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Occupational Health and Environment Research 1983: Health, Safety, and Environment Division

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**Occupational Health and Environment
Research 1983:
Health, Safety, and Environment Division**

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Abstract

The primary responsibility of the Health, Safety, and Environment (HSE) Division at the Los Alamos National Laboratory is to provide comprehensive occupational health and safety programs, waste processing, and environmental protection. These activities are designed to protect the workers, the public, and the environment. Many disciplines are required to meet the responsibilities, including radiation protection, industrial hygiene, safety, occupational medicine, environmental science, epidemiology, and waste management. New and challenging health and safety problems arise occasionally from the diverse research and development work of the Laboratory. Research programs in the HSE Division often stem from these applied needs. These programs continue but are also extended, as needed, to study specific problems for the Department of Energy (DOE) and to help develop better occupational health and safety practices.

Worker protection studies involve investigating respirators and protective clothing. Evaluation of respiratory protective equipment in 1983 included three devices for DOE contractors, the XM-30 and M17A1 military masks, use of MAG-1 spectacles in respirators, and eight self-contained units. The latter units were used in an evaluation of test procedures used for Bureau of Mines approval of breathing apparatuses. Preliminary results of studies on the penetration of selected respirator filters by asbestos fibers showed two of six respirators tested allowed penetration of 0.1% or more. A two-volume report on guidelines for the selection of chemical protective clothing was published.

Analyses of air samples from field studies of a modified *in situ* oil shale retorting facility were performed for total cyclohexane extractables and selected polynuclear aromatic hydrocarbons (PAH). Levels of vapor-phase PAH in the mine and at the surface were generally less than $20 \mu\text{g}/\text{m}^3$ except near areas where retort products were being handled or stored. Aerosol generation and characterization of effluents from oil shale processing were continued as part of an inhalation toxicology study. Generation and measurements of manmade mineral fibers were made as part of an inhalation toxicology study.

Additional data on plutonium excretion in urine are presented and point up problems in using the Langham equation to predict plutonium deposition in the body from long-term excretion data. Preliminary results are given on the distribution of plutonium in the whole body of a plutonium worker exposed 36 yr earlier. Relative risk of death was found to be no greater in persons with plutonium depositions of 2 nCi or more than among unexposed workers.

Environmental surveillance at Los Alamos during 1983 showed the highest estimated radiation dose from Laboratory operations to be about 26% of the natural background radiation dose. Several studies on radionuclides and their transport in the Los Alamos environment are described. The chemical quality of surface and ground water near the geothermal hot dry rock facility is described. Short- and long-term consequences to man from releases of radionuclides into the environment can be simulated by the BIOTRAN computer model, which is discussed briefly.

Several studies measured the penetration of high-efficiency particulate air filters by aerosols, including an evaluation of four different test aerosol materials. Preliminary data indicate that a laser aerosol spectrometer is a practical instrument for making aerosol measurements.

Introduction

Protection of its employees, the public, and the environment is a major concern of the Los Alamos National Laboratory. The mission of the Laboratory's Health, Safety, and Environment (HSE) Division is to ensure that this concern is successfully transformed into sound engineering and administrative approaches to health and safety at the Laboratory.

An important adjunct to achieving this goal is occupational health and environmental research for identifying and solving problems affecting Laboratory operations. Technical resources of the Division are also applied to nationally significant occupational health problems. These objectives are achieved through an integrated approach that combines technical support and applied research activities in health physics, industrial hygiene, occupational medicine, epidemiology, industrial safety and fire protection, nuclear criticality safety, waste management, and environmental surveillance.

The organizational structure and management personnel of the HSE Division are listed in Sec. IX of this report. In May 1983, the title of the Health Division was changed to the new name to describe more completely and accurately the broad scope of activities carried out by the Division.

Research programs within HSE Division are diverse and contribute information in many professional fields. This report has been divided into functional areas to keep related subject matter together. Much of this work is performed on specific programs funded by the DOE or other sponsors. Some work is closely related to operations at the Laboratory and is included to provide a broader perspective on the work done by the HSE Division staff.

RESPIRATOR STUDIES FOR THE DEPARTMENT OF ENERGY (DOE)

Authors: O. D. (Brad) Bradley and J. D. DeField

Technical Assistance: A. G. Trujillo, K. C. Carter, and J. Loibl

Group: Industrial Hygiene, HSE-5

Funding Organization: DOE, Office of Operational Safety (OOS)

This program helps ensure that DOE contractor personnel are adequately protected by personal respiratory protective equipment. Areas of support for this program include (1) technical consultation to DOE and DOE contractors; (2) acceptance testing of special respiratory protective equipment, that is, devices that cannot be approved by the existing National Institute for Occupational Safety and Health (NIOSH) and Mine Safety and Health Administration (MSHA) approval schedules; and (3) special short-term respirator studies as directed by the DOE/OOS.

Acceptance Testing of Unapproved Devices

One DOE contractor device was submitted to the Los Alamos National Laboratory, and a second device was reviewed for possible submission and testing. The contractor's standard operating procedures (SOPs) for one device have been reviewed, and the on-site inspections have been initiated in accordance with the DOE/Los Alamos test requirements.¹ It is anticipated that final testing and submission to the Respirator Advisory Committee (RAC) for review will be accomplished in FY 1984. Another contractor's supplied-air suit was submitted for testing but initial review of the SOPs showed it to be inadequate. This device is a modified version of a suit that has been approved for a different operational procedure. There is sufficient difference in the proposed use to require the newly submitted device, including hardware and SOPs, to be tested and reviewed by the RAC in accordance with DOE/LOS Alamos requirements.¹

A third contractor requested evaluation of a suit now being used at Ontario Hydro of Canada. A preliminary evaluation indicated that this device has some very good and usable qualities; however, the protection factor (PF) afforded (as reported by Ontario Hydro) will not meet the DOE requirement. A contractor decision to officially submit this device for complete DOE testing will be made during FY 1984.

Revised "Specifications and Test Procedures for Airline-Type Supplied-Air Suits"¹ and the "Respirator Advisory Committee Charter" have been reviewed by DOE/OOS and the RAC. Both documents have been revised to include reviewers' comments.

Testing of Commercial Devices

The results from testing ten commercial supplied-air devices and from special devices tested and accepted for DOE contractor use by DOE/OOS were assembled into a catalog entitled "Evaluation of Unapproved and Other Special Respiratory Protective Devices of Interest to the US Department of Energy." An initial review of this catalog by the RAC has been completed, and committee members' comments have been incorporated into a revised version that will be published in FY 1984.

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Technical Consultation

Consultations have been conducted with several contractors, area offices, and DOE/OOS. These consultations were conducted by site visits, telephone conversations, and memos. They involved subjects such as tritium permeation of suit materials, training programs, methods of determining respirator fit (qualitative and quantitative), beards and respirators, punctured ear drums and their effects on respirators, and selection of respirators.

Special Studies

Evaluation of Qualitative versus Quantitative Fit Test Procedures. An analysis of the relative advantages of qualitative and quantitative respirator fit testing programs was prepared to evaluate respiratory protection provided workers, management advantages, and costs associated with these two types of fit testing. This will allow OOS/DOE to assure that cost-effective respirator programs are provided for contractors. Comments received from OOS and the RAC on the first draft have been incorporated into a final draft and submitted to OOS for final review before publication of this document.

Respirator Program for Small Contractors. A draft model respirator program, containing the minimum requirements and designed to satisfy the intent of ANSI Z88.2-1980, was developed for DOE contractors with a limited or small number of personnel. During the first quarter of FY 1983, a first draft of this program was submitted for peer review. A second draft incorporating the comments and suggestions of reviewers will be submitted to the RAC in FY 1984. This will permit DOE/OOS to provide the appropriate guidance to facilities that do not have extensive health protection staffs, permitting them to operate adequate respirator programs. This information will be extremely useful for many non-DOE organizations facing similar problems.

Reference

1. W. H. Revoir, J. A. Pritchard, T. O. Davis, C. P. Richards, and L. D. Wheat, "Specifications and Test Procedures for Airline-Type Supplied-Air Suits," Los Alamos Scientific Laboratory report LA-5958-MS (May 1975).

TESTING AND EVALUATION OF MILITARY RESPIRATORY EQUIPMENT

Authors: O. D. (Brad) Bradley and J. D. DeField

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Group: Industrial Hygiene, HSE-5

Funding Organization: US Air Force (USAF), Life Support Systems Program Office

Several types of respiration protective equipment are presently undergoing tests and evaluations by USAF to see if they can provide high levels of respiratory protection and are compatible with ground crew and aircraft crew operations. These respiratory fit tests may indicate possible areas for improving the protection provided to wearers. This evaluation requires each unit to be tested on a selected panel of volunteers representing the different facial dimensions, sexes, ages, and facial and scalp hair of potential users of this equipment. These studies evaluate quantitatively the degree of protection provided to the eyes, forehead, and neck of the wearer.

During early FY 1983, details of Phase III of the continuing experimental program were developed in cooperation with the USAF. Activities included further evaluation of the XM-3,

establishment of a test protocol, design and construction of test equipment, and selection of a test panel for the HGU-51/P Integrated Chemical Defense System ensemble tests.

WORKER
PROTECTION

XM-30 Testing

The XM-30 (Fig. 1) was tested in five different configurations: (1) the Phase I (1981) XM-30 mask alone, (2) the Phase II (1982) XM-30 mask alone, (3) the Phase II XM-30 mask with new hood (pressurized), (4) the Phase II XM-30 mask with modified combat spectacles, and (5) a medium-size XM-30 mask manufactured by Mine Safety Appliance (MSA). The modified combat spectacles used in configuration (4) had the bridles shortened by 1 cm and the upper, outer corners of the frames rounded off. The new hood used in configuration (3) was modified to make the lens opening 1 in. larger in diameter and to add a 2-in. pleat at the back, center. The masks used in configuration (1) were the same devices tested in 1981. The masks used in configurations (2), (3), and (4) were the same devices tested in 1982.

Thirty-five male and female test subjects, selected by facial sizes, were used as an anthropometric testing panel. This panel is thought to represent 95% of the facial sizes of the general population, not necessarily the facial contours. Testing involved the use of a series of exercises to simulate typical work activities while being challenged by an oil mist atmosphere. Aerosol concentration inside and outside the mask is measured with a light-scattering photometer. A protection factor of 10 000 was used as the criterion to establish acceptable and nonacceptable fits.

A preliminary analysis of the data indicates the following:

- The XM-30 in configurations (1), (2), and (3) provides a fit factor (FF) in excess of 10 000 for 43 to 54% of the test population and a FF in excess of 1000 for 83 to 92% of the test population.
- The XM-30 mask and modified combat spectacles used in configuration (4) provides a FF in excess of 10 000 for 28% of the test population and in excess of 1000 for 69% of the test population.
- The medium-size XM-30 (manufactured by MSA) used in configuration (5) is different from the Scott XM-30. Limited testing indicated a similar FF for both devices.

FIGURE 1 (left).
XM-30 respirator.

FIGURE 2 (right).
Integrated Chemical De-
fense System (ICDS).

- The new hood in its pressurized mode gives a 6% decrease in acceptable fits when compared with configuration (2) without a hood.
- The rubber head strap of combat spectacles passing between the face and the sealing surface of the mask as tested in configuration (4) decreases the acceptable fits by 30% when compared with configuration (2) without glasses.
- The Valsalva procedure, which is included in the test maneuvers for all configurations, is a method of clearing the ears by pinching the nose shut, closing the mouth, and blowing. This procedure is so severe that the facepiece cannot maintain its seal. The data show a decrease of acceptable fits by 10 to 20%.

Evaluation of the Integrated Chemical Defense System (ICDS)

During late FY 1982, preliminary testing was conducted on the HGU-51/P ICDS (Fig. 2). The data from this testing was used to establish the test protocol and responsibilities in coordination with the Individual Protection Branch, Chemical Defense Division, Wright Patterson AFB, Ohio, and Gentex Corporation, Carbondale, Pennsylvania.

The ICDS helmet, visor, shroud assembly, oxygen hose, supply air hose, regulators, and connectors will each have quality assurance testing before protection level testing and at any time a unit may become suspect. This testing will be conducted by using a 16-m³ test chamber, forward-light-scattering photometer, full-bodied mannequin, and equipment for measuring pressure and flow. When no penetration of aerosol is detected by the monitoring equipment, the unit will be considered to be aerosol tight and acceptable for human test subject quantitative fit test (QNFT).

All QNFTs will be conducted in a 16-m³ test chamber that contains a polydispersed aerosol with a mass medium aerodynamic diameter (MMAD) of approximately $0.5 \pm 0.1 \mu\text{m}$ and a particle concentration of $27.5 \pm 1.3 \text{ mg/m}^3$. Total aerosol concentration in the chamber and sample air drawn from the eye cavity of the ICDS unit will be monitored with forward-light-scattering photometers. These samples will be taken at a sample rate of 1 L/min.

During the HGU-51/P tests, the single-particle-counter laser-aerosol spectrometer (LAS-X) will be operated simultaneously with a forward-light-scattering photometer to evaluate the correlation between the two measurement systems and will allow measurements beyond the operational capability of light-scattering equipment to be made.

All light-scattering photometers and the LAS-X have been set up and calibrated. A test panel has been confirmed and the quality assurance system constructed as outlined in the test procedures. Because of the delay of equipment delivery from the Gentex Corporation, the test schedule is now tentatively set for spring.

RESPIRATOR STUDIES FOR THE NUCLEAR REGULATORY COMMISSION (NRC)

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Technical Assistance: O. D. Bradley, K. C. Carter, and A. G. Trujillo

Group: Industrial Hygiene, HSE-5

Funding Organization: NRC, Office of Research

This project provides the NRC with information of respiratory protective devices and programs for their licensee personnel. The following activities were performed during FY 1983:

Alternate Test Aerosols for Filter Quality Assurance (QA) Testing

The standard method for QA testing of high-efficiency particulate air (HEPA) respirator filters is to challenge the filter with a monodisperse, thermally generated aerosol of di-2-ethylhexyl

phthalate (DEHP). Because of the potential carcinogenicity of DEHP and the difficulty of generating monodisperse aerosols, several alternative QA methods are being evaluated for suitability as replacement aerosol and test procedures. In this study the following challenge aerosols were compared: (1) a thermally generated DEHP aerosol utilizing the existing Q-127 test system; (2) a thermally generated, di-2-ethylhexyl sebacate (DEHS) aerosol utilizing the Q-127 test system; (3) a polydisperse, air-jet-generated DEHS aerosol; and (4) a polydisperse NaCl aerosol.

Respirator cartridge test filters were chosen from three sources: (1) shelf stock or issue filters, (2) filters currently in everyday use, and (3) filters that failed previous QA testing. Test systems were constructed and calibrated for each of the aerosols.

There is a good correlation between the results obtained when using air-generated DEHS and thermally generated DEHP.¹ An accurate conclusion regarding the correlation between NaCl and the other aerosols could not be reached because of limited equipment sensitivity by using the NaCl system. The results suggest that commercially available DEHS quantitative fit test equipment may be used for QA testing of respirator HEPA filters. Further studies may be required to gain additional information before definite conclusions can be reached in regard to all aspects of concern.

Evaluation of MAG-1 Spectacles with Positive- and Negative-Pressure Respirators

The need for prescription eyewear while using respirators is a great problem for NRC licensees. A 1982 study using the Criss Optical Manufacturing Company's MAG-1 spectacles (Figs. 3 and 4) indicated that the MAG-1 spectacles could be worn safely with positive-pressure respirators without a loss of wearer protection or without an increase in self-contained breathing apparatus (SCBA) air use under laboratory test conditions. This limited data could *not* be used to indicate or predict protection for any type of negative-pressure respirators.

To eliminate the possibility that these results were biased by excessive assistance with the donning of the MAG-1 spectacles and/or respirator facepieces, QNFTs of an additional limited panel (11 subjects) were performed. All test subjects received general donning instructions, but there was no actual assistance with donning of the spectacles and/or the respirators. The data analysis and report will be completed in 1984.

A study was also performed by using the Criss Optical Manufacturing Company's MAG-1 spectacles to determine whether the temple strap interfered with the face-to-facepiece seal of three negative-pressure full-facepiece respirators. A 25-person anthropometrically selected panel

FIGURE 3.
Criss Optical MAG-1 spectacles.

was tested two times in each respirator, once wearing the spectacles and once without. Chamber testing was completed; data analysis and a report will be completed in 1984.

Acceptance Testing

The unique health and safety problems associated with NRC contract licensees' work frequently necessitates the utilization of special respiratory protective equipment. Sometimes this requires the use of equipment that is not, or cannot readily be, approved by the existing National Institute for Occupational Safety and Health approval system. A procedure was developed to permit review and approval of such devices. This will involve formation of a Respirator Advisory Committee to review data obtained by testing the equipment under the specific operating procedure required by the licensee. The list of potential members has been agreed upon and the committee formation is scheduled for FY 1984.

Manual of Respiratory Protection in Emergencies Involving Airborne Radioactive Materials

This manual was previously entitled "Respiratory Protection in Emergency Situations" but was renamed to reflect the NRC's major concern in nuclear facilities. A final draft of the manual was forwarded to NRC. It is based on information obtained from visits to NRC licensee facilities, a literature search of problems in radiological emergencies, and opinions solicited from respiratory protection consultants. The manual details the emergency use of respirators and emphasizes the need for proper selection, fitting, training, and maintenance beyond normal practice because of the increased probability of respiratory hazards. To aid workers assigned to rescue, firefighting,

FIGURE 4.
MAC-1 spectacles with
dimensions of the original-
size bridles (unmodified)
(Phase I tests).

damage control, and radiation survey teams, the uses and procedures for each type of emergency respiratory protection are described and illustrated by example. Support equipment and functions provided in emergencies, such as portable compressed-air systems and assistance by off-site agencies, are discussed. The manual will be published by NRC as a NUREG document to complement NUREG-0041.²

Technical Assistance

Guidance was provided NRC licensees regarding respirator applications involving respirator protection factors, quantitative versus qualitative fit testing, with specific questions relating to the test agents, supplied-air-system problems, respirator QA, and respirator maintenance.

References

1. Harrison F. Kerschner, III, H. J. Ettinger, J. D. DeField, and Richard Beckman, "A Comparative Study of HEPA Filter Efficiencies When Challenged with Thermal- and Air-Jet-Generated Di-2-Ethylhexyl Sebecate, Di-2-Ethylhexyl Phthalate, and Sodium Chloride," Los Alamos National Laboratory report LA-9985-MS (December 1984).
2. "Manual of Respiratory Protection Against Airborne Radioactive Materials," US Nuclear Regulatory Commission, Office of Standards Development report NUREG 0041 (1976).

TESTING AND EVALUATION OF THE M17A1 RESPIRATOR

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Participants: O. D. Bradley, B. J. Skaggs, J. F. Stampfer, and J. D. DeField

Technical Assistance: K. C. Carter, A. G. Trujillo, and J. Loibl

Group: Industrial Hygiene, HSE-5

Funding Organization: US Army, Chemical Systems Laboratory

Evaluation of the M17A1 chemical protective mask was continued for the Chemical Systems Laboratory, now the Chemical Research and Development Center (CRDC). This involved a series of tests simulating field performance to determine what protection various masks could provide in the field without actual field experiments, to identify most probable leak points, and to assess mask performance.

Simulated Field Testing

This was a joint Los Alamos/CRDC effort. Los Alamos activities involved

- constructing the oil aerosol (di-ethylhexyl-sebecate) generation and detection equipment;
- mating this equipment to existing exposure chambers located at Edgewood Arsenal, Maryland;
- developing a data analysis method for oil aerosol respirator fit testing suitable for use by personnel from different agencies participating in this experiment;
- performing aerosol sizing and concentration measurements on the oil system and a companion salt aerosol system provided by CRDC; and
- performing a statistical data analysis independent of the effort by CRDC.

Mass concentrations and size distributions of the DEHS aerosol within the test chambers were measured repeatedly before testing and periodically during the several weeks of tests. Mass concentration was measured gravimetrically as well as with piezoelectric crystal mass monitors. The aerosol size distribution was measured primarily with a laser light-scattering aerosol spectrometer (LAS-X) and an automatic cascade impactor (CMCI).

Results of all the measurements are shown in Tables I and II. These are consistent with data obtained independently by a scientific team from Lawrence Livermore National Laboratory.

TABLE I. Aerosol Mass Concentration in Chemical Research and Development Center Chambers

Aerosol	Chamber	Gravimetric Mass Concentration (mg/m ³)	
		Mean	Std Dev
DEHS	No. 1	25.9	±0.9
DEHS	No. 2	29.2	±0.3
NaCl	No. 3	24.4	±3.9

TABLE II. Aerosol Particle Size Distribution in Chemical Research and Development Center Chambers

	Size Parameters			
	Median Diameter (μm)		(σg)	
	Mean	Std Dev	Mean	Std Dev
DHS, Chamber 1				
LAS-X data CMD	0.19	±0.01	1.31	+0.04
Impactor MMAD	0.43	±~0.08	1.6	±~0.3
DEHS, Chamber 2				
LAS-X data CMD	0.19	±0.01	1.37	±0.04
Impactor MMAD	0.41	±~0.08	1.6	±~0.3
NaCl, Chamber 3				
LAS-X data CMD	0.18	±0.01	1.26	±0.01
Impactor MMAD	0.42	±~0.08	2.0	±~0.04

The experiments were performed on 6 groups of 12 soldiers who were available for approximately 7 days of testing. Testing was defined for four distinctive phases:

Phase I. Each soldier donned a standard M17A1 chemical protective mask without assistance. The mask was issued before the beginning of the experiment. This phase evaluated the quality control within the Army distribution system and the Army mask-size selection procedures. Five replicate tests were performed.

Phase II. This phase evaluated the effects of standard Army chemical defense training on the ability of the individual soldier to protect himself with the chemical mask. Of the six soldier groups, three received the standard Army mask training, and three were trained on other topics. Five replicate tests were performed.

Phase III. In this phase each soldier was issued another mask. All masks used in this phase had been passed by the standard Army quality assurance methods before the experiment. Also, the mask size issued was changed to another when in the opinion of Army chemical training personnel, such a change was warranted.

Phase IV. The final phase was a test of a new experimental mask, the XM-30. Results of these experiments will be reported elsewhere.

Determination of Leak Points

A follow-up laboratory study was performed to identify the most likely location of the leaks that occur during fit testing.

