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SAFETY AND ENVIRONMENTAL PROTECTION DIVISION
PROGRESS REPORT FOR THE PERIOD

JANUARY 1, 1976 - DECEMBER 31, 1978

BROOKHAVEN NATIONAL LABORATORY
ASSOCIATED UNIVERSITIES, INC.

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Introduction

The basic service responsibilities of the Safety and Environmental Protection Division (S&EP) are supported by a research program in the areas of radiological and chemical physics, radiobiology (theoretical and experimental), applied health physics, risk assessment, industrial hygiene, and environmental mutagen studies. This combination of service and research has provided a balance that enhances both sides of the Division's work effort.

Within the past year responsibility for operation of the Radiological Research Accelerator Facility (RARAF) which is dedicated to research in radiobiology and dosimetry, was transferred to the Division.

The S&EP Division also conducts an extensive course in post-graduate health physics training as well as training in a wide variety of industrial health and safety areas.

A recent organizational chart for the Division is shown on the following page.

* Multiple responsibilities

** Part-time

September 1978

Total S&EP Employees: 152

Safety & Environmental Protection Representatives

<u>Accelerator</u>	R. Casey/G. Wall
<u>Admin Systems Data Processing</u>	P. Becker
<u>Applied Math</u>	P. Becker
<u>Biology</u>	C. Flood/ N. Carter
<u>Central Shops</u>	P. Becker
<u>Chemistry</u>	C. Flood/R. Zantopp
<u>Director's Office</u>	P. Becker
<u>Energy & Environment</u>	O. White/A. Lukas
<u>Fiscal</u>	P. Becker
<u>Instrumentation</u>	O. White/A. Lukas
<u>Light Source</u>	C. Flood/R. Zantopp
<u>Medical</u>	C. Flood/N. Carter
<u>Nuclear Energy</u>	O. White/A. Lukas
<u>Personnel</u>	P. Becker
<u>Photo/Graphic Arts</u>	P. Becker
<u>Physics</u>	C. Flood/R. Zantopp
<u>Plant Engineering</u>	P. Becker
<u>Purchasing</u>	P. Becker
<u>Reactor</u>	O. White/A. Humm
<u>S&EP</u>	O. White/A. Humm
<u>Supply & Materiel</u>	P. Becker
<u>Staff Services</u>	P. Becker
<u>Technical Information</u>	P. Becker
<u>Laboratory Emergency Supervisor:</u>	R. Young
<u>Cryogenic Safety Engineering:</u>	R. Casey
<u>Electrical Safety:</u>	G. Wall
<u>Emergency Plan. Coordinator:</u>	B. Brennan
<u>Hazardous Transportation Coord.</u>	S. Pearsall
<u>Material Handling Safety:</u>	D. DeAngelis
<u>Nonionizing Radiation Safety:</u>	G. Wall
<u>Affirmative Action Rep:</u>	C. Flood
<u>Deputy Affirm. Action Reps:</u>	P. Cahill/R. Mosley

RESEARCH SPECIALITIES

Environmental Studies

J. Ash
L. Emma
N. Greenhouse
F. Haughey
A. Hull
P. Kale
E. Lessard
J. Naidu
J. Steimers
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Dosimetry and Radiological Physics

J. Baum
C. Distenfeld
A. Kuehner
E. Levin
G. Levine
S. Marino
L. Phillips
N. Rohrig
J. Shonka
M. Varma

Emergency Monitoring Studies

C. Distenfeld
N. Greenhouse
G. Levine

Hazardous Waste Management Studies

L. Emma
A. Hull

Occupational Safety and Health Protection Studies

J. Deitz
M. P. O'Brien
H. Schulman
O. White

Health Risk and Environmental Assessment

J. Baum
L. Emma
F. Haughey
A. Hull
O. White

Mutagenic Effects

J. Baum
P. Kale

Environmental Protection

Andrew P. Hull

Historically, the principal concern of the environmental monitoring program has been the determination of the levels and concentrations of radioactivity. Recently, an increasing emphasis has been devoted to the assessment of other agents, particularly in the Laboratory's liquid effluents and in the receiving surface waters or ground water.

During the past two years, gross beta activity in liquid effluents has averaged 0.5% of the radiation concentrations guide and tritium 0.2% of the guide. All measured parameters have been within the conditions of the Laboratory's Discharge Permit (under the National Pollution Discharge Elimination System, effective 1/31/75) with the exception of infrequent pH levels slightly below the stipulated 5.8 minimum. Trace metals have been found to be within New York State Standards for surface or ground waters, with the exception of Fe and Zn, which exceed the standards in ground water in the immediate vicinity of the landfill utilized for on-site disposal of conventional solid wastes. Soil characteristics mitigate the spread of these elements and any radionuclides to off-site regions through the ground water system.

In addition to the on-site efforts, the Environmental Monitoring Group is involved in an assessment of the residual levels of atomic weapons testing produced environmental radioactivity on the Marshall Islands in the Pacific.

1977 Environmental Monitoring Report*

J. R. Naidu, A. R. Moorthy, J. E. Steimers, and A. P. Hull

The environmental levels of radioactivity and other pollutants found in the vicinity of Brookhaven National Laboratory (BNL) during 1977 are summarized in this report. As an aid in the interpretation of the data, the amounts of radioactivity and other pollutants released in airborne and liquid effluents from Laboratory facilities to the environment are also indicated. The environmental data includes external radiation levels; radioactive air particulates; tritium and iodine concentrations; the amounts and concentrations of radioactivity in and the quality of the stream into which liquid effluents are released; the concentrations of radioactivity in sediments and biota from the stream; the concentrations of radioactivity in and the quality of ground waters underlying the Laboratory; and concentrations of radioactivity in milk samples obtained in the vicinity of the Laboratory.

The external radiation dose for 1977 at the north boundary of the Laboratory attributable to an ecology forest irradiation source was 5.2 mrem a^{-1} ($5.1 \times 10^{-5} \text{ Sv a}^{-1}$) or 1% of the applicable Radiation Protection Standard.

At the boundary of the Laboratory, about 1.0 km northwest of the Alternating Gradient Synchrotron (AGS), the calculated dose due to skyshine (reflected radiation) was about 1.61 mrem a^{-1} ($1.61 \times 10^{-5} \text{ Sv a}^{-1}$), or 0.31% of the Standard. This was too small to be measured. Due to their limited range, the external radiation from the AGS and those from the gamma forest source did not produce a measurable additive effect at off-site locations.

Other than tritium, there was not indication of BNL radioactive effluents in environmental air and precipitation samples. The largest concentration of

*Summary of BNL Report 50813

tritium in air at the site boundary, 65 pCi m^{-3} ($6.5 \times 10^{-12} \text{ } \mu\text{Ci ml}^{-1}$ or $2.4 \times 10^{-5} \text{ Bq ml}^{-1}$) was 0.03% of the Radiation Concentration Guide (RCG). The largest average concentration of tritium in precipitation, $<203 \text{ pCi l}^{-1}$ ($2.03 \times 10^{-7} \text{ } \mu\text{Ci ml}^{-1}$ or $7.5 \times 10^{-3} \text{ Bq ml}^{-1}$) was 0.01% of the RCG for drinking water.

At the Central Steam Plant, the most (1977) measurement of the stack emission of air particulates indicated that the average rate was $0.078 \text{ lb/10}^6 \text{ Btu}$. A calculation based on meteorological parameters indicates that at the site boundary, the concentration of air particulates was $0.35 \text{ } \mu\text{g m}^{-3}$, 0.48% of the yearly average ambient Air Quality Standard. The calculated site boundary concentrations of SO_2 and NO_x emitted from the plant were 0.0015 and 0.0009 ppm, respectively, which were 4.7 and 1.6% of their respective ambient air quality standards.

About 86% of the sewage effluent released onto the sand filter beds of the Laboratory sewage treatment plant flowed directly into the Peconic River. The balance was assumed to have percolated into the ground water underlying the beds. The gross beta concentration of the bed output was 25.26 pCi l^{-1} ($2.51 \times 10^{-8} \text{ } \mu\text{Ci ml}^{-1}$ or $9.34 \times 10^{-4} \text{ Bq ml}^{-1}$), or 0.9% of the RCG. The tritium concentration was 11.6 nCi l^{-1} ($11.6 \times 10^{-6} \text{ } \mu\text{Ci ml}^{-1}$ or $4.3 \times 10^{-1} \text{ Bq ml}^{-1}$), or 0.6% of the RCG.

About 50% of the combined flow from the sand filter beds and from upstream of the Peconic River permeated into the groundwater. This percolation has occurred between the sewage treatment plant outfall and the Laboratory perimeter and seemed to take place mostly during the latter half of the year. As established at a midway stream sampling location, the gross beta concentration was 26.9 pCi l^{-1} ($2.69 \times 10^{-8} \text{ } \mu\text{Ci ml}^{-1}$ or $10 \times 10^{-4} \text{ Bq ml}^{-1}$), or 1% of the RCG, and the tritium concentration was 12.2 nCi l^{-1} ($12.2 \times 10^{-6} \text{ } \mu\text{Ci ml}^{-1}$), or 0.4% of the RCG. At the site boundary the gross beta concentration was 29.7 pCi l^{-1} ($2.97 \times 10^{-8} \text{ } \mu\text{Ci ml}^{-1}$ or $1.1 \times 10^{-3} \text{ Bq ml}^{-1}$), or 1% of the RCG, and the

tritium concentration was 9.3 nCi l^{-1} ($9.3 \times 10^{-6} \text{ } \mu\text{Ci ml}^{-1}$ or $3.4 \times 10^{-1} \text{ Bq ml}^{-1}$), or 0.3% of the RCG.

