPTION INDEX

- Annals of the New York Academy of Sciences, 145(3), 720-737 15
- Annals of the New York Academy of Sciences, 145(3), 755-758 69
- Annals of the New York Academy of Sciences, 145(3), 758-767 82
- Annals of the New York Academy of Sciences, 145(3), 813-844 87
- Annals of the New York Academy of Sciences, 145(3), 576-584 89
- Annals of the New York Academy of Sciences, 145(3), 724-727 105
- Annals of the New York Academy of Sciences, 145(3), 585-594 107
- Annals of the New York Academy of Sciences, 145(3), 817-829 149
- Annals of the New York Academy of Sciences, 145(3), 545-575 179
- Annals of the New York Academy of Sciences, 145(3), 767-774 381
- Annals of the New York Academy of Sciences, 145(3), 853-858 392
- Annals of the New York Academy of Sciences, 145(3), 798-825 396
- Annals of the New York Academy of Sciences, 145(3), 527-529 397
- Annals of the New York Academy of Sciences, 145(3), 411-416 402
- Annals of the New York Academy of Sciences, 145(3), 830-842 404
- Annals of the New York Academy of Sciences, 145(3), 716-723 405
- Annals of the New York Academy of Sciences, 145(3), 746-790 406
- Annals of the New York Academy of Sciences, 145(3), 674-699 407
- Annals of the New York Academy of Sciences, 145(3), 774-785 408
- Annals of the New York Academy of Sciences, 145(3), 555-607 410
- Annals of the New York Academy of Sciences, 145(3), 847-848 416
- Annals of the New York Academy of Sciences, 145(3), 748-754 417
- Annals of the New York Academy of Sciences, 145(3), 759-766 418
- Annals of the New York Academy of Sciences, 145(3), 751-797 419
- Annals of the New York Academy of Sciences, 145(3), 654-659 422
- Annals of the New York Academy of Sciences, 145(3), 614-641 432
- Annals of the New York Academy of Sciences, 145(3), 849-852 449
- Annals of the New York Academy of Sciences, 145(3), 660-673 450
- Annals of the New York Academy of Sciences, 145(3), 700-717 451
- Annals of the New York Academy of Sciences, 145(3), 623-633 472
- Annals of the New York Academy of Sciences, 145(3), 644-653 492
- Annals of the New York Academy of Sciences, 145(3), 523-850 523
- Annals of the New York Academy of Sciences, 145(3), 674-675 526
- Annals of the New York Academy of Sciences, 145(3), 806-810 541
- Annals of the New York Academy of Sciences, 145(3), 642-643 541
- Annals of the New York Academy of Sciences, 145(3), 608-622 547
- Annals of the New York Academy of Sciences, 145(3), 530-532 644
- Annual Progress Report for 1965 412
- Annual Progress Report, (pp. 115-131), 177 pp. (ARCU-3522) 79
- Annual Progress Report, (pp. 57-72), 177 pp. (ARCU-3522) 44
- Annual Progress Report, (pp. 73-85), 177 pp. (ARCU-3522) 34
- Annual Progress Report, (pp. 86-114), 177 pp. (ARCU-3522) 104
- Annual Progress Report, C.S. Stover, Jr. (Ed.), (pp. 219-224), 229 pp. (COO-218) 35
- Annual Progress Report, C.S. Stover, Jr. (Ed.), (pp. 121-145), 224 pp. (COO-218) 124
- Annual Progress Report, C.S. Stover, Jr. (Ed.), (pp. 213), 229 pp. (COO-21) 134
- Annual Report for 1967, B.C. Thompson, et al (Eds.), (pp. 323-334), 253 pp. (BHWL-714) 160
- Annual Report for 1968, B.V. Pearce (Ed.), (pp. 6-9) (BHWL-1051, Part 2) 501
- Annual Report for 1968, B.V. Pearce (Ed.), (pp. 1-6) (BHWL-1051, Part 2) 597
- Annual Report for 1969, B.C. Thompson (Ed.), (pp. 60-61), 90 pp. (BHWL-1306, Part 1) 164
- Annual Report for 1973, B.C. Thompson, et al (Eds.), (pp. 97), 162 pp. (BHWL-1850, Part 1) 159
- Annual Report for 1974, B.R. Vaughan (Ed.), (pp. 153-154), 238 pp. (BHWL-1950, Part 2) 261
- Annual Report for 1976, (pp. 91-93), 314 pp. (BHWL-2100, Part 1) 8
- Annual Report for 1976, (pp. 94-95), 314 pp. (BHWL-2100, Part 1) 9
- Annual Report for 1976, (pp. 95-97), 314 pp. (BHWL-2100, Part 1) 554
- Annual Report for 1977, (pp. 3.79-3.84) (PWL-2500, Part 1) 10
- Annual Report for 1977, (pp. 3.83-3.84) (PWL-2500, Part 1) 11
- Annual Report of the Radiation Center of Osaka Prefecture, 16, 28-30 247
- Annual Report of Work in Progress in the Internal Irradiation Program, (pp. 211) (COO-119-224) 5
- Annual Report of Work in Progress in the Internal Irradiation Program, (pp. 212-227) (COO-119-224) 26
- Annual Report of Work in Progress in the Internal Irradiation Program 58