A very flexible hood was attached to the mask between the periphery and all mechanical components (for example, valves, eye lens, and drinking tubes) in the face of the mask. (To avoid

confusion with the standard Army M6 hood that is normally attached to the mask, this lightweight, flexible hood hereinafter will be called a shroud. The M6 hood was not attached to the mask for these experiments.) During the initial fit tests, this shroud was rolled up so that both the front and periphery of the mask were exposed and a fit test conducted. The shroud was then unrolled and the free end was attached to a hole in the side of the test chamber. The same fit test procedure was repeated. Because only the periphery, not the face of the mask, was exposed to the chamber aerosol challenge, only leaks at the face-to-mask seal were detected. The shroud was then removed from the chamber wall and the open end passed over the subject's head and tucked under the top of a vest being worn by the subject. Again the fit test was conducted. In this configuration only the face of the mask was challenged. The subject then left the test chamber so that the leak could be located more precisely. This was accomplished by injecting aerosol from a probe around the regions at which leaks could occur.

The results of these tests showed that the most likely locations for the leaks that occurred during the testing of CRDC were at random positions around the mask-to-face seal and not in the mechanical components.

Performance Assessment

Additional laboratory tests using the M17A1 mask were performed with and without the M6 hood. A review of these test results and consideration of the extensive prior testing performed at Los Alamos indicated the following: (1) the M17A1 mask can afford good protection if the proper size, without the M6 hood attached, is donned correctly; (2) small masks fit a larger percentage of the tested population than is reflected in the existing Army mask-size tariff (distribution of sizes); (3) in assigning a specific mask size, the position of the periphery with respect to the wearer's ears and hairline is more important than the position of the eyes in the eye lenses; and (4) a donning procedure that would allow some adjustment of the head straps would improve, on the average, the FFs attained.

EVALUATION OF NEW 30 CFR 11 SELF-CONTAINED BREATHING APPARATUS TESTS

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Group: Industrial Hygiene, HSE-5

Funding Organization: Bureau of Mines

The self-contained breathing apparatus tests using human subjects listed in the Bureau of Mines approval regulations 30 CFR 11 may be inadequate. Stress levels in the existing approval tests may be significantly lower than the stresses imposed on mine rescue personnel during actual use. All test parameters are measured only during rest periods between exercises. The Bureau has proposed a new series of tests that incorporate higher work levels and continuous monitoring of key parameters. Using the new higher stress levels, Los Alamos evaluated eight different self-contained breathing apparatuses on a number of test subjects using a treadmill (Fig. 5).¹

During each test, a volunteer subject performed various tasks while continuous measurements were recorded of the following apparatus variables: temperatures of the air in the inhalation tube, the air exiting the sorbent canister, and the surface of the canister; pressures in the face mask and in the inhalation tube; concentrations of CO₂ and O₂ in the mask and in the inhalation tube; and the volume of excess gas vented from the apparatus.

These test procedures were approved by the Human Studies Review Committee of the Los Alamos National Laboratory. Each volunteer was required to successfully complete a maximal stress test under the supervision of a cardiologist before participating in this program.

A final report was issued indicating the following conclusions: (1) In general, the proposed tests are not too physically demanding. (2) As long as human test subjects are used, there should be a minimum test subject weight. (3) For certification purposes, the important apparatus variables to be measured are breathing resistance, temperature, and CO_2 and O_2 concentrations of the inhaled gas. (4) Because these variables can change markedly during rest periods, continuous monitoring should be employed. (5) New pass/fail criteria are needed that are based on realistic

FIGURE 5.
Test of SCBA use under
treadmill stress conditions.

estimates of the physiological requirements of the user, tempered by present and future engineering limitations. (6) When available, breathing machines, rather than human subjects, should be used for the majority of certification testing. (7) A more realistic ergonomics test than that presently proposed is needed. (8) A test for the gas tightness of the complete apparatus is needed. (9) A better test than that currently employed is needed to determine how well the mask fits the wearer.

Respirator certification requirements from the following foreign countries were reviewed: Australia, CEN (European Economic Community), Japan, and Great Britain. A comparison was then made with the US requirements. Certain requirements used by these countries, such as the flame resistance requirements of CEN and the extensive ergonomic tests required in Britain, should be incorporated into revised US regulations.

RESPIRATOR FIELD PERFORMANCE FACTORS

Authors: B. J. Skaggs, J. D. DeField, S. W. Strandberg, and C. R. Sutcliffe

Technical Assistance: K. C. Carter

Group: Industrial Hygiene, HSE-5

Funding Organizations: Occupational Safety and Health Administration and Nuclear Regulatory Commission

The use of protection factors (PFs) or fit factors (FFs) to predict the level of protection provided the worker under actual use conditions involves a major uncertainty caused by variations associated with field applications. This concern has been identified and has resulted in the definition of the terms Field Performance Factor (FPF) and Worker Use Factor (WUF)¹ to better represent the protection provided. To quantitate the FPF, a study was jointly sponsored by the Occupational Safety and Health Administration (OSHA) and the Nuclear Regulatory Commission (NRC) that would ultimately involve the measurement of respirator performance under actual use conditions. These tests would relate FPF to the FF measured at the work site by using a portable quantitative fit test system.

OSHA and NRC requested that before the field study, efforts be directed to Task I, a review of the problems associated with sampling aerosols within the respirator facepiece in order to determine FF or FPF, and Task II, an environmental chamber study to determine the effects of temperature and humidity on a respirator wearer. The field study would be Task III.

Task I—Literature Review on Aerosol Sampling Devices for Respirator Field Study. A literature search for information regarding particulate sampling devices was initiated. Literature on field testing of respirators was evaluated for sampling devices utilized and for the rates, flows, and other pertinent data necessary to perform comparisons and recommendations. The review was completed and a draft report was written.

Task II—A Study To Determine the Effects of Temperature and Humidity on Respirator Fit Under Stimulated Work Conditions. After a comprehensive evaluation of the many aspects of the environmental chamber study, it was decided to purchase and install an environmental chamber at Los Alamos. Specifications were written and the chamber will be ordered for delivery in 1984.

The study protocol will be presented to the Human Studies Review Committee for approval. Drafts of the necessary forms have been prepared and no problems are expected.

Design of the chamber test program has been completed and approved by OSHA and NRC. Major test program criteria follow:

- (1) An anthropometric panel will *not* be used.
- (2) The positive-pressure respirator tests would be conducted first. These respirators were identified and criteria set for determining prescreening acceptable fit.
- (3) The negative-pressure respirators were selected and prescreening acceptable fit criteria set. The normal head-movement fit exercises would be used.

- (4) The work exercises to be performed inside the environmental chamber by each test subject are to
- (a) move sand from one container to another with a shovel,
 - (b) pound on a railroad tie with a sledge hammer,
 - (c) step up and down a two-step ladder at a moderate rate,
 - (d) pick up clay bricks from the floor and lay them in a corner pattern with nonsolidifying mortar, and
 - (e) pound nails with claw hammer into a board located above the head of the subject.

Reference

1. A. Hack, C. Fairchild, and B. J. Skaggs, letter to "The Forum," *American Industrial Hygiene Association Journal* 43, A-16 (December 1982).

PENETRATION OF RESPIRATOR FILTERS BY FIBROUS AEROSOLS

Authors: L. W. Ortiz and S. C. Soderholm

Technical Assistance: F. O. Valdez

Group: Industrial Hygiene, HSE-5

Funding Organization: Occupational Safety and Health Administration (OSHA)

This project will measure the penetration of selected respirator filters by asbestos fibers. These data will assist OSHA in the development of revised asbestos standards for worker protection. This work is designed to test respirator filter media and will not evaluate leakage around the sealing interface between the respirator facepiece and the wearer's face. All respirator media scheduled for testing are filters that are currently approved by OSHA for use against asbestos. These filters will be challenged with well-characterized fibrous aerosols and the resultant penetration measured.

Experimental activities have primarily involved assembly of the test system, measurement of the penetration of several respirator filter models with a fibrous glass aerosol to proof the test system, and preparation for testing with an asbestos aerosol during 1984.

The test system that has been assembled is schematically illustrated in Fig. 6. The generator is a modified Timbrell-type device, which we have shown to be reliable in providing reproducible atmospheres of fibrous aerosols. Dilution air may be added to the generator output to aid in reaching the desired challenge concentration of fibers (5 to 50 fibers/cm³) in the aerosol containment chamber. The respirator filter is encased in a smaller removable Lucite chamber, which allows the aerosol to be drawn from the main containment chamber through the test respirator by a side port. There is provision to monitor the flow, nominally 64 L/min, through the respirator filter and the pressure drop across the filter. The aerosol upstream of the respirator filter is sampled by a 25-mm membrane filter through a port in the side of the Lucite chamber containing the respirator filter. All of the air that passes through the respirator filter is filtered by a 47-mm membrane filter that is used to determine the concentration of fibers downstream of the respirator filter. Respirator penetration is assessed by microscopic counting of fibers collected upstream compared with those downstream of the test respirator filter media. The membrane filters used for aerosol collection are the standard type recommended by OSHA (Millipore type AAWG, nominal pore size 0.8 µm).

Preliminary penetration measurements have been made using a fine-diameter fibrous glass aerosol. From previous studies at Los Alamos, the mean diameter of this aerosol is known to be 0.45

μm and the median length is about $5 \mu\text{m}$ with approximately 89% of the fibers being shorter than $10 \mu\text{m}$. Aerodynamic properties indicate that this aerosol is $\sim 70\%$ "respirable" by the criteria of the American Conference of Governmental Industrial Hygienists. The fiber challenge continued for 6 h with three filter samples collected upstream of the respirator filter over this period. All samples were prepared and counted by the standard National Institute for Occupational Safety and Health method using specified optical microscopy procedures (phase contrast optics at $400\times$ magnification). Table III lists the results of these preliminary measurements, which involved test durations of 6 h. Penetrations less than 0.1% are not reported in terms of an exact value because particle penetration of the seal between the respirator and face is expected to be much greater than this value. Only two respirator filters exhibited penetrations of $\geq 0.1\%$.

Five specific respirator filter types have been selected by mutual agreement with OSHA for testing with asbestos. The challenge aerosol for these tests will be produced from a standard

FIGURE 6.
Schematic diagram of test
system used to measure
penetration of respirator
filters by fibrous aerosols,
including asbestos.

reference chrysotile material obtained from the Union Internationale Contre le Cancer (UICC). These asbestos fiber penetration tests will be completed during 1984.

TABLE III. Penetration of Some Respirator Filters by a Fibrous Glass Aerosol

Respirator Model	Initial Pressure Drop (in. water)	Increase in Pressure Drop ^a (in. water)	Upstream Fibrous Aerosol Concentration (fibers/cc)	Fibrous Aerosol Penetration (per cent)
A	0.18	0.04	208	<0.1
A	0.32	0.02	132	<0.1
B	0.18	<0.01	160	<0.1
C	0.17	0.01	113	<0.1
D	0.17	0.01	153	<0.1
E	0.32	0.10	131	0.2
E	0.33	0.08	146	0.1
F	0.40	0.02	88	<0.1

^aIncrease in pressure drop across the test filter during a 6-h test at a flow rate of 64 L/min.

GUIDELINES FOR SELECTING PROTECTIVE CLOTHING

Authors: J. O. Jackson, J. F. Stampfer, and H. J. Ettinger

Group: Industrial Hygiene, HSE-5

Funding Organization: Environmental Protection Agency (EPA)

Knowledge concerning the protection afforded by Chemical Protective Clothing (CPC) is quite limited considering the highly complex and variable mixtures of toxic chemicals that workers may encounter at hazardous waste sites and environmental spills. Furthermore, there does not exist a unified and comprehensive set of guidelines to use in choosing appropriate CPC for workers. Recognizing the need for EPA personnel and associated workers to be protected when working at hazardous waste sites, EPA requested Los Alamos in FY 1982 to provide such guidelines for actual field use. A subcontract to Arthur D. Little, Inc. (ADL), resulted in a joint Los Alamos/ADL effort directed to this problem.

A two-volume report, "Guidelines for the Selection of Chemical Protective Clothing," was subsequently developed and published in March 1983. This report details a user's matrix that provides CPC recommendations for approximately 300 chemicals and 14 clothing materials. One, Matrix (A), presents the recommendations by specific chemicals and another, Matrix (B), presents recommendations for generic families or classes of chemicals. The chemicals in each family, on which the Matrix B recommendations are based, were determined from the data provided in Matrix A. The Guidelines also include extensive supporting information on permeation theory, limitations of the Guidelines, analysis of vendor's literature, sources of CPC materials and information, and instructions on the use of the matrices.

Professional response and reception of guidelines both within and outside EPA were very positive. Subsequently, EPA decided to pursue further development of the Guidelines and the information it contains. A portion of this work will again be performed by ADL under subcontract to Los Alamos.

The two-volume Guidelines are being printed by the American Conference of Governmental Industrial Hygienists. This allows effective and widespread dissemination of the Guidelines.

INDUSTRIAL HYGIENE FIELD STUDIES AT OIL SHALE FACILITIES

Authors: K. M. Hargis, M. T. Brandt, C. R. Sutcliffe, H. J. Ettinger, and J. O. Jackson

Technical Assistance: R. J. Sherman and L. D. Wheat

Group: Industrial Hygiene, HSE-5

Funding Organizations: DOE, Office of Health and Environmental Research and National Institute for Occupational Safety and Health

The Oil Shale and Related Synfuel Workers Health Study is a multidisciplinary program involving industrial hygiene, occupational medicine, and epidemiology. Industrial hygiene activities involve field studies that (1) provide information to determine if unique health hazards are associated with developing synfuel technologies, (2) provide information to assist in the design of toxicology studies, and (3) provide bulk materials for use in these studies. To date, emphasis has been placed upon the study of oil shale retorting technologies, although plans are being made to also address coal gasification beginning in 1984.

During 1983, analyses were completed of samples collected in late 1982 at the experimental modified *in situ* (MIS) oil shale retort of Occidental Oil Shale, Inc., Logan Wash, Colorado. The joint study with the National Institute for Occupational Safety and Health (NIOSH) was performed during simultaneous operation of two commercial-size MIS retorts, designated as Retorts 7 and 8. Two phases of air sampling were performed during the burn of the retorts, and one phase of sampling was performed during quenching of the retorts with water.

Samples were collected near the two MIS retorts at three levels of the underground mine, as well as at various locations around process units and areas outside the mine. No personal samples were collected.

Table IV summarizes the air contaminants sampled and the sampling and analytical techniques employed in the study. Results of analyses for total dust, quartz content of the dust, and inorganic gases and vapors were discussed in the 1982 Annual Report. Low or nondetectable levels of these substances were observed generally, although elevated concentrations of ammonia, carbon monoxide, and hydrogen sulfide were observed in specific areas. Average concentrations of the gases were less than threshold limit values at all sampling locations.

Los Alamos activities in 1983 focused on extraction and analysis of samples collected for organic compounds with particular emphasis on analysis for total cyclohexane-extractable material and selected polynuclear aromatic hydrocarbons (PAH). A sampler composed of a glass fiber/silver membrane sandwich backed up by a Tenax-GC vapor trap was used for sampling particles and vapors for these analyses. Filters were analyzed for total cyclohexane-extractable material and particulate-phase PAH, and Tenax sorbent samples were analyzed for vapor-phase PAH. Samples collected during Phase 1 of sampling (initial sampling during burn of retorts) were analyzed for seven selected PAH [fluorene, phenanthrene, anthracene, fluoranthene, pyrene, chrysene, and benzo(a)pyrene] by high-performance liquid chromatography (HPLC). Samples collected during Phases 2 and 3 (sampling near end of burn of retorts and during quenching of the retorts with water, respectively) were analyzed for 18 selected PAH and heterocyclic aromatic nitrogen compounds by HPLC. The 18 compounds consisted of the 7 PAH analyzed during Phase 1 plus carbazole, naphthalene, acenaphthylene, benzo(b)fluoranthene, benzo(g,h,i)perylene, indeno(1,2,3-c,d)pyrene, and coronene. In addition, a few samples collected during Phases 2 and 3 were analyzed for PAH by gas chromatography and gas chromatography/mass spectrometry (GC/MS) to evaluate major components of the cyclohexane extracts from these samples.

TABLE IV. Sampling at Occidental Retorts 7 and 8

Type of Sample	Contaminant or Parameter	Analysis Method
Direct-reading instruments	Carbon monoxide and hydrogen sulfide	Electrochemical cell
Solid sorbent tube (alumina, charcoal, silica gel, Tenax)	Formaldehyde Selected aliphatic and aromatic hydrocarbons and amines Selected PAHs	Colorimetry Gas chromatography
Passive dosimeters	Ammonia, nitrogen dioxide, and sulfur dioxide Selected aliphatic and aromatic hydrocarbons Mercury vapor	Colorimetry Gas chromatography Conductivity
Detector tubes	Ammonia, sulfur dioxide, nitrogen dioxide, carbon dioxide, hydrogen cyanide, carbon disulfide, formaldehyde, methyl mercaptan, and arsine	Length of stain
Various filters	Total and respirable dust Organic content Selected PAHs Free silica content Various elements	Gravimetric analysis Cyclohexane extraction HPLC X-ray diffraction Proton-induced x-ray emission (PIXE) analysis
Cascade impactors	Particle size distribution	Gravimetric analysis

Results of total cyclohexane extractables from filter samples ranged from less than the level of detection to $64 \mu\text{g}/\text{m}^3$. The maximum value was observed in a sample collected where the mine had retort gas leakage during quenching caused by blowers venting the retort offgases. Generally, total cyclohexane extractables were in the range of 5 to $30 \mu\text{g}/\text{m}^3$.

Particulate-phase PAH (sum of the selected PAH analyzed) ranged up to $4.8 \mu\text{g}/\text{m}^3$ with more than half of the filter extracts being nondetectable for any of the PAH analyzed. Vapor-phase PAH (sum of the selected PAH analyzed) ranged as high as $514 \mu\text{g}/\text{m}^3$, with almost all of the samples showing measurable levels of vapor-phase PAH. The higher levels of PAH during all three phases of sampling were observed near areas in which retort products (shale oil and retort water) were being handled or stored. Levels of vapor-phase PAH in other areas of the mine and surface were generally less than $20 \mu\text{g}/\text{m}^3$.

Analysis of filter and Tenax extracts by GC/MS showed major components of the extracts to be methyl-substituted naphthalenes and tri-, tetra-, penta-, hepta-, and octadecanes. Samples for selected aliphatic and aromatic hydrocarbons, amines, and PAH are being analyzed by NIOSH, but only limited results are available at this time. Preliminary indications are that concentrations of the parameters analyzed by NIOSH were very low, but the final analytical results are not yet available.

A final report detailing the results of this effort will be published in 1984.

Authors: J. O. Jackson and M. T. Brandt

Group: Industrial Hygiene, HSE-5

Funding Organizations: DOE, Office of Operational Safety (OOS) and Western Area Power Administration (WAPA)

Supplemental Environmental Program for the Great Plains Coal Gasification Project

The Great Plains Gasification Project (GPGP) will be the first commercial-scale coal gasification facility in the United States. The workers at this facility have the potential for being exposed to a wide range of occupational stresses. According to the provisions of a loan agreement between the GPGA and DOE, the GPGA is required to develop a supplemental environmental program (SEP) that addresses areas of environmental concern including occupational health. To assure that occupational health concerns were considered, an Occupational Health Subcommittee (OHS), which was one of five subcommittees considering various environmental issues, was formed in December 1982. This subcommittee was charged with recommending epidemiology, medical surveillance, and industrial hygiene tasks to be included as part of the SEP. Los Alamos Industrial Hygiene staff accepted a leadership role in the development and preparation of the occupational health input to the SEP document. The subcommittee developed (1) brief descriptions of eight tasks recommended for funding under the SEP, (2) a recommended occupational health program (OHP), and (3) descriptions of other suggested tasks that are not recommended for SEP funding. Members of the OHS included representatives from DOE/OOS, NIOSH, Brookhaven National Laboratory, US Synfuels Corporation, Argonne National Laboratory, Oak Ridge National Laboratory, and OSHA.

One of the eight recommended tasks involved the evaluation and design of an occupational health data management system to collect, store, and analyze epidemiology, industrial hygiene, medical, and environmental monitoring data. The OHS recommended that four additional tasks be integrated through the formation of a task force to coordinate the analysis of all environmental samples. The development and implementation of an epidemiology program was recommended to assist in the early detection of adverse health effects on the GPGP workers resulting from occupational exposure to a variety of toxicants. The final recommended task involved the integration and analysis of OHP elements. To accomplish this, an advisory research committee would be established to broadly address such areas as data quality assurance, project review and redirection, the avoidance of duplicate and interfering tasks, and conflicting priorities among the various tasks.

The objectives of the OHP developed by the subcommittee were twofold. The first objective would be the protection of the GPGP from adverse health impacts with particular concern for hazards that currently are not regulated, well characterized, or identified. The second objective would be the characterization of manifest and potential health hazards in the GPGP work force in sufficient detail to permit the development of technical requirements for health-protective plant designs and operations.

Industrial Hygiene Consultation to the Western Area Power Administration

Industrial hygiene problems within Western Area Power Administration (WAPA) facilities and operations were evaluated, with emphasis on evaluation of a transmission-line pole-treating operation. Guidance on such varied topics as toxicity of pentachlorophenol (PCP) to cattle, recommendations for WAPA contractors treating transmission-line structures with a mixture of PCP and diesel fuel, and the proper use of respiratory protection was provided. An industrial hygiene survey of employee exposure to asbestos, ficam pesticide, and polychlorinated biphenyls (PCBs)

was also performed. Finally, throughout the year toxicological data were provided to WAPA health and safety personnel upon request.

Two separate field studies were conducted during spraying of WAPA wooden transmission-line structures with a preservative mixture of PCP and diesel oil. In 1982, an initial study determined whether the linemen who sprayed the structures experienced skin irritation or dermatitis and quantified the levels of airborne contaminants and PCP absorbed by the workers. On the basis of the level of PCP in workers' urine (1 to 15 mg/L), PCP exposure was indicated. However, PCP was not detected in the vapor phase and there were no clinical symptoms of skin effects. The second study, performed in 1983, focused on quantifying the airborne concentrations of PCP vapor and oil mist, identifying and quantifying the hydrocarbon vapors present, verifying the workers' urinary PCP levels through the collection of urine specimens, and verifying the lack of obvious skin irritation or dermatitis demonstrated by the workers.

During the follow-up industrial hygiene field study, air samples were collected to quantify the concentration of PCP vapors, C₆–C₁₆ hydrocarbons, and oil mist; urine specimens were collected from the workers at the end of each work shift and analyzed for PCP; the pole-treating mixture was analyzed to identify its constituents on a weight per cent basis; and the exposed skin surfaces of the workers were evaluated for any sign of irritation, infection, or dermatitis.