About 2% of the total flow from the clarifier at the BNL sewage treatment plant was utilized by the Meadow-Marsh Project. The average gross beta concentration was 59.3 pCi l^{-1} ($5.93 \times 10^{-8} \text{ } \mu\text{Ci ml}^{-1}$ or $2.2 \times 10^{-3} \text{ Bq ml}^{-1}$), or 1.5% of the RCG, and its tritium concentration 5.5 nCi l^{-1} ($5.5 \times 10^{-6} \text{ } \mu\text{Ci ml}^{-1}$ or $2.0 \times 10^{-1} \text{ Bq ml}^{-1}$), or 0.1% of the RCG.

The sewage utilized by the Meadow-Marsh Project contained Cd in a concentration of 100 ppm or 1000 times the water quality standard Cu in a concentration of 1.9 ppm, which is about five times the standard, Fe in a concentration of 10.7 ppm, which is eighteen times the standard, and Zn in a concentration of 3.5 ppm, which is fifty-one times the applicable water quality standard. However, there is no direct runoff of these effluents and the project is designed to assess the retention of agents commonly present in sewage by various plant systems.

Except for 85 daily pH and 2% BOD₅ removal levels were "out of limit," all reportable parameters of the Laboratory sewage effluent were within the limits set forth in the Laboratory's permit, issued by EPA under the National Pollution Discharge Elimination System. The average water quality of the sewage treatment plant effluent at the point of discharge was at or within water quality standards for the receiving body of water.

Bimonthly sampling of the Peconic River water has indicated a decrease of concentrations of radioactivity as one proceeds downstream of the sewage treatment plant outfall. At a location 4.8 km downstream, the average gross beta concentration as established by bimonthly "grab" sampling was 6.9 pCi l^{-1} ($6.9 \times 10^{-9} \text{ } \mu\text{Ci ml}^{-1}$ or $2.6 \times 10^{-4} \text{ Bq ml}^{-1}$), or 0.20% of the RCG and the tritium

concentration less than 1.9 pCi l^{-1} ($1.9 \times 10^{-6} \text{ } \mu\text{Ci ml}^{-1}$ or $7.0 \times 10^{-2} \text{ Bq ml}^{-1}$), or 0.04% of the RCG. About 24 km downstream, at the river's mouth, there the flow was about 25 times that at the Laboratory's site boundary, the average concentration of gross beta activity was 8.1 pCi l^{-1} ($8.1 \times 10^{-9} \text{ } \mu\text{Ci ml}^{-1}$ or $3.0 \times 10^{-1} \text{ Bq ml}^{-1}$) and that of tritium was 0.9 nCi l^{-1} ($9 \times 10^{-7} \text{ } \mu\text{Ci ml}^{-1}$ or $3.3 \times 10^{-2} \text{ Bq ml}^{-1}$). Thus, it was apparent that the total gross beta activity in the river at that location greatly exceeded that at the Laboratory's site boundary. This difference is attributed to the fact that the total flow at the river's mouth is increased due to tributary additions which in turn have added fallout radionuclides that were present in the drainage area of the tributaries.

Seasonal sampling of Peconic River bottom sediments, stream vegetation and of miscellaneous aquatic fauna was conducted. The data indicated that concentration of ^{51}Cr , ^{60}Co and ^{65}Zn , which can be attributed to the Laboratory's effluents, as well as ^{22}Na , ^{137}Cs and ^{144}Ce , which represent fallout contributions were below the Minimum Detection Limits (MDL) of the system used and as such were not reported. The data from a few fish obtained from the river at the former site boundary, suggested the presence of small amounts of the Laboratory's effluent activity. The concentration of ^{137}Cs range from 1900 to 8500 pCi kg^{-1} (7×10^1 to $3 \times 10^2 \text{ Bq kg}^{-1}$). This concentration was 0.2 to 0.9% of the RCG based on an assumed ingestion of 50 g d^{-1} .

About 19 million liters of water per day were used for "once through" cooling and returned to groundwater in on-site recharge basins. The concentration of gross beta activity was about four times greater than that of the supply wells and was less than 0.1% of the RCG. Tritium concentrations were less than the MDL which is about 0.2% of the RCG.

Groundwater surveillance was conducted in a network of some 87 sampling wells installed adjacent to and downstream from identified areas where there is

a potential for the percolation to and migration of radioactivity and other contaminants in groundwater. Immediately adjacent to the sand filter beds and to the Peconic River on-site and at the site boundary, gross beta, tritium and ^{90}Sr concentrations approached those observed during the current or recent years in the Laboratory's liquid effluent. These were up to a few percent of the RCG's. The largest gross alpha concentration, 3.3 pCi l^{-1} ($3.3 \times 10^{-9} \text{ } \mu\text{Ci ml}^{-1}$) was 1.5% of the RCG for unidentified mixtures containing alpha activity other than ^{226}Ra . It was not directly relatable to any known Laboratory effluent releases. The largest average gross beta concentration, 30.2 pCi l^{-1} ($3.02 \times 10^{-8} \text{ } \mu\text{Ci ml}^{-1}$ or $1.1 \times 10^{-3} \text{ Bq ml}^{-1}$) was accompanied by a ^{90}Sr concentration of 0.2 pCi l^{-1} ($0.2 \times 10^{-9} \text{ } \mu\text{Ci ml}^{-1}$ or $7.4 \times 10^{-6} \text{ Bq ml l}^{-1}$), which was 0.3% of the controlling RCG. The largest average tritium concentration, $15.3 \times 10^{-6} \text{ } \mu\text{Ci ml}^{-1}$ or $5.7 \times 10^{-1} \text{ Bq ml}^{-1}$) was 0.5% of the RCG.

Concentrations of gross alpha and gross beta and ^{90}Sr radioactivity were found to be slightly higher in a sampling well about 305 m east of the site boundary, then those at the boundary itself. The gross alpha concentration, 2.0 pCi l^{-1} ($2.0 \times 10^{-9} \text{ } \mu\text{Ci ml}^{-1}$ or $7.4 \times 10^{-6} \text{ Bq ml}^{-1}$) was 2.0% of the RCG. However, this was not directly relatable to any known recently discharged Laboratory effluent. The gross beta concentration was 9.9 pCi l^{-1} ($9.9 \times 10^{-9} \text{ } \mu\text{Ci ml}^{-1}$ or $3.7 \times 10^{-4} \text{ Bq ml}^{-1}$), and the ^{90}Sr concentration was 3.0 pCi l^{-1} ($3.0 \times 10^{-9} \text{ } \mu\text{Ci ml}^{-1}$ or $1.1 \times 10^{-4} \text{ Bq ml}^{-1}$). The latter was 3.5% of the RCG.

Except for pH levels slightly lower than the Water Quality Standard, but within the local natural variation, most other indices of water quality in these surveillance wells were within the standards. In a limited sampling of a few on-site wells immediately adjacent to the sand filter beds and to the Peconic River on-site, Fe and Zn were found up to ten times their respective water quality standards. These levels exceeded those found in recent Laboratory liquid effluents, and might be an artifact produced by the sampling well

casing rather than being present in groundwater itself.

On-site, adjacent to the Solid Waste Management area, the landfill, the former open dump, the decontamination facility storm sewer sump, and at the Meadow-Marsh Project area, above ambient background concentrations of gross beta activity, ^{90}Sr , and tritium were found in a number of nearby groundwater surveillance wells. Much of the gross beta activity appeared to be related to ^{90}Sr .

At the Waste Management area, the largest ^{90}Sr concentration, 97.1 pCi l^{-1} ($9.7 \times 10^{-8} \text{ } \mu\text{Ci ml}^{-1}$ or $3.6 \times 10^{-3} \text{ Bq ml}^{-1}$), or 36% of the RCG, was found in a well 152 m south of the site. This level reflects the effects of a known inadvertent injection into groundwater which occurred in 1960.

At the landfill, a gross alpha concentration of 18.0 pCi l^{-1} ($1.8 \times 10^{-8} \text{ } \mu\text{Ci ml}^{-1}$ or $6.7 \times 10^{-6} \text{ Bq ml}^{-1}$), or 20% of the RCG, a gross beta concentration of 130.0 pCi l^{-1} ($1.3 \times 10^{-7} \text{ } \mu\text{Ci ml}^{-1}$ or $4.8 \times 10^{-3} \text{ Bq ml}^{-1}$), or 5% of the RCG, and a tritium concentration 735 nCi l^{-1} ($7.35 \times 10^{-6} \text{ } \mu\text{Ci ml}^{-1}$ or $2.7 \times 10^1 \text{ Bq ml}^{-1}$), or 10% of the RCG were the largest found. They occurred in wells between the landfill and a location 61 m south of the boundary of the working area.

At the decontamination facility storm sewer sump, a ^{90}Sr concentration of 29.5 pCi l^{-1} ($2.95 \times 10^{-8} \text{ } \mu\text{Ci ml}^{-1}$ or $1.1 \times 10^{-3} \text{ Bq ml}^{-1}$), or 10% of the RCG was found in a surveillance well about 46 m southeast of the sewer outfall into the sump.

