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Formerly Utilized MED/AEC Sites Remedial Action Program

**Radiological Survey of the Pennsylvania Railroad Landfill
Site, Burrell Township, Pennsylvania**

February 1979

Final Report

Prepared for

U.S. Department of Energy
Assistant Secretary for Environment
Division of Environmental Control Technology

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U.S. Department of Energy
Assistant Secretary for Environment
Division of Environmental Control Technology
Washington, D.C. 20545

Under Contract No. W-7405-ENG-26

By the
Oak Ridge National Laboratory
Oak Ridge, Tennessee 37830

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1. The purpose of this report is to provide a summary of the results of the research conducted by the author. The research was conducted in order to determine the effect of the independent variable on the dependent variable. The results of the research are presented in the following sections.

2. The first section of the report is a review of the literature. This section provides a summary of the research that has been conducted in this area. The second section of the report is a description of the methodology used in the research. This section provides a detailed description of the procedures used to collect and analyze the data.

3. The third section of the report is a presentation of the results of the research. This section includes a table of the data and a discussion of the findings. The fourth section of the report is a conclusion. This section summarizes the results of the research and provides recommendations for future research.

4. The fifth section of the report is a list of references. This section provides a list of the sources of information used in the research. The sixth section of the report is an appendix. This section provides additional information that is related to the research.

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PREFACE

This series of reports results from a program initiated in 1974 by the Atomic Energy Commission (AEC) for determination of the condition of sites formerly utilized by the Manhattan Engineer District (MED) and the AEC for work involving the handling of radioactive materials. Since the early 1940's, the control of over 100 sites that were no longer required for nuclear programs has been returned to private industry or the public for unrestricted use. A search of MED and AEC records indicated that for some of these sites, documentation was insufficient to determine whether or not the decontamination work done at the time nuclear activities ceased is adequate by current guidelines.

This report contains the results of a survey of the current radiological condition of the Pennsylvania Railroad Landfill Site, Burrell Township, Pennsylvania. Based upon the findings of the survey, there are low levels of radioactivity at spotty locations in this landfill and some type of remedial measures should be considered to preclude any future concern of inadvertent radiation exposure to people.

The work reported in this document was conducted by the following members of the Health and Safety Research Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee:

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RADIOLOGICAL SURVEY OF THE PENNSYLVANIA RAILROAD LANDFILL SITE
BURRELL TOWNSHIP, PENNSYLVANIA

ABSTRACT

A radiological survey was conducted at the Pennsylvania Railroad Landfill Site in Burrell Township, Pennsylvania. In 1956 and 1957, approximately 11,600 tons of radioactive material was dumped at this site and was apparently scattered over an area of less than 10 acres. The survey was undertaken to determine the location and quantities of radioactive materials on the site and to determine the extent of movement of radioactive substances to off-site locations by natural means such as surface run-off and atmospheric transport. The survey included measurement of the following: external gamma radiation at 1 m above the surface and at the surface throughout the site; beta-gamma dose rates at 1 cm from the surface throughout the site; concentrations of ^{226}Ra and ^{238}U in surface and subsurface soil on the site; concentrations of ^{210}Pb , ^{226}Ra , ^{230}Th , and ^{238}U in subsurface water on the site and in surface water on and near the site; and the extent of atmospheric transport of ^{222}Rn and progeny from the site. The general location of the residues transported to the site, except possibly small, scattered quantities of materials, was determined from this survey. In some areas on the site,

beta-gamma dose rates at 1 cm from the surface were above pertinent guidelines. Analyses of sediment from water samples taken from drainage areas near the site indicate that some radioactive material is being carried from the site by surface run-off. Results of this survey indicate that there is no significant atmospheric transport of ^{222}Rn from the site.

INTRODUCTION

At the request of the Department of Energy (DOE), a radiological survey was conducted at the Pennsylvania Railroad Landfill Site, located approximately one mile southeast of Blairsville, Pennsylvania (see Fig. 1). This property, owned by the Penn Central Transportation Company, Properties Division, lies between the Conemaugh River and the mainline tracks of Penn Central (see Figs. 1 and 2).

