AUXIER & ASSOCIATES, INC.

10317 TECHNOLOGY DRIVE
SUITE 1
KNOXVILLE, TENNESSEE 37932
PHONE: (423) 675-3669
FAX: (423) 675-3677
http://www.auxier.com

RADIOLOGICAL HEALTH, SAFETY, AND ENVIRONMENTAL CONSULTING

April 14, 1999

Mr. Bill. Adams
Environmental Protection Agency
Region 10
1200 Sixth Street
Seattle, WA 98101

Dear Mr. Adams:

Enclosed you will find 2 copies of the final report entitled "Elemental Phosphorus Slag Exposure Study, Phase 1 Final Report" as approved by you on January 19, 1999. You will also find 2 copies of the final Work Plan entitled "Exposure Study Phase 2 Work Plan" as approved by you on March 15, 1999. For your records, a CD ROM containing both documents is included with all files in MS WORD 97 (PC) format.

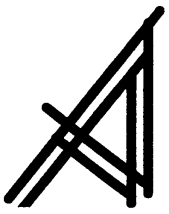
If you have any questions, please feel free to contact me at 423-675-3669.

Sincerely,

J.L. Alvarez, Ph.D., CHP
Project Manager

cc of each report:

J. E. Rice, FMC (includes CD)
M. J. Reape, FMC
W. S. Moore, FMC
R. L. Geddes, P4 Production (includes CD)
T. L. Clark, P4 Production
J. P. Hyland, P4 Production (includes CD)
T. F. Gesell, Idaho State University (includes CD)
Five EPA Information Repositories (includes CDs)
Project Files (includes CD)



ELEMENTAL PHOSPHORUS SLAG EXPOSURE STUDY
Phase I Final Report

April 14, 1999

Prepared for:

FMC Corporation
Highway 30 West
P.O. Box 4111
Pocatello, ID 83205

and

P4 Production, L.L.C.
State Highway 34 North
P.O. Box 816
Soda Springs, ID 83276

Prepared by:

Auxier & Associates, Inc.
10317 Technology Drive, Suite 1
Knoxville, Tennessee 37932
(423) 675-3669 Fax: (423) 675-3677

ELEMENTAL PHOSPHORUS SLAG EXPOSURE STUDY

Phase I Final Report

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Executive Summary

Phase I of the Exposure Study was conducted in Pocatello, Soda Springs, and Fort Hall Idaho. The Exposure Study identified residences that used phosphorus slag in the construction material and assessed above-background gamma radiation dose to individuals in the identified residences. Additionally, the study surveyed the three communities for phosphorus slag in community locations. Phosphorus slag has been used as a construction material as fill, gravel, and aggregate in asphalt and concrete. Generally, the slag has a higher concentration of uranium series radionuclides than is found in local soils and, consequently, generally emits more gamma radiation than local soils. Phase I of the study actively solicited community members for participation in the study. All elements of the Exposure Study will continue to be available to the communities in Phase II upon request of individuals or local authorities.

Goals. The goals of the Exposure Study were to:

- Assess individual dose and identify sources of exposure,
- Locate and inventory slag in the communities, and
- Implement GDGs.

Methodology. Participation in the Exposure Study was voluntary. Participants were solicited by various types of public announcements. Doses to individuals due to slag in residences were determined at the request of the participants. Community locations of slag were determined with the cooperation and by request of local authorities.

Dose to individuals was determined in phases. Screening methods were employed to determine if higher dose rates existed in residences, the existence of slag in the residence was determined, then, dose due to slag was assessed.

Slag within the communities was also located using dose rate screening. Identified locations of slag were entered on a community inventory.

Results. The number of residences participating were 1133 (8% of households) in Pocatello, 135 (16% of households) in Soda Springs, and 204 (27% of households) in Fort Hall. No houses in Pocatello or Fort Hall were found to have slag in the construction. Based on this sampling it was estimated that less than 0.5% of residences in these two communities might contain slag. Thirty-five percent of the houses surveyed in Soda Springs contained slag. Based on this sampling and the years of construction

with slag it was estimated that less than 12% of the residences in Soda Springs might contain slag.

Nine individual dose estimates exceeded 100 mrem/y or the dose level for implementation of the Graded Decision Guidelines. There were no requests for GDG implementation.

Nine individual dose estimates exceeded 100 mrem/y or the dose level for implementation of the Graded Decision Guidelines. Individuals and households were reminded of the availability of the GDGs when the doses were reported and subsequent reminders were sent if there was no response. There were no requests for GDG implementation.

The highest individual dose due to slag in a residence was estimated as 135 mrem/y. Based on the distribution of doses, the highest likely individual, residential dose was estimated as 215 mrem/y.

Few community structures, of those surveyed, were found to contain slag. All streets in the communities were surveyed. The percentage of streets by total miles of streets identified as containing slag were 27% in Pocatello, 23% in Soda Springs, and 20% in Fort Hall.

1.0 BACKGROUND

Phosphorus is produced in Southeastern Idaho near Soda Springs, Idaho by Monsanto Company (now P4 Production, L.L.C., a subsidiary of Monsanto Company and Solutia, Inc.), and near Pocatello, Idaho by FMC Corporation (the Companies). A byproduct of the phosphorus production process is a glassy slag (referred to in this report as "slag", "phosphorus slag", and "elemental phosphorus slag"). Phosphorus ore contains naturally occurring uranium and uranium progeny above the average concentrations in surface soils of Southeastern Idaho. As a consequence of the uranium and progeny content, the slag generally has associated gamma radiation levels above background soil.

FMC and P4 Production entered into an agreement with the U.S. Environmental Protection Agency (EPA) in 1992 to develop protocols for measuring slag-related radiation exposures. That agreement was embodied in a November 4, 1992 administrative order on consent (EPA 1992) issued under the authority of the Resource Conservation and Recovery Act (RCRA). Under this agreement, the Companies developed methods for measuring individual exposures to radiation from the slag and also participated in the development of guidelines (known as "Graded Decision Guidelines" or "GDGs") that set forth exposure levels at which corrective action was recommended (TWG 1995). A second agreement, also set forth in a RCRA administrative order on consent, was concluded on June 6, 1996. The Companies agreed under that consent order to carry out an Exposure Study to measure radiation exposures from the slag. The Companies also agreed, for exposures within the ranges for which the GDGs recommend action and upon the request of affected property owners, to implement corrective actions as set forth in the GDGs. The subject of this report is the activities performed under Phase I of the Exposure Study. The initial phase (Phase I) of the Exposure Study was initiated in June 1996 and is scheduled to conclude on December 31, 1998.

The Idaho Southeastern District Health Department (SDHD) was the primary interface between the public and the Exposure Study. A memorandum of understanding between the Companies and the SDHD was completed in April 1996 to establish this interface. The SDHD communicated with the public concerning the Exposure Study, solicited participation, provided education concerning the Study and the GDGs, and served as the repository for inventory information developed during the Study. The Companies provided the necessary support and funding for SDHD activities under the Study and implementation of the GDGs.

2.0 OBJECTIVES

The objectives of the Phase I Exposure Study were to:

- Assess individual doses and identify sources of exposure, and
- Locate and inventory slag in the communities of Pocatello, Soda Springs, and Fort Hall.
- Implement GDGs.

3.0 PROJECT OVERVIEW

The Exposure Study assessed doses to individuals from gamma radiation from elemental phosphorus slag (Residential Surveys) and located slag within the communities (Community Surveys). Participation in the Exposure Study was voluntary for both private and public property. The results of measurements on private property will be held in confidence, while the results of public property measurements will be part of the public record. Participation was solicited through public meetings, radio announcements, television advertisements, newspaper ads, and mass mailings of informational notices. Individuals wishing to participate in the study directed requests to the SDHD. Permission for Community Surveys of roads, parking lots, public buildings, etc., was obtained from responsible authorities or individuals. Detailed methodologies and procedures for field activities are presented in the Exposure Study Work Plan (A&A 1998, Revised) available at community locations listed in Table 1.

Residential surveys were generally conducted in phases. The typical sequence of events for Residential surveys is shown in Figure 1. Usually an initial Screening Survey was performed to determine the possible presence of slag. Screenings were performed with dose rate meters; two radiation levels were recorded for each of the lower two levels of the residence. Participants were offered a detailed dose assessment, if the Screening Survey identified dose rates greater than or equal to 20 μrem/h. Participants had the option to proceed to dose assessment without having a Screening Survey. Two options were available for dose assessments. One option was dose rate measurements, performed in a systematic and thorough manner throughout the residence, and time logs, indicating duration of potential exposure in different areas of the residence. The other option was for the individual to wear a thermoluminescent dosimeter (TLD) to screen for individual dose. Each interested individual in the household wore a TLD for approximately 90

days. Because a determination by TLD overestimated an individuals' dose due only to residential slag, eligibility for consideration under the GDGs, required a dose determination by the dose rate/time log method. Doses greater than or equal to 100 mrem/y above the local background were eligible for dose reduction evaluations under the GDGs.

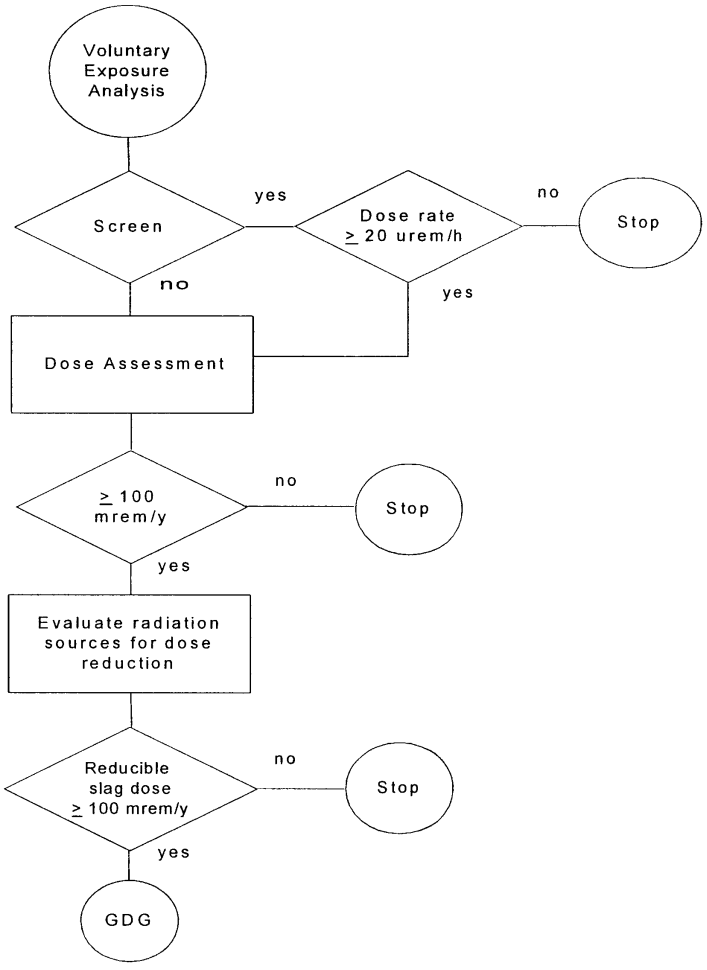


Figure1

Residential Dose Assessment Flow Chart

The general approach to Community Surveys is shown in Figure 2. The areas selected for Community Surveys were identified based on results from previous investigations (Berry 1987) where such survey data was available. Areas identified from those earlier investigations as exceeding 17 μrem/h were monitored using dose rate meters; areas such as streets and parking lots were initially surveyed from slow-moving vehicles, followed by more detailed surveys on foot where this monitoring identified levels equal to or greater than 20 μrem/h. Areas of the communities not covered by the aerial survey were surveyed in a similar manner, such as large portions of the Fort Hall Reservation. Additional areas were surveyed at the request of public officials. The results of the Community Surveys will be used by the local agencies to ensure that appropriate actions are taken to manage slag during activities such as construction or removal, which disrupt areas identified as containing slag.

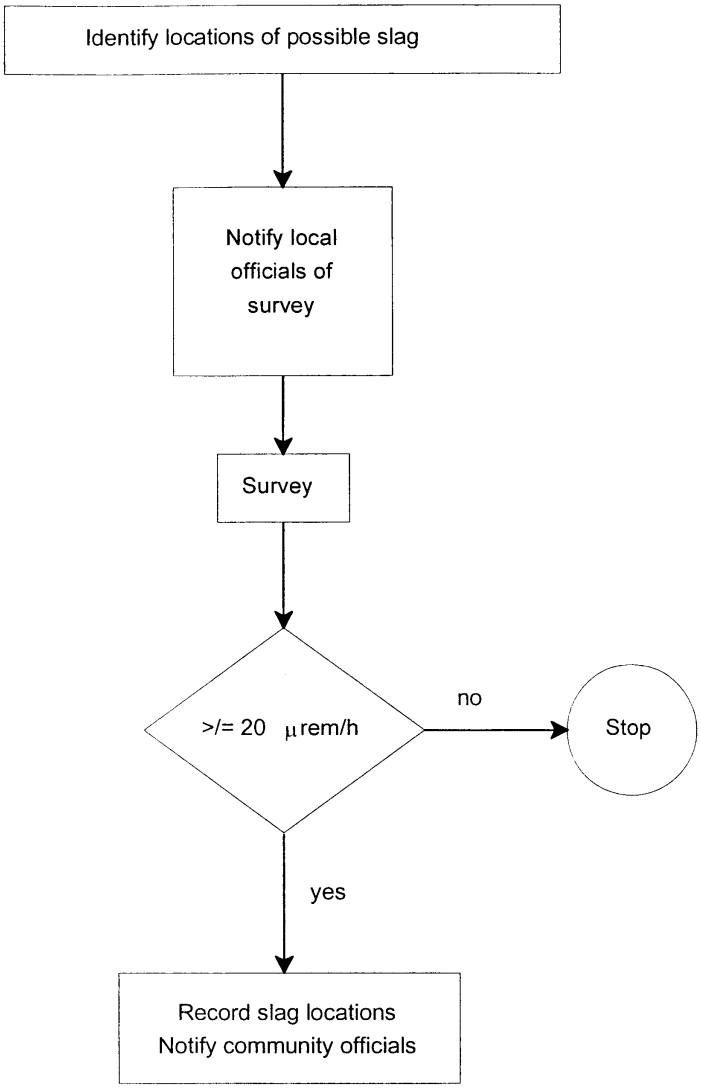


Figure 2

Community Surveys Flow Chart

4.0 ORGANIZATION

FMC and P4 Production managed Phase I of the Exposure Study through a Project Manager for each company. Field measurements and data analysis were performed by Auxier & Associates, Inc. (A&A). A&A also provided a Project Manager, who reported to the Company Project Managers. Additional positions of responsibility, provided through A&A were:

- Project Quality Assurance Officer
- Document Control Officer
- Site Survey Manager
- Survey Team Members

The Idaho Southeastern District Health Department served as the local information network for issues related to phosphorus slag, and was the contact point for participants in the Study, and distributed personnel dosimeters to volunteers who selected that method for estimating their potential radiation dose from slag. A&A project support also included a representative for the Fort Hall Community who assisted with educating Reservation residents regarding the Study, solicited Study participants, scheduled activities on the Reservation, distributed dosimeters, and developed field measurement data.

The project organizational chart is presented in Figure 3.

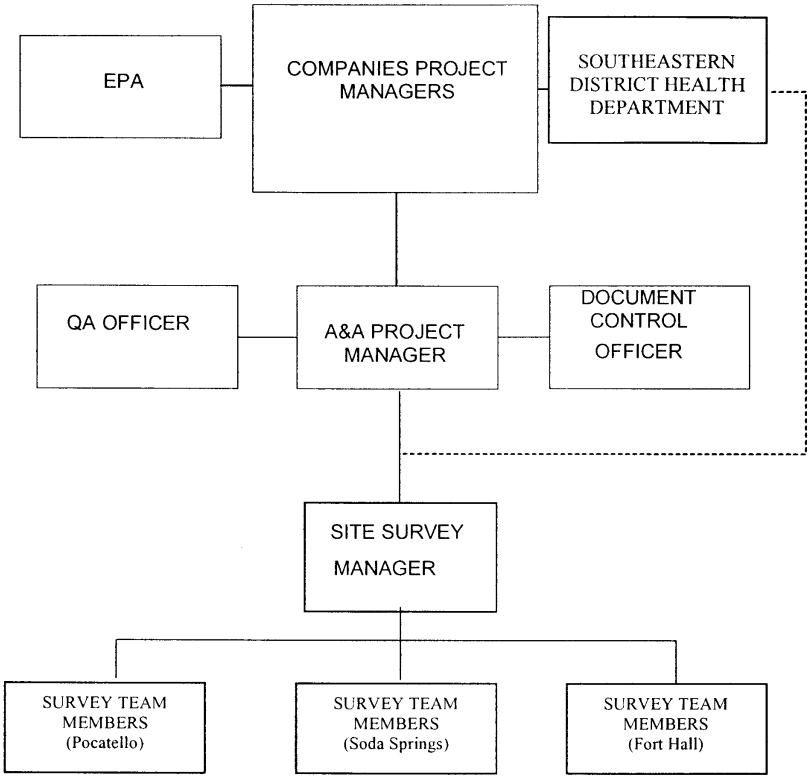


Figure 3

Exposure Study Organizational Chart

5.0 SUPPORTING DOCUMENTS

A Methods Development Study (MDS) was conducted prior to the Exposure Study to evaluate a variety of techniques for use in the Exposure Study and to develop the procedures for the techniques chosen for the Exposure Study. The Idaho Phosphorus Slag Exposure Study Work Plan, including the Project Management Plan, Health & Safety Plan, Quality Assurance Plan, Data Management Plan, and detailed Field Procedures with record forms, were developed based on the results of the MDS (IT 1994).

6.0 PUBLIC EDUCATION AND SOLICITATION OF EXPOSURE STUDY VOLUNTEERS

In June 1996 and October 1997, EPA conducted mass mailings, describing the Exposure Study and encouraging voluntary participation in the program, to homeowners in Pocatello, Soda Springs, and nearby communities. EPA and the SDHD also advertised the Exposure Study using local radio, TV, newspapers, and public group meetings. These advertisements continued throughout the period covered by this report. The Companies aided the advertisement by offering information on the Exposure Study at public events and internal Company meetings. Expressions of interest and requests to participate in the Exposure Study were received by the SDHD and forwarded to A&A survey personnel.

7.0 ACTIVITIES AND RESULTS

7.1 Solicitation for Study Participation

An answering machine, installed at the Pocatello office of SDHD, was connected to the published Exposure Study participation request lines. A dedicated computer was used to store records of requests by individuals for participation in the Exposure Study and actions taken for these requests.

Table 2 is a summary of public announcements and educational activities, relative to the Exposure Study, conducted during Phase I of the Study. Through November 1, 1998, there were 1719 initial contacts from potential participating households, requesting Screening Surveys, dosimeters for individual dose monitoring, and/or additional Study information. With few exceptions, requesting households included multiple members; additional details regarding the actual numbers of Study participants, for which individual

doses were estimated, are included in the following sections of the report. The actual number of active participants was 1564 because 154 of the initial contacts voluntarily withdrew from the Study or have not responded to attempts to schedule Study activities. There were 1187 active participants from Pocatello and nearby communities, 142 from Soda Springs and vicinity, and 235 from the Fort Hall Reservation.

7.2 Training

Prior to initiating field activities in June 1996, training was conducted in Pocatello for all personnel to be involved with Exposure Study data collection. This training also provided an opportunity to test and modify, as necessary, the draft field procedures. As personnel changes have occurred and procedures have been modified, additional training has been provided, as appropriate.

7.3 Data Collection

The following section briefly describes the measurement and data collection activities. Activities are summarized in Table 3.

7.3.1 Thermoluminescent Dosimeters

Shields for storage of thermoluminescent dosimeters (TLDs) were obtained and installed at the SDHD offices in Pocatello and Soda Springs. Shield background radiation levels were determined by pressurized ionization chamber (PIC) and dosimeter measurements. Average exposure rates determined with a PIC for the Pocatello and Soda Springs shields were 8.2 μR/h (range, 8.1 μR/h to 8.4 μR/h) and 9.1 μR/h (range, 8.6 μR/h to 9.6 μR/h), respectively. Average dose rates determined with TLDs for the Pocatello and Soda Springs shields are 7.3 μrem/h (range, 6.5 μrem/h to 8.4 μrem/h) and 6.7 μrem/h (range, 6.5 μrem/h to 7.1 μrem/h), respectively.

Multiple batches of thermoluminescent dosimeters (TLDs) were obtained from the vendor on an as-needed basis and placed into shields installed at the health department offices in Pocatello and Soda Springs. TLDs were removed from the shields as they were assigned to individuals. Two thousand TLDs were initially obtained, and half of the dosimeters were stored in each of the shields. In February 1997, 500 additional TLDs were obtained; 500 more were obtained in June 1997, 250 more in October 1997, and 800 more in February 1998.

Background radiation levels were determined by placing TLDs at 10 locations in each community of Pocatello, Soda Springs and the Fort Hall Reservation. Background dose

rates determined from TLD measurements are 11.0 μrem/h for Pocatello, 11.3 μrem/h for Soda Springs, and 11.4 μrem/h for Fort Hall.

Dosimeters were exposed to known levels of gamma radiation, for use in evaluating performance of the dosimetry service.

In Phase I, 1402 TLDs were issued to Study participants; the majority of these were for the purpose of initial screening, either as an alternative to actual surveys of residences or to supplement such surveys (more than half of the participants requested both methods). TLDs were issued to several households as an alternative or supplement to Follow-up Survey dose assessment by the dose rate/time log method.

Results of dosimeter measurements for individuals completed in Phase I are summarized in Table 4. Of the 949 (623 in Pocatello, 148 in Soda Springs, and 178 in Fort Hall) dosimeters issued, collected, and processed, 910 (96%) were less than 100 mrem. Thirty-nine (39) TLDs indicated annual above-background doses exceeding 100 mrem; 30 were between 100 and 200 mrem, 6 were between 200 and 300 mrem, 2 were between 300 and 400 mrem, 0 were between 400 and 500 mrem, and 1 was greater than 500 mrem. The maximum level measured was 510 mrem.

7.3.2 Screening Survey

Scheduling for residential screening surveys began the week of June 10, 1996 and the first surveys were performed the week of June 17, 1996. Through November 1, 1998, 1167 Screening Surveys were performed.

Seventy-one (71) residences with maximum direct radiation equal to or exceeding the action level of 20 μrem/h, or individual annual doses in excess of 100 mrem, as determined by TLD, have been identified and follow-up evaluation recommended to the owners (Table 5). Of these 71 properties, 35 have requested follow-up evaluations by survey/time-log and dose calculation. Twenty-eight (28) Follow-up Surveys have been completed (time-log data for one additional household has not yet been received), and scheduling of remaining surveys continues. Three households chose dose evaluation by TLD to complement the Follow-up Survey or as an interim evaluation method; 7 homeowners decided not to pursue follow-up evaluations. Survey personnel have been unable to contact and schedule follow-up activities for the remainder of these residences.

7.3.3 Follow-up Surveys

Dose estimates were performed for the 28 Follow-up Surveys completed, based on the measured radiation levels and time logs, provided by the residents. Residents in 8 of the properties in which Follow-up Surveys were performed, were calculated to have potential annual doses slightly above 100 mrem/y (see Table 6); the highest estimated annual dose is 132.4 mrem. At each of the Follow-up Survey locations with elevated direct radiation levels, slag was confirmed as the source of radiation by gamma spectrometry.

7.3.4 Radon Measurements

Two hundred and sixty-five (265) residences requested radon measurements; radon test kits have been deployed in 249 residences, recovered, and evaluated: 518 separate measurements have been performed. Radon concentrations measured are as follows: 75 are less than 0.5 pCi/l, 362 are between 0.5 and 3.9 pCi/l, 64 are between 4 and 10 pCi/l, and 17 are above 10 pCi/l. The maximum radon concentration measured was 27.8 pCi/l. Table 7 summarizes the results of the radon measurements.

7.3.5 Community Surveys

Locations in the Pocatello and Soda Springs communities exceeding 17 μrem/h were identified from the 1986 aerial surveys (Berry 1987). With few exceptions, all streets in these two communities and on the Fort Hall Reservation were surveyed. Results were summarized in separate reports and lists of slag-impacted streets and public facilities with radiation levels in excess of 20 μrem/h were prepared and provided to the SDHD. In Pocatello, 35 miles of road (28.5% of the miles surveyed) had dose rates greater than 20 μrem/hr. In Soda Springs and the Fort Hall Reservation the mileage was 63.8 (24.5%) and 6 (23.1%), respectively.

Of the 37 community buildings and facilities surveyed, 3 had small areas of elevated direct radiation exceeding 20 μrem/hr. These locations were the Road Maintenance Yard in Chubbuck and the airport and a school building in Soda Springs.

7.4 Quality Assurance Oversight

Data reviews and quality assurance assessments are performed by the A&A staff on a continuing basis. Non-conformances and discrepancies identified have been primarily related to record keeping and documentation practices; minor deviations from Exposure Study Procedures have also been noted. Deficiencies were resolved and procedural revisions were implemented, as appropriate. None of the non-conformances or discrepancies adversely impacted data quality.

Separate internal reviews of various major facets of the Program have been performed by the A&A staff. These reviews have included the use of TLDs for individual dose determinations, Follow-up Survey activities and dose calculations, and radon monitoring. Internal reviews have identified minor deficiencies in procedure implementation and have resulted in improvements in work practices and reevaluations of some procedure elements.

At the request of the Southeastern District Health Department, an independent quality assurance audit was performed by a staff member from Idaho State University. Findings were reviewed, a response prepared, and resolution of deficiencies completed.