PUBLICATION DESCRIPTION INDEX

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- Annual Report of Work in Progress in the Internal Irradiation Program, (Ed. 370) (CONF-119-220) 187
- Annual Reports of the Research Reactor Institute, Kyoto University, 1, 293-297 309
- Annual Review of Pharmacology, 3, 203-266 38
- Annual Review of Pharmacology, 13, 325-357 100
- Archives of Environmental Health, 27(5), 331-333 27
- Archives of Industrial Hygiene and Occupational Medicine, 6, 801-808 120
- Archives of Cell Biology, 2, 215-238 97
- Archives of Pathology, 60, 493-501 527
- Archives of Pathology, 62, 1-7 503
- Assessment of Airborne Particles, T.T. Mercer, P.E. Morrow and B. Steber (Eds.), Charles C. Thomas, Publisher, Springfield, Illinois, (pp. 003-020) 101
- Assessment of Airborne Particles, T.T. Mercer, T.T. Morrow and B. Steber (Eds.), Charles C. Thomas, Publisher, Springfield, Illinois, (pp. 331-360) 611
- Assessment of Radioactive Body Burdens in Man, Proceedings of a Symposium held in Heidelberg, Germany, May 11-16, 1964, Vol. 1, (pp. 369-393), 1003 pp. (CONF-040, STI/PUB/040) 93
- Assessment of Radioactive Body Burdens in Man, Proceedings of a Symposium held in Heidelberg, Germany, May 11-16, 1964, Vol. 1, (pp. 355-360), 1003 pp. (CONF-040, STI/PUB/040) 90
- Assessment of Radioactive Body Burdens in Man, Proceedings of a Symposium held in Heidelberg, Germany, May 11-16, 1964, Vol. 1, (pp. 195-215), 1003 pp. (CONF-040, STI/PUB/040) 230
- Assessment of Radioactive Body Burdens in Man, Proceedings of a Symposium held in Heidelberg, Germany, May 11-16, 1964, Vols. 1-2, 1003 pp. (CONF-040, STI/PUB/040) 003
- Assessment of Radioactive Body Burdens in Man, Proceedings of a Symposium held in Heidelberg, Germany, May 11-16, 1964, Vol. 2, (pp. 003-071), 1003 pp. (CONF-040, STI/PUB/040) 053
- Assessment of Radioactive Body Burdens in Man, Proceedings of a Symposium held in Heidelberg, Germany, May 11-16, 1964, Vol. 1, (pp. 169-190), 1003 pp. (CONF-040, STI/PUB/040) 500
- Assessment of Radioactive Organ and Body Burdens, Proceedings of a Symposium held in Stockholm, Sweden, November 22-26, 1971, (pp. 073-089) (CONF-711100, STI/PUB/290) 025
- Assessment of Radioactive Organ and Body Burdens, Proceedings of a Symposium held in Stockholm, Sweden, November 22-26, 1971, (pp. 091-503) (CONF-711100, STI/PUB/290, IAEA-SM-150) 009
- Assessment of Radioactive Organ and Body Burdens, Proceedings of a Symposium held in Stockholm, Sweden, November 22-26, 1971, (pp. 505-519) (CONF-711100, STI/PUB/290) 519
- Assessment of Radioactive Organ and Body Burdens, Proceedings of a Symposium held in Stockholm, Sweden, November 22-26, 1971, (pp. 005-021), 690 pp. (STI/PUB/290, IAEA-SM-150/10, CONF-711100) 520
- Assessment of Radioactive Organ and Body Burdens, Proceedings of a Symposium held in Stockholm, Sweden, November 22-26, 1971, (pp. 095-500), 692 pp. (STI/PUB/290, IAEA-SM-150/02, CONF-711100) 561
- Atomic Energy in Australia, 10(4), 12-31 701
- Atomic Energy Review, 12(1), 3-05 271
- Atomic Energy, 27(2), 803-807 275
- Atomic Energy, 35, 791-796 600
- Atomnaya Energiya, 35(3), 155-158 600
- Australian Journal of Soil Research, 10(1), 25-32 350
- Australian Machinery and Production Engineering, 19, 21-35 607
- Auswirkungen des Brennstoffkreislaufs auf den Brennstoffkreislauf des Thorium-Reichtemperaturreaktors, (1 pp.) (JUL-1200) 311
- BAG-393-0 297
- Bioassay and Analytical Chemistry, Proceedings of the 7th Annual Symposium held in Urbana, Illinois, October 12-13, 1961, (pp. 5-6), 100 pp. (ANL-6637) 72
- Bioassay and Analytical Chemistry, Proceedings of the 12th Annual Meeting held in Gatlinburg, Tennessee, October 13-16, 1966, (pp. 120-133), 230 pp. (CONF-661010) 562
- Biologia Contemporanea, 2(4), 166-170 201
- Biological and Medical Research Division Quarterly Report, August, September, October, 1950, A.E. Bruce (Ed.), (pp. 190) (ANL-0537) 111
- Biological Effects of Low-Level Radiation Pertinent to Protection of Man and his Environment, Proceedings of an International Symposium held in Chicago, Illinois, November 3-7, 1975, Vol. 1, (pp. 335-302), 051 pp. (CONF-751126, IAEA-SM-202/507, STI/PUB/009) 77
- Biological Effects of Low-Level Radiation Pertinent to Protection of Man and his Environment, Vol. 2, Proceedings of an International Symposium held in Chicago, Illinois, November 3-7, 1975, (pp. 171-180) (CONF-751126, IAEA-SM-202/006) 119
- Biological Effects of Low-Level Radiation Pertinent to Protection of Man and his Environment, Proceedings of an International Symposium held in Chicago, Illinois, November 3-7, 1975, (pp. 103-196) (IAEA-SM-202/01, CONF-751126) 610
- Biological Effects of Low-Level Radiation Pertinent to Protection of Man and his Environment, Proceedings of an International Symposium held in Chicago, Illinois, November 3-7, 1975, (pp. 325-333) (CONF-751126, IAEA-SM-202/500) 723
- Biological Effects of Radionuclides, Proceedings of the 2nd International Symposium held in Dornberg/Wurzburg, Germany, September 20, 1970, (1 pp.) (ANL-CONF-70-030-005, CONF-700992) 67
- Biological Implications of the Transuranic Elements, Proceedings of the 11th Sanford Symposium held in Richland, Washington, September 27-29, 1971, (pp. 793-001) (CONF-710919) 123
- Biomedical and Environmental Research Program of the IAEA Health Division, January-December 1976, B.F. Paterson and E.A. Sullivan (Comps.), (pp. 73-75) (IA-6090-70) 620
- BIG-371 532
- BO-IC-7669 600
- BRL-17070 590
- BWL-SM-3027 163
- BWL-SM-3419 162
- BWL-1051 (Part 2) 501, 597
- BWL-122 157
- BWL-1306 (Part 1) 160

PUBLICATION DESCRIPTION INDEX

BNWL-1050 (Part 1) 159	COWF-630535 226
BNWL-1950 (Part 2) 261	COWF-640011 704
BNWL-2100 (Part 3) 0, 9, 55a	COWF-641117 546
BNWL-2190 7a7	COWF-690400 59
BNWL-401 Part of Annual Report for 1966, (pp. 71-74) (BNWL-401, Part 2) 600	COWF-690910 207
BNWL-714 160	COWF-691000 712
91-97 06	COWF-691229 570, 502
British Journal of Industrial Medicine, 27, 207-290 536	COWF-700501 135
British Journal of Radiology, 29, 317-325 390	COWF-700931 162
British Journal of Radiology, 39, 101-106 399	COWF-701227 596
British Journal of Radiology, 30, 776-784 437	COWF-710320 543
British Journal of Radiology, 41, 755-761 479	COWF-710705 624, 635
British Journal of Radiology, 20, 615-619 500	COWF-710919 123
British Journal of Radiology, 31, 397-406 530	COWF-711104 425, 409, 519, 520, 561
British Journal of Radiology, 12(133), 54-60 630	COWF-720505 302
Bulletin of the Geological Society of Finland, 47(1-2), 71-78 216	COWF-7206201 66
Canada Fisheries Research Board Journal, 27, 677-684 110	COWF-720700 200, 347, 350, 365
Canadian Medical Association Journal, 115(5), 433-434 423	COWF-720805 369
Canadian Nuclear Association, Proceedings of an International Conference held in Ottawa, Ontario, Canada, June, 1975, (pp. 19-43) 600	COWF-730475 60, 131, 134, 139, 190, 394, 409, 413, 414, 415, 432, 433, 434, 435, 441, 448, 450, 455, 456, 462, 483, 484, 485, 505, 510, 525, 533, 534, 540, 542, 595
Casopis Lekarsky, 1000(40), 1450-1455 431	COWF-730503 290
CIA-COWF-1105 506	COWF-730603 617
CIA-COWF-2336 290	COWF-730907 International Radiation Protection Association, Proceedings of the 3rd International Congress held in Washington, D.C., September 9-10, 1973, Part 1, (pp. 736-742) (COWF-730907) 393
Chemical Engineering Progress, 67(4), 81-86 731	COWF-731117 587
Chemical Geology, 10, 215-225 366	COWF-740115 61
Chemosphere, 1, 35-40 574	COWF-7404100 299
CCWF-164 644	COWF-740529 199
CCWF-304-1 75	COWF-741010 657
CCWF-440 93, 102, 230, 443, 453, 590	COWF-741120 346, 352
CCWF-561 306, 447, 490, 511	COWF-7504102 627
CCWF-610601 726	COWF-750445 301
CCWF-650906 150	COWF-750662 267
CCWF-651069 625	COWF-750672 229
CCWF-660212 44	COWF-751101 306
CCWF-660301 629	COWF-751104 729
CCWF-660422 15, 69, 82, 87, 89, 105, 107, 109, 179, 301, 392, 396, 397, 402, 404, 405, 406, 407, 408, 410, 416, 417, 418, 419, 422, 430, 449, 450, 451, 472, 492, 523, 529, 541, 544, 567, 646	COWF-751126 77, 119, 614, 723
CCWF-661010 562	COWF-755105 219
CCWF-670521 636	COWF-760316 564, 630
CCWF-670800 94	COWF-760806 300, 602, 602
CCWF-670930 19, 101, 124, 174, 467	COWF-760992 67
CCWF-680100 560	COWF-761071 591
	COWF-770204 620
	COWF-780907 (Part 1) 228

PUBLICATION DESCRIPTION INDEX

39

Controlling Airborne Effluents from Fuel Cycle Plants, Proceedings of the ANS-NCNR Topical Meeting held in San Valley, Idaho, August 5-6, 1976, (pp. 11-1 - 11-8), 300 pp. (CONF-760806) 300

Controlling Airborne Effluents from Fuel Cycle Plants, Proceedings of the ANS-NCNR Topical Meeting held in San Valley, Idaho, August 5-6, 1976, (pp. 10-1 - 10-16), 300 pp. (CONF-760806) 602

Controlling Airborne Effluents from Fuel Cycle Plants, Proceedings of the ANS-NCNR Topical Meeting held in San Valley, Idaho, August 5-6, 1976, (pp. 17-11 - 17-13), 300 pp. (CONF-760806) 602

CCO-119-229 5, 26, 107

CCC-119-229 127

CCO-119-230 711

CCC-119-231 50, 100

CCO-119-233 53

CCO-119-236 51, 65, 103

CCC-119-237 218

CCC-119-240 15, 41, 51

CCC-119-242 175, 475

CCO-119-247 186

CCC-119-248 58

CCO-119-245 690

CCO-119-246 40

CCC-119-248 45, 473

CCC-119-249 91

CCO-119-250 178

CCC-218 35, 126, 130, 155

CCC-220 89, 80, 50, 100, 102, 150

CCC-222 50

CCC-223 52

CCC-225 40, 176

CCC-226 55, 125

CCO-228 56, 150, 173

CCO-119-250 92

Delayed Effects of Bone-Seeking Radionuclides, C.W. Rys, et al (Eds.), Proceedings of a Symposium held in San Valley, Idaho, September 12-14, 1967 19