With the exception of the presence of Fe and Zn in wells adjacent to the landfill area, all on-site water quality and purity parameters were within the established standards. Immediately adjacent to the landfill, the concentration of Fe was 136 ppm, or 230 times the standard and that of Zn was 0.8 ppm, or 1.3 times the standard.

All of the above on-site levels of radioactivity or other agents above ambient background in ground water appeared to be confined to within a few hundred feet of their origin, and would require decades of travel before reaching the site boundary. Concentrations of radioactivity, and water quality parameters, in ground water from perimeter surveillance wells (other than those adjacent to the Peconic River) were at or near background and only a few percent of RCG's.

Milk samples were obtained by the New York State Department of Environmental Conservation from two Suffolk County dairy farms, one 10 km southeast and one 40 km east of the Laboratory site, following the Chinese nuclear test in September 1977. The peak activity concentration of ^{131}I in milk from the closer farm was 16 pCi l^{-1} ($16.0 \times 10^{-9} \text{ } \mu\text{Ci ml}^{-1}$ or $6 \times 10^{-4} \text{ Bq ml}^{-1}$). The data was within the variations of ^{131}I concentrations in milk samples for that period within New York State. This activity concentration was considerably lower than those of the previous year (1976) of about 200 pCi l^{-1} (7.4 Bq l^{-1}) of milk.

The collective average dose equivalent rate (total population dose), for the population up to a distance of 80 km, attributable to Laboratory sources was calculated to be 19.92 rem a^{-1} (person-rem a^{-1}), as compared to a natural background dose equivalent rate to the same population of about $269,377 \text{ rem a}^{-1}$ (person-rem a^{-1}).

A similar report for 1976 is given in the BNL Report No. 22627, "1976 Environmental Monitoring Report."

Sewage Sludge Disposal on the Sanitary Landfill

J. R. Naidu

The sanitary landfill at Brookhaven National Laboratory cannot be used to dispose of sewage sludge as it contains radioactivity. A cost-benefit study has indicated that the sewage sludge can indeed be disposed of on the landfill. This study is a comparison between two options, that are:

- a. to continue the landfill disposal and show that the exposure to man through different pathways is insignificant, or
- b. to dispose it off-site through contractors and estimate the cost in comparison to the value given as \$1000/rem.

A report has been prepared based on option (a). It indicates the limiting concentration for specific radionuclides that could be disposed on the landfill. This is compared to the concentration of the same radionuclides in the sewage sludge and the results show the margin of safety to be between 1000 to 10,000 if we use the landfill to dispose of the sewage sludge. The report is under review.

Radiological Analyses of Marshall Islands Environmental Samples*
1974 - 1976

N. A. Greenhouse, R. P. Miltenberger, and F. T. Cua

Introduction

Brookhaven National Laboratory commenced environmental monitoring of the Marshall Islands for radioactivity in April 1974. Since then, members of the BNL staff have made a total of six field trips to the Marshall Islands to collect a representative cross section of vegetation, animals, fruits, soil, and water found on the Islands for the purpose of assessing the radiological effects of the U.S. Pacific Testing Programs.

The surveys covered Kwajalein, Wotho, Bikini, Rongelap, and Utirik Atolls. A total of 1200 analyses were performed on 400 samples. In general, all samples were analyzed for Sr-90, Pu-238, Pu-239/240 and any gamma emitters which may have been present at the time of analyses.

Most of the field sampling work was done in conjunction with and in cooperation with a related environmental monitoring program operated by the Laboratory for Radiation Ecology (LRE) of the University of Washington. The results of both programs will be published in a series of joint and separate reports, with emphasis on the terrestrial environment from BNL, and emphasis on the marine food chain from LRE.

*Published as a BNL Report, BNL 50796, December 12, 1977.

External Radiation Survey and Dose Predictions for Rongelap, Utirik,
Rongerik, Ailuk, and Wotje Atolls*

N. A. Greenhouse and R. P. Miltenberger

ABSTRACT

External radiation measurements were made at several atolls in the northern Marshall Islands, which are known or suspected to have been the recipients of tropospheric fallout during the Pacific Testing Programs. Sufficient data were available to ascertain realistic dose predictions for the inhabitants of Rongelap and Utirik Atolls where the 30 year integral doses from external sources exclusive of background radiations were 0.65 and 0.06 rem respectively. These estimates are based on realistic lifestyle models based on observations of each atoll community. Ailuk and Wotje Atolls were found to be representative of regional background radiation levels.

*Published as a BNL Report, BNL 50797, December 13, 1977.

Marshall Islands - Diet and Life Style Study*

Janakiam R. Naidu, Nathaniel A. Greenhouse, and Evelyn C. Craighead

One of the key requirements for dose assessments is the quantification of the pathways through which radionuclides or the radiations given off will reach man. To do such a study the authors observed while living on the Islands of Rongelap, Uterik, Ailuk, Likiep, Mejit, and Wotho, their life-style in terms of their various occupations such as food gathering, fishing, copra productions, and their consumption of local foods such as fish, breadfruit, pandanus, etc. The data has been collected and a report is being prepared. This study also forms part of the Northern Marshall Islands Radiological survey.

*To be published as a BNL report.

Dose Reassessment for Populations on Rongelap and Utirik
Following Exposure to Fallout from the BRAVO Incident (March 1, 1954)

J. R. Naidu and N. A. Greenhouse

Incidences of thyroid nodules, benign and malignant, in the exposed populations of Utirik and Rongelap have indicated critical differences in correspondence between nodule incidence and thyroid dose for the populations. The estimated external dose received from the time fallout began to the time of evacuation shows that the Rongelap population received an external dose (175 rads) which was about 13 times that for the Utirik population (14 rads), and the thyroid dose was about 10 times larger, whereas the incidence of thyroid nodules in the two populations was not significantly different.

A preliminary study has indicated that the critical area of investigation that could shed light is the period during fallout and evacuation for both the Islands. In addition, the fact that the Utirik population returned within 120 days following evacuation, whereas the Rongelap population returned only after three years, requires that we look closely at the Utirik population in terms of a longer exposure period, both internal and external. Further studies being conducted are:

- a. Examining all reports and evaluating all data pertaining to external radiation measurements, radionuclide concentrations in food pathways and meteorological data prevailing during the test.
- b. Determination of ¹²⁹I in soil samples collected during the fallout period and soon after and using this data to estimate concentrations of other short lived iodine isotopes.
- c. Using a computer simulation program to determine the transport and deposition of radioactive fallout following the BRAVO test.

The above studies are in progress.

Whole Body Counting Results From 1974 To 1979 For Bikini Island Residents

R. P. Miltenberger, N. A. Greenhouse, and E. T. Lessard

ABSTRACT

Three body burden measurements of the Bikini Island population were conducted from 1974 to 1978 at Bikini Island. During this time, the mean ^{137}Cs body burden of the adult Bikini population increased by a factor of 20. This dramatic elevation of the body burden appears to be solely attributable to increase availability of locally grown food products, specifically coconuts and coconut plant products. In January 1979, forty-five percent of the individuals that were whole body counted in April 1978 were recounted approximately one hundred and forty-five days after the Bikini Island population departed from Bikini Atoll. These results show that the adult population mean ^{137}Cs body burden decreased by a factor of 2.9 between the April 1978 and January 1979 in vivo measurements.

Dietary Radioactivity Intake from Bioassay Data: A Model Applied to
¹³⁷Cs Intake by Bikini Island Residents*

R. P. Miltenberger, N. A. Greenhouse, F. T. Cua, and E. T. Lessard

ABSTRACT

Previous publications of the ICRP and NCRP (ICRP 59, ICRP 68, ICRP 71, NCRP 77) describe mathematical models relating total radionuclide body burden and urinary activity excretion rate. This paper presents an equation with which the constant daily activity ingestion rate may be calculated from sequentially obtained whole body counting and urine bioassay data. The model was developed to relate whole body counting results to urinary activity excretion data for ¹³⁷Cs in the Marshallese population at Bikini Island for whom accurate dietary intake information was not available. The technique is applicable to radioactive material whose biological and physical removal mechanisms are linear first order processes described by appropriate rate constant which give the instantaneous fraction of atoms transferred from compartments in the body to urine per unit time, and the instantaneous fraction of atoms decaying per unit time.

*Submitted to Health Physics.

External Exposure Measurements At Bikini Atoll

N. A. Greenhouse, R. P. Miltenberger, and E. T. Lessard

Abstract

External exposure rate surveys were made of Bikini Atoll from 1975 to 1977. The islands surveyed were Nam, Eneu and Bikini. The average external exposure rates measured on each island were 24 $\mu\text{R/hr}$, 5.7 $\mu\text{R/hr}$, and 32 $\mu\text{R/hr}$ respectively. The exposure rate at Eneu Island is uniform whereas the exposure rates on Bikini and Nam Islands range from 7.0 to 80 $\mu\text{R/hr}$. Based on an assumed living pattern at Bikini Island, the adult male Bikinian is estimated to be in the presence of an external radiation field corresponding to 16 $\mu\text{R/hr}$ due to debris and fallout from the 1954 BRAVO incident. This corresponds to a 30 year dose equivalent of 2.8 rem.

