LA-11257-PR
Progress Report

UC-41
Issued: April 1988

LA--11257-PR

DE88 009099

*Health, Safety,
and Environment
Division*

Annual Report 1987

*Compiled by
Mary Ann Rosenthal*

MASTER

ms
DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

Los Alamos Los Alamos National Laboratory
Los Alamos, New Mexico 87545

Abstract 1

Industrial Hygiene 3

A Study of Ventilation Rates in Plutonium-Handling Laboratories	5
An Investigation of Laboratory Hood Airflow Characteristics Using Fast Thermal Anemometers	7
Evaluation of Negative-Air Systems Used in Asbestos Removal	9
Technical Support for Filter Test Facilities	12
Technology Transfer—High-Flow Alternate Filter Test System	14
Evaluation of Potential Dust-Related Health Hazards Associated with Drilling	15
Health Effects Study of a Commercial Coal Gasification Facility	17
Review of Beryllium Operations at Lawrence Livermore National Laboratory	19
The Resuspension of Small Particles from Protective Clothing	20
Automation of Guidelines for Selection of Chemical Protective Clothing	22
Respirator Studies for the Department of Energy	23
Effects of Temperature and Humidity on Respirator Fit Under Simulated Work Conditions	28
Sorbent Testing	31
Evaluation of Navy Escape-Type Breathing Apparatus	37
Technology Transfer—Automated Respirator Fit Test System	38

Health and Environmental Chemistry 39

Determination of Plutonium in Human Tissues	41
Environmental Chemistry for the National Park Service	52

REPRODUCED FROM
BEST AVAILABLE COPY

<i>Epidemiology</i>	53
Mortality Among Plutonium and Other Radiation Workers at the Rocky Flats Facility	55
Mortality Among Mound Employees: 1942–1979	56
Mortality Among Women Employed by the Los Alamos National Laboratory: 1943–1981	57
A 42-Year Follow-up of Manhattan Project Plutonium Workers	58
 <i>Environmental Surveillance</i>	 61
Environmental Surveillance at Los Alamos	63
Environmental Support Activities	70
 <i>Environmental Science</i>	 79
Contaminant Transport in Southwestern Ecosystems	81
Radionuclide Inventory and Distribution at the Nevada Test Site	84
Trench Cover Systems for Manipulating Water Balance on Low-Level Radioactive Waste Sites	85
Waste-Site Closure Demonstration— A Field-Scale Study	89
Development of an Arid-Site Closure Plan— A Modeling Study	91
Modeling of Radionuclide Transport at An Inactive-Material Disposal Area	92
Reactive Tracer Tests in the C-Wells and Other Wells in the Vicinity of Yucca Mountain	93
Surfactant Flooding Technology for Cleanup of Contaminated Soils and Aquifers	94
Vapor Transport of Organic Chemicals: Model Development	96
Sorption Modeling	98
Development of a Solar-Blind Raman LIDAR for Evapotranspiration Measurement	101
 <i>Publications</i>	 103
<i>Organization</i>	109

REPRODUCED FROM
BEST AVAILABLE COPY

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 environment protection. These activities are designed to protect the worker, 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 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 and to help develop better occupational health and safety practices.

REPRODUCED FROM
BEST AVAILABLE COPY

REPRODUCED FROM
BEST AVAILABLE COPY

A Study of Ventilation Rates in Plutonium-Handling Laboratories

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

M. Gonzales (Chemistry Health Protection, HSE-10)

Technical Assistance: *L. Romero (Health Physics, HSE-1),*

J. Bennett (Kaiser Engineers, Los Alamos, New Mexico),

and R. Lopez (Salem Services, Los Alamos, New Mexico)

Group: *Industrial Hygiene, HSE-5*

Funding Organization: *Department of Energy,*

Albuquerque Operations Office

The purpose of this ongoing study is to determine the effect of various ventilation rates on airborne contaminant releases in plutonium-handling laboratories. Disparate ventilation rates are now being used in such facilities with little apparent technical justification. The effect of changing ventilation rates on health-related parameters, such as contaminant clearance rates, time and position of maximum concentration, mixing factors, and turbulence, is largely unknown. In addition, little guidance is available to designers concerning the optimum type and location of air inlet and exhaust fixtures, effect of glove box arrangements on air patterns, etc.

Specifically, the primary objective of the study is to compare the effectiveness of different work-space ventilation air exchange rates through plutonium-handling laboratories on the basis of the following criteria:

- (1) health protection (as indicated by air monitoring, exposure, and bioassay data) provided to workers during operations under known ventilation conditions and
- (2) clearance time of tracer gases or aerosols (including clearance by deposition) during simulations of radioactive material release.

During the past year, data pertaining to criterion (1) have been gathered from Los Alamos (TA-55) and Rocky Flats Plant (RFP) records. Air sampling data from continuous-air monitors, filter samples, nose swipes, and other pertinent data recorded during plutonium releases were obtained from each facility. The data have been reduced to usable form, recorded in a data base, and subjected to some statistical analysis to examine similarities. Contour maps of contamination spread in each incident have been generated for the purpose of determining differences between incidents.

Ventilation rates at RFP, which are approximately twice those at TA-55, may exhibit different statistics of contamination concentration gradient, maximum concentration, or other features to indicate the effectiveness of the different ventilation rates.

Work on criterion (2) consisted of designing aerosol experiments to be performed in each of three laboratories, selecting and testing an aerosol detection system and anemometer array system, and development and preliminary validation of a theoretical model applicable to airflow patterns in large laboratories.

Testing of anemometric and aerosol equipment was performed, along with validation of a numeric code to model airflow patterns in an isothermal environmental chamber (EC), which is 3.3 m on each side (cubical). The Reactor Safety Analysis Group (N-6) provided modeling expertise to predict the airflow field in the EC using a three-dimensional numerical code, SOLA-DM, with the chamber empty and with a simulated glove box in place. The airflow field was then tested using a research thermal anemometer and a neutral-buoyancy bubble generator developed for this purpose. The model predicted well the flow vectors within the empty chamber but did not agree with measured vector fields with the glove box in place.

The three laboratories to be used for full-scale aerosol experiments are (1) a former, decontaminated plutonium production lab at Los Alamos (DP-West); (2) a production lab at TA-55; and (3) a production lab at RFP. The DP-West lab, which is 40 by 30 by 16 ft high, will provide a cold test facility for full-scale testing of anemometry and aerosol sampling arrays, developing experimental procedures, and improving the computer modeling before conducting experiments in actual plutonium laboratories. Mockup glove-box lines

(simulating those of a TA-55 laboratory) were installed, and the ventilation system was modified to simulate that of present TA-55 labs. Experiments were designed to determine the effect of three ventilation rates (~4, 8, and 16 air changes/hour) in each of these labs on (a) the spatial and temporal variation of the aerosol concentration, (b) clearance rates of aerosol from the

labs, (c) aerosol deposition, and (d) airflow patterns within the labs.

From the results of the experiments and modeling, recommendations will be made concerning the ventilation of such laboratories, and guidelines for the design of such facilities will be developed to supplement present DOE design criteria.

An Investigation of Laboratory Hood Airflow Characteristics Using Fast Thermal Anemometers

Author: C. I. Fairchild

Group: Industrial Hygiene, IISE-5

Funding Organization: Department of Energy,
Office of Operational Safety

A method that may be useful for field measurements of hood containment was described in detail previously.¹ A following, brief investigation of turbulence characteristics of the airflow into an operating fume hood, using the apparatus of the containment measuring system, was performed. The latter investigation, reported here, provided further insight into the mechanism of leakage from a fume hood.

In the development of the light photometer/aerosol system,¹ a forward scattering-light photometer (FSLP) and data acquisition system in combination with a submicron aerosol were used to determine quantitatively the containment of several laboratory hoods. Two FSLPs were used in tests to simultaneously compare leakage from two positions. To measure leakage, we compared the total light scattered from a concentrated aerosol released within the hood with the total light scattered from aerosol escaping the hood at a sampling position. For the present investigation, the FSLPs were replaced by a single high-speed, constant temperature, linearized thermal anemometer (TSI, Model 1054A) with output to a Hewlett-Packard (HP-85) computer. Velocity measurements were made at the same positions in one hood for which leakage measurements had been made.

Normally, concentration data had been taken in the containment study at a rate of 2 Hz and averaged every 2 s after experiments in which data were taken at faster and slower rates indicated this rate to be optimum. Consequently, velocity measurements were made at the same rate.

A typical leak concentration measured at one position below the hood sash (Figure 1) shows the rapid variation in concentration observed in all leaks near surfaces of the hood face. The typical average room aerosol (background) and the minimum concentration reading accepted by the computer, which was at least the background average plus two standard deviations, are shown by the lines near the bottom of the graph in Figure 1. The title legend identifies the average face velocity (125 ft/min) determined by a 12-point anemometer traverse, and the smaller legend gives sash and probe position referred to the center, bottom edge of

the sash, as well as information as to whether an auxiliary airfoil was used beneath the sash. (In Figure 1, the sash was 26 in. above the hood base; the probe position, -18 in., -0.5 in. This indicates that the probe was 18 in. to the left of the sash center and 1/2 in. below the sash edge.) The small legend also shows the average concentration (not integrated concentration) of the leak as a percentage of the aerosol release concentration (0.007%).

Figure 2 shows a velocity trace taken at the same position as the leakage trace of Figure 1. Although the data were taken at the same rate as for the two FSLPs, twice as many concentration data points are plotted because the FSLPs sampled alternately, producing a dead time of 2 s between each FSLP data point in Figure 1. Even though the apparent frequency of concentration readings is only half that of the velocity data, it is evident that the leakage (Figure 1) and the airflow velocity (Figure 2) have a similar high-frequency structure. The mean velocity of 61.2 ft/min, being much below the free-stream average velocity of 125 ft/min, indicates that the probe is in the turbulent boundary layer of the airflow entering the hood. Also, some of the velocity vectors may be out of the hood in the turbulent boundary layer flow because the anemometer probe used cannot discriminate flow direction. Leakage may occur during periods when the velocity reaches a minimum and when flow reversals occur. The velocity information also indicates that the turbulent boundary layer is an inherent feature of the flow into a hood at its bounding surfaces. Considerable study and aerodynamic design of the hood entrance, as described in Reference 1, would be required to decrease contaminant leakage.

Reference

1. C. I. Fairchild, "An Investigation of Laboratory Hood Containment Using a Light Photometer/Aerosol System," in H. J. Ettinger, Ed., "Industrial Hygiene Group 1986 Annual Report on Research and Special Activities," Los Alamos National Laboratory report LA-11100-MS (1987).

Figure 1. Typical hood leakage 0.5 in. beneath sash, illustrating rapid fluctuations in concentration.

Figure 2. Typical velocity fluctuations 0.5 in. beneath fume hood sash, illustrating high-frequency structure.

Evaluation of Negative-Air Systems Used in Asbestos Removal

Authors: J. M. Ortega, J. P. Ortiz, and E. D. Garcia

Group: Industrial Hygiene, HSE-5

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

In past years, asbestos was known as the "wonder material" and was praised for its unique physical properties. This fact was the reason for its many uses in the mid-1900s as insulation, fireproofing, and binder material. As its health effects became known, this material, used extensively during World War II, was credited with being a human carcinogen.

In the 1970s, the Environmental Protection Agency (EPA) initiated asbestos awareness programs, which made asbestos a major health and political issue nationwide. This awareness initiated a new industry. The asbestos abatement industry addresses removal or mediation of asbestos in buildings, presently primarily schools and commercial buildings. One major problem not addressed by either the EPA or other federal agencies was ensuring that the technology meets the needs of the industry. This fact has caused significant exposures to airborne asbestos because of removal operations.

One important aspect of asbestos abatement is negative-air machines (HEPA-filtered exhaust systems) used in conjunction with an enclosure to contain the asbestos removal operation. In this area, the federal agencies have not developed criteria that would ensure quality of the equipment presently used. Also, the rapid development of the asbestos abatement industry has caused development of equipment with no quality control or testing by the manufacturers or contractors. This problem is exemplified by the negative-air machines on the market today.

Recently, we had two outside contractors doing asbestos abatement work on site. As part of the contract, we monitored their negative-air machines and found that the machines did not meet our criterion of 99.95% efficiency. These systems tested in the 80% range, but after extensive modification and guidance, the best that could be achieved was 97%. These systems did use a HEPA filter with an efficiency of 99.97%, but the systems (holding systems for the filter) were not well constructed.

Later in the year, our contractor ordered two new systems from a leading manufacturer of negative-air machines for a removal project. Both units were tested and found to be only 10% and 60% efficient. We then contacted the manufacturer, who promptly sent two new units that he felt were of better quality, but these two additional units did not pass our tests. A review of the Occupational Safety and Health Administration (OSHA)¹ and EPA² guidelines for specific requirements was initiated, but they did not give any guidance beyond a sketch of a typical system (Figure 1).¹

Figure 1. An example of a HEPA-filtered exhaust unit. This scheme is one of several possible design.

We then approached DOE/OOS with a proposal to test commercially available systems for overall efficiency, which is required by the nuclear industry. The funding was approved, and seven commercially available negative-air machines were blindly purchased from vendors; that is, the vendors were not informed of the intended use of these units so that special units would not be sent. Table I lists the seven units purchased and their costs.

The test results were similar to those previously tested with only two systems passing our criteria, but of these two, only one system far exceeded the minimum criteria. Table II shows the results by manufacturer versus efficiency and decontamination factor (2000 equal to 99.95%). The two systems that passed our testing were systems with the HEPA filter located on the positive side of the fan. Also, the Microtrap and Red Baron systems, which the manufacturers claim to meet

Table I. HEPA-Filtered Exhaust Systems Tested

System	Cost (\$)
Airmop 2000	1995
CRSI 2000	2150
Microtrap MT-C	1850
Quad Air	2075
Red Baron ST2000	2270
Sentry 2000	2295
Tri-Dem Accu-2M3	1884

Table II. Test Results^a

System	Decontamination Factor	Efficiency (%)
Airmop 2000	811	99.88
CRSI 2000	2,308	99.96
Microtrap MT-C	1,078	99.91
Quad Air	650	99.85
Red Baron ST2000	43	97.7
Sentry 2000	8.6	88.37
Tri-Dem Accu-2M3	10,000	99.999+

^aAll systems operating at 2-in.-wg SP.

The test protocol was to ensure the units were not damaged in shipping, to verify that the HEPA filters had at least 99.97% efficiency, and to test each system for efficiency using our standard nuclear HEPA test methods.

The test methods used are those methods outlined by ANSI/ASME N510³ and NEF 341T.⁴ The aerosol was di-2-ethylhexyl sebacate at a mean diameter of 0.17 to 0.2 μm . The average challenge concentration was 6 to 9 mg/m^3 . Figure 2 shows the test apparatus, which used a laser spectrometer as the measuring device.

EPA,¹ ANSI,³ and EPA² standards, did not meet the minimum test criteria.

The units that passed the test may not pass the test with time and handling, but also the units that did not pass would further deteriorate largely because of the extensive use of silicone caulking in the equipment to make it airtight. Many of the units also used light-gauge metal, which may not stand up to the abuse and pressure differential and may account for their failure to meet the criteria.

Recommendations

This industry needs further evaluation as to the adequacy of its regulations and working standards. We strongly feel that criteria should be established and/or research be done to establish minimum construction and certification standards for negative-air machines used for asbestos work. Also, in-place testing procedures should be established to ensure that units are tested at least annually, after every filter change, or when damage is possible or suspected (dropping, high level of humidity, etc.).

We must also evaluate the need for two or more filters. This concern is because HEPA filters will be size

Figure 2. HEPA-filtered exhaust test setup.

selective and fibers that are smaller than 0.3 µm may be discharged from the exhaust system. The toxicology of these smaller asbestos fibers is unknown.

References

1. *Guidance for Controlling Asbestos-Containing Materials in Buildings (EPA 56015-85-024)* (United States Environmental Protection Agency, Washington, DC, 1985).
2. Code of Federal Regulations; Title 29, Part 1926.58: *Construction Safety, Asbestos, Tremolite, Anthophyllite and Actinolite* (U.S. Department of Labor, Washington, DC, 1986).
3. *Testing of Nuclear Aircleaning Systems (ANSI/ASME N510-1980)* (American National Standard/American Society of Mechanical Engineers, New York, New York, 1980).
4. *In-Place Testing of HEPA Filter Systems by the Single-Particle, Particle-Size Spectrometer Method (NE F 3-41T)* (U.S. Department of Energy Nuclear Energy Program, 1986).

Technical Support for Filter Test Facilities

Authors: A. L. Hack and R. C. Scripsick

Technical Assistance: A. G. Trujillo

Group: Industrial Hygiene, HSE-5

Funding Organization: Department of Energy (DOE),
Albuquerque Operations Office, Waste Management and
Transportation Division, Interim Waste Operations

Introduction

This program provides technical support to the DOE filter test facilities (FTFs) by carrying out scheduled activities and assisting in the solution of special problems that arise. Activities that have continued for several years include (1) initiating and reviewing round-robin tests (RRTs), (2) preparing reports summarizing yearly activities of the FTFs, and (3) providing technical consulting services to the FTFs. In addition to the scheduled activities, Los Alamos is available to provide technical assistance to the DOE and FTFs in addressing special problems that arise. For 1987 special assistance was provided for the transfer of the high-flow alternative filter test system (HFATS) both to the manufacturers of filters and to the FTFs.

Round-Robin Test Program

The RRT program monitors the consistency of FTF measurements by circulating six high-efficiency particulate air (HEPA) filters through each of the three FTFs. One of the FTFs serves as a reference and tests the filters before and after the filters are circulated. The reference testing serves to document that the test filters have not been affected by the test program and provides information on the internal consistency of the reference FTF. In 1987 Los Alamos coordinated two RRTs, interpreted the results of the RRTs, and examined data collected over the history of the RRT program for trends.

FTF Semiannual Report Summary

In the fall and spring, each FTF issues a report detailing numbers of filters accepted and rejected for each shipment during the previous six months. Los Alamos examines these data to assess the consistency of FTF tests and the quality of filters provided by individual manufacturers.

The FTF semiannual reports are archived on a Los Alamos data base so that the long term can be studied. These data also serve as a reference to assess the future performance of the FTFs and the quality of filters received from individual manufacturers.

HFATS Support Activities

An alternative to the current filter test system (Q107) used to test size 4 (500 ft³/min rated flow) and larger nuclear-grade HEPA filters at DOE FTFs has been developed at Los Alamos. This new test system, the HFATS, consists of a air-operated nozzle aerosol generator and a laser aerosol spectrometer (LAS)/diluter monitoring system. To proceed with the transfer of the HFATS, three major activities were performed: (1) a demonstration of the HFATS, (2) support of the FTFs in acquisition of their own HFATS, and (3) a comparison of filters tested by the various manufacturers on their own filter test equipment.

A demonstration of the HFATS was held in February at the Oak Ridge FTF. Participants in the demonstration included representatives of all three FTFs and seven filter manufacturers. In addition, the representative of the manufacturer of the Q-107 attended. Each session consisted of a brief introduction of the technology to be transferred, the schedule for adoption of the new technology by the DOE and the U.S. Army, a demonstration of the HFATS unit including testing of a filter, a discussion of the features of the HFATS, and perhaps most important, an opportunity for the participants to operate the HFATS while testing filters that they brought.

The support provided to the FTFs for the building of their own HFATS included the preparation of blueprints, specifications, and instruction manuals. In addition, computer software for operation of the laser spectrometer used with the HFATS was provided. Finally, a calibration service was established in which

spectrometers modified by the manufacturer specifically for HFATS use were calibrated before being sent to the FTFs. Flow calibration plates, which were designed last year, were manufactured to our specifications. These were sent to the Oak Ridge gas calibration facility and, after calibration, will be provided to each FTF. Use of the plates allows an exact flow determination to be made in the filter chuck of the HFATS at each of the three FTFs.

The filter manufacturers are participating in a comparison of filter performance measured by their filter test equipment compared with the HFATS prototype installed at Oak Ridge. Most of the manufacturers already have laser aerosol spectrometer filter test systems. Although not identical to the HFATS system, the laser spectrometer will permit a realistic comparison for filter performance. At year's end, we had received data from all the manufacturers except one. The comparison report will be issued next year.

Technology Transfer—High-Flow Alternate Filter Test System

Authors: A. L. Hack and R. C. Scripsick

Technical Assistance: A. G. Trujillo

Funding Organization: Product Assurance Directorate,
U.S. Army

The Product Assurance Directorate (PAD) of the U.S. Army has agreed to cooperate with the Department of Energy (DOE) in the development of improved technology for the testing of large air filters used by the DOE to protect the environment from radioactive materials. The Army's prime requirement for space filters is in the protection of buildings and vehicles from nuclear, biological, and chemical aerosols, called NBC protection. The standard test for large filters at present is the same as for respirator filters—use of a single-size (monodisperse) oil droplet aerosol to challenge the filter with detection of leakage by a light-scattering instrument.

The new high-flow alternate test system, developed for the DOE under the technical support for filter test activity, uses a multisize (polydisperse) aerosol and a laser aerosol particle spectrometer that can determine the efficiency of the filter over a range of particle sizes.

This year we developed detailed specifications for a special filter test system designed to meet PAD requirements. The Army requirements differ from those of DOE, that is, filters up to 4 by 4 ft, 2000ft³/min, and 8-in. water-column pressure drop. The higher pressure drop is required because, unlike DOE filters, the Army filters contain an additional charcoal bed for gas sorption.

Bids were solicited from vendors to build the test stand portion of the filter system, consisting of ducts, blowers, valves, controls, and pneumatic test chuck. A successful bidder was selected, but awarding of the bid awaits funding.

Also assembled at Los Alamos this year were aerosol generators, samplers, laser detector, and computer data acquisition system. In addition, modifications to the diluter system were tested to make the dilution ratio relatively immune to pressure changes in the duct supplying aerosol to the filter under test. The airflow in the duct is adjusted to the airflow required by the filter, which can vary from 100 to 2000 ft³/min. This change in flow causes a corresponding change in the pressure in the duct. A diluter is used to permit the aerosol detection instrument (a laser aerosol particle spectrometer) to sample the higher concentrations of aerosol upstream of the test filter. No diluter is required downstream.

After the vendor has completed construction of the test stand components, which will occur no earlier than fall 1988, we will supervise the mating of the components on location at Edgewood Arsenal; obtain a suitable aerosol; prove successful operation; train PAD personnel; and provide documentation, instructions, and technical support.

Evaluation of Potential Dust-Related Health Hazards Associated with Drilling

Authors: B. J. Skaggs, L. W. Ortiz, and B. L. Isom

Technical Assistance: L. D. Wheat and E. A. Vigil

Group: Industrial Hygiene, HSE-5

Funding Organization: Department of Energy,
Nevada Operations Office

The Nevada Nuclear Waste Storage Investigations (NNWSI) Project was established to evaluate the potential for storing radioactive wastes in geologic formations of Yucca Mountain (adjacent to the Nevada Test Site [NTS]). Before *in situ* tests in the Exploratory Shaft Facility at Yucca Mountain, field-scale tests are to be conducted in G-tunnel at NTS. The U.S. Geological Survey hydrologists have recommended that drilling or coring in support of tests be done dry (with air as the drilling fluid). The prototype air-coring test will address the technical feasibility of air coring short, horizontal holes in fractured, welded tuff; identify related problem areas; and provide holes for subsequent prototype tests.

Work to date at the Yucca Mountain site has indicated two areas of concern for potential health hazards to persons exposed to dust and fibers generated from rock at the site:

(1) The rock generally has high percentages of crystalline silica (including quartz, tridymite, and cristobalite), ranging from 20% to more than 70%. Achieving the current occupational exposure levels during dry drilling of rock containing high levels of silica will require excellent dust control procedures.

(2) Natural zeolites (predominantly clinoptilolite, mordenite, and heulandite) are also abundant. Some of the zeolites are fibrous, leading to a concern that inhalation of zeolite dusts may result in asbestos-like lung diseases. Erionite has been identified as a fracture-lining mineral in samples from only one borehole. Animal toxicology studies indicate that erionite may have a far greater potential for causing lung tumors than asbestos. Epidemiologic studies of a village in Turkey where airborne erionite is present also indicate high incidence of lung disease, including mesothelioma, which is usually associated only with asbestos exposure. Because this disease will not manifest itself for many years after exposure, the adequacy of engineering controls must be evaluated before drilling begins.

This program is designed to (1) identify and evaluate the potential for exposures to airborne silica, nuisance dusts, and fibrous zeolites; and (2) evaluate the effectiveness of the commercial dust control equipment to be attached to the drilling apparatus for this NNWSI project.

The program has been divided into four distinctive tasks as follows:

Analysis of bulk samples. Preliminary scanning electron microscope (SEM) preparations and photomicrographs were prepared from the bulk mineral samples collected in G-tunnel. The energy dispersive x-ray (EDX) analysis to distinguish types of fibers was unsuccessful because of high background concentration of nonfibrous particulates. Two mineral samples of erionite were also obtained for use as possible reference sources; however, preliminary examination by phase contrast microscopy seemed to indicate that morphology and count analyses would have to be conducted with the SEM.

Two pieces of Yucca Mountain core-material mineral samples were obtained from the Los Alamos Geology/Geochemistry Group, ESS-1. The samples were selected as likely candidates for containing mordenite and/or erionite. Preliminary SEM imaging and EDX were performed on these samples. An erionite sample from Pine Valley, Nevada, was also obtained from a commercial mineral supply source to be used as reference material, and the reference spectra were obtained from ESS-1.

Several detailed quality assurance (QA) procedures were developed, reviewed extensively, and approved.

Computerized literature searches covering 1982 to the present were initiated with the main Laboratory library to update existing information on lung diseases caused by zeolites. This material was reviewed and documents of interest were requested. A listing of zeolite documents on hand was also completed.

Field study. Available field sampling equipment was inventoried and the necessary equipment not available was ordered. Candidate laboratories for photon-induced x-ray emission (PIXE) analysis and crystalline silica analysis were requested to send QA/quality control information so each laboratory could be evaluated by the NNWSI QA liaison for this QA Level II project. QA Level II is the second most stringent level of QA for the NNWSI project and includes items or activities involved with (a) nonradiological health and safety of the general public; (b) nonradiological health and safety of the candidate site workers; and (c) reliability and maintainability of any item or activity that might present a hazard to the general public, the candidate site workers, or the environment. Elemental Analysis Corporation of Tallahassee, Florida, was awarded the contract for PIXE analysis and DataChem of Salt Lake City, Utah, was awarded the contract for silica analysis.

Project documentation was developed as required, such as the detailed test plan and the criteria letter for support at NTS. Additional detailed QA procedures were developed and approved for the field studies.

Evaluation of the drilling and dust control equipment. ESS-1 provided limited information on the dust control equipment being considered. Preliminary estimates of potential silica exposures for dry-drilling tests were developed for the drilling and dust collection equipment that had been recommended by the ESS-1 principal investigator and drilling consultant. These estimates were made using the stick model shown in Figure 1, which addresses operating parameters and fugitive emissions. Based on 70% free silica, airborne concentrations could exceed $1.2\text{mg}/\text{m}^3$ with the allowable exposure levels being between 0.07 and $1.5\text{mg}/\text{m}^3$. This would require all personnel in the area to wear appropriate respiratory protection. Significant dust concentrations from the dust collection system could be controlled by exhausting the air cleaner exhaust directly into the tunnel exhaust duct. An interim report was prepared on the evaluation of the dust collection systems recommended by ESS-1.

Figure 1. Potential emission sources.

Recommendations. Recommendations for operating procedures and health/safety requirements to be implemented during exploratory shaft studies at Yucca Mountain will be based on the data and conclusions from the bulk sample analysis, evaluation of dust control equipment, and field study sample analysis.

In late 1987, the budget for this project was cut because of the turmoil in the U.S. Congress relating to the number of sites to be evaluated for nuclear waste storage. The project may be reactivated when the evaluation of dry drilling is required.

Health Effects Study of A Commercial Coal Gasification Facility

Author: J. O. Jackson

Technical Assistance: W. E. Atencio and L. M. Woodrow

Group: Industrial Hygiene, HSE-5

Funding Organization: Department of Energy, Office of Health and Environmental Research

Since 1981, U.S. and Yugoslav scientists have been investigating the potential occupational health problems associated with operation of the commercial-scale coal gasification facility located near Prishtina, Kosova Province, Yugoslavia. The Lurgi technology used in Kosova is also used at Great Plains in Beulah, North Dakota, and is likely to be employed in any large U.S. gasification industry. Thus, evaluating the potential health effects associated with this technology will help develop appropriate control measures and is an appropriate and timely opportunity. U.S. organizations performing the study are Los Alamos National Laboratory, with responsibility for industrial hygiene studies, and Brookhaven National Laboratory (BNL), with responsibility for epidemiology and limited clinical medicine studies. The Yugoslav principal investigator is associated with the University of Kosova Medical College.

Area sampling was performed in 1984 to determine the type and extent of workplace contaminants. Personal sampling and some supplemental area sampling were accomplished in 1985. Tasks for 1986 included completion of all analytical work, data reduction and evaluation, and preparation of a draft final report, which is a three-volume joint publication of BNL and Los Alamos. Volume I is the summary,¹ Volume II describes the industrial hygiene program,² and Volume III³ describes the epidemiology program. Drafts of all volumes were prepared and reviewed by both Yugoslav and U.S. scientists in 1986. Volume II, prepared by the Los Alamos Industrial Hygiene Group, was finalized, printed, and distributed in 1987. Open literature publications are being written and expected to be submitted in 1988.

Results of the personal sampling are presented in Table I. These data show that personal exposures can occasionally reach and exceed U.S. standards. The table also shows the highest and second highest job categories for the specific analytes determined, along with the range and the geometric mean for each analyte.