8.0 DISCUSSION OF RESULTS

8.1 Participation in the Study

Of the households volunteering to participate in the study, 1322 (77%) have been from Pocatello and nearby communities, 155 (9%) have been from Soda Springs and vicinity, and 241 (14%) have been from the Fort Hall Reservation. Assuming populations of 60,000 for Pocatello, 3,000 for Soda Springs, and 3,000 for Fort Hall and an average household size of 4 persons, the combined participation in screening surveys is estimated as approximately 10.4% of the households. The Fort Hall Reservation is the highest individual community with 32% of the households participating.

8.2 Screening Survey

Of the Follow-up surveys recommended (either by Screening Survey or individual TLD), 21% were in the Pocatello and vicinity, as compared to 70% in Soda Springs and 9% in Fort Hall.

8.3 Follow-up Surveys

The 2 Follow-up Surveys completed in Pocatello and 19 of the 27 Follow-up Surveys completed in Soda Springs resulted in calculated dose estimates less than 100 mrem/y, above background, for all residents in the households. In 8 of the Soda Springs residences surveyed, at least 1 individual in each home was estimated to have an annual dose slightly higher than 100 mrem/y, above background. The highest estimated annual dose was 132.4 mrem. There were no Follow-up Surveys in Fort Hall.

A dose estimate by Follow-up Survey was necessary for eligibility under the Graded Decision Guidelines; therefore, efforts were made to complete all recommended follow-

up surveys. There were 72 recommendations for Follow-up and 32 completed Follow-ups.

The 72 recommendations for Follow-up were initially made by written notification. The participants had the option to request Follow-up either by mail or phone. Twenty-five requests for Follow-up (two by TLD) and 13 not interested in Follow-up resulted from the initial notification. Five of the 40 who did not respond to the initial notification where contacted by phone and indicated no interest. The remaining 35 could not be reached by phone and were mailed a second recommendation for Follow-up. These 35 re-notifications resulted in 15 requests (one by TLD), 6 not interested, and 14 did not reply. Five of the 15 declined the Follow-up when contacted for scheduling and one declined after scheduling. Follow-up measurements were made for the remaining nine, although two required re-scheduling 2 or more times after failing to meet their appointments. One participant declined to complete the time information to allow a dose calculation.

8.4 Community Surveys

The Community Surveys conducted to date have, in general, confirmed the results of the earlier aerial surveys. Some differences have been noted, as expected, because of resurfacing that may have been performed since the aerial surveys. Most of the streets in Soda Springs contain some slag, with many locations in excess of 20 μrem/h. A smaller portion of the surveyed streets in the greater Pocatello area and Fort Hall Reservation contains slag.

8.5 Implementation of Graded Decision Guidelines

Nine individual dose estimates exceeded 100 mrem/y (highest 135 mrem/y) or the dose level for implementation of the graded Decision Guidelines. Individuals and households were reminded of the availability of the GDGs when the doses were reported and subsequent reminders were sent if there was no response. These repeated attempts to solicit participation in the GDG process resulted in no requests for GDG implementation. Nevertheless, three households requested further information. Two of the households declined the GDG process after discussion by telephone. The third household requested further information after the discussion by telephone and was visited by two Health Physics professionals. Radiation measurement, dose, and risk were discussed with members of the family and further information and action under the GDGs was offered. Action under the GDGs was declined.

9.0 CURRENT PROJECT STATUS

At the end of September 1996, continuous on-site presence of A&A survey personnel was discontinued, due to the reduction in requests for survey-related activities. Since that time, survey scheduling has been performed from the Knoxville office, with survey teams conducting one- to three-week visits for field data collection. Effective November 1, 1998, a local contractor was selected to assist with the field activities. Management of the project will continue in the same manner and is described in the Phase II Work Plan (A&A 1998).

REFERENCES

Auxier & Associates, Inc., 1996, "Exposure Study Work Plan", Prepared by Auxier & Associates, Inc., Prepared for FMC Corporation/Monsanto Company. Revised September 17, 1996 and April 1, 1997.

Auxier & Associates, Inc., 1998, "Exposure Study Phase II Work Plan", Prepared by Auxier & Associates, Inc., Prepared for FMC Corporation/Monsanto Company. December 31, 1998.

Berry, H. A., 1987, "An Aerial Radiological Survey of Pocatello and Soda Springs, Idaho and Surrounding Area", EPA-8613, prepared for EPA by EG&G Energy Measurements, Inc., Las Vegas, NV.

IT Corporation, 1993, "Methods Development Study Work Plan (Draft)", Prepared by IT Corporation/Nuclear Sciences, Prepared for FMC Corporation/Monsanto Company.

IT Corporation, 1994, "Methods Development Study Report", Prepared by IT Corporation/Nuclear Sciences, Prepared for FMC Corporation/Monsanto Company.

Southeast Idaho Technical Work Group on Slag, "Graded Decision Guidelines for Individuals Exposed to Gamma Radiation from Slag", June 1995, Prepared by Southeast Idaho Technical Work Group on Slag, Prepared for the U. S. EPA.

U. S. Environmental Protection Agency, 1992, Administrative Order on Consent Docket No. 1092-11-04-7003, In the Matter of: Elemental Phosphorus Slag.

Table 1

Locations of the Exposure Study Work Plan for Public Access

The Exposure Study Work Plan is available at the following EPA Information Repositories:

Idaho State University Library
Government Documents Department
9th and Terry
P.O. Box 8089
Pocatello, Idaho 83209
(208) 236-2940

Portneuf District Library
5210 Stuart Street
Chubbuck, Idaho 83202
(202) 237-2192

Soda Springs Public Library
149 South Main
Soda Springs, Idaho 83276
(208) 547-2606

Marshall Public Library
113 South Garfield Avenue
Pocatello, Idaho 83204
(208) 232-1263

Shoshone-Bannock Library
Pima and Bannock
P.O. Box 306
Fort Hall, Idaho 83203
(208) 238-3882

Table 2

Exposure Study Solicitations and Educational Activities (as of November 1, 1998)

Date	Activity
May 2, 1996	Recruited six (6) video rental stores to house the slag educational video
May 20, 1996	Sent out bulk mailing to interested community members (approximately 180)
May 21, 1996	News release with three (3) television stations aired at 6:00 p.m. and 10:00 p.m.
May 21, 1996	Article in the Idaho State Journal "Volunteers Sought for Home Slag Testing", informed the community of the program and workshops available
May 22, 1996	Addressed the Soda Springs Citizens Advisory Board and received recommendations for presentation of the program to the community
May 23, 1996	Article in the Caribou County Sun "Home Testing for Slag Begins this Summer"
May 30, 1996	Public Service Announcements sent to six (6) radio stations requesting 30 announcements about the series of workshops available
May 30, 1996	Workshop held in Pocatello
June 4, 1996	Workshop held in Pocatello
June 17, 1996	Workshop held in Soda Springs
June 20, 1996	Workshop held in Pocatello
July 4, 1996	Drawing for prizes for Exposure Study participants in Soda Springs
July 9, 1996	Workshop held in Pocatello
August 13, 1996	Approximately 3-minute segment on 6:00 p.m. evening news
August 27, 1996	Met with the Tribal Business Council informing them of the program and asking for assistance in publicizing the program. They expressed support.
September 9, 1996	Met with Indian Health Director discussing timeline and staff available to assist the program
September 12, 1996	Workshop with Idaho State University, Health Education Class (approximately 45 students)
September 12, 1996	Addressed Board of Health (18 people)
September 17, 1996	Workshop with Caribou County Hospital Auxiliary group (18 people)
September 19, 20,22, 26, 27, and 29, 1996	Large advertisement in the Idaho State Journal with a large cut-out sign-up sheet
September 24, 1996	Addressed Tribal Business Council clarifying program objectives and timeline
September 27, 1996	Set up a display booth on the Fort Hall Reservation for a community fair
October 1, 1996	Workshop with Brotherhood of Locomotive Engineers (35 people)
October 15,1996	Workshop with Soda Springs Rotary Club (7 people)
November, 1996-January, 1997	Work with the TERO office in Fort Hall to coordinate reservation activities
December 10-12, 1996	Set up a display booth on the Fort Hall Reservation for a Health Fair

Table 2 (con't)

Exposure Study Solicitations and Educational Activities
(as of November 1, 1998)

Date	Activity
February-April, 1997	Caribou Counts Sun, 6 ads: Idaho State Bangal, 8 ads: Idaho State Journal, 5 ads: Sho-Ban News, 5 ads: Sample ad attached
February 5, 1997	Met with Pocatello Advisory Group
February 26, 1997	Workshop with Tribal Business Council on Fort Hall Reservation
March 3, 1997	Workshop with Bureau of Indian Affairs
March 5, 1997	Workshop with Tribal Court Administration
March 18, 1997	Open house workshop: Tribal Chambers, Fort Hall Reservation
March 21, 1997	Open house workshop; for all tribal employees on the reservation
March 27-29, 1997	Display at Holt Arena for Spring Fair
March 31-April 5, 1997	Display at ISU Ball Room for Native American Awareness Week
April 17-22, 1997	Display at ISU Ball Room for Earth Day/Eco Fair
May 17, 1997	Distribute information at Shoshone-Bannock Tribes annual meeting
June 11, 1997	Distribute information at HRDC Agency meeting
June 14, 1997	Booth at Health Fair
July 3, 1997	Distribute information at multiple holiday functions in Fort Hall
July 11, 1997	Display at Land Owners Commission meeting
August 8-10, 1997	Booth at annual Shoshone-Bannock Festival
August 21-22, 1997	Distribute information at Wellness Gathering in Fort Hall
August 30-September, 1997	Booth at Idaho State Fair and display at Pocatello Chamber of Commerce
September 3, 22, 26, and October 6, 1997	Distribute information at Tyhee Elementary School and PTA meetings
September 13 and 26, 1997	Displays at Shoshone High School
September 15, 1997	Open house at Soda Springs SDHD
September 20, 1997	Distribute information at Spud Days in Shelly, Idaho
September 25 and 26, 1997	Display at SDHD Health Fair
September 25, 1997	Distribute information at Fort Hall Indian Day Pow-Wow
September 26, 1997	Distribute information at Indian relay/rodeo
October 13 and 14, 1997	Fort Hall community workshop
October 14, 1997	Distribute information at Academy of Science meeting
October 30, 1997	Distribute information at Halloween family fun night
November20, 1997	Blackfoot Radon Education
November 21-22, 1997	Pocatello North Stake Health Fair

Table 2 (con't)

Exposure Study Solicitations and Educational Activities
(as of November 1, 1998)

Date	Activity
December 10-11, 1997	Fort Hall Health Fair and Christmas Bazaar
January 22, 1998	Diabetes Education at HIS
January 28, 1998	FBI Health Fair
January 29, 1998	Crafters Committee-Ginette Mannwarring
February 3, 1998	Land Owners Association Sho-ban Tribes
February 4, 1998	Ross Fork District Meeting, Fort Hall and Warm Dance, Buffalo Lodge
February 12, 1998	Talking Circle Sho-ban School
February 19, 1998	Talking Circle
February 20, 1998	Lava Senior Citizen center Health Fair
February 26-27, 1998	ISU Health Fair
March 5-7, 1998	Basketball Tournament
March 24, 1998	Bannock Creek District Meeting
March 25, 1998	Ross Fork District meeting, Putman Lodge
March 26, 1998	Gibson District meeting, Eagle Lodge 138KV-TCC
April 6, 1998	Idaho Power
April 6, 1998	Tribal Attorneys

Table 3

Project Status
(as of November 1, 1998)

Summary of Activities:	Pocatello	Soda Springs	Fort Hall	Total
Inquiries made-total	1322	155	241	1719*
Unable to contact/insufficient information	14	1	2	17
Decided not to participate further	121	12	4	137
Total in program	1187	142	235	1564
Screening Surveys:				
Households requesting -total	993	101	87	1181
Screenings performed-total	981	100	86	1167
TLDs:				
Households requesting-total	453	83	230	766
Total # of TLDs issued-total	819	194	389	1402
Follow-ups:				
Measurements recommended-total	15	50	6	71
Measurements requested-total	4	28	0	32
Measurements performed-total	4	28	0	32
Radon test kits:				
Households requesting-total	233	24	8	265
Households tested-total	219	23	7	249

* One inquiry was from an out of state resident

Table 4

Individual TLD Results
Pocatello

Residence ID #	Participant	Annual Dose Above Background	Residence ID #	Participant	Annual Dose Above Background
01P-000	Resident 1	4	01P-168	Resident 1	3
01P-004	Resident 1	20		Resident 2	13
	Resident 2	14	01P-181	Resident 1	0
01P-011	Resident 1	3	01P-184	Resident 1	0
01P-017	Resident 1	0		Resident 2	31
01P-034	Resident 1	0	01P-190	Resident 1	0
01P-042	Resident 1	9		Resident 2	68
	Resident 2	0	01P-194	Resident 1	7
01P-048	Resident 1	0		Resident 2	8
	Resident 2	0		Resident 3	0
01P-051	Resident 1	103	01P-196	Resident 1	28
01P-055	Resident 1	6	01P-199	Resident 1	18
01P-077	Resident 1	11	01P-200	Resident 1	40
	Resident 2	32		Resident 2	13
01P-082	Resident 1	0	01P-201	Resident 1	57
01P-088	Resident 1	26	01P-210	Resident 1	0
01P-089	Resident 1	53	01P-215	Resident 1	24
	Resident 2	15		Resident 2	27
	Resident 3	0	01P-217	Resident 1	9
01P-092	Resident 1	0	01P-220	Resident 1	3
	Resident 2	0	01P-223	Resident 1	1
01P-095	Resident 1	0		Resident 2	2
01P-099	Resident 1	6	01P-225	Resident 1	7
	Resident 2	0	01P-227	Resident 1	0
01P-102	Resident 1	35	01P-234	Resident 1	51
01P-103	Resident 1	0		Resident 2	3
01P-110	Resident 1	23	01P-240	Resident 1	0
01P-118	Resident 1	0		Resident 2	0
01P-131	Resident 1	0	01P-242	Resident 1	0
01P-140	Resident 1	28		Resident 2	0
	Resident 2	5	01P-243	Resident 1	0
	Resident 3	20		Resident 2	7
	Resident 4	13	01P-248	Resident 1	0
01P-142	Resident 1	0	01P-251	Resident 1	16
	Resident 2	0		Resident 2	5
01P-151	Resident 1	14	01P-256	Resident 1	0
01P-162	Resident 1	0	01P-261	Resident 1	70

Table 4 (con't)

Table 4 (cont'd)

Individual TLD Results
Pocatello

Residence ID #	Participant	Annual Dose Above Background	Residence ID #	Participant	Annual Dose Above Background
01P-264	Resident 1	13	01P-425	Resident 1	20
	Resident 2	28		Resident 2	0
01P-266	Resident 1	0	01P-433	Resident 1	29
01P-270	Resident 1	14	01P-438	Resident 1	0
01P-284	Resident 1	13		Resident 2	0
	Resident 2	0		Resident 3	0
01P-286	Resident 1	23	01P-440	Resident 1	67
	Resident 2	11	01P-442	Resident 1	44
01P-294	Resident 1	0	01P-452	Resident 1	52
	Resident 2	0		Resident 2	128
	Resident 3	25	01P-456	Resident 1	10
01P-301	Resident 1	2		Resident 2	14
01P-307	Resident 1	11	01P-457	Resident 1	29
01P-315	Resident 1	36	01P-470	Resident 1	34
	Resident 2	23		Resident 2	50
01P-318	Resident 1	17	01P-473	Resident 1	58
01P-329	Resident 1	20		Resident 2	0
01P-332	Resident 1	9	01P-479	Resident 1	15
01P-333	Resident 1	0	01P-486	Resident 1	0
01P-334	Resident 1	32		Resident 2	7
	Resident 2	73	01P-487	Resident 1	8
01P-336	Resident 1	76	01P-494	Resident 1	0
01P-350	Resident 1	30		Resident 2	0
	Resident 2	0	01P-507	Resident 1	0
01P-360	Resident 1	0	01P-515	Resident 1	15
	Resident 2	0	01P-521	Resident 1	2
01P-366	Resident 1	0	01P-525	Resident 1	23
01P-367	Resident 1	9		Resident 2	0
	Resident 2	12		Resident 3	6
01P-369	Resident 1	0	01P-527	Resident 1	13
01P-373	Resident 1	34	01P-532	Resident 1	19
01P-379	Resident 1	6	01P-537	Resident 1	0
	Resident 2	63	01P-549	Resident 1	83
01P-395	Resident 1	0		Resident 2	4
	Resident 2	0		Resident 3	0
01P-402	Resident 1	0	01P-555	Resident 1	0
01P-405	Resident 1	0	01P-560	Resident 1	0
01P-422	Resident 1	0		Resident 2	0
			01P-561	Resident 1	0

Table 4 (con't)

Individual TLD Results
Pocatello

Residence ID #	Participant	Annual Dose Above Background	Residence ID #	Participant	Annual Dose Above Background
01P-563	Resident 1	45	01P-713	Resident 1	7
01P-567	Resident 1	0	01P-715	Resident 1	6
01P-569	Resident 1	17	01P-720	Resident 1	0
	Resident 2	58	01P-721	Resident 1	65
01P-570	Resident 1	6	01P-723	Resident 1	18
01P-572	Resident 1	21		Resident 2	13
	Resident 2	51	01P-727	Resident 1	0
01P-575	Resident 1	2	01P-729	Resident 1	22
01P-577	Resident 1	0	01P-730	Resident 1	0
	Resident 2	49		Resident 2	0
01P-578	Resident 1	22		Resident 3	0
01P-584	Resident 1	1	01P-746	Resident 1	14
	Resident 2	0	01P-747	Resident 1	0
01P-593	Resident 1	2	01P-753	Resident 1	43
01P-596	Resident 1	94	01P-754	Resident 1	5
01P-613	Resident 1	0	01P-761	Resident 1	0
01P-619	Resident 1	2		Resident 2	28
01P-621	Resident 1	0	01P-764	Resident 1	12
	Resident 2	54		Resident 2	0
01P-623	Resident 1	0	01P-767	Resident 1	0
	Resident 2	0		Resident 2	0
01P-629	Resident 1	6	01P-768	Resident 1	0
	Resident 2	0		Resident 2	0
01P-643	Resident 1	19	01P-770	Resident 1	0
01P-645	Resident 1	45		Resident 2	0
	Resident 2	99	01P-775	Resident 1	0
01P-649	Resident 1	25	01P-777	Resident 1	23
	Resident 2	83	01P-781	Resident 1	59
01P-654	Resident 1	0	01P-785	Resident 1	35
01P-661	Resident 1	0		Resident 2	0
01P-664	Resident 1	6		Resident 3	0
01P-673	Resident 1	3	01P-790	Resident 1	0
01P-674	Resident 1	21		Resident 2	0
01P-693	Resident 1	9	01P-791	Resident 1	0
01P-698	Resident 1	0	01P-795	Resident 1	53
	Resident 2	0	01P-799	Resident 1	24
01P-708	Resident 1	10		Resident 2	6
	Resident 2	27	01P-801	Resident 1	0
				Resident 2	0

Table 4 (con't)

Table 4 (cont'd)

Individual TLD Results
Pocatello

Residence ID #	Participant	Annual Dose Above Background	Residence ID #	Participant	Annual Dose Above Background
01P-809	Resident 1	18	01P-985	Resident 1	15
01P-810	Resident 1	50		Resident 2	30
01P-813	Resident 1	26		Resident 3	0
01P-817	Resident 1	29	01P-987	Resident 1	3
	Resident 2	13	01P-991	Resident 1	20
01P-821	Resident 1	0	01P-998	Resident 1	29
01P-843	Resident 1	0	02P-005	Resident 1	26
	Resident 2	0	02P-017	Resident 1	45
01P-846	Resident 1	27	02P-023	Resident 1	0
	Resident 2	39	02P-029	Resident 1	14
	Resident 3	27		Resident 2	0
01P-864	Resident 1	5		Resident 3	33
01P-865	Resident 1	0	02P-031	Resident 1	0
	Resident 2	36		Resident 2	0
	Resident 3	27		Resident 3	0
01P-871	Resident 1	93		Resident 4	0
01P-882	Resident 1	50	02P-037	Resident 1	0
	Resident 2	0		Resident 2	0
01P-890	Resident 1	68		Resident 3	0
	Resident 2	78	02P-045	Resident 1	0
	Resident 3	5	02P-050	Resident 1	0
	Resident 4	4		Resident 2	0
	Resident 5	5	02P-055	Resident 1	0
01P-894	Resident 1	21		Resident 2	0
	Resident 2	0	02P-058	Resident 1	26
	Resident 3	0		Resident 2	0
01P-898	Resident 1	27	02P-059	Resident 1	38
01P-903	Resident 1	0	02P-66	Resident 1	17
01P-929	Resident 1	15	02P-069	Resident 1	14
	Resident 2	0		Resident 2	33
01P-932	Resident 1	44	02P-076	Resident 1	0
01P-939	Resident 1	0		Resident 2	0
	Resident 2	29	02P-082	Resident 1	7
	Resident 3	0		Resident 2	1
01P-954	Resident 1	6		Resident 3	23
01P-961	Resident 1	0	02P-086	Resident 1	1
	Resident 2	2	02P-091	Resident 1	17
01P-967	Resident 1	28	02P-095	Resident 1	0
01P-980	Resident 1	0		Resident 2	0
	Resident 2	3			

Table 4 (cont'd)

Individual TLD Results
Pocatello

Residence ID #	Participant	Annual Dose Above Background	Residence ID #	Participant	Annual Dose Above Background
02P-097	Resident 1	97	02P-199	Resident 1	0
	Resident 2	24	02P-206	Resident 1	0
02P-101	Resident 1	0		Resident 2	0
	Resident 2	0		Resident 3	10
	Resident 3	16	02P-214	Resident 1	7
02P-110	Resident 1	36	02P-224	Resident 1	3
	Resident 2	0		Resident 2	0
02P-113	Resident 1	12	02P-233	Resident 1	4
02P-118	Resident 1	31		Resident 2	0
	Resident 2	29	02P-235	Resident 1	0
	Resident 3	4		Resident 2	21
02P-119	Resident 1	0	02P-240	Resident 1	0
02P-127	Resident 1	50	02P-244	Resident 1	9
	Resident 2	40	02P-254	Resident 1	62
02P-131	Resident 1	0		Resident 2	0
02P-137	Resident 1	0	02P-264	Resident 1	63
	Resident 2	0		Resident 2	26
	Resident 3	0		Resident 3	0
02P-139	Resident 1	0		Resident 4	9
02P-147	Resident 1	43	02P-269	Resident 1	0
02P-154	Resident 1	0		Resident 2	33
02P-156	Resident 1	0		Resident 3	116
02P-169	Resident 1	0	02P-274	Resident 1	75
	Resident 2	0	02P-275	Resident 1	9
02P-170	Resident 1	8	02P-280	Resident 1	14
02P-172	Resident 1	0		Resident 2	31
	Resident 2	13	02P-286	Resident 1	15
02P-174	Resident 1	0		Resident 2	0
	Resident 2	16		Resident 3	8
02P-186	Resident 1	145	02P-295	Resident 1	42
	Resident 2	6		Resident 2	41
	Resident 3	43	02P-312	Resident 1	0
	Resident 4	49		Resident 2	67
	Resident 5	50	02P-314	Resident 1	0
	Resident 6	57		Resident 2	18
02P-188	Resident 1	0	02P-316	Resident 1	0
02P-195	Resident 1	91		Resident 2	0
	Resident 2	22	02P-319	Resident 1	0
	Resident 3	0		Resident 2	0

Table 4 (con't)

Individual TLD Results
Pocatello

Residence ID #	Participant	Annual Dose Above Background	Residence ID #	Participant	Annual Dose Above Background
02P-323	Resident 1	32	02P-455	Resident 1	27
02P-328	Resident 1	31	02P-463	Resident 1	0
02P-329	Resident 1	0		Resident 2	0
02P-331	Resident 1	0	02P-464	Resident 1	0
02P-334	Resident 1	0		Resident 2	0
	Resident 2	0		Resident 3	0
02P-343	Resident 1	0	02P-466	Resident 1	23
	Resident 2	87		Resident 2	0
	Resident 3	0	02P-468	Resident 1	0
	Resident 4	19	02P-476	Resident 1	33
02P-348	Resident 1	0	02P-479	Resident 1	0
02P-354	Resident 1	0		Resident 2	6
	Resident 2	0	02P-481	Resident 1	0
02P-355	Resident 1	0		Resident 2	0
	Resident 2	0	02P-491	Resident 1	0
02P-356	Resident 1	0	02P-497	Resident 1	60
02P-371	Resident 1	71		Resident 2	0
02P-391	Resident 1	0		Resident 3	17
	Resident 2	5		Resident 4	13
02P-396	Resident 1	0	02P-501	Resident 1	0
02P-398	Resident 1	0	02P-515	Resident 1	88
02P-399	Resident 1	0	02P-519	Resident 1	0
02P-406	Resident 1	36		Resident 2	0
02P-420	Resident 1	0	02P-525	Resident 1	15
	Resident 2	0	02P-530	Resident 1	0
02P-427	Resident 1	4	02P-539	Resident 1	0
	Resident 2	0		Resident 2	0
02P-429	Resident 1	0	02P-544	Resident 1	22
	Resident 2	0		Resident 2	0
02P-445	Resident 1	0	02P-548	Resident 1	0
	Resident 2	9		Resident 2	0
02P-450	Resident 1	4	02P-552	Resident 1	0
	Resident 2	0		Resident 2	0
02P-452	Resident 1	0		Resident 3	0
	Resident 2	7	02P-557	Resident 1	0
02P-453	Resident 1	0	02P-559	Resident 1	3
	Resident 2	1		Resident 2	0
	Resident 3	0	02P-563	Resident 1	0
02P-454	Resident 1	9	02P-564	Resident 1	11