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Delayed Effects of Bone-Seeking Radionuclides, C.W. Rys, et al (Eds.), Proceedings of a Symposium held in San Valley, Idaho, September 12-14, 1967. University of Utah Press, Salt Lake City, Utah, (pp. 323-336), 519 pp. (CONF-670930) 170

Delayed Effects of Bone-Seeking Radionuclides, C.W. Rys, et al (Eds.), Proceedings of a Symposium held in San Valley, Idaho, September 12-14, 1967. University of Utah Press, Salt Lake City, Utah, (pp. 29-49), 519 pp. (CONF-670930) 067

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DEW (FDA)-76-0061 529

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Distribution, Retention and Late Effects of Thorium Dioxide, R.L. Swann (Ed.), Proceedings of a Conference held in New York, New York, April 20-22, 1966, 336 pp. (CONF-660422) 523

Distribution, Retention, and Late Effects of Thorium Dioxide, R.L. Swann (Ed.), Proceedings of a Conference held in New York, New York, April 20-22, 1966, (pp. 726-737), 336 pp. (CONF-660422) 15

Distribution, Retention, and Late Effects of Thorium Dioxide, R.L. Swann (Ed.), Proceedings of a Conference held in New York, New York, April 20-22, 1966, (pp. 755-758), 336 pp. (CONF-660422) 69

Distribution, Retention, and Late Effects of Thorium Dioxide, R.L. Swann (Ed.), Proceedings of a Conference held in New York, New York, April 20-22, 1966, (pp. 730-747), 336 pp. (CONF-660422) 82

Distribution, Retention, and Late Effects of Thorium Dioxide, R.L. Swann (Ed.), Proceedings of a Conference held in New York, New York, April 20-22, 1966, (pp. 533-544), 336 pp. (CONF-660422) 87

Distribution, Retention, and Late Effects of Thorium Dioxide, R.L. Swann (Ed.), Proceedings of a Conference held in New York, New York, April 20-22, 1966, (pp. 576-584), 336 pp. (CONF-660422) 89

Distribution, Retention, and Late Effects of Thorium Dioxide, R.L. Swann (Ed.), Proceedings of a Conference held in New York, New York, April 20-22, 1966, (pp. 720-727), 336 pp. (CONF-660422) 105

Distribution, Retention, and Late Effects of Thorium Dioxide, R.L. Swann (Ed.), Proceedings of a Conference held in New York, New York, April 20-22, 1966, (pp. 505-594), 336 pp. (CONF-660422) 107

Distribution, Retention, and Late Effects of Thorium Dioxide, R.L. Swann (Ed.), Proceedings of a Conference held in New York, New York, April 20-22, 1966, (pp. 817-829), 336 pp. (CONF-660422) 109

Distribution, Retention, and Late Effects of Thorium Dioxide, R.L. Swann (Ed.), Proceedings of a Conference held in New York, New York, April 20-22, 1966, (pp. 545-575), 336 pp. (CONF-660422) 179

Distribution, Retention, and Late Effects of Thorium Dioxide, R.L. Swann (Ed.), Proceedings of a Conference held in New York, New York, April 20-22, 1966, (pp. 767-775), 336 pp. (CONF-660422) 181

Distribution, Retention, and Late Effects of Thorium Dioxide, R.L. Swann (Ed.), Proceedings of a Conference held in New York, New York, April 20-22, 1966, (pp. 853-858), 336 pp. (CONF-660422) 392

Distribution, Retention, and Late Effects of Thorium Dioxide, R.L. Swann (Ed.), Proceedings of a Conference held in New York, New York, April 20-22, 1966, (pp. 795-805), 336 pp. (CONF-660422) 396

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- Distribution, Retention, and Late Effects of Thorium Dioxide, R.L. Swann (Ed.), Proceedings of a Conference held in New York, New York, April 20-22, 1966, (pp. 811-816), 336 pp. (CONF-660022) 802
- Distribution, Retention, and Late Effects of Thorium Dioxide, R.L. Swann (Ed.), Proceedings of a Conference held in New York, New York, April 20-22, 1966, (pp. 876-882), 336 pp. (CONF-660022) 880
- Distribution, Retention, and Late Effects of Thorium Dioxide, R.L. Swann (Ed.), Proceedings of a Conference held in New York, New York, April 20-22, 1966, (pp. 710-713), 336 pp. (CONF-660022) 805
- Distribution, Retention, and Late Effects of Thorium Dioxide, R.L. Swann (Ed.), Proceedings of a Conference held in New York, New York, April 20-22, 1966, (pp. 766-769), 336 pp. (CONF-660022) 806
- Distribution, Retention, and Late Effects of Thorium Dioxide, R.L. Swann (Ed.), Proceedings of a Conference held in New York, New York, April 20-22, 1966, (pp. 676-679), 336 pp. (CONF-660022) 807
- Distribution, Retention, and Late Effects of Thorium Dioxide, R.L. Swann (Ed.), Proceedings of a Conference held in New York, New York, April 20-22, 1966, (pp. 776-785), 336 pp. (CONF-660022) 808
- Distribution, Retention, and Late Effects of Thorium Dioxide, R.L. Swann (Ed.), Proceedings of a Conference held in New York, New York, April 20-22, 1966, (pp. 595-607), 336 pp. (CONF-660022) 810
- Distribution, Retention, and Late Effects of Thorium Dioxide, R.L. Swann (Ed.), Proceedings of a Conference held in New York, New York, April 20-22, 1966, (pp. 740-750), 336 pp. (CONF-660022) 817
- Distribution, Retention, and Late Effects of Thorium Dioxide, R.L. Swann (Ed.), Proceedings of a Conference held in New York, New York, April 20-22, 1966, (pp. 759-766), 336 pp. (CONF-660022) 818
- Distribution, Retention, and Late Effects of Thorium Dioxide, R.L. Swann (Ed.), Proceedings of a Conference held in New York, New York, April 20-22, 1966, (pp. 791-797), 336 pp. (CONF-660022) 819
- Distribution, Retention, and Late Effects of Thorium Dioxide, R.L. Swann (Ed.), Proceedings of a Conference held in New York, New York, April 20-22, 1966, (pp. 650-659), 336 pp. (CONF-660022) 822
- Distribution, Retention, and Late Effects of Thorium Dioxide, R.L. Swann (Ed.), Proceedings of a Conference held in New York, New York, April 20-22, 1966, (pp. 620-661), 336 pp. (CONF-660022) 830
- Distribution, Retention, and Late Effects of Thorium Dioxide, R.L. Swann (Ed.), Proceedings of a Conference held in New York, New York, April 20-22, 1966, (pp. 809-852), 336 pp. (CONF-660022) 849
- Distribution, Retention, and Late Effects of Thorium Dioxide, R.L. Swann (Ed.), Proceedings of a Conference held in New York, New York, April 20-22, 1966, (pp. 660-673), 336 pp. (CONF-660022) 850
- Distribution, Retention, and Late Effects of Thorium Dioxide, R.L. Swann (Ed.), Proceedings of a Conference held in New York, New York, April 20-22, 1966, (pp. 760-717), 336 pp. (CONF-660022) 851
- Distribution, Retention, and Late Effects of Thorium Dioxide, R.L. Swann (Ed.), Proceedings of a Conference held in New York, New York, April 20-22, 1966, (pp. 613-633), 336 pp. (CONF-660022) 872
- Distribution, Retention, and Late Effects of Thorium Dioxide, R.L. Swann (Ed.), Proceedings of a Conference held in New York, New York, April 20-22, 1966, (pp. 640-653), 336 pp. (CONF-660022) 892
- Distribution, Retention, and Late Effects of Thorium Dioxide, R.L. Swann (Ed.), Proceedings of a Conference held in New York, New York, April 20-22, 1966, (pp. 670-675), 336 pp. (CONF-660022) 526
- Distribution, Retention, and Late Effects of Thorium Dioxide, R.L. Swann (Ed.), Proceedings of a Conference held in New York, New York, April 20-22, 1966, (pp. 806-810), 336 pp. (CONF-660022) 541
- Distribution, Retention, and Late Effects of Thorium Dioxide, R.L. Swann (Ed.), Proceedings of a Conference held in New York, New York, April 20-22, 1966, (pp. 642-643), 336 pp. (CONF-660022) 544
- Distribution, Retention, and Late Effects of Thorium Dioxide, R.L. Swann (Ed.), Proceedings of a Conference held in New York, New York, April 20-22, 1966, (pp. 600-622), 336 pp. (CONF-660022) 567
- Distribution, Retention, and Late Effects of Thorium Dioxide, R.L. Swann (Ed.), Proceedings of a Conference held in New York, New York, April 20-22, 1966, (pp. 530-532), 336 pp. (CONF-660022) 644
- Division of Biological and Medical Research, Quarterly Report, February, March, April, 1952, (pp. 71-81), 175 pp. (BML-6790) 71
- Division of Biological and Medical Research, Quarterly Report, August, September, October, 1950, (2 pp.), 199 pp. (BML-6537) 110
- Division of Sea Fisheries Investigational Report No. 99 279
- DS-123 737
- Geometry and Toxicity of Thorotrast, Proceedings of an International Symposium held in Vienna, Austria, October 6-7, 1965, (22 pp.) (CONF-651069) 625
- Earth and Planetary Science Letters, 6, 451-454 270
- Earth and Planetary Science Letters, 33, 200-210 331
- Earth and Planetary Science Letters, 33(1), 176 443
- Ecology (USSR), 2, 157-162 207
- Education and Research in the Nuclear Fuel Cycle, Chapter 15, R.W. Elliott and L.E. Weaver (Eds.), University of Oklahoma Press, Norman, Oklahoma, (pp. 263-287) 300
- EGC 1183-2326 (Rev) 377
- Ekologiya, 2(5), 467-469 360
- Ekologiya, 6, 107-108 202
- Ekologiya, 6, 75-78 21
- Electric Light and Power, 23-24 310
- Engineering and Mining Journal, 292-294 317
- Engineering Technology Division Quarterly Progress Report for Third Quarter Fiscal 1977, (pp. 1-52) (CONF-78-6025) 320
- Environmental Analysis of the Uranium Fuel Cycle, Part 1, Fuel Supply, Appendix, (pp. A-10 - A-30), 109 pp. (EPA-520/9-73-003-B) 72
- Environmental Behavior of Radionuclides Released in the Nuclear Industry, Proceedings of a Symposium held in Aix-en-Provence, France, May 16-18, 1973, (pp. 333-346) (CEA-CONF-2336, IAEA/SH/172-55, CONF-730503) 311
- Environmental Conservation, 1(1) 21-30 300
- Environmental Monitoring at Major U.S. Atomic Energy Commission Contractor Sites, Calendar Year 1972, (pp. 553-596), 1217 pp. (EASU-1259) 553
- Environmental Monitoring at Major U.S. Atomic Energy Commission Contractor Sites, Calendar Year 1972, (pp. 613-666), 1217 pp. (EASU-17870, EASU-1259) 590