Conclusions from the industrial hygiene study follow:

(1) An overall assessment of the project shows that the majority of objectives of this study were achieved. A personnel exposure data base was developed for use in the retrospective epidemiologic study. Data not available elsewhere were obtained in this study.

(2) In general, workplace contaminant levels found at Kosova are similar to those reported in U.S. synthetic fuel pilot plants and demonstration units.⁴⁻⁶

(3) U.S. or Yugoslav 8-h TWA occupational exposure limits were exceeded only in a few instances. This does not minimize the potential for acute exposures to approach dangerous levels, particularly for carbon monoxide and hydrogen sulfide. These situations occur because of fugitive leaks on process and blowdown lines.

(4) Because of extensive surface contamination throughout the gasification facility, a significant probability exists of worker contact with liquid process material. This is even more significant and of concern because the workers used little, if any, personal protective equipment.

(5) Worker exposures at the Kosova plant are lower than expected considering the size of the facility. Under normal operating conditions, contaminants are released at locations that are not permanent work stations, and releases are not usually the result of an operator's actions. Nevertheless, large quantities of toxic material are present, and under upset conditions or during major maintenance, it is likely the workers would directly handle and come in contact with these materials. Furthermore, engineering controls of health hazards are not used in the Kosova plant.

(6) The work environment contaminant concentrations are highly variable. This is caused, in part, by the plant being located outdoors, process leaks, and variable local micrometeorology. This variability was observed in direct-reading instruments, static monitoring devices, as well as in personnel monitoring.

Table 1. Summary of Personal Sampling Data in April and May 1985

Workplace Contaminant	Geometric Mean (mg/m ³)	Range (mg/m ³)	Job Categories with Highest and Next Highest Exposure
Benzene	0.1	<0.02–20	Phenosolvan and rectisol plant maintenance worker Rectisol plant outer-equipment operator
Toluene	0.1	<0.02–15	Phenosolvan and rectisol plant maintenance worker Rectisol plant outer-equipment operator
Total hydrocarbons	0.42	<0.02–43	Phenosolvan and rectisol plant maintenance worker Rectisol plant outer-equipment operator
PAHs	0.03	<0.002–0.2	Ash removal operator Lockhopper operator
Total dust	0.22	<0.01–10	Generator plant supervisor Ash removal operator
Respirable dust	0.10	<0.01–1.1	Water gas and gas-washing operator Ash removal operator
CTPV	0.03	<0.01–1.2	Lockhopper operator Phenosolvan pump operator

(7) Data acquired from 1981 to 1982 by the Yugoslavs are fairly consistent with our joint 1984 to 1985 study. The variability in (6) above was also noted in the 1981 to 1982 data.

(8) During this study period, the gasification plant was not operating at or near capacity; therefore, the personal and area sampling results may be lower than would be expected from a fully operating plant.

(9) Some differences exist between the U.S. and Yugoslav analytical data, particularly between some of the organic vapor and PAH samples.

Several conclusions of the retrospective epidemiology study performed by BNL follow:

(1) No evidence of skin cancer was observed even after more than 10 years of operation (as opposed to the Union Carbide study of Institute, West Virginia, where skin cancer was found within five years of first exposure).

(2) No statistically significant difference in incidence rates for the 12 disease categories investigated were found between gasification plant workers and lignite surface miners, the comparison group.

Although this multidisciplinary study yielded valuable information that can and should be applied to U.S. facilities, the latency period was insufficient to allow a complete assessment of the concerns (other than skin) related to occupational disease associated with coal conversion technologies. This limitation must be considered in any evaluation of the study.

References

1. S. Morris et al., "Kosova Coal Gasification Plant Health Effects Study, Vol. I. Summary," Brookhaven National Laboratory report BNL-40629 (1987).
2. M. T. Brandt et al., "Kosova Coal Gasification Plant Health Effects Study, Vol. II. Industrial Hygiene," Los Alamos National Laboratory report LA-10850 (1987).
3. S. Morris, J. Jackson, and M. Haxhiu, "Kosova Coal Gasification Plant Health Effects Study, Vol. III. Retrospective Epidemiology," Brookhaven National Laboratory report BNL-40629 (1987).
4. J. O. Jackson, R. T. Cheng, and J. F. Smith, "Industrial Hygiene Program for a Solvent Refined Coal Plant," presented at the 1977 American Industrial Hygiene Association Conference, New Orleans, Louisiana, May 1977.
5. J. O. Jackson, "Industrial Hygiene Aspects of Coal Conversion Operations," presented at the American Petroleum Institute Symposium on Coal Conversion Technology: Health and Environmental Considerations, Washington, DC, June 1978.
6. "Criteria for a Recommended Standard—Occupational Exposures in Coal Gasification Plants," National Institute for Occupational Safety and Health report NIOSH 78-191 (1978).

Review of Beryllium Operations at Lawrence Livermore National Laboratory

Authors: *K. M. Hargis and L. L. Garcia*

Technical Assistance: *W. E. Atencio*

Group: *Industrial Hygiene, HSE-5*

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

The DOE established the Industrial Hygiene Task Force at Los Alamos to provide assistance to the OOS. During 1987, these activities included participation in a special review of beryllium operations at the Lawrence Livermore National Laboratory (LLNL). Other activities under the Task Force included (1) testing of negative-air filtration systems used in asbestos abatement projects and (2) an investigation of laboratory hood airflow characteristics with fast thermal anemometers. Details of those activities are also contained within this report.

The Industrial Hygiene Task Force participated with personnel from DOE/OOS and Oak Ridge Associated Universities in a review of the industrial hygiene and medical programs for beryllium operations at LLNL, which included both the LLNL beryllium machine shop and the explosives operations at Site 300. Similar reviews of the beryllium operations at the Rocky Flats Plant and the Oak Ridge Y-12 Plant were conducted in 1986. These reviews were conducted in response to several possible cases of beryllium disease that have been identified in recent years at DOE facilities.

The reviews of the industrial hygiene programs emphasized evaluation of beryllium monitoring and exposure control aspects of the operations. The reviews

of beryllium monitoring included procedures and data for personal air sampling, area air sampling, swipe sampling for surface contamination, and the analytical program for beryllium samples. The review at LLNL by DOE and Task Force personnel also included collection of personal air samples on employees working in the beryllium machine shop.

The review of industrial hygiene controls included evaluation of engineering controls, administrative controls, personal protective equipment, and housekeeping. Reviews of programs for employee information and training included the status of hazard communication and employee notification of exposure levels.

A summary of findings and recommendations were developed for each of the facilities in conjunction with other members of the review group, and a report was prepared. Findings emphasized the presence of good, effective industrial hygiene and medical programs at the facilities. Recommendations were offered for improvement and greater consistency among the facilities and are being incorporated by OOS into an appendix to DOE Order 5480.10, "Contractor Industrial Hygiene Program."

The Resuspension of Small Particles from Protective Clothing

Author: M. I. Tillery

Technical Assistance: R. Lopez

Group: Industrial Hygiene, HSE-5

Funding Organization: U.S. Army, Chemical Research,
Development and Engineering Center

This study is directed at resuspension of aerosol particles from protective clothing. The principal concern is resuspension that might occur during the removal of contaminated clothing. Measurement of resuspension from a fully clothed individual would require a large wind tunnel and be difficult to quantitate. To avoid these problems, the experimental design calls for measurement of the resuspension from components of the protective suit in a small wind tunnel.

Figure 1 shows a schematic view of the tunnel. Air requirements are minimized by recirculation. The recirculating portion of the tunnel is 6-in.-diam polyvinyl chloride pipe, and the resuspension or experimental section is stainless steel. The resuspension section is rectangular in cross section with a height of 6 in. and a width of 10 in. The suit component is mounted near the start of the resuspension section at the center of the tunnel where the velocity profile is relatively constant across the entire surface of the cloth. Provision has been made to operate closure devices, such as zippers, snaps, Velcro strips, and draw strings, with externally mounted fixtures. Resuspension is determined by collection of air samples downstream of the cloth sample at four locations for concentration and one location for particle size. The resuspension section is followed by a HEPA filter to remove all airborne particles and a variable-speed centrifugal fan. Total flow is monitored by static pressure taps located along the vertical straight portion of the recirculating arm.

Three different loading methods are used for the cloth samples for the resuspension studies. In the first case, aerosol is collected on clean cloth samples by drawing aerosol-laden air through the cloth. The quantity of aerosol collected on the cloth is determined by comparing the aerosol concentration in the penetrating air with the challenge air. In the second and third cases, the cloth samples are first soiled by either standard dust (American Society of Heating, Refrigeration and Air Conditioning Engineers) or by

Figure 1. Schematic view of wind tunnel.

fuller's earth and then loaded with aerosol particles in the same manner as the clean cloth. Aerosol loading is carried out in a cylindrical chamber having a diameter of about 15 cm and an internal volume of about 36 L. The aerosol of sodium chloride particles tagged with a fluorescent dye is generated with a DeVilbiss Model 40 glass nebulizer.

Midline velocities at the location of the resuspension sample can be varied from 10 to 920 ft/min. Initial velocity profile measurements indicated a profile skewed toward the outer wall in the resuspension section. Two course screens (1/4-in. openings) were placed across the

circular duct just above the transition (circular to rectangular) section to flatten the velocity profile. This modification produced relatively flat velocity profiles across the rectangular tunnel in both directions.

Resuspension measurements will be carried out by placing the sample in a jig at the top of the resuspension section (Figure 1). The collection filters and the cascade impactor will be started before starting the wind tunnel. The wind tunnel will then be brought up to speed (264 ft/min or 3 miles/h). The operation of interest (exposure to known accelerations, disengagement of a

closure device, or exposure to the wind velocity) will then be carried out. The wind tunnel and samplers will then remain on to collect any resuspended particles. After several minutes, the wind tunnel speed will be returned to zero. The collection filters will then be stopped and removed for evaluation to determine the fraction of deposited material resuspended.

The final characterization and calibration measurements of the resuspension tunnel are completed and resuspension studies are under way.

Automation of Guidelines for Selection of Chemical Protective Clothing

Authors: J. O. Jackson, J. F. Stampfer,
and A. D. Schwopce (Arthur D. Little, Inc.)

Group: Industrial Hygiene, HSE-5

Funding Organization: Environmental Protection Agency

The Environmental Protection Agency (EPA) previously sponsored the development of the *Guidelines for Selection of Chemical Protective Clothing*¹ by Arthur D. Little (ADL) and Los Alamos. These guidelines were originally developed to reduce the risk of exposure to EPA employees during hazardous substance responses. Subsequently, EPA determined the need to update the guidelines and place them in an automated information system.

Activities for 1987 have concentrated on (1) moving the ADL data base from a mainframe to an IBM PC that uses PCFOCUS as the software, (2) entering new chemical resistance data for neat chemicals that were developed by Los Alamos and ADL under sponsorship of the U.S. Coast Guard, and (3) writing several computer programs and assisting EPA computer personnel to reproduce the updated guidelines in a format easily read by the EPA computer, and (4) preparing the final report.

The data base enhancement has been completed, resulting in a significant increase in the amount of information provided by vendors since the 1984 update.¹ The computer program development was more extensive than originally planned because of several factors. These included some changes in data base requirements by EPA computer personnel and the need for modifications of existing ADL data bases. The final report and all other aspects of the project were completed in 1987.

Reference

1. A. D. Schwopce, P. P. Costas, J. O. Jackson, and D. J. Weitzman, *Guidelines for the Selection of Chemical Protective Clothing*, 3rd ed. (American Conference of Governmental Industrial Hygienists, February 1987).

Respirator Studies for the Department of Energy

Authors: O.D. Bradley and B.D. Reinert

Technical Assistance: A.G. Trujillo and R. Henins

Group: Industrial Hygiene, HSE-5

Funding Organization: Department of Energy, Office of Operational Safety (DOE/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 cannot be approved by the existing National Institute for Occupational Safety and Health (NIOSH) and Mine Safety and Health Administration approval schedules, and (3) special short-term respirator studies as directed by the DOE/OOS.

Acceptance Testing of Unapproved Devices

Six supplied-air suits were submitted by the Savannah River Plant for testing in 1986. These six devices included one supplied-air hood, one 6-mil polyvinyl chloride (PVC) supplied-air suit with standard-size hood, one PVC supplied-air suit with a large hood to accommodate the wearing of a hard hat, one tritium suit with a large-size hood of 8-mil Saran/CPE plastic material, one welder's supplied-air suit of 6-mil PVC

with a welder's head harness inside the hood to hold it in place and a welder's faceplate in the front of the hood to provide eye protection, and a 7-mil polyurethane supplied-air suit. All six devices were tested using the test procedures and schedules outlined in "Acceptance-Testing Procedures for Air-Line Supplied-Air Suits."¹

The data obtained in this testing were presented to the DOE Respiratory Advisory Committee at their annual meeting on July 18, 1986. After reviewing the data, the committee requested that additional testing be conducted for three of the devices. This testing was conducted in early 1987 and included the polyurethane suit with a hard hat, the tritium suit, and the 6-mil PVC suit with small hood. All suits were in small and regular sizes. The retests were done for aerosol penetration and sound pressure levels. The small devices were worn by subject 1 and the regular size was worn by subjects 2 and 3. All devices retested produced a protection level of 20 k, with the sound pressure levels below the 80 dBA allowed by the DOE for use by its contractors (Table I). These new data were submitted to the committee and unanimously accepted.

Table I. Savannah River Plant Supplied-Air Suits Test Data						
	Fit Factors (k)			Sound Pressure Levels (dBA)		
	Airflow (ft ³ /min)			Airflow (ft ³ /min)		
	18	19	20	18	19	20
Polyurethane (small)	20	20	20	75.8	76.2	76.8
Polyurethane (regular)	20	20	20	68.7	71.5	71.5
Tritium (small)	20	20	20	77.2	77.9	78.8
Tritium (regular)	20	20	20	75.5	77.0	77.5
PVC (6 mil) (small)	20	20	20	71.8	72.1	72.5
PVC (6 mil) (regular)	20	20	20	67.0	67.5	68.5

Respirator Advisory Committee

The Respirator Advisory Committee (RAC) held its ninth annual meeting on October 23, 1987, in Toronto, Canada, with the following agenda:

- (1) decrease of O_2 and increase of CO_2 inside supplied-air suits without a supply of air,
- (2) acceptance of Savannah River Plant 12-mil PVC supplied-air suit, and
- (3) Savannah River Plant supplied-air hood.

The RAC made the following recommendations on item (1): (a) DOE/OOS should send a memo to DOE contractors, NIOSH, and OSHA outlining the test data and informing them of the possible problem; and (b) DOE/OOS should direct Los Alamos to make visits to all DOE sites that use supplied-air suits to determine how the suits are used. The person making these visits should be instructed to discuss the wearing of suits with the workers to determine if any problems could be associated with the O_2/CO_2 test data.

On item (2), the committee agreed unanimously to accept this device if the seam welds were adequate with the thicker material. Because the Savannah River supplied-air hood (3) is eligible for testing by NIOSH, the committee accepted it (July 18, 1986) for one year, during which time it was to be submitted to NIOSH for approval. This one-year period ended on July 18, 1987.

The committee agreed unanimously that DOE/OOS check with the Savannah River Plant to determine if they had submitted the device to NIOSH. If the device had not yet been submitted, OOS should give three months' extension for submittal. If at the end of the extension the hood had not been submitted to NIOSH, the acceptance should be withdrawn by DOE.

Special Studies

O_2 Decrease and CO_2 Increase with Air Supply Shut Off. Air-line supplied-air suits are submitted through the DOE/OOS to the Industrial Hygiene Group for testing and evaluation. This testing follows the DOE guidelines in Los Alamos report "Acceptance-Testing Procedures for Air-Line Supplied-Air Suits."¹

In FY86, the Savannah River Plant submitted a request for testing of the plant's supplied-air suits. In addition to normal testing, this testing was to investigate the levels of O_2 and CO_2 inside the suit during use when the supply of breathing air is shut off. Operations of this type could take place during donning, doffing, emergency escape, and training exercises. The RAC recommended at their FY86 meeting that all DOE supplied-air suits that had been previously accepted be

sent to Los Alamos and that this testing be performed on each of them.

The testing consisted of determining the time delay from when the breathing air was shut off to when the oxygen inside the suit helmet dropped to 16%. The percent of carbon dioxide was monitored and recorded at the time the O_2 level reached 16%. The testing was to determine the amount of time that could be allotted for a person to escape a contaminated area in a supplied-air suit with the air supply shut off.

Human Test Subjects. The Los Alamos Human Studies Committee gave permission to use human test subjects for this testing with the understanding that the subjects' medical records would be screened by the Los Alamos Medical Group and that each subject would be given a maximum stress EKG test by a cardiologist.

These requirements were met and three human test subjects who were experienced in wearing these suits were selected to obtain data for different size ranges. The largest of these test subjects was a 6-ft 4-in., 235-lb male; the second, a 5-ft 11-in., 135-lb male; the third, a 5-ft 6-in., 127-lb female.

Equipment Used. The breathing air was monitored in the helmet of the supplied-air suits with a Perkin Elmer medical gas analyzer, Model 1100, and data were recorded on Hewlett Packard strip chart recorders, Model 7155-B. This equipment was calibrated before each test using standard calibration gases from the Los Alamos gas facility.

R&D Modifications for Testing. An identical modification was made to each of the suits: probes were installed through the right glove by cutting off the tip of the index finger, installing the capillary probe line, and then taping the glove closed. The collection end of the probe was mounted in the nose-mouth breathing area of the hood. Other than this modification, the suits were donned and worn in the manner prescribed in the appropriate contractor's standard operating procedure (SOP) for supplied-air suits.

Test Procedures. Each of the suits was tested on each of the three test subjects in the following manner. The subject donned the device as prescribed in the contractor's SOP. Breathing airflow rates were set as prescribed by the owning contractor. The medical gas analyzer and strip chart recorders were activated. The test subject was instructed to begin running in place. After 1 min, the breathing air was shut off at the manifold and the subject continued to run in place. The O_2 content was monitored until it had decreased to 16%, at which time the air was turned on. A second strip chart

recorder was used for the CO₂ concentration; both recorders were operated simultaneously. [Table II, Phase I (the Savannah River suits), and Table III, Phase II, list these data.] The subject was allowed to rest. He was then instructed to begin running in place again. After 1 min, the breathing air was disconnected at the suit pigtail connection. The subject continued to run in place and the O₂ and CO₂ were again monitored using the same criteria. Suits 1 and 2 cannot be disconnected at the pigtail.

Observations. The data listed in Table II are those given for the original testing of the Savannah River Plant

suits and previously published in the Los Alamos Industrial Hygiene Group 1986 Annual Report.¹ They are restated here for a comparison with the new data listed in Table III.

The data in Tables II and III (O₂ column) become significant when applied to the known practices used in the workplaces of the DOE contractors. We know that for many of the procedures used, a worker may be inside the suit covering without a supply of breathable air for times that far exceed those displayed in these tables.

The RAC suit test procedures,² for example, call for the test "Aerosol Penetration Air Off" to be continued until the penetration inside the suit reaches a level of 1.0% or lasts 3 min (180 s). The maximum time

Table II. Phase I, FY86—O ₂ /CO ₂ Supplied-Air Suit Data							
		Subject 1		Subject 2		Subject 3	
		O ₂	CO ₂	O ₂	CO ₂	O ₂	CO ₂
Suit 1	A	25	7.1	67	6.8	17	7.1
	B						
Suit 2	A	15	7.4	19	5.6	12	5.8
	B	13	7.6	19	6.8	10	7.2
Suit 3	A	26	6.8	28	6.0	11	6.5
	B	23	6.9	25	6.4	12	7.2
Suit 4	A	40	5.7	60	5.1	20	6.2
	B	57	6.3	48	5.6	14	6.0
Suit 5	A	20	6.2	38	4.5	15	6.6
	B	24	5.8	48	5.3	16	6.8
Suit 6	A	29	5.4	31	5.2	39	6.8
	B	30	6.2	41	5.7	35	6.7
Note: A = air shut off at manifold B = air-line disconnected at suit pigtail (suit 1 cannot be disconnected at pigtail) O ₂ = time in seconds for O ₂ to drop to 16% CO ₂ = percent CO ₂ at the time O ₂ was at 16% Suit 1 = hood Suit 2 = welders Suit 3 = 6-mil small hood Suit 4 = 6-mil large hood Suit 5 = tritium Suit 6 = polyurethane							

obtained in this testing (Table III, O₂ column) was 2 min, 35 s (141 s), for subject 1, suit 7. This suit has a very large hood and the entire body area is open to the hood area; also there are no baffles or waistband to restrict the movement or mixing of the air. Suits 1 through 6, Table II, and 8 through 11, Table III, produced data in the O₂ column near or below the 60-s level. None of the suits listed in Table III have a neck or waistband similar to the Tyvek bands of the Savannah River designed suits (Table II), except suit 10, which is the same as suit 3 of Table II. With this limited data base, we can only assume that if the O₂ level drops from 21% to 16% in 3 min or less, the O₂ level could be critical in 3 min.²

Tables II and III (CO₂ column) list the corresponding data for CO₂ increase inside the hood of the devices. In the same time used to observe O₂ decrease, these CO₂ levels also become significantly elevated. The literature indicates no agreement on a limit at which CO₂ levels become critical; however, most researchers agree that at 4% to 6%, some symptoms begin to appear, and at 6% to 10%, a subject may lose some of his ability to function. The most noticeable symptoms would be increased ventilation, accompanied by a decreased threshold of fear, and increased possibility of panic.⁴ If these values from the literature were compared with the data obtained in this testing, the CO₂ column data would indicate that a wearer could begin to develop symptoms at these limited

Table III. Phase II, FPG - O ₂ /CO ₂ Summary by Suit and Subject							
		Subject 1		Subject 2		Subject 3	
		O ₂	CO ₂	O ₂	CO ₂	O ₂	CO ₂
Suit 7	A	141	4.8	90	4.9	45	5.8
	B						
Suit 8	A	45	4.6	60	5.3	58	7.6
	B	72	4.7	60	4.7	32	7.8
Suit 9	A	51	4.1	48	5.6	59	6.2
	B	57	5.0	66	6.5	62	6.3
Suit 10	A	31	5.0	42	4.8	16	6.4
	B	30	5.4	48	4.8	17	6.4
Suit 11	A	54	5.0	66	4.3	30	8.9
	B	30	7.3	66	4.0	29	8.6
Note: A = air shut off at manifold B = air-line disconnected at suit pigtail (suit 7 cannot be disconnected at pigtail) O ₂ = time in seconds for O ₂ to drop to 16% CO ₂ = percent CO ₂ at the time O ₂ was at 16% Suit 7 = Rocky Flats Suit 8 = Los Alamos National Laboratory Suit 9 = Oak Ridge (Y-12) Suit 10 = Oak Ridge National Laboratory (Savannah River design) Suit 11 = Monsanto Research Corp. (Mound)							

conditions and, in some cases, could get into trouble from high CO₂ levels during 1 min or less of air-off operation.

The data listed in the CO₂ column of Tables II and III are comparable for all suits, with a low of 4.0% for suit 11, subject 2, and a high of 8.9% for suit 11, subject 3.

Conclusions and Recommendations. Tables II and III show that the O₂ content decreases rapidly after the air supply is terminated. These tests were stopped when the O₂ content reached 16%.

Conclusions for the data listed in Table II, Phase I testing, and those in Table III, Phase II testing, are the same because of the nature of the data. The numbers for both the O₂ and the CO₂ data do vary slightly; however, there are no overall significant differences.

The more critical of the two sets of data may be in the CO₂ column of Tables II and III. The CO₂ percentages in the suit helmet reach levels at which most researchers believe CO₂ intoxication symptoms could be apparent in the subject.⁴

The results of this testing has prompted OOS to direct that all future and previously accepted supplied-air suits be tested using the same protocol.

Those DOE contractors using supplied-air suits or hoods should be instructed to investigate their emergency escape, donning/doffing, and training procedures. They should ensure that their personnel are not spending extended periods of time inside these devices without a continuous supply of breathing air.

Because of the observations and conclusions stated here, the DOE Respirator Advisory Committee recommended to the DOE/OOS that site visits be made to all DOE contractors using supplied-air suits and hoods to determine how the devices are being used, to discuss with the workers any problems associated with the O₂/CO₂ data, and to test all supplied-air hoods in use at DOE contractor sites.

Respirator Tests for Sandia National Laboratories. Sandia National Laboratories, Albuquerque, New Mexico, requested through DOE/OOS that Los Alamos test eight American Optical respirators (two full-face and six half-masks) constructed of both neoprene and silicone to determine (1) respiratory protection afforded to the wearer and (2) possible problems with using the masks. Aerosol testing was conducted using eight test subjects. We determined that the devices all gave respiratory protection fit factors of 15 to 20 k.

Some problems occurred with the devices themselves; the exhalation valve covers of the half-masks are loosely fitted and come off when bumped or touched during donning. Neoprene masks and silicone

masks are the same color and cannot be distinguished easily.

Technical Consultation

Consultations were conducted with several contractors, field offices, and DOE/OOS. These consultations involved subjects such as supplied-air suit design, operation, and DOE test and acceptance procedures; respirator selection, maintenance, and training programs; and methods of determining respirator fit.

Work in this area during 1987 included

(1) a site visit to Westinghouse Materials Company, Cincinnati, Ohio, to install an automated fit test system and to train their people on its use and maintenance;

(2) a continuation of representing DOE interests on the ANSI Z88.2 and Z88.10 consensus standards committees;

(3) attendance at and contributions to other meetings having special interests in respiratory protection, such as the ASTM F-23 Protective Clothing Committee and the International Society for Respiratory Protection;

(4) frequent telephone consultations with contractors in regard to program modifications, use of contact lens with respirators, and medical requirements for users;

(5) ongoing advice in air-supplied suit design and development to Savannah River, Oak Ridge, Rocky Flats, and Mound laboratories; and

(6) comments to NIOSH on their proposed revision of the respiratory protection certification rule (42 CFR 84).

References

1. H. J. Ettinger, Ed., "Industrial Hygiene Group 1986 Annual Report on Research and Special Activities," Los Alamos National Laboratory report LA-11100-MS (November 1987).
2. O. D. Bradley, "Acceptance-Testing Procedures for Air-Line Supplied-Air Suits," Los Alamos National Laboratory report LA-10156-MS (June 1984).
3. F. A. Patty, "Inorganic Compounds of Oxygen, Nitrogen, and Carbon," in *Industrial Hygiene and Toxicology* (Interscience Publishers, John Wiley and Sons, New York, 1967), Vol. II, Chap. XXV, p. 914.
4. H. Proctor and P. Hughes, *Chemical Hazards of the Workplace* (J. B. Lippincott Company, Philadelphia, 1978) p. 147.

Effects of Temperature and Humidity on Respirator Fit Under Simulated Work Conditions

Authors: B. J. Skaggs and E. C. Hyatt

Statistical Consultant: R. J. Beckman (Statistics, A-1)

Technical Assistance: K. D. Carter and O. D. Bradley

Group: Industrial Hygiene, HSE-5

Funding Organizations: Occupational Safety and Health Administration (OSHA) and Nuclear Regulatory Commission (NRC)

The primary objective of this effort was to assist OSHA and NRC in providing respiratory protective devices and programs for their workers that will prevent or limit exposure to airborne contaminants. The goal for this year was to finalize the report for the controlled-environment study.

Series I respirators included two helmet powered air-purifying respirators (PAPRs), one half-mask PAPR, one air-line hood (continuous flow), and one full-face air-line respirator (positive pressure). The Series II respirators included one full-facepiece negative-pressure respirator (three sizes) and one half-mask negative-pressure respirator (three sizes). Each respirator was worn by each test subject during six environmental conditions: (1) 32°C and 85% relative humidity (RH), (2) 0°C and 15% RH, (3) 32°C and 15% RH, (4) 0°C and 85% RH, (5) 21°C and 85% RH, and (6) 21°C and 15% RH.

Each test was composed of (1) PreFit exercises (standard respirator fit exercises),¹ (2) PreWork exercises, (3) SimWork (simulated work) exercises, and (4) PostWork exercises and lasted approximately 90 min. A test subject performed the PreFit exercises in a small fit chamber while a PreFit factor was determined. After entering the environmental chamber, he performed the PreWork exercises (the same movements as in PreFit) followed by SimWork exercises (for example, shoveling gravel) while a SimWork factor was determined. The subject finished with the PostWork exercises (same as in PreFit and Prework).

A total of 252 Series I tests and 120 Series II tests were analyzed for the study. Details of the test procedures and data analysis are provided in the 1985 and 1986 Industrial Hygiene Group annual reports.^{2,3}

During 1987, final analysis of the data was completed and the following conclusions and recommendations were developed.

Conclusions

(1) Tight-fitting half-mask PAPRs provided higher protection than helmets or loose-fitting PAPRs.

(2) Performance of the Racal PAPR helmet degrades at high temperatures. Data at low temperature and humidity suggest that simulated work has a greater effect on performance than temperature.

(3) The 3M PAPR helmet data showed no effect at any environmental chamber (EC) condition during PreWork exercises; however, during the SimWork exercises, there was minor degradation of fit factors (FFs).

(4) The high-temperature high-humidity condition had limited effect on the performance of the Mine Safety Appliance (MSA) Comfo II PAPR when half the subjects obtained FFs less than 20,000.

(5) Tests at all EC conditions and exercises confirmed the FF of 1000 for the half-mask PAPR proposed by Los Alamos in 1976.⁴

(6) There was limited effect on the performance of the Survivair full-facepiece pressure-demand supplied-air respirator at high temperature and high humidity.