Table 4 (con't)

Table 4 (cont'd)

Individual TLD Results
Pocatello

Residence ID #	Participant	Annual Dose Above Background	Residence ID #	Participant	Annual Dose Above Background
02P-566	Resident 1	0	02P-674	Resident 1	36
	Resident 2	22		Resident 2	0
02P-571	Resident 1	0		Resident 3	0
	Resident 2	3	02P-677	Resident 1	12
02P-573	Resident 1	7		Resident 2	57
	Resident 2	1	02P-678	Resident 1	0
	Resident 3	0	02P-682	Resident 1	0
02P-577	Resident 1	0	02P-685	Resident 1	0
	Resident 2	16	02P-696	Resident 1	7
02P-585	Resident 1	5	02P-706	Resident 1	0
	Resident 2	0	02P-707	Resident 1	0
02P-597	Resident 1	14	02P-710	Resident 1	28
	Resident 2	24	02P-715	Resident 1	6
	Resident 3	0	02P-720	Resident 1	17
02P-616	Resident 1	7		Resident 2	0
	Resident 2	0		Resident 3	0
02P-621	Resident 1	0	02P-733	Resident 1	0
	Resident 2	0		Resident 2	0
02P-631	Resident 1	0	02P-736	Resident 1	0
	Resident 2	0	02P-737	Resident 1	20
02P-635	Resident 1	0		Resident 2	0
02P-636	Resident 1	2	02P-742	Resident 1	2
	Resident 2	0		Resident 2	24
02P-639	Resident 1	0	02P-743	Resident 1	49
	Resident 2	1		Resident 2	10
02P-640	Resident 1	16		Resident 3	24
	Resident 2	0	02P-749	Resident 1	0
02P-645	Resident 1	0	02P-750	Resident 1	0
02P-646	Resident 1	3		Resident 2	0
	Resident 2	0		Resident 3	20
02P-649	Resident 1	0	02P-755	Resident 1	0
	Resident 2	73	02P-760	Resident 1	42
02P-651	Resident 1	0		Resident 2	21
	Resident 2	0	02P-773	Resident 1	20
	Resident 3	0		Resident 2	0
02P-658	Resident 1	0		Resident 3	14
	Resident 2	0		Resident 4	24
02P-661	Resident 1	56			

Table 4 (con't)

Individual TLD Results
Pocatello

Residence ID #	Participant	Annual Dose Above Background	Residence ID #	Participant	Annual Dose Above Background
02P-774	Resident 1	0	02P-840	Resident 1	0
	Resident 2	0		Resident 2	0
	Resident 3	2	02P-851	Resident 1	13
	Resident 4	22		Resident 2	27
02P-780	Resident 1	0		Resident 3	195
	Resident 2	0		Resident 3	206
02P-781	Resident 1	9	02P-864	Resident 1	0
02P-786	Resident 1	0		Resident 2	24
02P-790	Resident 1	0	02P-875	Resident 1	0
	Resident 2	10		Resident 2	8
02P-805	Resident 1	0		Resident 3	19
	Resident 2	0		Resident 4	1
	Resident 3	45	02P-876	Resident 1	19
	Resident 4	14		Resident 2	3
02P-812	Resident 1	1	02P-878	Resident 1	0
	Resident 2	8	02P-879	Resident 1	0
02P-825	Resident 1	5		Resident 2	0
	Resident 2	2	02P-891	Resident 1	2
02P-827	Resident 1	0		Resident 2	55
02P-828	Resident 1	5	02P-903	Resident 1	0
	Resident 2	0	02P-904	Resident 1	0
	Resident 3	15		Resident 2	0
02P-831	Resident 1	1		Resident 3	16
02P-833	Resident 1	0		Resident 4	0
	Resident 2	21		Resident 5	29
	Resident 3	22	02P-906	Resident 1	70
	Resident 4	29	02P-907	Resident 1	0
	Resident 5	0		Resident 2	0
02P-834	Resident 1	56	02P-921	Resident 1	2
02P-835	Resident 1	0	02P-925	Resident 1	0
	Resident 2	17	02P-936	Resident 1	0
02P-836	Resident 1	0	02P-941	Resident 1	12
	Resident 2	4	02P-952	Resident 1	34
02P-837	Resident 1	0	02P-956	Resident 1	0
	Resident 2	13		Resident 2	0
	Resident 3	0		Resident 3	0
02P-838	Resident 1	0	02P-964	Resident 1	6
	Resident 2	3	02P-966	Resident 1	0

Table 4 (con't)

Individual TLD Results
Pocatello

Residence ID #	Participant	Annual Dose Above Background	Residence ID #	Participant	Annual Dose Above Background
02P-967	Resident 1	18			
	Resident 2	22			
02P-980	Resident 1	4			
	Resident 2	22			
02P-982	Resident 1	22			
02P-993	Resident 1	6			
	Resident 2	4			
	Resident 3	0			
	Resident 4	0			
02P-998	Resident 1	15			

Table 4 (con't)

Individual TLD Results
Soda Springs

Residence ID #	Participant	Annual Dose Above Background	Residence ID #	Participant	Annual Dose Above Background
01S-000	Resident 1	59	01S-290	Resident 1	159
01S-005	Resident 1	144		Resident 2	85
01S-009	Resident 1	23		Resident 3	152
	Resident 2	214		Resident 4	24
01S-030	Resident 1	0	01S-318	Resident 1	10
01P-033	Resident 1	82	01S-359	Resident 1	0
01S-044	Resident 1	41		Resident 2	0
	Resident 2	39	01S-363	Resident 1	0
	Resident 3	4	01S-367	Resident 1	48
	Resident 4	47	01S-371	Resident 1	0
01S-082	Resident 1	41		Resident 2	0
	Resident 2	133	01S-414	Resident 1	30
01S-090	Resident 1	50		Resident 2	23
01S-107	Resident 1	56	01S-423	Resident 1	68
01S-191	Resident 1	93		Resident 2	138
	Resident 2	63		Resident 3	89
01S-192	Resident 1	0		Resident 4	122
	Resident 2	0	01S-446	Resident 1	193
01S-193	Resident 1	84		Resident 2	60
	Resident 2	35		Resident 3	81
	Resident 3	45		Resident 4	57
	Resident 4	0		Resident 5	217
	Resident 5	0	01S-477	Resident 1	0
	Resident 6	0		Resident 2	0
	Resident 7	0	01S-493	Resident 1	31
01S-204	Resident 1	104		Resident 2	7
	Resident 2	100		Resident 3	14
01S-229	Resident 1	0		Resident 4	0
	Resident 2	0	01S-502	Resident 1	82
01S-231	Resident 1	36		Resident 2	74
01S-239	Resident 1	24	01S-552	Resident 1	9
01S-250	Resident 1	0		Resident 2	16
	Resident 2	65	01S-553	Resident 1	10
01S-256	Resident 1	183	01S-567	Resident 1	15

Table 4 (con't)

Individual TLD Results
Soda Springs

Residence ID #	Participant	Annual Dose Above Background	Residence ID #	Participant	Annual Dose Above Background
01S-602	Resident 1	39	01S-795	Resident 1	19
	Resident 2	117		Resident 2	58
01S-616	Resident 1	19		Resident 3	133
01S-620	Resident 1	370		Resident 4	71
	Resident 2	149		Resident 5	95
01S-633	Resident 1	7	01S-796	Resident 1	34
	Resident 2	0		Resident 2	41
	Resident 3	5	01S-805	Resident 1	31
	Resident 4	0	01S-813	Resident 1	3
	Resident 5	0		Resident 2	0
	Resident 6	0		Resident 3	0
01S-642	Resident 1	129		Resident 4	0
01S-645	Resident 1	44		Resident 5	0
01S-664	Resident 1	4	01S-826	Resident 1	0
01S-674	Resident 1	67		Resident 2	0
	Resident 2	173	01S-872	Resident 1	64
01S-684	Resident 1	256		Resident 2	68
	Resident 2	38	01S-875	Resident 1	2
01S-721	Resident 1	23		Resident 2	39
	Resident 2	7		Resident 3	25
	Resident 3	70		Resident 4	17
01S-732	Resident 1	1		Resident 5	15
	Resident 2	12		Resident 6	3
	Resident 3	0	01S-883	Resident 1	81
	Resident 4	61		Resident 2	35
	Resident 5	61		Resident 3	130
	Resident 6	305		Resident 4	10
01S-735	Resident 1	0	01S-910	Resident 1	18
	Resident 2	0	01S-912	Resident 1	7
01S-741	Resident 1	108	01S-921	Resident 1	0
01S-752	Resident 1	115	01S-924	Resident 1	0
	Resident 2	17		Resident 2	0

Table 4 (con't)

Individual TLD Results
Soda Springs

Residence ID #	Participant	Annual Dose Above Background	Residence ID #	Participant	Annual Dose Above Background
01S-948	Resident 1	53	01S-998	Resident 1	49
	Resident 2	27		Resident 2	81
	Resident 3	48	01S-953	Resident 1	52
	Resident 4	17	01S-958	Resident 1	84
01S-959	Resident 1	21		Resident 2	58
01S-975	Resident 1	57		Resident 3	91
	Resident 2	101		Resident 4	107

Table 4 (con't)

Individual TLD Results
Fort Hall

Residence ID #	Participant	Annual Dose Above Background	Residence ID #	Participant	Annual Dose Above Background
01P-001	Resident 1	0	01P-235	Resident 1	8
	Resident 2	0	01P-241	Resident 1	7
	Resident 3	0	01P-266	Resident 1	90
01P-011	Resident 1	11	01P-279	Resident 1	0
01P-014	Resident 1	16	01P-289	Resident 1	120
01P-022	Resident 1	110		Resident 2	0
01P-023	Resident 1	35		Resident 3	6
	Resident 2	0	01P-291	Resident 1	16
01P-025	Resident 1	0	01P-309	Resident 1	0
	Resident 2	6	01P-316	Resident 1	107
01P-033	Resident 1	14		Resident 2	1
01P-049	Resident 1	0	01P-323	Resident 1	0
01P-052	Resident 1	34	01P-325	Resident 1	0
01P-070	Resident 1	56	01P-330	Resident 1	0
	Resident 2	3		Resident 2	0
	Resident 3	13		Resident 3	0
01P-072	Resident 1	3	01P-331	Resident 1	31
01P-111	Resident 1	14	01P-341	Resident 1	22
01P-114	Resident 1	0		Resident 2	36
	Resident 2	0		Resident 3	87
01P-136	Resident 1	0		Resident 4	68
01P-137	Resident 1	51	01P-346	Resident 1	0
	Resident 2	2	01P-357	Resident 1	7
01P-143	Resident 1	0		Resident 2	5
01P-144	Resident 1	11	01P-368	Resident 1	32
01P-146	Resident 1	45	01P-393	Resident 1	1
01P-147	Resident 1	0		Resident 2	25
01P-153	Resident 1	96	01P-411	Resident 1	66
	Resident 2	3	01P-429	Resident 1	15
	Resident 3	0		Resident 2	28
01P-163	Resident 1	64	01P-446	Resident 1	25
01P-178	Resident 1	0		Resident 2	11
	Resident 2	28	01P-447	Resident 1	0
	Resident 3	14	01P-448	Resident 1	18
01P-188	Resident 1	16	01P-449	Resident 1	68

Table 4 (con't)

Individual TLD Results
Fort Hall

Residence ID #	Participant	Annual Dose Above Background	Residence ID #	Participant	Annual Dose Above Background
01P-450	Resident 1	0	01P-618	Resident 1	7
01P-455	Resident 1	0	01P-620	Resident 1	27
01P-463	Resident 1	9		Resident 2	25
	Resident 2	0	01P-633	Resident 1	0
01P-484	Resident 1	0	01P-637	Resident 1	0
	Resident 2	23	01P-647	Resident 1	11
	Resident 3	0	01P-659	Resident 1	54
01P-497	Resident 1	70		Resident 2	85
01P-504	Resident 1	37	01P-663	Resident 1	0
01P-531	Resident 1	68	01P-665	Resident 1	5
01P-539	Resident 1	36	01P-678	Resident 1	26
01P-544	Resident 1	0	01P-680	Resident 1	4
	Resident 2	0	01P-681	Resident 1	118
01P-547	Resident 1	0	01P-683	Resident 1	24
	Resident 2	0	01P-685	Resident 1	12
01P-550	Resident 1	0	01P-696	Resident 1	11
01P-556	Resident 1	0		Resident 2	0
01P-564	Resident 1	92		Resident 3	7
01P-566	Resident 1	0		Resident 4	17
01P-571	Resident 1	0	01P-709	Resident 1	60
	Resident 2	49		Resident 2	0
01P-573	Resident 1	20	01P-711	Resident 1	15
01P-582	Resident 1	0	01P-717	Resident 1	0
01P-583	Resident 1	0	01P-733	Resident 1	58
	Resident 2	0	01P-736	Resident 1	18
	Resident 3	10	01P-742	Resident 1	3
01P-586	Resident 1	60	01P-760	Resident 1	0
	Resident 2	103		Resident 2	0
01P-589	Resident 1	11	01P-763	Resident 1	0
01P-601	Resident 1	11		Resident 2	4
01P-602	Resident 1	0	01P-773	Resident 1	1
01P-605	Resident 1	0	01P-819	Resident 1	13
	Resident 2	30		Resident 2	7
01P-606	Resident 1	0	01P-831	Resident 1	0
	Resident 2	3	01P-849	Resident 1	18
	Resident 3	7	01P-856	Resident 1	0
01P-612	Resident 1	15		Resident 2	9
01P-616	Resident 1	28	01P-866	Resident 1	44
01P-617	Resident 1	0	01P-883	Resident 1	29

Table 4 (con't)

Individual TLD Results
Fort Hall

Residence ID #	Participant	Annual Dose Above Background	Residence ID #	Participant	Annual Dose Above Background
01P-886	Resident 1	40	01P-936	Resident 1	51
01P-891	Resident 1	0	01P-950	Resident 1	40
	Resident 2	18		Resident 2	0
01P-899	Resident 1	0	01P-955	Resident 1	0
01P-901	Resident 1	0	01P-992	Resident 1	0
01P-905	Resident 1	35	01P-993	Resident 1	60
01P-907	Resident 1	510	02P-025	Resident 1	0
	Resident 2	0	02P-078	Resident 1	28
	Resident 3	0	02P-210	Resident 1	0
	Resident 4	0		Resident 2	0
	Resident 5	0	02P-270	Resident 1	45
01P-916	Resident 1	10	02P-656	Resident 1	0
01P-921	Resident 1	95	02P-683	Resident 1	0
	Resident 2	23	02P-972	Resident 1	0
01P-926	Resident 1	13			
01P-933	Resident 1	13			
	Resident 2	11			

Table 5

Summary of Follow-up Survey Status
(as of November 1, 1998)

	Activity								Annual Dose Calculated (mrem above background)				
Residence ID	Follow-up Survey Scheduled	Follow-up Survey Performed	Survey Requested Later	Unable To Contact	TLDs Requested	TLDs Issued	Withdrew From Study	Slag Confirmed	< 100	100 - 200	200 - 300	300 - 500	Comments
01P-022					yes	3/15/97	C						
01P-051					yes	3/5/97	A						
01P-289					yes	3/19/97	C						
01P-316					yes	3/3/97	C						
01P-383	yes	11/18/96			no			yes	X				
01P-425					Yes*	8/13/96	B						
01P-430					no		A						
01P-452					yes	3/6/97	B						
01P-586					yes	3/12/97	C						
01P-681					yes	3/20/97	C						
01P-785					Yes*	10/8/96							
01P-795	yes	10/22/96			yes	10/1/96		no	X				
01P-884					no		A						
01P-907					yes	3/17/97							
01P-928					Yes*		A						
02P-058					no		D						
02P-116					no		D						
02P-186					no		A						
02P-436					yes		C						Resident notified-TLDs not picked up.
02P-851					Yes*	6/19/98							
01S-005	yes	5/22/97			yes	6/21/96		yes		X			
01S-033	yes	8/13/97			yes	6/4/97		yes	X				
01S-044	yes	9/26/96			yes	7/16/96		yes	X				
01S-051	yes	8/5/98			no			yes	X				
01S-082					yes	11/4/96							
01S-101	yes	11/21/96			yes			yes		X			Resident notified-TLDs not picked up.
01S-107					yes	11/22/97	C						
01S-109					no								
01S-116					no		D						
01S-117	yes	8/5/98			no				X				
01S-148					no		C						
01S-152					no		C						

Table 5 (con't)

Summary of Follow-up Survey Status
(as of November 1, 1998)

	Activity								Annual Dose Calculated (mrem above background)				
Residence ID	Follow-up Survey Scheduled	Follow-up Survey Performed	Survey Requested Later	Unable To Contact	TLDs Requested	TLDs Issued	Withdrew From Study	Slag Confirmed	< 100	100-200	200-300	300-500	Comments
01S-173					no		C						
01S-204	yes	8/1/96			yes	7/1/96		yes	X				
01S-228	yes	8/1/96			no			yes		X			
01S-256					yes	7/1/96	A						
01S-283					no		D						
01S-290	yes	5/20/97			yes	6/17/96		yes	?	?	?	?	Awaiting time log from participant.
01S-317					no		A						
01S-320					no		C						
01S-747					no		D						
01S-358					no		A						
01S-422					Yes*	6/9/98							
01S-423					yes	6/21/96	B						
01S-446					yes	11/4/96	B						
01S-493	yes				yes	10/28/96	A						
01S-502	yes	5/20/97			yes	10/1/96		yes	X				
01S-551	yes	5/22/97			no			yes		X			
01S-552	yes	8/11/97			yes	10/28/96		yes	X				
01S-567	yes	11/21/96			yes	7/31/96		yes	X				
01S-585	yes	9/27/96			no			yes	X				
01S-602					yes	11/18/96	B						
01S-620	yes	10/23/96			yes	6/17/96		yes		X			
01S-642	yes	5/20/97			yes	7/8/96		yes		X			
01S-674	yes	5/20/97			yes	7/10/96		yes	X				
01S-684	yes	8/4/98			yes	6/17/96		yes	X				
01S-691	yes	8/13/97			no			yes	X				
01S-721	yes	5/20/97			yes	7/2/96		yes	X				
01S-732					yes	7/15/96	B						
01S-741	yes	11/19/96			yes	7/17/96		yes	X				
01S-752					yes	7/22/96	A						
01S-795	yes	5/20/97			yes	7/1/96		yes	X				
01S-796	yes	11/19/96			yes	8/19/96		yes	X				
01S-798	yes	8/13/97			yes			yes		X			Resident notified-TLDs not picked up.

Table 5 (con't)

Summary of Follow-up Survey Status
(as of November 1, 1998)

	Activity								Annual Dose Calculated (mrem above background)				
Residence ID	Follow-up Survey Scheduled	Follow-up Survey Performed	Survey Requested Later	Unable To Contact	TLDs Requested	TLDs Issued	Withdrew From Study	Slag Confirmed	< 100	100-200	200-300	300-500	Comments
01S-883	yes	5/22/97			yes	6/20/96		yes	X				
01S-917					yes		C						Resident notified-TLDs not picked up.
01S-950					no		A						
01S-958	yes	5/20/97			yes	10/21/96		yes	X				
01S-975					yes	7/15/96	A						
01S-998	yes	11/19/96			yes	7/2/96		yes		X			

*-Chosen as follow-up method

A-No longer interested via telephone

B-No longer interested via letter

C-Withdrawn: No response to letter sent 6/8/98

D-Withdrawn: No request

Table 6

Assigned Doses from Follow-up Surveys for Pocatello and Soda Springs

I.D. No.	Resident Number						
	1	2	3	4	5	6	7
01P-795	0.0	0.0					
01P-383	20.4	3.3	8.4	13.5	0.0	0.0	
01S-204	49.7	49.7					
01S-620	56.2	38.0	132.4				
01S-585	9.1	10.3	14.1	71.4	71.4	13.0	12.3
01S-044	3.1	7.3					
01S-228	120.3	97.8					
01S-741	62.8	57.7	50.0	63.5			
01S-998	85.0	73.1	77.2	77.2	122.0		
01S-567	34.9						
01S-101	35.2	37.0	114.7	62.1			
01S-796	58.6	60.4					
01S-642	105.8	35.7					
01S-674	34.1	65.3	33.0	44.3	98.7	98.7	98.7
01S-958	55.7	66.9	64.1	71.9			
01S-795	13.3	5.4	6.3	13.6	6.1		
01S-005	43.1	88.0	106.2	94.2	38.7		
01S-551	9.4	103.4	32.9	9.7	12.7		
01S-502	30.9	46.2	38.4	73.7	87.1	86.5	31.6
01S-883	16.2	2.2	1.8	17.9			
01S-033	24.7	36.6	38.9	59.8	31.1		
01S-552	9.1	56.2	31.5				
01S-691	11.1	13.8	53.6	15.8			
01S-798	20.0	29.6	107.7	102.0	40.3		
01S-721	26.9	30.5	95.6	44.2			
01S-051	80.0	18.2	2.3				
01S-117	19.8	17.1	13.8	10.5			
01S-684	30.0	27.6					

Dose Range	# Ind.
0 - 19.9 mrem/y	36
20 - 39.9 mrem/y	24
40 - 59.9 mrem/y	15
60 - 79.9 mrem/y	14
80 -100 mrem/y	11
>100 mrem/y	9

Table 6 (con't)

Assigned Doses from Follow-up Surveys for Pocatello and Soda Springs

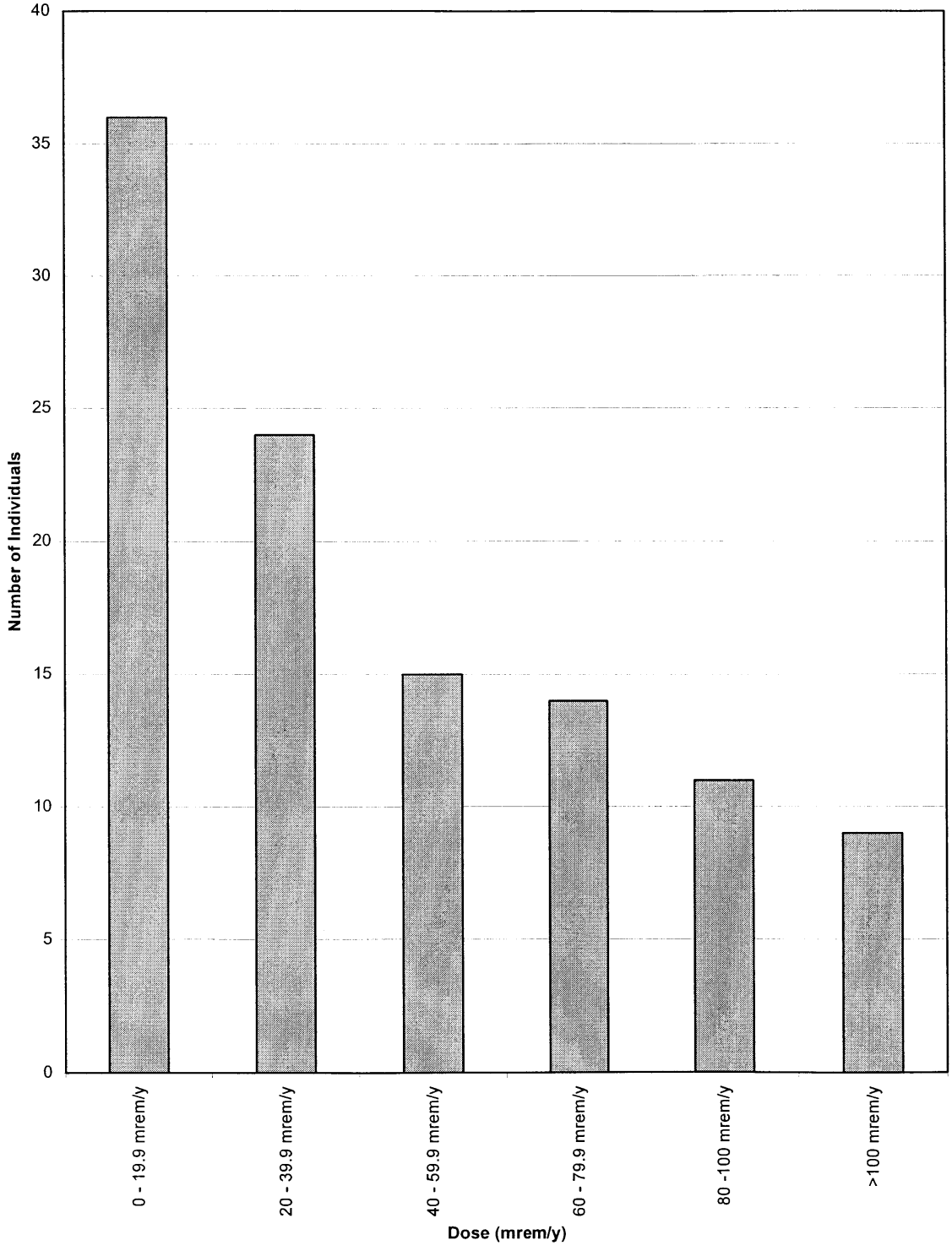
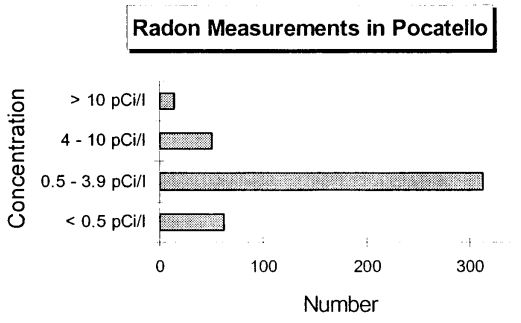
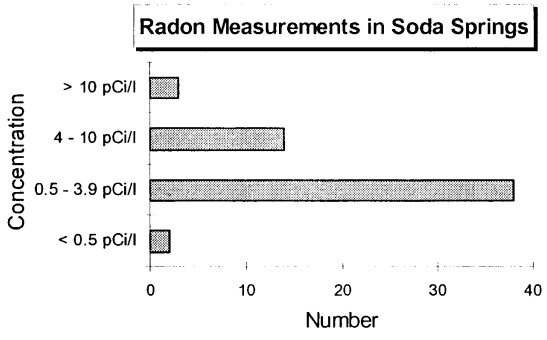


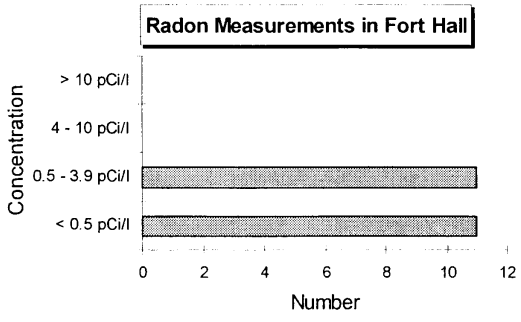
Table 7

Radon Test Kit Results

Radon Testing Results (pCi/l)	Pocatello	Soda Springs	Fort Hall
< 0.5 pCi/l	62	2	11
0.5 - 3.9 pCi/l	313	38	11
4 - 10 pCi/l	50	14	0
> 10 pCi/l	14	3	0
Total	439	57	22







ATTACHMENT A

TECHNICAL SUPPORT

ATTACHMENT B

GRADED DECISION GUIDELINES

ATTACHMENT C

INSTRUMENTATION

ATTACHMENT A

TECHNICAL SUPPORT

TABLE OF CONTENTS

A.1.0 BACKGROUND/HISTORY

A.1.1 Radiation Exposure from Elemental Phosphorus Slag

Elemental phosphorus slag is a byproduct of the production of elemental phosphorus from ore. The ore contains radioactive material from the naturally occurring uranium and thorium decay series (see Figures A-1 and A-2) at levels higher than found in most ordinary rock and soil in the Southeast Idaho region. Radioactive materials in the ore remain in the slag byproduct, resulting in the slag having associated radiation levels, higher than background. Phosphorus slag has been used in residential construction, streets, sidewalks, and construction fill in Pocatello, Soda Springs, Fort Hall, and nearby areas of southeastern Idaho, including Caribou, Bannock, and Power Counties.