During the period of October 1956, through January 1957, an estimated 11,600 tons¹ of radioactive material was shipped by rail from the Vitro Corporation's uranium processing plant in Canonsburg, Pennsylvania, and was dumped on the site. Records² indicate that the material contained approximately 6,000 tons (dry weight) of waste residues containing an average 0.097% U_3O_8 by weight. The uranium (approximately 6 tons of U_3O_8) was classified as "unrecoverable material-measured." The wet weight of the residues was estimated to be 10,000 tons and since the material was shipped wet, it appears that approximately 1600 tons of possibly nonradioactive materials were mixed with the radioactive materials during loading. The waste residues were generated under Atomic Energy Commission (AEC) contract AT-(30-1)-1683 and were comprised

of 130-H pitchblende (22 tons), Q-55 pitchblende (23 tons), 306 residues (76 tons), carbonate cake BFC-6 and S-109 (1350 tons), and calcium fluoride and magnesium fluoride (4,500 tons).²

The area where the residues were dumped was previously a portion of the Conemaugh River bed, created when the river was diverted approximately 500 ft to the south several years earlier. Photographs provided in Appendix V show the site and unloading operations at approximately the time the residues were dumped. Records² indicate that this site was chosen, in part, because the dumping site and scattering technique used in unloading from the railroad cars would cause the material to be widely dispersed and intermixed with large volumes of nonradioactive wastes. Furthermore, it was thought that the material would be confined in a large chasm approximately 30 or 40 ft deep. There were, and still are, no public thoroughfare passes through the site or in its immediate vicinity, other than the railroad. The nearest dwelling is approximately 500 ft from the site. There are probably a few persons, railroad workers or hunters, for example, who may be on the site occasionally.

On April 17, 1963, a radiological survey of the site was conducted by officials of the state of Pennsylvania.³ Area monitoring with a Geiger-Mueller survey meter held near the surface indicated that "the cover over the depleted uranium ore wastes was not of uniform depth throughout and (radiation) levels in excess of background were noted at several spots."³

The present radiological survey was conducted during the period of November 11 through December 9, 1977, by seven members of the Health and Safety Research Division of the Oak Ridge National Laboratory. The survey included measurements of the following:

- 1) beta-gamma dose rates at 1 cm from the surface, and external gamma radiation levels at the surface and at 1 m above the surface, throughout the site,
- 2) concentrations of ^{226}Ra and ^{238}U in surface and subsurface soil on the site,
- 3) concentrations of ^{226}Ra , ^{238}U , ^{230}Th , and ^{210}Pb in surface and subsurface water on the site,
- 4) gamma radiation levels at various depths in auger holes drilled on the site, as a means of estimating the ^{226}Ra concentrations at these locations,
- 5) concentrations of radon and daughters in air on and near the site.

In this report, "site" refers to the area shown in Fig. 1 as the land mass bounded on the north by the Penn Central Main Railroad, and on the other three sides by a heavy black line. The gridded area shown in Fig. 2 should not be interpreted as including the entire site. Rather, this area is that part of the site where a more detailed survey was considered necessary because of elevated radiation levels or historical information.

SURVEY METHODS

Instrumentation

Measurement of beta-gamma dose rates and external gamma radiation levels

Beta-gamma dose rates were measured with Geiger-Mueller (G-M) survey meters described in Appendix I. The meters were calibrated at Oak Ridge National Laboratory (ORNL) using sealed isotopic sources and by comparison

with a Victoreen Model 440 portable ionization chamber. It was determined that, for surfaces contaminated with ^{226}Ra in approximate equilibrium with ^{238}U and other radionuclides in the ^{238}U chain, an open-window reading of 2000 cpm is equivalent to approximately 1 mrad/hr.