PUBLICATION DESCRIPTION INDEX

- Environmental Monitoring at Major U.S. Atomic Energy Commission Contractor Sites, Calendar Year 1972, (pp. 247-287), 1217 pp. (MLC-1090, UNS-1259) 623
- Environmental Monitoring at Major U.S. Atomic Energy Commission Contractor Sites, Calendar Year 1972, (pp. 311-400), 1217 pp. (MEL-0007, UNS-1259) 637
- Environmental Research, 13, 347-357 259
- Environmental Research, 8, 139-159 403
- Environmental Science and Technology, 11(4), 593-596 225
- Environmental Sciences Division Publication No. 700 279
- Environmental Sciences Division Annual Progress Report for Period Ending September 30, 1973, (pp. 99-115), 253 pp. (ORNL-5193) 323
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- ESA-524/9-73-083-8 724
- ESA-660/2-74-030 565, 713
- ESA/TIR-28 451
- ESDA-93 301
- EUD-06751 563
- EUD-070.2 75
- EUD-5001-a 621
- Exploration for Uranium Ore Deposits, Proceedings of an International Symposium held in Vienna, Austria, March 29-April 2, 1976 (pp. 35-53) (CONF-760316, IAEA-SM-268/3) 540
- Exploration for Uranium Ore Deposits, Proceedings of an International Symposium held in Vienna, Austria, March 29-April 2, 1976, (pp. 107-120) (CONF-760316, IAEA-SM-268/55) 630
- Federation Proceedings, 20, 206-219 28
- GA-A9304 302
- GA-A9401 303
- GA-620 603
- Geochimica et Cosmochimica Acta, 27(2), 137-154 592
- Geograficheskoe Obozreniye SSSR Zashchit'otii Piliat. Inventiya Chita, 3(2), 67-81 357
- Geologica Carpathica, 26(1), 105-110 261
- Geological Survey of Japan, Bulletin, 20(7), 135-404 236
- Gigiena i Sanitariya 11, 55-58 490
- Gigiena i Sanitariya, 10, 45-48 137
- Gigiena i Sanitariya, 2, 112-118 251
- Gigiena i Sanitariya, 3, 71-74 549
- Gigiena i Sanitariya, 37(2), 60-64 73
- Gigiena i Sanitariya, 37(8), 53-57 709
- Gigiena i Sanitariya, 30(11), 55-58 250
- Gigiena i Sanitariya, 30(3), 53-58 308
- Gigiena i Sanitariya, 30(8), 45-47 121
- Gigiena i Sanitariya, 8, 45-47 122
- Gigiena i Sanitariya, 8, 52-55 442
- Gigiena i Sanitariya, 8, 69-71 200
- Gigiena i Sanitariya, 9, 30-38 710
- Giornale di Fisica Sanitaria e Protezione Contro le Radiazioni, 16(1), 1-6 260
- Groslan's Geological Undergraduate Report No. 60 367
- Guidelines to Radiological Health Lectures, Proceedings of an International Conference held in Montreal, Canada, August, 1967, (pp. 59-63) (IPHS-999-88-33, CONF-670040) 90
- Harford Biology Research Annual Report for 1964, R.C. Thompson and S.W. Woods (Eds.) (pp. 21-24), 216 pp. (ORNL-122) 157
- Harford Biology Research Annual Report for 1963, R.A. Kernberg and E.C. Swenson (Eds.), (pp. 50-51), 202 pp. (OR-00500) 161
- IASI-150 554
- Hazards Control Progress Report No. 30, September through December 1970, (pp. 7-9) (UCRL-50007-70-3) 506
- Health Physics Society, Proceedings of the 10th Annual Symposium held in Miami Beach, Florida, June 17-21, 1973, (10 pp.) (CONF-730603, OCL-74020) 617
- Health Physics Society, Proceedings of a Symposium held in Las Vegas, Nevada, June 12-16, 1961, (19 pp.) (CONF-610607) 726
- Health Physics, 1, 260-275 215
- Health Physics, 10(12), 1129-1135 490
- Health Physics, 10(12), 1137-1171 306
- Health Physics, 10(12), 1163-1170 467
- Health Physics, 10(12), 1163-1190 309
- Health Physics, 10(12), 1195-1201 511
- Health Physics, 10(12), 909-915 500
- Health Physics, 10, 1013-1020 100
- Health Physics, 11, 1275-1295 759
- Health Physics, 12, 333-340 374
- Health Physics, 13, 135-140 171
- Health Physics, 13, 375-378 420
- Health Physics, 13, 431-443 427
- Health Physics, 13, 45-50 693
- Health Physics, 10, 111-117 100
- Health Physics, 10, 461-472 57
- Health Physics, 15, 359-362 616
- Health Physics, 16, 257-267 439
- Health Physics, 17, 139-144 102
- Health Physics, 17, 429-432 450
- Health Physics, 17, 89-107 640
- Health Physics, 18, 263-266 710