Radioactive material in the slag emits gamma radiation, which is a type of radiation similar to medical x-rays. The gamma radiation from phosphorus slag delivers external radiation exposure to individuals near the slag. The average external dose rate from soil and rock in SE Idaho and from cosmic radiation is approximately 10 μrem/h. The average external dose rate above a large volume of slag, such as the slag storage piles, is approximately 60 μrem/h (this includes the natural background dose rate of 10 μrem/h). Construction material containing slag may have dose rates ranging from 10 to 60 μrem/h depending upon the amount of slag in the material.

This level of direct radiation from construction material prompted concern by EPA, regarding dose to individuals. This concern stems from the current theory governing radiation protection. This theory assumes that any dose of radiation has a potential to deliver harm, even levels associated with natural radiation. Radiation protection practice, therefore, attempts to limit or prevent additional radiation to individuals. The EPA's concern led to an investigation of slag radiation doses.

The EPA performed a study of the potential radiation doses from slag received by residents in southeastern Idaho. One of the conclusions was that some residents could be at increased risk of getting cancer due to long-term exposure to slag. The EPA Science Advisory Board reviewed the report of the study following its release in 1990 and made recommendations which included:

- Conduct further tests to determine actual radiation exposure to individuals.
- Establish a set of "graded decision guidelines" (GDGs) to help individuals interpret their exposure results and determine what, if any, actions should be taken to reduce that exposure. These guidelines should be based upon technical and economic factors for both short-term and long-term public exposure due to past uses of slag. The Science Advisory Board also recommended that the guidelines be made available for public review.
- Work with local and state officials, the public and industry to make measurements for individuals based on their particular exposure conditions.
- Locate sources of slag in the community for purposes of establishing an inventory of slag. The inventory should be used to consider disposal options and future disposition of the slag.

A.2.0 TECHNICAL WORK GROUP ACTIVITIES

To address the EPA Science Advisory Board recommendations, a Technical Work Group (TWG) was created in November of 1992. The Technical Work Group included representatives from:

- EPA,
- The State of Idaho,
- FMC Corporation,
- Monsanto Company (now P4 Production, L.L.C., a subsidiary of Monsanto Company and Solutia, Inc.),
- Shoshone-Bannock Tribes,
- Agency for Toxic Substances and Disease Registry,
- Community of Pocatello, and
- Community of Soda Springs.

The Technical Work Group was created to assist EPA and the companies in the design of the Exposure Study and to assist EPA in implementation of the exposure studies and the development of GDGs.

The TWG met on an irregular schedule dependent upon activities to be accomplished. *Ad hoc* committees were formed with assignments to be completed between committee meetings. The TWG examined the use of slag in the communities, relative to natural radiation, radiation risk, and methods for reducing risk.

A.2.1 Natural Radiation

Dose from various sources of radiation can be expressed in terms of a single quantity, millirem, which is abbreviated mrem. If all ordinary sources of radiation dose are included, such as from natural gamma rays, cosmic rays, radon, medical procedures, consumer products and miscellaneous sources, the U.S. national average dose is about 360 mrem per year. Annual doses received by specific individuals can vary considerably from this average value. The average dose from sources except slag in Pocatello and Soda Springs is expected to be about 400 mrem per year because levels of natural radiation are higher than the national average. The natural background, in the Pocatello and Soda Springs areas from natural gamma rays and cosmic rays alone, averages about 100 mrem per year.

A.2.2 Radiation Risk

Dose from slag radiation is in addition to the natural or background amounts. For radiation protection purposes, risk is usually assumed to be proportional to dose. According to the International Commission on Radiological Protection (ICRP), 100 mrem would have an associated potential risk of fatal cancer of five in one hundred thousand. Table A-1 lists examples of radiation exposures, standards and recommendations.

Table A-1

Examples of Radiation Exposures, Standards and Recommendations

Exposure Condition	Annual Dose (mrem)
Radiation worker limit	5,000
Radon daughter limit for uranium miners	4,000
Indoor radon level for which action is recommended by EPA[1] (4 pCi/L)	1,000
Lowest radon level for which EPA[1] recommends that homeowners consider remedial action (2 pCi/L)	500
NCRP[2] remedial action threshold (including background)	500
NCRP[2] recommended limit for infrequent exposure of the public from facilities that emit radiation or radioactivity	500
Average dose to U.S. citizen from all sources	360
Average radon exposure (0.8 pCi/L)	200
Gamma radiation limit for buildings contaminated with uranium mill tailings (above background)	175
Typical dose to civilian air crews	160
NCRP[2] recommended limit for continuous or frequent exposure of the public from facilities that emit radiation or radioactivity	100
U.S. average, natural gamma and cosmic background	54
U.S. average for diagnostic radiological medical procedures	53
One transcontinental round trip per year by air	5

[1]United States Environmental Protection Agency.

[2]National Council on Radiation Protection and Measurements (NCRP).

A.2.3 Risk Reduction

As indicated in Table A-1, limits or recommendations vary among the different exposure situations. The reason for the different limits is practical ability to reduce doses below those limits. In practice, doses are usually held well below the limits as experience is gained and techniques improve. Nevertheless, practical and ethical considerations require that dose reduction should not increase risk to an individual more than the reduction in risk from the radiation. A further practical limit to reducing doses is that the actual harm from radiation may be less than assumed by the theory. The theory is believed to be an upper limit of harm.

These considerations of a practical limit were a concern of the TWG in developing the GDGs. There was an additional consideration. This consideration was a further part of current radiation protection theory. The theory holds that prevention of future dose situations is inherently less risky to impose than is the reduction of existing exposure situations. Future exposure situations

can include radiation protection in design and development. Reducing or eliminating existing exposure situations, such as slag in building materials, may introduce risks larger than the risk being avoided.

The TWG recommended GDGs and implementing an Exposure Study. Essential elements of the GDGs and, consequently, important radiation levels to be considered in the Exposure Study are summarized as follows:

1. For individual doses which exceed 500 mrem per year including natural background, action is recommended if a reduction of at least 100 mrem per year from slag can be achieved. A list of actions to reduce exposure is available.

2. For individual doses less than 100 mrem per year above background, no action is recommended.

3. For individual doses between 100 mrem above background and 500 mrem including background, it is recommended that actions be considered to reduce exposure if a reduction of at least 100 mrem per year from slag can be achieved. A menu of options to reduce exposure is available.

Although not associated with slag or gamma radiation, indoor radon is an important contributor to radiation dose received in dwellings (Table A-1). For this reason it was recommended that radon measurements be offered to residents who volunteered in the Exposure Study. If the radon concentration exceeds the EPA action level of four picocuries per liter (pCi/L) of air, radon reduction is recommended to residents. EPA further recommends that if a level of two pCi/L of air is exceeded, residents should consider radon reduction. Radon reduction includes a graded series of actions such as sealing basement cracks, ventilating spaces with high radon levels, and installing sub-slab ventilation to reduce soil gas pressure under the foundation.

A.3.0 METHODS DEVELOPMENT STUDY

Concurrent with the TWG, a Methods Development Study was conducted to explore techniques and equipment to be used in the Exposure Study, to obtain preliminary results, and to develop protocols for the Exposure Study. The progress of the Methods Development Study was reported to the TWG to aid in decision making. Protocols for the Exposure Study were developed from the results of the Methods Development Study.

Major findings of the Methods Development Study were:

- Screening with dose rate survey meters easily identified residences with slag.
- The screening level for slag was recommended as 20 μrem/h.
- Gamma spectrometry could usually identify slag by a characteristic uranium series spectrum having a minimum number of counts in a spectral region. The identification was not diagnostic.
- The majority of individual dose from slag was usually from residences containing slag.
- Several techniques gave adequate indications of residential dose.

A.4.0 EXPOSURE STUDY

A.4.1 General

The Exposure Study was initiated in June 1996, in agreement with an administrative order on consent. Objectives of the Exposure Study were to:

- Assess individual doses and identify sources of exposure to slag.
- Locate and inventory slag in the communities of Pocatello, Soda Springs, and Fort Hall.

The Exposure Study was conducted in accordance with a Work Plan, developed on the basis of results of the Methods Development Study. The activities and results of the Exposure Study are described in this report.

Primary data analysis for the Exposure Study concerned doses to individuals and dose rates at locations. Details of these measurements are presented in the procedures and Work Plan. For some data evaluation, additional statistical analysis (e.g., least squares fit of data for TLD transit and shield doses) was employed. In this report, summarizing statistics are used to describe overall results. In the case of summarizing statistics, the distribution of the data is important for the application of the appropriate statistical methods (normal, log normal, and non-parametric). A technique for displaying a distribution is a probability plot. The probability plot is a graphical display of numerical value against its rank as a percent. The rank percent is the percent of the total number of points and is plotted as the standard normal quantile. A normal distribution plots as a straight line on a probability plot and a lognormal distribution plots as a straight line if the

logarithms of the values are plotted. Analysis of the plot allows statements as to the normality of the data and the appropriateness of the statistical method used for evaluation.

A method for preparing and analyzing probability plots is the normal scores or NSCORES method. This technique approximates the percent rank value then computes the standard normal quantile of the percent rank. The correlation of the values to their NSCORES position is a measure of the normality of the distribution. The NSCORES technique is easily evaluated in a spreadsheet. For the EXCEL program, the data are entered in a column, the column is sorted for ascending values, and the rank of the data is placed in an adjacent column. The percent rank is approximated using the Cunnane plotting position that is calculated for each rank as (rank – 0.4)/(highest rank + 0.2). The standard normal quantile is obtained from the EXCEL function NORMSINV of the Cunnane plotting position. A plot of the data against the standard normal quantile is an NSCORES plot.

Standard methods were used to assess precision and accuracy. Precision is the degree of reproducibility of measurements under a given set of conditions and is expressed as relative percent difference (RPD):

$$RPD = [(measurement - duplicate)/(measurement + duplicate)] \times 200$$

Accuracy measures the bias in a measurement system. Accuracy or percent difference (PD) is expressed as:

$$PD = [(measured - true)/true] \times 100$$

A.4.2 Residential Dose Rate Screening Surveys

Dose rate screening surveys were offered for residences to determine if radiation levels existed in a residence that could lead to an above-background dose of more than 100 mrem/y. The screening survey was a dose rate measurement and the screening level was 20 μrem/h. The above-background dose rate that delivers 100 mrem for full-time annual exposure of 8766 hours is 11.4 μrem/h. A dose rate of 17.1 μrem/h is necessary, if exposure is two-thirds of full time or 5844 hours – a value more closely representing the average annual time spent in the home by a resident. If the background dose rate is 10 μrem/h then the background plus above background dose rate would sum to 21.4 and 27.1 μrem/h total dose for the full-time and two-thirds of full time exposure, respectively. The Methods Development Study found that a total dose rate of 20 μrem/h was usually indicative of the presence of slag. A screening level of 20 μrem/h was chosen based on the Methods Development Study result and the expectation of less than full-

time exposure. Any measurement greater than or equal to 20 μrem/h was presumed to be due to the presence of slag.

A.4.2.1 Materials and Methods

Screening measurements were made with a Bicron Micro Rem meter by walking about an area to be surveyed while holding the instrument approximately 1 meter (3 feet) above the ground or floor and observing the analog instrument display. The instrument was observed for 10 seconds in order to obtain an average for the measurement location. The screening survey included two measurements on the ground floor of the residence and two in the basement. If there was no basement, the two ground-floor measurements were sufficient. The measurements were made approximately 1 meter above the floor and near the center of the room. The surveyor observed the instrument reading until a stable and average reading was obtained. The surveyor also observed the instrument while moving between locations to observe any anomalous dose rates.

The surveyor recorded all results on a standard form and submitted to the resident either a Follow-up Recommended or No Follow-up Recommended report. The Follow-up Recommended report was required if dose rates greater than or equal to 20 μrem/h were identified. The No Follow-up Recommended report was submitted if all readings were below 20 μrem/h or when an isolated source was found that was clearly not slag. Nevertheless, a Follow-up was offered to any residence where dose rates greater than or equal to 20 μrem/h were found.

A.4.2.2 Results

The fraction of residences in Pocatello and Fort Hall, expected to have slag as a construction material, is estimated to be within the 95% confidence intervals of 0 and 0.5% of all houses. This estimate is based on the total number of houses surveyed and the number in which dose rates were less than 20 μrem/h and using:

$$z = \frac{X - p \pm 1/2N}{\sqrt{p(1-p)/N}}.$$

Eq. A- 1

In the equation, z is the ±0.975 normal quantile, X is the number of houses 20 μrem/h or greater divided by N, the number of houses surveyed, and p is the probability limit of z. The *1/2N* in the equation is + for the upper limit and – for the lower limit. This estimate assumes that the sample of houses screened was randomly selected and all houses have an equal chance of containing slag. However, the houses were selected on a voluntary basis and the bias would be expected to be toward a likelihood of slag. The number of houses that would be expected to have slag as a construction material is probably lower.

Similarly, the fraction of residences in Soda Springs that are expected to have slag as a construction material is between 28 and 43%. As in Pocatello and Fort Hall, the houses were selected on a voluntary basis and the bias should have been toward a likelihood of slag. Further, slag was available for construction from 1960 to 1976. Only houses built during this period would be expected to contain slag. Approximately 25 % of the houses in Soda Springs were built during this time. The Soda Springs residents were aware of the time frame for slag in construction. If it is assumed that 35% of the houses built between 1960 and 1976 (25% of the total houses) contain slag, then 7 to 11% of all houses in Soda Springs are likely to contain slag.

A.4.3 Individual Screening Dose by TLD

Two options were available to individuals for measurement of dose from slag. These methods were dose rate/time log and thermoluminescent dosimeters (TLDs). TLD has the advantage that dose is summed from all locations, but with the disadvantage that dose from a specific location is not known. Because TLD doses include doses from residential and non-residential locations and from slag and non-slag sources, it is to be expected that the doses measured by TLD would be an over estimate of the residential slag dose. Therefore, individual dose by TLD was considered a screening method, also.

A.4.3.1 Materials and Methods

Procedures in the Exposure Study Work Plan describe in detail the methods used to perform these measurements. The TLDs used in the Slag Exposure Study were Al_2O_3, Landauer Model X-9 Environmental/Low Level dosimeters, packaged in the form of a key fob. TLDs were received from the vendor and placed in shields (large gun safes) at the Southeastern District Health Department (SDHD) offices in Pocatello or Soda Springs. The TLDs were maintained in the safes when not assigned. Dosimeters were assigned to participants at the time the request was made and were worn for approximately a 3-month period. At the end of the 3-month period, the TLDs were stored in the safe until returned to the vendor for analysis. From the time the TLDs were shipped from the vendor until they were returned to the vendor for analysis, the total dose to the TLD included dose from multiple sources. These potential sources included exposure:

- To any slag proximate to the individual;
- To natural background (for the purposes of this report, the dose due to natural background that the TLD received during the deployment period);
- To other natural sources such as construction material in the workplace;
- Received in transit to and from the vendor;

- Received while stored in the shield;
- To industrial radionuclides and x-rays;
- To medical procedures; and
- To commercial products.

The Methods Development Study determined that "An above-background exposure detection limit of approximately 30 mrem/y was found to be possible" and "A dose of 100 mrem/y is sufficiently above the detection limit to ensure reliable quantification." The determination of an above-background dose required the total dose to the TLD be corrected for natural background, transit, and storage doses. The methods used to estimate background, transit, and storage doses and to correct for their contributions are described below and the results evaluated.

A.4.3.1.1 Transit Dose and Shield Dose Rate

These parameters were measured together. Two TLDs were returned to the vendor at approximately the same time the TLDs were placed in the shields. Additional pairs were returned approximately every 21 days. The values for each pair were averaged and a linear regression performed; dose was the dependent variable and time in the shield was the independent variable. The resulting dose intercept is an estimate of the transit dose and the slope of the line is an estimate of the dose rate in the shield, as illustrated in Figure A-3.

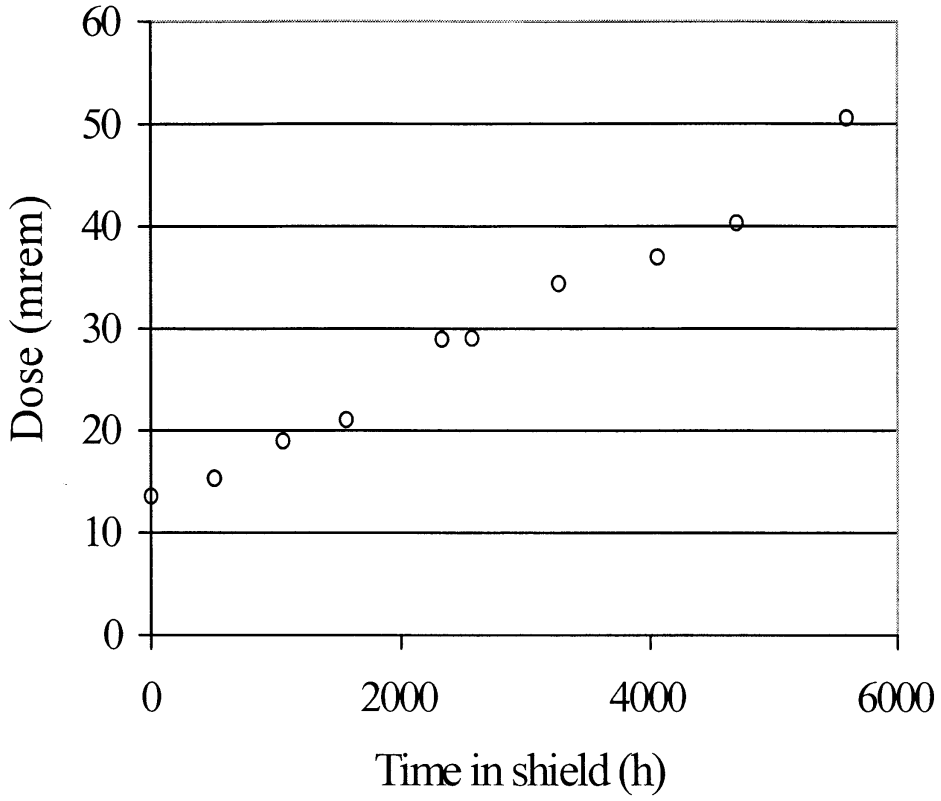


Figure A-3

Example of Dose to TLDs in the Shield with Time
(The slope is the dose rate in the shield and the intercept is the transit dose)

The transit dose, calculated by the slope and intercept method, is the average of the transit doses for the set. Each returned pair of TLDs was handled and shipped in the same manner, but no control of the TLDs was possible once they were delivered to the shipping agent. Table A-2 is a list of the transit doses and shield dose rates calculated for 8 different batches of TLDs, using this method.

Table A-2

Transit Dose and Shield Dose Rates Determined for the TLD Sets

TLD Set	Transit dose (mrem)	Shield dose rate (μrem/h)
1 P	12.06*	6.5
2 P	3.78	6.6
3 P	6.67	6.6
4 P	5.73	6.3
5 P	5.83	5.6
2 SP	9.97**	8.4**
1 S	12.49*	7.2
2 S	5.45	6.5

*Start of the study was delayed after receipt of the TLDs. Both sets were stored in a safe other than the shield safes until start of the study. This additional storage dose was assigned as the transit dose.

**This TLD set was transferred from Soda Springs to Pocatello. The transfer resulted in a non-linear dose-time curve. The results are reported here as the best linear fit.

As Table A-2 shows, with exception of TLD batches 1P, 1S, and 2SP, for which management deviated slightly from the standard method, the calculated transit dose (3.78 to 6.67 mrem) and shield dose rate (5.6 to 6.6 μrem/h) are reasonably constant.

A.4.3.1.2 Blanks

One blank TLD was sent to the vendor for every 50 TLDs used. The purpose of the blanks was general QC of the TLD method; however, the blanks can also be used as an additional data set to confirm the shield and transit doses. The calculation methods are similar to those described above for the transit dose and shield dose rate TLDs. As an example, the values for TLD batches 1P and 1S were calculated by this method. The resulting transit dose and shield dose rate for batch 1P are 13.6 mrem and 5.3 μrem/h, respectively, and the transit dose and shield dose rate for TLD batch 1S, as calculated from the blanks, are 13.5 mrem and 6.7 μrem/h, respectively. The relative percent differences in the values as determined by the two methods ranged from approximately 7 % to 20 %. Such agreement is considered good for environmental measurements and confirms the quality of the transit dose and shield dose rate data for those two TLD batches.

Shield exposure rates were also measured using the PIC. The PIC detector was placed in the shield and counts were accumulated until adequate statistics were obtained. The exposure rates determined were converted to dose rates by multiplying the exposure rates by 0.95. Results of these PIC shield dose rate measurements (in μrem/h) are shown in Table A-3 and compared to the dose rates determined by the intercept and slope method.

Table A-3

Comparison of Shield Dose Rate Measurements

	PIC (μrem/h)	Slope (μrem/h)	Relative Percent Difference
Pocatello	7.7	6.5	16.9 %
	7.8	6.6	16.7 %
Soda Springs	8.4	7.2	15.4 %
	9.1	6.5	33.3 %

A.4.3.1.3 Background Measurement by TLD

TLDs were placed at background locations in the three study areas. Ten background measurement locations each were selected in Pocatello, Soda Springs, and Fort Hall. These background locations were specifically selected to be unaffected by direct radiation from slag and were surveyed using a microrem meter to ensure that the surroundings were unaffected by slag or other radiation sources and uniform in dose rate. Two TLDs (measurement and duplicate) were placed in plastic containers with security seals to identify tampering and deployed at the locations for three or more months. The background measurements were performed four times for Pocatello and Fort Hall and three times for Soda Springs at the same locations and at different times of the year to allow for seasonal variations. The results of the background measurements are shown in Figures A-4, A-5, and A-6.