(7) EC conditions and exercises had no obvious effect on the performance of the Bullard continuous-flow supplied-air hood.

(8) All subjects testing the two Series I negative-pressure respirators, with preselection criteria of $FF \geq 100$ for the half-mask facepiece and $FF \geq 1000$ for the full facepiece, met the minimum on all six PreFit tests.

(9) FFs developed with the exercises presently recommended in ANSI Z88.2 1980 for loose-fitting respirators and used for Series I tests do not adequately simulate work factors.

(10) Performance of the MSA negative-pressure high-efficiency filter half-mask and full-facepiece respirators degraded during fit tests at high humidity and high temperatures in the EC.

(a) FFs of the half-mask respirator degraded at high humidity at both ambient and high temperatures, in some cases because of the facepiece sliding down the nose from sweating during SimWork and PostWork exercises.

(b) SimWork exercises are more effective in degrading FFs for the half-mask and the full-facepiece respirators than the PreWork or PostWork exercises.

(11) The FFs of the MSA negative-pressure full-facepiece respirator degraded at cold temperature/high humidity during SimWork exercises for 50% of the subjects and during cold temperature/low humidity for 30% of the subjects. Some of the data suggest that cold (0°C) temperature may have caused the exhalation valve to freeze partly closed, resulting in lower FFs.

(12) Quantitative fit tests with the MSA negative-pressure full-facepiece respirator at high temperature indicated some apparent but nonsignificant reduction of FFs, possibly caused by mask movement from sweating during SimWork.

(13) The six PreFit FFs at room temperatures show poor reproducibility for

(a) six of ten subjects testing the Racal PAPR helmet, which had the largest variation of Series I;

(b) six of ten subjects testing the MSA Comfo II negative-pressure half-mask respirators; and

(c) seven of ten subjects testing the MSA UltraTwin negative-pressure full-facepiece high-efficiency respirator.

(14) The preselection FF criteria originally used for subject selection in Series II tests were not met during PreFit tests by most subjects.

(a) For the full-facepiece respirator, 2 of 10 met the preselection criteria ($FF \geq 3000$) on all 6 tests.

(b) For the half-mask respirators, 4 of 10 met the preselection criteria ($FF \geq 1000$).

(15) FFs developed with the exercises presently recommended in ANSI Z88.2 1980 for tight-fitting respirators and used for Series II tests do not adequately simulate work factors.

(16) Test subjects' comments regarding comfort show the following:

(a) Respirator users are more comfortable using continuous-flow respirators in hot and humid conditions than using tight-fitting pressure-demand devices such as the Survivor.

(b) Continuous-flow hoods are the most comfortable of all devices in hot and humid conditions.

(c) Most test subjects commented that the MSA Comfo II facepiece was uncomfortable across the bridge

of the nose. They also said that the half-mask facepiece seemed to slide on their faces when they sweated.

(d) The MSA UltraTwin was reported to cause uncomfortable pressure across most subjects' foreheads. All subjects remarked about the large amount of moisture that accumulated in the facepiece from sweat and exhaled moisture.

Recommendations

(1) PAPRs should be divided into two classes: those with tight-fitting facepieces and those with helmets or loose-fitting facepieces. This classification change is being considered by the present ANSI Z88.2 committee.

(2) More dynamic full-body movement exercises should be used to better duplicate work situations, especially those motions in which the individual bends over and stands up repeatedly.

(3) Efforts should be made to solve the problem of half-mask respirators sliding down the nose because of sweating when workers must wear them in hot and humid conditions. Some commercially available solutions to consider follow:

(a) a five-point suspension head harness with the fifth point connected to the half-mask nosepiece from above (used on Comfo for over 20 years by Canadian Atomic Power Plant workers),

(b) a hairnet-type head harness similar to one used by Scott to stabilize facepieces, and

(c) the top headband split or divided over crown of head to form a yoke and help stabilize the half-mask (used for decades in Europe and currently available from most U.S. manufacturers on request).

(4) A more extensive study should be conducted with a larger number of manufacturers' negative-pressure respirators, especially at hot and humid conditions and simulated work.

(5) The field study originally proposed for the third phase of this project should be conducted for a better understanding of the relationship between laboratory-developed FFs and actual work-use factors.

(6) Studies of SimWork conditions can be used to determine the effects of field variables that are found in real work conditions. This information better prepares the field surveyor to obtain realistic data from well-planned and -executed field studies.

(7) The study data seem to suggest that the negative-pressure full-facepiece respirator should be assigned a protection factor greater than the 50 presently recommended in 10 CFR Part 20 for NRC. However, more data must be collected to substantiate this change.

(8) The Racal chin strap offered as auxiliary equipment should be an integral part of the respirator to improve the performance of the device. We understand

that Racal has already acted on this suggestion and is now selling their device with the chin strap as standard equipment.

(9) The MSA PAPR and Racal power switches should have a guard installed to protect the unit from being inadvertently switched off.

(10) Diligent quality assurance control of all respiratory protective devices must be emphasized by all respirator manufacturers. A defective respirator, such as found among the new respirators purchased for this study, could be quite harmful to an unsuspecting worker.

Careful cleaning, maintenance, and inspection with good employee training will help correct many problems and provide reliable use of respiratory protective devices.

References

1. "Tight- and Loose-Fitting Respirator Exercises (ANSI Z88.2 1980)," *Practices for Respiratory Protection* (American National Standards Institute Inc., New York, 1980).
2. B. J. Skaggs, "Respirator Environmental Chamber Fit Factors," in H.J. Ettinger, Ed., "Industrial Hygiene Group 1985 Annual Research Report," Los Alamos National Laboratory report LA-10800-MS (1986).
3. B. J. Skaggs, "Respirator Environmental Chamber Fit Factors," in H. J. Ettinger, Ed., "Industrial Hygiene Group 1986 Annual Report on Research and Special Activities," Los Alamos National Laboratory report LA-11100-MS (1987).
4. E. C. Hyatt, "Respirator Protection Factors," Los Alamos Scientific Laboratory report LA-6084-MS (1976).

Sorbent Testing

Authors: J. F. Stampfer and G. O. Wood

Group: Industrial Hygiene, HSE-5

Funding Organizations: U.S. Army, Chemical Research
Development and Engineering Center; Los Alamos
National Laboratory

The program has two major objectives:

- to experimentally test respirator sorbents against specific gas and vapor challenges of interest and
- to develop a method to predict sorbent lifetimes and efficiencies without the necessity of experimental testing.

A brief description of the experimental systems that are used is given below.

Two automated test systems have been employed to test the efficiencies of various sorbents against challenge compounds. One system tests whole canisters and is installed in the Los Alamos Chemical Surety Facility. Gas chromatography and mass spectrometry are the analytical techniques used.

Sorbent samples are used with the other test system in which six samples can be run simultaneously. Mass spectrometry is the analytical technique used. In normal operation, the effluent from each sample is analyzed every 8 min, although this period can be shortened. Up to six different charcoal sorbents were tested against a variety of challenge vapors and gases in both dry and humid atmospheres. In this case, the flow was a steady linear velocity of 740 cm/min through the beds.

During the past year, we had no call for testing canisters against any specific challenges.

To develop a predictive method, an integrated approach is being pursued. A data base is being created to develop and then test predictive models. The data base currently consists of the results from 152 experiments in which ASC charcoal was challenged with dry (less than 15% relative humidity) air containing 1 of 25 different compounds (Table I).

The penetration fraction as a function of time was measured. Three different challenge concentrations, 340, 680, and 1360ppm (v), were used. The sorbent beds, 4.55 g of ASC carbon, 2.3-cm diam, and 2.0 cm deep, were contained in stainless steel tubes. These tubes, up to a total of six, were attached to a manifold through which the challenge atmosphere passed. A pump drew 3.07 L/min of the challenge atmosphere through each of the sample tubes. The effluent from each tube could be sampled independently.

Compound	Molecular Weight	Boiling Point
Ethene	28.1	169
1,1-Difluoroethene	64.0	190
Trifluoroethene	82.0	222
Tetrafluoroethene	100.0	197
Propene	42.1	226
3,3,3-Trifluoropropene	96.1	257
Hexafluoropropene	150.0	244
1-Butene	56.1	267
Cis,Trans-Butene-2	56.1	274
Propyne	40.1	250
Perfluorobutene-2	200.0	274
Isobutene	56.1	266
2-Trifluoromethylpropene	110.1	280
Butyne-2	54.1	300
Perfluorobutyne-2	162.0	249
Heptene-1	98.2	367
3-Methylbutene-1	70.1	293
3,3,3-Trifluoropropyne	54.1	225
Butadiene-1,3	132.0	269
1,1,3,3,3-Pentafluoropropene	82.0	252
3,3,4,4,4-Pentafluorobutene-1	146.0	277
Perfluorocyclobutene	162.0	279
1,1,2-Trifluoroethane	84.0	226
Pentafluoroethane	120.0	224
Butane	58.1	273

Challenge and downstream compound concentrations were measured with a mass spectrometer. Each experiment was usually run in duplicate. In a few cases, the results from duplicates were inconsistent and a third replicate was run. In one case, there was only enough compound to run one experiment. The times for 0.01, 0.1, 0.25, 0.50, and 0.75 fractional penetration (P_F) were determined visually and the average values for duplicate

runs calculated. The raw data were also used to create a data base on a VAX computer.

Although several equations have been proposed to describe breakthrough curves, the one we are using is

$$t = \alpha - \beta \ln \left(\frac{\gamma}{P_F} - 1 \right), \quad (1)$$

where

t = time,
 P_F = penetration fraction, and
 α, β, γ = constants.

The data from replicate runs were combined and fit with this equation. If $\gamma = 1$, this equation is the same as the Yoon and Nelson modification of the Wheeler equation. The α is an estimate of the time to reach $0.5P_F$, β is the slope of the semilog plot, and γ is an estimate of the asymptotic value of P_F . From the curve fits, times for $P_F = 0.01, 0.1, 0.25, 0.50$, and 0.75 to be achieved were calculated. Linear regression analyses of these calculated times, against the times determined for the same P_F by visual inspection of the data, gave the results shown in Table II. For a perfect match, the slope, intercept, and correlation coefficient (R^2) should be 1.00, 0.00, and 1.00, respectively. Although not perfect, the correlations for $P_F = 0.1, 0.25, 0.5$, and 0.75 are good enough to allow the calculated values to be used. The same is not true of $P_F = 0.01$, in which case in all but 2 of 79 cases, the experimental times are longer than the calculated ones. This means that Equation (1) predicts more rapid early penetration than is found in practice. Unless noted otherwise, only $P_F > 0.1$ are considered in the following discussions.

It is obvious that in any one experiment, the time for a given penetration fraction will be longer than the time for a smaller penetration fraction. It is not so obvious that there should be reasonably good correlations between the times for different penetrations when the data from all the experiments are involved. Table II shows the results of regressing the times for each of the four P_F s we are considering, $0.1, 0.25, 0.50$, and 0.75 , against each of the others.

Using the correlations between various penetration fractions, we can draw the entire penetration curve if we know one penetration and the correlation equations. As an example, the solid line in Figure 1 shows the penetration curve for butadiene-1,3 at 680 ppm. The dashed line is calculated assuming the times for $0.1P_F$

and γ are known. The calculated curve agrees fairly well with the experimentally determined one.

To predict a penetration curve by using the above correlations requires a knowledge of the time for one of the four penetration fractions and the value of γ . However, α and β of Equation (1) are reasonably well corrected. Using this relationship, we can show the following:

$$T = \left(\frac{T_o + BX_o}{1 - AX_o} \right) (1 - AX) - BX, \quad (2)$$

where

T = time for any $P_F > 0.10$,
 T_o = known time for any known $P_F^o > 0.10$,

$$X = \ln \left(\frac{1}{P_F} \right),$$

$$X_o = \ln \left(\frac{1}{P_F^o} \right), \text{ and}$$

A, B = constants of equation $\beta = A\alpha + B$.

Note that in Equation (2) and all that follow, γ has been forced to be 1.0.

Figure 2 shows the results of calculating the times for $P_F = 0.5$, assuming the T_o s for $P_F = 0.10$ are known. Table III shows the results of linear regressions of the predicted times against the actual times for $P_F = 0.25, 0.5$, and 0.75 , again if we know the time for $P_F = 0.1$. We can assume that using known times for any other P_F should result in agreements equally as good as shown in Figure 2 and Table III. Thus, at least for the types of compounds that have been used to produce our data base, it appears that knowing the time for one P_F allows the times for any other P_F to be calculated with some degree of confidence. As noted earlier, below $P_F = 0.1$, the calculated penetration is probably greater than that actually present.

A useful principle is that the lower the boiling point of a challenge vapor, the higher the penetration. We have correlated the boiling points with various penetration measures and find that they correlate fairly well with the charcoal capacity for the different vapors.

Table II. Linear Regressions of Penetration Times

CX/EX	CX = I + S (EX)		R ²
	I	S	
C01/E01	-1.53	0.77	0.92
C10/E10	-0.20	1.01	0.999
C25/E25	0.10	1.01	0.9997
C50/E50	0.04	0.99	0.9996
C75/E75	-0.36	1.01	0.998

CY/CX	CY = I + S (CX)		R ²
	I	S	
C25/C10	1.59	1.19	0.996
C50/C10	3.41	1.36	0.987
C75/C10	5.88	1.52	0.970
C25/C50	-1.19	0.87	0.998
C25/C75	-2.36	0.77	0.987
C50/C75	-1.46	0.89	0.995

Table III. Linear Regressions of Breakthrough Times^a

Calculated Time = I + S (Experimental Time)			
P _F	I	S	R ²
0.25	1.604	0.946	0.98
0.50	1.745	0.938	0.98
0.75	1.605	0.965	0.96

^aCalculated from known times of P_F = 0.10 versus experimental time.

Figure 1. Experimental and predicted penetration times.

Figure 2. Times for P_F = 0.5 calculated from known times for P_F = 0.10 versus experimentally determined times.

$$\begin{aligned}\log(\text{capacity}) &= -42.0742 + 8.177 \log(\text{boiling point}) \\ &\quad + 0.442 \log(\text{concentration}), \\ n &= 70, \text{ and} \\ R^2 &= 0.92.\end{aligned}\quad (3)$$

In this correlation, two data points have been omitted, those for heptene-1, which coincidentally exhibits the highest boiling point, 367 K. The next highest boiling point is 300 K.

The first term α of Equation (1) is the stoichiometric time term and is the first approximation to the bed service life. For the "symmetrical" breakthrough curves described by this equation, with $\gamma = 1$, the stoichiometric point is at the inflection point where the curvature changes from positive to negative. The time at which this occurs is also, to a first approximation, the time T50 for $P_F = 0.5$. The T50 can also be calculated from a knowledge of the capacity:

$$T50 = 43.3 \left(\frac{\text{Capacity}}{\text{Concentration}} \right). \quad (4)$$

The constant 43.3 is based on experimentally set parameters. The T50s were calculated in this way from capacities calculated from Equation (3). They were then used with Equation (2) to calculate the time for $P_F = 0.10, 0.25, 0.50$, and 0.75 .

Table IV shows the results of regression analyses of the calculated versus experimentally determined times. Figure 3 shows the results for $P_F = 0.1$. Although the agreement is obviously not perfect, it does appear that the breakthrough curve can be calculated for compounds of the same type as those that are part of the data base and that have boiling points of 300 K or less. Recent results indicate that graph theory may improve the correlation with higher-boiling materials.

These same experimental data can be treated in a different way in which the chemical and physical properties and processes in the bed are considered. Many isotherm equations have been proposed to describe experimental equilibrium data. If the stoichiometric inflection point α can be identified for different challenge concentrations, the isotherm can be defined. The ideal Langmuir isotherm, Equation (5), often approximates Type I isotherm data over a limited range:

$$W_e = q = \frac{q_s K_L C_o}{1 + K_L C_o}, \quad (5)$$

where

W_e = q = equilibrium bed capacity at C_o ,
 q_s = maximum capacity approached at higher concentrations,
 K_L = Henry's Law coefficient, and
 C_o = challenge vapor concentration.

This has the advantage of including only two adjustable parameters, both of which have physical and thermodynamic significance. The Langmuir parameter q_s in Equation (5) for a fixed bed weight and airflow rate, represents the upper limit in capacity as the vapor concentration becomes very large. The K_L is the Henry's Law coefficient, approached theoretically at low vapor concentrations. No preknowledge, such as the saturation vapor pressure, is required to fit data to this isotherm.

Equation (1), with $\gamma = 1$, can be written

$$t = \frac{W_e W}{C_o Q} - \frac{W_e \rho_B}{k_v C_o} \ln \left(\frac{1}{P_F} - 1 \right), \quad (6)$$

where

W = weight of carbon bed,
 Q = volumetric flow rate,
 ρ_B = bed packing density, and
 k_v = first-order rate coefficient.

As noted previously, the first term,

$$\frac{W_e W}{C_o Q} = \alpha, \quad (7)$$

is proportional to the equilibrium bed capacity W_e at a fixed challenge concentration C_o and volumetric flow rate Q .

Figures 4 and 5 show empirical correlations of α at 1360 ppm with the number of carbon atoms and number of fluorine atoms in the alkenes studied. Boiling points (K) are also shown. Clearly, there is a good correlation between the capacity and the number of carbons in the homologous series without fluorines. The correlation between capacity and boiling point is also good.

Table IV. Linear Regressions of Breakthrough Times^a

P_F	Calculated Time = I + S (Experimental Time)		
	I	S	R^2
0.1	0.098	0.994	0.87
0.25	-0.002	0.994	0.88
0.50	0.132	0.988	0.88
0.75	0.442	0.979	0.88

^aCalculated from boiling point versus experimental time.

Figure 4. Stoichiometric breakthrough time (α) as a function of number of carbon atoms.

Figure 3. Times for $P_F = 0.1$ calculated from boiling point of challenge compounds versus experimentally determined terms.

Figure 5. Stoichiometric breakthrough time (α) as a function of number of fluorine atoms.

Increasing substitution of fluorines on ethene corresponds to increased molar capacities. However, with propene and butenes, added fluorines can actually decrease the molar capacities. Capacities are less related to boiling point.

The capacity value at each concentration, proportional to each stoichiometric time α , actually represents one point on the equilibrium adsorption isotherm for each compound. Perhaps more elementary parameters, such as the Langmuir isotherm parameters K_L and q_s , can be more consistently correlated with molecular size or boiling point. To investigate this possibility, we combined Equations (5) and (7) to give

$$\frac{1}{\alpha} = \frac{Q}{Wq_s K_L} + \left(\frac{Q}{Wq_s} \right) C_0 \quad (8)$$

Linear least-square fits were done for each compound that had been tested at the three different concentrations. Using these intercepts and slopes, we calculated values of q_s and K_L .

Figure 6 shows a consistent increase of the K_L values with number of carbons for the unsaturated hydrocarbons, apparently independent of degree of unsaturation. The correlation with boiling points (also shown in Figure 6) is less consistent. Effects of fluorine substitution were more varied. After the number of fluorines exceeds the number of carbon atoms in ethene and propene, additional fluorines increase K_L . However, K_L values for the various butenes and fluorinated butenes are essentially the same. Henry's Law coefficients for fluorinated ethanes are consistent with those of fluorinated ethenes.

The upper limit parameter q_s was also found to increase with number of carbons in the compound, independent of degree of unsaturation and independent of the degree of fluorination.

Because at low P_F s Equations (1) and (6) are equal, k_v is proportional to α/β . For the experimental conditions used, the proportionality coefficient is 370 min^{-1} . Values of the kinetic coefficients were calculated in this way at each concentration and for each compound. No consistent trends were observed in the calculated k_v values with challenge concentrations. Again, no effect of degree of unsaturation or fluorination was apparent. The values of k_v increase approximately linearly with number of carbon atoms or boiling points, but the data scatters were too much to get good correlations.

In summary, from this bed modeling approach, alkenes, alkynes, and butadiene with the same number of

Figure 6. Apparent Henry's Law coefficient versus number of carbon atoms in unsaturated hydrocarbons.

carbon atoms appear to have equivalent values of K_L , q_s , and k_v . Most of the fluorinated analogs of these hydrocarbons with the same number of carbons also appear to have equivalent values of K_L , q_s , and k_v . The most obvious exceptions are fluorinated ethene, ethane, and propene with more fluorines than carbons, which apparently increase the Langmuir isotherm parameter K_L significantly. Fewer data are available for alkanes and fluorinated alkanes, but these also appear to fit right in with the others.

Other trends that have been observed are an approximately exponential increase of K_L and approximately linear increases of q_s and k_v with number of carbon atoms. On the other hand, the changes of the calculated parameters K_L and q_s with normal boiling point were not consistent. The increase of k_v with boiling point appeared more consistent, but the data were quite scattered.

Good correlations of capacities of alkenes (Figure 4) and the Henry's Law parameter K_L (Figure 6) with number of carbons were obtained. However, the data scatter in attempting to correlate the Langmuir maximum capacity parameter q_s for all compounds with number of carbons was excessive, even when only those compounds with good Langmuir fits ($R_2 > 0.96$) were used. Although moderate data scatter of k_v versus number of carbons was obtained, this correlation was encouraging because all compounds were included and because the scatter may be reduced by better capacity data (K_L and q_s).

At this time, the scatter in the data, particularly for q_s , is too much to proceed from observing trends to quantitative correlations and predictions. Better capacity (adsorption isotherm) data are required.

Evaluation of Navy Escape-Type Breathing Apparatus

Author: A. L. Hack

Technical Assistance: R. J. Henins

Group: Industrial Hygiene, HSE-5

Funding Organization: Naval Sea Systems Command, U.S. Navy

Introduction

The Scram (Scott Aviation) 15-min self-contained breathing apparatus is the standard escape device carried aboard ship for purposes of crew escape from a below-deck fire or other emergency. Because of the large number of units already installed aboard ship, the Navy would like to determine if the five-year shelf life can be extended. Los Alamos was requested to examine and test units that had been in storage at least five years.

Scram 15-min Breathing Apparatus

The Scram is a closed-circuit or rebreather apparatus. In use, oxygen is generated by an exothermic chemical reaction in a chlorate salt. The oxygen is injected into the hood worn around the wearer's head; the contents of the hood are mixed and forced through a lithium hydroxide scrubber that removes exhaled carbon dioxide. The entire gaseous content of the hood is eventually driven through the scrubber. Limited previous testing had been done by the National Institute for Occupational Safety and Health (NIOSH) for the Navy using a sodium chloride aerosol. However, in the operation of this type of apparatus, some question exists as to whether an aerosol test agent can simulate a gas. It was suspected that the filters in line with the scrubber might remove the challenge aerosol present in the hood but have no effect on a gas leak agent. Specifically, the Navy wanted to determine if a toxic gas such as carbon monoxide from a fire would be treated differently in the Scram from an aerosol such as the sodium chloride used by NIOSH or the oil mist used at Los Alamos. Accordingly, Los Alamos offered to test with both aerosol and gas.

Gaseous Test Agents

Although a variety of gaseous test agents are suitable, our first attempt was to use carbon monoxide, the chief toxic gas produced in a fire. Because Los Alamos has been a pioneer in the use of stable isotopes, isotopically labeled carbon monoxide was used. A mixture of

$C^{13}O^{16}$, mass 29, and $C^{13}O^{18}$, mass 31, is available from stock. Normal carbon monoxide is mass 28 and little normal background is at mass 31, so mass spectrometry would be a logical choice for detection. However, the spectroscopy dedicated to this analysis was used for detection of another enriched isotope, $N^{15}O^{16}$, also mass 31; therefore, the background at that mass was too great to permit sensitive analysis of mass 31 carbon monoxide.

After the failure of detection of isotopically labeled carbon monoxide, an attempt was made to use other instruments, a gas chromatograph mass spectrometer and a gas chromatograph flame ionization detector (GC/FID). A special column was obtained for the first instrument, but problems prevented its use. The GC/FID was available. However, an unexplained background of carbon monoxide was discovered, possibly caused by the catalyst hydrogenator (all of the carbon monoxide is converted to CH_4 for FID measurement). Clearly, another change was needed if this experiment was to be completed on time.

Freon 12 was finally selected because it met requirements for low toxicity and a detector was readily available. The instrument finally chosen was a gas chromatograph with electron capture detector, a device highly sensitive to the electronegative ions of Cl^- and F^- . A sensitivity of a few parts per million (used with a challenge concentration of 1000 ppm) will provide adequate detection.

Preliminary Results

A sampling system permitting simultaneous collection of a gas sample, with real-time aerosol measurement, is functioning. All testing will be completed early in 1988. A small number of preliminary tests have been completed. In all cases, the leakage into the hood measured by aerosol has been lower (0.1% or less, a fit factor of 1000 or more) than was detected by Freon (several percent for a fit factor of about 50). This confirms that the Scram unit is best fit tested with a gas.

Technology Transfer—Automated Respirator Fit Test System

Author: A. L. Hack

Technical Assistance: A. G. Trujillo and O. D. Bradley

Group: Industrial Hygiene, HSE-5

Funding Organization: Lawrence Livermore National Laboratory
and Westinghouse Materials Production Facility

In 1987 the computer-controlled automated respirator fit test system was installed at two additional DOE contractor installations, the Lawrence Livermore National Laboratory and the Westinghouse Fuel Fabrication Facility. Computer systems are now in use at four different installations. Previously, systems had been installed at the Rocky Flats Plant (Rockwell International) and at Los Alamos, where they are used both for routine fitting of employees and in research.¹

The new users of the automated system expect to obtain the same benefits as the existing customers: ability to perform a standardized test for all subjects, control of multiple tests by a single operator, automatic integration of mask leakage and calculation of protection factor, and recording of test data with printed output and on magnetic disc.

The automated respirator fit test system performs a fit test almost exactly as it would be done manually by an operator. The system uses a desktop computer (Hewlett Packard HP-85B) to control the respirator fit test, keep track of the name and length of each exercise, record data, and calculate mask leakage in percentage. The computer controls a data logger, which in turn

switches solenoids to select the sample of aerosol either from the test chamber or from within the mask. Aerosol concentration is detected by a forward light-scattering photometer, whose signal is measured by a voltmeter in the data logger and sent to the computer. Resultant mask leakage is displayed both on the screen and as printed record. A screen menu allows the selection of up to 14 different exercise series. Control programs are prepared beforehand for each series, including the name and duration of each exercise and rest period.

In addition to a printed record of the test, a magnetic disc is prepared with a summary of the test results, including identification of the test subject and mask and of the leakage during each exercise.

Reference

1. A. L. Hack and T. O. Moore, "Technology Transfer—Automated Respirator Fit Test System," in H. J. Ettinger, Ed., "Industrial Hygiene Group 1986 Annual Report on Research and Special Activities," Los Alamos report LA-11100-MS (1987).

REPRODUCED FROM
BEST AVAILABLE COPY

Determination of Plutonium in Human Tissues

Authors: J. F. McInroy, J. J. Miglio, E. R. Gonzales,
D. Noveroske, and L. C. Willis

Group: Health and Environmental Chemistry, HSE-9

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

Distribution of ^{239}Pu in Three Whole Bodies Donated to the U.S. Transuranium Registry

The skeleton and soft tissues of three whole bodies of former Los Alamos National Laboratory employees have been analyzed for ^{239}Pu . Each of the three persons had been exposed by inhalation to various chemical forms of airborne plutonium early in their employment at the Los Alamos Laboratory. The years at risk (time from first exposure to death) ranged from 37 to 38 years. The first individual (Case 26-118) was a male chemical engineer who died in 1982 at age 62 from respiratory failure associated with pneumonia. He had a clinical history of congestive heart failure. During his working lifetime, this donor was involved in operations with potential for exposure to plutonium from January 1945 until retirement in February 1982, approximately 10 months before his death. Exposure history was judged to be greatest in the early years of employment. The most likely exposures were inhalation of airborne particulates of ^{239}Pu in the form of oxalate, oxide, or fluoride. Several contamination accidents, involving airborne particulates of ^{239}Pu , were sources of further exposure in the late 1950s and early 1960s. After 1970, exposure potential was markedly reduced because of changes in job responsibilities, which removed him from direct contact with plutonium operations. During his employment at Los Alamos, 178 radiourinalyses for plutonium were completed.

The second donor (Case 40-002) died in 1984 at age 69 of a pulmonary infarction. He had suffered a cerebral vascular accident approximately eight years before his death. This individual began work at Los Alamos as a chemist in 1946 and received his only significant exposures to plutonium between May 1946 and March 1947 when he was operations foreman in the plutonium reduction and dry chemistry operations. Eighty-seven radiourinalyses for plutonium were completed. He retired from the Laboratory in 1977 following the stroke and was physically inactive for the remainder of his life.

The third whole-body donor (Case 40-070), also a chemist, began work at the Laboratory in July 1946 and

was subject to potential airborne plutonium exposure from that time until his retirement in 1979. Involvement in potential accidents occurred in 1946, 1947, 1957, and 1967. He died in 1984 of small-cell undifferentiated carcinoma of the lung. During his working lifetime, 187 urine samples were analyzed for plutonium.

Organs and tissues were removed from the chest and abdominal cavities during the postmortem examinations at Los Alamos and were taken directly to the analytical laboratory. The bodies were flown to Richland, Washington, by chartered plane, and a team of scientists, assembled by the U.S. Transuranium Registry, completed the dissection of the body. The methods used for the subdivision of the skeleton have been previously described.¹ All tissues and bones were frozen and shipped to Los Alamos for analysis. The analytical procedure has also been described.¹

The general distribution of ^{239}Pu in these three bodies is shown in Tables I-III. In Case 26-118, 42% of the plutonium retained in the systemic system (whole-body deposition minus the respiratory track) was in the liver and 44% was in the skeleton. Striated muscle contained 7%, the skin contained 2%, and all remaining soft tissues contained 5% of the systemic plutonium. These data compare favorably with the distributions recommended by the International Commission on Radiological Protection (ICRP) Publication 30 for the early deposition of plutonium, that is, 45% for the fractional deposition from blood to liver, 45% in bone, and the remaining 10% in all other tissues and early excreta. The lung and associated tissues of the respiratory track retained about 53% of the total whole-body deposition, indicating a much longer residence half-time than the 500 days suggested by the ICRP.