PUBLICATION DESCRIPTION INDEX

- Health Physics, 10, 431-432 446
 Health Physics, 19(6), 757-767 14
 Health Physics, 19, 235-243 436
 Health Physics, 19, 511-520 509
 Health Physics, 19, 657-662 497
 Health Physics, 19, 713-729 510
 Health Physics, 2, 225-230 62
 Health Physics, 20, 485-490 480
 Health Physics, 21(4), 499-510 391
 Health Physics, 21, 197-204 172
 Health Physics, 22(6), 793-801 123
 Health Physics, 22, 102-103 411
 Health Physics, 22, 441-450 599
 Health Physics, 22, 471-482 421
 Health Physics, 23(3), 416-417 446
 Health Physics, 23, 163-164 716
 Health Physics, 23, 437 460
 Health Physics, 23, 575-576 465
 Health Physics, 22, 860-861 487
 Health Physics, 24, 301-310 577
 Health Physics, 24, 403-409 129
 Health Physics, 25(3), 310-315 165
 Health Physics, 25, 239-250 114
 Health Physics, 25, 505-502 173
 Health Physics, 26, 399-403 429
 Health Physics, 27, 265-272 549
 Health Physics, 28, 225-231 400
 Health Physics, 28, 639-644 559
 Health Physics, 29(5), 826-827 537
 Health Physics, 29(6), 839-851 700
 Health Physics, 29(6), 906 373
 Health Physics, 29, 155-162 376
 Health Physics, 29, 410-419 516
 Health Physics, 29, 767-775 517
 Health Physics, 31(3), 277-278 196
 Health Physics, 31, 109-110 401
 Health Physics, 32(1), 50 615
 Health Physics, 32, 234-241 576
 Health Physics, 33, 393-404 641
 Health Physics, 7, 191-204 699
 Health Physics, 8, 17-25 204
 Health Physics, 8, 279-297 726
 Health Physics, 8, 725-730 29
 Health Physics, 9, 153-163 105
 Health Physics, 9, 165-176 24
 Human Cytoprotection, Proceedings of a 3rd Symposium held in Sydney, Australia, March 26, 1971, (9 pp.) (CONF-710320) 543
 HU-00500 161
 HU-01933 719
 HU-01964 718
 HU-03204 713
 Hygiene and Sanitation, 35(1-3), 63-71 133
 IAEA-SR-112/11 570
 IAEA-SR-112/13 582
 IAEA-SR-116/3 59
 IAEA-SR-144/40 620
 IAEA-SR-144/61 635
 IAEA-SR-150 479
 IAEA-SR-150/10 120
 IAEA-SR-150/02 561
 IAEA-SR-150/11 350
 IAEA-SR-150/31 200
 IAEA-SR-150/50 347
 IAEA-SR-150/51 345
 IAEA-SR-100/22 107
 IAEA-SR-104/11 199
 IAEA-SR-171/13 352
 IAEA-SR-191/3 346
 IAEA-SR-190 267
 IAEA-SR-199/51 219
 IAEA-SR-202/004 119
 IAEA-SR-202/010 610
 IAEA-SR-202/507 77
 IAEA-SR-204/3 564
 IAEA-SR-204/05 630
 IAEA-SR-3/5 627
 IAEA/SR-112/10 546
 IAEA/SR/172-55 290
 ICRP Publication 10a 445
 ICRP Publication 11 444
 ICRP Publication 19 116
 ICR-015 571
 Indian Medical Journal, 66(10), 191-195 237
 Industrial Hygiene Association Journal, 20, 155-163 23
 Industrial Hygiene Association Journal, 20, 430-436 262
 Industrial Hygiene Association Quarterly, 13(4), 191-195 697
 Industrial Laboratory, 4(10), 1059-1061 610

PUBLICATION DESCRIPTION INDEX

- Inhaled Particles and Vapors, Proceedings of the 2nd International Symposium held in Cambridge, England, September 27-30, 1965, (pp. 291-297) (CONF-650906) 150
- Inhaled Particles, Proceedings of the 3rd International Symposium held in London, England, September 21-23, 1970, (26 pp.) (CONF-700931, IAEA-SM-3479) 162
- Inhaled Radioactive Particles and Gases, Proceedings of the Banford Symposium held in Richmond, Washington, May 4-6, 1964, (26 pp.) (CONF-561) 386
- Inhaled Radioactive Particles and Gases, Proceedings of the Banford Symposium held in Richmond, Washington, May 4-6, 1964, (11 pp.) (CONF-561) 447
- Inhaled Radioactive Particles and Gases, Proceedings of the Banford Symposium held in Richmond, Washington, May 4-6, 1964, (8 pp.) (CONF-561) 490
- Inhaled Radioactive Particles and Gases, Proceedings of the Banford Symposium held in Richmond, Washington, May 4-6, 1964, (7 pp.) (CONF-561) 511
- Initial Reports of the Deep Sea Drilling Project, Vol. 23, (pp. 951-952) 613
- Interaction of Radioactive Contaminants with the Constituents of the Marine Environment, Proceedings of a Symposium held in Seattle, Washington, July 10-14, 1972, (pp. 499-525) (CONF-720700, IAEA-SM-154/11) 261
- Interaction of Radioactive Contaminants with the Constituents of the Marine Environment, Proceedings of a Symposium held in Seattle, Washington, July 10-14, 1972, (pp. 747-755) (CONF-720700, IAEA-SM-154/50) 347
- Interaction of Radioactive Contaminants with the Constituents of the Marine Environment, Proceedings of a Symposium held in Seattle, Washington, July 10-14, 1972, (pp. 177-173) (CONF-720700, IAEA-SM-154/11) 350
- Interaction of Radioactive Contaminants with the Constituents of the Marine Environment, Proceedings of a Symposium held in Seattle, Washington, July 10-14, 1972, (pp. 757-769) (CONF-720700, IAEA-SM-154/57) 365
- International Journal of Applied Radiation and Isotopes, 19, 665-676 573
- International Journal of Applied Radiation and Isotopes, 20(8), 727-731 607
- International Journal of Applied Radiation and Isotopes, 20, 575-578 631
- International Journal of Nuclear Medicine and Biology, 2(1), 31-33 63
- International Journal of Radiation Biology, 20(3), 233-243 132
- International Radiation Protection Association, Proceedings of the 3rd International Congress held in Washington, D.C., September 9-14, 1973, (pp. 532-537), 1975 pp. (CONF-760907) 228
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- Isotope Ratios as Pollutant Source and Behavior Indicators, Proceedings of a Symposium held in Vienna, Austria, November 10-22, 1974, (pp. 169-170), 489 pp. (CONF-741120, STI/P08/302, IAEA-SM-191/3) 346
- Isotope Ratios as Pollutant Source and Behavior Indicators, Proceedings of a Symposium held in Vienna, Austria, November 10-22, 1974, (pp. 255-265), 489 pp. (CONF-741120, STI/P08/302, IAEA-SM-191/13) 352
- Italian Association for Health Physics and Protection from Radiation, Proceedings of the 10th National Conference held in Forno, Italy, May 29, 1968, (CONF-680535) 226
- Investiya Sibirskogo Otdeleniya Akademii Nauk SSSR, 4, 108-110 208
- JARSI-5017 633
- Japan Analyst, 7, 401-404 272
- Journal of Agricultural and Food Chemistry, 16, 231-239 355
- Journal of Air Pollution Control Association, 25(7), 721-724 583
- Journal of Analytical Chemistry, 25(7), 99-105 264
- Journal of Analytical Chemistry (USSR), 32(2), 253-257 545
- Journal of Chemical Education, 3(7), 1267-1287 401
- Journal of Chemical Physics, 4, 30-42 653
- Journal of Clinical Investigation, 43(4), 705-719 36
- Journal of Geophysical Research, 80(30), 6153-6162 276
- Journal of Geophysical Research, 73(10), 3125-3142 666
- Journal of Hygiene, Epidemiology, Microbiology, and Immunology, 19(2), 237-245 539
- Journal of Industrial Hygiene and Toxicology, 13(4), 177-180 513
- Journal of Industrial Hygiene and Toxicology, 22(3), 69-99 579
- Journal of Industrial Hygiene and Toxicology, 20(7), 36-45 677
- Journal of Pharmacology and Experimental Therapeutics, 196, 286-290 147
- Journal of Pharmacology and Experimental Therapeutics, 196, 317-324 198
- Journal of Radiation Research, 17(1), 43 328
- Journal of Radiation Research, 17(1), 21-22 350
- Journal of Radioanalytical Chemistry, 37, 927-943 100
- Journal of Radioanalytical Chemistry, 10, 45-51 227
- Journal of Radioanalytical Chemistry, 33, 139-152 230
- Journal of Radioanalytical Chemistry, 30, 299-308 601
- Journal of Research of the U.S. Geological Survey, 5(1), 83-91 645
- Journal of Sedimentary Petrology, 43(4), 985-997 301
- Journal of Soil and Water Conservation, 32(4), 171-176 670
- Journal of Soil Science, 24(3), 360-379 372
- Journal of the Air Pollution Control Association, 25(9), 910-917 312
- Journal of the American Medical Association, 160(7), 1-3 461
- Journal of the American Medical Association, 85(23), 1769-1776 470
- Journal of the American Medical Association, 230(5), 423 530
- Journal of the National Cancer Institute, 49(3), 461-464 471
- Journal of the Oceanographical Society of Japan, 29, 76-83 27
- Journal of the Oceanographical Society of Japan, 26(3), 130-136 354
- Journal of the Reticuloendothelial Society, 6, 1-23 145