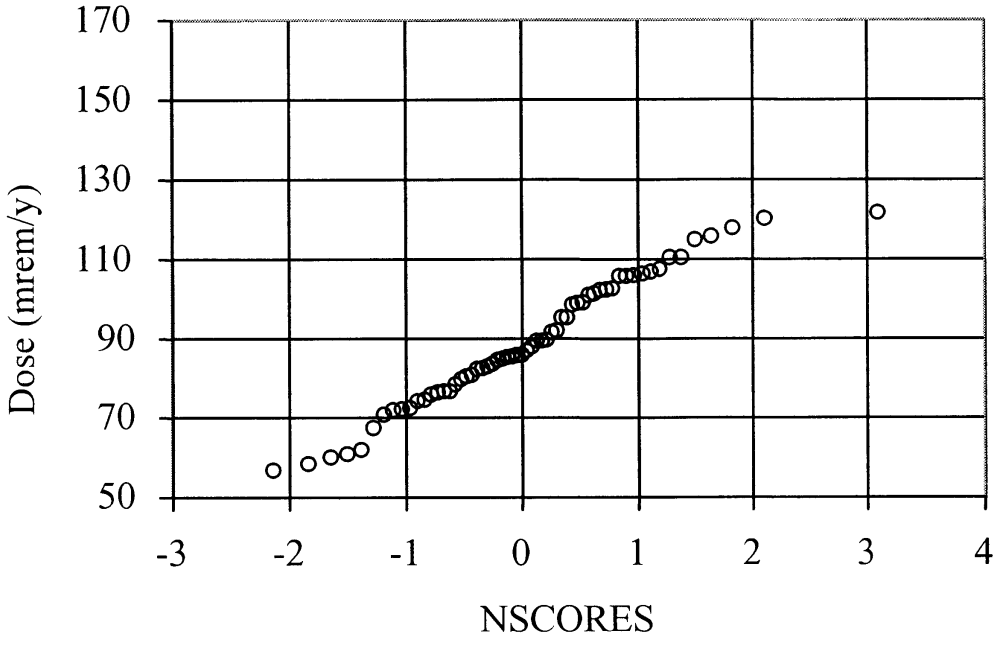


Figure A-4

Annual Dose from Background in Pocatello as Measured by TLD

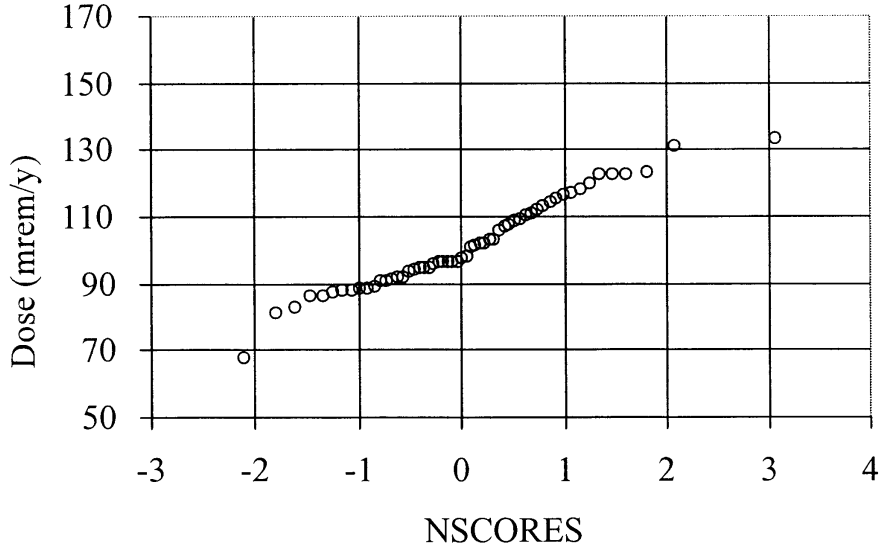


Figure A-5

Annual Dose from Background in Soda Springs as Measured by TLD

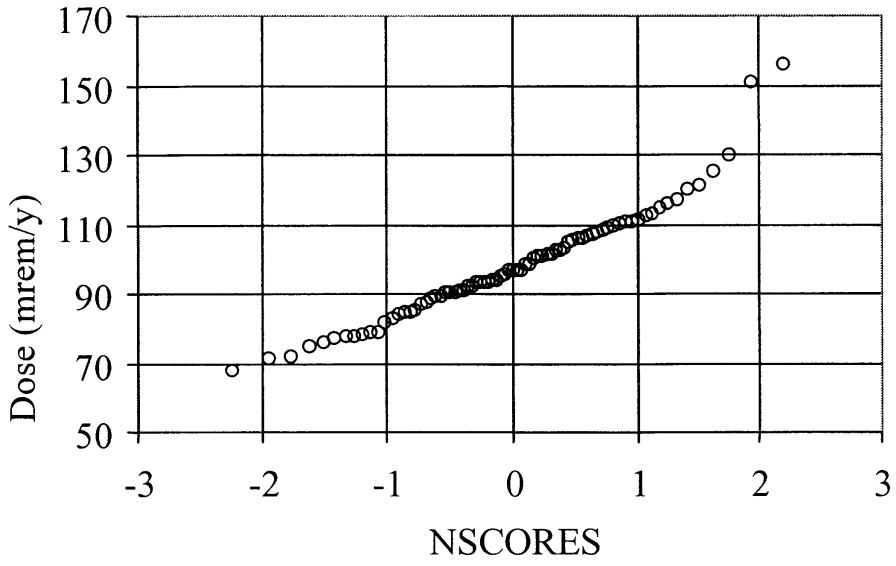


Figure A-6

Annual Dose from Background in Fort Hall as Measured by TLD

The data plotted in each of the above Figures are normally distributed based on the PRCC test[1] at an α [2] of 0.25. The average annual backgrounds and their standard deviations were determined from a least squares fit to the TLD data against the NSCORE; results are presented in Table A-5. These calculations assumed equal weight for all individual background measurements, although the time represented by individual measurements was not the same. For comparison, the average background dose for each community was also calculated, taking into account the variation in exposure time periods. The results for Pocatello are 88.4 +/- 15.8 mrem for the least squares method as compared to 96.4 mrem for the time-weighted calculation. The results for Soda Springs are 101.1 +/- 13.1 mrem vs. 99.0 mrem, and those for Fort Hall are 97.6 +/- 15.0 mrem vs. 99.9 mrem. The background values determined by the two different methods agree for each community within the range typically considered acceptable for environmental measurements.

[1] PRCC (Probability Plot Correlation Coefficient), Looney, S. W., and t. R. Gulledge, Use of the Correlation Coefficient with Normal Probability Plots, *The American Statistician*, Vol. 39, pages 75-79, 1958.

[2] The α level determines the goodness of fit. The ability to detect non-normality increases with the size of α. The value 0.25 is the largest possible value for α. Looney, S. W., and T. R. Gulledge, Probability Plotting Positions and Goodness of Fit or the Normal Distribution, *The Statistician*, Vol. 34, pages 297-303, 1958.

Variability, among background measurement locations and variability between duplicate dosimeters at the same location, was evaluated for each of the communities using PD and RPD, respectively.

Table A-4

Range of Values for PD and RPD for Background Determinations for Each Community

Community	Range of Percent Difference	Range of Relative Percent Difference
Pocatello	-41 to 76	-18 to 25
Soda Springs	-31 to 32	-22 to 25
Fort Hall Reservation	-32 to 92	-35 to 38

The ranges for these parameters demonstrate the variability of measurements performed at environmental levels.

Table A-5

Annual Background Dose in the Three Communities

	Mean and standard deviation (mrem/y)
Pocatello	88.4 ± 15.8
Soda Springs	101.1 ± 13.1
Fort Hall	97.6 ± 15.0

A.4.3.2 Results

Individuals were asked to place the TLD fob on their key ring in order to keep the TLD near their person for the wear period. The results of the individual measurements for the three communities compared to the background measurements are shown in Figures A-7, A-8, and A-9.

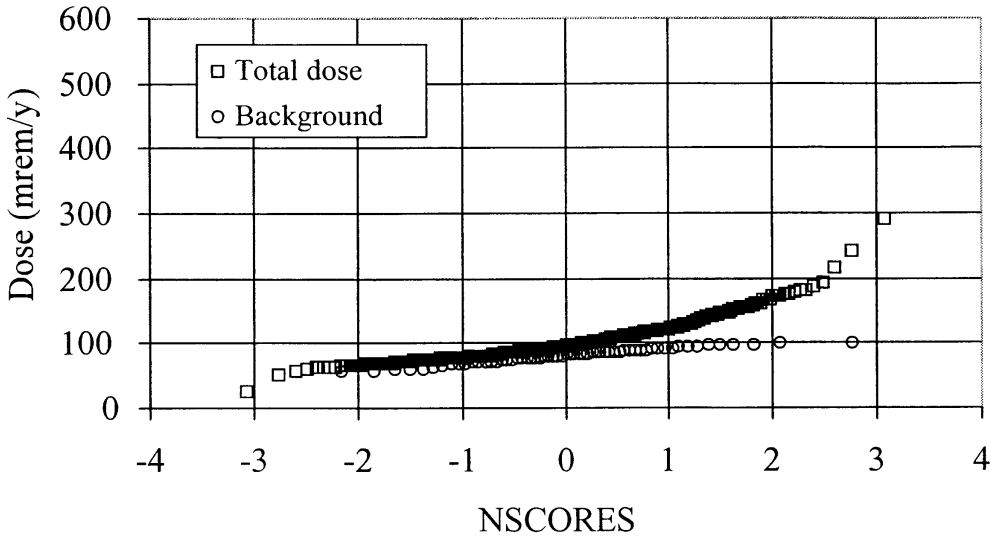


Figure A-7

Total Dose to Individuals in Pocatello
as Measured by TLD Compared to Annual Background Dose

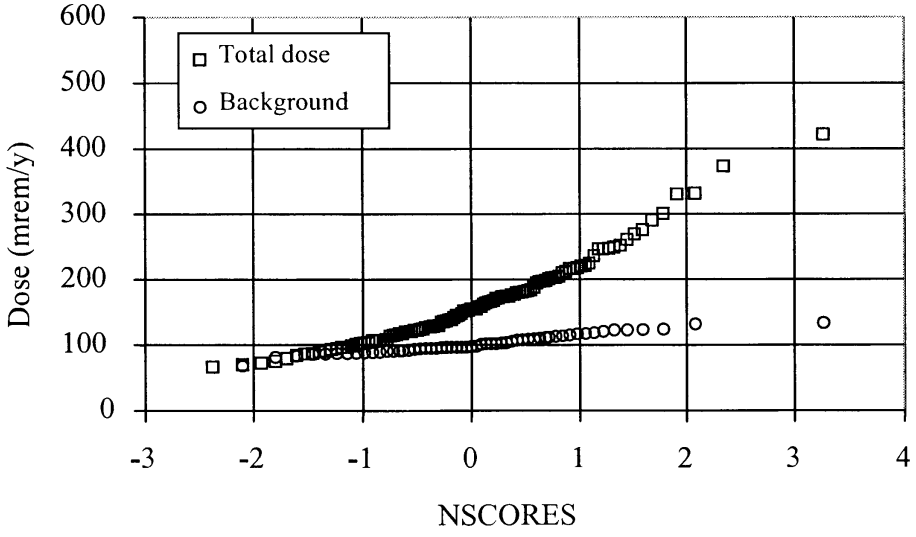


Figure A-8

Total Dose to Individuals in Soda Springs
as Measured by TLD Compared to Annual Background Dose

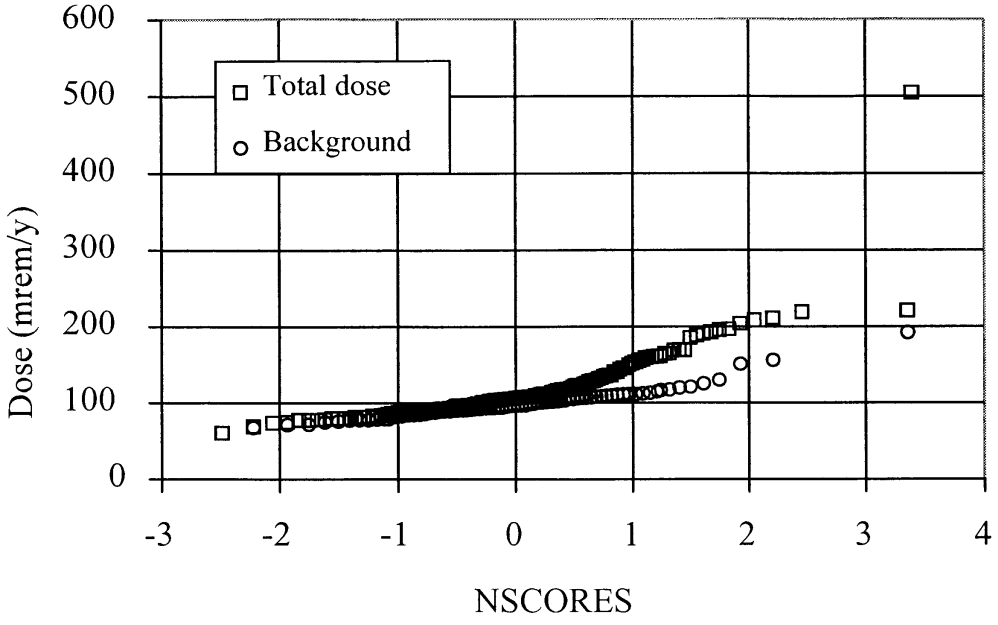


Figure A-9

Total Dose to Individuals in Fort Hall
as Measured by TLD Compared to Annual Background Dose

As evidenced by these Figures, the distribution of individual doses diverges from the distribution of background doses. The individual measurements differ from the background measurements in one important manner, i.e., individual doses were an integration of doses received from all the locations the individual visited, while the background doses were received at a single, fixed location. Assuming that the background distribution represents the true distribution of the dose rates of all locations within each community, then we could expect that individuals could have a different dose distribution than background, because of individual time distributions at locations. This does not explain how a person's total dose can exceed the highest background dose observed.

There are several possible explanations to account for the higher than background doses. An obvious possibility, other than slag, is that the background distribution is not the true distribution. It is possible that individuals were exposed to background levels higher than measured by the background TLDs. The range of background measurements for Pocatello was 56.9 to 121.1 mrem/y, with an average of 88.4 ± 15.8 mrem. Based on the mean and standard deviation, it is probable that 1% of the Pocatello population was exposed to a dose rate that could

have delivered a background dose of ≥136 mrem/y based on a TLD measurement. Further, because the 10 TLD background locations (5 indoors and 5 outdoors) were not randomly selected, the certainty that these locations represent background are reduced. Nevertheless, there is a 95% certainty that the actual mean is within 88.4 ± 31.0 mrem/y.

Another explanation for the higher than background doses is possible industrial and medical exposure to radionuclides and radiation. Finally, exposure to slag may account for the higher than background doses. These exposures to slag could occur from employment or from community locations of slag. Figure A-10 allows an evaluation of the dose from slag in Pocatello if all the above background dose is assumed from slag.

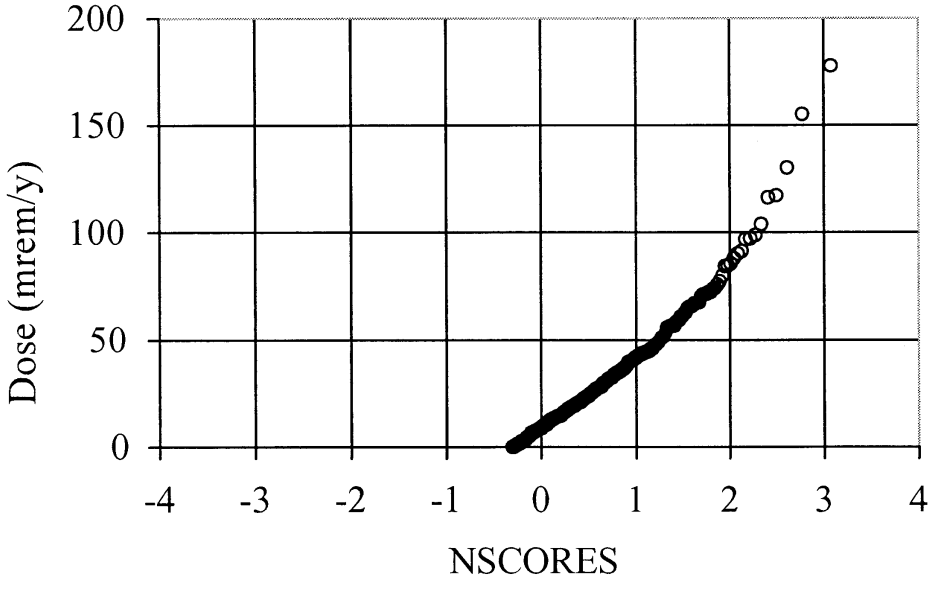


Figure A-10

Above Background Doses in Pocatello as Measured by TLD

Subtracting a randomly generated background of 88.4 ± 15.8 mrem/y from the total dose distribution produced Figure A-10. The above-background distribution is log normal with a geometric mean of 5.5 mrem/y and a geometric standard deviation of 1.7. The normal approximation of the above-background distribution was 63 ± 30 mrem/y. The median difference (Hodges-Lehmann estimator) between the background and total dose distributions is 2.9 (-1.9, 7.4) mrem/y.

The 95-percentile dose above background in Pocatello is 170 mrem/y. Based on the measurements in this study, this upper-bound dose is not due to a residential slag dose. Follow-up measurements indicated that some Pocatello residences had dose rates slightly in excess of 20 μrem/h and the dose rate was primarily from a uranium series gamma spectrum.

The probability of a residence in Pocatello/Chubbuck having slag as a construction material delivering a dose greater than 100 mrem/y is less than 0.5%. This estimate is based on the TLD survey of 454 residences in Pocatello/Chubbuck out of an estimated 15,000 residences and assuming a random selection of residences surveyed. The selection was voluntary, not random. It is likely that voluntary selection biased the distribution of houses toward the possibility of slag in the construction material; therefore, the probability may be lower.

Figure A-11 allows an evaluation of the dose from slag in Soda Springs if all the above background dose is assumed from slag.

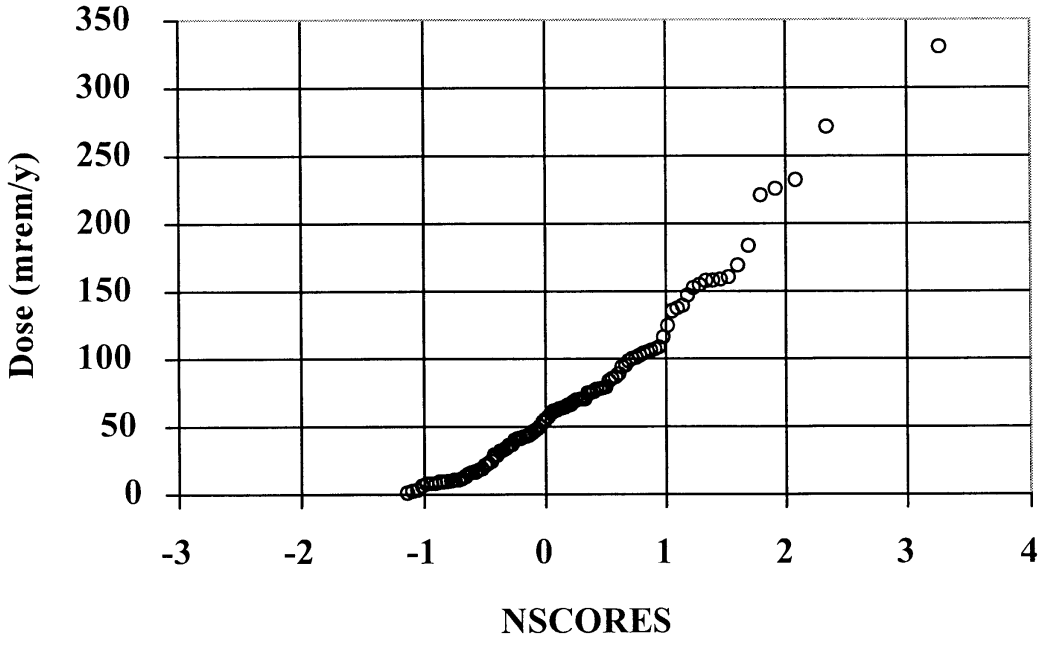


Figure A-11

Above Background Doses in Soda Springs as Measured by TLD

Subtracting a randomly generated background of 101.1 ± 13 mrem/y from the total dose distribution for Soda Springs produced Figure A-11. The above-background distribution is log normal with a geometric mean of 57 mrem/y and a geometric standard deviation of 2.3. The median difference between the background and total dose distributions is 53 (39, 66) mrem/y.

Figure A-11 shows a highest measured dose in Soda Springs of 330 mrem/y. This dose was measured for an individual while the other family members averaged 100 mrem/y with a maximum value of 150 mrem/y. This dose is sufficiently different from the other family members and from the Follow-up dose calculations to discount the dose as TLD error or inadvertent dose from a non-slag source. Excluding this anomalous dose, the 95th-percentile dose above background in Soda Springs is 275 mrem/y. Based on the measurements in Pocatello, this upper-bound dose is not exclusively due to a residential slag dose. Subtracting a randomly generated above background community dose (based on Pocatello) of 63 ± 30 mrem/y from the total dose distribution for Soda Springs produced a 95th-percentile residential slag dose in Soda Springs of 227 mrem/y.

The probability of a residence in Soda Springs having slag as a construction material delivering a dose greater than 100 mrem/y is between 9 and 14%. This estimate is based on the TLD survey of 82 residences in Soda Springs out of approximately 750 residences and assuming a random selection of residences surveyed. The selection was voluntary, not random. It is likely that voluntary selection biased the distribution of houses toward the possibility of slag in the construction material; therefore, the probability may be lower.

Figure A-12 allows an evaluation of the dose from slag in Fort Hall if all the above background dose is assumed from slag.

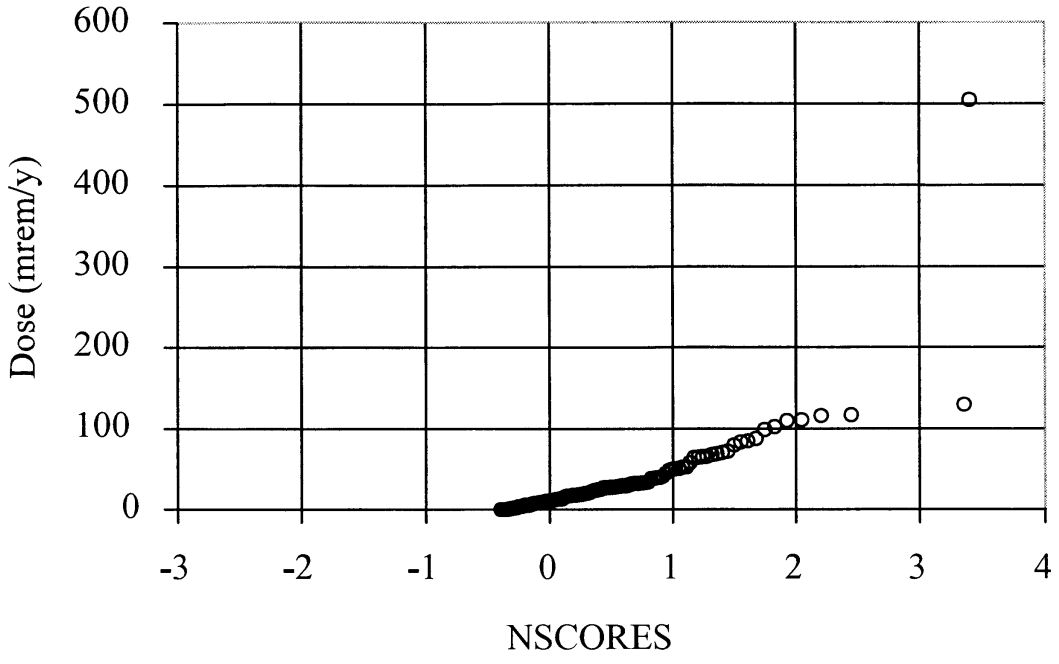


Figure A-12

Above Background Doses in Fort Hall as Measured by TLD

Subtracting a randomly generated background of 97.6 ± 15 mrem/y from the total dose distribution produced Figure A-12. The above background distribution is normal with a mean of 17.5 ± 35 mrem/y. The median difference (Hodges-Lehmann estimator) between the background and total dose distributions is 10.8 (5.5, 16.5) mrem/y.

Figure A-12 shows a maximum measured dose in Fort Hall of 505 mrem/y. This dose was measured for an individual while the other family members averaged <100 mrem/y with a maximum value of 100 mrem/y. This dose is sufficiently different from the other family members to discount the dose as TLD error or inadvertent dose from a non-slag source. Excluding this anomalous dose, the 95th-percentile dose above background in Fort Hall is 120 mrem/y. Based on the measurements in this study, this upper-bound dose is not due to a residential slag dose. Screening measurements indicated that no Fort Hall residences had dose rates in excess of 20 μrem/h.

The probability of a residence in Fort Hall having slag as a construction material delivering a dose greater than 100 mrem/y is less than 0.5%. This estimate is based on the survey of 230 residences in Fort Hall out of approximately 750 residences and assuming a random selection of

residences surveyed. The selection was voluntary, not random. It is likely that voluntary selection biased the distribution of houses toward the possibility of slag in the construction material; therefore, the probability may be lower.

A.4.4 Follow-up Surveys

The dose rate/time log dose estimation method was used for Follow-up Surveys. Using this method, the dose at a location can be estimated by the dose rate at a location and time spent at that location. The major disadvantage to dose rate/time log is that many locations must be measured for total dose with a corresponding time estimate for each location. Follow-up Survey of an entire residence was necessary, along with an estimate of time spent at locations in the residence, in order to obtain individual annual doses due to slag in the residence.

The usual sequence for a Follow-up Survey was a Screening Survey or TLD result that produced a recommendation for follow-up, a request for follow-up by the owner of the residence, then a scheduled Follow-up Survey. Although, anyone wishing to begin with the Follow-up dose assessment was permitted to do so, there were no requests to directly proceed to Follow-up dose assessment.

A.4.4.1 Materials and Methods

The Follow-up Survey began with an inspection for slag. A Bicron Micro Rem meter was observed during the inspection for slag. Slag was sought at high dose-rate locations, generally in the basement. A geologist trained all personnel performing measurements for the Exposure Study in the identification of slag by physical techniques. A gamma spectrum was taken near the location of highest dose rate. If bare concrete could not be found in the dwelling, gamma spectrometry was the only slag measurement performed. A gamma spectrum characteristic of natural uranium was indicative that the aggregate might be slag.