None of the air samples demonstrated any excessive exposure to airborne contaminants. However, urinalyses again indicated worker exposure to PCP with values ranging from 0.31 to 7.70 mg/L, with most samples exceeding the criterion of 1 mg/L. None of the workers exhibited signs of skin irritation or the development of dermatitis; however, two of the four workers examined exhibited facial blackheads.

WAPA officials were provided with detailed recommendations to assist and guide them in the development of an industrial hygiene program for WAPA facilities and operations. The recommended program addressed industrial hygiene policy, industrial hygiene staff and technical support requirements, program responsibilities, health hazard identification and evaluation, hazardous materials management, medical surveillance, hearing conservation, respiratory protection, personal protective equipment, recordkeeping requirements, limited egress/confined space, and employee training. Following each program element, short- and long-term goals were established, where appropriate, to assist WAPA in setting priorities to their program implementation efforts. Several appendices provided WAPA with information on the principles of an industrial hygiene survey, a survey check list, the Occupational Safety and Health Administration's Hearing Conservation Amendment to the Occupational Noise Exposure standard (29 CFR 1910.95), the American National Standards Institute respiratory protection standard (ANSI Z88.2 1980), and various industrial hygiene survey and data collection forms.

AEROSOL SUPPORT FOR OIL SHALE INHALATION TOXICOLOGY STUDIES

Authors: C. I. Fairchild and M. I. Tillery

Technical Assistance: G. W. Royer

Group: Industrial Hygiene, HSE-5

Funding Organization: DOE, Office of Energy Research (Office of Health and Environmental Research)

In the continuing inhalation toxicology study of the effluents from oil shale processing conducted jointly with the Life Sciences Division, two Laramie-type, 3.5-in.-diam vertical retorts with a 15-lb oil shale capacity were operated in several experiments, including a 6-month exposure experiment using rodents. The two retorts are operated in either the direct or indirect heating mode. Computer-controlled external heating produces an overnight warmup and stabilization period at 250 to 300°C, followed by an 8-h (direct) or 36-h (indirect) "burn." During the

burn, a demister receiver below each retort collects by-product liquid, while gases and smoke pass into either an exhaust dump system (during the stabilization period) or the effluent dilution and conditioning system. Progress of the burn front is monitored by the computer, which records readings from thermocouples positioned at 6-in. intervals down the retort centerline. While one retort is in the burn cycle, the other retort may be unloaded, cleaned, and reloaded for the next burn.

Gaseous and particulate retort effluent passes, after measured dilution or conditioning, to two nose-only, small animal exposure chambers (Fig. 7) in an adjoining room.¹ Electrochemical gas analyzers are employed to continuously monitor the exposure chamber CO concentration. Total hydrocarbon concentrations within the chambers are monitored using flame ionization detection (FID). Specific organic compounds, as well as CO, CO₂, and O₂, are determined periodically by a gas chromatograph (GC) using both FID and thermal conductivity detection (TCD). All gas composition information from the monitors and GC is recorded by the computer.

A 6-month exposure to retort effluent of two groups of rodents previously exposed to spent shale dust for 6 months was initiated. In the indirect heating mode in which the average shale temperature was held to 525°C and 4 L/min of pure N₂ were passed through the retort, each retort burn lasted 48 h. This allowed an exposure protocol of 6 h/day for 4 days/wk with two burns per week. Some initial problems were encountered in the computerized control of the retorts for these burns. Gas analyses to date indicate that the effluent contains less CO but more total hydrocarbons and complex organics (PAHs, PNAs, and amines) than do direct combustion burns. Also, indirect burns produced extremely low smoke concentration (<25 µg/m³) in the effluent.

The nose-only chronic exposure of rodents to oil shale dusts 4 days/wk, 6 h/day continued. Each group of 62 animals was exposed simultaneously in one chamber to shale dusts at measured concentrations. Table V shows a summary of exposures made in the past year and size parameters of the dust. After completion of 6 months of exposure to the dust listed, exposure of animal groups 1 and 3 to retort effluents (previously described) was started. Group 2, which was exposed to dust along with groups 1 and 3, was placed in a holding chamber without exposure as a control group.

FIGURE 7.
Nose-only small animal exposure chamber.

Groups 4, 5, and 6 are undergoing long-term dust exposures. Group 4 has already completed its 2 yr of exposure. As a positive control, group 6 is being exposed to silica dust at a concentration of 1.0 mg/m^3 . In addition, two other control groups, not listed, were (1) a sham control group that breathes only clean air but is placed in chambers like the exposed groups and (2) a group that is not placed in chambers but lives under the same cage and feeding conditions. All of the dusts contained $>60\%$ respirable fraction (as defined by the American Conference of Governmental Industrial Hygienists) by measurements with Andersen impactors. Postexposure examination of all

FIGURE 8.
Vertical 4.5-in.-diam retort.

animals will be performed by the Life Sciences Division staff and the health effects reported in Life Sciences Division reports. During the year, animal exposure records from 1979 to the present were transferred to a computer data base to simplify access to the exposure history of any particular animal.

The installation of two new vertical, 4½-in.-diam retorts is nearing completion (Fig. 8). These retorts incorporate improved design features resulting from experiments with the Laramie retorts. Principal design improvements include (1) greater ease of loading and unloading shale using a retort pivot mechanism, (2) better heating uniformity and control through the use of a single muffle furnace rather than two, (3) improved temperature measurement using an encased thermocouple bundle, and (4) improved gas flow control employing computer-controlled flow valves instead of rotameters. Chronic exposure of small animals to effluents from these retorts will be controlled by a computer and monitored by gas analyzers and aerosol measurement equipment.

Reference

1. M. I. Tillery and C. I. Fairchild, "Aerosol Support for Oil Shale Inhalation Toxicology" in "Occupational Health and Environmental Research Program of the Health Division, 1982," Los Alamos National Laboratory report LA-9958-PR (September 1984), pp. 27-30.

TABLE V. Summary of Animal Exposure to Oil Shale Dust

Groups	Material	Aerosol				Remarks
		Mass Conc. (mg/m ³) ^a		Size Dist. ^b		
		Nominal	Actual	MMAD (μm) ^c	(σg) ^d	
1	Paraho raw shale	38	37.8	2.2	1.9	Start April 1983, end Oct. 1983
2	Paraho raw shale	38	39.3	2.2	1.9	Same
3	Paraho raw shale	8	7.85	2.2	1.9	Same
4	Paraho raw shale	25	30.6	2.1	2.0	Start May 1981, end June 1983
5	Paraho raw shale	10	13.6	2.3	2.2	Start Jan. 1982, continuing
6	Silica	1	1.15	1.2	2.3	Start Jan. 1982, continuing

^aMass concentrations shown are total concentrations. Respirable concentrations are nominally 25 mg/m³ for groups 1 and 2, 5 mg/m³ for 3, 15 mg/m³ for 4, 6 mg/m³ for 5, and 0.9 mg/m³ for 6.

^bAnderson impactor sampling conditions normally were as follows: sample taken directly from exposure chamber; 30 min, 28.3 L/min (1 cfm).

^cMass median aerodynamic diameter.

^dGeometric standard deviation.

MANMADE MINERAL FIBER INHALATION TOXICOLOGY STUDY

Authors: L. W. Ortiz and D. M. Smith*

Groups: Industrial Hygiene, HSE-5; *Life Sciences Division, LS-1

Funding Organization: Thermal Insulation Manufacturers Association (TIMA)

Inhalation toxicology studies are being conducted to assess the potential long-term effects of exposure of laboratory animals to inhaled manmade mineral fibers (MMMFs). Osborne-Mendel rats and Syrian hamsters are being exposed in a "nose-only" confinement mode to aerosols produced from various commercially available MMMFs. Fibrous materials being tested include four types of glass fiber, one ceramic and one mineral wool fiber. Crocidolite asbestos has been included as a positive control aerosol material. The exposure protocol for these studies calls for exposing two species (hamsters and rats) 5 h/day, 5 days/wk for 24 months.

To date, inhalation exposure experiments have been completed with four different fiber types. Four groups of animals were exposed for 24 months to two levels of a 0.45- μm -mean-diam fibrous glass aerosol at levels of ~ 2500 and ~ 250 fibers/cm³. Two additional animal groups were exposed to a crocidolite aerosol at a level of ~ 3000 fibers/cm³. Two groups were also exposed to a 3.1- μm -mean-diam fibrous glass building insulation, "Blowing Wool," at a level of ~ 100 fibers/cm³. Two groups were exposed to a 6.1- μm -mean-diam binder-coated building insulation at a level of ~ 25 fibers/cm³.

Additional groups of 64 rats and 80 hamsters are currently being chronically exposed to either (1) a 5.4- μm -mean-diam flame-attenuated fibrous glass at high- and low-concentration levels of ~ 75 and ~ 10 fibers/cm³, (2) 1.8- μm -mean-diam ceramic fibers, or (3) 2.7- μm -mean-diam mineral wool at a level of ~ 200 fibers/cm³. There is also a sham control group.

Aerosol exposure concentrations continue to be measured by daily gravimetric sampling procedures, and airborne fiber sizing experiments are conducted on a regular basis by using Scanning Electron Microscopy (SEM). These data serve to monitor and characterize each challenge aerosol throughout the exposure. Preliminary aerosol sizing and characterization data for each fibrous exposure material have been reported in the 1981 and 1982 HSE Division annual research reports.

Supplementary aerosol characterization data for all six MMMFs have been obtained by using nylon cyclone samplers. These cyclone data serve to complement existing sizing data in providing an estimate of the "respirable" mass fraction of these exposure aerosols. Cyclone sampler penetration data for all MMMF fibrous aerosol materials are summarized in Table VI. Each cyclone penetration value listed is the mean penetration obtained from at least nine separate sets of cyclone sampling runs. Each set of cyclone sampling runs consists of the mean cyclone penetration value obtained from three separate cyclone samplers operated simultaneously at various sampling locations within the exposure chambers. The aerosol mass fraction penetrating the cyclones was obtained by measuring the fibrous mass collected downstream of each cyclone and comparing this value with the average challenge mass determined from two open-face filter samples operated simultaneously within the aerosol chamber. All samplers were operated at 1.7 L/min for a 30-min collection period. Cyclone samplers were the 10-mm nylon (Dorr-Oliver) models that are the standard for coal dust sampling and follow the American Conference of Governmental Industrial Hygienists curve defining "respirable dust."^{1,2} Earlier experiments demonstrated their usefulness in sampling fibrous aerosols.³ Gravimetric measurements for these tests were conducted by using 25-mm Gelman DM-800 membrane filters for the collection media.

Data listed in Table VI indicate that the aerosol produced from the fine-diameter (0.45- μm mean diam) fibrous glass has the largest mass fraction penetrating the cyclones at $\sim 81\%$, followed by ceramic fibers (1.8- μm mean diam) at $\sim 35\%$, glass "Blowing Wool" (3.1- μm mean diam) at $\sim 30\%$, binder-coated building insulation (6.1- μm mean diam) at $\sim 19\%$, mineral wool fibers (2.7- μm mean diam) at $\sim 15\%$, and flame-attenuated building insulation (5.4- μm mean diam) at $\sim 13\%$.

TABLE VI. Cyclone Sampler Penetration Data

Fibrous Aerosol Material	Challenge Aerosol Mass Conc. (mg/m ³)		Cyclone Penetration (wt %)		No. of Cyclone Samples
	Mean	Std Dev	Mean	Std Dev	
Fibrous glass (0.45- μ m mean diameter)	2.4	0.5	81.0	3.7	48
Ceramic fibers (1.8- μ m mean diameter)	10.8	3.4	34.5	7.1	39
"Blowing Wool" building insulation (3.1- μ m mean diameter)	4.4	1.7	30.1	5.7	51
Binder-coated building insulation (6.1- μ m mean diameter)	7.0	3.0	18.7	8.5	27
Mineral wool fibers (2.7- μ m mean diameter)	7.8	3.1	15.2	7.7	27
Flame-attenuated building insulation (5.4- μ m mean diameter)	9.9	3.8	12.7	4.8	30
Total samples					222

These cyclone penetration data provide a rough estimate of the "respirable" mass fraction of each challenge aerosol. It is important to recognize that these data are derived from measurements of the *total* aerosol mass penetrating the cyclones. There may be a significant difference between a measured aerosol mass and the mass from fibers only. Coarse building insulations such as the 5.4- and 6.1- μ m-mean-diam materials and mineral wool are heterogeneous products and produce heterogeneous aerosols. Aerosols generated from these materials contain significant quantities of nonfibrous particulates, capable of penetrating cyclone samplers. Thus, for these coarse, heterogeneous materials, cyclone penetration does not reflect a direct relationship to mean fiber diameter as observed with the more homogeneous fibrous aerosols such as the 0.45- μ m ceramic and "Blowing Wool" materials.

All inhalation experiments in this project are longevity studies. Inhalation experiments with four fiber types have been completed and three others are under way. At present, no other fibers are scheduled for toxicological testing under the TIMA program. These studies are scheduled to conclude in 1985. Updated details of toxicology results are reported by the Life Sciences Division.

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DISSOLUTION OF URANIUM OXIDE MATERIALS IN SIMULATED LUNG FLUID

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Group: Industrial Hygiene, HSE-5

Funding Organization: US Air Force

Depleted uranium (DU) oxide aerosols prepared in the laboratory and collected in the field were tested to characterize their dissolution in simulated lung fluid and to determine how dissolution is affected by aerosol preparation. DU, a by-product of the uranium fuel cycle, has been selected by the US military for use in several types of munitions. During development, manufacture, testing, and use of these munitions, opportunities exist for inhalation exposure to various (usually oxide) aerosol forms of DU. The hazard potential associated with such exposures is closely related to the chemical form, the size of the DU aerosol material, and its dissolution properties. Five DU sample materials produced by exposing uranium alloy penetrators to certain controlled oxidation atmospheres¹ were studied (oxidation temperatures ranged from 500 to 900°C). In addition, two DU sample materials collected in the field were provided by the US Air Force. All sample materials were generated as aerosols using a Wright dust feed. The "respirable fraction" of these aerosols, according to the British Medical Research Council criteria, was separated and collected using a size-selective horizontal elutriator.

Bulk and respirable fraction samples analyzed by x-ray diffraction indicated the uranium crystalline material was α - UO_2 and α - U_3O_8 . Some amorphous material was detected in the respirable fraction of one of the field sample materials. This analysis also showed a significant difference between the composition of bulk and respirable fraction sample materials. The UO_2 content was greater in the bulk samples.

Respirable fraction samples of each study material were subjected to *in vitro* dissolution analysis. A gross-gamma technique^{2,3} was used to determine the sample mass content of uranium before dissolution. Individual samples were then sandwiched between 0.1- μm -pore-size Nucleopore filters. The sandwich was placed in a one-sided radial flow dissolution chamber. A simulant of lung serum at a temperature of $37^\circ\text{C} \pm 0.5^\circ\text{C}$ and a pH of 7.4 ± 0.1 was pumped past the filter sandwich. Eluate from each system was collected and analyzed for uranium by a delayed-neutron activation technique.

Analysis of the data from the dissolution study indicates that multiple-phase (apparently, three different phases) dissolution behavior occurred in all samples. Long-term dissolution parameters were independently calculated in two ways, one using a weighted nonlinear least-squares analysis³ and the other using a simple averaging technique.^{2,3} Additional details for the calculational technique may be found in the referenced work.^{2,3} Both calculation methods resulted in long-term dissolution half-times (third phase) that ranged from 170 to 490 days. The fraction of material associated with the second dissolution phase varied from 4 to 25% with the dissolution half-times in this phase being <2 days. The initial dissolution rate is extremely rapid (in contrast to the rate during the second phase) and could not be accurately measured.

Particular trends regarding the physiochemical character of uranium oxides described by other investigators were supported by the data generated in this study, which suggest that under some conditions a rapidly dissolving U_3O_8 fraction may be formed concurrent with the production of UO_2 . This fraction may play an important role in determining hazard potential associated with inhalation exposure to certain uranium aerosols.

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ADDITIONAL SHORT-TERM PLUTONIUM URINARY EXCRETION DATA FROM THE 1945-1947 PLUTONIUM INJECTION STUDIES

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Group: Industrial Hygiene, HSE-5

Funding Organization: Los Alamos National Laboratory

A recent publication by Rundo¹ on the long-term urinary excretion of plutonium, 10 000 days after intravenous injection of known amounts, has shown that the amount of plutonium excreted per day is significantly higher than predicted by the Langham power function model.² The Langham equation for daily urinary (Y_u) excretion rates, in per cent/day of the injected dose at time t (days) after the intake, follows:

$$Y_u = 0.2t^{-0.74} \quad (1)$$

Complete details on the Langham experiment are given in the Langham report and in a follow-up publication by Durbin.³

A review of the original injection experimental records was made because the published 10 000-day excretion data and observations made at Los Alamos⁴ and at the Oak Ridge National Laboratory⁵ have shown that at long times after occupational exposure, the urinary plutonium excretion deviates from the Langham power function model. Each of the Los Alamos National Laboratory notebooks used to record the analytical data was taken from storage and was studied for details that could influence the published findings. The most interesting discovery from this review was that there were additional urine excretion data for case HP-3. This case was one of the two cases from which Rundo obtained the 10 000-day excretion rate. The reason the data were not used in the original Langham publication is unknown, but remarks included in the notebooks suggest that there were some questions about the analytical methodology and an uncertainty with regard to the collection order. These two remarks may have influenced the exclusion of the data from the Langham report. The other case considered by Rundo was HP-6.

Table VII lists the results for case HP-3, recorded in the Los Alamos notebooks, starting with day 1 through day 23 and for days 321 through 324. Additional urine excretion data referenced in the Langham² publication from day 1645 (reported as four daily samples showing an average daily urinary excretion of 0.0008% for the injected dose) and the Rundo data at day 9934 are also listed in Table VII. The Los Alamos notebook records did not identify the data from day 1645, but two samples collected on day 1674 are noted in the notebook and are included in Table VII. The recorded values for these two samples are 1.29 and 0.83 counts/min and correspond to 0.0004% and 0.0002% of the injected dose. These values do not relate to the per cent excreted value of 0.0008% reported by Langham. There were no records of spiked control samples analyzed concurrently with the injection study samples, and there is no record of correction factors being applied to the recorded results to correct for chemical losses. Each of the samples through day 324 was analyzed in duplicate. When a serious procedural problem was noted with either of the aliquots, the result was not utilized by Langham in the mathematical treatment of the data to calculate his model.

The data for case HP-6 are given in Table VIII. The samples collected on day 523 and day 1610,

referred to in the Langham report, were not identified in the notebooks. Two results for days 1626 and 1627 are identified and are listed in Table VIII along with the 10 008-day data. All remarks relative to each sample's collection and analysis are also included in this table.

The excretion data for HP-3 and HP-6 are plotted in Figs. 9 and 10. Power function least-square curve fits for these data from day 3 to day 22 or 23 are also shown in the figures. The first data points for the HP-3 and HP-6 cases were not used to calculate the curve fit because they do not represent 24-h collection periods. The second data points were also excluded because of the influence of the short first-day collection period. Also shown on this graph is the Langham power

TABLE VII. Individual Urinary Excretion Values for Case HP-3 Expressed as Counts per Minute per Aliquot Analyzed and as Per Cent of Dose Excreted per Collection Period

Days Post-Injection (11/27/45)		Counts per Aliquot ^a		Per Cent of Dose ^b		Remarks from Notebook
		1 (counts/min)	2 (counts/min)	1	2	
0.4	9 h	563.9	509.1	0.3281	0.2962	
0.9	12 h	437.0	446.8	0.2543	0.2600	
1.9	24 h	299.1	496.6	—	0.2890	Aliquot No. 1 discarded
3	24 h	191.4	lost	0.1114	—	
4	24 h	190.3	176.7	0.1107	0.1028	
5	24 h	138.7	129.0	0.0807	0.0751	
6	24 h	73.1	74.6	0.0425	0.0434	Shipping material moist
7	24 h	70.0	77.0	0.0407	0.0448	
8	24 h	74.3	94.1	0.0432	0.0548	
9	24 h	45.2	32.9	0.0263	0.0191	
10	24 h	46.6	lost	0.0271	—	
11	24 h	46.8	45.2	0.0272	0.0263	
12	24 h	26.5	23.7	0.0154	0.0138	
13	24 h	34.1	33.9	0.0198	0.0197	
14	24 h	34.2	34.1	0.0199	0.0198	
15	24 h	49.5	45.6	0.0288	0.0265	
16	24 h	41.9	43.3	0.0244	0.0252	
17	24 h	30.4	41.3	0.0177	0.0240	
18	24 h	34.3	23.1	0.0200	0.0134	
19	24 h	29.5	31.6	0.0172	0.0184	
20	24 h	17.6	24.1	0.0192	0.0140	
21	24 h	32.1	51.8	0.0187	0.0185	
22	24 h	23.6	24.0	0.0137	0.0140	
23	24 h	23.6	23.5	0.0137	0.0137	
321	24 h	3.1	4.5	0.00180	0.00262	Ran these two bottles separately, both with same date, as we understood four 24-h samples had been sent.
322	24 h	5.0	4.3	0.00291	0.00250	
323	24 h	7.4	4.5	0.00431	0.00262	
324	24 h	8.2	9.1	0.00477	0.00471	
1645	c			(×1)		
1674	d		1.29	0.0008		Ref. 2
1674	d		0.83	0.0002		
9934	c		8.6 ± 1σ, 0.9	0.00252		Corrected for tracer recovery

Note: Dose, 3443 725 counts/min; injection time, 11:00 a.m.

^aEach aliquot = one-half of sample.

^bCounts per aliquot/dose × 2 × 100 = per cent of dose excreted per sample.

^cFour 24-h daily collections.

^dCollection period not recorded.

^eThe 14- to 24-h samples.

function curve that was derived from the use of all the published data including data collected from occupationally exposed workers. The occupational exposure data were used by Langham to extend the power function fit to 1750 days of postexposure.