Cases 40-002 and 40-070 have somewhat similar distributions of plutonium but differ greatly from Case 26-118. The fraction of the whole-body content retained in the respiratory track was 38% and 18%, respectively. In the systemic deposition, 25% was in the

Table 1. Distribution of radioactivity in the body of a rat (g)				
Tissue/Organ	Wet Weight (g)	Ash Weight (g)	Activity (Bq)	Distribution (%)
Respiratory track	1,337		130.0	52.75
Liver	1,863		48.6	19.74
Kidneys	326		0.1	0.03
Spleen	258		1.5	0.59
Smooth muscle organs	1972		0.6	0.24
Striated muscle	24,659		8.6	3.48
Other muscle	968		0.3	0.12
Skin	19,688		2.6	1.06
Other soft tissue	1,806		3.0	1.23
Testes	14		0.0	0.00
Bones and teeth	8,691	2681	51.1	20.76
Total whole body	61,583		246.4	100.00

Table 2. Distribution of radioactivity in the body of a rat (g)				
Tissue/Organ	Wet Weight (g)	Ash Weight (g)	Activity (Bq)	Distribution (%)
Respiratory track	971		85.6	37.75
Liver	1,600		35.7	15.74
Kidneys	375		0.2	0.07
Spleen	103		0.1	0.04
Smooth muscle organs	2,699		0.8	0.35
Striated muscle	25,685		12.8	5.64
Other muscle	1,111		0.8	0.37
Skin	7,082		1.4	0.61
Other soft tissue	1,355		1.0	0.42
Testes	29		0.1	0.03
Bones and teeth	8,407	2600	88.4	38.97
Total whole body	49,417		226.9	100.00

Table III. Distribution of ^{239}Pu in Case No. 40-070

Tissue/Organ	Wet Weight (g)	Ash Weight (g)	Activity (Bq)	Distribution (%)
Respiratory track	1,698		56.3	18.57
Liver	2,604		47.8	15.77
Kidneys	670		0.5	0.16
Spleen	236		1.6	0.53
Smooth muscle organs	2,518		1.3	0.43
Striated muscle	23,930		12.3	4.06
Other muscle	835		0.8	0.27
Skin	12,720		3.9	1.27
Other soft tissue	2,071		3.9	1.28
Testes	38		0.2	0.05
Bones and teeth	9,084	2850	74.8	57.61
Total whole body	56,404		303.4	100.00

liver and 63% in the skeleton of Case 40-002; 19% and 71% were in the liver and skeleton, respectively, of Case 40-070. These distributions are similar to the revised values reported in ICRP Publication 48³ of 50% in the skeleton and 30% in the liver. However, ICRP 48 states that "the variability of the deposition of plutonium between individuals is such that, for radiation protection purposes, the ICRP 30 model of equal distribution between skeleton and liver (45% in each) remains an adequate assumption."

Table IV lists data on the measured plutonium concentrations in selected soft tissues not often collected in routine autopsies for chemical analyses. If one identifies muscle as a nonconcentrating organ for plutonium, then the concentrations in other tissues and organs can be compared. Relatively high concentrations in at least one case were observed in spleen, organs of the digestive system (esophagus, stomach, and duodenum), circulatory system (heart, pericardium, aortic arch, and descending aorta), gall bladder, prostate, and pituitary.

The three whole bodies described above will also be analyzed for their ^{241}Am content and comparisons will

be made of the distribution of ^{239}Pu and ^{241}Am .

Additionally, two other bodies from individuals having significant plutonium depositions are currently being analyzed, and these data will contribute to improving the models used for radiation protection purposes.

References

1. J. F. McInroy, H. A. Boyd, B. C. Eutsler, and D. Romero, "The U.S. Transuranium Registry Report on the ^{241}Am Content of a Whole Body, Part IV: Preparation and Analysis of the Tissues and Bones," *Health Physics* **49**, 587-621 (1985).
2. International Commission on Radiological Protection, "Limits for Intakes of Radionuclides by Workers," *ICRP Publication 30* (Pergamon Press, Oxford, 1978).
3. International Commission on Radiological Protection, "The Metabolism of Plutonium and Related Elements," *ICRP Publication 48* (Pergamon Press, Oxford, 1986).

Table 1. Organismal Data			
Case No.	26-118	40-002	40-070
Total Body Content (Bq)	247.9	225.7	284.9
Tissue/Organ	Concentration (mBq/kg wet weight)		
Lung	68,733	43,400	20,667
Trachea	4,233	23,283	11,500
Liver	26,100	22,300	18,367
Kidneys	233	417	717
Spleen	5,083	983	6,750
Esophagus	NA	NA	9,667
Stomach	1,133	783	567
Duodenum	NA	NA	1,267
Intestine, small	NA	133	367
Intestine, large	67	167	200
Heart	167	467	1,317
Pericardium	18,717	NA	NA
Tongue	183	450	1,150
Diaphragm	467	1,033	683
Testes	717	617	3,917
Adrenals	800	1,133	1,817
Aortic arch	NA	6,950	45,900
Aorta, descending	NA	2,867	3,317
Blood	33	100	867
Pancreas	1,550	3,833	333
Bile	467	NA	NA
Gall bladder	4,017	733	NA
Prostate	4,083	383	833
Bladder, urinary	183	417	367
Hair	100	833	217
Cerebrum	117	267	467
Cerebellum	250	NA	1,083
Meninges	433	883	2,300
Spinal cord	183	NA	817
Eyes	8,767	267	683
Fat	1,133	NA	350
Salivary glands	667	517	1,050
Thyroid	750	583	1,617
Pituitary	28,750	833	5,200
Muscle	350	500	533
Skin	133	200	300
Skeleton	5,833	10,500	16,667

Simultaneous Determination of Plutonium and Americium by Liquid Scintillation Counting

Occupational exposure to plutonium and americium requires the analysis of tissue and/or excreta samples to determine the magnitude of the exposure and the appropriate course of treatment, if any. In cases where the exposure levels are low, ^{242}Pu and ^{243}Am are added as tracers, plutonium and americium are chemically separated and electroplated, and plated samples are counted by alpha spectroscopy. This entire procedure takes approximately one week. When exposure levels are higher, plutonium and americium may be determined by liquid scintillation counting. Until recently, this method of analysis required a determination of the gross alpha count in one aliquot followed by a plutonium analysis with an extractant cocktail on a second aliquot. The americium was determined by the difference between the gross alpha count and the plutonium count. The advantage of liquid scintillation counting was that an analysis could be completed in an eight-hour period.

We have developed a method for the simultaneous determination of plutonium and americium with a liquid scintillation counter to eliminate the need for two separate counts on two different aliquots.¹ In this new method, a two-phase cocktail that separates the plutonium and americium was developed. After the plutonium and americium are distributed in the appropriate phases, the sample is counted in a multichannel instrument. The difference in the efficiency of the energy transfer processes in each phase gives rise to spectral peaks that do not overlap and permit the quantitation of plutonium in one channel and americium in the other channel with a single count.

This method for the simultaneous determination of plutonium and americium takes advantage of the ability of plutonium to be oxidized to Pu(IV) by nitric acid, whereas americium remains as Am(III) . After ashing, the samples were treated in a counting vial with concentrated nitric acid and then evaporated to dryness. The nitric acid treatment and subsequent evaporation to dryness were repeated a second time. The residues were dissolved in 3 mL of 0.15-M nitric acid. Ten milliliters of a slightly modified Bray's cocktail² were added, followed by 0.8 mL of a cocktail containing bis(2-ethylhexyl) hydrogen phosphate (D2EHPA) in toluene.³ Under these conditions, a two-phase cocktail, with scintillators present in both phases, was formed with Am(III) located in the Bray's phase while Pu(IV) was extracted into the D2EHPA phase.

After being shaken on a platform shaker, the sample was counted in a Packard Model 3320 liquid scintillation counter. Plutonium was counted at 2% gain in a window that extended from 100 divisions to 500 divisions, while

americium was counted in a second channel at 20% gain in a window that extended from 25 divisions to 1000 divisions. The spectra of ^{239}Pu and ^{241}Am are shown in Figure 1.

Figure 1. Spectra of ^{239}Pu and ^{241}Am at 2%, 6%, and 20% gain.

Recoveries of plutonium and americium from spiked solutions were between 95% and 105% for activity levels from 80 counts per minute (cpm) to 6000 cpm. Background count for plutonium was 21 cpm and for americium was 40 cpm.

A 100-mg tissue sample from an individual exposed to a mixture of ^{239}Pu , ^{241}Pu , and ^{241}Am was analyzed for ^{239}Pu and ^{241}Am using the two-phase cocktail technique and compared with results obtained from liquid scintillation counting using two separate counts (ZnS scintillation counting and alpha spectroscopy).⁴ A second analysis of the tissue sample was conducted by liquid scintillation counting with the two-phase cocktail

Method of Analysis ^a	Activity Ratio Am/Pu	Total Activity (Bq)
L.S. counting Two-phase cocktail Set 1	1.13 ± 0.01	762 ± 15
L.S. counting Two-phase cocktail Set 2 (extra shielding)	1.15 ± 0.04	838 ± 15
L.A. counting Insta-Gel cocktail	^b	851 ± 4
L.A. counting D2EHPA cocktail	1.14 ± 0.02 ^c	^b
ZnS scintillation counting (100-μL aliquots)	^b	847 ± 15
ZnS scintillation counting (250-μL aliquots)	^b	866 ± 15
α-Spectroscopy ^d	1.19 ± 0.03	^e
α-Spectroscopy ^f	1.2	814
^a Samples analyzed in triplicate unless noted. ^b Cannot be determined by this technique. ^c Value determined with data from L.S. counting in Insta-Gel cocktail and L.S. counting in D2EHPA cocktail. ^d Plutonium and americium not separated by ion exchange before electrodeposition. ^e Not determined. ^f Single sample analyzed by G. Martinez; plutonium and americium separated by ion exchange before electrodeposition.		

after additional lead shielding had been added above and below the counting chamber. The results are shown in Table I. The two-phase technique gave results comparable with the other methods and was the only method that was able to detect the presence of ²⁴¹Pu, a beta emitter. In addition, the two-phase cocktail was the fastest method of analysis. The additional shielding of the counting chamber lowered the background in the americium channel to 22 cpm but had no effect on the background in the plutonium channel. This lowering of the americium background will lower the limits of detection.

The liquid scintillation counter used in these studies is currently being modified to operate at temperatures below 4°C. This is being done to determine the effect of temperature on the width of the emission bands of the solvent and scintillators. The ultimate goal is to see what effect temperature has on the width of the spectral peaks. The width of the spectral peaks is a factor in determining the energy resolution of the liquid scintillation counter.

References

1. J. J. Miglio, "Simultaneous Determination of Americium and Plutonium by Liquid Scintillation Counting Using a Two-Phase Cocktail," *Analytical Chemistry* **58**, 3215-3218 (1986).
2. G. A. Bray, "A Simple Efficient Liquid Scintillator for Counting Aqueous Solutions in a Liquid Scintillation Counter," *Analytical Biochemistry* **1**, 279-285 (1960).
3. R. F. Keough and G. J. Powers, "Determination of Plutonium in Biological Materials by Extraction and Liquid Scintillation Counting," *Analytical Chemistry* **42**, 419-421 (1970).
4. J. J. Miglio and L. C. Willis, "Simultaneous Liquid Scintillation Determination of ²³⁹Pu and ²⁴¹Am in Tissue" (submitted to *Journal of Radioanalytical and Nuclear Chemistry*, 1987).

Evaluation of a Technique for Separating Organic Material from Mineral Bone in Individuals Occupationally Exposed to Plutonium

Knowledge of the distribution of plutonium among the tissues of occupationally exposed individuals is of importance in explaining and predicting any health effects. Previous studies have shown that approximately 70% of the systemic plutonium is found in the bone.^{1,2} In these previous studies, no attempt was made to separate the organic component of bone from the mineral component. A knowledge of the location of the plutonium within the bone is important because the biological consequences will be determined by the plutonium distribution. If plutonium is concentrated in the marrow, there may be an increased risk of leukemia, whereas if the plutonium is concentrated in the mineral component, the potential for bone cancer may be increased.³

A complete separation of organic material from mineral bone by aqueous solutions of ethylenediamine has been previously accomplished.^{4,5} However, these studies did not involve the determination of plutonium, and as a result it was necessary to determine if ethylenediamine treatment removed plutonium from or deposited plutonium on bone surfaces during the separation procedure. It was also necessary to determine if plutonium could be quantitatively recovered from solutions of ethylenediamine.

The shaft from the left femur of an individual exposed to plutonium in a work environment was chosen for study. After removal of the distal and proximal ends, the shaft was cut in three segments: a segment adjacent

to the proximal end (PE shaft) approximately 60 mm in length, a segment (mid shaft) approximately 140 mm in length, and a segment adjacent to the distal end (DE shaft) approximately 90 mm in length. Marrow was removed from the central cavities of each segment by pushing a piece of filter paper through the lumen with a glass rod. The recovery of plutonium from solutions of ethylenediamine was determined by spiking solutions of ethylenediamine with ²⁴²Pu, boiling the solutions for 8 h, adding an equal volume of water, and analyzing the resulting solution for plutonium.

Segment PE shaft was cut in half along the vertical axis. One segment was treated with a 20% (v/v) solution of ethylenediamine and the other segment was treated with an 80% (v/v) solution for 8 h, each followed by an 8-h wash cycle with water. The mid-shaft segment was cut into four nearly identical segments along the vertical axis. The four segments were treated at the same time with a 20% solution of ethylenediamine. After an 8-h extraction and an 8-h wash cycle with water, one segment (MS 1) was removed from the extractor. After an additional 8-h extraction and an 8-h wash, a second segment (MS 2) was removed from the extractor. A third segment (MS 3) was removed after an additional 16-h extraction period followed by a 8-h wash, and the fourth segment (MS 4) was removed after a further 16-h extraction followed by a 8-h wash. Segment DE shaft was treated with a 20% (v/v) ethylenediamine for 16 h followed by an 8-h wash.

Sample No.	Extraction Time (h)	Wash Time (h)	Concentration ²³⁹ Pu (Bq/kg Ash)
MS 1	8	8	27 ± 1 ^a
MS 2	16	16	28 ± 1 ^a
MS 3	32	24	32 ± 1 ^b
MS 4	48	32	27 ± 1 ^c

^a±1 std dev of measurement, n = 1.
^b±1 std dev of mean, n = 3.
^c±1 av dev, n = 2.

Table II. Concentration of ^{239}Pu in Mineral Bone				
Sample No.	Dry Weight (g)	Ash Weight (g)	Concentration ^{239}Pu (Bq/kg Dry) (Bq/kg Ash)	
PE shaft	32.47	30.05	33 ± 2	35 ± 2
Mid shaft	94.19	82.11	25 ± 2	29 ± 2
DE shaft	58.42	45.44	21 ± 2	27 ± 2
Note: Errors indicated are due to counting statistics.				

Table III. Concentration of ^{239}Pu in Marrow from Lumen				
Sample No.	Dry Weight (g)	Ash Weight (g)	Concentration ^{239}Pu (Bq/kg Dry) (Bq/kg Ash)	
PE shaft	5.51	0.08	3.8 ± 0.3	259 ± 18
Mid shaft	19.36	0.25	4.5 ± 0.2	348 ± 13
DE shaft	9.35	0.20	2.5 ± 0.2	117 ± 8
Note: Errors indicated are due to counting statistics.				

In addition to the above samples, two sections of femur shaft from an individual with no known exposure to plutonium were spiked with ^{238}Pu and extracted with ethylenediamine. One segment was extracted for 16 h with a 20% (v/v) solution of ethylenediamine, and the other segment was extracted with a 80% (v/v) solution. Other bone samples from this individual had been previously analyzed for ^{238}Pu and none was found.

The average recovery of plutonium from two solutions of ethylenediamine was 104% of the amount added. Thus plutonium can be quantitatively recovered from solutions of ethylenediamine.

The bone segments from the individual with no known exposure to plutonium contained less than 4% of the ^{238}Pu added. This small amount of plutonium was due to organic material that remained in the bottom of the thimble after the extraction process, a small amount of which adhered to the bone as it was removed from the thimble. These results indicate that plutonium is not removed from the bone during the extraction procedure nor is it deposited on the bone by hydrolysis of plutonium from the removed organic material.

The results for the marrow, remaining organic material, and mineral bone from the individual exposed to plutonium in the workplace are shown in Tables I, II,

and III. The essentially identical results for the plutonium concentration in the mid-shaft segments show that plutonium is not removed from the bone during the extraction procedure.

References

1. J. F. McInroy, "The Los Alamos Scientific Laboratory's Human Autopsy Tissue Analysis Study," *The Health Effects of Plutonium and Radium*, W. S. Jee, Ed. (The J. W. Press, Salt Lake City, Utah, 1976).
2. R. G. Thomas, J. W. Healy, and J. F. McInroy, "Plutonium Partitioning Among Internal Organs," *Health Physics* **46**, 839-844 (1984).
3. J. Vaughn, "Plutonium—A Possible Leukaemic Risk," *The Health Effects of Plutonium and Radium*, W.S.Jee, Ed. (The J. W. Press, Salt Lake City, Utah, 1976).
4. A. Martin, "A Comparison of Bone Ashing Techniques," *Health Physics* **13**, 1351-1352 (1967).
5. J. B. Williams and J. W. Irvine, Jr., "Preparation of the Inorganic Matrix of Bone," *Science* **119**, 771-772 (1954).

A Comparison of Methods for Separation of the Organic Component from the Mineral Component of Bones from Individuals Occupationally Exposed to Plutonium

The distribution of plutonium among the components of bone of individuals exposed to plutonium in a work environment can determine health effects. If the dose to bone is calculated from the plutonium concentration, an assumption is made that the plutonium is uniformly distributed throughout the sample. However, if plutonium is concentrated in the marrow, for example, there will be an increased radiation dose to marrow compared with the dose calculated if a uniform distribution is assumed. Thus, the potential for leukemia may be higher than if a uniform dose is assumed.¹ Otherwise, if plutonium is concentrated in the endosteum or periosteum, the localized dose to the bone surface will be much higher than that calculated if a uniform distribution of plutonium is assumed.

Several methods have been or are being used to separate the organic component from the mineral component of bone.^{2,3,4} These methods have been used in different laboratories on different types of samples, and they have not been evaluated by a direct comparison of the techniques using similar bone samples from an individual. To determine which method would best suit the needs of the United States Transuranium Tissue Analysis Project, a comparison of the methods was made by using vertebral bodies from an individual exposed to plutonium.

The four methods chosen were the following: chemical separation with ethylenediamine, mechanical separation by a stream of water, mechanical separation by ultrasonic agitation, and thermal separation by heating in an autoclave. Chemical separation with ethylenediamine was chosen as the standard method for comparison because it was known to remove all organic material from mineral bone.⁵

Four vertebrae—the twelfth thoracic vertebra (T-12) and the first, second, and fourth lumbar vertebrae (L-1, L-2, and L-4)—were obtained at autopsy. Discs associated with each vertebra were removed with a scalpel, and the arches were removed with an autopsy saw. Each body was cut in half sagittally: the right half (A) of each body was separated into two components

with ethylenediamine, and the left half (B) was separated by one of the other methods (Table I). Calcium was determined in bone and separated organic material by titration past the endpoint with ethylenediamine-tetraacetic acid followed by back titration and a standard zinc solution. Eriochrome Black T was used as the indicator.

The experimental results are shown in Tables I, II, and III. The ethylenediamine technique provided the most complete separation of organic material from mineral bone but was the most time consuming (~4 days) of the four methods studied. The water jet and the ultrasound methods give comparable results for the concentration of plutonium in the organic material. The autoclave technique appears to remove only water and fat. Neither fat nor water contained a significant amount of plutonium. The ethylenediamine technique is capable of providing more information than any of the other methods tested because only this method can determine the total amount of plutonium in the organic material and therefore the distribution of plutonium between the organic material and bone. If the concentration of plutonium in organic material is the only quantity that is to be determined, then either the water jet or the ultrasound technique is the method of choice due to the short time necessary to complete the procedure (~2 h). The autoclave procedure was not satisfactory for any purpose.

No calcium was found in the organic material separated by the ethylenediamine, ultrasound, or autoclave techniques. A small amount of calcium was in the organic material separated by the water jet technique because of a small amount of bone dust created during the sample cutting step. The calcium content of the mineral component is listed in Table III. Approximately 88% of the plutonium present was associated with the mineral component in bodies separated by ethylenediamine, whereas 95% of the total plutonium was associated with the bone in bodies separated by the water jet or sonication technique. This suggests that 7% of the plutonium activity may be associated with the endosteum and periosteum and 5% with the red bone marrow.

Sample No.	Separation Method	Wet Weight Bone (g)	Bone Ash (g)	Weight Organic Material (g)
T-12-A	Ethylenediamine	24.42	3.43	20.69
T-12-B	Water jet	33.73	4.72	11.51
L-1-A	Ethylenediamine	26.90	7.61	17.33
L-1-B	Ultrasound	23.13	4.35	6.25
L-2-A	Ethylenediamine	31.88	9.57	17.25
L-2-B	Autoclave	29.61	6.55	8.16
L-4-A	Ethylenediamine	23.91	4.92	16.85
L-4-B	Autoclave	29.81	7.08	17.80

Sample ID	Separation Method	Bone Ash (Bq Pu/kg) ^a	Organic Material (Bq Pu/kg) ^a	% Pu in Mineral Component
T-12-A	Ethylenediamine	104 ± 4	3.14 ± 0.14	84.6
T-12-B	Water jet	106 ± 7	2.93 ± 0.18	93.7
L-1-A	Ethylenediamine	56.3 ± 1.9	4.35 ± 0.21	85.1
L-1-B	Ultrasound	93.0 ± 3.2	0.98 ± 0.24	95.6
L-2-A	Ethylenediamine	62.0 ± 2.0	2.79 ± 0.15	92.5
L-2-B	Autoclave	90.5 ± 3.0	0.85 ± 0.11	98.8
L-4-A	Ethylenediamine	86.6 ± 3.1	2.82 ± 0.16	90.0
L-4-B	Autoclave	81.2 ± 2.7	0.17 ± 0.03	99.5
^a Std dev of ±1; error due to counting statistics.				

Sample ID	Separation Method	Bone Ash (kg Ca/kg) ^a	Bq Pu/kg Ca ^b	Wet Weight (kg Ca/kg)
T-12-A	Ethylenediamine	0.338	309 ± 11	0.0474
T-12-B	Water jet	0.365	289 ± 20	0.0511
L-1-A	Ethylenediamine	0.326	173 ± 6	0.0923
L-1-B	Ultrasound	0.340	273 ± 9	0.0640
L-2-A	Ethylenediamine	0.342	183 ± 6	0.103
L-2-B	Autoclave	0.348	260 ± 8	0.0769
L-4-A	Ethylenediamine	0.331	262 ± 9	0.0681
L-4-B	Autoclave	0.330	246 ± 8	0.0784
^a Average kg Ca/kg bone ash = 0.340 ± 0.012.				
^b Std dev of ±1; error due to counting statistics.				

References

1. J. Vaughn, "Plutonium—A Possible Leukaemic Risk," *The Health Effects of Plutonium and Radium*, W. S. Jee, Ed. (The J. W. Press, Salt Lake City, Utah, 1976).
2. B. J. McClanahan, "Comparison of Methods for Separating Bone Marrow from Bone," *Pacific Northwest Laboratory Annual Report for 1977 to the DOE Assistant Secretary for Environment, Part 1—Biomedical Sciences*, W. R. Wiley and staff members, Eds. (Battelle Pacific Northwest Laboratories, Richland WA 99352, 1978).
3. G. B. Schofield, British Nuclear Fuels Limited, Windscale & Calder Works, Sellafield, Seascale, Cumbria, United Kingdom CA20 1PG, personal communication, 1983.
4. J. J. Miglio, J. F. McInroy, and L. C. Willis, "The Concentration of Pu in Mineral Bone and in the Organic Material Removed from the Bone of an Occupationally Exposed Individual," presented at the 31st Annual Conference on Bioassay, Analytical and Environmental Chemistry, Chalk River Nuclear Laboratories, Chalk River, Canada, October 8-10, 1985.
5. J. J. Miglio and L. C. Willis, "Evaluation of a Technique for Separating Organic Material from Mineral Bone in Individuals Occupationally Exposed to Pu" (accepted for publication in *Health Physics*, 1987).

Environmental Chemistry for the National Park Service

Authors: R. W. Ferenbaugh and E. S. Gladney

Group: Health and Environmental Chemistry, HSE-9

Funding Organization: Air Quality Division,
National Park Service

The Los Alamos National Laboratory (LANL) has entered into an interagency agreement with the National Park Service through which LANL will perform studies at various national parks and monuments to investigate potential impacts from nearby pollution sources. These studies are being conducted by personnel from the Health and Environmental Chemistry Group, HSE-9. The following studies are currently under way.

Sulfur Dioxide Fumigation of Pinon Pine

The National Park Service is concerned about potential impacts on national parks and monuments throughout the Southwest as a result of sulfur dioxide emissions from various sources, mostly power plants and smelters. An experimental fumigation facility has been constructed at LANL to investigate the effects of controlled exposures of selected plant species to selected chemicals. Extensive studies have been carried out on both acute and chronic exposure of pinon pine seeds and seedlings to sulfur dioxide. Pinon pine was selected because it is a ubiquitous and representative southwestern plant species. Preliminary evaluation of the fumigation data indicates that pinon pine is relatively resistant to sulfur dioxide.

Baseline Sulfur Concentrations at Four Corners

There is concern about long-term impacts of sulfur dioxide emissions from the large power plant at Four Corners. Consequently, samples of pinon pine foliage and soil were collected from five national parks and monuments in the Four Corners area to be analyzed for sulfur content. This will provide a baseline against which to compare the sulfur content of similar samples taken at some future date. The five national parks and monuments that were sampled were Bandelier National Monument, Canyonlands National Park, Chaco Culture National History Park, Mesa Verde National Park, and

Petrified Forest National Park. The pinon pine foliage collected was separated into year classes of needles, and the soil was stratified into surface and subsurface layers. About 6000 sulfur analyses are involved. The foliage analyses have been completed, and preliminary evaluation of the data reveals no temporal or geographical trends. Analysis of soil samples is still in progress.

Saguaro National Monument

The saguaro population at Saguaro National Monument has been declining for some time. This previously was attributed to natural climatic or population cycle factors, but recently nearby smelters and the Tucson metropolitan area have become suspected contributors to the decline as emission sources of metals and sulfur dioxide. Samples of saguaro tissue and soils were collected from the monument to be analyzed for various chemicals to see if elevated levels of these chemicals could be detected. Tree cores were collected from ponderosa pine trees in the nearby Rincon Mountains (also part of Saguaro National Monument) to see if analysis of the annual rings would show increases in chemical concentrations over time. Tree cores were collected from ponderosa pine trees in Chiricahua National Monument, about 100 miles distant, to provide a control for any trends in annual ring concentrations that might be detected. Chemical analysis of the collected samples has just begun.

Everglades National Park

Pine needles from Everglades National Park will be analyzed for chemical content to evaluate impacts on the park. Samples will be collected by National Park Service personnel and shipped to LANL, which will provide only analytical chemistry support for this project. No samples have been received to date.

REPRODUCED FROM
BEST AVAILABLE COPY

Mortality Among Plutonium and Other Radiation Workers at the Rocky Flats Facility

Authors: G. S. Wilkinson, G. L. Tietjen (Statistics, A-1),
L. D. Wiggs, W. A. Galke, J. F. Acquavella,
M. Reyes, G. L. Voelz, and R. J. Waxweiler

Group: Occupational Medicine, HSE-2

Funding Agency: DOE, Office of Health and Environmental
Research, Human Health and Assessments Division

Mortality among 5413 white males who were employed for at least two years at Rocky Flats was investigated to measure the effect of exposure to plutonium and external radiation.¹ For the complete cohort, fewer deaths than expected were found for all causes of death, all cancers, and lung cancer when compared with the U.S. white male population. No deaths due to bone cancer were identified in the cohort. An excess of brain tumors was observed.

The impact of exposure to plutonium and external radiation was assessed by stratified rate ratio analysis, followed by regression analyses of directly adjusted rates for dose response relationships. Elevated rate ratios (a measure of relative risk) for all causes of death and all hemato-lymphopoietic cancers (Codes 200-209, *International Classification of Diseases*, 8th Revision) were found when employees with plutonium body burdens of 2 nCi or more were compared with those with body burdens less than that, while accounting for age, calendar period, and induction time. Increased rate ratios were noted for esophageal, stomach, colon, and prostatic cancers and for lymphosarcoma/reticulum cell sarcoma. However, rate ratios were not elevated for bone and liver cancers, which are cancer types that have been observed in experimental animals exposed to plutonium.

Comparisons of employees with cumulative external radiation exposures of 1 rem or more with those exposed to less than that resulted in suggestively elevated rate ratios for myeloid leukemia, lymphosarcoma and

reticulum cell sarcoma, liver neoplasms, and unspecified brain tumors. In all cases, the lower 90% confidence limits were less than unity, which suggests the role of chance in producing these findings is not ruled out.