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Surface Analysis Techniques and Their Use in Pollution Detection and Measurement*

M. N. Varma and J. W. Baum

ABSTRACT

Surface analysis techniques such as Auger electron spectroscopy (AES), electron spectroscopy for chemical analysis (ESCA), secondary ion mass spectrometry (SIMS) and ion scattering spectrometry (ISS) are reviewed. The advantages and limitations of these methods are compared with bulk analysis techniques such as x-ray fluorescence spectroscopy, atomic absorption and emission spectroscopy, gas chromatography, and neutron activation analysis. Results obtained using ESCA, AES, SIMS, ISS and x-ray fluorescence analysis from auto exhaust, laboratory prepared, clean air and biological samples are discussed. Possible future areas of research using surface techniques are discussed.

*Presented at the Symposium on Assessing the Industrial Hygiene Monitoring Needs for the Coal Conversion and Oil Shale Industries, Brookhaven National Laboratory, November 6-7, 1978.

Singlet Molecular Oxygen Reaction Rate Studies*

M. Varma

Singlet oxygen is an intermediate species in many reactions in the atmosphere and in biological systems. The knowledge about the reaction rate of these species is of utmost importance in areas where information on mechanisms of interaction of biological systems with pollutants is needed.

Preliminary measurements were made to determine the reaction rate of singlet molecular oxygen in the presence of varying concentrations of oxygen gas. Singlet molecular oxygen species were generated by a microwave discharge. The concentrations of oxygen molecules was 7.1, 8.6, and 10.3 (moles/liter $\times 10^4$). Concentrations of singlet molecular oxygen species in the system was determined by measuring the intensity of emission at 634 nm resulting from the dimol emission. These measurements provided the rate constant for collisional quenching of singlet molecular oxygen by oxygen, and also the wall loss rate constant resulting from the collision of singlet molecular oxygen species with the walls of the reaction vessel.

*Studies done in collaboration with the Division of Radiation Protection, Bhabha Atomic Research Center, Trombay, Bombay, India.

Measured Radial Distributions of Dose and LET for Alpha and
Proton Beams in Hydrogen and Tissue-Equivalent Gas*

C. L. Wingate and J. W. Baum

Experimental measurements of the radial distribution of dose and radially restricted linear energy transfer (L_r) are reported for alpha and proton beams of 1-3 MeV from a Van de Graaff accelerator. The method employs a large cylindrical ionization chamber filled with tissue-equivalent gas (or hydrogen) at variable low pressure for L_r measurement. For radial dose determination, a small movable ionization chamber of transparent mesh located inside the large cylinder is used to measure ionization by secondary electrons around the charged particle beam. Results are presented for simulated tissue radii from about 10^8 Å to a few thousand angstroms. Comparison of the measured dose distributions with recent calculations by H. G. Paretzke indicates fair agreement except for large radii, where the local energy deposition is a small part of the total.

*Abstract of article published in Radiation Research 65, (1976), 1-19.

Ames Collaborative Study of Cosmic Ray Neutrons*

J. E. Hewitt, L. Hughes, J. B. McCaslin, L. D. Stephens, A. Rindi,
A. R. Smith, R. H. Thomas, R. V. Griffith, C. G. Welles, J. W. Baum, and A. V. Kuehner

Hess and his co-workers made one of the first measurements of the cosmic-ray neutron differential energy spectrum. They determined the spectrum between 0.01 eV and 10 GeV at several aircraft altitudes. More recent data cast doubt on both the reported flux intensities and the spectral shape. In particular, the existence of a broad evaporation peak near 1 MeV is questioned and it is suggested that a larger fraction of the flux (and hence the contribution to the dose) consists of neutrons with energies greater than 10 MeV.

This report describes the results of a collaborative study to define both the flux and the spectrum more precisely and to develop a dosimetry package that can be flown quickly to altitude for solar flare events. Instrumentation and analysis techniques are used which were developed to measure accelerator-produced radiation. The instruments are flown in the Ames Research Center high-altitude aircraft. Neutron instrumentation consists of Bonner spheres with both active and passive detector elements, threshold detectors of both prompt-counter and activation-element types, a liquid scintillation spectrometer (developed by New York University) based on pulse-shape discrimination, and a moderated BF_3 counter neutron monitor. In addition, charged particles are measured with a Reuter-Stokes ionization chamber system and dose equivalent with an instrument on loan from Brookhaven National Laboratory. Preliminary results from the first series of flights at 12.5 km (41,000 ft) are presented, including estimates of total neutron flux intensity and spectral shape and of the variation of intensity with altitude and geomagnetic latitude.

*Abstract of article published in NASA Technical Memorandum, NASA TM X-3329, January, 1976.

A Simple Heavy-Ion Beam Monitor*

M. N. Varma

A simple heavy ion beam monitor is described for measuring beam intensity from accelerators to an accuracy of better than 1%. The principle of secondary electron emission is employed. The beam monitor consists of two thin nickel foils (0.6 μm) separated by a few mm . A positive voltage is applied to the downstream foil and current is collected from the upstream foil. This beam monitor is operated at a pressure of less than 10^{-6} torr. The beam monitor is calibrated using a Faraday cup. Beam intensity of heavy ions like oxygen and ^4He have been successfully measured to an accuracy of better than 1%.

*Nuclear Instruments and Methods 133 (1976) 205-207.

Nanometer Dosimetry of 377 MeV/nucleon ^{20}Ne Ions *

M. N. Varma and J. W. Baum

ABSTRACT

Dose as a function of radial distance from a ^{20}Ne ion beam was determined. These ions had 377 MeV/nucleon energy and were obtained at the Bevalac facility of Lawrence Berkeley Laboratory. A variable pressure ionization chamber and a double mesh wall ionization chamber (approximating a wall-less ionization chamber) were used. Linear energy transfer restricted in distance (LET_r) was also determined and the data were extrapolated to obtain LET_∞ . Radial distances studied were from about 58 Å to 1010 μm of tissue assumed to have a density of 1 g/cm³. Experimental results were compared with theoretical calculations, the experimental values were consistently lower by about 13% over the range of distances studied, except at two radii, 0.2 and 1010 μm , at which the experimental values were higher.

*Informal Report, BNL-22756, April, 1977.

An Intercomparison of Dosimetry Techniques in Radiation Fields
at Two High-Energy Accelerators*

J. B. McCaslin, A. R. Smith, L. D. Stephens, R. H. Thomas, T. M. Jenkins,
G. J. Warren, and J. W. Baum

A comparison of radiation intensity measurements outside the shielding of the Bevatron and the 20 GeV Electron Linear Accelerator at Stanford is described. Measurements were made using several different techniques by workers from Brookhaven National Laboratory, Lawrence Berkeley Laboratory, and the Stanford Linear Accelerator Center. The measurements indicate large discrepancies (factors of two or more) between different techniques of measurement and illustrate the need for improvement in high-energy accelerator dosimetric techniques.

*Abstract of article published in Health Physics 33, (1977), 611-620.

Indose - Program for Calculating Radial Energy Deposited Due to Scattered Particles*

M. N. Varma, J. Meo, A. V. Kuehner, and J. W. Baum

ABSTRACT

A computer program, INDOSE, is described which was used to calculate energy deposited as a function of radial distance from an ion path for scattered incident particles and scattered target gas atoms. Classical Rutherford scattering theory is used to calculate scattering cross-sections. Linear energy transfer data of Northcliff and Schilling¹ were used for electronic stopping power and Lindhard, et al.² theory was used to estimate nuclear stopping power. Results are given for 2.65 MeV incident ⁴He ions and 41.1 MeV incident ¹⁶O ions.

*BNL Report, BNL-21469.

Radial Dose, LET, and $\bar{W}$ for ^{16}O Ions in N_2 and Tissue-Equivalent Gases*

M. N. Yarma, J. W. Baum, and A. V. Kuehner

Average energy to produce an ion pair ($\bar{W}$), distance restricted, and total linear energy transfer and dose as a function of radial distance $D(r)$ from the ion's path were measured for 41.1-MeV ^{16}O ions in nitrogen and Rossi-type tissue-equivalent gas. Results for $\bar{W}$ were 38.9 ± 0.54 eV/ion pair for nitrogen and 33.4 ± 0.47 eV/ion pair for tissue-equivalent gas. Results for total linear energy transfer (LET_∞) were $6507 \text{ MeV}\cdot\text{cm}^2 \text{ g}^{-1}$ for tissue-equivalent gas and $6210 \text{ MeV}\cdot\text{cm}^2 \text{ g}^{-1}$ for nitrogen. Results for $D(r)$ were used to calculate similar values to be expected in tissue-like material having a density of 1 g/cm^3 . The range of radial distances covered was from 0.2 to 300 nm in tissue. Results are compared with calculations based on Paretzke's continuous slowing down model. Measured $D(r)$ values in nitrogen were randomly distributed about the calculated values between radial distances of 0.56 and 286 nm. The mean deviation between the experimental and the calculated value was 1.3% (the experimental value being higher). For tissue-equivalent gas, previously measured $D(r)$ values were also randomly distributed about the calculated values, with a mean deviation of 4% (the experimental value being lower) between radial distances of 1.5 and 140 nm.

*Radiation Research 70, (1977), 511-518.