It is apparent in Figs. 9 and 10 that a power function fit is a good choice to describe the early urinary plutonium excretion. The later period (300-, 500-, and 1600-day) results, along with the 10 000-day results, however, show a significant departure from the single power function model used to describe long-term plutonium excretion. The 300-, 500-, 1600-, and 10 000-day data may represent a distinctly different segment of the Pu excretional model for humans. This would be in keeping with the observations made by Stover⁶ and Clark⁷ that there were two distinct excretion segment rates for dog and swine plutonium excretion as a function of time following injection of plutonium (IV) citrate. The dog data showed a change in the first segment after 20 days and the swine data changed after 10 days. Durbin has concluded that within the Langham published data,

TABLE VIII. Individual Urinary Excretion Values for Case H-6 Expressed as Counts per Minute per Aliquot Analyzed and as Per Cent of Dose Excreted per Collection Period

Days Post-Injection (11/27/45)	Counts per Aliquot ^a		Per Cent of Dose ^b		Remarks from Notebook	
	1	2	1	2		
	(counts/min)	(counts/min)				
0.26	6.3 h	312.3	331.9	0.1690	0.1800	Splattering in oven, Aliquot No. 2, broken pipette
0.76	12.0 h	324.2	315.2	0.1755	0.1710	
1.76	24 h	404.9	391.8	0.2192	0.2121	Aliquot No. 2 splattered Sample ignited, vigorous reaction Spilled in centrifuge, indicator trouble
3	24 h	225.8	241.8	0.1222	0.1310	
4	24 h	206.0	135.7	0.1115	lost	
5	24 h	138.3	140.7	0.0749	0.0762	
6	24 h	99.5	112.3	0.0539	0.0608	
7	24 h	80.5	81.7	0.0436	0.0442	
8	24 h	81.3	80.7	0.0440	0.0437	
9	24 h	63.3	54.0	0.0343	0.0292	
10	24 h	48.1	66.4	0.0260	0.0359	Great loss in ashing Leakage
11	24 h	lost	lost	—	—	
12	24 h	43.4	45.9	0.0234	0.0248	Burned in oven
13	24 h	43.3	40.9	0.0235	0.0221	
14	24 h	36.9	35.3	0.0200	0.0191	Approximately 100 cc lost
15	24 h	40.7	39.0	0.0220	0.0201	
16	24 h	30.4	33.2	0.0164	0.0180	
17	24 h	25.0	23.0	0.0135	0.0124	
18	24 h	27.7	28.2	0.0150	0.0153	
19	24 h	29.0	27.4	0.0157	0.0148	
20	24 h	23.7	22.7	0.0128	0.0122	
21	24 h	23.7	20.2	0.0128	0.0109	
22	24 h	23.3	20.6	0.0126	0.0111	
523	c			(×1) 0.002		Ref. 2
1 610	c			0.0011		Ref. 2
1 626	d		4.54	0.0012		
1 627	d		4.26	0.0012		
10 008	c		5.45 ± 1σ, 0.6	0.00141		Result corrected for tracer recovery

Note: Dose, 369 500 counts/min; injection time, 1:40 p.m.

^aEach aliquot = one-half of sample.

^bCounts per aliquot/dose × 2 × 100 = per cent of dose excreted per sample.

^cFour daily samples.

^dCollection period not recorded.

^eEight 24-h samples.

there is evidence of two to four distinct segments in the excretion data and that the segments were dependent on how long the excretion data were collected. The evidence from the animal data, the additional results on day 324 for case HP-3, on day 523 for case HP-6, and on the 10 000-day data for both cases support the evidence of at least a two-segment model for the two human cases. The 1600-day data for cases HP-3 and HP-6, however, appear to be a departure from a simple two-segment model for the human excretion data.

Because the 1600-day data are inconsistent with a simple two-segment model to describe human plutonium excretion, the notebook records for this time period (1950) were reviewed for identifiable events that could have affected the reported results. As previously stated, only two results for each case at the 1600-day period were identified by the patient's name in the notebook records. The HP-3 results did not relate to the percentage given by the Langham report; therefore, we cannot identify the source of the reported 0.0008% of dose excreted on day 1645 for case HP-3. The notebook records, 4.54 and 4.26 counts/min, for case HP-6 are equivalent to the 0.0011% excretion values reported by Langham. These results can be assumed to be one of the sources of the data reported by Langham for the 1610-day excretion for case HP-6. The notebook records indicate that these "special" samples were analyzed along with other routine bioassay samples and that no special attention was given to the samples. However, these samples were analyzed by a different analytical procedure than was used to report results analyzed before the year 1950. In October 1949, the bismuth phosphate analytical method replaced the cupferron procedure that had been used since 1945.⁸ The lower chemical recovery and wider standard deviation of the bismuth phosphate procedure are significant variables that could have influenced the 1600-day HP-3 and HP-6 results. The influence of this lower recovery and larger precision is also evident within the routine bioassay sample data obtained from personnel with histories of positive plutonium excretion.⁹

In contrast to the data collected and analyzed through day 1600, which may be low because of losses associated with the analytical procedure, the 10 000-day data reported by Rundo are

FIGURE 9.
Excretion data for case HP-3. A power function curve for data collected on days 3-23 is shown by the solid line between the # symbols. The power function for these data, days 2-23, where t = days of postexposure, is per cent excreted per day = $0.34t^{-1.04}$, $r = 0.92$. The Langham power function model through day 1750 is indicated by the solid line drawn between the \$ symbols.

corrected by the use of ^{242}Pu tracer to 100% of the excreted amount of ^{239}Pu in each 24-h collection.

The 10 000-day data, therefore, are the only data we have from the injection study cases that have a reliable estimate of analytical sources of error associated with the excretion data. The correction of the other data for the appropriate chemical recovery factors would change the estimates of the amounts excreted and will significantly bring the day 1600 data closer to the profile of long-term plutonium excretion for the two cases, as evidenced by the data on either side of the 1600-day data. We have not introduced these factors into the data listed in Tables VII and VIII. We do, however, suggest that the 1600-day results be used with caution because of possible errors introduced by the analytical method used in 1950 and because of the available evidence, which shows that samples analyzed in 1950 were not as carefully supervised as were the samples analyzed during the period when the injection study samples were first under investigation in 1945-47 and again in 1973.

The previously unreported additional plutonium excretion data from HP-3 at day 324 and the evidence of the reported HP-6 data at day 524, plus the 10 000-day data on each case, support the conclusion that for these two cases, plutonium excretion departs from a power function curve fit as early as 300 days' postinjection. These data also support the evidence seen in occupationally exposed workers that the long-term excretion of plutonium deviates from the Langham power function model after the early excretion period.

We have refrained from the development of a new mathematical model to describe plutonium excretion using these data because of the limited data and possible sources of error noted. We do feel that the use of the Langham equation to predict plutonium body burdens from long-term excretion data should be discouraged. It is obvious that the use of the 523- and 1600-day data from the HP-3 and HP-6 cases influenced the mathematical development of the Langham power function equation, and application of this equation to occupational exposure excretion data will bias the resulting estimates of plutonium body deposition.

FIGURE 10. Excretion data for case HP-6. A power function curve for data collected on days 3-23 is shown by the solid line between the # symbols. The power function for these data, days 2-23, where t = days of postexposure, is per cent excreted per day = $0.53t^{-1.24}$, $r = 0.99$. The Langham power function model through day 1750 is indicated by the solid line drawn between the \$ symbols.

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RADIOANALYSIS OF TISSUES FROM OCCUPATIONALLY EXPOSED WORKERS

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Group: Epidemiology, HSE-14

Funding Organization: DOE, Office of Energy Programs (Office of Health and Environmental Research)

The US Transuranium Registry (USTR) instituted a program for whole-body donations in 1976 to improve the data on the distribution of transuranics within the entire skeleton and those tissues not available from a routine autopsy.¹ Whole-body donations are reserved for individuals with a systemic burden estimated to be 10% or greater of the maximum permissible body burden for a specific radionuclide. The USTR has obtained permission for 22 whole-body examinations. Two whole bodies have been submitted for radiochemical analyses. The first, an ^{241}Am exposure, has been described in an earlier report.² The second whole-body donor died at age 62 of congestive heart failure resulting from generalized atherosclerosis. The primary exposure was to ^{239}Pu in 1945. This individual, a chemist, was a member of the Manhattan Project and had been followed medically as a subject of Los Alamos health studies.³ At the time of his death, it was estimated on the basis of urine bioassay that he had a body burden of 26.6 nCi of ^{239}Pu and 0.2 nCi of ^{238}Pu .

The internal organs were obtained at the time of autopsy. The remainder of the body was dissected at a later date in Richland, Washington, by the same team that dissected the first body. The bones of the right side of the skeleton were sectioned and identified for analyses in the same manner as the first skeleton so that direct comparisons of Am/Pu deposition ratios could be made. The bones and soft tissue (mainly skeletal muscle and skin) were frozen and shipped to Los Alamos

for analyses. All tissues are being analyzed for plutonium and americium by using the standard analytical procedures used by this Laboratory.⁴

The summarized ²³⁹Pu results of the analyses are shown in Table IX. The ²⁴¹Am results are not complete at the time of this writing. The preliminary estimates of the total body deposition of ²³⁹Pu is 6.5 nCi. Independent of these measurements and before the completion of the analysis, the computer code used to estimate the body burden of plutonium from urine assays was modified. The new code uses the Langham power function and a single 100-yr half-life exponential component, as proposed by ICRP Publication 19. It provides a better overall correlation between calculated and autopsy estimates of the body burden.* The revised computer code calculated a body burden of 7.3 nCi ²³⁹Pu for this individual.

Table X lists the relative distribution of ²⁴¹Am and ²³⁹Pu in the skeletons of the first two whole bodies analyzed. The distribution is remarkably similar with major differences only in the amount found in the spine and pelvis and in the legs and feet. A more detailed study is in progress to determine exactly wherein the differences lie.

TABLE IX. Preliminary Data on the Distribution of ²³⁹Pu in the Whole Body of a US Transuranium Registry Case

Tissue	²³⁹ Pu Content	
	(dis/min)	(nCi)
Respiratory tract ^a	8 150	3.67
Liver	2 920	1.32
Kidneys	5	—
Spleen	90	0.04
Smooth muscle organs ^b	30	0.01
Striated muscle and skin ^c	320	0.14
Other soft tissue	40	0.02
Skeleton	2 940	1.32
Total	14 495	6.52

^aLung, trachea, tracheobronchial lymph nodes.

^bIntestinal tract, urinary bladder.

^cMuscle, skin, heart, tongue, ears.

^dBrain, adrenals, prostate, eyes, pancreas, thyroid, pituitary.

TABLE X. Preliminary Estimates Comparing the Distribution of ²⁴¹Am and ²³⁹Pu in Two Whole Skeletons

Skeletal Units	Fraction of Total Skeletal Deposition (%)	
	²⁴¹ Am	²³⁹ Pu
Head	14.1	14.3
Spine and pelvis	17.8	28.7
Shoulder and rib cage	9.0	8.3
Arms and hands	13.1	1.2
Legs and feet	46.0	37.5

Of the total whole-body deposition of ²³⁹Pu in the latter case, 6.52 nCi, 56%, remained in the lung and tracheobronchial lymph nodes; 44% (2.86 nCi) was distributed throughout the systemic

*This information provided by J. N. P. Lawrence, Health, Safety, and Environment Division, Los Alamos National Laboratory, Los Alamos, New Mexico, in December 1983.

system with 46% of this burden in the liver and 46% in the skeleton. The liver/skeleton ratio is in good agreement with ICRP Publication 30 recommended 45%/45% distribution.⁵ A more detailed report of the measured soft tissue and individual bone values is in progress.

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DEPOSITION OF INHALED PARTICLES IN THE RESPIRATORY TRACT AS A FUNCTION OF AGE AT EXPOSURE

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Group: Division Office, HSE-DO

Funding Organization: DOE, Office of Operational Safety

The lung model initially recommended by the ICRP¹ was developed to be applied in the workplace. Thus, it used only adult values for anatomical and physiological input parameters, such as those dealing with tidal volume and breathing rate. To deal with environmental exposures of humans, the model was changed to accommodate such parameters as the population changes with age from 1 month to adulthood. The alterations required age-related input concerning the respiratory tract gross anatomy and respiratory physiology. Quantification of these parameters is not precise and is highly variable among individuals, but ample data are available to make acceptable estimates.

The wide use of the ICRP lung model¹ led us to generally follow its derivation for extrapolation from adults to children, realizing that much sophistication has been applied to the respiratory tract anatomy and physiology since its publication in 1966. We chose to use Landahl's basic approach,² which incorporates much of Findeisen's original work,³ utilizing a respiratory tract divided into only 11 airway segments. Weibel⁴ and Yeh and Schum⁵ have recently suggested the use of 23-25 airway segments, with individual branching angles for each segment. The Landahl model divides the respiratory tract into more broader segments by radius, length, and volume than do some of the newer models. Landahl² also used constant branching and gravitational angles throughout his calculations. Our major goal was to develop a respiratory tract deposition model that would accommodate age 1 month to adulthood as an initial step in calculating radiation dose following inhalation.

Deposition in each of the airways of the respiratory tract is by the forces of inertia (impaction), gravitation (sedimentation), and diffusion. The importance of each of these forces will differ according to particle size, airflow, and dimensions of the airway. Approximations of the deposition

by Landahl² were used for impaction and sedimentation, and the equations of Gormley and Kennedy⁶ as implemented by Hofman et al.⁷ were applied to diffusion.

The approach to changing respiratory tract and physiological parameters to be applicable to children was to derive an analytical function describing the ratio of the child value to the value for a reference adult with the desired characteristics. Functions were derived for the number of airways, radius of the airway, volume of the airway, tidal volume, and breathing rate. In some cases data were available only as a function of body weight, and these were used with an average curve for body weight versus age to convert from body weight to age. As would be expected, the results from this process have a sizable uncertainty but are believed to be adequate for radiation protection purposes.

A computer program has been written to carry out the tracing of airflow through the respiratory tract and deposition in each of the sections for monodispersed particles of known density and diameter. The program is now being debugged, although some preliminary results are available.

Work for the future includes finishing the program and studying the effect on age of monodispersed particles. Attention will then turn to examining logarithmic distributions and the derivation of a reasonable model analogous to the ICRP model for the calculation of radiation dose to organs.

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MORTALITY AMONG PLUTONIUM AND OTHER WORKERS AT ROCKY FLATS

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Funding Organization: DOE, Office of Energy Research (Office of Health and Environmental Research)

A detailed study of mortality and radiation exposure for Rocky Flats workers was reported at the Sixteenth Mid-Year Topical Symposium of the Health Physics Society in January 1983.¹ We found significantly fewer deaths than expected due to all causes, all malignant neoplasms, lung cancer, and cancer of the digestive organs. No bone cancers were observed and cancers commonly associated with radiation exposure were not more frequent than expected (Table XI). Significantly more deaths than expected were observed for two causes, cancer of the prostate and benign and unspecified neoplasms. Further investigation revealed that the deaths from benign and unspecified neoplasms all involved intracranial tumors. A case control study² found no association between

TABLE XI. Standardized Mortality Rates (SMRs) for Selected Causes of Death Among White Males Employed at Least 2 Yr

Cause (ICD)	Observed	Expected	SMR	95% CI
All causes (1-998)	334	522.44	64	57-71
All cancers (140-209)	79	105.02	75	60-94
Lung (162,163)	22	35.9	62	38-93
Liver (155,156)	3	1.75	171	31-500
Pancreas (157)	(157)	5.73	70	19-179
Bone (196)	0	0.54	0	0-674
Brain (191-192)	6	4.04	149	54-324
Benign and unspecified neoplasms (204-207)	6	1.48	405	148-881
Leukemia and aleukemia (204-207)	5	4.26	117	38-274
Lymphopoietic (200-209)	8	11.27	71	31-140

Note: See Ref. 1.

TABLE XII. Relative Risk for Workers Exposed to ≥ 2 nCi Plutonium Compared with Workers Exposed to <2 nCi

Cause of Death	White Males Employed at Least 2 Yr		
	No. Cases Exposed	Risk Ratio	95% CI
All causes	67	1.16	0.88-1.52
All cancers	14	0.98	0.55-1.75
Lung	1	0.20	0.03-1.26
Leukemia and aleukemia	1	0.98	0.11-8.75
All lymphopoietic	3	2.64	0.67-10.49

TABLE XIII. Relative Risk for Workers Exposed to ≥ 1 rem External Radiation Compared with Workers Exposed to <1 rem

Cause of Death	White Males Employed at Least 2 Yr		
	No. Cases Exposed	Risk Ratio	95% CI
All causes	155	1.07	0.83-1.33
All cancers	37	1.09	0.69-1.72
Lung	10	0.97	0.41-2.28
Pancreas	1	0.36	0.04-3.25
Brain	3	1.10	0.21-5.69
Benign and unspecified neoplasms	4	2.86	0.46-17.62
Leukemia and aleukemia	3	1.64	0.28-9.77
All lymphopoietic	4	1.17	0.29-4.81

these brain tumors and exposure to radiation, including plutonium depositions or type of occupation. The excess deaths from intracranial tumors remain unexplained but do not appear to be associated with employment at Rocky Flats.

Relative risks among Rocky Flats workers with cumulative plutonium depositions of 2 nCi or more did not indicate a significantly greater risk of death among workers exposed to plutonium than among unexposed workers (Table XII). Similar results were found for workers with cumulative radiation exposure of at least 1 rem (Table XIII).

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CANCER INCIDENCE AMONG WORKERS AT THE LOS ALAMOS NATIONAL LABORATORY

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Funding Organization: DOE, Office of Energy Research (Office of Health and Environmental Research)

An analysis of cancer incidence among Los Alamos workers was reported at the Sixteenth Mid-Year Topical Symposium of the Health Physics Society.¹ Cancer incidence was especially low among Anglo-American males for cancer of the lung and oral cancer, cancer sites commonly associated with cigarette smoking (Table XIV). No cases of cancer of the lung, oral cavity, pancreas, or bladder were observed among Anglo-American females in the population. Standard-

ized incidence ratios for cancer of the breast and cancer of the uterine corpus exceeded one; however, these findings were not statistically significant (Table XV). These findings are consistent with expectation for a population of high socioeconomic class, such as the Laboratory work force. Therefore, working conditions at the Laboratory do not appear to have affected cancer incidence in this population.

TABLE XIV. Comparison of Observed and Expected Incident Cancers Among Anglo-American Male Employees, Los Alamos National Laboratory 1969-1978

Cancer	(ICD 8)	Observed	Expected	SIR	Exact 95% CI
All cancers ^a	(140-209)	61	100.88	0.60	0.46-0.78
Oral	(140-149)	2	7.87	0.25	0.03-0.92
Stomach	(151)	2	2.67	0.75	0.09-2.71
Colon	(153)	8	7.79	1.03	0.44-2.02
Rectum	(154)	1	4.14	0.24	0.01-1.35
Liver	(155,156)	1	0.90	1.11	0.03-6.19
Pancreas	(157)	2	2.96	0.68	0.08-2.44
Lung	(162,163)	6	24.23	0.25	0.09-0.54
Bone	(170)	1	0.49	2.04	0.05-11.37
Melanoma	(172)	3	4.85	0.62	0.13-1.81
Prostate	(185)	10	8.86	1.13	0.54-2.08
Testes	(186,187)	3	2.75	1.09	0.22-3.19
Bladder	(188)	3	5.25	0.57	0.11-1.67
Brain	(191,192)	2	2.82	0.71	0.08-2.56
Thyroid	(193)	2	1.52	1.32	0.16-4.75
Lymphosarcoma, reticulosarcoma	(200)	5	2.01	2.49	0.81-5.81
Hodgkin's disease	(201)	1	1.48	0.68	0.02-3.76
Leukemia and aleukemia	(204-207)	4	3.39	1.18	0.32-3.02
Other lymphatic tissue	(202,203,208)	1	1.78	0.56	0.01-3.13

^aIncludes also one cancer of ill-defined sites (ICD 199), one cancer of retroperitoneum and other digestive organs (ICD 158), one cancer of connective and other soft tissue (ICD 171), and one cancer of the breast (ICD 174).

TABLE XV. Comparison of Observed and Expected Incident Cancers Among Anglo-American Female Employees, Los Alamos National Laboratory 1969-1978

Cancer	(ICD 8)	Observed	Expected	SIR	Exact 95% CI
All cancers ^a	(140-209)	32	26.44	1.21	0.83-1.71
Melanoma	(172)	2	1.09	1.83	0.22-6.63
Breast	(174)	14	9.34	1.50	0.82-2.51
Cervix uteri	(180)	1	1.50	0.67	0.02-3.71
Corpus uteri	(181-182)	2	0.25	8.00	0.97-28.90
Other genital	(183-184)	3	1.47	2.04	0.42-5.96
Eye	(190)	1	0.08	12.50	0.32-69.65
Brain	(191-192)	2	0.41	4.88	0.59-17.62
Thyroid	(193)	3	0.75	4.00	0.82-11.69
Other lymphatic	(202,203,208)	2	0.35	5.71	0.69-20.64

^aIncludes also one cancer of ill-defined sites (ICD 199) and one cancer of connective and other soft tissue (ICD 171).

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ANALYSES OF MORTALITY AMONG WORKERS AT THE PANTEX NUCLEAR WEAPONS FACILITY

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Groups: Epidemiology, HSE-14; *Industrial Hygiene, HSE-5; **Analysis and Assessment Division, S-1

Funding Organization: DOE, Office of Defense Programs

An analysis of mortality¹ among white males employed at the Pantex Plant nuclear weapons facility did not reveal any unusual patterns of total or cause-specific mortality. We observed significantly fewer deaths than expected based on US rates for all causes, all cancers, digestive cancers, lung cancer, arteriosclerotic heart disease, and digestive diseases. No cause of death occurred significantly more often than expected. Similar results were observed when duration of employment, time since first employment, and radiation exposure greater than 1 rem were examined. We found no evidence that mortality from any cause was increased by employment at Pantex.

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OIL SHALE WORKERS HEALTH STUDY: EPIDEMIOLOGY

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Funding Organization: DOE, Office of Energy Programs (Office of Health and Environmental Research)

The oil shale industry in the United States is expected to employ a substantial number of persons in the future. Given the experience of the industry in Scotland and Estonia, there is a definite potential for adverse occupational health effects. The DOE recognized this potential; consequently, at their request, we have compiled a review of all anticipated health outcomes related to the industry and made recommendations for epidemiologic surveillance of the work force. The full report, titled "Considerations for the Epidemiologic Study of Oil Shale Workers," has been completed. It includes a critical comparison of different epidemiologic approaches for studying each of the anticipated health issues. These comparisons are based on available data bases, mechanisms for cooperation, work force size, and cost effectiveness. Prospective cohort mortality and morbidity studies standardized across the entire industry were proposed as viable alternatives to a disease registry.