In none of the dose response analyses was a statistically significant coefficient of exposure greater than zero observed. Standardized rate ratios increased in a monotonic fashion with increasing exposure for all causes of death, all cancers, and digestive cancers among the plutonium burdened with five years of latency; this finding was also noted for all hemato-lymphopoietic cancers and unspecified brain tumors with two years of latency among the external radiation exposed.

Except for analyses of combined categories of causes of death, and perhaps lung cancer, confidence intervals were wide, indicating limited precision. Nevertheless, these findings suggest that increased risks for several types of cancers cannot be ruled out at this time for individuals with plutonium body burdens of ≥ 2 nCi. Continued follow-up of this cohort is required to better understand the potential association between plutonium and human health effects.

Reference

1. G. S. Wilkinson, G. L. Tietjen, L. D. Wiggs, et al., "Mortality Among Plutonium and Other Radiation Workers at a Plutonium Weapons Facility," *American Journal of Epidemiology* **125** (2), 231-250 (February 1987).

Mortality Among Mound Employees: 1942-1979

Authors: M. Reyes, G. S. Wilkinson,

G. L. Tietjen (Statistics, A-1), and L. D. Wiggs

Group: Occupational Medicine, HSE-2

Funding Organization: DOE, Office of Health and Environmental
Research, Human Health and Assessments Division

An epidemiologic investigation of mortality among 4697 white males employed by the Mound Facility between 1942 and 1979 has been conducted. This investigation compared observed mortality among the Mound workers with expected mortality based on U.S. death rates. Standardized mortality ratios (SMRs) did not indicate elevated cause-specific mortality among the cohort of workers employed between 1942 and 1979 (Table I). Specific categories, not shown on Table I, of mortality from digestive cancers and accidents were significantly less than expected.

A significantly elevated lung cancer SMR was observed for the subcohort of workers employed from 1942 to 1959, a period characterized by ^{210}Po operations at Mound. Examination to determine the impact of

World War II (WWII) selection factors found that the lung cancer excess occurred among persons employed during WWII (1942 to 1945). The excess of lung cancer was not observed for the period following WWII (1946 to 1959). Similar results were observed for all causes and all cancer SMRs, which were elevated during the wartime (WWII) period but which were not subsequently elevated after WWII.

Further investigations on mortality among Mound employees will examine the impact of exposure to external radiation and internal emitters such as polonium and plutonium. These investigations will compare mortality experience for radiation-exposed Mound workers with that of nonexposed workers.

Table I. Standardized Mortality Ratios Among White Male Employees at Mound Plant Between 1942 and 1979

Cause (CDA-8)	Observed	SMR	90% Exact CI ^a
All causes (1-99)	826	96	91-102
All cancers (140-209)	157	96	84-110
Circulatory diseases (390-458)	406	94	86-102
Cerebrovascular diseases (430-438)	55	98	77-123
Respiratory diseases (460-519)	48	104	81-132
Digestive diseases (520-577)	45	101	78-129
Genitourinary diseases (580-998)	17	137	87-205
All causes (800-998)	88	85	71-101

^a A 90% confidence interval is equivalent to a one-sided test at alpha = 0.05.

Mortality Among Women Employed by the Los Alamos National Laboratory: 1943-1981

Authors: L. D. Wiggs and C. A. Weber

Group: Occupational Medicine, HSE-2

Funding Organization: DOE, Office of Health and Environmental
Research, Human Health and Assessments Division

A historical cohort analysis of 6790 women employed by the Los Alamos National Laboratory has been conducted. This epidemiologic investigation focused on two questions. First, did mortality among members of the cohort overall and among the radiation-exposed subcohorts differ significantly from mortality among females in the United States population? Second, did female workers who were exposed to radiation in their jobs have an increased risk of dying, especially from cancer, compared with workers who were never exposed to radiation?

To address the first question, standardized mortality analyses were conducted using U.S. death rates to generate expected values. In general, observed mortality was less than expected and no cause significantly exceeded expectation. The standardized mortality ratios (SMRs) were 76 and 78 for all causes and all cancers respectively, with 100 as the value for the expected.

When mortality among the radiation-exposed subcohorts was compared with expected mortality based on the rates for the U.S. population, an excess of suicide mortality was observed. The suicide SMR for workers monitored for external radiation was 350 (95% confidence interval or CI = 140, 720). For workers with at least 1 rem of cumulative exposure to ionizing radiation, the suicide SMR was 928 (95% CI = 104, 3352).

To address the second question, stratified analyses directly comparing mortality rates for radiation-exposed and nonexposed members of the cohort were conducted.

Rate ratios, comparing mortality between workers monitored for external ionizing radiation and those not monitored, were significantly elevated for cancers of the ovary and pancreas. Previous epidemiologic evidence indicates that these cancers may be associated with radiation exposure. In this cohort, radiation exposure appears unlikely to explain these findings because of the low levels of exposure among these women. Other cancers, previously reported to be associated with radiation exposure, for example, leukemias, were not found to be elevated among the members of this cohort.

At 10 and 15 years of induction, an elevated risk of all causes of death among external-radiation monitored workers compared with nonmonitored workers was explained by an elevated risk of suicide among the external-radiation monitored workers. Suicide rate ratios of 11.55 (95% CI = 3.25, 41.06) and 6.67 (95% CI = 1.66, 26.85) were observed for 10 and 15 years of induction, respectively.

Elevated suicide was observed both when mortality for radiation workers was compared with expected values based on U.S. rates and when mortality rates for radiation-monitored workers were compared with the rates for nonmonitored workers. These findings, while probably not associated with any biologic effects of exposure, have not yet been explained by other factors. Additional work needs to be conducted to understand these results.

A 42-Year Follow-up of Manhattan Project Plutonium Workers

Authors: G. L. Voelz, A. R. Stevenson (Cell Biology, LS-4), and C. C. Stewart (Cell Biology, LS-4)

Group: Occupational Medicine, HSE-2

Funding Organization: DOE, Office of Health and Environmental Research, Human Health and Assessments Division

Twenty-six male subjects who worked with plutonium during World War II at Los Alamos have been given medical examinations periodically over the past 42 years to identify potential health effects. Inhalation was the primary mode of plutonium exposures. The latest examinations, including *in vivo* measurements for radioactivity, were performed in late 1986 and 1987. Current estimates of individual plutonium depositions, including lung burdens, range from 1.4 to 85 nCi with a median value of 12.5 nCi. Eight subjects have depositions in excess of 40 nCi, often considered the lifetime maximum permissible body burden for workers. Table I summarizes information on four subjects in the group who have died. Table II compares the mortality of this group with expected deaths based on U.S. age and calendar year adjusted rates for white males. This comparison shows the mortality in the group to be low, but the small number of persons in the group severely limits the precision of estimates. The average age of the 22 living subjects is 66 years. The diseases and physical changes noted in

these individuals are characteristic of a male population in its 60s. The study yields no evidence suggesting that adverse health effects have resulted from the 42 years of exposure to internally deposited plutonium.

As part of the clinical examination, a special study of the classification of lymphocyte subtypes and their radiation sensitivity was made on 18 of these persons. Elevated T-cell helper/suppressor ratios were skewed to higher ratios for plutonium workers compared with 14 age-matched controls. This was due to a depression of suppressor cells with normal numbers of helper cells. *In vitro* radiation studies indicate the suppressor cells were more radiosensitive than the helper cells for both control and plutonium-exposed individuals, but the sensitivity was greater for the plutonium workers. These findings may suggest an enhanced immune-response potential in some individuals after plutonium deposition due to decreased numbers of suppressor cells. Further investigations into the effects of chronic low-dose radiation to the immune system are needed.

Table 1. Summary of Deaths Through September 1986				
ID No.	Pu Burden	Age at Death	Year of Death	Cause of Death
10	14	71	1985	Lung cancer
15	10	36	1959	Myocardial infarction
16	19 ^a	52	1975	Trauma from auto/pedestrian accident
27	7 ^a	62	1982	Respiratory failure from pneumonia and congestive heart failure
^a Plutonium body burden estimated by extrapolation of autopsy data.				

Table 2. Observed and Expected Deaths in the Cohort			
Categories of Deaths	Observed	Expected ^a	O/E Ratio
All causes of death	4	9.2	0.44
All malignant neoplasms	1	2.0	0.49
All diseases of circulatory system	1	4.3	0.23
All respiratory disease	1	0.5	1.99
All diseases of digestive system	0	0.5	—
All external causes	1	1.07	0.93
Characteristics of Cohort:			
Average year of entry	1944.9		
Average age of entry	24.1		
Total person-years of survival	1026.1		
^a Expected deaths based on U.S. age and calendar year adjusted rates for white males.			

Environmental Surveillance

REPRODUCED FROM
BEST AVAILABLE COPY

Environmental Surveillance at Los Alamos

Authors: *Environmental Surveillance Group*

Group: *Environmental Surveillance, MSE-8*

Funding Organization: *Indirect*

Monitoring Operations

The Laboratory maintains an ongoing environmental surveillance program as required by U.S. Department of Energy (DOE) Orders 5480.1A ("Environmental Protection, Safety, and Health Protection Programs," August 1981) and 5484.1 ("Environmental Protection, Safety, and Health Protection Information Reporting Requirements," February 1981). The surveillance program maintains routine monitoring for radiation, radioactive materials, and chemical substances on the Laboratory site and in the surrounding region. This activity documents compliance with appropriate standards, identifies trends, provides information for the public, and contributes to general environmental knowledge. More detailed, supplemental environmental studies are carried out to determine the extent of the potential problems, to provide the basis for any specific remedial actions, and to provide further information on surrounding environments. The monitoring program also supports the Laboratory's policy to protect the public, employees, and environment from harm that could be caused by Laboratory activities and to reduce environmental impacts to the greatest degree practicable. Environmental monitoring information complements data on specific releases, such as those from radioactive

liquid waste treatment plants and stacks at nuclear research facilities.

Monitoring and sampling locations for various types of measurements are organized into three groups: (1) Regional stations are located within the five counties surrounding Los Alamos County (Figure 1) at distances up to 80 km (50 mi) from the Laboratory. They provide a basis for determining conditions beyond the range of potential influence from normal Laboratory operations. (2) Perimeter stations are located within about 4 km (2.5 mi) of the Laboratory boundary, and many are in residential and community areas. The stations document conditions in areas regularly occupied by the public and potentially affected by Laboratory operations. (3) On-site stations are within the Laboratory boundary, and most are in areas accessible only to employees during normal working hours. These stations document environmental conditions at the Laboratory in areas where the public has limited access.

Samples of air particulates and gases, waters, soils, sediments, and foodstuffs are routinely collected at these stations for subsequent analyses (Table I). External penetrating radiation from cosmic, terrestrial, and Laboratory sources also is measured by thermoluminescent dosimeters.

Table I. Number of Sampling Locations			
Typing of Monitoring	Regional	Perimeter	On Site
External radiation	4	12	139
Air	3	11	12
Surface and ground water ^a	6	32	37
Soils and sediments	16	16	34
Foodstuffs	10	8	11
^a An additional 22 stations for the water supply and 33 special surface and ground-water stations related to the Fenton Hill Geothermal Program were also sampled and analyzed as part of the monitoring program.

Figure 1. Regional location of Los Alamos.

Additional samples are collected and analyzed to gain information about particular events, like major surface runoff events, nonroutine releases, or special studies. More than 25,000 analyses for chemical and radiochemical constituents were carried out for routine and special environmental samples during 1986. Resulting data were used for comparisons with standards and background levels of dose calculations and for interpretation of the relative risks associated with Laboratory operations.

Estimated Doses and Risks from Radiation Exposure

Radiation Doses. Estimated individual radiation doses to the public attributable to Laboratory operations are compared with applicable standards in this report. The doses are expressed as a percentage of the DOE Radiation Protection Standard (RPS). The RPS is for doses from exposures excluding contributions from natural background, fallout, and radioactive consumer products. Estimated doses are those believed to be potential doses to individuals under realistic conditions of exposure.

Historically, estimated doses from Laboratory operations have been less than 7% of the 500-mrem/yr standard that was in effect before 1985 (Figure 2). These doses have principally resulted from external radiation from the Laboratory's airborne releases. In 1985, DOE issued interim guidelines that lowered its RPS to 100 mrem/yr (effective dose) from all exposure pathways. In addition, exposure through the air pathway is further limited to 25 mrem/yr (whole body) in accordance with requirements of the U.S. Environmental Protection Agency (EPA). In 1986 the estimated maximum individual dose was 11.5 mrem, 46% of the EPA 25-mrem air emission standard. This dose resulted mostly from external radiation from short-lived airborne emissions from a linear particle accelerator, the Los Alamos Meson Physics Facility (LAMPF).

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 9% of the 127 mrem from background radioactivity in Los Alamos in 1986.

Risk Estimates. Estimates of the added risk of cancer were calculated to provide a perspective for comparing the significance of radiation exposures. Incremental cancer risk to residents of Los Alamos townsite due to 1986 Laboratory operations was estimated to be 1 chance in 77,000,000 (Table II). This risk is less than 0.2% of the cancer risk of 1 chance in 26,000 from natural

Figure 2. Summary of estimated maximum individual and maximum Laboratory boundary doses (excluding contributions from cosmic, terrestrial, and medical diagnostic sources) from Laboratory operations.

background radiation and the risk of 1 chance in 110,000 from medical radiation.

The Laboratory's potential contribution to cancer risk is small when compared with overall cancer risks. The overall lifetime risk in the United States of contracting cancer is 1 chance in 4. The lifetime risk of cancer mortality is 1 chance in 5.

External Penetrating Radiation

Levels of external penetrating radiation (including x rays 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 147 locations.

The TLD network monitoring radiation from airborne activation products released by the LAMPF measured 18 ± 3 mrem/yr (excludes background radiation from cosmic and terrestrial sources). This measured external radiation level was used to calculate radiation dose by taking into account shielding by buildings and self-shielding by the body. The value measured in 1986 was slightly higher than the measured 11 ± 2 mrem/yr obtained in 1985 (Figure 2). The increase is probably caused by differences in weather patterns between the two years rather than differences in LAMPF operations because airborne emissions from LAMPF decreased in 1986 (Table III).

Radiation levels (including natural background radiation from cosmic and terrestrial sources) were also

Table II. Added Individual Lifetime Cancer Mortality Risks Attributable to 1986 Radiation Exposure

Exposure Source	Incremental Dose (mrem) Used in Risk Estimate	Added Risk (Chance) to an Individual of Cancer Mortality
Average exposure from Laboratory operations		
Los Alamos townsite	0.13	1 in 77,000,000
White Rock area	0.09	1 in 110,000,000
Natural radiation (cosmic, terrestrial, self-irradiation, and radon exposure) ^a		
Los Alamos townsite	127	1 in 26,000 ^b
White Rock area	117	1 in 27,000 ^b
Medical x-rays (diagnostic procedures)		
Average whole-body exposure	92	1 in 110,000

^aA lung exposure of 0.2 WLM was used to estimate the risk from inhaling ²²²Rn and its transformation products.
^bThe risks from whole-body natural radiation were estimated to be 1 chance in 80,000 in Los Alamos and 1 chance in 86,000 in White Rock. The risk of lung cancer from radon exposure was estimated to be 1 chance in 38,000 for both locations. Risk estimates are derived from ICRP Publication 26.

measured at regional, perimeter, and on-site locations in the environmental TLD network. Some measurements at on-site stations were above background levels, as expected, reflecting ongoing research activities at the Laboratory. In addition, three perimeter stations had slightly elevated values during one or more of the three calendar quarters. The reason for these elevated values is not known. *In situ* spectral measurements are planned to determine the cause.

Air Monitoring

Airborne radioactive emissions were monitored at 87 release points at the Laboratory. In general, airborne radioactive emissions declined from 1985 (Table III). This was principally due to a slight decrease in releases of air activation products from LAMPF. Changes in operation resulted in these reduced emissions from LAMPF.

Ambient air is routinely sampled for tritium, uranium, plutonium, americium, and gross beta activity at 26 sampling stations. Measurements of radioactivity in the air are compared with concentration guides based upon the DOE RPS. These guides are concentrations of radioactivity in air breathed continuously throughout the year that result in effective doses equal to the DOE RPS

of 100 mrem/yr for off-site areas ("Derived Concentration Guides for Uncontrolled Areas") and to the occupational RPS for on-site areas ("Concentration Guides for Controlled Areas"). Hereafter they will be called guides for on-site and off-site areas).

Only the tritium air concentrations showed any measurable impact from radionuclides due to Laboratory operations. Annual average concentrations of tritium remained much less than 0.1% of DOE guides at all stations and posed no environmental or health problems in 1986. Annual average concentrations of longer-lived radionuclides in air were also less than 0.1% of the guides during 1986.

On April 26, 1986, an accident occurred at the fourth unit of the Chernobyl Nuclear Power Station in the U.S.S.R. As a result of this accident, large amounts of fission products were ejected into the atmosphere. These fission products were detected by the Laboratory's air-monitoring network in the weeks following the accident. However, potential doses received from this accident were locally low, <0.1% of the DOE RPS for the general public.

Water, Soil, and Sediment Monitoring

Liquid effluents containing low levels of radioactivity were routinely released from one waste

Table III. Comparison of 1985 and 1986 Radioactive Releases from the Laboratory

Radionuclide	Units	1985	1986	Ratio 1986:1985
<i>Airborne Emissions</i>				
³ H	Ci	8,638	10,700	1.2
³² P	μCi	53	70	1.34
⁴¹ Ar	Ci	390	276	0.7
¹³¹ I	μCi	146	38	0.3
Uranium	μCi	728	847	1.2
Plutonium	μCi	213	207	1.0
Gaseous Mixed Activation Products	Ci	126,079	112,000	0.9
Mixed Fission Products	μCi	1,230	2,570	2.1
Particulate/Vapor Activation Products	Ci	0.2	0.1	0.5
Total		135,107	122,976	0.9
<i>Liquid Effluents</i>				
³ H	mCi	76,850.0	89,710.0	1.2
^{89,90} Sr	mCi	10.3	9.9	1.0
¹³⁷ Cs	mCi	<0.1	18.0	—
²³⁴ U	mCi	0.6	2.4	4.1
^{238,239,240} Pu	mCi	9.7	5.1	0.5
²⁴¹ Am	mCi	5.5	3.2	0.6
Other	mCi	271.0	1,166.7	4.3
Total		77,147.1	90,915.3	1.2

treatment plant and one sanitary sewage lagoon system. Concentrations at all discharge points were well below the DOE concentration guides for on-site areas. The only major trend was an increase in tritium discharge from the TA-53 lagoons (Table III). Discharge generally increased at the lagoons because of increased concentrations of radionuclides in the lagoon waters.

Surface and ground waters are monitored to detect potential dispersion of radionuclides from Laboratory operations. Only the surface and shallow ground waters in on-site liquid effluent release areas contained radioactivity in concentrations that are above natural terrestrial and worldwide fallout levels. These concentrations are minute fractions (<0.1%) of DOE guides for on-site areas. These on-site waters are not a source of industrial, agricultural, or municipal water supplies. The radiochemical quality of water from regional, perimeter, and on-site areas that receive or

received no direct discharge showed no significant effects from Laboratory releases.

The potable water supply met all applicable EPA radiochemical and chemical standards. Lack of hydrologic connection to the deep ground-water aquifer was confirmed by lack of radioactive or chemical contamination in municipal water supply sources.

Measurements of radioactivity in samples of soils and sediments provide data on less-direct pathways of exposure. Measurements of radioactivity in soils and sediments are also useful for monitoring and understanding hydrological transport of radioactivity that occurs in intermittent stream channels in and adjacent to low-level radioactive waste management areas. On-site areas within Pueblo, Los Alamos, and Mortandad canyons all had concentrations of radioactivity on sediments at levels slightly higher than attributable to natural terrestrial sources or worldwide fallout. The low

levels of cesium, plutonium, and strontium in Mortandad Canyon are from treated liquid effluents of a waste treatment plant. No above-background radioactivity on sediments or in water has been measured in sampling locations beyond the Laboratory boundary in Mortandad Canyon. However, small amounts of radioactivity on sediments in Pueblo Canyon (from pre-1964 effluents) and upper Los Alamos Canyon (from 1952 to current treated effluents) have been transported during runoff events to the Rio Grande. Theoretical estimates, confirmed by measurements, show the incremental effect on Rio Grande sediments from this transported radioactivity is insignificant when compared with concentrations of radioactivity in soils and sediments attributable to worldwide fallout and natural sources.

Environmental monitoring is done at 1 active and 11 inactive waste management areas at the Laboratory. The general public is excluded from these controlled-access sites. There is some transport by surface runoff of low-level contamination from the active and several of the inactive disposal areas into controlled-access canyons. Leachate extracts (following EPA guidelines) from the surface contamination indicate no presence of constituents in excess of EPA criteria for hazardous waste determination.

Foodstuffs Monitoring

Most fruit, vegetable, fish, bee, and honey samples from regional locations showed no radioactivity distinguishable from that attributable to natural sources or worldwide fallout. Some produce samples from on-site locations had slightly elevated tritium concentrations. These levels were 2% or less of DOE guides for tritium in water. (There are no concentration guides for produce.)

Unplanned Release

During 1986, there were four unplanned airborne releases of radioactive or hazardous material—three involving tritium and one involving hydrochloric acid (HCl). All releases were small and resulted in radiation doses or air concentrations that were fractions of regulatory guidelines.

July 22 Tritium Release at TA-33. On July 22, 1986, approximately 1700 Ci of tritium were released at TA-33. Air samples collected from five air samplers in areas downwind from the release showed no detectable increase in tritiated water. The chemical form of the release was elemental hydrogen gas; hence, the organ receiving the largest dose was the lung. Calculations from meteorological modeling of the release indicated

that the dose to the maximum exposed individual would be less than 0.01 mrem (lung). The calculated maximum dose from this unplanned release is less than 0.01% of the EPA air emission standard of 75 mrem/yr for a member of the public.

October 30-31 Tritium Release at TA-33. An estimated 633 Ci of tritium were released at TA-33 over a 23-h period on October 30-31, 1986. The released material was conservatively assumed to be in the form of tritiated water. The estimated maximum individual dose was 0.05 mrem (whole body). This dose is 0.2% of the EPA air emission standard of 25 mrem/yr. Samples were collected at five stations of the airborne radioactivity monitoring network and analyzed for tritium. The tritium concentrations were less than 0.5% of the DOE concentration guide for off-site areas.

November 14 Tritium Release at TA-33. On November 14, 1986, 11.5 Ci of elemental tritium were released at TA-33. For elemental tritium, the organ receiving the highest dose is the lung. The maximum lung dose to a member of the public was calculated to be less than 0.01 mrem. This dose is less than 0.01% of the EPA air emission standard of 75 mrem/yr (organ dose). Air samples from five environmental monitoring stations all indicated that atmospheric levels of tritiated water were less than 0.5% of the DOE concentration guide for off-site areas.

December 8 HCl Release at TA-3. A cylinder containing a mixture of 5% hydrogen chloride (HCl) and 95% helium developed a leak during the morning of December 8, 1986, at TA-3. The maximum amount of HCl released was estimated to be 600 g. Based on this release amount, maximum air concentrations occurred on site (outside the building where the cylinder was taken) and were estimated to be 0.06 ppm by using an atmospheric dispersion model and the wind conditions during the release. Although HCl has no environmental exposure limit, the maximum concentration is a small percentage of the occupational exposure limit, 5 ppm.

Environmental Compliance Activities

Resource Conservation and Recovery Act (RCRA). The RCRA regulates hazardous wastes from generation to ultimate disposal. The EPA has transferred full authority (with the exception of the Hazardous and Solid Waste Amendment of 1984) for administering RCRA to the New Mexico Environmental Improvement Division (EID). In 1986, the Laboratory had numerous interactions with EID and prepared documentation to

comply with RCRA requirements. The Laboratory has revised RCRA Parts A and B permit applications, originally submitted in 1985. The latest revisions were submitted November 1986.

Clean Water Act. Regulations under the Clean Water Act set water quality standards and effluent limitations. The Laboratory's two primary programs to comply with the Clean Water Act are the National Pollutant Discharge Elimination System (NPDES) and the Spill Prevention Control and Countermeasure (SPCC) program.

The NPDES requires permits for nonradioactive constituents at all point source discharges. A single NPDES permit for the Laboratory authorizes liquid effluent discharges from 95 industrial outfalls and 11 sanitary sewage treatment outfalls; the permit expires in March 1991. The Laboratory was in compliance with the NPDES permit in about 93% and 98% of the samples collected at sanitary and industrial waste discharges, respectively. Chronically noncompliant, sanitary discharge outfalls are being upgraded under an EPA/DOE Federal Facility Compliance Agreement.

Another NPDES permit authorizes liquid effluent discharge from the Fenton Hill geothermal project. The permit for a single outfall was issued to regulate the discharge of mineral-laden water from the recycle loop of the geothermal wells.

The SPCC program provides for prevention and cleanup of spills and requires preparation of an SPCC plan. The laboratory assembled a formal SPCC plan that will be adopted and implemented in 1987.

National Environmental Policy Act. The Laboratory Environmental Review Committee reviews environmental documentation required by National Environmental Policy Act legislation as well as identifies other environmental items of concern to the Laboratory. An environmental evaluations coordinator helps prepare required DOE documentation and identify other items requiring committee attention. Documentation usually consists of action description memorandums (brief environmental evaluations) or environmental assessments (more detailed evaluations). During 1986, the committee approved 33 action description memorandums, 4 environmental assessments, and 2 environmental remarks for the DOE.

Clean Air Act. During 1986, the Laboratory's operations remained in compliance with all federal and state air quality regulations. State regulations are required to be as stringent as federal regulations, and many state standards are more stringent. Over 70 asbestos removal jobs involved the disposal of 250 m³ (1000/ft³) of asbestos. Permits were issued by the state

for two beryllium machine shops. All beryllium shops met emission performance requirements.

Safe Drinking Water Act. Municipal and industrial water supply for the Laboratory and community is from 16 deep wells and 1 gallery (collection system fed by springs). The wells range in depth from 265 to 942 m (869 to 3090 ft). The chemical quality of the water met the EPA National Interim Primary Drinking Water Standards (40 CFR 141) in 1986.

Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). The FIFRA requires registration of all pesticides, restricts use of certain pesticides, recommends standards for pesticide applicators, and regulates disposal and transportation of pesticides. The Laboratory stores, uses, and discards pesticides in compliance with this act.

Archaeological and Historical Protection. The Laboratory's environmental evaluation coordination and quality assurance programs provide protection as mandated by law for the hundreds of archaeological and historical resources located on Laboratory land. Pursuant to federal regulations implementing Section 106 of the National Historic Preservation Act of 1966, as amended, clearance for construction where no resource will be affected and mitigation of unavoidable adverse effects from Laboratory activity are determined in consultation with the New Mexico State Historical Preservation Office. Archaeologists performed 32 cultural resource surveys during 1986.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). The CERCLA of 1980 mandated cleanup of toxic and hazardous contaminants at closed and abandoned hazardous waste sites. The Superfund Amendments and Reauthorization Act of 1986 extensively amended CERCLA. Laboratory compliance activities at hazardous waste sites are part of the Comprehensive Environmental Assessment and Response Program (CEARP) of the DOE Albuquerque Operations Office. The program is evaluating all areas at the Laboratory for possible contamination.

Toxic Substances Control Act (TSCA). TSCA regulates the manufacture, processing, distribution, use, storage, and labeling of chemical substances, including polychlorinated biphenyls (PCBs). The Laboratory has EPA authorization to bury PCB wastes at its chemical waste landfill and to burn PCB contaminated wastes at its controlled air incinerator (99.9999% combustion efficiency). The Laboratory is in compliance with EPA's permit conditions for authorizing on-site disposal of PCB-contaminated wastes.

Authors: *Environmental Surveillance Group*

Group: *Environmental Surveillance, IISE-8*

Funding: *U.S. Department of Energy (DOE)
and Indirect*

Use of Floristic Surveys in Magnetometer Studies for Detecting Former Burial Sites (N. Becker and T. Foxx)

The DOE/AL Comprehensive Environmental Assessment and Response Program (CEARP) provides information for compliance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). Accordingly, Los Alamos National Laboratory is investigating areas of former hazardous and toxic waste disposal.

Former waste disposal Area F was used during 1946 for disposal of unsalvageable objects. The location of the pits was not established with survey markers until nearly 20 years after the pits were closed, and the area was not fenced until 1963. Therefore, it can be assumed that the fenced locations are approximate and that burial sites may exist outside of fenced areas. Because exact locations are unknown and the areas to be surveyed are large, magnetic surveys have been conducted to locate former burial sites. Floristic composition was combined with magnetics to better define suspect areas and to delineate former sites of waste burial.

Before the establishment of Los Alamos National Laboratory, homesteads dotted the mesa tops. The homesteads were condemned in 1940 to make way for the Manhattan Project. Many of the former waste burial sites were located in areas cleared for homesteading. At Area F, which was decommissioned in 1946, the nearby homestead field has remained fallow for 46 years and the waste burial sites for over 40 years. Successional patterns have resulted in a mosaic of vegetation types throughout the site. Examination of the floristic patterns in aerial photographs and on-site reconnaissance revealed historic archaeological features such as a homestead trash depository and an old road, as well as suspect areas for waste burial.

Soil conditions were indicative of former usage. Soils undisturbed since the condemnation of the homestead had a soil crust of lichens and mosses, whereas areas disturbed by waste burial activities were devoid of soil crusts. Vegetative patterns were also important. Areas that had remained fallow since

condemnation of the homestead had a cover of wormwood, bitterweed, and various grasses. Areas disturbed by waste burial activities had a cover of sweet clover, false tarragon, and other disturbed soil species.