Beta radiation cannot penetrate the closed-window on the G-M probe; hence, only gamma radiation levels can be measured with the window closed. A conversion factor of 3200 cpm = 1 mR/hr for gamma radiation was determined at ORNL using a ^{226}Ra source. A significant difference in the open-window and closed-window readings on the G-M survey meter at some point indicates the presence of beta-emitting surface contamination, since most beta particles can penetrate only a few millimeters of dense materials.

External gamma radiation levels were measured both with closed-window G-M survey meters and with the NaI scintillation meters described in Appendix I. The scintillation detectors were calibrated daily on the site through the use of sealed isotopic sources. The observed meter responses were standardized by comparison with the closed-window G-M meters at gamma radiation levels high enough that the ratemeters on the instruments could be accurately read.

Measurement of radon and radon daughters in air

Continuous measurements of radon concentrations in air were made outdoors on and near the site using an instrument developed by Wrenn et al.⁴ and referred to as a Wrenn chamber. This instrument, described in Appendix II, was equipped with a printer which recorded automatically numbers proportional to the radon concentrations at intervals of 2000-sec. Because some radon and progeny from previous 2000-sec intervals

remain in the Wrenn chamber, each reading actually represents a concentration which has been integrated over a period of 2 to 4 hr.

For the measurement of radon daughter concentrations in air outdoors on and near the site, air was pumped for 10 min at approximately 12 liters per min through a membrane filter with a maximum pore size of 0.4 μm . The filter was counted using an alpha spectrometry technique described in Appendix II.

Methods Used to Analyze Samples

Samples of soil collected on the site were packed in plastic bags and returned to ORNL, where they were dried for 24 hr at 110°C and then pulverized to a particle size no greater than 500 μm in diameter (-35 mesh). Next, aliquots from each sample were transferred to plastic bottles or petri dishes, weighed, and counted using a NaI detection system to obtain a preliminary estimate of the ^{226}Ra concentration. This system is coupled with a multi-channel analyzer which sorts pulses corresponding to different gamma-ray energies. The ^{226}Ra estimate is obtained by a computer program which integrates under photon peaks corresponding to 352, 609, 1120, and 1764 KeV; these are gamma-ray energies associated with daughters of ^{226}Ra . These initial estimates of ^{226}Ra concentrations are presented in this draft report.

To obtain slightly more accurate estimates of ^{226}Ra concentrations and also estimates of ^{232}Th and ^{227}Ac concentrations for the final report, each sample will be counted using a Ge(Li) detector and a multi-channel analyzer. The spectra obtained in this way are also analyzed by computer techniques. A description of the Ge(Li) detector and soil counting techniques is given in Appendix III.

A measurement of the ^{238}U concentration in each sample was obtained by neutron absorption techniques.⁵

Water and sediment samples collected on and near the site were analyzed by the Analytical Chemistry Division of ORNL for ^{210}Pb , ^{226}Ra , and ^{230}Th , using techniques described in Appendices to the ORNL Master Manual. The samples were analyzed for ^{238}U using the neutron absorption techniques previously mentioned.⁵ The activity reported for each radionuclide in the water sediment samples represents only that percentage of the activity (normally between 50 and 100%) available by hot HNO_3 leaching.

Survey Procedures

An area considered large enough to encompass all the radioactive material on the site was divided into 100 ft x 100 ft "survey blocks" by the rectangular grid system shown in Fig. 2. Next, an area encompassing the region where highest radiation levels had been measured during a preliminary survey was subdivided into 50 ft x 50 ft survey blocks by dividing each 100 ft x 100 ft survey block in this area into 4 equal parts (see Fig. 3). At each grid point (that is, at each corner of the survey blocks), open- and closed-window G-M survey meter readings were taken at 1 cm from the surface and a gamma scintillation survey meter reading was taken at the surface and at 1 m above the surface. (These duplicate gamma measurements at the surface provided a continuous cross-check of the instruments.) Then, each survey block was scanned with a gamma scintillation survey meter held at 1 m above the surface. The maximum observed gamma radiation level in the block was recorded; and at

the maximum gamma point, open- and closed-window G-M measurements were taken at 1 cm from the surface and a gamma scintillation detector reading was taken at the surface.