ADSORPTION OF POLYCHLORINATED BIPHENYLS ON GLASS SURFACES

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Group: Industrial Hygiene, HSE-5

Funding Organization: Los Alamos National Laboratory

While developing a method for analyzing samples containing polychlorinated biphenyls (PCBs), we found that PCBs were reported to adsorb onto the glass walls of vials in which they were stored at PCB concentrations of 1 ng/ μ L.¹ Other laboratories have also reported PCB contamination of their glassware,² supposedly because of PCB adhering to the glass surfaces. The extent of this process was of concern since some of the samples analyzed for PCB could be stored up to a month before analysis was completed.

Silanization has been suggested as a method for decreasing PCB adsorption. When the glass surface comes in contact with a silanization reagent, such as a 5% solution of dimethyldichlorosilane, any active sites present on the glass surface become inert. It was observed that differences in PCB concentration were obtained from one vial to the next, but silanization eliminated any vial-to-vial variations.¹ However, silanization is not a common practice among laboratories that routinely analyze samples for PCBs. It has also been observed that any water vapor or oxygen in contact with the glass surface reacts with any active sites present. Consequently, any adsorption mechanism after this reaction is unlikely.³ With this conflicting information, a study was initiated to determine whether the extent of PCB adsorption taking place in our system was significant in comparison with the error involved in making our PCB determinations and whether a process, such as silanization, decreased any adsorption taking place.

Two sets each of silanized and nonsilanized vials containing five different concentrations in the range of 0.06 to 11.3 ng/ μ L of Aroclor 1260 (a high-molecular-weight PCB) in toluene were prepared. The two sets allowed determination of the error involved in preparing the solutions. By making triplicate PCB determinations, the error involved in measuring concentrations was determined. This determined the total error involved in PCB measurements to compare with any adsorption taking place. A concentration range covering approximately three orders of magnitude was used in order to determine any concentration effects on PCB adsorption.

PCB determinations were made by gas chromatography using electron capture detection. The Aroclor 1260 was resolved into approximately 50 peaks corresponding to compounds containing differing degrees of chlorination on the parent biphenyl group and different isomers. Low-molecular-weight PCBs elute first, high-molecular-weight PCBs later. By studying peaks at the beginning and end of the chromatogram, we determined if there were any adsorption differences dependent on the molecular weight of the specific PCB.

The first results indicated no differences in silanized and nonsilanized vials even after storage for 3 months. Figure 11 shows the slopes of the lines corresponding to silanized and nonsilanized vials are the same within experimental error, indicating no differences. To increase the glass surface area available for adsorption, we added silanized and nonsilanized glass beads to the vials to increase the area by three times, and measurements were made. Again, no differences were found for the silanized and nonsilanized vials.

From these experiments it was concluded that either there is no adsorption taking place or silanization does not affect PCB adsorption. A comparison of concentration measurements between vials with and without beads (Fig. 12) showed these measurements to be equivalent. If PCB

adsorption was taking place, a difference in concentration measurements between vials with and without beads would be observed because of the threefold increase in glass surface area. Apparently, PCB adsorption greater than the experimental error does not take place. In addition, no differences in adsorption between high- and low-molecular-weight PCBs were observed.

These results indicate no measurable adsorption was observed when PCB solutions were stored in glass using toluene as a solvent. The experimental error between measurements was 5%, and the error in preparing standards was 4%. Any small differences between silanized and nonsilanized vials appear to be within the cumulative error defined by these values. If we assume a model of PCB adsorption to be a molecule lying flat on the surface and adsorbing as a monolayer, we can calculate that at low concentrations all PCB molecules would be adsorbed, and at high concentrations (~ 10 ng/ μ L) approximately 10% of the PCB molecules would be adsorbed. This is further

FIGURE 11 (top).
Storage study of PCB in
glass vials.

FIGURE 12 (bottom).
Differences in glass surface
contact area.

evidence that PCB adsorption should be measurable but is not taking place in this system. It must be noted that other systems using different polarity solvents may react differently.

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ENVIRONMENTAL SURVEILLANCE AT LOS ALAMOS DURING 1983

Group: Environmental Surveillance Group, HSE-8

Funding Organization: Los Alamos National Laboratory

Monitoring Operations

Routine monitoring for radiation, radioactive materials, and chemical substances on the Laboratory site and in the surrounding region documents compliance with appropriate standards, identifies undesirable trends, provides information for the public, and contributes to general environmental knowledge. It also helps fulfill the Laboratory's policy to protect the general public, employees, and environment from any harm that could be caused by Laboratory activities and to reduce environmental impacts to the greatest degree practicable. Information from monitoring of the environment complements data on specific releases, such as those from radioactive waste treatment plants and various stacks at nuclear research facilities.

Monitoring and sampling locations for various types of measurements are organized into three main groups. Regional stations are located within the five counties surrounding Los Alamos County (Fig. 13) at distances up to 80 km (50 mi) from the Laboratory. They provide a basis for determining natural conditions beyond the range for potential influence of Laboratory operations. Perimeter stations are located primarily within about 4 km (2.5 mi) of the Laboratory boundary and emphasize locations in adjacent residential and community areas. They document conditions in areas regularly occupied by the general public and likely to be influenced by Laboratory operations. On-site stations are within the Laboratory boundary and most are in areas accessible only to employees during normal working hours. Their data are useful for continuity of interpretation and for documentation of conditions in parts of the Laboratory site where the public has limited access (for example, commuters on cross-site roads or near some boundaries). The number of stations in each group is shown in Table XVI.

TABLE XVI. Number of Sampling Locations

Type of Monitoring	Regional	Perimeter	On-site
External radiation	4	12	139
Air	3	11	12
Surface and ground water ^a	6	33	27
Soils and sediments	16	16	32
Foodstuffs	8	5	9

^aAn additional 23 stations for the water supply and 37 special surface and ground-water stations related to the Fenton Hill Geothermal Program were also sampled and analyzed as part of the monitoring program.

The types of routine monitoring conducted at these stations include measurements of radiation and collection of samples of air particulates, waters, soils, sediments, and foodstuffs for subsequent analysis. External penetrating radiation (the x and gamma rays and charged-particle contributions from cosmic and terrestrial sources, plus any Laboratory contributions) is also measured by thermoluminescent dosimeters.

Additional samples are collected at various times and locations to gain information about

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FIGURE 13.
Regional location of Los Alamos.

particular events, such as major runoff events in intermittent streams, nonroutine releases, or special studies. During 1983, more than 18 000 analyses for chemical and radiochemical constituents were performed on these environmental samples. Resulting data are used for comparison with standards and background levels of radiation, dose calculations, and other interpretations.

Summary of 1983 Results

Radiation Doses. Calculated individual whole-body radiation doses to the public attributable to Laboratory operations are compared with applicable Radiation Protection Standards in this report. They are expressed as a percentage of the 500-mrem/yr Radiation Protection Standard for

FIGURE 14 (top). Summary of estimated maximum individual and maximum Laboratory boundary doses (excluding contributions from cosmic, terrestrial, and medical diagnostic sources) from Laboratory operations.

FIGURE 15 (bottom). Annual above-background radiation TLD measurements (and TLD measurements as per cent of standard) due to operation of the Los Alamos Meson Physics Facility during the past 6 yr.

whole-body radiation. This Radiation Protection Standard is for doses from exposures that exclude contributions from background radiation (cosmic, terrestrial, global fallout, and self-irradiation sources). The doses calculated are those believed to be possible doses to individuals under realistic conditions of exposure.

Calculated maximum boundary doses and maximum individual doses for the past 6 yr are shown in Fig. 14. These estimated doses historically have been less than 4% of the 500-mrem/yr standard. In 1983 the estimated maximum individual dose was 6.8% of the Radiation Protection Standard. The increase in this dose between 1982 and 1983 resulted from a combination of increased airborne emissions from the Los Alamos Meson Physics Facility, a shift in the isotopic ratio of the emissions, and a slight change in meteorological conditions.

Another perspective is gained by comparing these estimated doses with the estimated whole-body dose attributable to background radiation. The highest estimated dose caused from Laboratory operations was about 26% of the dose attributable to naturally occurring radioactivity in Los Alamos in 1983.

Significance of Radiation Doses. To provide a perspective for comparing the significance of radiation exposures, estimates of the added risk of cancer were calculated. Increases in risk estimated for average individual exposures to ionizing radiation from 1983 Laboratory operations are in Table XVII, along with estimated incremental risks from natural and medical diagnostic radiation. The maximum potential Laboratory contribution to cancer risk is small when compared with overall cancer risks. The overall United States lifetime risks of contracting some form of cancer from all causes is one chance in four. The lifetime risk of cancer mortality is one chance in five. The Los Alamos incremental dose attributable to the 1983 Laboratory operations is equivalent to the additional exposure from cosmic rays a person would get flying in a commercial jet for 1.6 h.

TABLE XVII. Added Individual Lifetime Cancer Mortality Risks Attributable to 1983 Radiation Exposure

Exposure Source	Added Risk (Chance) to an Individual of Cancer Mortality	Incremental Dose (mrem) Used in Risk Estimate
Average exposure from Laboratory operations		
Los Alamos townsite	1 in 29 000 000	0.35
White Rock area	1 in 32 000 000	0.31
Natural radiation (cosmic, terrestrial, and self-irradiation)		
Los Alamos townsite	1 in 76 000	132
White Rock area	1 in 83 000	121
Medical X-rays (diagnostic procedures)		
Average whole-body exposure	1 in 97 000	103

External Penetrating Radiation. Levels of external penetrating radiation (including x and gamma rays and charged-particle contributions from cosmic, terrestrial, and manmade sources) in the Los Alamos area are monitored with thermoluminescent dosimeters (TLDs) at 155 locations divided into 3 networks. The TLD network, monitoring radiation from airborne activation products released by the Los Alamos Meson Physics Facility (a linear particle accelerator), measured 48 ± 3 mrem/yr (excludes background radiation from cosmic and terrestrial sources), which is 9.6% of the Department of Energy's Radiation Protection Standard. Figure 15 shows this measurement has increased over the past few years. This trend is primarily from higher operating levels (beam currents) in the particle accelerator. Engineering design modifications (increasing the holdup

time of the airborne emissions, moving the stack, and improving the beam stop) to reduce exposure from airborne activation products have been conceptually designed and included in Laboratory funding requests.

Radiation levels (including natural background radiation from cosmic and terrestrial sources) are also measured at regional, perimeter, and on-site locations (Fig. 16) in the environmental network. No measurements at the regional or perimeter locations showed any statistically distinguishable increase in radiation that could be attributed to Laboratory operations. Some measurements at on-site stations were slightly above background levels, as expected, reflecting ongoing research activities at the Laboratory.

Radiation levels were measured by a TLD network covering one active and eight inactive low-level radioactive solid waste management areas. The general public is excluded from these waste management sites because they are controlled-access areas. Several transient elevated measurements at the one active site were caused from waste management operations (handling and storing).

Radioactivity in Air and Water. Measurements of radioactivity in air and water are compared with standards, known as Concentration Guides, that are set by the Department of Energy. The Concentration Guides are concentrations of radioactivity in air breathed continuously or water constituting all that is drunk during a year that results in whole-body or organ doses equal to the Radiation Protection Standards. For 1983 the annual averages (including amounts from cosmic, terrestrial, and global fallout sources) of the principal radionuclides in air and water potentially influenced by Laboratory operations were all less than 1% of the Concentration Guides.

Radioactivity in Air. During 1983, atmospheric concentrations of tritium, gross beta, americium, plutonium, and uranium were measured at regional, perimeter, and on-site sampling locations. The annual averages for 1983 for all these radioactive constituents were much less than 1% of the Department of Energy's Concentration Guides. Only the atmospheric tritium concentrations showed any measurable impact from Laboratory operations. The impact was insignificant and does not pose an environmental or health problem.

Radioactivity in Water. Surface and ground waters are monitored to provide routine surveillance of potential dispersion of radionuclides from Laboratory operations. Only the waters in on-

FIGURE 16. Quarterly radiation TLD measurements, which include contributions from cosmic, terrestrial, and Laboratory radiation sources for regional, perimeter, and on-site locations for the past 5 yr.

site liquid effluent release areas contain radioactivity in concentrations that are above natural terrestrial and worldwide fallout levels. However, these concentrations are still small fractions of the Concentration Guides. These on-site waters are not a source of industrial, agricultural, or municipal water supplies. Results for the 1983 radiochemical quality analyses of water from regional, perimeter, water supply, and on-site areas (where no effluents are released) indicate no significant effect from effluent releases from the Laboratory.

The water supply met all applicable US Environmental Protection Agency chemical quality and radioactivity standards. The integrity of geological formations protecting the deep ground-water aquifer was confirmed by lack of any measurements indicative of nonnatural radioactivity or chemical contamination in municipal water supply sources.

Radioactivity in Other Media. Measurements of radioactivity in samples of soils, sediments, and foodstuffs are made to provide information on less direct natural mechanisms that could result in exposures to people.

Measurements of radioactivity in soils and sediments are also useful for monitoring and understanding hydrologic transport of some radioactivity that occurs in intermittent stream channels in and adjacent to low-level radioactive waste management areas. Pueblo, Los Alamos, and Mortandad Canyons have concentrations of radioactivity on sediments at levels higher than those attributable to natural terrestrial or worldwide fallout concentrations. Some radioactivity on sediments in Pueblo Canyon (from pre-1964 effluent disposal) and upper Los Alamos Canyon (from 1952 to current treated-effluent disposal) has been transported during runoff events to the Rio Grande. Theoretical estimates, confirmed by measurements, show the incremental effect on Rio Grande sediments is small in comparison with levels of activity on soils and sediments attributable to worldwide fallout and to variability in such measurements. The low levels of radioactivity in Mortandad Canyon are from treated liquid effluents from the treatment plant. No

TABLE XVIII. Comparison of 1982 and 1983 Radioactive Releases from the Laboratory

Airborne Stack Emissions				
Radioactive Constituent	Units	Activity Released		Ratio 1982/1983
		1982	1983	
²⁴¹ Am	μCi	0.035	0.095	2.7
⁴¹ Ar	Ci	342	418	1.2
³ H	Ci	15 856	7 847	0.5
¹³¹ I	μCi	785	83	0.1
³² P	μCi	4.8	2.7	0.6
^{238,239,240} Pu	μCi	112	113	1.0
Uranium	μCi	1 373	888	0.7
Gaseous mixed activation products	Ci	251 000	461 111	1.8
Mixed fission products	μCi	1 184	843	0.7
Particulate/vapor activation products	Ci	182	2 640	14.5
Total	Ci	267 380	472 016	1.8
Liquid Effluents				
Radioisotopes		Activity Released (mCi)		Ratio 1982/1983
		1982	1983	
^{238,239,240} Pu		19.9	53.3	2.7
²⁴¹ Am		19	38.4	2.0
^{89,90} Sr		25	59.3	2.4
³ H		15 330	10 350	0.7
¹³⁷ Cs		210	45.0	0.2
²³⁴ U		2.1	2.1	1.0
Total		15 606	10 548	0.7

radioactivity on sediments or in water has been transported past the Laboratory boundary in Mortandad Canyon. Radionuclide concentrations in on-site soil samples were at or below natural terrestrial and global fallout background levels.

Most fruit, vegetable, fish, and honey samples from off-site locations showed no increments of radioactivity distinguishable from that attributable to natural sources or worldwide fallout. Fruit from on-site trees had slightly elevated tritium concentrations. A person eating all the fruit from the trees with the maximum tritium concentration would receive a dose of 0.017% of the Department of Energy's Radiation Protection Standard. Game fish samples from Cochiti Reservoir, when compared with samples from the background stations, had slightly higher uranium concentrations. These levels are believed to be caused by natural phenomena. Eating a year's supply of fish with these levels would give a 50-yr dose commitment of 0.016% of the Radiation Protection Standard. Doses from eating honey from hives located on Laboratory land would be a maximum of 0.012% of the Radiation Protection Standard.

Other Monitoring Results. Airborne radioactive emissions were monitored as released from 84 points at the Laboratory. The results are summarized in Table XVIII and show an approximate 77% increase (about 205 000 Ci more) in total radioactivity released during 1983 versus 1982. Almost all this increase was caused from higher operating levels of the linear particle accelerator at the Los Alamos Meson Physics Facility. This increased the quantities of short-lived (2- to 20-min half-lives) airborne activation product emissions. Liquid effluents from two radioactive waste treatment plants (Table XVIII) and one sanitary sewage lagoon system contained some radioactivity, all at levels well within the Concentration Guides.

Nonradioactive airborne emissions from the beryllium fabrication shop, gasoline storage and combustion, power plant, gases and volatile chemicals, waste explosive burning, and dynamic testing did not result in any measurable or theoretically calculable degradation of air quality. A single National Pollutant Discharge Elimination System (NPDES) permit covers 103 industrial discharge points and 11 sanitary sewage treatment facilities. This year 9 of 11 sanitary sewage treatment facilities exceeded one or more of the NPDES limits (biochemical oxygen demand, total suspended solids, fecal coliform, and/or pH) in 1 or more months. Fewer than 4% of all samples from the domestic and industrial outfalls exceeded NPDES limits.

DEVELOPMENT OF WATER SUPPLY WELL PM-5

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Group: Environmental Surveillance, HSE-8

Funding Organization: Los Alamos National Laboratory

Construction of water supply Well PM-5 began in December 1981 with the drilling of the pilot hole and was completed in September 1982 when the well was test pumped. The well is located about 3.4 km northwest of Well PM-4 on the Pajarito Plateau at an elevation of 2162 m. The pilot hole was drilled to a depth of 948 m. Stratigraphic units¹ penetrated by the well in descending order are the Bandelier Tuff, Basaltic Rocks of Chino Mesa, Puye Conglomerate, and Tesuque Formation (Table XIX).

The top of the main aquifer of the Los Alamos area (only aquifer capable of municipal and industrial water supply) was encountered at a depth of about 368 m in the fanglomerate member of the Puye Conglomerate. The lower member of the Puye Conglomerate, the Totavi Lentil, and Tesuque Formation are within the main zone of saturation at the well.

Step tests to determine the size (pumping rate) of the permanent pump were made at rates of 48 to 79 L/s. The tests were made over about an 11-h period with the higher pumping rate at the start of the test. At a pumping rate of about 79 L/s for about 3 h, the drawdown was 44 m with a specific capacity of 1.8 L/s of draindown. On the basis of the step test, the contractor recommended a pump that will produce about 76 L/s.

TABLE XIX. Generalized Geologic Log of Supply Well PM- 5

Stratigraphic Units	Thickness (m)	Depth^a (m)
Bandelier Tuff	225	225
Basalt (Rocks of Chino Mesa)	6	231
Puye Conglomerate		
Fanglomerate Member	14	245
Basalt (Rocks of Chino Mesa)	38	283
Puye Conglomerate		
Fanglomerate Member	11	294
Basalt (Rocks of Chino Mesa)	55	349
Puye Conglomerate		
Fanglomerate Member	99	448
Totavi Lentil	24	472
Tesuque Formation		
Sandstone	66	538
Basalt	12	550
Sandstone	24	574
Basalt	3	577
Sandstone	14	591
Basalt and breccias	41	632
Sandstone	20	652
Basalt and breccias	59	711
Siltstone, claystone	14	725
Basalt and breccias	110	835
Siltstone, claystone, and sandstone	113	948

^aTop of main aquifer at 368 m.

The well is in an area where a better yield was expected. The contractor used a large quantity of drilling mud and lost circulation material from a depth of about 368 to 732 m. It is quite possible that the aquifer still contains significant amounts of drilling mud and lost circulation material. When the well is put into service, the specific capacities may improve as some of the material plugging the aquifer is removed. This has occurred in Well PM-4 and other wells on the Pajarito Plateau.

Water from Well PM-5 is a sodium and bicarbonate type and is similar to water from Well PM-4. Water from Well PM-5 has a hardness of 52 mg/L and total dissolved solids of 211 mg/L. The concentrations of constituents in water samples collected during the aquifer test are below Primary, Secondary, and Radiochemical Standards of the Environmental Protection Agency.

The well will not be added to the system until mid-1984 after completion of the pump station, transmission lines, and a storage tank, which are currently being built. Specific details of the well construction and testing are found in a Laboratory report.²

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CHEMICAL QUALITY OF WATER AT THE FENTON HILL SITE

ENVIRONMENTAL
PROTECTION

Authors: W. D. Purtymun, N. M. Becker, R. W. Ferenbaugh, M. N. Maes, and H. Adams*

Groups: Environmental Surveillance, HSE-8; *Waste Management, HSE-7

Funding Organization: Los Alamos National Laboratory

Introduction

The Los Alamos National Laboratory is currently evaluating the feasibility of extracting thermal energy from the hot dry rock geothermal reservoir at the Fenton Hill Geothermal Site (TA-57). The site is located about 45 km west of Los Alamos on the southwestern edge of the Valles Caldera. The hot dry rock energy concept involves drilling two deep holes, connecting these holes by hydraulic

FIGURE 17.
Water sampling locations
in the vicinity of Fenton
Hill Geothermal Site
(TA-57).

fracturing, and bringing the thermal energy to the surface by circulating water through the system. Environmental monitoring is done at the site to assess any impacts of the geothermal operations.

Chemical Quality of Surface and Ground Water

The chemical quality of surface and ground water in the vicinity of TA-57 (Fig. 17) has been determined for use in geohydrologic and environmental studies. These water quality studies began before construction and testing of the hot dry rock system. Results of the studies and detailed data are published elsewhere.¹

Surface-water stations (12 on the Jemez River, the Rio Guadalupe, and their tributaries) are divided into four general groups based on common chemical properties of predominant ions and TDS (Table XX). The predominate ions are (1) sodium and chloride, (2) calcium and bicarbonate, (3) calcium and sulfate, and (4) sodium and bicarbonate.

Ground-water stations (five mineral and hot springs, one well, and five springs) are grouped with predominant ions: (1) sodium and chloride, (2) calcium and bicarbonate, and (3) sodium and bicarbonate (Table XX).

There was no significant change in the chemical quality of surface and ground water at the individual stations in 1983 when compared with previous years' chemical analyses. Some slight variations are caused by normal seasonal variations.