After ground reconnaissance of the floristic composition and definition of suspect areas, a magnetic field survey was performed with a Geometrics G826 proton precision magnetometer. Magnetic anomalies of considerable magnitude were found to coincide in all instances with suspect areas identified during the floristic survey. One suspect area, which produced a magnetic anomaly but was not identified by the floristic study, was within an old roadbed with compacted soils and devoid of vegetation.

At the Laboratory, burial areas that have remained fallow for a number of years may be defined by patterns in floristic composition. Patterns in vegetation can be a useful guide in geophysical surveys such as magnetics and reconnaissance activities.

Environmental Monitoring at the Fenton Hill Site [W. Purtymun, R. Ferenbaugh (N.Becker, M. Maes, and M. Williams, HSE-9)]

The 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 (28 mi) west of Los Alamos on the southern edge of the Valles Caldera. The hot-dry-rock energy concept involves drilling two deep holes, connecting these holes by hydraulic fracturing, and bringing the thermal energy to the surface by circulating water through the system. Environmental monitoring is performed adjacent to the site to assess impacts of the geothermal operations.

The chemical quality of surface and ground water in the vicinity of TA-57 (Figure 1) 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.¹ The samples were collected in December 1985.

Figure 1. Sampling stations for surface and ground water near the Fenton Hill site (TA-57).

Surface-water stations (13 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 I). 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 also grouped according to predominant ions. These ions are (1) sodium and chloride, (2) calcium and bicarbonate, and (3) sodium and bicarbonate (Table I).

There was no significant change in the chemical quality of surface and ground water at the individual stations in December 1985 when compared with the previous years' chemical analyses. The slight variations that have occurred were caused by normal seasonal variations.

Samples of vegetation and soil from the channel bottom and the canyon bank below Pond GTP-3 have been collected annually (except for 1984) since 1978. The samples are analyzed for arsenic, boron, cadmium, fluoride, and lithium. The sampling locations are

Table I. Quality of Surface and Ground Waters at Fenton Hill Geothermal Site—December 1985^a

Surface Water			
	<i>Na</i>	<i>Cl</i>	<i>TDS</i>
Sodium Chloride			
Redondo Creek (U)	8	10	78
Jemez River (R)	52	88	364
Jemez River (S)	73	96	376
	<i>Na</i>	<i>HCO₃</i>	<i>TDS</i>
Calcium Bicarbonate			
San Antonio Creek (N)	12	58	124
Rio Cebolla (T)	21	70	71
Rio Guadalupe (Q)	43	172	200
Lake Fork 1 (LF-1)	15	49	111
Lake Fork 2 (LF-2)	17	66	127
Lake Fork 3 (LF-3)	11	52	115
Lake Fork 4 (LF-4)	14	64	160
	<i>Ca</i>	<i>SO₄</i>	<i>TDS</i>
Calcium Sulfate			
Sulphur Creek (V)	41	220	404
Sulphur Creek (F)	20	110	221
	<i>Na</i>	<i>HCO₃</i>	<i>TDS</i>
Sodium Bicarbonate			
Jemez River (J)	15	56	16

Ground Water			
	<i>Na</i>	<i>Cl</i>	<i>TDS</i>
Sodium Chloride			
JF-1 (Hot Spr)	159	71	1670
JF-5 (Hot Spr)	302	6600	3146
	<i>Ca</i>	<i>HCO₃</i>	<i>TDS</i>
Calcium Bicarbonate			
FH-1 (Supply Well)	34	109	228
Loc. 39 (Spr)	16	38	111
	<i>NA</i>	<i>HNO₃</i>	<i>TDS</i>
Sodium Bicarbonate			
JS-2, 3 (Spr)	16	77	146
JS-4, 5 (Spr)	15	73	165
Loc. 4 (Spr)	30	123	224
Loc. 31 (Spr)	11	52	122
RV-2 (Hot Spr)	22	45	162
RV-4 (Hot Spr)	52	107	221
RV-4 (Hot Spr)	19	73	128

^aConcentrations in mg/L. Figure 1 shows sampling locations. One sample taken at each location.

Table II. Most Recent Available Data on Environmental Samples from Fenton Hill Geothermal Site^a

Location ^b	As	B	Cd	F	Li
Roots (bank)					
100 m ^c	1.8	29	180	33	6.5
200 m	1.6	37	100	32	8.2
400 m	1.6	30	170	18	7.2
1000 m	0.9	34	—	31	6.0
Roots (channel)					
100 m	8.5	114	200	49	11
200 m	7.0	139	530	51	19
400 m	9.3	130	260	39	10
1000 m	1.5	30	330	12	5.1
Lower canyon	0.6	32	320	37	4.6
Foliage (bank)					
100 m	0.02	11	<20	0.9	0.8
200 m	0.03	13	28	2.0	0.6
400 m	0.08	32	47	3.8	0.5
1000 m	0.10	9	55	2.8	0.5
Foliage (channel)					
100 m	0.2	188	120	6.4	12
200 m	0.2	434	53	7.3	57
400 m	0.04	110	83	4.0	4.8
1000 m	0.08	12	—	4.3	2.6
Lower canyon	0.1	13	49	1.8	1.0
Soil (bank)					
100 m	3.1	14	80	79	15
200 m	3.1	23	160	140	30
400 m	3.9	17	80	99	18
1000 m	5.4	31	510	160	26
Soil (channel)					
100 m	12	49	210	260	28
200 m	17	104	440	240	38
400 m	12	54	220	150	43
1000 m	2.9	18	210	130	30
Lower canyon	2.8	15	140	300	51

^aData presented as µg/g.

^bOne sample per location.

^cDistance downstream channel from Fenton Hill geothermal site.

distances of 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 at its junction with Lake Fork Canyon. The discharge from the pond is drilling fluids or waters used in the circulation loop of the geothermal system. The discharge of the effluents is restricted so that all effluents infiltrate into the alluvium of the dry canyon within 150 m of the effluent outfall.

The most recent vegetation and soil data are shown in Table II. Since last year's surveillance report, the only new data are 1986 data for fluoride and the 1985 data for lithium in foliage and roots. The data are quite variable but generally do not seem to represent a great change from previous years. The data for lithium in foliage and roots and fluoride in foliage still seem to indicate a decrease in concentration with progression down the stream channel, a trend that was apparent in previous years' data. This trend is not as obvious in the data for soil from the stream channel.

Reference

1. U.S. Environmental Protection Agency, "Code of Federal Regulations," *Protection of the Environment* 40, Parts 190 to 399, *Federal Register*, Part 261, App. II (July 1, 1985).

Storm Water Runoff Sampling (L. Soholt, K. Jacobsen, and F. Brown)

In September 1984, the EPA promulgated regulations that could require the NPDES to permit some of the Laboratory's outfalls that receive storm-water runoff from conveyance systems, for example, channels or culverts. The application must contain results of analyses from runoff samples that the Laboratory has reason to believe contain nonconventional, priority pollutants in concentrations in excess of 10 µg/L (100 µg/L for some pollutants). During August and September, runoff samples were obtained once each at 17 outfalls around the Laboratory. Samples were collected in TA-3 (7 stations), TA-21 (3), TA-35 (3), TA-50 (1), TA-53 (2), and TA-59 (1). Samples were analyzed for approximately 30 inorganic pollutants and 145 organic pollutants.

The majority of organic pollutants occurred at levels below the minimum limits of detection by the analytical methods used. However, methylene chloride was detected in two samples from TA-35 and from TA-50 and exceeded 8 µg/L in one sample. Fluoranthene and

phenol were also detected in one sample from TA-35. These three organics are found with a frequency of >10% of urban runoff. None of these detected pollutants exceeded EPA criteria for reporting in the NPDES permit application. Levels of chloroform exceeded these criteria in one sample from TA-35 and one from TA-59. General phenolic levels were at or above the EPA reporting criteria in all but one sample (Table III). Oil and grease were present in three samples from TA-3 at levels near the reporting criteria.

As expected, inorganic pollutants were commonly detected in storm-water runoff (Table III). Most metals and anions we analyzed exceeded reporting criteria in one or more samples. For several elements, the analytical level of detection exceeded the reporting criteria. In these cases levels may have exceeded reporting criteria, but this cannot be determined from the data. Aluminum and iron were the most abundant metals in runoff. This probably reflects their natural abundance in the geosphere.

Survey of Sediments in Major Stream Channels for Toxic and Hazardous Waste (W. Purtymun and M. Maes)

Treated industrial and sanitary effluents from the Laboratory are released into the canyons that traverse the Pajarito Plateau. The volume of effluents is not great enough to maintain surface flow off Laboratory lands. Flow is depleted by evapotranspiration and infiltration into the alluvium. Some inorganic and organic compounds in the effluents have an affinity for attachment to the sediments by ion exchange or adsorption. These sediments are subject to transport with storm runoff. The presence of inorganic and organic compounds in the sediment of the intermittent stream channel could indicate potential for transport of contaminants off site.

A survey to determine if there has been major transport of organic or inorganic contamination from the Laboratory was made by collecting sediment from 10 canyons that cross the Laboratory and 4 canyons near or adjacent to the Laboratory. Two of the off-site canyons (Guaje and Frijoles canyons) could be considered as background data because they do not drain the Laboratory. The other two (Bayo and Pueblo canyons) drain former Laboratory areas. The sediment samples were leached and the leachate was analyzed for metals, pesticides, herbicides, and volatile organics. In all, 14 samples were taken and 55 analyses performed on each. Methods for preparation of the sample and analyses are outlined by the EPA.¹

Frequency of Detected Occurrence				
17	11-16	5-10	1-4	0
Aluminum	Chromium	Arsenic	Antimony	Bromide
Barium	Lead	Fluoride	Beryllium	Cyanide
Chloride	Nitrate		Boron	Mercury
Copper	Phenols		Cadmium	Molybdenum
Iron	Titanium		Cobalt	Selenium
Magnesium			Nickel	Silver
Manganese			Nitrate	Tin
Sulfate			Oil and grease	
Zinc			Thallium	

Table A2: Water Quality Data by Quarter				
Parameter	Third Quarter 1985	Fourth Quarter 1985	First Quarter 1986	Second Quarter 1986
Precipitation (in.)	0.5 (0.0-1.74)	0.52 (0.0-6.04)	0.14 (0.0-1.11)	0.40 (0.0-1.3)
Field pH (std units)	4.76 (4.23-4.92)	4.82 (4.49-5.33)	4.78 (4.71-4.85)	5.05 (4.66-6.80)
Calcium	161.5 (5.0-879.7)	39.9 (0.5-152.7)	29.4 (0.5-139.2)	186.9 (0.5-713.6)
Magnesium	29.7 (0.8-113.5)	9.9 (0.0-46.9)	7.4 (0.0-44.4)	29.8 (0.0-93.8)
Potassium	16.2 (0.8-47.0)	2.9 (0.2-10.5)	2.1 (0.0-12.3)	9.6 (0.0-45.0)
Sodium	33.2 (1.3-132.2)	12.5 (0.9-60.4)	3.1 (0.4-41.8)	29.4 (1.3-86.6)
Ammonium	158.4 (67.1-387.5)	69.1 (6.1-181.3)	32.5 (0.6-93.7)	140.4 (31.0-359.8)
Nitrate	256.7 (6.2-787.2)	55.5 (10.2-267.3)	116.1 (9.8-417.4)	228.5 (0.8-545.9)
Chloride	53.4 (1.7-162.4)	8.2 (1.1-29.6)	12.8 (1.1-55.6)	34.3 (1.1-85.7)
Sulfate	258.4 (2.7-925.0)	119.2 (4.0-646.8)	73.4 (0.8-211.3)	269.8 (5.6-802.2)
Phosphate	2.46 (0.00-8.84)	1.90 (0.00-13.00)	0.47 (0.32-0.63)	5.53 (0.63-10.4)
^a Mean; range in parentheses.				

Metals

The sediments from the 14 stations (canyon crossings at State Road 4, except for Frijoles at Park headquarters) were analyzed for 13 metals and anions as well as pH. Eight of the constituents (arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver) have limits set for EPA toxic concentrations. Sediment concentrations were below detectable limits and well below the toxic limits as described by the EPA. The remaining six constituents (nickel, beryllium, cyanide, sulfate, nitrate, and pH) have no EPA limits but were analyzed to provide additional information. The concentrations of beryllium and nickel were below detectable limits. Nickel at 9.5 mg/L (detectable limits of 0.05 mg/L) was reported from sediments taken from Fence Canyon at State Road 4. This canyon drains a small area that contains some firing sites. The nickel could be from the firing sites. Sulfate concentrations ranged from 1.1 to 1.9 mg/L in sediments from all stations. The concentrations are background, within the range found at the control stations in Guaje and Frijoles canyons. Nitrate concentrations ranged from <0.2 to 1.0 mg/L and are within the same range as background. The pH of the samples varied considerably, from 5.1 to 7.6. The two background canyons contained sediments with pH of 5.1 and 7.5, at the extremes of the range of measurements. Hence, the variations are probably related to normal variation among canyons. Variation could be related to frequency of runoff in each canyon, particle size distribution, or makeup of the soils from which drainage occurs.

Pesticides and Herbicides

Pesticides analyses (lindane, endrin, methorychlor, and toxaphene) were performed on sediments from the 14 stations. The results were below detectable limits and well below the maximum EPA toxic concentrations.

Herbicide analyses [2,4-D and silvex (2,4,5-TP)] were performed on sediments from the 14 stations. The results were below the detection limits and well below the maximum EPA toxic concentrations.

Volatile Organics

The sediments from the 14 stations were analyzed for 36 EPA priority-pollutant, volatile, organic compounds. Detection limits ranged from 2 to 50 µg/kg (ppb). Of the 36 organic compounds, only two were identified in the sediments. The compound 1,1,2,2-tetrachloroethane was detected in sediments from Canada del Buey (12 µg/kg), Pajarito (6 µg/kg), Potrillo (7 µg/kg), and Water (6 µg/kg) canyons. The concentrations are only

slightly above the detection limits of 5 µg/kg. A similar compound (1,1,1,2-tetrachloroethane) was also found in sediments from Canada del Buey (9 µg/kg) and Water (6 µg/kg) canyons. This compound's detection limit is 2 µg/kg. Both compounds are used as solvents, degreasers, paint removers, varnishes, and lacquers in photographic film, organic syntheses, solvents, insecticides, fumigants, and weed killers. Although the concentrations are low, additional investigations will be conducted.

National Atmospheric Deposition Program (NADP) Network Station (D. Nochumson and M. Trujillo)

Group HSE-8 operates a wet deposition station that is part of the NADP network at the Bandelier National Monument. Composite precipitation samples are collected weekly. The samples are initially weighed and analyzed for pH and conductivity before being sent out for the analysis of ionic species. Summary statistics of the data for the four latest complete quarters are presented in Table IV.

The magnitude of the ionic species deposition was generally highest in the third quarter of 1985 and lowest during the first quarter of 1986. The amount of precipitation was also lowest during the first quarter of 1986. The amount of deposition is variable and reflects the variability in the cleanliness in the atmosphere that storm clouds have contacted. The ions in the rainwater are from both nearby and distant, manmade, and natural sources. High nitrate and sulfate levels are most likely caused by manmade sources (motor vehicles, copper smelters, and power plants).

The natural pH of the rainfall without manmade contribution is unknown. The natural pH is most likely higher than 5.6 for rainwater in equilibrium with atmospheric carbon dioxide because of the contribution from alkaline soils. All but one of the weekly samples, in which enough precipitation was present to measure field pH, had a pH below 5.6, which indicates contributions from acidic species other than carbon dioxide.

Environmental Studies of TA-49 (W. Purtymun and A. Stoker)

Hydronuclear experiments were conducted in underground shafts at the Los Alamos National Laboratory in Area TA-49 in 1959-1961. Area TA-49 is located on Frijoles Mesa in the southwest corner of the Laboratory between TA-28 and TA-33. These

experiments involved a combination of conventional (chemical) high explosives, usually in a nuclear weapon configuration, and fissile material whose quantity was reduced far below the amount required for a nuclear explosion. Between January 1960 and August 1961, a total of 35 hydronuclear experiments and 9 related equation-of-state and criticality experiments was conducted, all involving some fissile material. Other experiments involving high explosives, but no fissile materials, were conducted starting in October 1959 and extended through the same period.

The hydronuclear experiments and directly related operations deposited various residuals and wastes in the immediate vicinity of TA-49. A total of about 41 kg (90 lb) of plutonium, 93 kg (200 lb) of enriched uranium, 82 kg (180 lb) of depleted uranium, and 15 kg (33 lb) of beryllium was used. These materials were dispersed in the bottoms of the shafts by detonation of the conventional (chemical) high explosives.

Some plutonium contamination was measured at the surface in one experimental area in December 1960 and was traced to cuttings from a shaft drilled during October and November. Plutonium had apparently been dispersed through fractures in the tuff by the detonation of an experiment in an adjacent experimental shaft. All surface soil contamination ascertainable by standard procedures and instruments of the time was cleaned up and placed back in the shaft from which it originated.

Routine monitoring has not shown any migration of contaminants from TA-49. All monitoring of ground water in the main aquifer, surface-water runoff, and sediments will be continued as part of the routine annual environmental surveillance program carried out by Group HSE-8. These results will continue to be reported in the annual environmental monitoring reports. Supplementary on-site monitoring results will be included in the periodic reports prepared for the Interim Waste Management Program or CEARP reports as appropriate.

Preliminary, summary information on TA-49 was included in the CEARP, Phase 1, installation assessment document for Los Alamos released in October 1987. A more detailed summary of the environmental conditions of TA-49 was prepared in 1987. A detailed plan for field investigation of TA-49 will be prepared under the auspices of the CEARP. This will result in a CEARP, Phase 2, confirmation site-specific monitoring plan. The site-specific monitoring plan will include detailed evaluation of all known existing data. This evaluation will be the basis for developing a detailed sampling plan that will meet all guidelines required by DOE under its applicable programs and those required by EPA for a remedial investigation under CEARP. The site-specific sampling plan will be made available to the EPA and

appropriate New Mexico agencies for information and review.

BIOTRAN Modeling Program (A. Gallegos)

BIOTRAN model development focused on expansion of the ground- and surface-water modules to complete the hydrological cycle portions of the code. The surface hydrology of the Department of Agriculture SPUR model was combined with BIOTRAN to develop the capability to simulate intermittent flow for area canyons coupled with ground-water recharge of perched aquifers. A water mass balance approach was used for the Los Alamos mesa, canyon, and ground-water watersheds.

Dispersion Analysis of Airborne Radioactive Emissions from the Los Alamos Meson Physics Facility (B. Bowen, W. Olsen, I. Chen, and D. VanEtten)

An array of seven portable pressurized ionization chambers measures external radiation levels caused by radionuclides emitted from the Los Alamos Meson Physics Facility (LAMPF). The monitoring was at three close off-site locations, averaging 800 m north and northeast of the source, as well as at four locations east and south of LAMPF.¹ A Gaussian-type atmospheric dispersion model, using on-site meteorological and stack release data, was tested during this study. A more complex finite model, which takes into account the contribution of radiation at a receptor from different locations of the passing plume, was also used.

Comparison of predicted and measured daily external radiation levels has indicated a high degree of correlation. The model also gives accurate estimates of measured concentrations over longer times.

Reference

1. B. Bowen, W. Olsen, I. Chen, and D. VanEtten, "Measurement and Modeling of External Radiation During 1985 from LAMPF Emissions," Los Alamos National Laboratory report LA-11150-MS (November 1987).

Development of the Mobile Ranger Radiation Mapping System (D. VanEtten and W. Scoggins)

The Ranger Radiation Mapping System is being developed and deployed to map radioactive material—principally transuranic—concentrations over

areas of tens/hundreds of acres of potentially contaminated land. Ranger uses a commercial microwave ranging and tracking system interfaced with computer graphics to provide isopleths of radioactive material concentrations on the soil surface. A new detector for transuranic contamination, Violinist II, is used to measure the radiation levels.

The system was first field tested in August 1987 and again in December 1987 as part of the DOE Accident Response Group functions.

***Comprehensive Environmental Restoration Program
(K. Rea, M. Martz, A. Stoker, R. Vocke, and
R. Gonzales)***

The U.S. DOE facilities operate under a policy of full compliance with applicable environmental regulations. The DOE Albuquerque (AL) Operations Office initiated the Comprehensive Environmental Restoration Program (CERP) in mid-1984 (then Comprehensive Environmental Assessment and Response Program) to help fulfill that commitment at installations within the AL complex, including facilities in California, Colorado,

Florida, Missouri, New Mexico, Ohio, and Texas. The program assists the U.S. DOE in setting environmental priorities and in justifying funding enhancements of existing programs or remedial actions. Implementation of CERP is being accomplished through the combined efforts of the AL complex. LANL is providing programmatic guidance/management and technical support to AL for CERP implementation at AL installations.

The program is designed to identify, assess, and correct existing or potential environmental concerns. The scope includes the review of major environmental regulations, with emphasis on the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the Resource Conservation and Recovery Act (RCRA). The program includes evaluation of management practices for hazardous substances. Additionally, assessment of pollution control and monitoring programs for hazardous substances emphasizes both adequate understanding of environmental pathways and regulatory compliance. Implementation of CERP is intended to fulfill the DOE obligation for federal facilities under the EPA CERCLA program.

REPRODUCED FROM
BEST AVAILABLE COPY

Contaminant Transport in Southwestern Ecosystems

Authors: E. P. Springer (Principal Investigator),
M. A. Devaurs, G. J. Langhorst, J. L. Martinez,
K. V. Bostick, and T. E. Hakonson

Group: Environmental Science, HSE-12

Cooperators: Pennsylvania State University;

University of Nevada, Reno;

New Mexico Institute of Mining and Technology;

USDA-Agricultural Research Service, Aridland

Watershed Management Unit, Tucson, Arizona; and

University of California, Los Angeles

Funding Organization: DOE Office of Health and Environmental
Research, Ecological Research Division

Research at the Nevada Test Site (NTS) in Plutonium Valley and near Mercury, Nevada, focuses on hydrology and the transport of radionuclides by runoff and erosion. Various facets of this work include the application of precipitation with the rainfall simulator (Figure 1) to measure the hydrologic response, including contaminant transport, of natural and disturbed soil surfaces and modeling of contaminant transport by runoff and erosion.

Results from the rainfall simulator studies at NTS are described in several papers in the proceedings of the Rainfall Simulator Workshop jointly sponsored by HSE-12, USDA, and the Society for Range Management.¹ A major finding of this research was that runoff, erosion, and contaminant transport were a strong function of level of disturbance of the soil surface, season, and soil moisture. For example, sediment yields from plots in Plutonium Valley at NTS (Table I) were as much as 100 times higher on treatments where both the vegetation and the natural rock covering (called erosion pavement) were removed compared with the undisturbed (natural) or clipped (only the vegetation removed) treatments. Sediment yields were also correlated with season (generally higher in the fall because of crusting of the soil surface) and with soil moisture status just before the simulator runs (the wetter the soil, the higher the runoff and erosion).

The "cleared" treatment simulates the level of disturbance expected during a proposed cleanup of radionuclides associated with the soil surface in Plutonium Valley. It is apparent from the data for the cleared plot treatment in Table 1, that a cleanup operation that does not completely remove the soil contaminant would subject the residual contaminant to an accelerated rate of transport by hydrologic erosion. One possible remedy to reduce erosion, and hence

		Spring		Fall	
Treatment ^a	Dry ^b	Wet	Dry	Wet	
Natural	1.3	1.2	4.4	3.6	
Clipped	1.2	16	72	22	
Cleared	83	208	305	349	

^aNatural = undisturbed; clipped = vegetation removed; cleared = vegetation and erosion pavement removed.
^bSoil moisture status before application of precipitation with the rainfall simulator.

contaminant transport, would be to apply a gravel mulch on the disturbed soil surface to reduce sediment (and contaminant) yields to the lower levels measured on the natural (undisturbed) soil surface.

Simulation of contaminant transport from Plutonium Valley requires information on the hydrologic parameters governing runoff and soil erosion. Rainfall simulation studies have been conducted at Mercury and Plutonium Valley since 1983. Data are being analyzed to parameterize models such as CREAMS.² Figure 2 illustrates the application of these data.

Two simulations were conducted using hydrologic and soil erosion parameters to reflect current or "natural" conditions and using treated conditions to reflect disturbances due to remedial actions. The simulations used a 4-ha area similar in topography to the bottom area of Plutonium Valley.

Figure 1. Rainfall simulator and erosion plot technique used to evaluate hydrologic response of natural and disturbed ecosystems.

Figure 2. Cumulative probability distribution of total plutonium transport for a 50-year period from 4-ha area with characteristics of the Plutonium Valley Watershed using a stochastic weather generator. Natural conditions are the current conditions at the site, and treated conditions (erosion pavement and vegetation removed) are a remedial action with 90% removal of the plutonium.

Weather data were stochastically generated using Las Vegas, Nevada, information to parameterize the weather generator. Fifty sequences, each fifty years long, were simulated, and the results of cumulative transport of plutonium for the fifty years are plotted in Figure 2. The triangles are the values for the natural conditions, and the circles are for the remedial action, which was assumed to be 90% effective in removing the original plutonium.

Figure 2 shows that the probability of transporting plutonium increases with disturbance, even though the total amount of plutonium available for transport after cleanup is substantially lower. These results are qualitative because Las Vegas weather was used. A 17-year weather record from Yucca Flats at NTS has been obtained and will be used to conduct further analyses. One difference between the Las Vegas and Yucca Flats weather records is that the average annual precipitation at Yucca Flats is double the precipitation at Las Vegas.

These types of analyses require considerable data from various sources, but no analysis is possible without the rainfall simulator data providing the basis for parameter estimation for natural and treated conditions.

References

1. L. J. Lane, Ed., "Erosion on Rangelands: Emerging Technology and Data Base," *Proceedings of the Rainfall Simulator Workshop*, January 14-15, 1985, Tucson, Arizona (Society for Range Management, Denver, Colorado, ISBN: 0-9603692-4-4, 1986).
2. W. G. Knisel, "CREAMS: A Field Scale Model for Chemicals, Runoff, and Erosion from Agricultural Management Systems," USDA, Conservation Research Report No. 26 (1980), 640 pp.

Radionuclide Inventory and Distribution at the Nevada Test Site

Author: E. H. Essington (Principal Investigator)

Group: Environmental Science, HSE-12

Cooperators: Lawrence Livermore National Laboratory,

EG&G, TMA/NORCAL, REECo, and Desert Research Institute

Funding Organization: Department of Energy, Nevada Operations
Office, Health Physics & Environmental Division

As a result of past atmospheric or near-surface testing of nuclear weapons, radioactive by-products were deposited on the land surface in a number of areas of the Nevada Test Site (NTS). Many of those areas have significant levels of radioactive contamination that can disperse or affect subsequent testing operations. The Radionuclide Inventory and Distribution Program (RIDP) was conducted to provide information on the location and amounts of radionuclides in areas of known contamination and to provide a means of estimating the contamination levels of large portions of the accessible environment not associated with specific test sites.

The program uses (1) airborne surveys of external exposure rate; (2) ground-based, *in situ* gamma spectrometry; and (3) soil sampling and analysis to assess radionuclide distribution and to estimate the amount of specific medium- to long-lived manmade radionuclides. Los Alamos National Laboratory, Group HSE-12, has participated in the RIDP program by providing consultation on these items to the technical director and has participated as the referee. The referee

designed and conducted a quality assurance program for sampling and analysis of collected samples.

During fiscal year 1987, inventory and distribution evaluation was completed for Areas 3, 7, 8, 9, and 10 on NTS.¹ Similar efforts were completed for Areas 18 and 20, and the final draft report was completed.² The referee's evaluations of the reliability of the analytical data are included in these reports.

References

1. R. D. McArthur and S. W. Mead, "Nevada Test Site Radionuclide Inventory Distribution Program: Report #3. Areas 3, 7, 8, 9, and 10," Desert Research Institute, Water Resources Center report DOE/NV/10384-15 (1987).
2. R. D. McArthur and S. W. Mead, "Nevada Test Site Radionuclide Inventory and Distribution Program: Report #4. Areas 18 and 20," Desert Research Institute, Water Resources Center report DOE/NV/10384-22 (1987).

Trench Cover Systems for Manipulating Water Balance on Low-Level Radioactive Waste Sites An Intermediate-Scale Demonstration Project

Authors: J. W. Nyhan (Principal Investigator),

B. J. Drennon, J. L. Martinez, and T. E. Hakonson

Group: Environmental Science, HSE-12

Cooperators: USDA-Agricultural Research Service,

Aridland Watershed Management Unit,

Tucson, Arizona; and National Soil Erosion

Laboratory, Purdue University

DOE Office of Health and Environmental Research,

Ecological Research Division

Colorado State University

Funding Organization: DOE National Low-Level
Radioactive Waste Management Program

The Environmental Science Group at Los Alamos National Laboratory began studies of water balance on low-level waste trench caps in 1981 as the arid site for the DOE National Low-Level Radioactive Waste Management Program. Those studies were conducted in a 9-ha field site designated as the Los Alamos Experimental Engineered Test Facility¹ and relied on rainfall simulator technology² to evaluate the hydrologic response of a variety of trench cover designs. Large caissons (3-m diam by 6 m deep) were also used to investigate subsurface processes, including the influence of capillary barriers on percolation. Results of that work have been published in 138 journal papers, symposia proceedings, and government and Laboratory reports.