PUBLICATION DESCRIPTION INDEX

- JOL-1206 311
 K/CP-219 306
 K/OD-241 296
 KFK-2022 671
 Khaliya v shko Khonyainov, 13(2), 70-71 353
 LI-12001 655
 LI-6090-P2 620
 LI-7062-02 554
 Late Somatic Effects of Ionizing Radiation, (pp. 137-138), 310 pp. (TID-20310) 194
 LEL-914 349
 LI-tr-1 74
 LI-tr-41 690
 LI-21 184
 Limnology and Oceanography, 14, 263-268 156
 Limnology and Oceanography, 15, 943-955 203
 Limnology and Oceanography, 16, 250-253 210
 Limnology and Oceanography, 16(5), 763-770 354
 Limnology and Oceanography, 21(2), 294-299 109
 Manual on Radiation Acoustology, Chapter 21, (pp. 215-242) (STI/DOC/10) 535
 NRC-63153 685
 Medical Physics, 1(1), 36 715
 Medicine--Analytical Reviews of Internal Medicine, Gerontology, Neurology, Pediatrics and Psychiatry, 31, 221-229 390
 Microscope, 20, 175-182 222
 Minerals Yearbook, 1974, (pp. 1269-1276) 319
 Minerva Fisicocnucleare, 13, 86-92 226
 Mining Engineering, 46-48 643
 MIT-951-3 412
 Monographie Botanicae, 35, 161-203 213
 Morphology of Experimental Respiratory Carcinogenesis, P. Wettstein, et al (Eds.), Proceedings of a Conference held in Gatlinburg, Tennessee, May 13-16, 1970, (pp. 417-436) (CONF-700507) 135
 National Bureau of Standards Handbook No. 52 496
 Natural Radiation Environment, Proceedings of a Symposium held in Houston, Texas, August 7-11, 1972, (54 pp.) (LEL-914 CONF-720805) 369
 Nature, 181, 510-521 531
 Nature, 187(4737), 575-576 117
 Nature, 187, 152-195 206
 Nature, 187, 248-211 210
 Nature, 203(4943), 352-355 30
 Nature, 203, 129-143 263
 Nature, 210, 551-593 448
 Nature, 221, 1207-1209 12
 Nature, 245(5591), 227-229 230
 New Zealand Journal of Science, 19, 375-382 331
 New Zealand Journal of Science, 19, 243-247 335
 NIOSH-75-171 679
 NRC-1090 623
 NRC-1130 620
 NRC-770 240
 NE-10670 495
 NE-20310 379
 NRS-20 491
 Nuclear Engineering International, 22(250), 64-68 676
 Nuclear Metallurgy, IAS Special Report Series No. 1, (pp. 39-63) 245
 Nuclear Methods in Environmental Research, University of Missouri, (pp. 30-31) 622
 Nuclear News, 12(4), 23-24 649
 Nuclear Power Project Planning and Implementation, Proceedings of an Interregional Training Course held in Karlsruhe, Germany, September 6-November 30, 1976, 48 pp. (NEP-COOP-76-640-020) 330
 Nuclear Safety, 17(3), 351-362 268
 Nuclear Safety, 5(4), 382-389 465
 Nuclear Techniques and Mineral Resources in Developing Countries, Proceedings of a Panel held in Krakow, Poland, December 8-12, 1969, (pp. 163-184) (CONF-691229, IAEA-SM-112/11) 570
 Nuclear Techniques and Mineral Resources in Developing Countries, Proceedings of a Panel held in Krakow, Poland, December 8-12, 1969, (pp. 187-196) (CONF-691229, IAEA-SM-112/13) 582
 Nuclear-Medizin, Supplementum, 9, 579-585 452
 Nucleonics Week, 10(26), 7 329
 Nucleonics, 10(8), 60-64 232
 Nucleonics, 8(3), 66-78 721
 Nucleonics, 8(4), 59- 722
 NTO-2577-8 700
 NTO-3273-9 496
 NTO-4700 (Rev.) (Suppl. 1) 590
 Occupational Health Experience with Uranium, Proceedings of a Symposium held in Arlington, Virginia, April 28-30, 1975, (pp. 25-64), 441 pp. (CONF-750405, EMBL-93) 301
 Operational Health Physics, Proceedings of the Health Physics Society 9th Winter Topical Symposium held in Denver, Colorado, February 9-12, 1976, (6 pp.) (OHL-77106) 610
 OHL-7N-3548 296, 730
 OHL-7N-4323 695
 OHL-7N-4724 732
 OHL-7N-4783 730
 OHL-tr-2905 494
 OHL-tr-4382 671
 OHL-tr-4496 330
 OHL-tr-4497 122

PFI TITLE DESCRIPTION NUMBER

- OFBL-tr-8090 353
- OFBL-tr-8099 402
- OFBL-tr-8500 509
- OFBL-tr-8501 357
- OFBL-tr-8503 251
- OFBL-tr-8510 370
- OFBL-tr-8526 270
- OFBL-tr-8592 211
- OFBL-tr-87 706
- OFBL-8930 200
- OFBL-5109 710
- OFBL-5193 323
- OFBL-5204 670
- OFBL/80000/70-0 735
- OFBL/80000/70-5 739
- OFBL/80000/70-7 700
- OFBL/70-5565 309
- OFBL/70-5909 321
- OFBL/70-6025 320
- OFB-SID-72-1 717
- OFB/LV-76-9 575
- Paper No. 1900 300
- Pathology Annual, S. Sommers (Ed.), Vol. 6, (pp. 107-169) 020
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- Ph.D. Thesis, University of Rochester 7, 130
- PIS-999-80-33 90
- Physical Review, 50, 013-021 662
- Physics in Medicine and Biology, 21(1), 52-59 372
- Physics in Medicine and Biology, 19(0), 060-071 303
- Physics in Medicine and Biology, 1, 125-137 500
- Physics in Medicine and Biology, 1, 130-140 509
- Physics in Medicine and Biology, 3, 101-110 510
- Physics in Medicine and Biology, 1, 57-70 632
- Physics in Medicine and Biology, 15, 762 705
- Physiologia Bohemoslovaca, 20(5), 059 090
- Plant and Soil, 40, 397-003 206
- Plutonium Information, Proceedings of a Symposium held in Los Alamos, New Mexico, January 4-5, 1970, (pp. 30-55), 96 pp. (CONF-700115) 61
- PML-2500 (Part 7) 10, 11
- PML-2503 600
- Pechvedenje, 3, 55-67 303
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- Power Engineering, 00, 56-60 650
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- Proceedings of the Society for Experimental Biology and Medicine, 105, 351-356 90
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- Radiation Botany, 10, 293-296 202
- Radiation Data and Reports, 11, 001-000 605
- Radiation Data and Reports, 13(3), 100-107 609
- Radiation Data and Reports, 13(0), 109-190 650
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- Radiation Research, 12, 657-671 151
- Radiation Research, 17, 625-601 60
- Radiation Research, 27, 505 60
- Radiation Research, 30, 501-522 20

PUBLICATION DESCRIPTION INDEX

- Radiation Research, 43(4), 71 557
- Radiation Research, 43, 393-432 31
- Radiation Research, 43, 56-70 43
- Radiation Research, 47(4), 254 187
- Radiation Research, 48, 291-302 585
- Radiation Research, 48, 319-331 42
- Radiation Research, 51, 15-30 32
- Radiation Research, 59, 250 81
- Radiation Research, 5, 438-444 476
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- Radioekologicheskie Issledovaniya v Prirodnykh Biogeotsenozakh, Izdatel'stvo Nauk, Moscow, USSR, (pp. 243-256) (RFF-Trans-167) 292
- Radioekologicheskie Issledovaniya v Prirodnykh Biogeotsenozakh, Izdatel'stvo Nauka, I.V. Verkhovskaya (Ed.), Moscow, USSR, (pp. 42-53) 361
- Radioekologicheskie Issledovaniya v Prirodnykh Biogeotsenozakh, Izdatel'stvo Nauka, I.V. Verkhovskaya (Ed.), Moscow, USSR 362
- Radioekologicheskie Issledovaniya v Prirodnykh Biogeotsenozakh, Izdatel'stvo Nauka, I.V. Verkhovskaya (Ed.), Moscow, USSR 364
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- Radiological Health and Safety in Nuclear Materials Mining and Milling, Vol. 2, Proceedings of a Symposium held in Vienna, Austria, August, 1963, (pp. 475-487) (CONF-1004) 644
- Radiological Health Data and Reports, 12(3), 119-120 568
- Radiological Health Data and Reports, 4(5), 225-278 647
- Radiological Health Data and Reports, 5(8), 351-409 648
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- Radiology, 51, 831-835 387
- Radiology, 60, 573-578 540
- Radiology, 68, 358-365 426
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PUBLICATION DESCRIPTION INDEX