Holes were drilled with a motorized rig equipped with an 8-in. diameter auger, usually to depths of 30 to 50 ft, at the locations shown in Fig. 4. A plastic pipe with a 4-in. outer diameter was placed in each hole, and a NaI scintillation probe was lowered inside the pipe. The probe was encased in a lead shield with a narrow opening on the side. This arrangement allowed measurements of gamma radiation intensities resulting from contamination within small fractions of the hole depth. Measurements were usually made at 1-ft intervals. This "logging" of the core holes was done as a first step in determining the extent of subsurface contamination at each location. Moreover, the loggings were used to estimate the ^{226}Ra concentration in contaminated regions. The procedure used for these estimates is described in Appendix III. For each hole, where the logging showed elevated gamma levels, a sample of the material brought up by the auger was selected (on the basis of elevated G-M meter readings) for analysis of ^{226}Ra and ^{238}U . The purpose of this type of sample was to help determine the ^{226}Ra to ^{238}U ratio of the subsurface contaminant. (The use of this ratio is discussed in Appendix III.) The ^{226}Ra and ^{238}U concentrations in these samples should not be interpreted either as maximum or average concentrations at the given location. At many of the auger hole locations where loggings indicated no contamination, a sample of the material brought up by the auger was selected at random and was analyzed for ^{226}Ra and ^{238}U as a check against the logging data.

The auger hole loggings were used to select locations where further soil sampling would be useful. At points as close as practical to selected auger holes, a split-spoon sampler was used to collect soil at intervals from 1 to 3 ft throughout the contaminated zone. The concentrations of ^{226}Ra and ^{238}U were determined for these samples.

Surface samples were collected at the locations shown in Fig. 5. Most of the surface sampling locations (as well as the drilling locations) were chosen to provide random and representative sampling. However, those locations labeled "B" in Fig. 5 are "biased" in that they were chosen for sampling because of high radiation levels at these points.

Water samples were taken from each auger hole in which water was found. In addition, water samples were taken from the drainage areas and from the Conemaugh River at the locations shown in Fig. 6. The samples were analyzed for ^{226}Ra , ^{238}U , ^{230}Th , and ^{210}Pb .

Concentrations of radon in air were measured at several locations adjacent to the site. In addition, some measurements of radon daughters in air were made on the site (see Fig. 6).

Background Measurements

Background external gamma radiation levels at 1 m above the ground were measured between one and two miles from the site at points north-east, east, northwest, southwest, and south of the site. These measurements ranged from 5 to 9 $\mu\text{R/hr}$ and averaged 7 $\mu\text{R/hr}$. Soil samples taken at the same locations showed, on the average, 1.9 pCi $^{226}\text{Ra/g}$ and 0.9 pCi $^{238}\text{U/g}$.

Background beta-gamma dose rates, as measured with the G-M survey meters used on the site, typically average approximately 0.01 or 0.02

mrads/hr. Geiger-Mueller meter readings in this range, however, are not accurate; for this reason dose rates in this range were estimated using the more sensitive gamma scintillation probe, provided there was no distinguishable difference between open- and closed-window G-M survey meter readings.

All direct survey meter readings reported in this document represent gross readings; background radiation levels have not been subtracted. Similarly, background levels have not been subtracted from radionuclide concentrations measured in environmental samples, except where explicitly stated to the contrary.