In 1984, the results from several previous studies were used to design and emplace a cover demonstration called the Low-Level Integrated Systems Test Project.³ The purpose of the demonstration was to monitor and compare water balance⁴ on a conventional trench cap design with that on an improved design. The latter design incorporated our best available knowledge on methods to control erosion,^{5,6} percolation,⁷⁻¹⁰ and biological intrusion.⁷

The demonstration plots were designed and instrumented so that a complete accounting of precipitation falling on the plots could be made. The plots, which were about 3 by 10 m, were constructed and instrumented (Figures 1 and 2) to provide measures of runoff and erosion, soil water storage, and seepage, as measured by leachate production at the various drains.³ Only natural precipitation was added to the plots during the study.

Figure 1. Conventional trench cap design on the Integrated systems Test plots. Instrumentation for measuring soil water also includes thermocouple psychrometers and tensionmeters. The CsI tracer was used to indicate plant root intrusion. The surface had a 0.5% downslope gradient and a 60% to 70% gravel mulch and grass cover.

The technology for controlling erosion on the plots consisted of applying a 60% to 70% cover of gravel (2-cm diam) and a plant cover of blue gramma (*Bouteloua gracilis*) and western wheat grass (*Agropyron smithii*) to a mild slope of 0.5%. Experimental results leading to this erosion control design were developed from rainfall simulator studies at Los Alamos^{6,11} and at the Nevada Test Site where the influence of the natural

Figure 2. Improved trench cap design on the Integrated Systems Test plots. Instrumentation for soil water also includes thermocouple psychrometers and tensiometers. The CsI and LiBr were used to indicate direction of water flow and plant root intrusion. The surface had a 0.5% downslope gradient and a 60% to 70% gravel mulch and grass cover.

erosion pavement, which covers the soil surface in the northern Mojave Desert, on water balance has been extensively studied.¹²⁻¹⁴

Percolation or seepage control uses the pea gravel portion of the layered rock component (Figure 2) of the trench cap to provide a capillary barrier to downward water flow.^{3,13} The difference in saturated hydraulic conductivities of the rock and the overlying soil causes downward water flow to be impeded at the soil-rock interface. A 5% lateral slope on the interface between the soil and gravel allows gravity to convert the downward flow to a lateral flow component. Lateral flows can then be diverted away from the trench, precluding the movement of water through the cover into the trench. The integrity of the soil-rock interface is maintained with a geotextile fabric (Figure 2) (MIRAFI Inc., 22672 Lambert Street, Suite 602, El Toro, CA 92630). Failure of the capillary barrier can occur when the soil at the interface becomes saturated with water. The objective, then, is to keep soil overlying the capillary barrier as dry as possible by maximizing evapotranspiration losses.

The cobble layer underlying the gravel layer prevents plant root and animal intrusion and was designed on the basis of the results of several field tests at the Experimental Engineered Test Facility and at several low-level waste sites at Los Alamos.⁷ It prevents or minimizes plant root intrusion because the spaces

between the cobble are relatively free of soil and water. As long as a limited source of nutrients and water is in the cobble, plant root penetration into this zone will be minimized. The cobble also prevents most burrowing animals from digging through the waste simply because the stones are too heavy to move.

Three years of data have been collected on the Low-Level Integrated Systems Test plots. During that time we have demonstrated that with the improved cover design we can eliminate or reduce erosion, percolation, and biointrusion over that measured on the conventional cover design. From May 1984 to March 1987, a total of 210 cm of precipitation fell on the plots, which on an annual basis greatly exceeds the average annual precipitation of about 46 cm for Los Alamos. In the winter and spring of 1984-1985, Los Alamos had 250% above the annual snowfall of 130 cm. During the winter of 1986-1987, 335 cm of snow fell on the plots, which broke the existing snowfall record of 312 cm at Los Alamos.

Leachate production from the various drains are summarized in Table 1. Over the three-year period, the conventional cover design produced drainage on two occasions, both of which followed large snowfall. On the first occasion (April-May 1985), 161 L of leachate were produced amounting to about 0.65% of the precipitation that had fallen on these plots. The second period of drainage in November 1986 to March 1987 followed a heavy snowfall of 137 cm and produced 3047 L of leachate, amounting to 5% of the total precipitation incident on the plots to that time.

The improved design (Figure 2) performed considerably better than the conventional design in controlling percolation during the two episodes of drainage. During the first period of April-May 1985, there was no drainage from the bottom of the improved cover designs. However, a lateral flow totaling 335 L did occur and represented about 1% of the accumulative precipitation. During the second drainage episode in November 1986 to March 1987, both the lateral and bottom drains generated leachate. The lateral flow generated 500 L, representing about 0.69% of the accumulative precipitation, while the bottom drain generated 769 L, representing 1.1% of the total precipitation that fell on the plots.

Altogether, about 1.2% of the precipitation falling on the plots from May 1984 to March 1987 was diverted laterally through the soil above the capillary barrier, reducing the amount of percolation to deeper zones in the cover profile by over half. The improved cover design also reduced the bottom drainage or leachate production by a factor of 4 over the conventional design (769 L vs 3208 L, Table I).

The light covering of gravel (60% to 70% cover to a depth of about 2 cm), gentle slope (<1%), and dense cover (70% to 80%) of native grasses effectively eliminated runoff and erosion over three years despite the occurrence of several intense rainstorms. Likewise, the use of a combination capillary wick-biointrusion barrier reduced percolation by a factor of 4 over the

conventional cover design and diverted a significant amount of percolating water laterally, reducing the amount of deep percolation by a factor of over 2. The cobble component of the rock barrier also completely prevented plant root intrusion through the cover into a simulated waste.

Table 1. Leachate Production from the Los Alamos Integrated Systems Test Plot Trench Cover Designs from May 1984 to March 1987

Treatment	Date	Drainage (L)	% Total Precipitation to Date Drainage Stopped
<i>Conventional Design (Figure 1)</i>			
	April–May 1985	161	0.60 ^a
	Nov. 1986–April 1987	3047	4.6 ^b
	Total	3208	4.9
<i>Improved Design (Figure 2)</i>			
Lateral drain above capillary barrier	March–May 1985	335	1.1 ^c
Bottom drain below capillary barrier	March–May 1985	0	0 ^c
Lateral drain above capillary barrier	February–April 1987	500	0.63 ^d
Bottom drain below capillary barrier	March 1987	769	0.97
Total			
Lateral drain		835	1.1
Bottom drain		769	0.97
^a Total precipitation on conventional cover design when drainage stopped was 26,700 L. ^b Total precipitation on conventional cover design when drainage stopped was 66,150 L. ^c Total precipitation on modified cover design when drainage stopped was 32,040 L. ^d Total precipitation on modified cover design when drainage stopped was 79,380 L.			

References

1. G. L. DePoorter, "The Los Alamos Experimental Engineered Waste Burial Facility: Design Consideration and Preliminary Experimental Plan," in *Waste Management '81*, R. G. Post and M. E. Wacks, Eds. (University of Arizona Press, 1981), pp.667-886.
2. K. G. Renard, "Rainfall Simulators and USDA Erosion Research: History, Perspective, and Future," L. J. Lane, Ed., in "Erosion on Rangelands: Emerging Technology and Data Base," *Proceedings of the Rainfall Simulator Workshop*, Tucson, Arizona, January 14-15, 1985, Society for Range Management, Denver, Colorado, ISBN:0-9603692-4-4 (1986), pp. 3-6.
3. W. V. Abecle, J. W. Nyhan, T. E. Hakonson, B. J. Drennon, et al., "Low-Level Integrated System Test," Los Alamos National Laboratory report LA-10572-MS (1986).
4. T. E. Hakonson, L. J. Lane, J. G. Steger, and G. L. DePoorter, "Some Interactive Factors Affecting Trench Cover Integrity of Low-Level Waste Sites," in *Proceedings of Low-Level Waste Disposal: Site Characterization and Monitoring*, Arlington, Virginia, June 16-17, 1982, NUREG/CP-0028, CONF-820674, Vol. 2 (1982), pp. 377-400.
5. J. W. Nyhan and L. J. Lane, "Erosion Control Technology: A User's Guide to the Use of the Universal Soil Loss Equation at Waste Burial Sites," Los Alamos National Laboratory report LA-10262-M (1986), p. 67.
6. J. W. Nyhan and L. J. Lane, "Rainfall Simulator Studies of Earth Covers Used in Shallow Land Burial at Los Alamos, New Mexico," in "Erosion on Rangelands: Emerging Technology and Data Base," *Proceedings of the Rainfall Simulator Workshop*, January 14-15, 1985, Tucson, Arizona, Society for Range Management, Denver, Colorado, ISBN:0-9603692-4-4.
7. T. E. Hakonson, "Evaluation of Geologic Materials to Limit Biological Intrusion into Low-Level Radio-active Waste Disposal Sites," Los Alamos National Laboratory report LA-10286-MS (1986), p. 91.
8. L. J. Lane, "Surface Water Management: A User's Guide to Calculate a Water Balance Using the CREAMS Model," Los Alamos National Laboratory report LA-10177-M (1984), p. 49.
9. L. J. Lane and J. W. Nyhan, "Water and Contaminant Movement: Migration Barriers," Los Alamos National Laboratory report LA-10242-MS (1984).
10. J. W. Nyhan and L. J. Lane, "Use of a State of the Art Model" in "Generic Designs of Shallow Land Repositories for Low-Level Waste," in *Waste Management '82*, R. G. Post, Ed. (University of Arizona Press, Tucson, Arizona, 1982), pp. 235-244.
11. J. W. Nyhan, G. L. DePoorter, B. J. Drennon, J. R. Simanton, and G. R. Foster, "Erosion on Earth Covers Used in Shallow Land Burial at Los Alamos, New Mexico," *Journal of Environmental Quality* 13, 361-366 (1984).
12. J. R. Simanton, C. W. Johnson, J. W. Nyhan, and E. M. Romney, "Rainfall Simulation on Rangeland Erosion Plots," L. J. Lane, Ed., in "Erosion on Rangelands: Emerging Technology and Data Base," *Proceedings of the Rainfall Simulator Workshop*, January 14-15, 1985, Tucson, Arizona, Society for Range Management, Denver, Colorado, ISBN:0-9603692-4-4 (1986).
13. T. E. Hakonson, L. J. Lane, G. R. Foster, and J. W. Nyhan, "An Overview of Los Alamos Research on Soil and Water Processes in Arid and Semi-arid Ecosystems," L. J. Lane, Ed., in "Erosion on Rangelands: Emerging Technology and Data Base," *Proceedings of the Rainfall Simulator Workshop*, January 14-15, 1985, Tucson, Arizona, Society for Range Management, Denver, Colorado, ISBN: 0-9603692-4-4, 7-10 (1986), pp. 7-10.
14. E. M. Romney, R. B. Hunter, and A. Wallace, "Shrub Use of Water from Simulated Rainfall in the Mojave Desert," L. J. Lane, Ed., in "Erosion on Rangelands: Emerging Technology and Data Base," *Proceedings of the Rainfall Simulator Workshop*, January 14-15, 1985, Tucson, Arizona, Society for Range Management, Denver, Colorado, ISBN:0-9603692-4-4 (1986), pp. 25-29.

Waste-Site Closure Demonstration—A Field-Scale Study

Authors: *F. J. Barnes (Co-Principal Investigator),
J. Warren (Co-Principal Investigator, HSE-7),
P. M. Rich, E. A. Lopez, W. J. Herrera, and
E. J. Antonio*

Group: *Environmental Science, HSE-12*

Cooperators: *P. R. Kemp, New Mexico Museum
of History*

Funding Organization: *DOE Defense TRU Waste
Management Program*

The overall goal of the Waste-Site Closure Demonstration is to apply and evaluate a cost-effective and efficient waste-site closure methodology for Los Alamos that maximizes surface stability and minimizes site maintenance. In the initial phase of the project (FY87–89), the objective is to modify a pre-existing closure study at Area B so as to demonstrate the effects of gravel mulches on soil erosion, plant biomass, and soil water storage under natural precipitation regimes. The following phase will involve design and application of an optimization cover to Area E (FY90) and follow-up monitoring of that site to assess cover performance (FY91–92).

Previous studies at Los Alamos have demonstrated that the closure methods and design of a trench cap are highly correlated with subsequent site stability and integrity. Water and soil dynamics, as influenced by physical and biological factors, account for most of the performance-related problems. For example, erosion associated with surface runoff can breach the trench cap relatively quickly and expose waste. Soil profile depth and soil layer characteristics can greatly influence plant growth, storage of soil water after precipitation events, and hence the likelihood of precipitation percolating below the trench cap and into the waste.

The installation of the closure demonstration at Area B was largely completed in FY87. The demonstration consists of twelve plots, four in each of three clusters, on the Area B closed waste site (Figure 1). Two clusters (east control and west control) have soil profiles similar to the standard trench cap cover profile used at Los Alamos (15-cm soil over 75-cm crushed tuff). The central cluster has a profile consisting of

15-cm soil and 45-cm crushed tuff over a gravel-cobble layer designed to act as a barrier to biointrusion by plants and animals, as well as a barrier to capillary moisture flow. Soil moisture measuring devices were installed on each plot. Soil moisture was measured every two weeks by two different methods. Plant biomass or ground cover was estimated by several different methods with varying success. A meteorological weather station was also installed and data collected daily. Runoff from natural precipitation from each plot was collected after each rainfall and sediment load transport determined.

When runoff (as percent of total precipitation) is averaged over all events for each plot (Table I), a definite trend is immediately obvious. The plots with gravel mulch in addition to the vegetation have much lower runoff rates than those with only a grass or shrub cover. Thus, the gravel plots have much higher water infiltration rates than the nongravel plots. The higher amount of available water resulted in greater vegetation growth and higher plant survival rates on the gravel plots.

The wide range in runoff on all plots and between plots with the same treatment is the result of the many factors not accounted for in this brief summary. In particular, runoff was affected greater by storm intensity and antecedent moisture conditions (that is, whether rain had occurred in the couple of days preceding the event). Within treatments, soil profiles differ among plots with results particularly noticeable between the biobarrier plots (5, 6, 7, and 8) and the others. Slopes and extent of plant cover also differed among plots. These factors will all be used in analysis of the results as the project continues.

Figure 1. Area B—low-level waste site.

Table 1. Runoff on Demonstration Plots in 1987			
Treatment	Plot	Mean Runoff ^a	Runoff Range ^a
Shrub + gravel	1	3.89	0.09-11.53
	8	0.77	0.05-1.59
	9	4.53	0.54-10.69
Grass + gravel	3	8.81	1.20-27.53
	5	0.69	0.19-1.29
	11	8.27	0.16-44.87
Grass	4	23.25	0.34-50.24
	6	1.05	0.50-1.65
	12	18.77	0.46-48.78
Shrub	2	32.14	1.45-63.65
	7	29.31	1.00-68.10
	10	20.27	1.59-48.78
^a Runoff as percent of total precipitation.			

Development of an Arid-Site Closure Plan—A Modeling Study

Authors: *J. W. Nyhan (Principal Investigator)*
and F. J. Barnes

Group: *HSE-12*

Funding Organization: *DOE National Low-Level
Radioactive Waste Management Program*

Federal regulations stipulate that landfill cover technology ensures the long-term stability and integrity of a hazardous waste landfill system. Specific guidance for achieving compliance with these regulations requires cover designs that manage the water balance on the landfill site. Special attention must be given to the design of the soil profile and the establishment of a stable vegetative cover to minimize erosion of the surface soils and the percolation of water into the waste. Recommendations for a specific landfill must be based on a combination of field and laboratory data and on computer modeling of water balance to assess specific design scenarios. The purpose of this study was to investigate the utility of two hydrologic models (CREAMS and HELP) for assisting in the design of landfill cover systems that are stable and free of maintenance requirements.

Results of the modeling study suggest that, overall, CREAMS performs more satisfactorily than HELP in accurately predicting the soil water storage in the soil profile, although more detailed calibration of HELP will probably improve model performance. Although relative estimates of runoff, deep percolation, and evapotranspiration are useful for comparing different cover designs, absolute quantitative estimates of these values are subject to considerable error. Choice of values for soil parameters requires more experience and

more detailed data than is indicated by the documentation for either model. The results of this study have demonstrated unequivocally that the role of native vegetation in determining site stability and integrity must be evaluated and considered in designing a hazardous waste landfill cover system.

It is apparent that native species are much hardier than cultivated species. Given sufficient time with no human interference (that is, no maintenance), native species will invade and colonize a landfill site, and some sequence of succession will proceed thereafter. Unfortunately, these processes are not well documented, especially for severely disturbed sites or on constructed soil profiles.

The use of simple hydrologic models to simulate the water balance of landfill cover systems can assist the process of designing soil and vegetative systems for site closure. Two models (CREAMS and HELP) were used to simulate eight experimental cover designs on a landfill site at Los Alamos, New Mexico. Careful parameterization of the models was a key to successful simulation. Few data exist for leaf area indices and rooting depths of native plant species. Values of hydrologic parameters of soils may be quite different in the constructed soil profiles of landfill covers than under laboratory or natural conditions. These areas are in critical need of further research.

Modeling of Radionuclide Transport at An Inactive-Material Disposal Area

Author: M. A. Devaurs (Principal Investigator)

Group: Environmental Science, HSE-12

Funding Organization: Department of Energy, Los Alamos National Laboratory Comprehensive Environmental Restoration Program

Site TA-21 was chosen as one of the sites for Phase 2 follow-up under the Environmental Restoration Program. Area T is an inactive-material disposal area at TA-21, designated for further site characterization work.

In 1943, Los Alamos National Laboratory constructed four adsorption beds filled with gravel and cobble for disposal of radioactive liquid wastes. About 98% of the estimated 10 Ci of plutonium discharged to the adsorption beds was added between 1945 and 1952. At infrequent intervals after 1952 until 1967, a few hundred gallons of wastes were discharged to the adsorption beds, after which waste treatment operations shifted to a new treatment plant. The results of a 1953 study undertaken by the USGS at this site determined that vertical migration of plutonium occurred within 6 m of the surface of the beds. In 1959 another study was undertaken to document vertical distribution at 12 sampling points spaced at 61-cm intervals along the depth of a caisson drilled near one of the beds. As a result of information from these studies, researchers attempted to change the distribution of plutonium beneath the beds by adding 10.8 m of effluent containing plutonium in July 1961 and 9.7 m of tap water a month later. In 1978, a major field study was undertaken to determine the vertical distribution of americium-241, plutonium, and water beneath the beds by drilling and sampling to a depth of 30.5 m through two of the beds.

The objective of this study was to use existing data to estimate radionuclide movement by estimating the (1) vertical extent of contamination and (2) potential for contaminant migration. Adsorption bed 1, where tap water was added in 1961, was used as a "worst case" of potential migration of radioactive waste contaminants. The goal is to use existing data to extract meaningful information on radionuclide movement to assist in design of future studies. Recommendations are made on how this information could guide further drilling/sampling for contamination at Area T.

Spatial moment methodology is used to obtain estimates of plume mass, location, movement, dilution, and spreading for plutonium and americium. Spatial

moment analysis predictions are input into a one-dimensional convective dispersive solute transport equation for solute movement prediction.

Preliminary results indicate that moment-predicted velocities and dispersion coefficients are greater for bed 1 where water was added, resulting in model predictions of radionuclide movement to a greater depth in bed 1. This agrees with 1978 observed data. Varying estimates of plutonium input concentration give different estimates of when plutonium would reach ground water at a 350-m depth. The most conservative estimate is year 2397. The best example of plutonium concentration predicted by the convective dispersive equation compared with observed 1978 data is given in Figure 1. Further modeling estimates of radionuclide movement below adsorption beds and recommendations for further drilling/sampling activities are currently being developed.

Figure 1. Comparison between observed and model-predicted (0.10598-mg/L initial concentration) plutonium concentrations in 1978.

Reactive Tracer Tests in the C-Wells and Other Wells in the Vicinity of Yucca Mountain

Authors: E. P. Springer (Principal Investigator),
W. L. Polzer, E. H. Essington, and G. J. Langhorst

Group: Environmental Science, HSE-12

Cooperators: H. R. Fuentes, University of Texas at El Paso;

G. M. Lopez, University of Texas at El Paso; and

B. D. Newman, University of Texas at El Paso

Funding Organization: DOE Nevada Nuclear Waste Storage
Investigations (NNWSI)

Los Alamos has primary responsibility for geochemical characterization of the candidate, high-level waste repository site at Yucca Mountain, Nevada, in the NNWSI program. The geochemical characterization includes mineral composition of geologic material, solubility and sorption of important radionuclides, and diffusion and transport characteristics of the nuclides. Many of the experiments to complete these characterizations will be conducted in the laboratory, and concerns have been expressed about extrapolating the laboratory-derived parameters to the actual site. This study represents an initial attempt to determine the validity of laboratory-derived parameters to a field-scale experiment. A single process, sorption, will be examined. The field experiments are currently planned for the C-well complex at Yucca Mountain. Experiments may be conducted in other wells depending on the results of the initial experiments in the C-wells.

The study is divided into laboratory and field phases with the laboratory experiments being initiated in 1987. To understand the sorption phenomenon, a mechanistic approach was taken. Sorption has many definitions from different disciplines, so initial efforts concentrated on defining the sorption mechanisms and identifying

laboratory experiments to determine the sorption of a particular solute by a prevailing mechanism. These efforts involved literature reviews and interactions with experts from various fields such as soil science, aquatic chemistry, and chemical engineering. Three sorption mechanisms were identified as being potentially important at Yucca Mountain: (1) electrostatic, (2) chemical, and (3) molecular sieve. The objective of the laboratory tasks was to identify at least one tracer that will be sorbed predominantly by one of the three mechanisms that are listed. Also, the laboratory experiments will provide the parameters for the appropriate sorption expression to be used in conjunction with transport models to describe the field experiment.

Laboratory experiments were initiated in 1987 using tuff from Yucca Mountain and lithium bromide as the tracer. Electrostatic sorption is expected to be the prevailing mechanism for lithium. Both equilibrium and kinetics experiments were conducted, and the results are currently being analyzed. Also, potentiometric titrations and electrophoretic mobility experiments are being conducted to assist in the interpretation of the prevailing mechanism.

Surfactant Flooding Technology for Cleanup of Contaminated Soils and Aquifers

A Feasibility Study

Author: C. Porzucek (Principal Investigator)

Group: Environmental Science, HSE-12

Funding Organization: LANL Institutionally Supported Research and Development

A feasibility study was initiated in November 1987 to investigate the use of surfactant flooding technology to clean up contaminated aquifers and soils. This project has direct application for fuel spills that are commonly found on Air Force and Army bases. Some of these spills are located in areas that are difficult or impossible to excavate and decontaminate. For these areas some form of *in situ* cleanup is necessary. The surfactant flooding technology will allow *in situ* cleanup of these contaminated soils.

A computerized literature search has been instituted to investigate previous research on the subject. One study has shown surfactant flooding technology to be feasible for some classes of contaminants and soils under laboratory conditions.¹ However, a recent report by the EPA and the Air Force concerning a field-scale test of the technology has shown *in situ* enhanced soil washing by surfactant flooding to be an ineffective cleanup method for contaminated soils.² However, too large a jump was made between the soil saturated conditions of the laboratory experiments and the multicontaminated, unsaturated, undisturbed soils used in the pilot test. Multiphase flow in the vadose zone is not well-enough understood and may have contributed significantly to the failure of the pilot studies. Other literature is currently being reviewed and investigated.

If surfactants are to be injected into soils and aquifers, it is apparent that some surfactant will not be recovered with the contaminant. Some surfactant will be left trapped in dead-end pores while some will be left adsorbed on soil material. Therefore, it is essential that the surfactants to be injected are biodegradable. Reports from the Shell Chemical Company indicate which surfactants are the most biodegradable.³⁻⁵ Straight-chain alcohol ethoxylate surfactants biodegrade most rapidly. In addition, the rate of biodegradation of these types of surfactants is not affected greatly by seasonal temperature fluctuations. Also, the alcohol ethoxylate surfactants are nonionic and will therefore not disperse the clays that are present in soils. Other surfactants, such

as alkylphenol ethoxylates, linear alkyl sulfonates, alcohol ethoxysulfates, and alpha olefin sulfonates, are slower to biodegrade and hence are not as desirable. In addition, the majority of these are ionic surfactants. These surfactants contain ions that will disperse the clays present in the soils. These dispersed clays will eventually plug pores and can result in a failure of the flooding process.

With a tentative class of surfactants selected, more literature reviewing is planned. The phase behavior of straight-chain alcohol ethoxylate surfactants with various contaminants must be investigated. The phase behavior between surfactant and contaminant must be examined from several viewpoints. The surfactant solutions must not be too viscous or injection may be too difficult. Also, the surfactant solutions should produce ultralow interfacial tensions when contacted with the contaminant. The ultralow interfacial tensions are necessary for high recovery of contaminant. Depending on the availability of literature on the phase behavior, it may be necessary to perform some simple laboratory phase behavior studies between the surfactants and sample contaminants.

Following the investigation into the phase behavior of the selected surfactants, simulations will be performed. An existing surfactant/polymer flooding simulator used for enhanced oil recovery studies⁶ will be modified for use here. The simulations will indicate the amount of contaminant that might be removed in an ideal case. This will tell if the process of surfactant enhanced soil washing *in situ* is feasible.

References

1. W. D. Ellis, J. R. Payne, A. N. Tafuri, and F. J. Freestone, "The Development of Chemical Countermeasures for Hazardous Waste Contaminated Soil," presented at the 1984 Hazardous Material Spills Conference, April 9-12, 1984, Nashville, Tennessee.

2. J. H. Nash, "Field Studies of *In Situ* Soil Washing," report for Hazardous Waste Engineering Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio (1986).
3. L. Kravetz, H. Chung, K. F. Guin, W. T. Shebs, and L. S. Smith, "Primary and Ultimate Biodegradation of an Alcohol Ethoxylate and a Nonylphenol Ethoxylate Under Average Winter Conditions in the United States," presented at the American Oil Chemists' Society 74th Annual Meeting, Chicago, Illinois, May 1983. Also *Technical Bulletin* SC:779-83 for Shell Chemical Company.
4. L. Kravetz, "Biodegradation of Nonionic Surfactants Used by the Textile Industry," presented at the 61st National Technical Conference of the American Association of Textile Chemists and Colorists, Atlantic City, New Jersey, October 1982. Also *Technical Bulletin* SC:744-83 for Shell Chemical Company.
5. L. Kravetz, H. Chung, and J. C. Rapean, "Ultimate Biodegradation Studies of Alpha Olefin Sulfonates," presented at the American Oil Chemists' Society 68th Annual Spring Meeting, New York, New York, May 1977. Also *Technical Bulletin* SC:243-82 for Shell Chemical Company.
6. C. Porzucek, "Optimal Injection Strategies for Surfactant Flooding Enhanced Oil Recovery Using a Streamtube Reservoir Simulator," Ph.D. dissertation, University of Colorado, Boulder, Colorado (1987).

Vapor Transport of Organic Chemicals: Model Development

Authors: E. P. Springer (Principal Investigator) and
C. Porzucek

Group: Environmental Science, HSE-12

Funding Organization: LANL Institutionally Supported
Research and Development

The objective of this work was to test a model to predict the vapor phase flow of a single organic component in soils. This information is important to predict the transport of many potentially toxic or hazardous compounds such as fuels and solvents commonly used in everyday activities. These compounds typically have low solubility in water and are volatile, so they are expected to behave differently from contaminants that are soluble in water and are not volatile. The volatile organics may be toxic in small concentrations (parts per billion), and the potential for migration as a vapor followed by resolubilization provides a mechanism for ground-water contamination through an unsaturated porous medium.

The mathematical foundation of a computer model to predict vapor phase movement of organic chemicals in porous media was developed. Free convection is assumed to govern convective movement in the vapor phase. A mass transport equation including convective, diffusive, and source terms was formulated:

$$\alpha \frac{\partial C_A}{\partial t} + \nabla \cdot (C_A \mathbf{V}^T) - \theta_D \nabla \cdot (\tau D_{AB} \nabla y_A) = \theta_D S(x, y, z, t),$$

where

- α = $\theta_D + \rho_w(\theta_t - \theta_D) K_w + \rho_s(1 - \theta_t) K_s$,
 C_A = molar concentration of species A in gas phase (gmole/cm³),
 $\mathbf{V}^T$ = average molar velocity vector (cm/s),
 C = total molar concentration (gmole/cm³),
 τ = tortuosity,
 D_{AB} = mass diffusivity or binary diffusion coefficient (cm²/s),

- y_A = mole fraction of component A in the vapor phase,
 S = rate of addition of species A into the gas phase (gmole/cm²s),
 θ_D = drained or gas-filled porosity (cm³g/cm³),
 θ_t = total porosity (cm³/cm³),
 ρ_w = density of aqueous phase,
 ρ_s = density of solid phase,
 K_w = partition coefficient for species A between gas and aqueous phases,
 K_s = partition coefficient for species A between gas and solid phases, and
 t = time (s).

The equation that defines the free convective velocity term is described in detail by Porzucek and Springer.¹

Partitioning of a species between gas and soil water is allowed by the equation as well as adsorption of a species from the gas to the soil surface. The source term assumes instantaneous equilibrium between the liquid and vapor phases. Activity coefficients governing the vapor liquid equilibrium for the trichloroethylene (TCE)/water system were estimated from available experimental data^{2,3} and were shown not to equal 1.¹ However, the range of activity coefficients for TCE was small enough to ignore the concentration dependence and to use an average value. A plot of the estimated activity coefficients for TCE in water versus mole fraction TCE is provided in Figure 1. A three-dimensional heat equation will be included to provide temperature control for source generation, control over the diffusivity, and convective flow. The latent heat of vaporization that is required to change the state of the organic will be a source/sink term in the heat equation.

A numerical algorithm will be implemented to solve the system of equations. The solution procedure and verification cases will be the subject of other reports. We expect to apply this computer code to the same data set used by Springer⁴ for validation purposes.