Dependence of $\bar{W}$ on the Charge of Heavy Ions*

M. N. Varma and J. W. Baum

ABSTRACT

$\bar{W}$ values (average energy required to form an ion pair) were determined for ^{35}Cl ions in nitrogen and tissue-equivalent gas. These values were compared to previously reported $\bar{W}$ values for oxygen ions and alpha particles in the same media. This comparison was made at two specific values of energy per atomic mass unit of the incident ions. At an energy of 2.57 MeV/AMU, the comparison shows $\bar{W}$ is 12% and 10% higher for oxygen ions in tissue-equivalent and nitrogen gas, respectively, relative to alpha particle $\bar{W}$. At an energy of 0.77 MeV/AMU, a similar comparison shows $\bar{W}$ is 20% higher for ^{35}Cl ions and 12% higher for ^{16}O ions in tissue-equivalent gas; and 13% and 10% higher, respectively, in nitrogen gas, relative to alpha particle $\bar{W}$. These results indicate that $\bar{W}$ values depend not only on the energy per atomic mass unit of heavy ions but also on their charge.

*BNL-23394, IAEA-SM-222/02, October 1977.

A Precise Alpha Source Calibration for Thermoluminescence Dating¹

M. N. Varma and G. W. Carriqueau*

ABSTRACT

A cylindrical ionization chamber was used to determine the total energy deposited in nitrogen gas from a 100 microCurie curium-244 source. The total ionization current produced by the alpha particles was measured; previously determined $\bar{W}$ values (average energy required for an ion pair) for alpha particles in nitrogen gas were used to determine the total emission energy of the collimated source. Measurements indicate that calibration of a source, in terms of total energy per second, can be made to an accuracy better than +1%. A solid state detector was also used to determine the energy distribution of alpha particles as a function of angle and distance from the source. We suggest that the unit energy per second is a more convenient parameter than the conventional use of rads or disintegrations per second for thermoluminescent dating.

¹ Presented at the Proceedings of a Specialist Seminar on Thermoluminescence Dating, University of Oxford, England, July 3-8, 1978.

*Guest Scientist, Chemistry Department, Brookhaven National Laboratory, research at Brookhaven performed under the auspices of the U.S. Department of Energy.

Energy Dependence of $\bar{W}$ for Alpha Particles in N_2 , CO_2 , CH_4 , Ar, H_2 and
Rossi-type Tissue-Equivalent Gases*

M. N. Varma and J. W. Baum

Average energy required to form an ion pair ($\bar{W}$) was determined in N_2 , CO_2 , CH_4 , Ar, H_2 and Rossi-type tissue-equivalent gas. Alpha particles from a ^{241}Am source were used. $\bar{W}$ was determined at alpha energies of 5.37, 3.12, 1.08, and 0.46 MeV. The ratio of total ionization produced (for fixed alpha particle energy) in experimental gas to that produced in argon was measured. This ratio was then multiplied by the previously determined $\bar{W}$ value for argon gas (26.29 eV per ion pair) to yield $\bar{W}$ for various experimental gases. Energy of the ^{241}Am alpha particles was degraded by using air as an absorbing material. Empirical relations $\bar{W} = a + b E^{-1/2}$ and $\bar{W} = a_1 + b_1 E^{-1}$ were fitted to the experimental data. Both functions fit reasonably well in the range 0.4-5.37 MeV. Below about 0.4 MeV the first function provides a better fit to the data of Boring et al. (1965).

*Phys. Med. Biol. 23, 6 (1978), 1162-1172.

Dependence of the $\bar{W}$ -Value on the Atomic Number of Heavy Ions*

M. N. Varma and J. W. Baum

ABSTRACT

$\bar{W}$ -values (the average energy required to form an ion pair) were determined for ^{35}Cl ions in nitrogen and tissue-equivalent gas. These values were compared with previously reported $\bar{W}$ -values for oxygen ions and alpha particles in the same media. This comparison was made at two specific values of energy per atomic mass unit (u) of the incident ions. At an energy of 2.57 MeV/u, the comparison shows that $\bar{W}$ is 12% and 10% higher for oxygen ions in tissue-equivalent and nitrogen gas, respectively, relative to the alpha particle $\bar{W}$. At an energy of 0.77 MeV/u, a similar comparison shows that $\bar{W}$ is 20% higher for ^{35}Cl ions and 10% higher for ^{16}O ions in tissue-equivalent gas; and 12% and 10% higher, respectively, in nitrogen gas relative to the alpha particle $\bar{W}$. These results indicate that $\bar{W}$ -values depend not only on the energy per atomic mass unit of heavy ions but also on their charge.

*National and International Standardization of Radiation Dosimetry, Vol. II, IAEA-SM-222/02, 65-71, IAEA, Vienna, 1978.

Microdosimetric Results Obtained by Proportional Counter and
Ionization Chamber Methods: A Comparison*

M. N. Varma, J. W. Baum, and P. Kliuga

Energy deposition in one micron diameter volumes at distances of one and two microns from the ion's path has been estimated based on previously reported radial dose measurements made using a mesh wall ionization chamber. In these estimations it was assumed that radial dose varied inversely as the square of the radial distance. Ionization chamber measurements were reported for heavy ions (atomic number 1 to 53) having specific energies from 0.25 to 2.5 MeV per atomic mass unit (MeV/AMU) and from 230 to 377 MeV/AMU. Energy depositions were also measured using a wall-less gas proportional counter, and were reported by Kliuga and Rossi. Ions used in the proportional counter technique were 6.6 MeV/AMU lithium and 10 and 23 MeV/AMU protons. A comparison of results estimated from ionization chamber studies and measured using proportional counters is reported here. This comparison was facilitated by normalization in terms of Z_{eff}^2 and specific energy of the incident ions.

Proportional counter results were in apparent agreement with ion chamber results for 23 MeV/AMU protons but were lower than ion chamber results by approximately 50% for 10 MeV/AMU protons and 60% for 6.6 MeV/AMU lithium ions.

*BNL Report No. BNL-24330, presented at The Sixth Symposium on Microdosimetry, Brussels, Belgium, May 22-26, 1978.

Measurements of $\bar{W}$ for Protons, Helium-4 Ions, and Carbon-12 Ions in Tissue-Equivalent Gas¹

Norman Rohrig and Robert D. Colvett

ABSTRACT

Absolute measurements of $\bar{W}$ (the mean energy expended in a gas per ion pair formed) have been conducted in methane-based tissue-equivalent gas. A monoenergetic particle beam enters a 1-m-long tank filled with gas in which the particle stops. The ionization created is collected on a 3-mm-diameter rod. The negative electron pulse at the rod is amplified and the pulse height is analyzed to accumulate a particle energy spectrum. The pulse-height spectrum is integrated to give the number of particles. The charge collected on the rod is simultaneously measured with a vibrating reed electrometer. Measured values of $\bar{W}$ varied from 30.2 to 31.4 eV for 2.8- to 0.15-MeV protons, from 30.9 to 35.3 eV for 7.8- to 0.36-MeV helium-4 ions, and from 34.7 to 47 eV for 5.6- to 0.12-MeV carbon-12 ions. Uncertainties are considered in detail and vary from 0.3 to 1.2%. The energy dependence is smooth and for energies greater than 1.5 MeV is consistent with a constant value of differential W .

¹Abstract for paper in Radiation Research 76, 225-240 (1978).

R. D. Colvett and N. Rohrig

Experiments examining the role of interaction distance in radiobiology have been undertaken using molecular beams which dissociate in thin Mylar cell substrates. The separate particles diverge because of multiple scattering but remain correlated. The separation between the particles follows a distribution with a characteristic separation determined by the material thickness. The relative effects of irradiation with correlated and uncorrelated particles measure an effect of interaction between the two separate tracks of the pair of particles. This paper describes the experimental facilities and dosimetry for this family of experiments. Multiple scattering measurements are described and the shape and width of the distribution is consistent with published works. The calculations of characteristic separations between correlated pairs as they proceed through the Mylar substrate into the cell at various depths are discussed. The associated radiobiology experiments described in accompanying articles were conducted using 33 keV/ μm deuterons or protons with characteristic separations between 100 and 400 nm.

*Abstract of paper accepted by Radiation Research.

Stopping Power and Radial Dose Distribution Around 42 MeV Bromine Ions

M. N. Varma, J. W. Baum, and A. V. Kuehner

Linear energy transfer restricted in range (LET_x) and total linear energy transfer (LET_∞) was determined for 42 MeV Bromine ions in tissue-equivalent gas. A variable pressure cylindrical ionization chamber was used. Dose as a function of distance from the ion's path was also determined using a mesh wall ionization chamber placed inside the cylindrical chamber. The range of distances studied was from 5 to 710 Ångstroms in simulated tissue of unit density. Experimentally obtained values of radial dose were compared with Paretzke's model calculations. Agreement was reasonably good. Stopping power for these ions in tissue-equivalent gas was extrapolated from proton stopping power in constituent gases. In this calculation, effective charge of the ions was obtained from the formula given by Nikolaev and Dimitriev. This calculated value was 6.37×10^4 MeV/gm/cm². The experimentally determined value was 7.82×10^4 MeV/gm/cm². The discrepancy between calculated and experimental values can be due to uncertainty in effective charge used in calculations. Uncertainty on the experimental value of LET_∞ was estimated to be approximately 5%.