SURVEY RESULTS

Measurement of Beta-Gamma Dose Rates and External Gamma Radiation Levels

Grid point measurements of gamma radiation levels at the surface and at 1 m above the surface, and measurements of beta-gamma dose rates at 1 cm from the surface are reported in Table 1. Maximum gamma radiation levels in individual survey blocks and beta-gamma dose rates observed at the maximum gamma point are reported in Table 2. The beta-gamma and external gamma measurements, together with soil sample results discussed in a later section, indicate that almost all radioactive materials lying on or near the surface on this site are contained in the area indicated by shading in Fig. 7 (although subsurface contamination was found in other areas). A radiation intensity profile for that part of the site where most above-background radiation levels were observed, is shown in Fig. 7. It should be emphasized that this profile reflects only average external gamma radiation levels at 1 m for the

areas indicated and should not be interpreted as showing point-by-point radiation levels. It should also be pointed out that since the highest background external gamma radiation level measured in the vicinity of the site was 9 $\mu\text{R/hr}$, all measurements of 10 $\mu\text{R/hr}$ or above were considered "above-background" in Fig. 7. None of the external gamma measurements at 1 m observed north of the railroad tracks (Fig. 7) exceeded 12 $\mu\text{R/hr}$.

In addition to the shaded area shown in Fig. 7, above-background external gamma levels and beta-gamma dose rates were observed in three small areas (each less than 5 m^2) at locations indicated by arrows in Fig. 5. At points B6, B7, and B8, the gamma radiation levels at the surface were 160 $\mu\text{R/hr}$, 60 $\mu\text{R/hr}$, and 30 $\mu\text{R/hr}$, respectively. There was no significant beta radiation at these points.

The maximum observed external gamma radiation level at 1 m from the ground on this site was 630 $\mu\text{R/hr}$. Several external gamma measurements exceeding 300 $\mu\text{R/hr}$ were observed in the western part of the shaded region shown in Fig. 7. The maximum observed beta-gamma dose rate at 1 cm from the surface on this site was 5.4 mrad/hr . According to Nuclear Regulatory Commission (NRC) guidelines for the release of property for unrestricted use, average and maximum* beta-gamma dose rates measured at 1 cm should not exceed 0.20 mrad/hr and 1.0 mrad/hr , respectively. Since areas on this site where elevated beta-gamma dose rates were observed were usually considerably larger than 100 cm^2 , it appears that beta-gamma measurements reported in Tables 1 and 2 should be compared with the guideline value 0.20 mrad/hr . The results indicate that beta-gamma dose rates at 1 cm are below NRC guidelines over most of this

* Measurements may not be brought below limits by averaging over more than 1 m^2 . The maximum level applies to an area of not more than 100 cm^2 .

site. There are, however, several areas in the shaded region in Fig. 7 where beta-gamma dose rates exceed 0.20 mrad/hr.

Results of Surface Soil Sample Analyses

Surface soil samples were collected at the points shown in Fig. 5. As discussed earlier, most sampling locations were chosen according to a scheme devised to provide random, unbiased sampling. Those locations labeled "B" in Fig. 5 are "biased" in the sense that they were chosen for sampling because of high radiation levels at these points.

Concentrations of ^{226}Ra and ^{238}U in surface samples are listed in Table 3. Radium-226 concentrations in these samples were as high as 5,000 pCi/g and ^{238}U concentrations were as high as 360 pCi/g. The ^{226}Ra concentration in the random samples taken in the area showing general surface contamination (the entire area shown in Fig. 7) averaged approximately 10 pCi/g, as compared with an average background concentration of approximately 1.9 pCi ^{226}Ra /g. The average ^{238}U concentration in the same samples was approximately 3.9 pCi/g, as compared with an average background concentration of 0.9 pCi ^{238}U /g.

In addition to the surface contamination found in the area indicated by shading in Fig. 7, elevated ^{226}Ra and ^{238}U concentrations were found in a sample taken at location B6, indicated in Fig. 5 (see Table 3), and, as mentioned earlier, elevated gamma radiation levels were measured at locations B7 and B8 indicated in the same figure. Also, a piece of metal approximately 4 in. in diameter and showing a beta-gamma dose rate of 20 mrad/hr was found at location B14 (Fig. 5). Analysis of this metal with the Ge(Li) detector system described in Appendix II indicated that the metal had been contaminated with a ^{226}Ra -bearing material.