Figure 1. Activity coefficient for trichloroethylene and water using data from Fuentes et al.² and Thompson.³

References

1. C. Porzuczek and E. P. Springer, "VAPTOC-Vapor Phase Transport of Organic Chemicals, I. Model Development," Los Alamos National Laboratory document LA-UR-87-3773 (1987).
2. H. R. Fuentes, W. L. Polzer, J. L. Smith, S. C. Bell, and M. A. Fisher, "Partitioning of Trichloroethylene (TCE) and Ortho-Xylene in Multiphase Solutions of Bandelier Tuff," Los Alamos National Laboratory document LA-UR-86-4358 (1987).
3. K. A. Thompson, "Vertical Diffusion of Selected Volatile Organic Contaminants Through Unsaturated Soil from a Water Table Aquifer: Field and Laboratory Studies," University of Arizona thesis (1985).
4. E. P. Springer, "Modeling of Organic Vapor Movement at Area L Disposal Site," Los Alamos National Laboratory document LA-UR-86-4359 (1986).

Sorption Modeling

Author: W. L. Polzer (Principal Investigator)

Group: Environmental Science, IISE-12

Cooperator: H. R. Fuentes, University of Texas at El Paso

Funding Organization: Department of Energy,
Nevada Nuclear Waste Storage Investigations

The objective of this work is to evaluate various conventional equilibrium (isotherm) expressions to determine how well they represent actual laboratory sorption of radionuclides. This information is required to predict with confidence the sorption of radionuclides under various scenarios in the stratigraphic units of the candidate high-level radioactive waste repository at Yucca Mountain in Nevada. The data sets were collected from laboratory batch experiments designed for purposes other than isotherm evaluation¹ in which tuff materials from the vicinity of Yucca Mountain were equilibrated with well water from the same vicinity.

The equilibrium isotherms that are being evaluated include the linear, Langmuir, Freundlich, and modified Freundlich expressions. The modified Freundlich is a general expression for heterogeneous sorption of solutes, and the other expressions are specific cases of the general one. The parameters of the modified Freundlich are measures of a mean sorption energy and the spread of individual sorption energies about the mean. The general isotherm expression will aid in understanding the retardation and flow dynamics of solutes during transport.² Initial results indicate that the Freundlich and the modified Freundlich expressions generally represent the data sets.

The modified Freundlich has been extended to allow the maximum sorptive capacity (CEC) to vary, thus data of sorption on tuff materials containing different CECs were incorporated into the same isotherm.³ The results indicate that in most cases the isotherm represents the data from samples within the same stratigraphic unit.

Figure 1 shows a plot of cesium sorption data according to the modified Freundlich isotherm expression for the Topopah Spring formation. The isotherm represents the sorption data over eight orders of magnitude. Figure 2 shows a plot of the two isotherm parameters, K_D and B , for strontium and cesium sorption on materials within each of five stratigraphic units of Yucca Mountain. The modified Freundlich is a more

sophisticated isotherm than those used in most currently available solute transport computer codes for site characterization. However, it is still simple enough to be incorporated into those codes. The information from these modeling efforts will also be used to make recommendations to design experiments specifically for isotherm development.

Figure 1. Modified Freundlich isotherm plot of cesium on Topopah Spring tuff media.³

Figure 2. Modified Freundlich isotherm parameters for strontium and cesium sorption on Yucca Mountain tuff media. The parameter values with their standard errors are plotted relative to stratigraphic units.³

References

1. W. R. Daniels, K. Wolfsberg, R. S. Rundberg, A. E. Ogard, et al., "Summary Report on the Geochemistry of Yucca Mountain and Environs," Los Alamos National Laboratory report LA-9328-MS (1982).
2. H. R. Fuentes, W. L. Polzer, J. Gruber, B. Lauctes, and E. H. Essington, "Preliminary Report on Sorption Modeling," Los Alamos National Laboratory report LA-10952-MS (1987).
3. W. L. Polzer and H. R. Fuentes, "The Use of a Heterogeneity-Based Isotherm to Interpret the Transport of Reactive Radionuclides in Volcanic Tuff Media," Los Alamos National Laboratory document LA-UR-87-2901 (1987).

Authors: T. E. Hakonson (Principal Investigator),
P. M. Rich (Postdoctoral Fellow), and P. A. Johnson (ESS-4)
Group: Environmental Science, HSE-12
Collaborator: Dr. V. Klemas, University of Delaware
Funding Organization: DOE Office of Health and
Environmental Research, Ecological Research Division

Our ultimate goal is to provide an effective field tool for noninvasive, *in situ* study of soil strata. Successful preliminary laboratory and field experiments suggest that elastic wave techniques developed for geophysical studies of rock strata can be applied to high-resolution imaging of soil strata, with the possibility of distinguishing water content and root density within soil strata. We will undertake a three-year program of laboratory and field studies with the following specific objectives:

(1) To optimize elastic wave transmitter and receiver design so as to maximize energy transmission and improve signal-to-noise ratio.

(2) To evaluate the application of cross-borehole elastic wave techniques for characterization of soil strata.

(a) Can we produce signals at useful distances in soils?

(b) Can we distinguish soil strata?

(c) Can we distinguish water content and root biomass within soil strata?

(3) To improve elastic wave travel-time inversion algorithms and computer techniques used to create two- and three-dimensional tomographic reconstructions.

(4) To improve cross-borehole data collection and processing techniques.

(5) To apply cross-borehole techniques in a study of soil strata at the Los Alamos DOE National Environmental Research Park.

(6) To compare cross-borehole elastic wave results with findings from ground-penetrating radar and elastic wave surface reflection techniques.

In laboratory experiments conducted between January and August 1987, we observed 80-kHz signals at distances in excess of 40 cm, achieving a resolution of at least 1.5 cm. These experiments were conducted in a mixture of fine and coarse-grained, water-saturated sandy soil. Various transmitter and receiver devices were tested. To date, the best devices for both transmitter and receiver are cylindrical piezoelectric transducers with a center frequency response of 40 kHz,

manufactured by Channel Industries, Inc. These devices were housed in polypropylene containers filled with silicon oil and enclosed in Faraday shields for electrical isolation. A 25- by 45-cm container was filled with sand to a depth of 25 cm, and a transmitter and a receiver were positioned below the surface at opposite ends of the container. A third transducer was placed next to the transmitter to monitor the source signal. The transmitter was operated in pulsed mode by an HP-3314A function generator and was monitored by an oscilloscope with signal stacking capability. The observed signal amplitude at 40 cm between transmitter and receiver was of sufficient amplitude that a longer travel path length would be possible, but we were limited by the experimental container size.

In July and August 1987, we conducted a series of preliminary field experiments between boreholes. These experiments were designed to field test the laboratory equipment described above. Because deep, well-developed soil does not exist in our vicinity, we conducted field tests in the existing rock, a thick welded tuff deposited from various volcanic eruptions originating from the Jemez Mountain caldera near Los Alamos. This rock is very porous, yet water unsaturated and highly fractured. Unlike soil, it is nearly impossible to add water to the rock, which in some soil may be desirable to increase energy transmission. These characteristics of the rock make it a poor conductor of elastic wave energy, much like soil. Boreholes were drilled at various distances from each other, lined with plastic sleeves, and filled with water to optimize coupling. A transmitter and receiver, of identical design as for laboratory experiments, were lowered into adjacent boreholes. We transmitted elastic waves to approximately 36-cm distance with a resolution that suggests a higher-energy transmitter and improved signal-to-noise ratio may permit cross-borehole tomography of soil strata.

Development of a Solar-Blind Raman LIDAR for Evapotranspiration Measurement

Authors: *F. J. Barnes (Principal Investigator),
R. R. Karl (ESS-7), and P. M. Rich (Postdoctoral Fellow)*

Group: *Environmental Science, HISE-12*

Collaborators: *G. Salzman (LS-4),*

J. Gosz (University of New Mexico), and

*B. Reginato (USDA, Agricultural Research Service,
Salinity Laboratory)*

Funding Organization: *DOE, Office of Health and
Environmental Research, Ecological Research Division*

Recent developments in light detection and ranging (LIDAR) enable remote measurement of atmospheric constituents such as water vapor, while yielding information about air temperature and movement. In essence, LIDAR remote sensing of the atmosphere involves (1) pulsed firing of a high-powered laser of appropriate wave length into the atmosphere, (2) detection of returning backscatter, Raman, or fluorescence signals, and (3) interpretation to determine concentration of the target substance as a function of distance. Distance is calculated as a function of the return time of the signal.

We have begun to develop and apply LIDAR techniques for determination of evapotranspiration (ET) from natural vegetation, agricultural land, and managed waste sites. ET from vegetated landscapes is the dominant component of water balance, especially in arid and semiarid regions where up to 100% of the annual precipitation may be returned to the atmosphere by this mechanism.

Accurate measurements of ET are necessary for addressing a broad range of theoretical and management problems. ET over large areas is difficult to measure because it is highly variable in time and space. Current methods for measuring ET involve extrapolation from limited point-estimates of water vapor, temperature, and

wind profiles above vegetation and are therefore subject to considerable error.

LIDAR techniques offer a sensitive tool capable of performing three-dimensional remote analyses of atmospheric constituents, including water vapor, on a fast time scale. Previous experimenters have developed the Raman LIDAR to perform at better than 5-m spatial resolution. A solar-blind system, based on excitation by a 248-nm krypton-fluoride (KrF) laser, can accurately measure moisture content both day and night at ranges to at least 2 km. With higher spectral resolution, the system can simultaneously obtain the temperature from the rotational Raman intensities. LIDAR capabilities are proved and suitable for immediate application to various areas of atmospheric research, including the study of ET.

LIDAR for measurement of water content has capabilities in excess of classical point detectors that permit (1) remote operation at places inaccessible to point monitors; (2) rapid data acquisition with measurements that are nearly instantaneous and repeatable up to many times per second; (3) noninvasive measurement; (4) high spatial resolution with better than 5-m resolution along the laser axis; (5) high sensitivity; and (6) three-dimensionality, allowing pattern recognition of eddies, turbulence, and diffusion.

REPRODUCED FROM
BEST AVAILABLE COPY

Radiation Protection (HSE-1)

Lawrence, J.N.P., "Some Further PUQFUA Studies," Proceedings of DOE Workshop on Radiobiology and Internal Dosimetry, PNL-SA-14043, Albuquerque, New Mexico, January 20-22, 1986 (National Technical Information Service, Springfield, Virginia, 1987), pp. 107-122.

Occupational Medicine (HSE-2)

Barnwell, M., and W. Galke, "An Epidemiologic Analysis of Fatal Home Accidents in North Carolina," *Journal of Environmental Health* **49**, 208-213 (1987).

Mahoney, M. C., and G. S. Wilkinson, "Smoking Patterns Among Los Alamos National Laboratory Employees," Los Alamos National Laboratory report LA-10650 (June 1987).

Tietjen, G. L., "Plutonium and Lung Cancer," *Health Physics* **52**, 625-628 (1987).

Voelz, G. L., "Acute and Long-Term Health Effects of Radiation," *Proceedings of International Conference on Non-Military Radiation Emergencies*, Washington, D.C. (American Medical Association, 1986), pp. 123-145.

Voelz, G. L., "Ionizing Radiation," in *Occupational Medicine*, C. Zenz, Ed. (Year Book Medical Publishers, Inc., 1987), Chap. 26.

Voelz, G. L., "Radiation Injury," in *Principles and Practice of Emergency Medicine*, G. R. Schwartz, P. Safar, J. H. Stone, P. B. Storey, and D. K. Wagner, Eds. (W.B. Saunders Co., Philadelphia, 1986), Chap. 81, pp. 1542-1548.

Wiggs, L. D., "Mortality Among Females Employed by the Los Alamos National Laboratory: An Epidemiologic Investigation," Ph.D. dissertation, University of Oklahoma (November 1987).

Wiggs, L. D., C. A. Weber, and G. S. Wilkinson, "Injury Mortality Among Employees of Los Alamos National Laboratory," Los Alamos National Laboratory report LA-10812-MS (November 1986).

Wilkinson, G. S., "The Epidemiology of Radiation Effects Among Employed Populations" (Abstract), *American Journal of Epidemiology* **126**, 780-781 (1987).

Wilkinson, G. S., G. L. Tietjen, L. D. Wiggs, W. A. Galke, J. F. Acquavella, M. Reyes, G. L. Voelz, and R. J. Waxweiler, "Mortality Among Plutonium and Other Radiation Workers at a Plutonium Weapons Facility," *American Journal of Epidemiology* **125**, 231-250 (1987).

Wilkinson, G. S., W. A. Galke, G. L. Tietjen, and L. D. Wiggs, "Residual Confounding in Follow-up Studies with Time-dependent Doses" (Abstract), *American Journal of Epidemiology* **124**, 526-527 (1986).

Industrial Hygiene (HSE-5)

Brandt, M. T., et al., "Kosova Coal Gasification Plant Health Effects Study, Vol. II. Industrial Hygiene," Los Alamos National Laboratory report LA-10850 (1987).

Ettinger, H. J., Ed., "Industrial Hygiene Group 1986 Annual Report on Research and Special Activities," Los Alamos National Laboratory report LA-11100-MS (1987).

Fairchild, C. I., and J. F. Stampfer, "Particle Concentration in Exhaled Breath," *American Industrial Hygiene Association Journal* **48** (11), 948-949 (1987).

Morris, S., J. O. Jackson, et al., "Kosova Coal Gasification Plant Health Effects Study, Vol. I. Summary," Brookhaven National Laboratory report BNL-40629 (1987).

Ortiz, L. W., S. C. Soderholm, and F. O. Valdez, "Penetration of Respirator Filters by an Asbestos Aerosol," Los Alamos National Laboratory document (submitted to the *American Industrial Hygiene Association Journal*).

Schwepce, A. D., P. P. Costos, J. O. Jackson, and D. J. Weitzman, *Guidelines for the Selection of Chemical Protective Clothing*, 3rd Edition (American Conference of Governmental Industrial Hygienists, February 1987).

Scripsick, R. C., R. L. Smitherman, and S. A. McNabb, "Operational Evaluation of the High Flow Alternative Filter Test System," in Proceedings of the 19th DOE/NRC Nuclear Air Cleaning Conference, NUREG/CP-0086, Conf-860820 (1987), Vol. II, pp. 863-886.

Smith, D. M., L. W. Ortiz, R. A. Archuleta, and N. F. Johnson, "Long-Term Health Effects in Hamsters and Rats Exposed Chronically to Man-Made Vitreous Fibers," Los Alamos National Laboratory document (submitted to *Annals of Occupational Hygiene*).

Stevens, R. R., and M. I. Tillery, "Measurement of Oxygen Transport Rate Across Perfluorocarbon Liquids," Los Alamos National Laboratory document (submitted to *American Industrial Hygiene Association Journal*).

Tillery, M. I., C. I. Fairchild, M. Gonzales, E. Vigil, and G. Royer, "Aerosol Support for Oil Shale Inhalation

- Toxicology Studies," Los Alamos National Laboratory report (in process).
- Wood, G. O., "A Model for Adsorption Capacities of Charcoal Beds, I. Relative Humidity Effects," *American Industrial Hygiene Association Journal* **48**, 622-625 (1987).
- Wood, G. O., "A Model for Adsorption Capacities of Charcoal Beds, II. Challenge Concentration Effects," *American Industrial Hygiene Association Journal* **48**, 703-709 (1987).
- Wood, G. O., "A Theoretical Model Describing Vapor Concentration Effects on Adsorption Capacities of Carbon Beds," in Proceedings of the 1986 U.S. Army Chemical Research, Development and Engineering Center Scientific Conference on Chemical Defense Research, CRDEC-SP-87008 (1987), pp. 137-142.
- Wood, G. O., and M. W. Ackley, "A Testing Protocol for Activated Carbon and Canisters" (submitted to Proceedings of the 1987 U.S. Army Chemical Research, Development, and Engineering Center Scientific Conference on Chemical Defense Research).
- Wood, G. O., Letter to the Editor (Technical), *American Industrial Hygiene Association Journal* **48**, A-578 (1987).
- Woodrow, L. M., "An Evaluation of Four Quantitative Laboratory Fume Hood Performance Test Methods," Los Alamos National Laboratory report LA-11143-T (1987).
- Environmental Surveillance (HSE-8)**
- Bowen, B., W. Olsen, I. Chen, and D. VanEtten, "Measurement and Modeling of External Radiation During 1985 from LAMPF Emissions," Los Alamos National Laboratory report LA-11150-MS (November 1987).
- Buhl, T., D. VanEtten, and W. Hansen, "Investigation of Thorium Contamination at Two Target Areas at White Sands Missile Range," Los Alamos National Laboratory report LA-10893-MS (February 1987).
- Environmental Surveillance Group, "Quality Assurance Project Plans," Los Alamos National Laboratory document LA-UR-87-1076 (February 1987).
- Purtymun, W., and A. Stoker, "Environmental Status of Technical Area 49, Los Alamos, New Mexico," Los Alamos National Laboratory report LA-11135-MS (November 1987).
- Purtymun, W., A. Stoker, and M. Maes, "Water Supply at Los Alamos During 1986," Los Alamos National Laboratory report LA-11046-PR (August 1987).
- Purtymun, W., R. Ferenbaugh, N. Becker, M. Williams, and M. Maes, "Water Quality in the Vicinity of Fenton Hill, 1983 and 1984," Los Alamos National Laboratory report LA-10892-PR (January 1987).
- Purtymun, W., R. Peters, T. Buhl, M. Maes, and F. Brown, "Background Concentrations of Radionuclides in Soils and River Sediments in Northern New Mexico, 1974-1986," Los Alamos National Laboratory report LA-11134-MS (November 1987).
- Sautter, C., "High Resolution, *In Situ*, Gamma-Ray Spectrometry Procedures Manual," Los Alamos National Laboratory report LA-11146-M (December 1987).
- VanEtten, D., and W. Olsen, "Improvement of a Portable Ionization Chamber with the Addition of a Microprocessor Datalogger," Los Alamos National Laboratory report LA-11014-MS (July 1987).
- Wenzel, W., T. Foxx, A. Gallegos, G. Tierney, and J. Rodgers, "Cesium-137, Plutonium-239/240, Total Uranium, and Scandium in Trees and Shrubs Growing in Transuranic Waste at Area B," Los Alamos National Laboratory report LA-11126-MS (November 1987).
- Health and Environmental Chemistry (HSE-9)**
- Bower, N. W., D. K. Kim, and E. S. Gladney, "Determination of Water in Nineteen USGS Geochemical Reference Standards Using Coulometry and Neutron-Capture Prompt Gamma-Ray Spectroscopy," *Geostandards Newsletter* **11**, 37-40 (1987).
- Efurd, D. W., R. E. Perin, and J. F. McInroy, "Neptunium-237 in Human Tissue Samples," *Health Physics* **51** (5), 665-666 (1986).
- Gautier, M. A., and E. S. Gladney, "A Quality Assurance Program for Health and Environmental Chemistry," *American Laboratory* **19** (7), 17-22 (1987).
- Gautier, M. A., E. S. Gladney, W. D. Moss, M. Phillips, and B. T. O'Malley, "Quality Assurance for Health and Environmental Chemistry: 1986," Los Alamos National Laboratory report LA-11114-MS (1987).
- Gladney, E. S., and I. Roelandts, "Distribution of NBS, USGS, and CCRMP Reference Material Data in the Literature (1951-1985)," *Geostandards Newsletter* **11**, 133-142 (1987).
- Gladney, E. S., and I. Roelandts, "Compilation of Boron Concentration Data for NBS, USGS, and CCRMP Reference Materials," *Geostandards Newsletter* **11**, 167-186 (1987).

- Gladney, E. S., B. T. O'Malley, I. Roelandts, and T. E. Gills, "Compilation of Elemental Concentration Data for NBS Clinical, Biological, Geological, and Environmental Standard Reference Materials," NBS Special Publication 260-111 (1987).
- Kathren, R. L., J. F. McInroy, and M. J. Swint, "Actinide Distribution in the Human Skeleton," *Health Physics* **52** (2), 179-192 (1987).
- Kathren, R. L., J. F. McInroy, M. M. Reichert, and M. J. Swint, "Partitioning of ^{238}Pu , ^{239}Pu and ^{241}Am in Skeleton and Liver of U.S. Transuranium Registry Cases," *Health Physics* **54** (2), 181-188 (1988).
- Lynch, T. P., R. L. Kathren, and J. F. McInroy, "Macrodistribution of ^{241}Am and ^{239}Pu in Four Human Half-Skeletons," Pacific Northwest Laboratory, Richland, Washington, report PNL-SA-14569 (1987).
- McInroy, J. F., R. L. Kathren, G. L. Voelz, and M. J. Swint, "U.S. Transuranium Registry Report on the ^{239}Pu Distribution in a Human Body" (Abstract), *Health Physics* **52** (1), S37 (1987).
- Miglio, J. J., "Simultaneous Determination of Americium and Plutonium by Liquid Scintillation Counting Using a Two-Phase Cocktail," *Analytical Chemistry* **58**, 3215-3218 (1986).
- Miglio, J. J., and L. C. Willis, "Evaluation of a Technique for Separating Organic Material from Mineral Bone in Individuals Occupationally Exposed to Plutonium," *Health Physics* **52** (2), 763-767 (1987).
- Singh, N. P., J. F. McInroy, M. E. Wrenn, E. R. Gonzales, F. T. Cross, and P. O. Jackson, " ^{238}U , ^{234}U and ^{230}Th in Dog Lungs Exposed to Uranium Ore Dust: An Interlaboratory Comparison," *Health Physics* **50** (2), 292-296 (1986).
- Environmental Science (HSE-12)**
- Barnes, F. J., "Gas Exchange Characteristics of *Pinus Edulis* and *Juniperus Monosperma*" (Abstract), *Bulletin of the Ecological Society of America* **68** (3), 259 (1987).
- Barnes, F. J., and J. C. Rodgers, "Evaluation of Hydrologic Models in the Design of Landfill Cover Systems," Final Report IAG DW89930235-0101 (U.S. EPA Office of Research and Development, Cincinnati, Ohio, 1987).
- Barnes, F. J., and J. C. Rodgers, "Hydrologic Modeling of Soil Water Storage in Landfill Cover Systems," in *Proceedings of International Conference on Measurement of Soil and Plant Water Status* (Utah State University, Logan, Utah, 1987), pp. 173-182.
- Barnes, F. J., and R. R. Karl, "Development of a Solar-Blind Raman LIDAR for 3-D Evapotranspiration Measurements" (Abstract), *EDS Transaction of the American Geophysical Union* **68** (44), 1294 (1987).
- Bostick, K. V., J. R. Simanton, L. J. Lane, and T. E. Hakonson, "Preliminary Results of Erosion and Contaminant Transport Research on the Nevada Test Site," in *The Dynamics of Transuranics and Other Radionuclides in Natural Environments*, W. A. Howard and R. G. Fuller, Eds., NVO-272 (DE87014456) (1987), pp. 517-526.
- Foster, G. R., and T. E. Hakonson, "Erosional Losses of Fallout Plutonium," in *The Dynamics of Transuranics and Other Radionuclides in Natural Environments*, W. A. Howard and R. G. Fuller, Eds., NVO-272 (DE87014456) (1987), pp. 527-557.
- Fuentes, H. R., and W. L. Polzer, "Interpretative Analysis of Data for Solute Transport in the Unsaturated Zone," Los Alamos National Laboratory report LA-10817-MS, NUREG/CR-4737 (1987).
- Fuentes, H. R., W. L. Polzer, and E. H. Essington, "Intermediate-Scale Experiments in Solute Transport Studies at Los Alamos: Role and Experiences," in *Proceedings of the 1987 Specialty Conference, Environmental Engineering*, J. D. Dietz, Ed. (American Society of Civil Engineers, New York), pp. 461-468 (1987).
- Fuentes, H. R., W. L. Polzer, E. H. Essington, and B. D. Newman, "Identification and Characterization of Reactive Tracers for C-Well Tracer Investigations," NNWSI Milestone R379 (1987).
- Fuentes, H. R., W. L. Polzer, and E. P. Springer, "Effects from Influent Boundary Conditions on Tracer Migration and Spatial Variability Features in Intermediate-Scale Experiments," Los Alamos National Laboratory report LA-10981-MS, NUREG/CR-4901 (1987).
- Fuentes, H. R., W. L. Polzer, J. Gruber, B. Lauctes, and E. H. Essington, "Preliminary Report on Sorption Modeling," Los Alamos National Laboratory report LA-10952-MS (1987).
- Lane, L. J., "Hydrologic Research at the Nevada Test Site," in *The Dynamics of Transuranics and Other Radionuclides in Natural Environments*, W. A. Howard and R. G. Fuller, Eds., NVO-272 (DE87014456) (1987), pp. 511-516, .
- Lane, L. J., T. E. Hakonson, and G. R. Foster, "Watershed Erosion and Sediment Yield Affecting Contaminant Transport," in *The Dynamics of Transuranics and Other Radionuclides in Natural Environments*, W. A. Howard and R. G. Fuller, Eds., NVO-2/2 (DE87014456) (1987), pp. 121-130.

- Nyhan, J. W., B. J. Drennon, and R. M. Gaylor, "Field Evaluation of a Tensiometer Data Acquisition System for Hydrologic Studies of Waste Disposal Site Design," in *Proceedings of the International Conference on Measurement of Soil and Plant Water Status 1* (Utah State University, Logan, Utah, 1987) pp. 145-150.
- Nyhan, J. W., and F. J. Barnes, "Development of an Arid Site Closure Plan," in *Proceedings of the Ninth Annual DOE Low-Level Radioactive Waste Management Conference*, Denver, Colorado, August 25-27, 1987 (EG&G, Idaho, 1987), 21 pp.
- Polzer, W. L., and H. R. Fuentes, "The Use of a Heterogeneity-Based Isotherm to Interpret the Transport of Reactive Radionuclides in Volcanic Tuff Media," Los Alamos National Laboratory document LA-UR-87-2901 (1987).
- Polzer, W. L., H. R. Fuentes, R. Raymond, D. L. Bish, E. S. Gladney, and E. A. Lopez, "Characterization of Crushed Tuff for the Evaluation of the Fate of Tracers in Transport Studies in the Unsaturated Zone," Los Alamos National Laboratory report LA-10962-MS, NUREG/CR-4875 (1987).
- Porzucek, C., and E. P. Springer, "VAPTOC-Vapor Phase Transport of Organic Chemicals, I. Model Development," Los Alamos National Laboratory document LA-UR-87-3773 (1987).
- Rich, P. M., "Development Anatomy of the Stem of *Welfia Georgii*, *Iriarteia Gigantea*, and Other Arborescent Rainforest Palms: Implications for Mechanical Support," *American Journal of Botany* **74**, 792-802 (1987).
- Rich, P. M., "Mechanical Structure of the Stem of Arborescent Palms," *Botanical Gazette* **148**, 42-50.
- Rich, P. M., S. Lum, L. Munoz, and M. Quesada, "Shedding of Vines by the Palms *Welfia Georgii* and *Iriarteia Gigantes*," *Principles* **31**, 31-40 (1987).
- Romney, E. M., E. H. Essington, E. B. Fowler, T. Tamara, and R. O. Gilbert, "Plutonium in the Desert Environment of the Nevada Test Site and the Topopah Test Range," in *Environmental Research on Actinide Elements*, J. E. Pinder III, J. J. Alberts, K. W. McLeod, R. G. Schreckhise, Eds., U.S. DOE, CONF-841142 (DE86008713) (1987), pp. 121-130.
- Springer, E. P., "Modeling of Organic Vapor Movement at Area L Disposal Site Los Alamos, New Mexico," Los Alamos National Laboratory document LA-UR-86-4359 (1987).
- Springer, E. P., "Reactive Tracer Experiments in the C-Wells at Yucca Mountain, Nevada," presented at DOE Workshop on Hydrologic Behavior of Rock Discontinuities, Lawrence Berkeley Laboratory, Berkeley, California, April 22-23, 1987 (in press as workshop proceedings).

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 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 accessory in achieving this goal is occupational health and environment 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 (see accompanying chart).

HEALTH, SAFETY, AND ENVIRONMENT DIVISION

JESSE ARAGON
DIVISION LEADER

Total Staff: 428.2

SM: 164.0

Support: 264.2

November 1, 1987

DIANNE LEE, ASST. DIV. LDR.
FOR PROPERTY AND FINANCE
MARVINE GARCIA, PERSONNEL
MARY ANN ROSENTHAL,
ADMINISTRATION

RONALD G. STAFFORD
DEPUTY DIVISION LEADER
HEALTH PROTECTION

MEDICAL DIRECTOR
WILLIAM A. GREENDYKE, MD
OCCUPATIONAL MEDICINE
HSE-2

THOMAS C. GUNDERSON
DEPUTY DIVISION LEADER
FOR ENVIRONMENT

HSE-1
RADIATION PROTECTION
ALLEN M. VALENTINE

HSE-3
SAFETY
W. CLARENCE COURTRIGHT

HSE-5
INDUSTRIAL HYGIENE
JAMES O. JACKSON

HSE-6
NUCLEAR
CRITICALITY SAFETY
THOMAS P. McLAUGHLIN

HSE-10
CHEMISTRY
HEALTH PROTECTION
W. JAY WENZEL

HSE-11, ACCELERATOR
HEALTH PROTECTION
A. JEROME MILLER

HSE-7
WASTE MANAGEMENT
RALPH A. KOENIG

HSE-8, ENVIRONMENTAL
SURVEILLANCE
T. C. GUNDERSON, ACTING

HSE-9, HEALTH AND
ENVIRONMENTAL
CHEMISTRY
RONALD C. GOOLEY

HSE-12
ENVIRONMENTAL SCIENCE
THOMAS E. HAKONSON

Los Alamos