The Follow-up Survey for dose rate was performed with the Bicron Micro Rem meter. The survey was performed with the instrument held approximately 1 meter above the floor. The instrument was observed while walking about each room of the residence. Coverage of the room area was at minimum the perimeters and diagonals of the room. If the room was found to be acceptably uniform (no obvious gradients in dose rate), then a single reading in the center of the room was used for the room dose rate. A 10-second observation of the meter was used to establish an average reading. When the room exhibited an obvious gradient, 10-second measurements were made every 3 feet along the gradient and the average of the measurements was used for the room dose rate.

Room dose rates obtained in this fashion were used to calculate annual dose to individuals spending time in the rooms. The background dose rate was subtracted from the measured room dose rates. An estimate of time spent in each room on an average basis was obtained for each individual living in the residence. The product of above-background dose rate, average hours per day, and days per year yielded the annual dose per room. The sum of doses for all rooms was the total annual above-background dose for the individual resulting from slag in the residence.

A.4.4.2 Results

Of the 28 total Follow-up Surveys performed, the 2 in Pocatello and 18 in Soda Springs resulted in above-background dose estimates of less than 100 mrem/y. The remaining 8 Follow-up Surveys performed in Soda Springs produced at least one individual in each residence with an estimated above-background dose greater than 100 mrem/y. The highest estimated, annual, above-background dose was 132.4 mrem. These Follow-up Surveys yielded above-background dose estimates for 100 individuals. The distribution of the dose estimates is shown in Figure A-13.

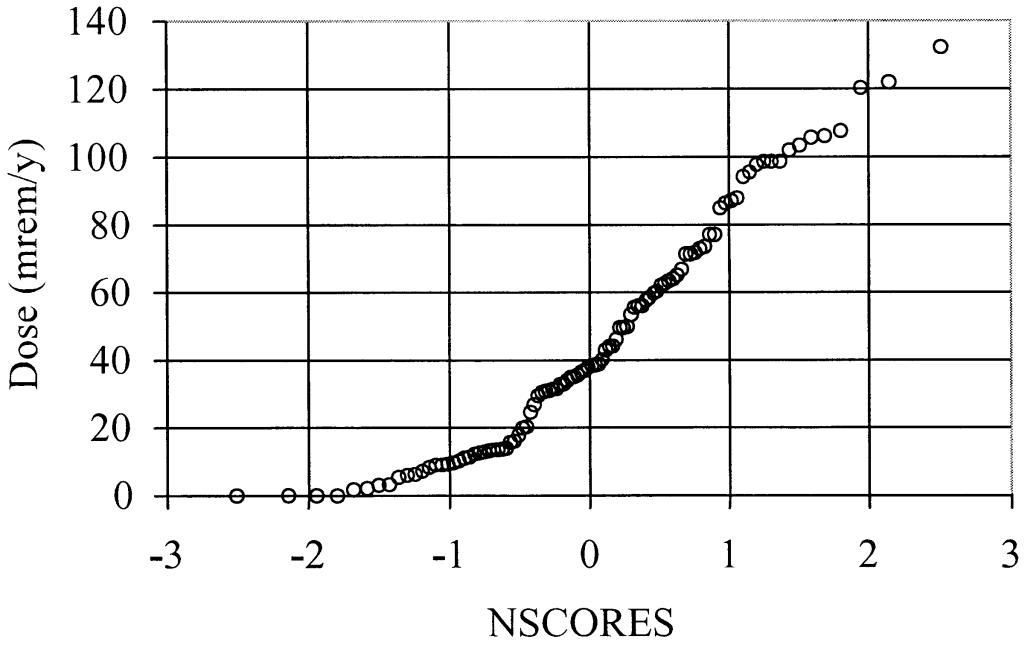


Figure A-13

Distribution in Soda Springs of the Above-Background Annual Doses in Houses Containing Slag Estimated by Dose Rate

The distribution in Figure A-13 is best fit with two straight lines. Two straight lines indicate a bimodal distribution, each of which is normally distributed. A likely explanation for two distributions is time spent in the residence and/or the Exposure Study practice of subtracting a fixed background from the measurements (negative values were assigned as zeros). Those employed outside the home may comprise the lower distribution while those who spend a greater time at home are the higher distribution. The best fits to the two distributions are shown in Figure A-14.

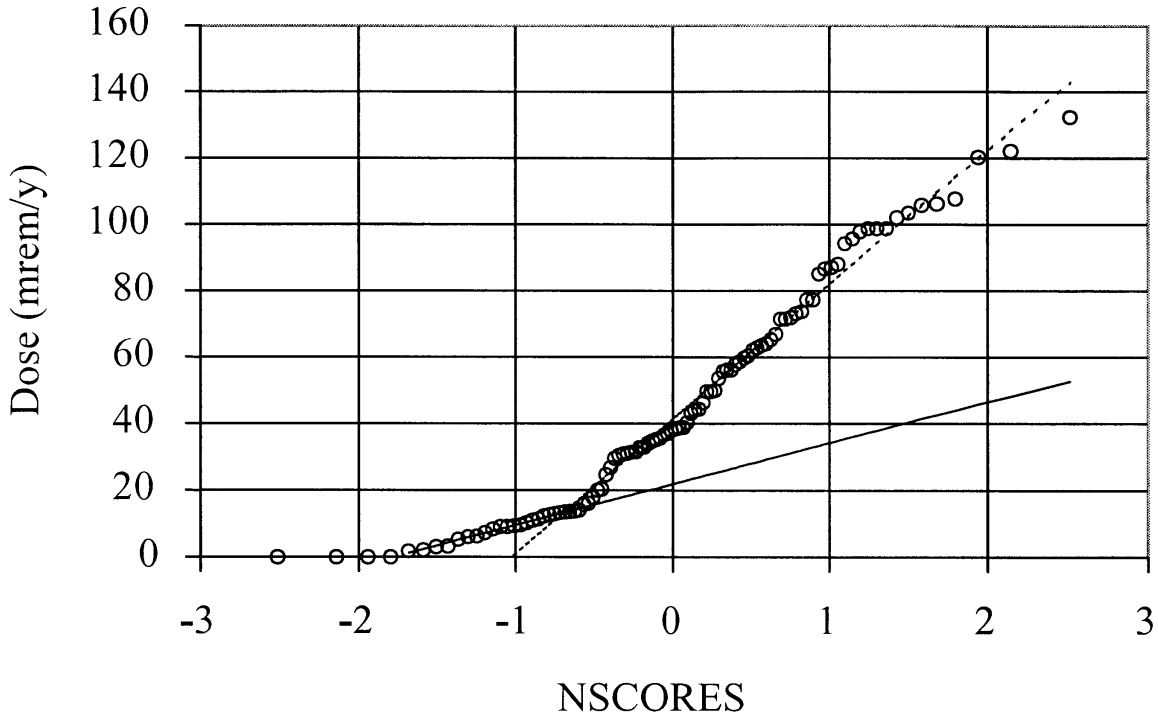


Figure A-14

Distribution in Soda Springs of the Above-Background Annual Doses in Houses Containing Slag Estimated by Dose Rate with Best Fits to a Bimodal Distribution

The bimodal fit indicates that the mean dose from residential slag is 42 mrem/y with a 95th-percentile expectation of 140 mrem/y. The TLD estimations for the same quantities are a mean of 63 mrem/y and 95th-percentile expectation of 227 mrem/y.

A.4.5 Slag Identification

In order to assign a measure dose or dose rate above the background mean as due to slag, it was necessary to identify slag as the source of exposure. Two methods were used to identify slag, visual identification and gamma spectrometry.

A.4.5.1 Materials and Methods

Slag can be identified when accessible by standard mineralogical techniques. These techniques include color, hardness, appearance of fracture surfaces, and porosity. A qualified geologist in the identification of slag trained all personnel making measurements for the Exposure Study. In most cases, the slag was accessible for identification, but in about 10 percent of the cases of either asphalt or concrete, the slag was not accessible on the surface. No attempt was made to core or otherwise aggressively remove slag for identification. In all cases the additional method of gamma spectrometry was used to indicate the presence of slag. The gamma spectrometry technique does not unambiguously identify slag since other materials may exhibit the same spectrum. The spectrum intensity usually indicated slag as discussed below.

Phosphorus slag contains naturally occurring uranium and progeny that are essentially in radioactive equilibrium, i.e., each radionuclide in the decay series is present at nearly the same activity. Uranium (U-238 and U-234) is primarily an alpha emitter; the level of gamma radiation it emits is low and is difficult to measure by gamma measurements at low uranium concentrations. The uranium series contains gamma emitters, which, if equilibrium can be assumed, enables uranium to be detected and quantified by gamma spectrometry. Uranium is ubiquitous in nature, so detection of uranium is not synonymous with detection of slag. The uranium in slag is usually higher in concentration than the average concentration of uranium in most construction materials. Therefore, a difference from an average uranium concentration may indicate the presence of slag. The gamma spectrometer used to identify the gamma contribution to the dose rate was an Aptec Odyssey 5 multichannel analyzer with a 3 inch x 3 inch sodium iodide detector. Figure A-15 shows a background gamma spectrum of soil containing the natural uranium series. The spectrum also shows a presence of naturally occurring potassium-40 and the thorium decay series.

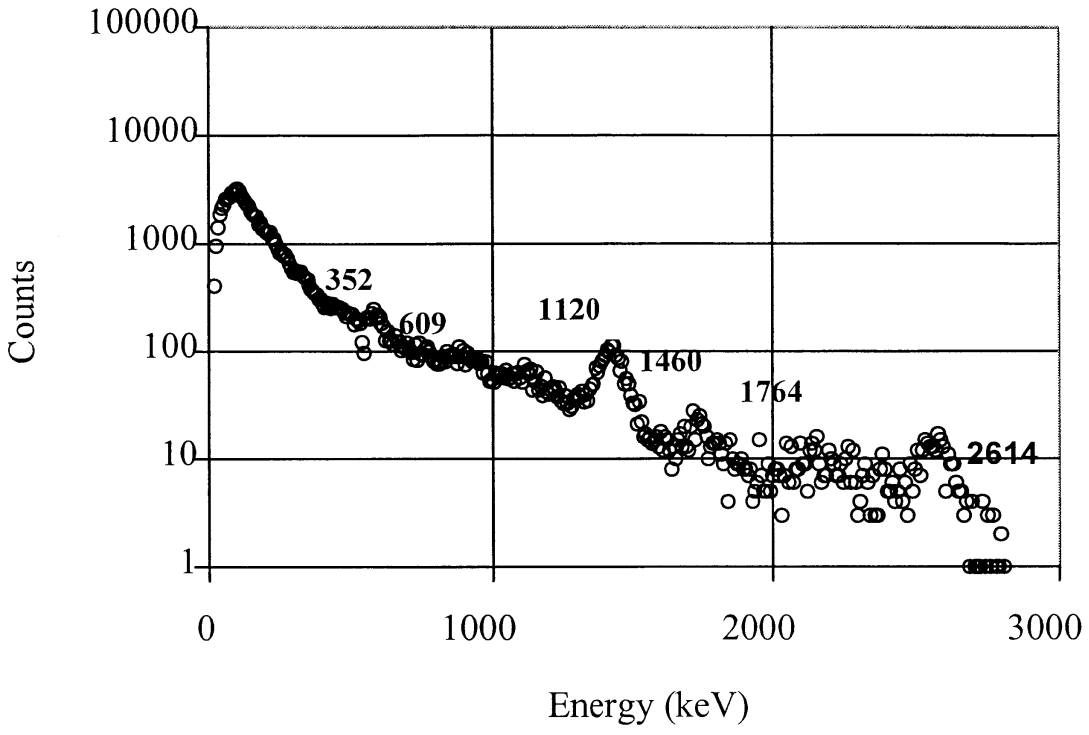


Figure A-15

Gamma Spectrum of a Background Location
Showing Spectral Lines Belonging to Uranium, Potassium-40, and Thorium

The spectral lines belonging to the uranium series are 352, 609, 1120, and 1764 keV. The numbers in Figure A-15 indicating the energy of the spectral line are placed to the left of its peak in the spectrum. The 1460 keV line is characteristic of potassium-40 and the 2614 keV line is one of the characteristic lines of the thorium series.

The thorium series spectrum is important to the background spectrum because it contributes more gamma dose than either the uranium series or potassium-40 at equivalent concentrations. The conversion factors for direct gamma dose rate from soil for the three radioactive materials are listed in Table A-6.

Table A-6

Dose Rate Conversion Factor for Background Radionuclides in Soil

	Dose Rate Conversion Factor ((μrem/h)/(pCi/g))*
Uranium series	1.8
Thorium series	2.7
Potassium-40	0.17

*Helfer, I. K., Miller, K. M. Calibration factors for Ge detectors used for field spectrometry. Health Phys. 55:15-29; 1988. The values were given in the article as (μR/h)/(pCi/g). The tabular values were converted by multiplying by 0.95 (μrem/h)/(μR/h).

The characteristic spectrum of the natural thorium series is shown in Figure A-16 as a calibration spectrum for the spectrometer. The spectrum of thorium is important to cases where the gamma contribution may be substantially from thorium, rather than uranium from slag.

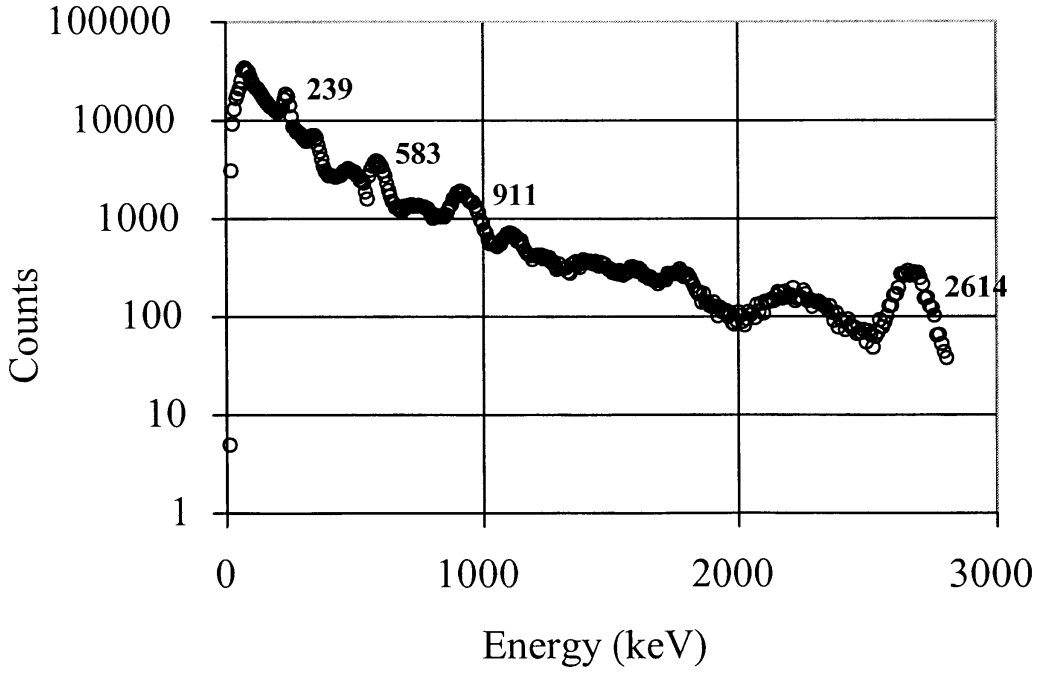


Figure A-16

The Gamma Spectrum of Thorium from a Calibration Source

The figure shows that in addition to the 2614 keV line thorium has characteristic gamma lines at 239, 583, and 911 keV. Figure A-17 shows a spectrum taken in a basement where slag was identified as present in the basement concrete. The spectrum exhibits a strong uranium spectrum with a small increase in the amount of thorium, based on the 2614 keV spectral line.

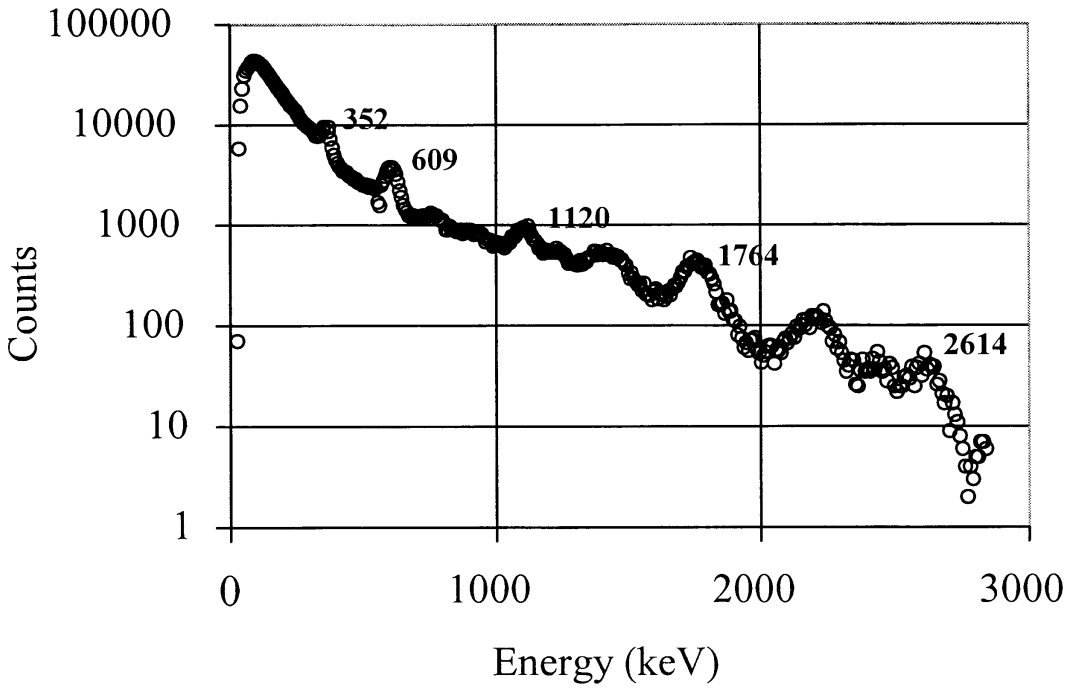


Figure A-17

Gamma Spectrum from a Basement Constructed of Concrete Containing Slag

Figure A-18 shows basement concrete that contains slag, but there is also a large gamma component from thorium as evidenced by the strong 2614 keV line.

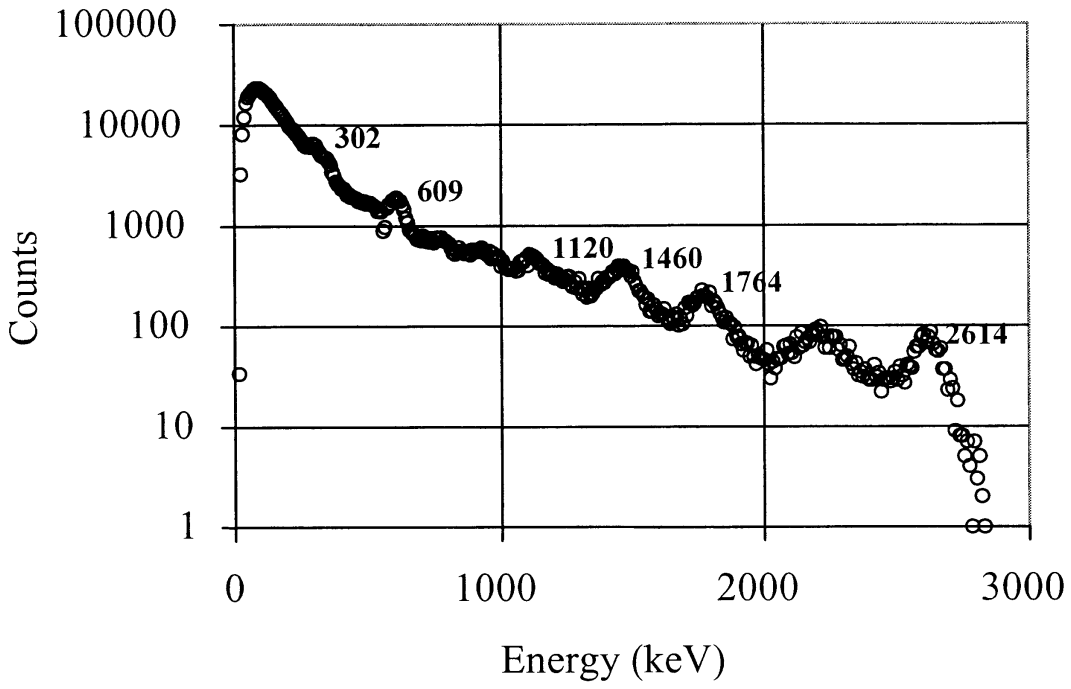


Figure A-18

Gamma Spectrum of Concrete Containing Slag and Exhibiting a Strong Thorium Spectrum

The figure also shows a clear potassium-40 line at 1460 keV and a peak at 302 keV that may be a combination of the uranium line at 352 keV and the thorium line at 239 keV.

At locations having dose rates greater than or equal to 20 μrem/h, gamma spectra were obtained to identify the radionuclides contributing to the external radiation. Spectral measurement locations for a specific residence or site were selected to be the point of maximum dose rate as determined by portable instrument surveys. The spectrometer was calibrated with a low-activity source containing natural thorium (Th-232 plus progeny). The spectral measurement sequence included 1) a preliminary 300 second measurement of the thorium check source to assure the general performance of the system; 2) a 600 second spectrum of the radiation field of interest; and 3) a 300 second remeasurement of the thorium check source to provide data for an energy calibration of the spectrometer system. Each of these spectral measurements was recorded and interpreted by computer evaluation of the spectra. The evaluation process included developing an energy calibration curve on the basis of the thorium source spectrum; identifying photopeaks in the site spectrum; establishing photopeak energies on the basis of the thorium calibration

curve; and determining the area (number of net photopeak counts) for the spectral peak at 1764 keV.

Spectra were initially obtained at five background locations and at five locations each with asphalt or concrete paving, having direct radiation levels in excess of 20 μrem/h. These spectra were analyzed for the 1764 keV peak area in the manner described above. Background and site counts were then plotted against normal probability and best-fit lines entered on the plot for the two data sets (refer to Figure A-19). The intersection of the two lines indicates the count rate, above which the number of counts present in the 1764 keV peak area is indicative of Ra-226, a member of the naturally occurring uranium decay series, at above-background levels. For this study, a photopeak area of 200 net counts for over a count time of 600 seconds indicates the presence of above-background concentrations of Ra-226 (and likely the uranium decay series).

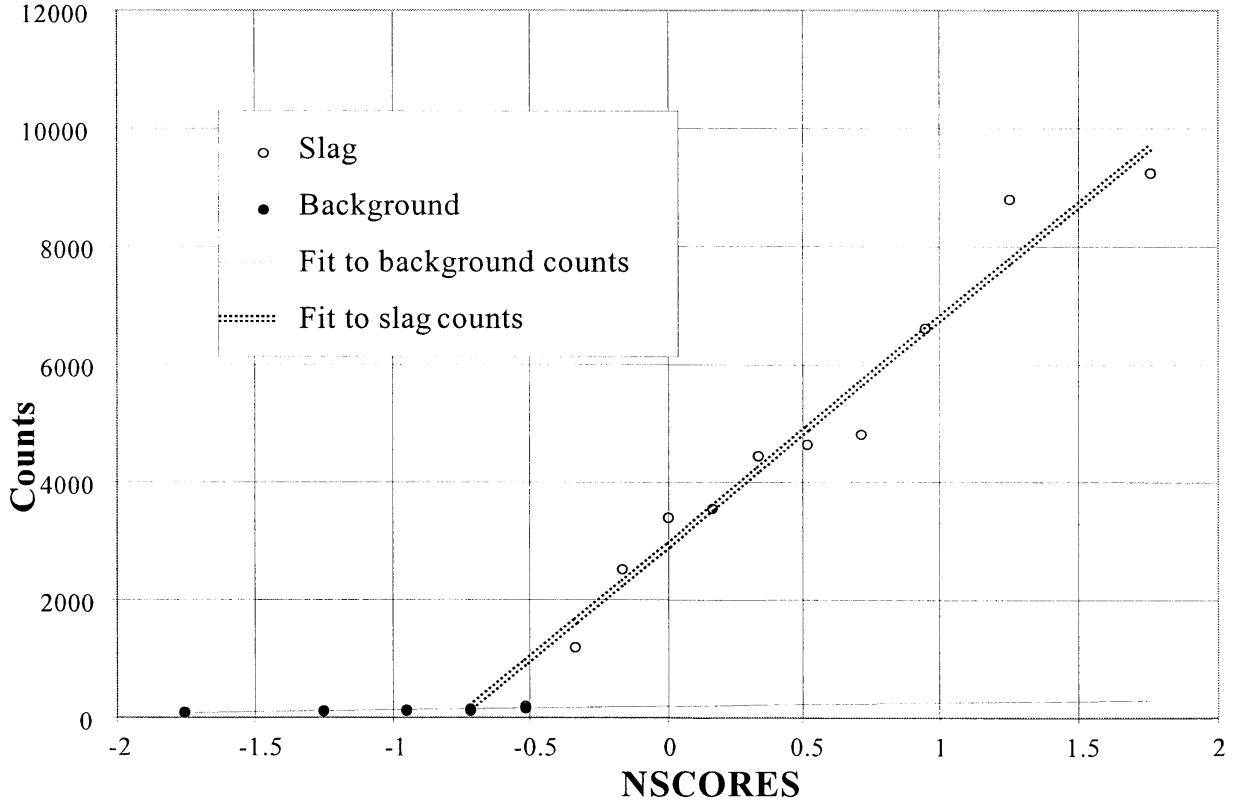


Figure 19

Relation of Counts in the 1764 keV Photpeak to Slag Content of Concrete

The area of the 1764 keV photopeak from a property of interest was compared with the decision-level photopeak area (200 net counts), determined from the probability plots. If the peak area was less than 200 counts, it was concluded that phosphate slag was not the source of elevated direct radiation. A peak area of greater than 200 net counts indicated that slag was the likely source of the direct radiation. For all properties that had direct radiation levels in excess of 20 μrem/h, the gamma spectral analysis identified the presence of phosphate slag.