Tests on Mutagenic Effects of Strong Magnetic Fields*

John W. Baum, Lloyd A. Schairer and Kenneth L. Lindahl

SUMMARY

Several tests on effects of magnetic fields have been made using Tradescantia clone 4430 and one using clone 02. In most tests, cuttings were employed, however, one study employed a single potted plant with various influorences exposed to different field intensitites. End points studied included (a) pink stamen hair mutations, (b) pollen abortion and (c) micro-nuclei formation in the tetrad stages of pollen production.

During these studies, exposures were made using permanent magnets for fields up to 0.7 tesla, an electromagnet with 15 cm diameter pole pieces for fields from 0.8 to 1.2 tesla and a (warm bore) cryogenic magnet for fields from 2.1 to 3.7 tesla. Exposures with the permanent magnet were made in a temperature, light and in some cases humidity controlled growth chamber (except for experiment No. 1) and others were made at room temperature with only partial light and humidity control.

Results obtained in eight separate tests are summarized in Table 1. A 2×2 contingency test (χ^2) was made on each set of data. If this test indicated a probable difference at the 90% confidence level, a student's "t" test was also performed to obtain a better estimate reflecting variability as well as mean differences. Only one result (pink mutation) on a rather small experiment seemed significant at 90% confidence when the "t" test criterion was employed, but this difference was not of a detrimental nature. All

*Paper presented at the workshop on Biomagnetic Effects, Lawrence Berkeley Laboratory, University of California, Berkeley, California, April 6-7, 1978.

pollen abortion results showed less effect in exposed cells than in controls but not at a statistically significant level.

Statistical analyses of the results for pink mutations, for fields from 0.8 to 3.7 tesla, were lumped together to increase sensitivity. The lumped data indicated 2.7×10^{-4} (1σ) pink mutations per hair over control values. In Table 2, this result is compared to mutation induction rates from other toxic agents.

Table 1

Summary

<u>Tesla</u>	<u>Days</u>	<u>Δ, %</u>	<u>Effect</u> <u>(Score Days)</u>	<u>Probability</u>	
				χ^2	"t" test
0.002 to 0.7	5 to 28	-	Pinks (5-28)	-	-
0.067	6	-0.14 -0.6	Pinks (7-12) Pollen (11-15)	0.014 0.11	0.07
0.067	6	+0.2 -1.8	Pinks (11-15) Pollen (18-20)	0.56 <10 ⁻⁵	0.17
*0.17	6	+0.04	Pinks (6-17)	0.15	
0.0	6	-0.04 -0.2	Pinks (11-15) Pollen (18-21)	0.5 0.6	
0.92	0.9	+1.6	Micronuclei	0.07	0.5
0.94	6	+0.04 -0.9	Pinks (7-12) Pollen (7-12)	0.26 0.008	0.5 0.28
3.7	2	+0.03 -0.08	Pinks (11-21) Pollen (18-19)	0.32 0.89	

*Clone 01; all others are 4430

Table 2

Comparisons

<u>Agent</u>	<u>Permissible Dose</u>	<u>Mutations, %</u>
DBE	20 ppm	1
SO ₂	50 ppm	0.2
NO ₂	50 ppm	0.1
X rays	20 mrem	0.015*
O ₃	0.1 ppm	0.002*
Magnetic fields	0.02 tesla**	$\leq 8 \times 10^{-5}$ *

*Extrapolated values

**Interim limit employed at some labs

Sensitivity of *Drosophila Melanogaster* to Low Concentrations of the
Gaseous 1,2-Dibromoethane: I Acute Exposures*

P. Kale and J. W. Baum

SUMMARY

Drosophila melanogaster males were exposed to gaseous 1,2-dibromoethane at concentrations lower than those used in aerosol treatments of suspect mutagens by other investigators. Premeiotic stages appear to be more sensitive than postmeiotic stages to gaseous mutagens. At an exposure of 125 ppm·hr, significant numbers of mutations were induced in spermatids, spermatocytes and in spermatogonia. Since this exposure increased the mutation rate in spermatogonial stages by a factor of 20 to 40 times over the spontaneous rate, it appears that the lowest detectable exposures may be much lower than 125 ppm·hr for 1,2-dibromoethane.

*BNL Report, BNL-25314R. In press, Environmental Mutagenesis, Vol. 1, No. 1, 1979.

Sensitivity of *Drosophila Melanogaster* to Low Concentrations of Gaseous
Mutagens: II Chronic Exposures*

P. G. Kale and J. W. Baum

SUMMARY

Sex-linked recessive lethal mutations were induced in *Drosophila melanogaster* males by gaseous 1,2-dibromoethane at concentrations ranging from 0.2 to 2 parts per million. Significant numbers of mutations could be induced at all these concentrations. Pronounced germ cell sensitivity differences were observed. For low exposures, spermatids and spermatocytes were about 10 to 20 times more sensitive than spermatozoa. The dose effect relation was linear below 60 ppm·hr for the three cell types. At higher exposures, sterility prevented mutation detection in spermatocytes and in spermatogonia. The lowest effective exposure for spermatozoa was 18 ppm·hr (0.25 ppm for 72 hours) In spermatids, the lowest exposure tested, 2.3 ppm·hr (0.2 ppm for 11 hours) induced four times the spontaneous mutation rate. Therefore, using prolonged exposure periods one may be able to detect concentrations in the range of parts per billion. Thus, *Drosophila* appears suitable as a system for detecting very low concentrations of gaseous mutagens in industrial, agricultural, and environmental atmospheres.

*BNL Report, BNL-25430, Submitted to Mutation Research, 1978.

Multiple Simultaneous Event Model for Radiation Carcinogenesis *

J. W. Baum

ABSTRACT

A mathematical model is proposed which postulates that cancer induction is a multievent process, that these events occur naturally, usually one at a time in any cell, and that radiation frequently causes two of these events to occur simultaneously. Microdosimetric considerations dictate that for high LET radiations the simultaneous events are associated with a single particle or track.

The model predicts: (a) linear dose-effect relations for early times after irradiation with small doses, (b) approximate power functions of dose (i.e. D^x) having exponent less than one for populations of mixed age examined at short times after irradiation with small doses, (c) saturation of effect at either long times after irradiation with small doses or for all times after irradiation with large doses, and (d) a net increase in incidence which is dependent on age of observation but independent of age at irradiation.

Data of Vogel, for neutron induced mammary tumors in rats, are used to illustrate the validity of the formulation. This model provides a quantitative framework to explain several unexpected results obtained by Vogel. It also provides a logical framework to explain the dose-effect relations observed in the Japanese survivors of the atomic bombs.

*Health Physics 30, (1976), 85-90.

Cancer Risk Estimates and Neutron RBE Based on Human Exposures*

John W. Baum

ABSTRACT

Analysis of data on Japanese survivors in Hiroshima and Nagasaki was incomplete in both the BEIR and UNSCEAR reports issued in 1972 due to dosimetry results reported in terms of kerma for tissue in air rather than mean absorbed dose in the whole body or in bone marrow. Recently, published data on conversion of kerma to dose were, therefore, used to arrive at mean dose to bone marrow and to deduce risk estimates and neutron RBE values for radiation induced leukemia and total malignancies. Results were deduced for various time periods and using various control groups. For total lifetime risks from all malignancies, results were: (a) 5.6 or 1.6 deaths per 10^4 person/rad gamma using national rates or low dose groups as controls, respectively, (b) 104 or 30 deaths per 10^4 person-rad for neutron exposures, and (c) RBE's of about 10 for leukemia and 19 for total malignancies.

*Proceedings of IV International Congress of the International Radiation Protection Association, Paris, France, April 24-30, 1977.

A Rationale for Nonlinear Dose Response
Functions of Power Greater or Less Than One*

J. W. Baum

SUMMARY

Risk estimates and radiation protection standards are generally made using a nonthreshold premise and linear extrapolations from existing data to estimate effects at lower doses and at lower dose rates. This seems reasonable in light of the variety of shapes of dose-effect relations which have been observed both in animal studies and in human epidemiological studies (1). An unexplained observation in several studies was a response which followed a power function of dose (effect $\propto D^x$) with exponent less than one. One explanation offered for this type of response in humans was a postulated population of heterogeneous sensitivity (2). An alternate, though related, way of considering this question is in terms of multiple-stresses.

Consider age-specific mortality rates for lung cancer shown on Fig. 1. This response presumably reflects the effects of several stresses or agents which act collectively or additively to produce lung cancer. Any added stresses are expected to contribute to the total and cause effects to be observed at earlier ages. The effectiveness of added stresses is reflected in the value of the ordinate at the age corresponding to the individuals life expectancy. For example, a 40 year old male had a 32 year (additional) life expectancy in 1960. Stresses added at age 40 are likely to operate at an effectiveness of about 200 units on the ordinate (age 72). Here, the response curve is just beyond

*Paper presented at the workshop on Repair Mechanisms and Exposure Standards, Institute for Energy Analysis, Oak Ridge Associated Universities, Oak Ridge, Tenn, June 28-30, 1977.

the peak, therefore, additional stresses would produce progressively less effect per unit dose since they would be operating on the declining portion of the age response curve. This causes a response function of exponent less than one. Responses of exponent greater than one would be expected at much earlier ages.

Figure 1. Lung cancer mortality rate for U.S. white males, 1958

(1) Baum, J. W., BNL-16241, 1972.