TABLE XX. Predominate Ions in Surface and Ground Waters and Ponds at Fenton Hill Geothermal Site (concentrations in mg/L)

SURFACE WATER				GROUND WATER				
Location	Na	Cl	TDS	Location	Na	Cl	TDS	
Sodium Chloride				Sodium Chloride				
Redondo Creek (U)	13	8	77	Loc. JF-1 (Hot Spr)	500	690	1902	
Jemez River (R)	78	102	428	Loc. JF-5 (Hot Spr)	925	1400	3876	
Jemez River (S)	78	102	380		Ca	HCO ₃	TDS	
	Ca	HCO ₃	TDS	Calcium Bicarbonate				
Calcium Bicarbonate				FH-1 (Supply Well)	41	115	236	
San Antonio Creek (N)	16	60	139	Loc. 39 (Spr)	17	50	106	
Rio Cebolla (T)	20	75	102		Na	HCO ₃	TDS	
Rio Guadalupe (Q)	49	150	207	Sodium Bicarbonate				
Lake Fork 1 (LF-1)	14	45	89	JS-2, 3 (Spr)	23	97	151	
Lake Fork 2 (LF-2)	16	55	116	JS-4, 5 (Spr)	20	85	164	
Lake Fork 3 (LF-3)	14	65	133	Loc. 4 (Spr)	38	130	190	
Lake Fork 4 (LF-4)	16	70	142	Loc. 31 (Spr)	17	60	97	
	Ca	SO ₄	TDS	RV-2 (Hot Spr)	26	50	154	
Calcium Sulfate				RV-4 (Hot Spr)	53	115	231	
Sulphur Creek (V)	60	325	442	RV-5 (Hot Spr)	23	75	137	
Sulphur Creek (F)	25	62	150					
	Na	HCO ₃	TDS					
Sodium Barcarbonate								
Jemez River (J)	20	60	131					
PONDS—FENTON HILL								
Location	SO ₄	Cl	F	TDS	As	B	Cd	Li
Upper GTP-1	84	1250	4.3	3488	0.065	40	<0.001	18
Lower GTP-3	40	46	0.6	202	0.200	1.3	0.002	0.7

Notes: 1. See Fig. 17 for sampling locations indicated in parentheses.
2. One sample taken at each location.

The ponds at the Fenton Hill Geothermal Site contain water used in drilling operations and in the hydraulic fracturing operations. The water (November 1983) was highly mineralized in Pond GTP-1 (TDS was 3488 mg/L) adjacent to the deep wells. Certain elements in the ponds (SO_4 , Cl, and TDS) are of interest in monitoring the quality of adjacent waters, whereas other elements (As, B, Cd, F, and Li) must be monitored as specified in the National Pollutant Discharge Elimination System Permits (NPDES) for the site. Water in the ponds is sometimes released into a dry canyon adjacent to the site. Release is at a rate that allows the water to infiltrate into the alluvium and underlying rock of the canyon floor within 100 m from the point of effluent discharge. The water from the ponds does not reach surface water in the area. Monitoring of the surface water (Stations LF-1, 2, 3, and 4) and ground water (Stations 31 and 39) below the site failed to detect any change in chemical constituents that could be related to release of water from the ponds.

Soil and Vegetation Samples

Samples of vegetation and soil from the channel bottom and the canyon bank below Pond GTP-3 have been collected semiannually since 1978 to determine the effect of release of pond water on vegetation and soil. The collected samples are analyzed for arsenic, boron, cadmium, fluorine, and lithium. The sampling locations are at distances of about 100, 200, 400, and 1000 m down the canyon from the Pond GTP-3 discharge point. An additional sample is collected from the canyon bottom far down the canyon at its junction with Lake Fork Canyon. The data obtained to date from these samples are in Table XXI.

The behavior in the environment of each of the five elements monitored reflects its varying soil physiochemical and plant biophysiological properties. Each element is discussed separately in the following paragraphs.

The data indicate that there is a slight arsenic accumulation in plant roots (Table XXI). This agrees with published information,² which notes that arsenic accumulates in much larger amounts in or on plant roots than in foliage. Foliar content is low (0.5 ppm), which also agrees with the literature. Leibig notes that arsenic toxicity limits plant growth before large amounts of arsenic are absorbed and translocated to the foliage. The foliar arsenic level at which toxicity occurs apparently varies widely, being reported at 0.05 to 250 ppm, depending on plant species, arsenic source, soil type, and other factors. Natural foliar arsenic levels range up to about 10 ppm.³ The measured soil concentrations are well within the normal range of 0.3 to 38 ppm.²

Boron shows a definite accumulation pattern in soil, plant roots, and plant foliage (Table XXI), although the accumulation in plant foliage is the most pronounced. Excess foliar boron levels are generally considered to be anything above 200 ppm, although tissue levels may reach 1000 ppm without visible damage symptoms.⁴ Recent foliar boron levels at the Fenton Hill Site have exceeded 200 ppm in portions of the canyon within 200 m of Pond GTP-3, although there is no visual evidence of foliar damage. Soil boron content is within the normal range of 2 to 100 ppm, although soils in the upper end of this range may cause plant damage under appropriate conditions. There is evidence that plant damage may occur as a result of a boron-fluoride synergistic effect,⁵ which is a consideration because fluoride is also present in the effluent discharged from Pond GTP-3.

The data received to date on cadmium are scanty and insufficient on whether there is any accumulation (Table XXI). The single set of foliage data from 1981 indicates that some foliar accumulation might be occurring. However, the levels are still well below critical levels of 10 to 15 ppm.⁶

The data for fluoride show some evidence that there is a slight accumulation in soils, but no trends are apparent in root and foliar analyses (Table XXI). Soil buildup is to be expected because nearly all fluoride compounds are relatively insoluble. However, all measured soil concentrations are still within the normal range of 20 to 500 ppm. With the exception of the fall 1981 root samples, the vegetation analyses all fall into the normal fluoride content range of up to 20 ppm.^{7,8} Toxic levels vary widely among species, ranging from about 30 to several hundred ppm.⁹ Also, as mentioned previously, there is the possibility of a detrimental fluoride-boron synergistic effect.

Lithium data also are rather scanty. There does appear to be some accumulation in soils and roots and there is a definite accumulation in plant foliage (Table XXI). Soil concentrations are well within the normal range of 10 to 100 ppm, but foliage analyses of plants from that portion of the canyon affected by the Pond GTP-3 effluent are considerably above the normal range of 0.5 to 1.5 ppm.¹⁰ Lithium toxicity symptoms have been reported at as low as 13 ppm for sensitive species, although critical levels for a grass (barley) were reported in the range of 22 to 60 ppm.¹¹ In spite of the fact that measured foliar lithium concentrations in the canyon are potentially in the toxic range, no apparent damage is evident on the grasses or aspen growing there.

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TABLE XXI. Most Recent Available Data on Environmental Samples from Fenton Hill Geothermal Site

Location*	As		B		Cd		F		Li	
	Date	Concentration (ppm)	Date	Concentration (ppm)	Date	Concentration (ppb)	Date	Concentration (ppm)	Date	Concentration (ppm)
Roots (Bank)										
100 m ^b	Fall 1981	3.8	Fall 1982	29	Spring 1982	740	Fall 1982	45	Spring 1982	1.4
200 m	Fall 1981	2.2	Fall 1982	37	Spring 1982	200	Fall 1982	52	Spring 1982	1.9
400 m	Fall 1981	2.9	Fall 1982	30	Spring 1982	120	Fall 1982	40	Spring 1982	42
1000 m	Fall 1981	5.7	Fall 1982	34	Spring 1982	250	Fall 1982	43	Spring 1982	1.3
Roots (Channel)										
100 m	Fall 1981	13	Fall 1982	114	Spring 1982	260	Fall 1982	78	Spring 1982	3.4
200 m	Fall 1981	5.7	Fall 1982	139	Spring 1982	220	Fall 1982	170	Spring 1982	13
400 m	Fall 1981	6.5	Fall 1982	130	Spring 1982	270	Fall 1982	61	Spring 1982	1.6
1000 m	Fall 1981	1.9	Fall 1982	30	Spring 1982	280	Fall 1982	37	Spring 1982	1.2
Lower Canyon	Fall 1981	1.1	Fall 1982	32	Spring 1982	350	Fall 1982	77	Spring 1982	19
Foliage (Bank)										
100 m	Fall 1981	0.11	Fall 1982	11	Spring 1982	28	Fall 1982	12	Spring 1982	0.5
200 m	Fall 1981	0.08	Fall 1982	13	Spring 1982	43	Fall 1982	170	Spring 1982	1.3
400 m	Fall 1981	0.35	Fall 1982	32	Spring 1982	19	Fall 1982	10	Spring 1982	0.5
1000 m	Fall 1981	<0.06	Fall 1982	9	Spring 1982	22	Fall 1982	2	Spring 1982	2.4
Foliage (Channel)										
100 m	Fall 1981	<0.11	Fall 1982	188	Spring 1982	44	Fall 1982	70	Spring 1982	89
200 m	Fall 1981	0.09	Fall 1982	434	Spring 1982	31	Fall 1982	84	Spring 1982	126
400 m	Fall 1981	0.45	Fall 1982	110	Spring 1982	65	Fall 1982	8	Spring 1982	15
1000 m	Fall 1981	0.24	Fall 1982	12	Spring 1982	38	Fall 1982	19	Spring 1982	0.5
Lower Canyon	Fall 1981	0.30	Fall 1982	13	Spring 1982	44	Fall 1982	28	Spring 1982	1.1
Soil (Bank)										
100 m	Fall 1982	3.1	Fall 1982	14	Fall 1982	80	Spring 1982	80	Spring 1982	31
200 m	Fall 1982	3.1	Fall 1982	23	Fall 1982	160	Spring 1982	130	Spring 1982	26
400 m	Fall 1982	3.9	Fall 1982	17	Fall 1982	80	Spring 1982	200	Spring 1982	32
1000 m	Fall 1982	5.4	Fall 1982	31	Fall 1982	510	Spring 1982	220	Spring 1982	33
Soil (Channel)										
100 m	Fall 1982	12	Fall 1982	49	Fall 1982	210	Spring 1982	240	Spring 1982	44
200 m	Fall 1982	17	Fall 1982	104	Fall 1982	440	Spring 1982	200	Spring 1982	48
400 m	Fall 1982	12	Fall 1982	54	Fall 1982	220	Spring 1982	150	Spring 1982	51
1000 m	Fall 1982	2.9	Fall 1982	18	Fall 1982	210	Spring 1982	190	Spring 1982	30
Lower Canyon	Fall 1982	2.8	Fall 1982	15	Fall 1982	140	Spring 1982	200	Spring 1982	46

^aOne sample per location.

^bDistance downstream channel from Fenton Hill Geothermal Site.

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DISTRIBUTION OF MOISTURE, TRITIUM, AND PLUTONIUM IN THE ALLUVIUM, AQUIFER, AND UNDERLYING TUFF IN MORTANDAD CANYON

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Funding Organization: Los Alamos National Laboratory

Introduction

Mortandad Canyon received industrial effluents containing trace amounts of radionuclides from the treatment plant at TA-50 (Fig. 19). The effluents and surface runoff recharge a shallow aquifer in the canyon. The shallow aquifer in the alluvium is perched (separated by about 290 m of unsaturated volcanics and sediments from the main aquifer) on the underlying tuff.¹ The aquifer is of limited extent as water in the aquifer is depleted by evapotranspiration and infiltration into the underlying tuff. This investigation was made to determine the distribution of infiltration (moisture) and radionuclides in the alluvium and underlying tuff in a section of Mortandad Canyon.

Concentrations of radionuclides in water of the shallow aquifer decrease downgradient in the canyon from the effluent outfall. This reduction is caused by adsorption or ion exchange of the radionuclides with silt or clay minerals in the alluvium or dilution of the effluent by storm runoff. The distribution of the radionuclides in the aquifer is monitored by seven observation wells.²

At observation Well MCO-6, three core holes were drilled at right angles to the stream channel. Two other holes were cored to obtain background information. Cores taken from five holes were analyzed to determine moisture content and concentrations of tritium and plutonium (Table XXII).

The alluvium in the canyon is derived from the weathering of the Bandelier Tuff. At Well MCO-6, the alluvium is thickest beneath the stream channel and thins away from the channel (Fig. 18). The alluvium is a silty sand that includes a thin layer of silty clay of weathered tuff at the base. The light pinkish gray tuff is moderately welded and is composed of quartz and sanidine crystals and crystal fragments, with small rock fragments of rhyolite, latite, and pumice in an ash

TABLE XXII. Distribution of Moisture, Tritium, and Plutonium from Core Holes in Mortandad Canyon

Sample	Depth (m)	Moisture (vol %)	^3H (10^{-6} $\mu\text{Ci/mL}$)	^{238}Pu (pCi/g)	$^{239,240}\text{Pu}$ (pCi/g)	Sample	Depth (m)	Moisture (vol %)	^3H (10^{-6} $\mu\text{Ci/mL}$)	^{238}Pu (pCi/g)	$^{239,240}\text{Pu}$ (pCi/g)
Core Hole 1 (In channel)						Core Hole 3 (12 m south of channel)					
	1.8	7	10 ± 0.8	0.001 ± 0.002	0.000 ± 0.003		1.8	3	18 ± 1.0	0.004 ± 0.004	0.000 ± 0.004
	3.4	12	29 ± 1.4	-0.003 ± 0.004	0.016 ± 0.008		2.9	2	—	-0.002 ± 0.002	0.003 ± 0.003
	4.9	12	21 ± 1.2	0.001 ± 0.002	0.004 ± 0.003		4.9	6	2.4 ± 0.8	-0.003 ± 0.003	-0.002 ± 0.003
	6.4	12	14 ± 1.0	-0.001 ± 0.002	0.008 ± 0.006		6.4	4	6.0 ± 1.2	-0.001 ± 0.002	-0.001 ± 0.003
	7.9	28	8.5 ± 0.8	0.006 ± 0.003	0.010 ± 0.004		7.9	4	17 ± 1.0	0.000 ± 0.003	0.000 ± 0.003
	9.4	32	23 ± 1.2	0.000 ± 0.003	0.003 ± 0.004		9.4	—	14 ± 1.0	0.000 ± 0.001	-0.001 ± 0.002
	11.0	19	—	—	—		11.0	7	13 ± 1.0	0.000 ± 0.004	0.017 ± 0.006
	12.5	20	150 ± 4.0	0.003 ± 0.003	0.002 ± 0.002		12.5	8	13 ± 1.0	-0.002 ± 0.003	0.002 ± 0.004
	14.0	27	391 ± 12	0.003 ± 0.003	0.004 ± 0.003		14.0	8	16 ± 1.0	0.000 ± 0.002	0.003 ± 0.004
	15.2	18	106 ± 3.6	0.005 ± 0.003	0.000 ± 0.002		15.5	9	25 ± 1.2	-0.002 ± 0.001	0.015 ± 0.004
	15.5	17	101 ± 3.4	-0.001 ± 0.002	0.002 ± 0.002		17.1	9	35 ± 1.6	-0.003 ± 0.002	0.003 ± 0.004
	17.1	12	91 ± 3.0	0.003 ± 0.003	0.002 ± 0.003		18.6	9	50 ± 2.0	-0.001 ± 0.001	0.010 ± 0.004
	18.6	16	118 ± 3.8	0.001 ± 0.003	0.001 ± 0.002		20.1	10	44 ± 1.8	-0.001 ± 0.003	0.010 ± 0.004
	20.1	11	115 ± 3.8	-0.001 ± 0.001	0.004 ± 0.003		21.6	12	53 ± 2.0	-0.001 ± 0.001	0.022 ± 0.006
	21.6	14	107 ± 3.6	0.000 ± 0.002	0.000 ± 0.002						
Summary: $\bar{x} \pm 2s$		17 ± 14	92 ± 198	0.001 ± 0.005	0.004 ± 0.009	Summary: $\bar{x} \pm 2s$		7 ± 6	28 ± 39	-0.001 ± 0.003	0.006 ± 0.015
Core Hole 2 (6 m south of channel)						Core Hole 4 (control)					
	1.8	8	7.9 ± 0.8	-0.001 ± 0.000	0.010 ± 0.004		1.8	5	4.5 ± 0.8	-0.002 ± 0.002	-0.002 ± 0.003
	3.4	4	—	0.002 ± 0.002	0.043 ± 0.008		3.4	5	1.6 ± 0.8	0.000 ± 0.003	-0.001 ± 0.003
	4.9	4	11 ± 1.0	-0.002 ± 0.004	0.020 ± 0.006		4.9	5	1.3 ± 0.6	—	—
	6.4	6	16 ± 1.0	-0.001 ± 0.003	0.001 ± 0.003		6.4	3	—	-0.001 ± 0.002	0.004 ± 0.003
	7.9	18	62 ± 2.2	0.001 ± 0.002	0.008 ± 0.004	Summary: $\bar{x} \pm 2s$		4 ± 2	2.5 ± 3.5	-0.001 ± 0.002	0.000 ± 0.006
	9.3	29	291 ± 10	0.000 ± 0.002	0.010 ± 0.004						
	4	29	277 ± 8.0	-0.001 ± 0.002	0.035 ± 0.008	Core Hole 5 (Control)					
	11.0	19	169 ± 6.0	0.002 ± 0.004	0.006 ± 0.004		1.8	3	0.0 ± 0.8	-0.002 ± 0.004	-0.004 ± 0.003
	12.5	25	138 ± 4.0	0.003 ± 0.003	0.010 ± 0.004		3.4	3	1.7 ± 0.4	-0.002 ± 0.002	-0.001 ± 0.002
	14.0	14	541 ± 18	-0.001 ± 0.002	0.005 ± 0.003		4.9	2	—	0.000 ± 0.002	-0.001 ± 0.004
	15.5	12	60 ± 2.2	-0.001 ± 0.002	0.004 ± 0.004		6.4	5	3.8 ± 0.8	-0.001 ± 0.002	-0.003 ± 0.002
	17.1	11	34 ± 1.4	-0.001 ± 0.003	0.000 ± 0.002	Summary: $\bar{x} \pm 2s$		3 ± 2	3.8 ± 4.3	-0.001 ± 0.002	-0.002 ± 0.003
	18.6	11	65 ± 2.4	-0.001 ± 0.002	0.002 ± 0.002						
	20.1	10	80 ± 2.8	-0.001 ± 0.002	0.002 ± 0.003	Core Holes 4 and 5 (Control)					
	21.6	11	139 ± 4.0	-0.001 ± 0.003	0.002 ± 0.002	Summary: $\bar{x} \pm 2s$		4 ± 2	3.0 ± 3.5	-0.001 ± 0.002	-0.001 ± 0.005
Summary: $\bar{x} \pm 2s$		14 ± 17	135 ± 296	0.000 ± 0.003	0.011 ± 0.025						

Notes: 1. One sample taken at each depth.

2. The $\pm$ value is twice the uncertainty for that analysis.

matrix. The tuff beneath the aquifer is weathered; the ash matrix contains some light brown silts and clays. The amount of silt and clays (degree of weathering) decreases at depth and with distance from the aquifer.

Moisture Distribution

The distribution of moisture in the alluvium and tuff is shown in Fig. 19. In core holes 1 and 2 the moisture content approaches 30% by volume from 1 to 3 m above the top of the aquifer. This anomaly above the aquifer is in a silty clay unit within the alluvium. The water table fluctuates twice a year because of seasonal runoff from snowmelt and summer precipitation. At the time the holes were cored, the water table was declining.

The moisture content of the aquifer material ranged from 20 to 25% by volume. There is some infiltration of water into the tuff beneath the aquifer. At core hole 1, the moisture content ranges from about 10 to 27% to a depth of 8 m below the base of the aquifer. At core hole 2, the moisture content is lower, ranging from 10 to 18% to a depth of 8 m below the aquifer. Core hole 3 indicates some horizontal component of movement of moisture from the aquifer only in the low-moisture range, greater than 5% by volume below a depth of 13 m (Fig. 20). Natural moisture content of the tuff is about 5% by volume.

FIGURE 18 (top). Regional surface water, sediment, and soil sampling locations.

FIGURE 19 (left). Distribution of moisture in alluvium and tuff in Mortandad Canyon.

FIGURE 20 (right). Distribution of tritium in alluvium and tuff in Mortandad Canyon.

Tritium Distribution

Water distilled from the cores was analyzed for tritium (^3H). Tritium, a part of the water molecule, moves with the water and is not affected by adsorption or ion exchange with clay minerals. The average ^3H concentration in water in the aquifer (1978 when core was taken) at Well MCO-6 was $303 \times 10^{-6} \mu\text{Ci/mL}$, having declined from a high of $1760 \times 10^{-6} \mu\text{Ci/mL}$ in 1976. The core from hole 1 contained a high of $400 \times 10^{-6} \mu\text{Ci/mL}$ about 1 m below the aquifer and was about $550 \times 10^{-6} \mu\text{Ci/mL}$ at the same depth below the aquifer in core hole 2 (Fig. 20). The ^3H concentrations generally decline with depth below the aquifer. The high concentrations in the tuff below the aquifer probably reflect the movement of tritium beneath the aquifer; in the tuff, possibly from the high concentrations that occurred in 1976. At core hole 2, a high concentration of ^3H ($290 \times 10^{-6} \mu\text{Ci/mL}$) occurred in the silt and clay base alluvium at a depth of about 10 m. This is above the aquifer. The ^3H in core hole 3 increases slightly with depth and is above background (Table XXII). The concentrations are low, less than $50 \times 10^{-6} \mu\text{Ci/mL}$, but the ^3H concentrations reflect the same pattern of the movement of moisture from the aquifer (Figs. 20 and 21).

Plutonium Distribution

Samples of water taken from observation wells were filtered through a $45\text{-}\mu\text{m}$ -pore membrane filter to remove fine sediments. The filtrate and the filter were analyzed for ^{238}Pu and $^{239,240}\text{Pu}$. The data indicated little, if any, plutonium was retained on the filter and most, if not all, of the plutonium was in solution. This is in direct contrast with what occurs in the channel when the effluent is released from the treatment plant. The plutonium in the effluent is readily adsorbed or attached to silt and clays in the alluvium in the channel. Concentrations in solution and on sediments decrease downgradient in the canyon.

Cores taken through the alluvium, aquifer, and into the underlying tuff were analyzed for plutonium to determine if there was any transport or buildup of plutonium in silts and clays beneath the channel in the alluvium, aquifer, or tuff. When the cores were taken in 1978, the alluvium in the channel contained about 2.7 pCi/g of ^{238}Pu and 4.0 pCi/g of $^{239,240}\text{Pu}$. Water in the

FIGURE 21.
Sampling locations in
vicinity of the Los Alamos
Meson Physics Facility's
lagoons.

aquifer contained an average of 2.2×10^{-6} $\mu\text{Ci/mL}$ of ^{238}Pu and 0.28×10^{-6} $\mu\text{Ci/mL}$ of $^{239,240}\text{Pu}$ at Well MCO-6. Results of the analyses of cores indicate no significant concentrations of ^{238}Pu in silts and clay of the alluvium aquifer or underlying tuff (Table XXIII). A comparison of the $^{239,240}\text{Pu}$

TABLE XXIII. Average Plutonium Concentration in Soil Cores from Mortandad Canyon

Location	$\bar{x} + 2s$	
	^{238}Pu (pCi/g)	^{239}Pu (pCi/g)
Core Hole 1	0.001 ± 0.005	0.004 ± 0.009
Core Hole 2	0.0000 ± 0.003	0.011 ± 0.025
Core Hole 3	-0.001 ± 0.003	0.006 ± 0.015
Core Hole 4 (Control)	-0.001 ± 0.002	0.000 ± 0.006
Core Hole 5 (Control)	-0.001 ± 0.002	-0.002 ± 0.003

concentrations are low, being much lower than those found in solution in the aquifer or attached to sediments in the stream channel.