A.4.5.2 Results

No results are reported separately under this topic, but are found under A.4.4.2.

A.4.6 Community Surveys

Slag was used throughout the region as construction gravel. Uses for the slag included loose surfacing material, railroad ballast, roadbed fill, backfill material, and aggregate in asphalt and concrete. An Exposure Study objective was to locate and inventory slag in the communities. The purpose of the inventory was to assist in assessing slag-related radiation exposures and for local agencies to ensure appropriate management of phosphorus slag during future construction and removal activities.

The extent of the use of slag had been indicated as a part of the Idaho Radionuclide Study conducted by the EPA. Aerial radiological surveys were conducted in June and July 1986 by the U.S. Department of Energy's Remote Sensing Laboratory, over the communities of Fort Hall, Pocatello/Chubbuck and Soda Springs and selected portions of the Fort Hall Reservation, using the Aerial Measurement System operated by EG&G Measurements, Inc. of Las Vegas Nevada (Berry 1987). The aerial survey produced maps comprising aerial photographs of the communities and the surrounding areas, overlain with gamma radiation measurement contours. The maps identified multiple areas in the communities with direct radiation generally above average background and additional smaller, isolated areas with direct radiation further elevated above the average background. For the purpose of planning the Community Surveys, it was presumed that all areas of elevated radiation contained slag.

Ground-level surveys of locations indicated as containing slag by the aerial survey showed that where slag was present, the aerial survey tended to average the radiation dose rate over a much broader area than the actual extent of slag. The ground surveys found that the dose rate was generally higher than indicated by the aerial survey but smaller in extent. The aerial maps of dose rate were particularly revealing as concerned the extent of slag use, but were of little value to producing an actual slag inventory.

The Exposure Study conducted radiological surveys to identify slag on public roads and in community facilities for the inventory of slag during the summers of 1996 and 1997. The initial scope of these surveys was established from the 1986 aerial radiological survey maps. Locations with elevated direct radiation levels (i.e., above 17 μR/h) were identified for ground survey. The identification of actual locations proved difficult. The tendency by the earlier aerial survey to broaden the area and average dose rate over the broader area was a major concern. The elapsed time since the aerial survey was a further concern, since considerable construction occurred in the interim. The scope of the ground surveys included most Community streets to ensure coverage of slag containing streets.

A.4.6.1 Materials and Methods

Access permission was obtained from local authorities for surveys of streets and other public property. Surveys were performed by driving and/or walking over the locations of interest while observing the response of a Bicron Micro Rem meter. Roads were initially surveyed from a moving vehicle; the vehicle speed was maintained at approximately 10 m/sec or less, with the survey instrument on the floorboard inside the vehicle (approximately 0.5 m above the road surface). Radiation measurements were recorded directly onto Community maps. Surveyors were observant of visible changes in road surface and sudden changes (>50 %) in dose rate. The vehicle speeds were reduced when such changes were noted and/or walkover surveys were used to assist in distinguishing boundaries of areas of elevated direct radiation. At locations where vehicle monitoring identified levels equal to or greater than 20 μrem/h, the vehicle was stopped and radiation levels were measured outside the vehicle at a height of 1 m above the road. All the paved roads in the three Communities – approximately 123 miles in Fort Hall, 260 miles in Pocatello/Chubbuck, and 26 miles in Soda Springs - were surveyed in this manner.

Manufacturer's specifications indicated that on a meter scale of "x 0.1" the Bicron Micro Rem meter display reaches 90 % of its final maximum value within < 15 seconds; this was empirically confirmed under field conditions. If an area of elevated direct radiation of 20 μrem/h was encountered, while traveling at a vehicle speed of 10 meters per second in a background radiation field of approximately 8 μrem/h, the instrument response would increase to > 50 % above background within a distance of approximately 10 meters. At this speed, the instrument response to such a radiation level would reach above 18 μrem within a distance of approximately 40 meters. Such significant changes in dose rate were observed to occur over distances of 50 meters or less, only at the boundaries of impacted and non-impacted street sections. These transition regions were surveyed on foot to identify those boundaries. It was determined by field experience that street surfaces of more than 20 meters in length, which exceeded 20 μrem/h, could be accurately identified from a slow moving vehicle. Many roads contained multiple

patches of varying size, shape and appearance. Most of such areas were too small or the radiation levels were too low to allow them to be identified by surveys from a moving vehicle.

A.4.6.2 Results

Table A-7 summarizes the results of the road survey in the three communities; miles of road having radiation levels in the ranges of < 20 μrem/h, 20 – 30 μrem/h, 31 - 40 μrem/h, and > 41 μrem/h are listed.

Table A-7

Distribution of Radiation Levels on Community Roads

Community	< 20 μrem/h	20 – 30 μrem/h	31 – 40 μrem/h	> 41 μrem/h
Pocatello/Chubbuck	196.2 miles	58.9 miles	4.6 miles	0.3 miles
Soda Springs	20 miles	3.1 miles	2.6 miles	0.3 miles
Fort Hall	88 miles	31.8 miles	3.2 miles	0 miles

The maximum levels measured on roads in the three communities were:

- Pocatello/Chubbuck, 45 μrem/h
- Soda Springs, 50 μrem/h
- Fort Hall, 35 μrem/h

Approximately one-fourth of the paved roads exhibited radiation levels equal to or greater than 20 μrem/h. The fractions in each community were 25.5 % in Pocatello/Chubbuck, 23.1 % in Soda Springs, and 28.5 % in Fort Hall. Compared with the results of the 1986 aerial survey, there appears to be a smaller portion of the roads with elevated radiation levels. This is likely due to a combination of attrition through routine resurfacing with non-slag material, application of surface sealer coats, and complete replacement of paving and paving base during various construction activities.

At the specific request of community officials, 2 municipal facilities were surveyed in Pocatello/Chubbuck, 18 public buildings and other facilities were surveyed in Soda Springs, and 17 public buildings were surveyed in Fort Hall. Surveys were performed by walking over the property while observing the response of a Bicron Micro Rem meter held at 1 m above the surface.

Of the 37 Community buildings and facilities surveyed, three had small areas of elevated direct radiation exceeding 20 μrem/h. These locations were the Road Maintenance Yard in Chubbuck and the airport and a school building in Soda Springs. The highest level measured at these locations was 45 μrem/h. All other locations surveyed were indistinguishable from background levels.

Visual identification of slag in paving or surface material was possible at most locations of elevated direct radiation. Gamma spectrometry was also performed at nine such street locations and at two locations at a road maintenance facility; this procedure confirmed phosphate slag as the source of elevated radiation at each of these locations. Screening Survey reports were provided to the responsible Community agencies when the source of elevated direct radiation above 20 μrem/h in public buildings and facilities could not be visually identified as phosphate slag. Follow-up Surveys were offered in all such cases to determine whether phosphate slag was the source of elevated radiation.

An inventory list of Community locations, identified by the survey as having locations of direct radiation levels equal to or greater than 20 μrem/h, was prepared and provided to the Idaho SDHD. Finally, reports, summarizing Community Survey activities and results, were prepared and provided to the Companies, Communities, SDHD, and EPA.

A.4.7 Radon Measurements

Earlier examinations of the level of radon in buildings that had slag in its construction material found no increase in radon due to the slag. Radon measurements were offered as a part of the Exposure Study to allow residents of the communities to fully examine their radiation exposure levels.

A.4.7.1 Materials and Methods

Charcoal radon test kits were used to measure radon levels in residences. Radon test kits were deployed as per vendor instructions. Two test kits were deployed for 2-4 days. One kit was deployed in the lowest living level and one in the main "live-in" area.

A.4.7.2 Results

Of the 1719 participants, 256 tested for radon. The distributions of results for the communities are shown in Figures A-20, A-21, and A-22. The EPA recommended action level for radon remediation is for concentrations greater than 4 pCi/L.

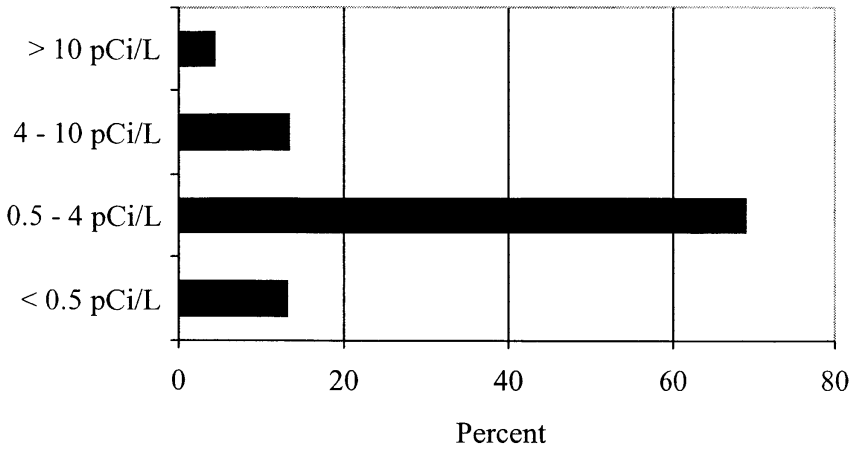


Figure A-20

Radon Concentrations in Pocatello, Shown as a Percent of Measurements

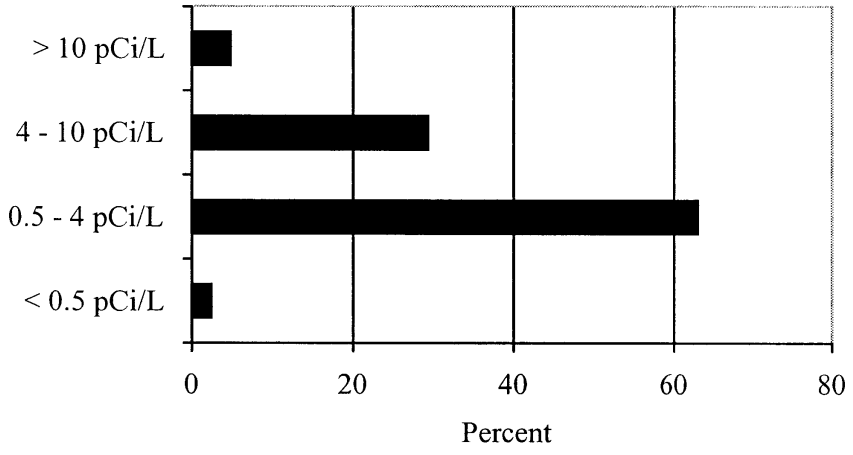


Figure A-21

Radon Concentrations in Soda Springs, Shown as a Percent of Measurements

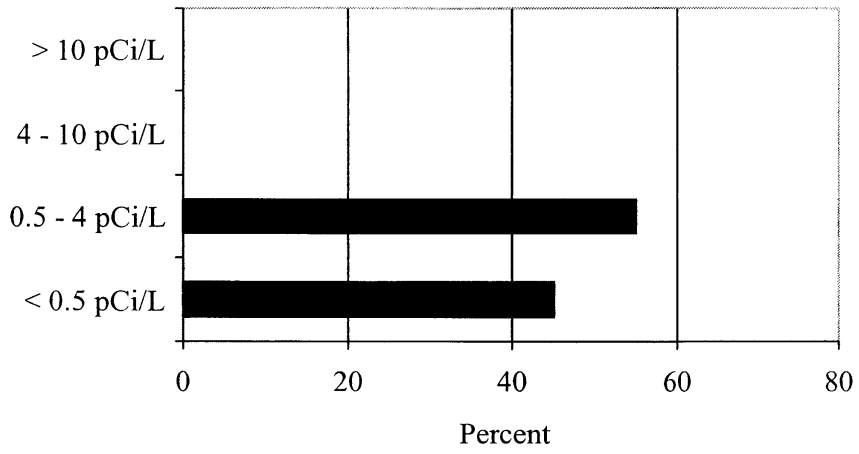


Figure A-22

Radon Concentrations in Fort Hall, Shown as a Percent of Measurements

The results show that no homes surveyed in Fort Hall were above the EPA action level. The number of homes above the action level was nearly 20% in Pocatello and 35% in Soda Springs. The small number of homes (7) that were measured for radon in Fort Hall means that the results are likely not representative of the entire community. Though a larger number of homes was measured in Soda Springs, the total number (24) is too small to state that there is a difference in the distribution of concentrations from Pocatello where 225 homes were measured.

The results for houses with slag as a construction material generally confirms the earlier result that slag does not contribute to indoor radon. The radon concentration by dose rate in dwellings that contain slag is shown in Figure A-23. The figure shows that 6 of the 11 measurements are at or below 4 pCi/L, which is approximately the same fraction as found in dwellings with no slag. The figure shows that there is no trend with increasing slag dose rate.

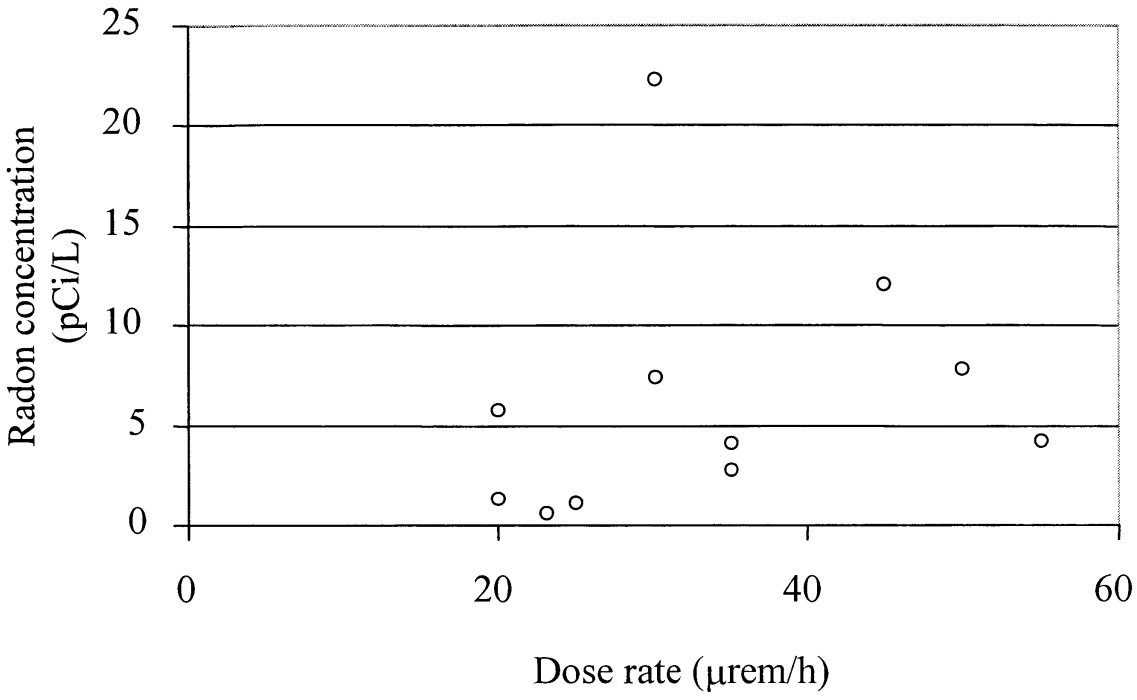


Figure A-23

Radon Concentration as a Function of Dose Rate in Houses Containing Slag

ATTACHMENT B

GRADED DECISION GUIDELINES

TABLE OF CONTENTS

B.1.0 INTRODUCTION

Graded Decision Guidelines (GDGs) were developed to help individuals interpret their radiation doses from slag as estimated by the Exposure Study and to determine what, if any, action should be taken to reduce the dose. These guidelines were developed by the Technical Work Group (TWG) and were based on technical and economical factors associated with exposure to slag.

B.1.1 Process

The GDG and Exposure Study processes are given in more detail below. The flow chart of Figure B-1 illustrates the processes and each "box" in the chart is described in a numbered list corresponding to the numbers on the flow chart (Section IV). The recommended processes for collecting data to support the GDGs are included and discussed briefly for clarity where appropriate.

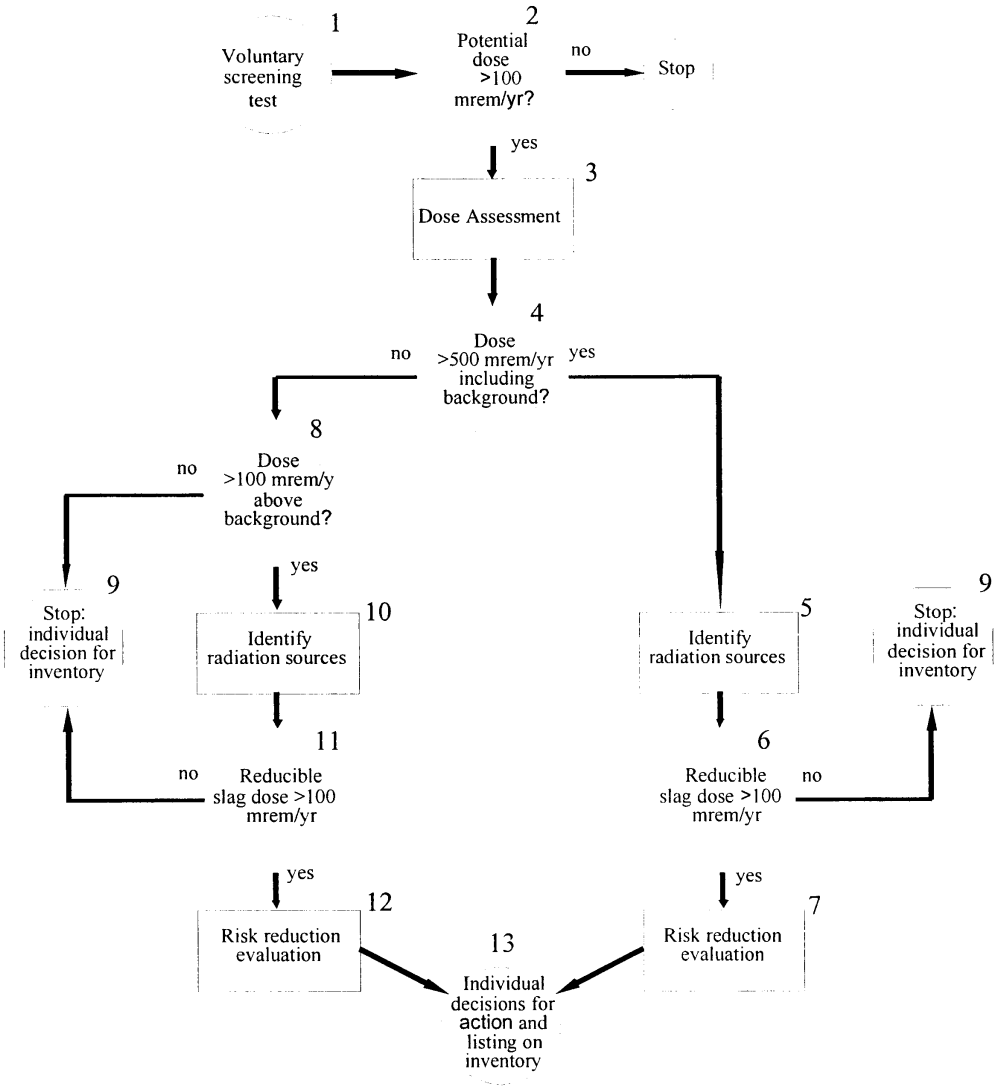


Figure B-1

Exposure Study and Graded Decision Guidelines Flow Diagram

B.1.1.1 Details of the Process of the Graded Decision Guidelines

The numbers below correspond to the numbered blocks on the flow chart of Figure B-1:

1 Residents in the designated areas are offered an opportunity to participate in a screen test for exposure rate.

Residents are offered screening with a portable survey instrument (meter). If accepted, the dwelling is surveyed with a sensitive meter capable of measuring in the μrem/h range. As a practical matter, if the exposure rate is less than 20 μrem/h, it will be assumed that there is no potential for residents to equal or exceed 100 mrem per year above background.

For residents wishing to enter the process but who do not wish to allow technicians into their homes to perform screening with a meter, a dose assessment with TLD is offered (item 3).

2 If the exposure rate in and around the dwelling does not have the potential to cause individual dose to equal or exceed 100 mrem per year above background, or if the residents decline a dose assessment, the process stops. If the exposure rate in and around the dwelling has the potential to cause residents to equal or exceed 100 mrem per year above background, a dose assessment is offered (item 3).

3 A dose assessment is different from a screening test in that actual dose to the residents of the dwelling is assessed rather than the exposure rate in the dwelling. Options available for dose assessment include TLDs and survey meters.

4 If the assessed dose exceeds 500 mrem per year, including natural background from external sources, a survey to identify radiation sources is offered.

If the resident accepts, the survey to identify radiation sources is performed (item 5).

If the resident declines the survey to identify radiation sources, the process stops. If the property owner wishes the property to be listed on an inventory, this is done (item 9).

5 A survey to identify radiation sources is performed in an effort to determine the type and magnitude of the sources leading to the dose exceeding 500 mrem including background. Various techniques are available -including exposure rate measurement, visual and chemical identification of slag and gamma ray spectrometry. These methods are detailed in the Exposure Study Work Plan.

6 Based upon item 5 above, reducible slag dose is determined. Reducible dose comes from slag in dwellings. Examples of sources of dose that would <u>not</u> be considered reducible

slag dose are dose from non-slag radioactive building materials in dwellings and dose received occupationally from slag.

If the survey to identify radiation sources indicates that reducible slag dose equals or exceeds 100 mrem per year, action is recommended (item 7).

If the reducible slag dose does not equal or exceed 100 mrem, the process stops. If the property owner wishes the property to be listed on an inventory, this is done (item 9).

7 A list of possible actions for doses above 500 mrem including background is described in Section B.2.3 of this document.

8 If the assessed dose is less than 100 mrem per year above background, the process stops. If the property owner wishes the property to be listed on an inventory, this is done (item 9). If the dose exceeds 100 mrem per year above background, then a survey to identify radiation sources is offered (item 10).

If the resident accepts, the survey to identify radiation sources is performed (item 10).

If the resident declines a survey to identify radiation sources, the process stops. If the property owner wishes the property to be listed on an inventory, this is done (item 9).

9 Whenever a structure that contains slag is eliminated from further consideration for action, or slag remains after action is taken, listing of the structure on the slag inventory is offered to the owner. The permission of the owner (for private property) or the responsible public official (for public property) is required prior to listing.

10 A survey to identify radiation sources is performed in an effort to determine the type and magnitude of the sources leading to the dose exceeding 100 mrem above background. Various techniques are available including exposure rate measurement, visual and chemical identification of slag and gamma ray spectroscopy. These methods are detailed in the Exposure Study Work Plan.

11 Based upon item 10 above, reducible slag dose is determined.

If the survey to identify radiation sources indicates the reducible dose due to slag equals or exceeds 100 mrem per year, risk reduction evaluation is offered (item 12).

If the reducible slag dose does not equal or exceed 100 mrem, the process stops. If the property owner wishes the property to be listed on an inventory, this is done (item 9).

12 A "menu" of possible risk reduction options for doses in the range of 100 mrem per year above background to 500 mrem per year including background is available and is described in Section B.2.2.

13 The affected individual makes the final decision on action to be taken. If slag remains after action is taken, permission of the owner (for private property) or the responsible public official (for public property) would be required prior to listing on the inventory.

B.2.0 MENU OF OPTIONS FOR RISK REDUCTION ACTIONS UNDER THE GRADED DECISION GUIDELINES

B.2.1 General Options

It is recommended that actions be considered to reduce exposure if a reduction of at least 100 mrem per year from slag can be achieved. The potential options identified for risk reduction actions are as follows:

- Education, counseling, and attrition
- Use modification
- Remodeling, shielding, and/or partial removal
- Additional living space

These options are defined in Section B.2.4 below. Some options are more difficult, time consuming, and costly than others. The options listed start with the easiest and least expensive and range up to the most difficult and costly. In general, simpler and easier options would be more appropriate for lower doses (near 100 mrem above background). More difficult options would be more appropriate at higher doses. The options on the risk reduction "menu" are not mutually exclusive and several or all could be used if needed. Other actions may be possible.

B.2.2 Menu for 100 mrem per Year Above Background to 500 mrem per Year Including Background

Since decisions regarding actions are up to the individual and involve specific and detailed evaluation of the home, the TWG considered whether the ranking of options within a "menu" provided sufficient guidance to individuals. The TWG also considered whether sufficient data

were available to provide a basis for recommending that particular options from a "menu" be associated with specific dose levels. A majority of the TWG agreed that some additional detail was needed to show dose levels for which the various options could apply. These dose levels are intended as recommended guidance which is likely to be appropriate in most cases.

The following guidelines for risk reduction recommendations are intended to be general guidelines that are appropriate for the majority of people who are considering options to reduce their dose due to slag. These guidelines are not intended to restrict individual choice in reducing risk, but it should be understood that funds may not be available to address options outside these guidelines.