(2) Baum, J. W., Health Physics 25 97.

Rationale for One Double Event in Model for Radiation Carcinogenesis*

J. W. Baum

Dear Sir:

In their recent letter, Cattell and Cook (Ca77) suggest that two double events should have been considered in the development of the Multiple Simultaneous Event Model for Radiation Carcinogenesis (Ba76). Two double events were considered! As stated on p. 88, "Tests of models which involved principally single, triple, or two double events were also made. These gave significantly poorer fits to the experimental data." Thus, it is not an implicit assumption, but rather a deduction from data analysis which leads to the conclusion that two double events were apparently not contributing significantly to the observed effects.

To provide a rationale for the absence of two double events one needs only to imagine these events are gene alterations and that two of the five are sufficiently close together to make simultaneous alterations highly probable. For example, two genes located near each other at the end of a chromosome may both be lost due to a terminal deletion. There may be no similar mechanism for a second double event in the same cell (or its' ancestors).

A second possibility is that the first double event sensitized the cell to subsequent cell killing by ionizing radiation. This sensitization could be permanent or temporary. If temporary, a chronic exposure might permit recovery and a second double event might then become apparent. This could be tested in future chronic or split dose type studies, but would not have been observed in the acute studies analyzed to date.

Finally, the critics refer to "numerous claims that he makes for the predictive power of the model". Obviously, this model is tentative and was used to make predictions primarily so that experiments could be designed to further test and

*Letter to the Editor, Health Physics 35, 581-582 (1978).

improve the model. No claims were made concerning the probability that any of the predictions would be born out. In fact, since some of them (e.g. possibly greater effectiveness for chronic than acute exposure) are at variance with "conventional wisdom", one would not be surprised if they proved incorrect. However, the object of the analysis and proposed tests is to explore various possibilities in order to gain a better understanding of both physical and biological mechanisms which may be operational. Only when the mechanisms are understood can we place much confidence in our model predictions. If the scientific foundations of Health Physics are to be sound, the classical model/hypothesis/experiment protocol is still recommended.

References

Ba76 Baum J. W., 1976, "Multiple Simultaneous Event Model for Radiation Carcinogenesis", Health Phys. 30, 85.

Ca77 Cattell, F. C. R. and Cook J. E., 1977, "Multiple Simultaneous Event Model for Radiation Carcinogenesis", Health Phys. 33, 347.

Monitoring of Radioiodine from Releases from Contaminant Accidents

Carl H. Distenfeld and J. R. Klémish

SUMMARY

Nuclear reactors are considered to be safe power sources. In spite of a low accident history, a small possibility exists for damaging accidents. This could lead to radioactive releases from containment and to human exposure.

Inhalation is expected to be the most important initial pathway. Air monitoring can provide the data base for exposure control.

Approximately 45 relatively volatile radionuclides may be released including the five prominent iodine isotopes. Radionuclide mix is affected by the detailed failure mode and delay time. Thus, an air monitoring means must be specific for iodine in the presence of noble fission gases and other particulate fission products. Single channel or multichannel gamma analysis can be used to provide an iodine specific output.

Costly measurement methods using gamma analysis can be avoided by developing a sampler specifically for iodine, thereby any beta or gamma detector could be used for iodine measurement. Adsorption of iodine on solid adsorbers concentrates the iodine, allowing use of less sensitive and cheaper detectors. Noble fission gas collection can be reduced by heat and selection of an appropriate adsorber. Particulate fission products include dozens of noniodine radionuclides. Prefiltering the solid adsorber bed separates the activity into gaseous and particulate fractions. The gaseous iodine, in any known chemical form, is efficiently adsorbed by either an impregnated charcoal or silica gel. Some of the particulate activity is also due to elemental iodine. A study of the time dependent fraction on the particulate filter allows corrections to be made to account for all iodine.

*Health Physics Society Annual Meeting, Atlanta, GA, July 3-8, 1978.

An Inorganic Radioiodine Absorber with Low Noble Gas Retention*

C. Distenfeld and J. Klemish

ABSTRACT

A silver loaded silica gel was developed as an absorber for air monitoring subsequent to a release from containment power reactor accident. Requirements of high efficiency for known radioiodine species under wide ambient conditions of humidity and temperature and low noble gas adsorption efficiency are satisfied by the material.

Silver loadings from 2 to 24% by absorber weight have been tested against organic radioiodine, hypiodous acid, elemental radioiodine, and noble fission gases. Relative humidity was varied between 5 and 99%, and stay times of .11, .073, and .055 seconds were used.

Silver loading requirements depend on sampling duration and relative humidity. Environmental monitoring, to define safe living areas, requires about 25 ft³ of air be sampled and analyzed by the proposed system of an air mover, an absorber, and a civil defense readout instrument. A silica gel adsorber can be used with a 4% silver loading for an efficiency of better than 93% with a .11 second stay time, and for all ambient conditions tested. Similar tests using 4% silver loaded 13X molecular sieve or about 60% silver zeolite yielded lower efficiencies.

Xenon absorption was $< 5 \times 10^{-3}\%$ at 55° C with no post-release flushing. This value was about 1/20 of the value for charcoal under the same conditions.

A silver loading apparatus was developed to easily process ~5 Kg of silica gel per day. The method involves prehumidification, boiling under high vacuum, oven drying, sieving, and finally packaging.

*Published in the Proceeding of the 15th DOE Nuclear Air Cleaning Conference, Boston, MA, August 7-10, 1978, CONF-780819.

High Efficiency Mixed Species Radioiodine Air Sampling,
Readout, and Dose Assessment System*

C. Distenfeld and J. Klemish

ABSTRACT

Reactor accidents require monitoring to assess the impact to persons in the environment. This implies methods and apparatus to accurately and economically sample and evaluate possible released activity.

In this regard the Defense Civil Preparedness Agency awarded a contract to the Safety and Environmental Protection Division. Among other specifications the contract required the development of a prototype iodine air sampling system, that could differentiate against noble gas activity and could be evaluated by standard Civil Defense instrumentation.

The apparatus developed can efficiently (95%) collect organic or inorganic, particulate or gaseous radioiodine in concentrations below stable atmospheric iodine, and under severe ambient conditions. Response to noble fission gases was reduced to $<4 \times 10^{-4}$ of an equal iodine airborne activity by heating the collector to approximately 100°C . Reliable sample size, $\pm 5\%$, was achieved by using a simple air flow regulator. Thyroid dose commitment was mathematically and graphically related to the iodine isotope distribution expected in the environment and to the response of the Civil Defense CDV-700 instrument used to evaluate the sample. Sensitivity of the method allows dose assessment of 1-2 rads to a child's thyroid.

*A summary is included in IAEA, Handling of Radiation Accidents 1977, Vienna.

This study was supported by Project Order DCPA 01-74-C-0325 with the Defense Civil Preparedness Agency.

Criteria for Occupational Health Monitoring in the
Fossil Fuel Conversion Industries*

Otto White, Jr.

ABSTRACT

The occupational health professional is being confronted with the monumental problem of identifying and evaluating the potential health hazards associated with the emerging fossil fuel conversion industries. The problem is enhanced by the complex composition of the base materials. Wiser's (1) proposed structure of coal contains many analogs of known hazardous organic compounds. Coal also contains many metals with known health consequences. Kerogen, the base material for the oil shale industry, also represents a structurally complex material as illustrated by the reduced chlorophyllin model proposed by Jackson and Decora (2). Kerogen's pyrolysis products are comparable with their toxic counterparts derived from coal.

Treatment of these base materials, which vary widely in carbon to hydrogen ratios as well as distribution of trace elements, with heat, pressure and various gas and solvent streams results in the generation of a host of chemicals which produce health effects ranging from simple asphyxiation to cancers and death. Characterization studies of process and effluent streams have identified a host of chemicals which are known or suspected to be hazardous to man.

Although the literature, when studied chronologically, represents a strong case in demonstrating a positive relationship between increased cancer incidence and exposure to certain fossil-derived materials, the absence of a strong epidemiological base does not permit the traditional assignment of priorities for occupational health protection.

*Proceedings of Symposium on Assessing the Industrial Hygiene Monitoring Needs for the Coal Conversion and Oil Shale Industries, Brookhaven National Laboratory, Upton, NY, November 6-7, 1978.

The mandate to provide workers in the coal conversion and oil shale industries a safe and healthy work environment is clear. Protection of this work force will require monitoring for the following purposes:

1. Health hazard evaluation
2. Performance trends in engineering controls
3. Development of design requirement for new engineering controls
4. Documentation of exposure levels
5. Compliance determination
6. Measurement of process losses
7. Selection of suitable respiratory protection devices
8. Identification of contamination sources
9. Assessment of emergency conditions
10. Establishment of baseline data

The focus of this paper is to provide the occupational health professional with a criteria that will assist in establishing priorities in occupational health monitoring programs for the fossil fuel conversion.

References

1. Wiser, W. H., "Some Chemical Aspects of Coal Liquefaction. In paper-- Short Course on Coal Characteristics and Coal Conversion Processes, 1973, Pennsylvania State University, University Park, Pennsylvania.

2. Jackson, L. P. and Decora, A. W., "Thermal Reactions of Shale Oil Components: Plant Pigments as Probable Precursors of Nitrogenous Compounds in Shale Oil," BM-RI 8018, U.S. Department of Interior, Washington, D.C.