29

Rapid Methods for Measurement of Radioactivity in the Environment, Proceedings of an International Symposium held in Neuchâtel, Switzerland, July 5-9, 1971, (pp. 163-197) (COSY-710705, IAEA-54-149 161) 615

RT/B-3523 615

Records of Oceanographic Works in Japan, 9(2), 189-195 277

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Research in Radiobiology, U.S.S. Joe, Annual Report of Work in Progress in the Internal Irradiation Program, T.F. Dougherty (Ed.), (pp. 9-119), 330 pp. (COO-119-209) 91

Research in Radiobiology, Annual Report of Work in Progress in the Internal Irradiation Program, T.F. Dougherty (Ed.), (pp. 243-261) (COO-119-240) 19

Research in Radiobiology, Annual Report of Work in Progress in the Internal Irradiation Program, T.F. Dougherty, (pp. 272-281), 189 pp. (COO-119-246) 40

Research in Radiobiology, Annual Report of Work in Progress in the Internal Irradiation Program, T.F. Dougherty, (pp. 224-242) (COO-119-240) 41

Research in Radiobiology, Annual Report of Work in Progress in the Internal Irradiation Program, T.F. Dougherty, (pp. 9-109), 409 pp. (COO-119-246) 45

Research in Radiobiology, Annual Report of Work in Progress in the Internal Irradiation Program, T.F. Dougherty (Ed.), (pp. 7-85) (COO-119-240) 57

Research in Radiobiology, Annual Report of Work in Progress on the Chronic Toxicity Program, T.F. Dougherty, (pp. 75-77), 225 pp. (COO-220) 80

Research in Radiobiology, Annual Report of Work in Progress on the Chronic Toxicity Program, T.F. Dougherty, (pp. 150-165), 225 pp. (COO-220) 98

Research in Radiobiology, Annual Report of Work in Progress on the Chronic Toxicity Program, T.F. Dougherty, (pp. 99-143), 225 pp. (COO-220) 100

Research in Radiobiology, Annual Report of Work in Progress in the Internal Irradiation Program, T.F. Dougherty, (pp. 97-125), 268 pp. (COO-119-236) 103

Research in Radiobiology, Annual Report of Work in Progress on the Chronic Toxicity Program, T.F. Dougherty, (pp. 85-98), 172 pp. (COO-119-231) 104

Research in Radiobiology, Annual Report of Work in Progress on the Chronic Toxicity Program, T.F. Dougherty, (pp. 215-220), 225 pp. (COO-220) 150

Research in Radiobiology, Annual Report of Work in Progress in the Internal Irradiation Program, T.F. Dougherty (Ed.), (pp. 211-242) (COO-119-242) 175

Research in Radiobiology, Annual Report of Work in Progress on the Chronic Toxicity Program, T.F. Dougherty (Ed.), (pp. 43-47), 134 pp. (COO-225) 176

Research in Radiobiology, Annual Report of Work in Progress in the Internal Irradiation Program, U.S.S. Joe (Ed.), (pp. 197-209), 281 pp. (COO-119-250) 178

Research in Radiobiology, Annual Report of Work in Progress in the Internal Irradiation Program, T.F. Dougherty, (pp. 181-187) COO-119-237 218

Research in Radiobiology, Annual Report of Work in Progress in the Internal Irradiation Program, T.F. Dougherty (Ed.), (pp. 378-400), 400 pp. (COO-119-248) 473

Research in Radiobiology, Annual Report of Work in Progress in the Internal Irradiation Program, T.F. Dougherty, (pp. 385-401) (COO-119-242) 475

Research in Radiobiology, Report of Work in Progress in the Internal Irradiation Program, T.F. Dougherty, (pp. 218-251), 268 pp. (COO-119-236) 65

Research in Radiobiology, Report of Work in Progress on the Chronic Toxicity Program, T.F. Dougherty, (pp. 144-148), 225 pp. (COO-220) 102

Research in Radiobiology, Semiannual Report of Work in Progress on the Chronic Toxicity Program, (pp. 3-55), 185 pp. (COO-228) 56

Research in Radiobiology, Semiannual Report of Work in Progress on the Chronic Toxicity Program, T.F. Dougherty, (pp. 61-65), 185 pp. (COO-228) 154

Research in Radiobiology, Semiannual Report of Work in Progress on the Chronic Toxicity Program, T.F. Dougherty (Ed.), (pp. 95-108), 185 pp. (COO-228) 173

Review of Scientific Instruments, 6, 99-112 578

RFP-Trans-162 292

RFP-Trans-222 452

RISO-254 69, 131, 134, 139, 190, 394, 409, 413, 414, 415, 432, 433, 434, 435, 441, 446, 454, 455, 456, 467, 483, 484, 485, 505, 514, 525, 533, 534, 540, 542, 545

RISO-294 485, 514, 533

RISO-317 619

RLO-2213 (Suppl. 2) 326

Royal Society of Edinburgh, Series B, 72, 167-192 327

Safety Series No. 43 672

SC-N-67-3044 220

Science of the Total Environment, 5(2), 171-179 223

Science of the Total Environment, 7(1), 45-52 285

Science, 173(3991), 47-48 661

Search, 7(8), 345-353 499

Sel'skhozisistannaia Biologia, 11(3), 449-452 200

Semi-Annual Report of Work in Progress on the Chronic Toxicity Program, T.F. Dougherty (Ed.) (pp. 78-84), 175 pp. (COO-226) 125

Semiannual Progress Report, (pp. 57-61), 80 pp. (AECU-3109) 1

Semiannual Progress Report, (pp. 51-54), 80 pp. (AECU-3109) 4

Semiannual Progress Report, (pp. 71-73), 80 pp. (AECU-3109) 136

Semiannual Progress Report, (pp. 4-12), 80 pp. (AECU-3109) 193

Shin Kizoku, 18(5), 118-123 522

SN-125/1 712

Soil Science, 105(1), 44-50 344

Soil Science, 110(1), 31-36 341

Soil Science, 123(4), 241-248 385

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South African Journal of Science, 73, 53-57 636

Southern Medical Journal, 69(4), 510-512 669

Soviet Journal of Ecology, 7(5), 467-469 368

Soviet Journal of Ecology, 2(6), 502-503 282

Soviet Journal of Ecology, 3(6), 545-547 21

Soviet Soil Science, 2(3), 290-302 363

Soviet Soil Science, 3(1), 126 659

State of the Art: Uranium Mining, Milling, and Refining Industry, (pp. 90-101), 113 pp. (EPA-660/2-74-038) 565

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STI/DOC/10 535

STI/PUB/195 710

STI/PUB/290 425, 489, 519, 520, 561

STI/PUB/353 587

STI/PUB/375 199

STI/PUB/402 386, 352

STI/PUB/406 267

STI/PUB/409 77

STI/PUB/410 627

STI/PUB/44 93, 102, 230, 403, 453, 590

Summary Technical Report for the Period October 1, 1965 to December 31, 1965, (pp. 1.1-1.22) (SLCO-970) 243

Swedish Resistitochtbl, 40(17), 372-376 296

SZS-100 66, 603

SZS-3/6' 74

Talanta, 16, 345-350 239

Talanta, 20, 1303-1308 241

Talanta, 20, 185-192 224

Talanta, 20, 892-895 257

Talanta, 21(12), 1231-1245 245

Talanta, 23, 295-300 242

Technical Reports Series No. 123 535

Technical Reports Series No. 52 295, 305, 310, 313, 314, 315, 316, 336, 600

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TID-24310 190

TID-24919 720

TID-25006 552

TID-26502 337

TID-4840 (1st ed.) 642

To be published in Journal of Environmental Quality, 1978 322

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Toxicity of Thorotrast, H. Faber (Ed.), Proceedings of the 3rd International Meeting held in Copenhagen, Denmark, April 25-27, 1973, (pp. 281-292) (CONF-730475, NISO-294) 139

Toxicity of Thorotrast, H. Faber (Ed.), Proceedings of the 3rd International Meeting held in Copenhagen, Denmark, April 25-27, 1973, (pp. 61-71) (CONF-730475, NISO-294) 190

Toxicity of Thorotrast, H. Faber (Ed.), Proceedings of the 3rd International Meeting held in Copenhagen, Denmark, April 25-27, 1973, (pp. 110-125) (CONF-730475, NISO-294) 390