Cost effective risk reduction options should be considered on a case-by-case basis and each homeowner should have an opportunity to discuss their specific concerns with a radiation risk professional.

In the range from 100 mrem above background to 500 mrem including background, the guidance in Table B-1 is recommended by the TWG to aid individuals in selecting options if a reduction of at least 100 mrem per year from slag can be achieved.

Table B-1

Summary of Guidelines for Risk Reduction Actions for the Range of 100 mrem per Year to 500 mrem per Year including Background

Dose range (mrem per year)	Action
More than 100 above background	Education, counseling, and attrition
More than 200 above background	Above actions plus: use modification
More than 300 above background up to 500 including background	Above actions plus: remodeling, shielding, and/or partial removal

B.2.3 Options for Greater than 500 mrem per Year including Background

For doses greater than 500 mrem per year including background, the TWG recommends that all options from the menu plus "additional living space" be considered for risk reduction if a reduction of at least 100 mrem per year from slag can be achieved. The options for greater than 500 mrem per year including background are not mutually exclusive and several could be used.

B.2.4 Explanations of Action Term

1. Education/ Counseling - *Applicable dose range: more than 100 mrem above background*

   Education and counseling would include a balanced discussion of radiation risk and radiation protective measures. Commonly asked questions would be anticipated and answered. This would include exploring the range of possible actions that could be taken to reduce an individual's dose such as possible changes in use patterns (for example, spend less time in basement by moving primary living areas from basement to upper floors).

2. Attrition - *Applicable dose range: more than 100 mrem above background*

   Attrition means removing slag once a structure's useful life has ended. Attrition includes 1) listing the location of the slag that triggered a dose over a Graded Decision Guideline level, 2) tracking the disposition of the material, and 3) eventually managing the disposal of the material. For example, once a structure has been listed on the inventory and is scheduled for demolition, the slag matrix would be picked up and removed to a disposal location. If an owner agreed to attrition, the owner would be automatically agreeing to the listing, tracking and disposal process.

3. Use modification - *Applicable dose range: more than 200 mrem above background*

   Use modification refers to actively facilitating changes in home use that would reduce the amount of time that individuals spend in a space where slag significantly contributes to individual dose. An example is converting a basement bedroom to an alternative use for which individuals spend less time in the room.

4. Remodeling / shielding / partial removal - *Applicable dose range: more than 300 mrem above background*

   Remodeling includes altering the design of a room to replace an existing slag-containing space that contributes significantly to individual dose. Or it may be feasible to remove the slag only in the area of elevated exposure rate. For example the shielding or removal of one wall in a high exposure rate area may reduce most of the individual dose in that particular area.

5. Additional living space - *Applicable dose range: more than* 500 *mrem including background*

   This option would provide additional living space to eliminate current home use patterns that contribute to an elevated individual dose. For example building a new bedroom or other addition to replace a basement bedroom would reduce dose.

ATTACHMENT C

INSTRUMENTATION

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The Exposure Study employed techniques of exposure rate, dose rate, dose by TLD, gamma spectrometry, and statistical difference from background to assign dose due to slag. The instruments are described in this attachment.

C.1.0 EXPOSURE RATE

Exposure rate was measured using a pressurized ionization chamber or PIC. The PIC is a transportable, semi-permanent device for measuring ionizing radiation exposure rate. The PIC has been extensively tested around the world and is generally excepted as the standard for human exposure rate.

The PIC is a two-unit device comprising the ion chamber unit and the electronics unit. Both units and connecting cables are designed for long-term outdoor installation. The ion chamber is a 16 cm diameter steel sphere filled with argon at 300 psi. The electronics package supplies the voltage for the ion chamber and processes the ion chamber signal to produce units of exposure rate. The PIC employed in the Exposure Study was a RSS-112 Reuter-Stokes Environmental Monitoring System. A photograph of the PIC is shown in Figure C-1.

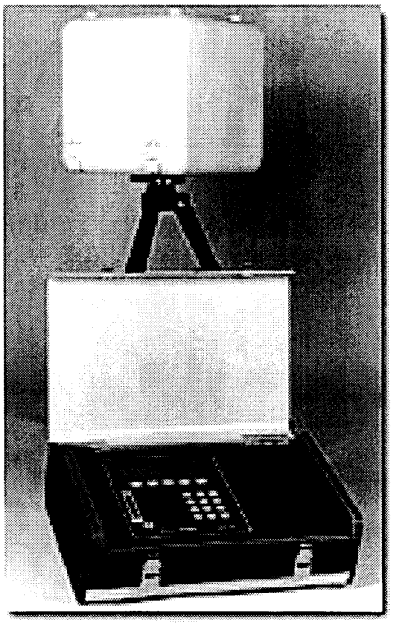

Figure C-1

Pressurized Ionization Chamber (PIC)
Showing Ion Chamber Unit (on Tripod) and Electronics Unit

The PIC can be operated in several modes: exposure rate, integrated exposure, and recording. Measurements for the Exposure Study were made in the integrate mode. Twelve successive 5-second integrations within 5% of the average exposure were accumulated for each exposure measurement to ensure adequate statistics.

Dose rate, rather than exposure rate, was necessary for calculating dose for the Exposure Study. Dose rate in μrem/h was obtained from the PIC measurements by multiplying μR/h by 0.95 when comparing PIC exposure rate to dose rate measurements using the μrem/h meter or TLDs.

C.2.0 DOSE RATE

Dose rate was measured using portable microrem meters. The instrument used for dose rate was the Bicron Micro Rem meter (microrem meter). This instrument measures scintillations from a tissue equivalent plastic and yields dose response over a broad energy range. The microrem meter compares very well to PIC measurements and the instrument is lightweight and much easier to use than the PIC. The microrem meter is shown in Figure C-2.

Figure C-2

Bicron Micro Rem meter

C.3.0 QUALITY CONTROL

All instruments used in the Exposure Study had a valid, traceable calibration to either Cs-137 or Co-60 within 12 months of any measurement taken for the study. A daily instrument response test was performed for all instruments to a check source and the result was placed in the instrument file on a weekly basis. Source checks were performed each day measurements for the study were made. The source checks were performed prior to and at the completion of the measurements made on that day. The same source that was used to establish the instrument response was used as the check source. All source checks were recorded in the daily instrument log.

The microrem meter was periodically compared to the PIC. The comparison was made at known exposure locations established for the TLD program. Exposure rates at the

background locations were measured with the microrem meters and the PIC. It was expected that the microrem meter readings would equal 0.95 times the PIC readings. Results of the measurements are shown in Table C-1.

Table C-1

Comparison of the Microrem Meters (listed by serial numbers) and the PIC (All Values in μrem/h)

	July 1996				November 1996				April 1997			March 1998			
Location	PIC	B864M	B846M	B294W	PIC	B844M	B846M	B294M	PIC	B864M	B294W	PIC	B864M	B294W	B844M
1	11.8	11	11	11	11.4	10	10	8							
2	30.6	25	30	25											
3	41.9	40	40	40	41.3	40	45	65	43.7	35	35				
4	23.9	25	25	20	20	20	25	20	26.6	19	19				
5	59.7	60	55	50	57	55	55	50	58.9	45	42				
6	11.4	10	9	10	10.5	10	10	10	11.4	8.5	8.2	13.8	8	9	10
7	16.2	14	16	15	15.5	14	18	12	17.1	13.2	13.5	18.7	15	17	14
8	21.6	20	19	18	19.4	20	20	17.5	22.8	15	15.5	22.1	16	14	17
9	35.8	35	35	32	31.4	35	35	30	36.1	28	28	34.4	25	30	30
10	61.7	62	57	58											
11									28.5	21	20				
12									61.3	52	48				
13									13.3	7.5	7				
14												42.8	30	35	40
15												42.9	30	35	35
16												15.9	12	11	13

Figure C-3 is a plot of these data.

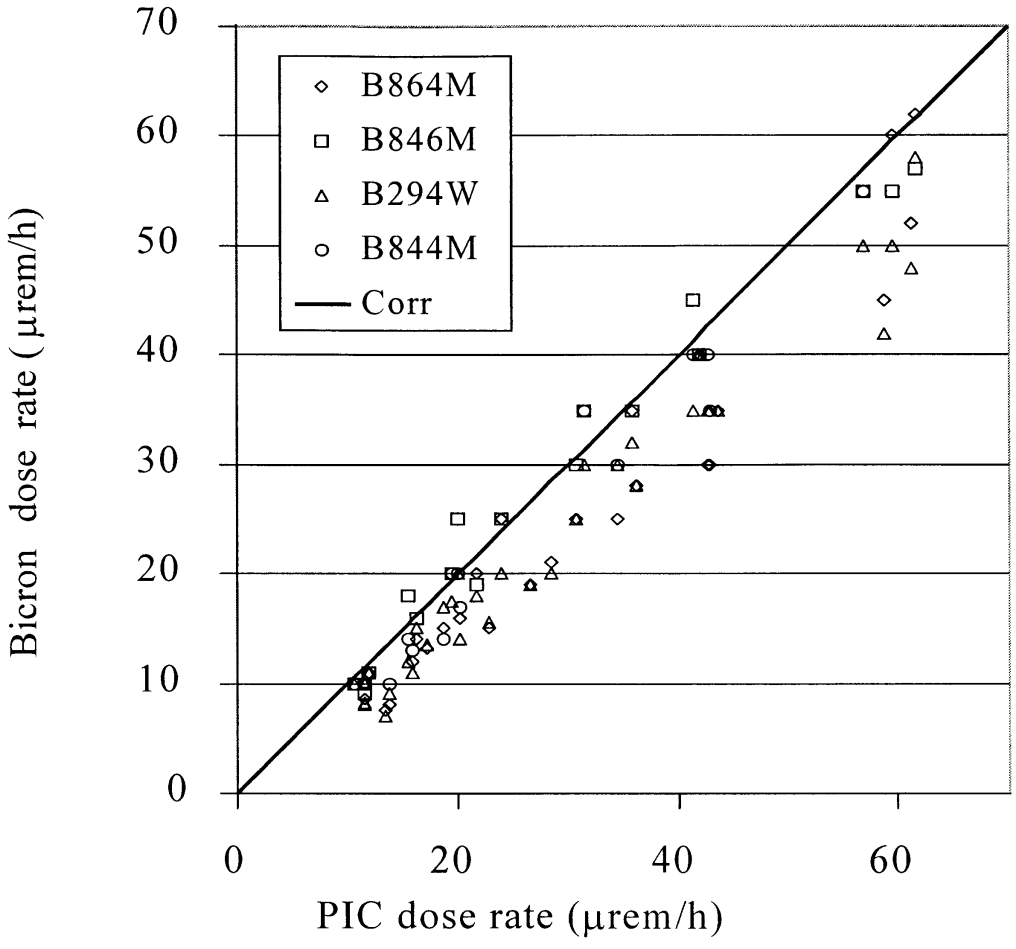

Figure C-3

Bicron Dose Rate Measurements for Four Instruments (listed by serial numbers) Compared to the PIC Dose Rate as 0.95 Times the µR/h Result and a Line Indicating Correspondence Between the Methods

The microrem data lies below a diagonal line that would represent correspondence of the two methods. Regression of the summed microrem results against the expected dose rate from the PIC resulted in

$$Bicron(\mu rem/h) = -1.5 + 0.92 * PIC(\mu rem/h)$$

Eq. C-1

The microrem meters were low by 2.3 μrem/h at 10 μrem/h and 10 μrem/h at 100 μrem/h, assuming the PIC is correct after converting from μR/h to μrem/h. Nevertheless, although the Bicron instruments tended to slightly underestimate the PIC dose rates, the results were well within experimental error. Any differences between the two techniques had little to no effect on the evaluations performed for the Exposure Study.

C.4.0 DOSE BY TLD

Dose by TLD was measured with Landauer X9 Environmental/Low Level Dosimeters. These dosimeters use two aluminum oxide chips in a small plastic holder. The X9 has a reported sensitivity of 0.1 mrem. The TLD package was designed as a key fob to be worn on a key ring that was normally kept on the person. An example of the Landauer X9 as used in this study is shown in Figure C-4 and is compared to the size of a dime.

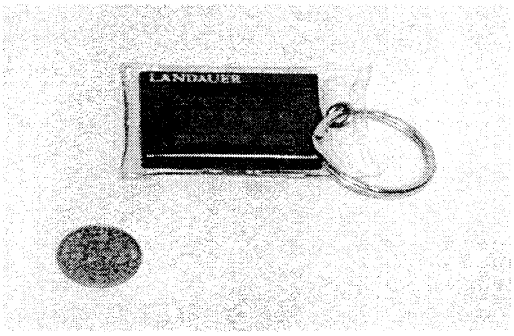

Figure C-4

Launder X9 TLD

C.4.1 Known Exposure and Known Exposure Duplicates

TLDs from each set of TLDs received from the vendor were subjected to known exposures as part of the quality assurance (QA) program. TLDs were drawn from each set and exposed to a known dose rate field for a predetermined time. There were 4 known exposure locations at the FMC plant in Pocatello where the dose rate was known and TLDs were placed for known exposure evaluations. These locations were selected to have exposure rates of approximately 5, 10, 25, and 50 μrem/h above background. Exposure rates at these locations were measured with a PIC and the PIC value for dose rate was used as the known dose rate. This process also allowed comparison of the TLDs to the PIC. Twenty-six TLDs were initially placed in a sealed container at each location and 2 were removed approximately every 21 days (1 measurement and 1 duplicate) and

returned to the shield until sent to the vendor for analysis. The results of the TLD data, compared to PIC measurements (in µrem/h) are presented in Table C-2.

Table C-2

Known Exposure TLDs Compared to PIC Measurements

PIC Dose Rate (µrem/h)	TLD Dose Rate Mean ± 2 Sigma (µrem/h)	Relative Percent Difference of TLD Mean from PIC	Relative Percent Difference from TLD Mean
15.9	18.4 ± 3.2	15.8	-23.6 to 25.1
20.5	21.3 ± 4.6	4.1	-34.0 to 23.3
33.6	38.3 ± 4.6	14.1	-8.6 to 14.3
61.7	73.3 ± 8.6	18.8	-18.5 to 8.7

TLDs generally indicate a higher dose rate than the PIC. The individual TLDs range generally less than ± 30% of the TLD mean, which is considered acceptable for environmental measurements. The TLD results for each location were normally distributed as the NSCORE plot of Figure C-5 shows.

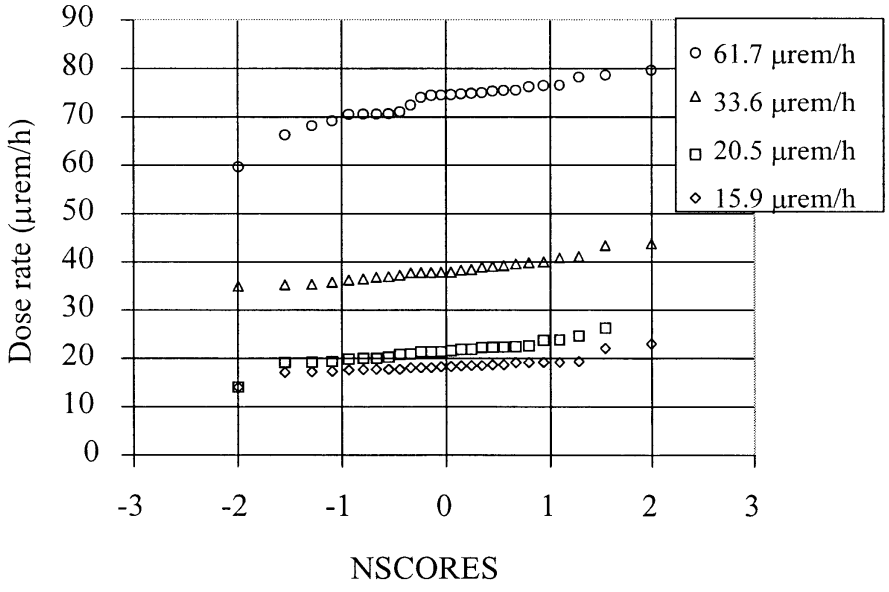

Figure C-5

NSCORE Plot of Known Exposure for TLDs Placed at Different Dose Rate Locations

Figure C-6 is a plot of the uncorrected vendor dose for the time at the known exposure location. The slopes of this plot are the dose rates at the known locations. All of the curves intercept at the same point, 55 mrem.

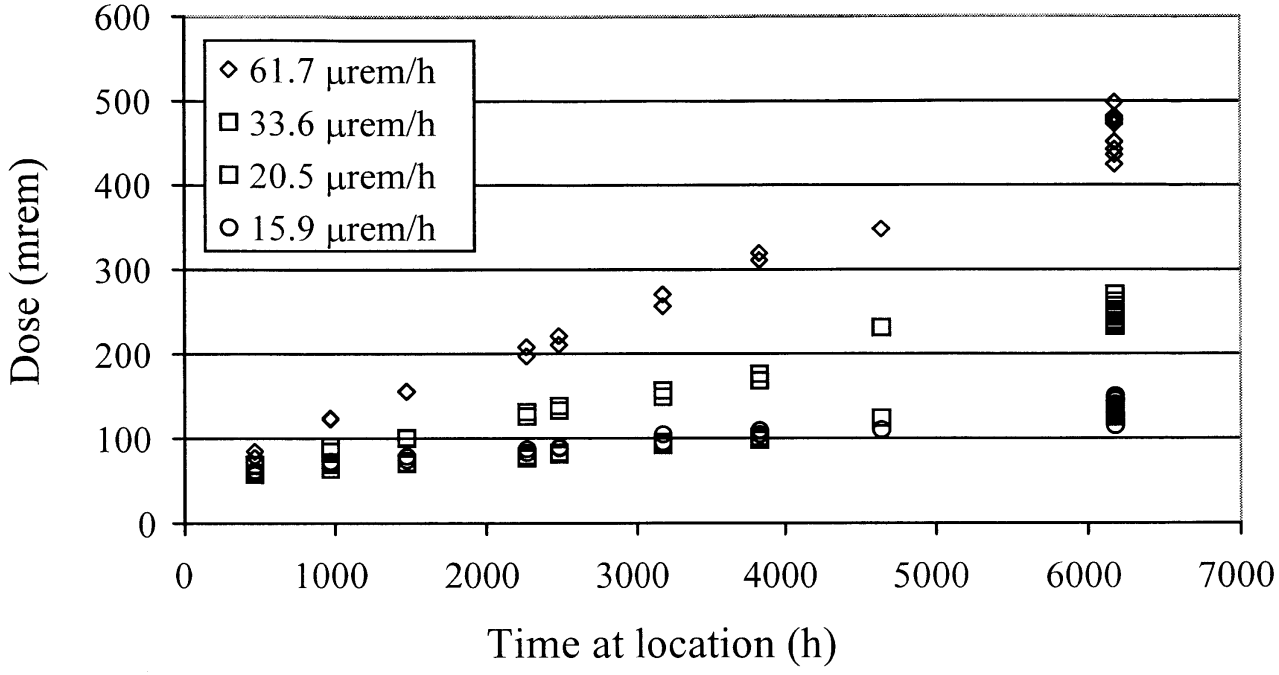

Figure C-6

Dose with Time at Known Exposure Locations as Measured by TLDs Placed at Different Dose Rate Locations and Exposed for Different Times

The intercept of Figure C-6 is the sum of the transit dose and the storage dose. The storage dose is the dose that a TLD would have received if it had been in the shield for the full time of the experiment. The slope is, therefore, the dose rate of the location in excess of the shield dose rate. All the dose rates estimated by the slope would be expected to be less than the dose rate estimate by the PIC because the PIC dose rate includes the background dose rate. The measured slopes of the doses at the known exposure locations is compared to the PIC measurements in Table C-3.

Table C-3

Slopes of Dose of Known Exposure TLDs Compared to PIC Measurements

PIC Dose Rate (μrem/h)	TLD Dose Rate Slope Mean ± 2 Sigma (μrem/h)	Relative Percent Difference of TLD Slope Mean from PIC
15.9	12.2 ± 2.7	23.3
20.5	13.3 ± 5.8	35.1
33.6	30.9 ± 6.9	8.0
61.7	65 ± 14.6	-6.8

The differences from the PIC measurements in several cases and the range of TLD response raised concerns that the known exposure TLDs at the slag locations might be influenced by factors that produced a non-constant dose rate. Those factors were change in ground cover conditions, snow and rain, change in dose rate from relocation of source material, and inadvertent tampering. (One container of TLDs was 'found' by a worker and taken to his supervisor.) To ensure a known exposure rate for subsequent sets of TLDs, the known exposure TLDs were exposed to a calibrated Cs-137 source for a sufficient time to deliver an exposure of 30 mR (28.5 mrem). The results of two sets of exposures of 9 TLDs each are shown in Table C-4.

Table C-4

TLD Known Exposure to Cs-137

TLD Dose (mrem)	Relative Percent Difference from Delivered Dose
18.6	-34.6
25.6	-10.0
26.0	-8.8
27.5	-3.6
27.8	-2.5
27.9	-2.2
27.9	-2.0
29.5	3.6
29.7	4.3
30.1	5.6
30.2	5.9
31.4	10.2
31.5	10.4
31.8	11.6
31.9	11.8
32.0	12.4
33.3	16.7
38.0	33.2

The average TLD dose in Table C-4 was 29.5 ± 8 mrem when the delivered dose was 28.5 mrem. The distribution of doses from the known Cs-137 exposure is shown in Figure C-7.

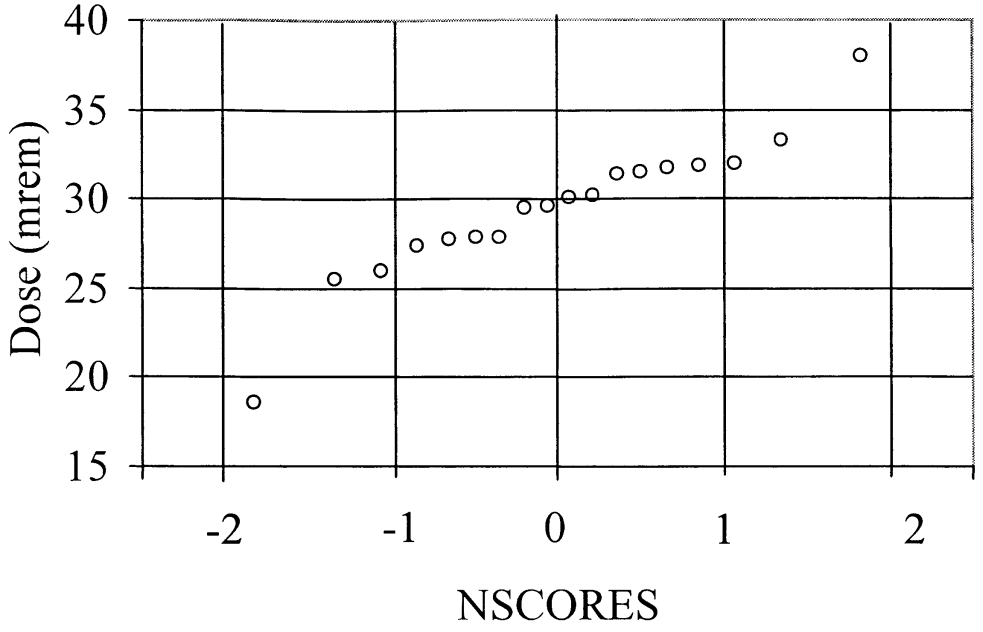

Figure C-7

Distribution of Dose by TLD Exposed to Cs-137

The distribution in Figure C-7 is acceptably normal. The range of doses is not the result of lack of control of the TLDs but is the distribution of the response of the individual TLDs.

C.5.0 GAMMA SPECTROMETRY

Gamma spectrometry was used to examine the gamma spectrum from suspected slag-containing material to determine if the gamma spectrum was consistent with radium in equilibrium with its progeny. The radium spectrum was indicative of the possible presence of slag. The radium spectrum was part of the process to identify slag as the source of elevated dose rate. An Aptec, Inc. Odyssey 5, portable gamma spectrometer was used to acquire the spectrum. The gamma detector was a 3-inch x 3-inch NaI crystal coupled to a photomultiplier tube. The Odyssey 5 electronics and analyzer unit is shown in Figure C-8.

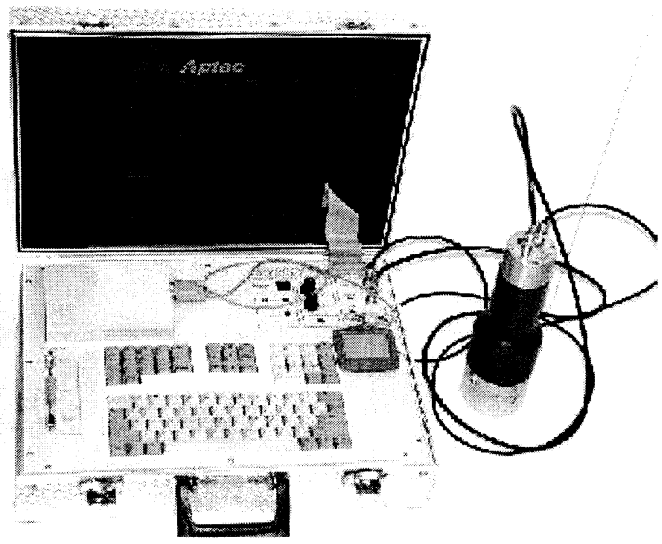

Figure C-8

Odyssey 5 Spectrum Analyzer

A gamma spectrum was acquired for 10 minutes at locations exhibiting greater than 20 μrem/h.