Working Group on Assessing Industrial Hygiene Monitoring
Needs for the Coal Conversion and Oil Shale Industries¹

Otto White, Jr.

EXECUTIVE SUMMARY

Procedures involved in converting solid coal and oil shale into more usable liquid or gaseous fuel result in the utilization and generation of many hazardous substances with potential emission into the environment and the workplace. These substances range from simple inorganic compounds, such as carbon monoxide, to complex organic compounds, such as 7,12-dimethylbenz(a)anthracene. The severity of the health effects resulting from exposure to these compounds range from nuisance and mild irritation to cancer and death, while the response interval can range from immediate to 25 and 30 years. To add to the complexity of the problem, many of these compounds enhance or accelerate the actions of other compounds when present together. The Department of Energy and Brookhaven National Laboratory formed a working group to assess instrumentation needs to assure the work force of these emerging industries a safe and healthful working environment. It is hoped that early efforts to identify and monitor hazards to health will result in avoiding situations such as the current one billion dollar annual compensation payments to victims of black lung disease and the controversial retrospective epidemiological studies.

The composition of the working group designated to assess the Industrial Hygiene Monitoring needs for the Coal Conversion and Oil Shale Industries is:

Otto White, Jr., Co-chairman	Brookhaven National Laboratory
Samuel Morris, Co-chairman	Brookhaven National Laboratory
Thomas R. Cessario, Secretary	Brookhaven National Laboratory
Edward Baier*	National Institute for Occupational Safety and Health

¹A final report to DOE to be published in March 1979.

*Present affiliation is Diamond Shamrock Corporation.

Richard Brief	Exxon Corporation
Morton Corn	University of Pittsburgh
Harry Ettinger	Los Alamos Scientific Laboratory
David Fraser	University of North Carolina
Morton Lippmann	New York University
Andrew Sharkey	Pittsburgh Energy Research Center

This group met for the first time during the annual American Industrial Hygiene Association Conference in Los Angeles, California, on May 9, 1978.

The second meeting took place during a two day visit to the Pittsburgh Energy Technology Center where the group sharpened its focus on industrial hygiene problems in coal conversion by inspecting specific processes and work practices.

The third meeting of the group was held at Brookhaven National Laboratory in conjunction with a two day symposium on Assessing the Industrial Hygiene Monitoring Needs for the Coal Conversion and Oil Shale Industries.

The symposium program included presentations centering around the themes: "Recognition of Occupational Health Monitoring Requirements for the Coal Conversion and Oil Shale Industries" (November 6, 1978) and "Status of Dosimetry Technology for Occupational Health Monitoring for the Coal Conversion and Oil Shale Industries" (November 7, 1978). This information proved to be invaluable when the working group met following the symposium for a third day (November 8, 1978) to draft its final report.

Marshall Islands - Educational Program*

J. R. Naidu

Extensive studies, environmental and health aspects in relation to exposure to fallout, have been conducted in Rongelap and Uterik. However, the inhabitants of these Islands have felt that we should help them understand what these studies portend in terms of their continued habitation on the Islands and the use of the land and surrounding waters as sources of food. Towards this end the author spent six weeks each on Rongelap and Uterik. During this period every effort was made to learn the language and interpret the nature of the bomb, the fallout, the effects of radiation then and now, the meaning of the medical and environmental studies, and finally the need to continue these studies into the future. The success of the initial program is reflected in the questions elicited from the inhabitants. The program is expected to continue.

*To be presented at the Health Physics Society Annual Meeting, Philadelphia, PA, 1979.

S&EP Training Programs

E. T. Lessard

ABSTRACT

Training programs for the Laboratory involve a level of instruction that is commensurate with the degree of hazard involved. The maintenance of these programs assure a knowledge of the effects of potentially hazardous phenomena sufficient to protect the employee and his associates. In addition, knowledge is imparted concerning all safety and emergency procedures to assure the continued safety of personnel and the facility and to assist Laboratory emergency forces, facility users and visitors in times of an emergency. A list of representative programs is given in Table 1.

Table 1

<u>Program Title</u>	<u>Objectives</u>
Departmental Safety Coordinator Training	To explain the role and responsibilities of the departmental safety coordinator.
Fork Truck Safety	To train the initial operators, as well as, to give a refresher course for experienced operators. Forktruck fundamentals, operation, safety, accidents, and operational checks are emphasized.
New Employee Safety Orientation	To develop and maintain minimum safe work procedures in all aspects of safety and to inform Laboratory personnel of their responsibilities towards safety.
General Safety	To impart awareness of common accidents (work, home, pleasure, and driving), causes of muscle strains and hernias, need for respiratory protection and methods of extinguishing fires.
Respirator Program	To provide trainees with knowledge of the need, types, use, inspection, test, and limitations of various types of respiratory equipment.

Table 1 (cont'd.)

<u>Program Title</u>	<u>Objectives</u>
Radiation Worker Training	To train persons in the basic principles of radiation protection and control.
Cardiopulmonary Resuscitation	To fulfill the requirements of the American Red Cross course, "CPR Modular System."
Multimedia System First Aid	To teach basic first aid and accident prevention.
Standard First Aid and Personal Safety	To meet the requirements for the ARC certification,
Advanced First Aid and Emergency Care	To meet the requirements for ARC certification.
Basic Radiation Training	To familiarize firefighters and police force emergency response personnel with CDV700, CDV715, and other radiation detection instrumentation.
Facility Observation Training for Health Physics Technicians	To provide the technician with practical experience.
Health Physics Training Program	To provide qualified graduate students with a thorough understanding of the practical aspects of health physics.
Health Physics Training-Certification Part I Review	To prepare participants for American Board of Health Physics certification.
Facility Observation Training for Police Captains	To inform emergency response personnel about current hazards associated with the operation of a facility, to update local emergency plan information and to familiarize personnel with the current floor plan of the building.
RAP Team Training	To refine radiological emergency response skills and to inform members on current duties and responsibilities.
Laboratory Emergency Exercise	To present emergency response personnel with a realistic set of problems and to evaluate and improve the response.

Table 1 (cont'd.)

<u>Program Title</u>	<u>Objectives</u>
Basic Concepts of Radiological Protection/ Health Physics	To provide assistance and support in the event of a radiological incident, to relate the biological effects of radiation to exposure and time, to explain the nature and magnitude of the radiation hazards at the Laboratory, to operationally check radiological instruments and to assist in qualifying for the NRRPT exam.
Gas Chromatography	To provide practical training in the use of gas chromatograph as an analytical tool for determining the air and water concentration of organic chemicals in the environment.
Management by Objectives	To establish S&EP employee responsibilities and work objectives.
Basic Management Program	To review the functions of the manager's job and what is expected of them as supervisors in S&EP Division, to understand the need for effective communications, to know how to analyze a job and conduct a successful interview, to diagnose human performance problems, and to review methods for conducting employee appraisal.
Improved Technical Reading Skills	To achieve higher reading speeds with increased comprehension.
Effective Presentation Program	To improve public speaking skills and presentation skills.
ALARA/ALAP Concepts in Radiation Protection	To provide health physicists with current knowledge and perspective on radiation protection practices in reactor, medical, university, and nuclear industry related environments.
Radiochemistry Facility Observation and Practical Experience	To familiarize the participants with low level radiochemistry techniques.

Table 1 (cont'd.)

<u>Program Title</u>	<u>Objectives</u>
Practical Industrial Hygiene	To provide practical exposure to an existing industrial hygiene program and its interaction with other areas of safety.
Occupational and Environmental Safety in the Utilization of Radioactive Materials	To provide off-site professionals with exposure to health physics operations at a national laboratory.
S&EP Open House	To inform the general public about the activities of the Safety and Environmental Protection Division.
Basic Applied Health Physics	To provide off-site reactor personnel with the fundamentals of health physics.
New S&EP Employee Indoctrination	To present the overall activities and responsibilities of the S&EP Division to new personnel.
S&EP Technician Seminars	To provide the technician with current information in industrial hygiene, health physics, and general safety.
Health Physics and Safety Training for Reactor Operators	To expose reactor operator trainees to radiation protection procedures.
Reactor Shift Supervisor Health Physics and Safety Training	To thoroughly indoctrinate the trainee in the radiation safety aspects of his work as a shift supervisor.
Advanced Health Physics Facility Observation Training	To acquaint the technician with health physics procedures in an operational reactor. The program emphasizes high and low level radiation and contamination problems.
Biannual HFBR Training	To retrain reactor operators, research coordinators, and reactor supervisors in the areas of health physics and safety.
S&EP Orientation with HFBR	To acquaint fire and police groups with health physics, industrial hygiene, and accident procedures related to emergency response.

Table 1 (cont'd.)

<u>Program Title</u>	<u>Objectives</u>
Reactor Machine Shop and Reactor Instruments Groups - HFBR Health Physics Training	To provide participants with knowledge of radiation standards and to relate radiation and contamination problems associated with RMSG and RIG work.
AGS Emergency Man Reorientation	To provide accelerator S&EP technicians with HFBR emergency access and potential hazard information.
HFBR Indoctrination for Building Access	To allow people access to the HFBR and to review the building emergency plan.
Mobile Crane Safety	To provide practical experience in the operation and safe use of mobile cranes.