Summary

In summary, a study of the distribution of moisture, tritium, and plutonium in the Mortandad Canyon aquifer indicates some infiltration of water into the underlying tuff. This infiltration was accompanied by similar movement of tritium. The concentrations of plutonium on the sediments in the aquifer were low when compared with the high concentrations in solution in an ionic complex that does not readily exchange or is adsorbed by clay minerals in the alluvium.

References

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TRANSPORT OF RADIONUCLIDES FROM THE LAMPF LAGOONS

Authors: R. W. Ferenbaugh and W. D. Purtymun

Group: Environmental Surveillance, HSE-8

Funding Organization: Los Alamos National Laboratory

Monitoring of the discharge water from the Los Alamos Meson Physics Facility lagoons continued during 1983. Sampling frequency has been reduced to twice a year, in June and December. The list of radionuclides being monitored has been expanded so that it now includes ^7Be , ^{57}Co , ^{134}Cs , ^3H , ^{54}Mn , ^{22}Na , and ^{83}Rb . The sampling locations are shown in Fig. 21 and the data

obtained to date are shown in Table XXIV. Movement of radionuclides around the lagoons has been described in a previous report.¹

Reference

1. Environmental Surveillance Group, "Environmental Surveillance at Los Alamos During 1982," Los Alamos National Laboratory report LA-9762-ENV (April 1983).

TABLE XXIV. Most Recent Available Data from Samples Taken Below Los Alamos Meson Physics (TA-53) Lagoons

Analysis	Units	1983 Sampling Date	Sampling Location*							
		1	2	3	4	5	6	7	8	
Sediment										
⁷ Be	pCi/g	June	1500 ± 150	3100 ± 310	14 000 ± 1400	660 ± 70	1700 ± 170	560 ± 60	11 ± 1.2	-0.10 ± 0.25
⁷ Be	pCi/g	December	1900 ± 190	2700 ± 270	4300 ± 430	1700 ± 170	180 ± 18	40 ± 4	7.5 ± 0.8	0.59 ± 0.06
⁵⁷ Co	pCi/g	June	97 ± 10	460 ± 46	450 ± 46	13 ± 1.3	110 ± 11	96 ± 10	3.7 ± 0.4	0.03 ± 0.02
⁵⁷ Co	pCi/g	December	300 ± 30	550 ± 55	680 ± 68	250 ± 25	120 ± 12	30 ± 3.0	7.9 ± 0.8	0.14 ± 0.01
¹³⁴ Cs	pCi/g	June	330 ± 32	470 ± 48	1220 ± 120	150 ± 15	550 ± 55	180 ± 18	8.0 ± 0.8	0.03 ± 0.03
¹³⁴ Cs	pCi/g	December	340 ± 34	580 ± 58	1100 ± 110	180 ± 18	270 ± 27	67 ± 6.7	5.5 ± 0.6	0.18 ± 0.02
³ H	10 ⁻⁴ µCi/mL	June	4.3 ± 0.4	4.2 ± 0.4	4.3 ± 0.4	4.2 ± 0.4	2.4 ± 0.2	0.88 ± 0.09	0.18 ± 0.02	0.028 ± 0.004
³ H	10 ⁻⁴ µCi/mL	December	11 ± 1.1	10 ± 1.0	11 ± 1.1	9.7 ± 1.0	1.5 ± 0.2	0.035 ± 0.004	0.03 ± 0.004	0.042 ± 0.005
⁵⁴ Mn	pCi/g	June	110 ± 11	240 ± 24	730 ± 73	150 ± 15	340 ± 34	86 ± 8.7	3.3 ± 0.3	0.061 ± 0.028
⁵⁴ Mn	pCi/g	December	190 ± 19	350 ± 35	320 ± 32	82 ± 8.2	91 ± 9.1	32 ± 3.2	6.2 ± 0.6	0.19 ± 0.02
²² Na	pCi/g	June	5.4 ± 0.5	15 ± 1.6	5.5 ± 0.6	3.5 ± 0.4	6.7 ± 0.7	2.7 ± 0.3	0.92 ± 0.10	-0.22 ± 0.03
²² Na	pCi/g	December	4.4 ± 0.4	15 ± 1.5	4.8 ± 0.5	8.1 ± 0.8	7.4 ± 0.7	1.0 ± 0.1	1.1 ± 0.1	0.095 ± 0.010
⁸³ Rb	pCi/g	June	200 ± 20	360 ± 36	230 ± 23	160 ± 16	350 ± 35	80 ± 8.0	2.0 ± 0.2	0.082 ± 0.040
⁸³ Rb	pCi/g	December	43 ± 4.3	100 ± 10	52 ± 5.2	57 ± 5.7	55 ± 5.5	14 ± 1.4	6.3 ± 0.6	0.31 ± 0.03
Water										
⁷ Be	10 ⁻⁶ µCi/mL	June	160 ± 16	1600 ± 160	460 ± 46	Dry	Dry	Dry	Dry	-0.043 ± 0.004
⁷ Be	10 ⁻⁶ µCi/mL	December	510 ± 51	520 ± 52	440 ± 44	420 ± 42	Dry	Dry	Dry	Dry
⁵⁷ Co	10 ⁻⁶ µCi/mL	June	24 ± 2.4	130 ± 13	59 ± 6	Dry	Dry	Dry	Dry	-0.012 ± 0.001
⁵⁷ Co	10 ⁻⁶ µCi/mL	December	15 ± 1.5	15 ± 1.6	14 ± 1.4	11 ± 1.1	Dry	Dry	Dry	Dry
¹³⁴ Cs	10 ⁻⁶ µCi/mL	June	13 ± 1	100 ± 10	120 ± 12	Dry	Dry	Dry	Dry	-0.008 ± 0.001
¹³⁴ Cs	10 ⁻⁶ µCi/mL	December	6.7 ± 0.7	9.5 ± 1.0	5.0 ± 0.5	3.1 ± 0.3	Dry	Dry	Dry	Dry
³ H	10 ⁻⁴ µCi/mL	June	4.3 ± 0.4	4.3 ± 0.4	4.3 ± 0.4	Dry	Dry	Dry	Dry	0.026 ± 0.004
³ H	10 ⁻⁴ µCi/mL	December	11 ± 1.1	11 ± 1.1	11 ± 1.1	11 ± 1.1	Dry	Dry	Dry	Dry
⁵⁴ Mn	10 ⁻⁶ µCi/mL	June	24 ± 2.4	150 ± 15	60 ± 6	Dry	Dry	Dry	Dry	0.045 ± 0.005
⁵⁴ Mn	10 ⁻⁶ µCi/mL	December	2.7 ± 0.3	3.7 ± 0.4	2.6 ± 0.3	2.2 ± 0.2	Dry	Dry	Dry	Dry
²² Na	10 ⁻⁶ µCi/mL	June	7.7 ± 0.8	8.3 ± 0.8	8.9 ± 0.9	Dry	Dry	Dry	Dry	0.001 ± 0.0001
²² Na	10 ⁻⁶ µCi/mL	December	6.5 ± 0.7	5.5 ± 0.6	5.9 ± 0.6	5.6 ± 0.6	Dry	Dry	Dry	Dry
⁸³ Rb	10 ⁻⁶ µCi/mL	June	9.9 ± 1.0	50 ± 5	10 ± 1	Dry	Dry	Dry	Dry	0.010 ± 0.001
⁸³ Rb	10 ⁻⁶ µCi/mL	December	2.0 ± 0.2	1.8 ± 0.2	1.8 ± 0.2	1.5 ± 0.2	Dry	Dry	Dry	Dry

*See Fig. 21 for map of sampling locations. One sample per location.

*The ± value is the uncertainty (10%) of the analytical result.

Authors: W. J. Wenzel, A. F. Gallegos, and J. C. Rodgers*

Groups: Environmental Surveillance, HSE-8; *Life Sciences Division, LS-6

Funding Organization: Los Alamos National Laboratory

The BIOTRAN¹ model was developed at Los Alamos to help predict short- and long-term consequences to man from releases of radionuclides into the environment. It is a dynamic model that simulates on a daily and yearly basis the flux of biomass, water, and radionuclides through terrestrial and aquatic ecosystems. Biomass, water, and radionuclides are driven within the ecosystems by climate variables stochastically generated by BIOTRAN each simulation day. The climate variables influence soil hydraulics, plant growth, evapotranspiration, and particle suspension and deposition. BIOTRAN has 22 different plant growth strategies for simulating various grasses, shrubs, trees, and crops. Ruminants and humans are also dynamically simulated by using the simulated crops and forage as intake for user-specified diets. BIOTRAN has been used at Los Alamos for long-term prediction of health effects to populations following potential accidental releases of uranium² and plutonium.^{3,4}

BIOTRAN has been restructured into manageable structured subroutines. All variables and their units have been defined and code logic charts have been made. Graphical output for each subroutine both during and after an execution has greatly increased the efficiency of using BIOTRAN. The streamlined graphical output allows the user to scan output quickly, instead of reviewing long tables of numbers. This is particularly useful for three-dimensional analysis of radionuclide flow in soils and between lake water layers.

Three new subroutines have recently been developed for BIOTRAN. HUMTRN⁵ is a human dynamic physiological and metabolic model that simulates male and female intake, organ uptake, and radiation doses in age groups. Simulated crops, meat, and daily air radionuclide concentrations from BIOTRAN become intake to humans on a user-specified diet. Daily intake of food and water are adjusted by HUMTRN based on amount of physical activity, growth, age, sex, and food availability from BIOTRAN.

The soil hydrology and irrigation model, WATFLX, was developed based on Hillel's Darcy equation⁶ for movement of water in silt, sand, and clay. Soil is modeled as layers. Each layer is considered a unit contributing to the evapotranspiration losses for the plant in the soil profile. Uptake is simulated to occur as a function of the root biomass in each soil layer simulated.

Limnetic nutrient and radionuclide cycling in multiple fresh-water lake layers is modeled in the AQUAT subroutine as a function of daily solar radiation intensity and plankton kinetics. AQUAT will later be coupled with a shoreline (littoral) model to develop the transition terrestrial/aquatic coupling needed for BIOTRAN.

Several areas of BIOTRAN development are in progress. The Los Alamos health effects model, REPCAL,⁷ is being analyzed for addition to HUMTRN/BIOTRAN. It will allow age- and sex-specific cancer mortality to be simulated dynamically. At present BIOTRAN predicts uranium and plutonium transport and consequences to humans. BIOTRAN is being changed to follow cesium as well as strontium environmental transport. With the addition of these elements, a major addition to BIOTRAN will be required, namely, mineral cycling. Once mineral and nutrient cycling for Ca, K, P, N, and Si is complete, then extensions to more elements and even organic compounds could be rapidly developed as the need arises.

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MEASUREMENT AND MODELING OF GAMMA-ABSORBED DOSES DUE TO ATMOSPHERIC RELEASES FROM LOS ALAMOS MESON PHYSICS FACILITY

Authors: B. M. Bowen, A. I. Chen, W. A. Olsen, and D. M. Van Etten

Group: Environmental Surveillance, HSE-8

Funding Organization: Los Alamos National Laboratory

Introduction

Portable, high-pressure ionization chambers (HPICs) measure short-term gamma radiation levels caused by air activation products from the Los Alamos Meson Physics Facility's (LAMPF)

emissions. The HPICs are situated at the nearest (~ 800 m) off-site location from LAMPF (designated Station 6, East Gate). These measurements are in addition to those made by the thermoluminescent dosimeter network that routinely measures long-term gamma radiation levels. A Gaussian-type atmospheric dispersion model, which accounts for gamma radiation from various radioisotopes in the LAMPF plume, is used to predict gamma-absorbed doses.

Short-term gamma-absorbed doses were measured by one HPIC at an azimuth of 12° from the LAMPF stack during the January 1 through February 8 operating cycle. Two HPICs were in the field during the September 8 through December 31 operating cycle, one north and the other north-northeast of the LAMPF stack, but they did not provide reliable data. Meteorological data were also measured at both East Gate and LAMPF. Airborne emission data were taken at the stack.

Results

The predominant winds are typically south-southwesterly and southwesterly over LAMPF. Figure 22 shows the wind rose for the periods in 1983 when LAMPF was operating. The high frequency of south-southwesterly and southwesterly winds is due in large part to the afternoon Rio Grande Valley upwind. These predominant winds blow toward East Gate.

Daily model predictions, based on the integration of modeled 15-min periods, were made for the first LAMPF operating cycle and were compared with the measured data. Figure 23 shows the comparison of the predicted and measured daily gamma doses due to LAMPF emissions. There is very good correlation between measured and predicted values. During 39-day operating cycles, the model predicted an absorbed dose of 10.3 mrad compared with the 8.8 mrad that was measured, an overprediction of 17%.

FIGURE 23.
Predicted versus measured
daily gamma doses.

Further Study

Three portable HPICs will be used during the next LAMPF operating cycle. The instruments will be placed in the directional sectors of north, north-northwest, and northeast from the LAMPF stack toward East Gate. A TLD will also be placed by each HPIC. It is hoped that the dimensions of the plume can be better defined over short time periods. Also, the short-term model's accuracy and precision can be tested further. Finally, comparisons of HPIC data with TLD data of model predictions will be made.

DELTA COUNT-RATE MONITORING SYSTEM

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Group: Environmental Surveillance, HSE-8

Funding Organization: Los Alamos National Laboratory

Detection of radioactive contaminants in the environment often requires surveying large areas. A need for a more effective way to rapidly search for gamma-ray contamination over large areas led to the design and construction of a very sensitive gamma detection system. This system alerts the user to small changes in the count rate, or delta, which can locate areas of potential radioactive contamination.

Environmental surveys are frequently done in areas with rugged off-road conditions in adverse weather. For this reason, the delta count-rate monitoring system was installed in a four-wheel-drive van instrumented for environmental surveillance and accident response.

The system consists of four main sections: (1) two scintillation detectors, (2) high-voltage power supply amplifier and single-channel analyzer, (3) delta count-rate monitor, and (4) count-rate meter and recorder. The van's 6.5-kW generator powers the standard nuclear instrument modular design system. The two detectors are mounted in the rear corners of the van and can be run singly or jointly. A solid-state bar-graph count-rate meter mounted on the dashboard can be read easily by both the driver and passenger. Mounted just to the right of the driver is a solid-state strip chart recorder, which shows trends and provides a permanent record of the data. An audible alarm is sounded at the delta monitor and at the dashboard count-rate meter if a detected radiation level exceeds the set background level by a predetermined amount.

Reference

1. D. Van Etten and W. Olsen, "Delta-Count Rate-Monitoring System," Los Alamos National Laboratory report LA-9855-M (September 1983).
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SAMPLING AND INSTRUMENTATION REQUIREMENTS FOR LONG-RANGE D&D ACTIVITIES AT INEL

Author: A. J. Ahlquist

Group: Environmental Surveillance, HSE-8

Funding Organization: EG&G

Assistance was requested to help determine sampling and instrumentation requirements for the long-range decontamination and decommissioning activities at the Idaho National Engineering Laboratory. Through a combination of literature review, visits to other DOE contractors, and a

determination of the needs for the INEL program, a draft report has been prepared that is now under review. The final report should be completed in FY 84.

PLUTONIUM CONCENTRATIONS REFLECTING WORLDWIDE FALLOUT

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Group: Environmental Surveillance, HSE-8

Funding Organization: Los Alamos National Laboratory

Special analyses for plutonium were performed on 1-kg soil samples from six regional stations (Fig. 24). This is 100 times the usual mass used for analyses. These larger samples increase the sensitivity of the plutonium analyses, which is necessary to evaluate background plutonium concentrations in fallout from atmospheric nuclear weapons tests. The samples at each station were collected by taking 5 plugs, 75-mm diam and 50 mm deep, at the center and corners of a square area 10 m on a side. The five plugs were combined into one sample for radiochemical analyses. (One set of samples from Santa Cruz Lake consisted of 1-kg plugs at the four corners and center and were taken to determine variability in radionuclide concentrations within a sampling

TABLE XXV. Radiochemical Analyses of Special Regional Soils

Analysis	Units	No. of Samples	1981 ($\bar{x} \pm 2s$)	1983 ($\bar{x} \pm 2s$)
^{137}Cs	(pCi/g)	6	0.68 ± 0.80	0.55 ± 0.68
^{238}Pu	(pCi/g)	6	0.00040 ± 0.00049	0.00054 ± 0.00090
$^{239,240}\text{Pu}$	(pCi/g)	6	0.0091 ± 0.0098	0.00819 ± 0.01105
^{90}Sr	(pCi/g)	6	0.49 ± 0.50	0.32 ± 0.22
Total uranium	($\mu\text{g/g}$)	6	—	2.4 ± 1.2
Gross gamma	(counts/min/g)	6	—	3.0 ± 2.8
$^{239,240}\text{Pu}/^{238}\text{Pu}$	—	6	23	15

FIGURE 24.
Special regional soil sam-
pling locations.

grid.) The 1-kg samples were analyzed for ^{238}Pu and $^{239,240}\text{Pu}$. Analyses for ^{137}Cs , ^{90}Sr , total uranium, and gross gamma were done on standard-size samples.

In Table XXV the analytical results in 1983 from the six stations are compared with similar data from 1981. There is no significant difference in the concentrations of ^{137}Cs , ^{238}Pu , or ^{90}Sr . The average $^{239,240}\text{Pu}/^{238}\text{Pu}$ ratios for both sets of samples are similar at 23 (1981) and 15 (1983).

TRANSPORT OF RADIONUCLIDES IN SNOWMELT RUNOFF, 1983

Authors: W. D. Purtymun, M. N. Maes, and R. J. Peters

Group: Environmental Surveillance, HSE-8

Funding Organization: Los Alamos National Laboratory

The major transport of radionuclides from canyons that have received or are now receiving treated low-level radioactive effluents is by surface runoff (solution and sediments). Radionuclides in the effluents become adsorbed or attached to sediment particles in the stream channels.

Surface runoff, the major transport mechanism, occurs in two modes. Spring snowmelt runoff occurs over a long period of time (days) at a low discharge rate and sediment load. Summer runoff from thunderstorms occurs over a short period of time (hours) at a high discharge rate and sediment load.

Samples of the runoff were collected and analyzed for radionuclides in solution and suspended sediments (Table XXVI). Radioactivity in solution is defined as the filtrate passing through a 0.45- μm -pore-size filter; radioactivity in suspended sediments is defined as the residue on the filter. The solution was analyzed for ^{137}Cs , ^{238}Pu , $^{239,240}\text{Pu}$, ^3H , total uranium, and gross gamma, whereas suspended sediments were analyzed for ^{238}Pu and $^{239,240}\text{Pu}$.

During 1983, snowmelt runoff was monitored at Los Alamos Canyon at State Road 4 (SR-4) and at Otowi near the Rio Grande (Fig. 25). Los Alamos Canyon and tributary Pueblo Canyon have

TABLE XXVI. Average Radiochemical and Chemical Concentrations in Snowmelt Runoff

Measured Element	Units	Los Alamos Canyon		
		SR-4	Otowi	Pajarito Canyon
Radiochemical				
(solution)				
¹³⁷ Cs	10 ⁻⁹ μCi/mL	20 ± 65	16 ± 44	4 ± 60
²³⁸ Pu	10 ⁻⁹ μCi/mL	0.003 ± 0.018	-0.001 ± 0.008	-0.005 ± 0.019
^{239,240} Pu	10 ⁻⁹ μCi/mL	0.014 ± 0.021	0.008 ± 0.008	0.007 ± 0.005
³ H	10 ⁻⁶ μCi/mL	2.4 ± 1.1	2.4 ± 1.0	3.1 ± 1.4
Total uranium	μg/L	0.1 ± 0.7	0.6 ± 1.1	0.3 ± 0.8
Gross gamma	counts/min/L	49 ± 67	33 ± 47	41 ± 56
Radiochemical				
(suspended sediments)				
²³⁸ Pu	pCi/g	0.27 ± 0.40	0.15 ± 0.24	0.20 ± 0.59
^{239,240} Pu	pCi/g	4.7 ± 6.4	2.3 ± 3.0	0.18 ± 0.53
Chemical				
Cl	mg/L	11	13	31
F	mg/L	0.1	0.2	0.1
NO ₃	mg/L	1.5	1.0	0.9
TDS	mg/L	118	131	192
pH	—	7.5	7.8	7.7

received low-level radioactive effluents from treatment plants, so the channel sediments contain radionuclides that are subject to transport surface runoff.

Snowmelt runoff was also monitored in Pajarito Canyon at SR-4, which forms the eastern boundary of the Laboratory. There are no industrial effluents released into Pajarito Canyon. Runoff was also monitored because it drained several of the Laboratory's technical areas, one of which is used for the disposal and storage area for low-level solid radioactive wastes.

The concentrations of ^{137}Cs , ^{238}Pu , $^{239,240}\text{Pu}$, ^3H , total uranium, and gross-gamma activity in solution samples from Los Alamos Canyon at SR-4 and Otowi were indistinguishable from radioactivity concentrations in solution samples from Pajarito Canyon (Table XXVI).

There was no significant difference in concentrations of ^{238}Pu in suspended sediment in Los Alamos Canyon at SR-4 and at Otowi when compared with those ^{238}Pu concentrations in Pajarito Canyon. There was, however, a significant difference in the $^{239,240}\text{Pu}$ concentrations in suspended sediments in Los Alamos Canyon when compared with those concentrations in Pajarito Canyon. The average concentrations of $^{239,240}\text{Pu}$ in suspended sediments in Los Alamos Canyon ranged from 4.7 pCi/g at SR-4 to 2.3 pCi/g at Otowi. These were about 26 and 13 times greater than the average background $^{239,240}\text{Pu}$ concentrations in Pajarito Canyon. The concentrations of $^{239,240}\text{Pu}$ in sediments declined downstream in Los Alamos Canyon as the sediments dispersed and mixed with uncontaminated sediments in the channel.