Toxicity of Thorotrast, H. Faber (Ed.), Proceedings of the 3rd International Meeting held in Copenhagen, Denmark, April 25-27, 1973, (pp. 81-94) (CONF-730475, NISO-294) 409

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Toxicity of Thorotrast, H. Faber (Ed.), Proceedings of the 3rd International Meeting held in Copenhagen, Denmark, April 25-27, 1973, (pp. 137-147) (CONF-730475, NISO-294) 414

Toxicity of Thorotrast, H. Faber (Ed.), Proceedings of the 3rd International Meeting held in Copenhagen, Denmark, April 25-27, 1973, 340 pp. (CONF-730475, NISO-294) 415

Toxicity of Thorotrast, H. Faber (Ed.), Proceedings of the 3rd International Meeting held in Copenhagen, Denmark, April 25-27, 1973, (pp. 259-266) (CONF-730475, NISO-294) 432

Toxicity of Thorotrast, H. Faber (Ed.), Proceedings of the 3rd International Meeting held in Copenhagen, Denmark, April 25-27, 1973, (pp. 233-247) (CONF-730475, NISO-294) 433

Toxicity of Thorotrast, H. Faber (Ed.), Proceedings of the 3rd International Meeting held in Copenhagen, Denmark, April 25-27, 1973, (pp. 193-211) (CONF-730475, NISO-294) 434

Toxicity of Thorotrast, H. Faber (Ed.), Proceedings of the 3rd International Meeting held in Copenhagen, Denmark, April 25-27, 1973, (pp. 219-232) (CONF-730475, NISO-294) 435

Toxicity of Thorotrast, H. Faber (Ed.), Proceedings of the 3rd International Meeting held in Copenhagen, Denmark, April 25-27, 1973, (pp. 317-319) (CONF-730475, NISO-294) 441

Toxicity of Thorotrast, H. Faber (Ed.), Proceedings of the 3rd International Meeting held in Copenhagen, Denmark, April 25-27, 1973, (pp. 126-137) (CONF-730475, NISO-294) 448

Toxicity of Thorotrast, H. Faber (Ed.), Proceedings of the 3rd International Meeting held in Copenhagen, Denmark, April 25-27, 1973, (pp. 10-30) (CONF-730475, NISO-294) 454

Toxicity of Thorotrast, H. Faber (Ed.), Proceedings of the 3rd International Meeting held in Copenhagen, Denmark, April 25-27, 1973, (pp. 40-51) (CONF-730475, NISO-294) 455

PUBLICATION DESCRIPTION INDEX

Toxicity of Thorotrast, H. Faber (Ed.), Proceedings of the 3rd International Meeting held in Copenhagen, Denmark, April 25-27, 1973, (pp. 104-113) (CONF-730475, NISC-294) 454

Toxicity of Thorotrast, H. Faber (Ed.), Proceedings of the 3rd International Meeting held in Copenhagen, Denmark, April 25-27, 1973, (pp. 167-174) (CONF-730475, NISC-294) 462

Toxicity of Thorotrast, H. Faber (Ed.), Proceedings of the 3rd International Meeting held in Copenhagen, Denmark, April 25-27, 1973, (pp. 175-192) (CONF-730475, NISC-294) 463

Toxicity of Thorotrast, H. Faber (Ed.), Proceedings of the 3rd International Meeting held in Copenhagen, Denmark, April 25-27, 1973, (pp. 320-333) (CONF-730475, NISC-294) 484

Toxicity of Thorotrast, H. Faber (Ed.), Proceedings of the 3rd International Meeting held in Copenhagen, Denmark, April 25-27, 1973, (pp. 320-333) (CONF-730475, NISC-294) 485

Toxicity of Thorotrast, H. Faber (Ed.), Proceedings of the 3rd International Meeting held in Copenhagen, Denmark, April 25-27, 1973, (pp. 95-103) (CONF-730475, NISC-294) 505

Toxicity of Thorotrast, H. Faber (Ed.), Proceedings of the 3rd International Meeting held in Copenhagen, Denmark, April 25-27, 1973, (pp. 151-156) (CONF-730475, NISC-294) 510

Toxicity of Thorotrast, H. Faber (Ed.), Proceedings of the 3rd International Meeting held in Copenhagen, Denmark, April 25-27, 1973, (pp. 212-218) (CONF-730475, NISC-294) 525

Toxicity of Thorotrast, H. Faber (Ed.), Proceedings of the 3rd International Meeting held in Copenhagen, Denmark, April 25-27, 1973, (pp. 163-168) (CONF-730475, NISC-294) 533

Toxicity of Thorotrast, H. Faber (Ed.), Proceedings of the 3rd International Meeting held in Copenhagen, Denmark, April 25-27, 1973, (pp. 157-162) (CONF-730475, NISC-294) 538

Toxicity of Thorotrast, H. Faber (Ed.), Proceedings of the 3rd International Meeting held in Copenhagen, Denmark, April 25-27, 1973, (pp. 248-258) (CONF-730475, NISC-294) 540

Toxicity of Thorotrast, H. Faber (Ed.), Proceedings of the 3rd International Meeting held in Copenhagen, Denmark, April 25-27, 1973, (pp. 52-60) (CONF-730475, NISC-294) 542

Toxicity of Thorotrast, H. Faber (Ed.), Proceedings of the 3rd International Meeting held in Copenhagen, Denmark, April 25-27, 1973, (pp. 148-150) (CONF-730475, NISC-294) 552

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TR-490-75 769

Transactin's Isotope Nuclear Data, Proceedings of the INEA Advisory Group Meeting held in Karlsruhe, Germany, November 3-7, 1975, (15 pp.) (CONF-751104) 729

Transactions of the American Nuclear Society, 19, 211 266

Transactions of the American Nuclear Society, 18, 392-353 728

Transactions of the British Mycological Society, 64(2), 175-193. 212

Transactions of the Japan Institute of Metals, 17(7), 426-434 258

Transuranium Nucleides in the Environment, Proceedings of an International Symposium held in San Francisco, California, November 17-21, 1975, (20 pp.) (IAEA-SR-199/51, CONF-755105) 219

Trudy Bykynskogo Instituta Estestvennykh Nauk Seriya Fizikal'no-Matematicheskaya, 5, 141-149 211

U.S. Geological Survey Professional Paper, 900-C, (pp. 199-201) 444

UCLA-12-916 291

UCRL-17166 609

UCRL-50047-70-3 506

UCRL-50163 (Part 4) 288

UCRL-74024 617

UCRL-77106 610

Vestnik in Wissenschaft und Technik, 74(24), 803 273

University of Utah Press, Salt Lake City, Utah, (pp. 471-480), 519 pp. (CONF-670930) 19

UR-142 83

UR-190 84

UR-49-1153 7

UR-592 183

UR-605 22

Uranium 234, Chapter 7, Keter Press, Jerusalem, Israel, (pp. 177-270), 234 pp. 269

Use of Nuclear Techniques in the Prospecting and Development of Mineral Resources, Proceedings of a Symposium held in Buenos Aires, Argentina, 1969, (pp. 147-161) (CONF-681117, CEA-CONF-1105, IAEA/SN-112/10) 546

Utilization of Thorium in Power Reactors, (pp. 169-171) 295

Utilization of Thorium in Power Reactors, (pp. 55-76) 305

Utilization of Thorium in Power Reactors, (pp. 199-211) 310

Utilization of Thorium in Power Reactors, (pp. 127-137) 313

Utilization of Thorium in Power Reactors, (pp. 106-114) 314

Utilization of Thorium in Power Reactors, (pp. 353-373) 315

Utilization of Thorium in Power Reactors, (pp. 46-54) 316

Utilization of Thorium in Power Reactors, (pp. 106-190) 316

Utilization of Thorium in Power Reactors, (pp. 343-352) 680

Vestnik Moskovskogo Universiteta, Biologiya, Pochvovedenie, 20, 91-96 371

Vestnik Zoologii, 4(2), 12-75 100

Vestnik Moskovskogo Universiteta, Seriya Biol. Pochvovedenie, 20(6), 91-96 370

WASH-1259 553, 594, 623, 637

Water Research, 11, 289-290 231

Water Research, 9(8), 741-749 558

Water, Air, and Soil Pollution, 4(1), 3-8 324

PUBLICATION DESCRIPTION (CONT)

Williams and Wilkins Company, Baltimore, Maryland 16

81/82 882

V-VI-53 227

Zvezdskaya laboratoriya, 81 (10), 1193-1195 619

Zeitsung der Vindertwiltunde, 118, 117-127 857

Zhurnal: Ispolnitel'skii Zhurnal, 32(2), 321-326 545

Technische listy, 75(3), 265-270 106

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