The average chemical concentrations of the runoff at each of the three stations are also shown in Table XXVI. The chloride and total-dissolved-solids concentrations in runoff in Pajarito Canyon were higher than those in Los Alamos Canyon. This was probably caused by the smaller drainage area of Pajarito Canyon. This resulted in smaller volume of runoff in Pajarito Canyon at SR-4 (about $11 \times 10^4 \text{ m}^3$) compared with that in Los Alamos Canyon at SR-4 ($52 \times 10^4 \text{ m}^3$).

There was little, if any, transport during 1983 of radionuclides in solution surface runoff in Los Alamos Canyon, which has received treated low-level radioactive effluents. There is little, if any, transport of ^{238}Pu in suspended sediments. The major transport of radioactivity in the suspended sediments was of $^{239,240}\text{Pu}$. This was the major isotope of plutonium released by the treatment plants into DP and Pueblo Canyons, which are tributaries to Los Alamos Canyon. The runoff in Los Alamos Canyon carries trace amounts of plutonium to the Rio Grande in silts and clays (suspended sediments).

FIGURE 25.
Locations of surface runoff
sampling stations.

RADIOLOGICAL SOIL SURVEY ADJACENT TO TA-35, TA-48, TA-50,
AND TA-55**Authors:** W. D. Purtymun, N. M. Becker, and M. N. Maes**Group:** Environmental Surveillance, HSE-8**Funding Organization:** Los Alamos National Laboratory

Preoperational radionuclide soil concentrations were established around the Laboratory site TA-55 (Plutonium Processing Facilities) in 1977. Soil samples were collected and analyzed from nine locations around TA-55. A second survey was made in 1983. However, the original sampling locations had been disturbed by construction, so five new locations in undisturbed soil were established in the areas around TA-35, TA-48, TA-50, and TA-55 (Fig. 26). Each of these technical areas has processed or is now processing radioactive materials and can release trace amounts to the atmosphere through filters in the ventilation system. This results in deposition of radionuclides on the soil.

The ^{137}Cs concentrations in soil from the five new locations are at or below the maximum levels (1.4 pCi/g) found in regional soils. The ^{238}Pu and $^{239,240}\text{Pu}$ soil concentrations at Station 2 were greater than were those found in regional soils (Table XXVII, 1977 and 1978-1982 Summaries). Station 2 is located south of TA-50 (Fig. 26). The total uranium soil concentrations exceed regional background concentrations at all stations. However, these levels do not indicate

FIGURE 26.
Soil sampling locations
near TA-35, TA-48, TA-50,
and TA-55.

TABLE XXVII. Radiochemical Resurvey of Technical Areas 35, 48, 50, and 55 (July 6, 1983)

Description	^{137}Cs (pCi/g)	^{238}Pu (pCi/g)	$^{239,240}\text{Pu}$ (pCi/g)	Total U ($\mu\text{g/g}$)	Gross Gamma (counts/min/g)
Station 1	0.34 ± 0.15	-0.002 ± 0.004	0.019 ± 0.004	4.5 ± 1.0	6.6 ± 0.26
Station 2	0.54 ± 0.23	0.011 ± 0.005	0.420 ± 0.040	5.4 ± 1.0	6.4 ± 0.26
Station 3	0.97 ± 0.40	0.001 ± 0.004	0.049 ± 0.012	7.2 ± 1.4	7.4 ± 0.26
Station 4	1.4 ± 0.58	-0.002 ± 0.010	0.058 ± 0.026	8.4 ± 1.6	7.6 ± 0.28
Station 5	0.31 ± 0.14	0.002 ± 0.004	0.050 ± 0.020	4.7 ± 1.0	6.3 ± 0.26
Summary for 1983					
No. of Analyses	5	5	5	5	5
Minimum	0.31 ± 0.14	-0.002 ± 0.004	0.019 ± 0.004	4.5 ± 1.0	6.3 ± 0.26
Maximum	1.4 ± 0.58	0.011 ± 0.006	0.420 ± 0.040	8.0 ± 1.6	7.6 ± 0.26
$\bar{x} \pm 2s$	0.71 ± 0.93	0.002 ± 0.011	0.12 ± 0.34	6.1 ± 3.4	6.9 ± 1.2
Summary for 1977					
No. of Analyses	9	9	9	9	9
$\bar{x} \pm 2s$	0.31 ± 0.50	0.003 ± 0.004	0.030 ± 0.060	5.1 ± 3.4	6.6 ± 0.76
Regional Background					
Average Minimum for 1978-1982 ($\bar{x} \pm 2s$)	0.59 ± 0.83	0.001 ± 0.005	0.020 ± 0.061	2.6 ± 1.3	—

contamination but reflect natural uranium leached from soil derived from the tuff. These concentrations are similar to the data collected in 1977 (Table XXVII). Uranium concentrations in soils vary and depend on the rock type that has weathered to form the soil. A comparison of the averages and standard deviations of radiochemical analyses collected in 1977 and 1983 indicates only slight variations between the 2 yr.

The five new stations established in 1983 will provide long-term monitoring of the possible airborne deposition of contaminants in the areas around TA-35, TA-48, TA-50, and TA-55. Comparing 1977 with 1983 data indicates no significant increase in radioactivity of the soil adjacent to these technical areas.

CULTURAL RESOURCES SITES

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Funding Organization: Los Alamos National Laboratory

For national security reasons, the Laboratory is expanding into an area currently occupied by two cultural resource sites, the historic Romero homesteading complex (Laboratory of Anthropology Site No. 16806) and a prehistoric Indian lithic scatter (Site No. 22766). A major archeological salvage and research effort is planned for these sites. The Romero Cabin, of unusual historical significance, will be relocated. The cabin dates from the homesteading period on the Pajarito Plateau, early in the twentieth century.

A permanent site for the Romero Cabin should optimally provide easy access and ongoing historical interpretation to the public. The Laboratory is doubtful whether these considerations can be met by resiting the cabin on Laboratory land. Consequently, the Department of Energy has offered the cabin to the Los Alamos Historical Society. The Society is responsible for managing the Los Alamos County Historical Museum and is well qualified to provide both continuing upkeep and public interpretative services. It has accepted the cabin offer.

Field work for the project is expected to extend over several months. One or more Laboratory reports will publicize the information gained. Laboratory Consulting Archeologist David Snow is overseeing technical aspects of the mitigation under the overall direction of personnel in HSE-8, Environmental Surveillance. Snow has prepared a mitigation plan that assesses the significance of the sites and outlines the Laboratory's mitigation procedures. A historical preservationist will direct actual cabin removal, which will probably involve disassembling and reassembling the structure.

QUALITY ASSURANCE TESTING OF HIGH-EFFICIENCY PARTICULATE AIR (HEPA) FILTERS

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Technical Assistance: L. D. Wheat

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Funding Organization: DOE, Airborne Waste Management Program Office

Quality assurance (QA) penetration testing of size 5 (1000-cfm) high-efficiency particulate air (HEPA) filters at the Department of Energy (DOE) filter test facilities (FTFs) is primarily based on MIL-STD-282, which requires using a thermally generated monodispersed di-2(ethylhexyl)-phthalate (DEHP) aerosol with a particle size of 0.3- μ m-diam. Since the adoption of MIL-STD-282, there have been many advances in aerosol technology that could improve test reproducibility, accuracy, and ease of operation. In addition, the continued use of DEHP has been questioned because of findings by the National Toxicology Program (NTP) regarding the potential carcinogenicity of this material. For these reasons, an evaluation of alternative QA filter penetration test methods, aerosol generation techniques, aerosol-monitoring instrumentation, and aerosol materials was undertaken.

A penetration test using a polydisperse aerosol appeared to have some promise as an alternative to the presently used monodisperse aerosol test. Such a test could measure filter penetration for 0.3- μ m particles (the current standard), maximum penetration independent of challenge aerosol size, and penetration integrated over a given particle size range and representative of the mass or radioactivity passing the filter. This approach would also simplify the equipment and procedures used for aerosol generation.

Evaluation of a multiple Laskin nozzle aerosol generation system indicated that it could provide an aerosol with a mass concentration of ~ 5 mg/m³, a count median diameter of ~ 0.18 μ m, and a geometric standard deviation of ~ 1.4 . This represented a full-scale demonstration that the multiple Laskin nozzle aerosol generation system could be used to test size 5 HEPA filters.

An evaluation of aerosol-monitoring instruments for use in QA filter penetration measurements was also initiated in 1983. The instruments selected for evaluation were a laser aerosol spectrometer (LAS); a differential electric mobility analyzer, which incorporates an electrostatic aerosol classifier (EC) to segregate aerosols by size; and either a LAS, a condensation nuclei counter (CNC), or an aerosol electrometer to measure EC output concentration. A series of experiments evaluated the response of each instrument over the range of aerosol sizes and concentrations encountered in QA filter penetration testing.

A comparison of number concentration measurements of a polydisperse aerosol by a LAS and a CNC is shown in Fig. 27. In most cases, the LAS measurement was somewhat lower (approximately 10%) than that of the CNC and independent of aerosol concentration. These results showed sufficient agreement between the two instruments to warrant performing a more definitive comparison (during 1984) by using nearly monodisperse aerosols. Preliminary size measurement comparisons between the LAS and EC sizing for aerosol sizes between LAS and EC were also completed in 1983. These indicated a discrepancy between LAS and EC sizing for aerosol sizes between 0.1 μ m and 0.25 μ m. More comprehensive size comparisons will be undertaken to further define this apparent discrepancy and to assess its importance in QA testing of HEPA filters. Preliminary filter penetration measurements using the LAS showed maximum penetration occurring in the vicinity of 0.2 μ m.

A collaborative field experiment was performed at the Rocky Flats FTF with investigators from the Inhalation Toxicology Research Institute to independently compare the aerosol size distributions in a HEPA filter test system by using the LAS and an electrical aerosol analyzer. The data indicate that (1) there is good agreement between the aerosol size measurements of the two instruments, and (2) the size distribution measured had a count median diameter of $\sim 0.17 \mu\text{m}$ with a geometric diameter of ~ 1.4 , which is smaller than the diameter of $0.3 \mu\text{m}$ indicated by the Owl. This is consistent with results obtained at other FTFs in 1982.

Potential alternative aerosol materials were evaluated with respect to published toxicological and physical criteria. Oleic acid was the only material to satisfy all of the criteria regarding toxicological safety. Other materials appeared to be safe, but definitive data documenting this safety were lacking in many instances because of the lack of interest in testing materials that are probably not hazardous.

This program also supports aerosol activities at the three FTFs. During 1983, technical advice was provided to the DOE Writing Group for drafting a set of nuclear standards governing operation of the HEPA filter QA programs at the FTFs. In addition, a program was initiated to proof-test use of a LAS for aerosol sizing at the FTFs. A long-term study was initiated to determine if the LAS could replace the Owl under typical FTF operating conditions. Initially, a 6-month pilot study was conducted at the Hanford FTF. This study shows that the FTF aerosol had an average geometric mean diameter of $0.173 \pm 0.006 \mu\text{m}$ with an average geometric standard deviation of 1.36 ± 0.01 . This is consistent with previous data obtained at the FTFs. In addition, the study indicated that use of the LAS was practical. A 1-yr study of this nature involving all three FTFs is now in progress and will be complete in 1984.

FIGURE 27.
Results of a preliminary comparison between the LAS and CNC number concentration measurements of a polydisperse aerosol. These results show sufficient agreement between the two instruments to warrant performing a more definitive comparison using nearly monodisperse aerosols.

IMPROVED METHODS OF ROUTINELY MEASURING PENETRATION OF HIGH-EFFICIENCY (HEPA) FILTERS BY AEROSOLS

WASTE
MANAGEMENT

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Group: Industrial Hygiene, HSE-5

Funding Organization: US Army, Chemical Research and Development Center (CRDC)

High-efficiency particulate air (HEPA) filters routinely undergo extensive quality assurance (QA) testing using a di-2(ethylhexyl) phthalate (DEHP) aerosol formed by condensation of vapors generated by continuous heating of bulk material. Penetration of the aerosol through the filter is measured with a light-scattering photometer, and aerosol particle size is determined by using an Owl, which analyzes the polarization ratio of light scattered at 90° to the illuminating beam.

After a National Toxicology Program Technical Report of the National Cancer Institute designated DEHP as a potential carcinogen, glycols, glycol esters, and oleic acid were identified as potential replacement aerosol materials. It was also recognized that penetration testing methods might be improved using alternative generation techniques and modern aerosol sizing and measurement instruments. Under the sponsorship of the US Army Chemical Research and Development Center, A. D. Little, Inc. (ADL), developed a new respirator filter penetration test system that attempted to avoid some of the disadvantages of current systems by (1) nebulizing the bulk liquid and then passing the aerosol through a furnace tube to produce vapor for subsequent condensation to minimize the exposure of the material to high temperature and (2) sizing the aerosol in a device that determines the polarization ratio at two scattering angles rather than just one.

The Los Alamos program was designed to evaluate alternative materials, devices, and procedures that could improve laboratory tests of HEPA filter performance and could lead to a new generation of QA test equipment. The ADL device was initially used as the test system to evaluate alternative materials.

Evaluation of Alternative Test Materials

Experimental studies were performed to determine whether chemical decomposition of selected alternative materials was detectable at a temperature needed to form a condensation aerosol in the ADL generator. The three alternative materials chosen for evaluation were pentaethylene glycol (PTAEG), tetraethylene glycol dipropionate (TEGDP), and oleic acid (OLEI). The ADL tube furnace was operated at a series of different temperatures and the aerosol size distribution was measured with a single-particle laser spectrometer (LAS-X). Chemical composition was determined using gas chromatography/mass spectrometry techniques. This procedure defines the temperature range that produces a relatively monodisperse condensation aerosol and identifies the onset of chemical decomposition.

The principal results for the four materials are shown in Figs. 28–31. Each figure shows the GC/MS chromatograms on the left and the corresponding LAS-X-defined size distributions on the right for each of several furnace temperatures. The appropriate temperature range for each material can then be identified. In general, the following trends were seen: (1) increasing numbers and quantities of decomposition products were seen at higher temperatures; (2) the particle sizes were relatively small and broadly distributed at the lowest temperatures; (3) at higher temperatures the size distribution was larger and more monodisperse, indicative of a vaporization condensation process; and (4) at still higher temperatures, the size distribution became broader again, perhaps because of nonuniformity in the cooling/condensation stage or because of some effect from the formation of decomposition products.

For DEHP, the best condensation aerosol (Fig. 28) appeared to form near a furnace temperature of 170°C where there is little evidence of decomposition in the aerosol phase. For PTAEG (Fig. 29), two sets of size distributions obtained several weeks apart are shown together with one set of GC/MS samples. The differences in the two sets of size distributions indicate the variability in

FIGURE 28 (this page).
DEHP temperature series
results (130 to 210°C):
GC/MS chromatograms are
shown on the left (x-axis is
retention time in minutes;
y-axis is proportional to
total ion current). Cor-
responding size distribu-
tions are shown on the
right at the indicated
furnace temperature.

FIGURE 29 (opposite).
PTAEG temperature series
results (50 to 130°C): GC/MS
chromatograms are shown
on the left (x-axis is reten-
tion time in minutes; y-axis
is proportional to total ion
current). Corresponding
size distributions are
shown on the right at the
indicated furnace tempera-
ture.

FIGURE 30.
TEGDP temperature series
results (50 to 150°C): GC/MS
chromatograms are shown
on the left (x-axis is reten-
tion time in minutes; y-axis
is proportional to total ion
current). Corresponding
size distributions are
shown on the right at the
indicated furnace tempera-
ture.

FIGURE 31.
OLEI temperature series results (90 to 190°C): GC/MS chromatograms are shown on the left (x-axis is retention time in minutes; y-axis is proportional to total ion current). Corresponding size distributions are shown on the right at the indicated furnace temperature.

the experimental series. Suitable temperatures were near 90°C. Almost no evidence of decomposition products was seen. For TEGDP (Fig. 30), furnace temperatures from 90 to 111°C seemed to yield a relatively monodisperse condensation aerosol. There were a number of small peaks in the GC/MS chromatogram of the aerosol material collected at 70°C that did not appear at 90, 110, or 130°C. For OLEI (Fig. 31), the optimum furnace temperature appeared to lie near 110°C. Almost no decomposition products were seen in the aerosol phase at any temperature up to 190°C.

These tests indicated that (1) all four materials (DEHP, PTAEG, TEGDP, and OLEI) exhibited a temperature range in which an aerosol with a narrow size distribution appeared to form by condensation in this generator; (2) only TEGDP showed traces of decomposition products in the aerosol phase at a temperature lower than that needed for producing a narrow condensation aerosol; and (3) it is possible that the test materials may decompose in the aerosol phase sampled. The absence of decomposition products would simplify the evaluation of health hazards associated with potential exposures to these aerosols.

Evaluation of A. D. Little Sizer

The ADL particle sizer determines the median size and distribution of the aerosol by measuring the polarization ratio of light scattered at two angles, namely, 82° and 116°. Based on Mie calculations, the range of applicability of the device is claimed only for size distributions having geometric mean diameters between 0.27 and 0.33 μm and geometric standard deviations less than about 1.2.

Evaluation of this size analyzer involved generating a well-defined and nearly monodisperse aerosol within the stated range of applicability of the ADL sizer using the TSI, Inc., Model 3071 Electrostatic Classifier (EC). The response of the ADL sizer was then compared with the size indicated by the EC. This approach was not successful because of leaks in the sizer chamber, deposition of aerosol on the ADL sizer optical windows, and relatively low aerosol concentration produced by the EC. A secondary approach was to note the sizer's response to known polydisperse aerosols and compare them with predictions of the sizer's response based on Mie calculations. This work is still in progress.

GEOLOGICAL INVESTIGATIONS AT TA-54 (WASTE DISPOSAL AREA G)

Authors: W. D. Purtymun, N. M. Becker, and M. N. Maes

Group: Environmental Safety, HSE-8

Funding Organization: Los Alamos National Laboratory

Introduction

Technical Area 54 (TA-54), Area G, is used for disposal of solid low-level radioactive wastes. Area G is located on a mesa named Mesita del Buey. Mesita del Buey trends southeast and is about 3.2 km long and 0.4 km wide. The surface slopes from an elevation of about 2100 m near its western end to about 2010 m at the eastern end of Area G. It is bounded on the north and south by canyons cut 15 to 30 m below the mesa surface, and several small side drainages serrate the edge of the mesa.

The surface and underlying rocks of Mesita del Buey are ash flows and ash flows of rhyolite tuff that are underlain by volcanic basalts and interbedded with sediments. The tuff is about 75 m thick. There is no known perched water at Area G between the surface of the mesa and the main aquifer of the Los Alamos area. The main aquifer (capable of municipal and industrial water supply) lies at a

depth of 250 m below the surface of Mesita del Buey. Movement of water in the aquifer is to the east and southeast where a part is discharged into the Rio Grande.¹

In 1956, Area G was designated for the disposal of solid radioactive waste (Fig. 32). The wastes range from potentially contaminated rubber gloves and glassware to parts of obsolete buildings and equipment that cannot be decontaminated. They are buried in pits ranging in size from 9 to 30 m wide, 45 to 180 m long, and 4 to 10 m deep. The waste is placed in layers 1 to 2 m deep and each layer is covered with approximately 0.5 m of crushed tuff. The pits are filled to within 1 m of the land surface and covered with 1.5 to 2 m of crushed tuff. This final cover is slightly mounded above the original grade to encourage surface runoff. Some wastes are placed in vertical shafts, which range from 0.6 to 1.8 m in diameter and up to 20 m deep. Wastes in the shafts are layered with crushed tuff, the same practice used for the pits; the final cover is about 1 m thick.

Guidelines for the construction of pits were issued by the US Geological Survey in 1965.² These were revised and reissued in 1980 by the Waste Management Group (HSE-7) and Environmental Surveillance Group (HSE-8) of the Los Alamos National Laboratory.³ The pits are inspected and photographs taken to determine if they comply with the guidelines.

Construction of Pit 26

Pit 26 was constructed in Area G during 1983 using heavy earthmoving equipment. It is about 95 m long and 15 m wide, with a maximum depth of 10 m. The floor of the pit is ramped at the long dimension to allow construction and vehicle access during disposal operations. The total volume of tuff excavated was 17,000 cm³. The long dimension of the pit is northeast-southwest. The "spill point" or lowest area is the southwest corner of the pit.

Pit 26 is dug into Unit 2b of the Tshirege Member of the Bandelier Tuff.⁴ The unit in the pit consists of two ash flows. Contact between the two flows occurs about 6 m below land surface. The contact is shown by an increase in the amount and size of dark gray devitrified pumice fragments in the top of the ash flow. The contact is nearly horizontal, though in places becomes indistinct. The tuff in both flows is a gray moderately welded tuff, consisting of quartz and sanidine crystals and crystal fragments with a few rock fragments of rhyolite, latite, and pumice in a gray ash matrix.

The tuff in the walls of the pit is broken by joints that formed as the ash flows cooled. Most of the major joints are vertical or nearly vertical. They range from closed to open. Beneath the thin soil zone (less than 0.5 m thick), the joints are filled with clay. At depth the joints may also be

FIGURE 32.
Surface-water gaging station in Area G (TA-54) and sediment sampling stations adjacent to Area G.

weathered with a thin layer of clay. The new joint faces exposed in the pit walls are the result of excavation of the pit. The frequency of the joints is about one master joint for every 2 to 3 m of wall or the pit. This frequency is normal at Area G. The floor of the pit is covered with a layer of crushed tuff. The joint openings in the walls or joint systems in the floor (filled with tuff) are small and do not require remedial action.

The inspection and documentation in November 1983 of Pit 26 indicate that the pit is in compliance with the guidelines and is suitable for disposal of wastes.

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NUCLEAR WASTE POLICY ACT (NWPA) AND HANFORD HIGH-LEVEL WASTE EIS DRAFT REVIEWS

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Groups: Environmental Surveillance, HSE-8; *Life Sciences Division, LS-6

Funding Organization: DOE, Office of Environmental Compliance (OEC)

Nine Environmental Assessments (EAs) have been written by DOE for the NWPA deep geologic repository for disposal of commercial nuclear waste and spent fuel. The Los Alamos reviewers have focused on four drafts of the Nevada and Hanford sites' NWPA EAs. The reviews concentrated on geological, hydrological transportation, and performance assessment aspects.

For the Hanford high-level waste EIS, a preliminary analysis of the Tank Farms inventory in relation to possible disposal options was made and reported to the OEC.

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December 31, 1983

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