Results of Subsurface Soil Sample Analyses

Holes were augered at the locations shown in Fig. 4, to depths of up to 50 ft. At most of these locations, the material brought up by the auger was probed with an open-window G-M meter, and a sample of material showing elevated readings (or a sample taken at random, if no elevated readings were observed) was taken for analysis of ^{226}Ra and ^{238}U . The concentrations of these radionuclides in samples taken in this fashion are reported in Table 4. Because of the method by which these samples were collected, the results in Table 4 should not be interpreted as showing either maximum or average ^{226}Ra and ^{238}U concentrations for the given locations. As discussed in Appendix III, these samples were used to estimate the ratio of ^{226}Ra to ^{238}U in the contaminated material on the site.

At locations 74, 75, and 76, the holes were "cored" rather than augered; that is, a split-spoon sampler was used to collect subsurface samples at known depths. Concentrations of ^{226}Ra and ^{238}U in the core samples are listed in Table 5. Coring was extremely difficult on this site because the split-spoon sampler would not penetrate the railroad ties and other materials which can be found beneath the surface throughout the site. On the other hand, holes could usually be "augered" to the desired depth since the auger would penetrate most of the subsurface materials encountered.

Each of the auger holes and core holes was "logged" with a gamma scintillation probe as described in the section "Survey Methods". By comparison of the subsurface gamma radiation levels and the ^{226}Ra concentrations at the core hole locations, a procedure for estimating ^{226}Ra

concentrations in subsurface soil from auger hole "loggings" was developed (see Appendix III). Estimates concerning the extent of the contaminated soil, the depth of maximum contamination, and the ^{226}Ra concentrations in the contaminated regions in the auger holes are given in Table 6.

The general region in which subsurface contamination was found is indicated in Fig. 8. The radioactive residues in this region were scattered widely and were found at depths varying from the surface to 36 ft. The method described in Appendix III was used to estimate that the total (above-background) activities of ^{226}Ra and ^{238}U in the soil in this region are approximately 4 Ci and 1.3 Ci, respectively. Since it is estimated that the radioactive materials dumped on this site contained 5.8 tons of U_3O_8 , corresponding to approximately 1.5 Ci of ^{238}U , it would appear that nearly all the residues were dumped in this region. It should be pointed out, however, that the method of estimating the total activities of ^{226}Ra and ^{238}U in the region shown in Fig. 8 is based on the assumption that representative data for the region were obtained from auger hole loggings. It is also assumed that the average ratio of above-background ^{226}Ra activity to above-background ^{238}U activity in the residues is $3.0 \pm 9\%$. This is the average (and standard deviation of the mean) determined from all (21) composite subsurface samples taken from auger holes and showing ^{226}Ra or ^{238}U contamination significantly higher than background.

Results of Water Sample Analyses

The concentrations of ^{226}Ra , ^{230}Th , and ^{238}U in water samples taken from auger holes are given in Table 7. In each sample the concentrations of the radionuclides were below the concentration guide for water (CG_w 's) stated in 10 CFR 20, Appendix B. (See also ERDAM 0524.)

Four water samples were taken from drainage pathways leading from the site to the Conemaugh River. Concentrations of ^{210}Pb , ^{226}Ra , and ^{230}Th in these water samples, as well as in sediment from these samples, are listed in Table 8. Sampling locations are shown in Fig. 6. The concentrations of the radionuclides in the water samples are below the CG_w 's stated in 10 CFR 20, Appendix B. However, the ^{210}Pb and/or ^{230}Th concentrations in the sediment from some of the samples are several orders of magnitude above normal background concentrations (typically near 1 pCi/g) of these radionuclides.

Water samples were taken from each of the ponds or "lagoons" shown in Fig. 6. Concentrations of ^{210}Pb , ^{226}Ra , and ^{230}Th in these samples and in sediment from these samples are listed in Table 9. The ^{210}Pb concentrations in the sediments were several times higher than typical background concentrations.

Results of Radon and Radon Daughter Measurements

Concentrations of radon and radon daughters in outdoors air, both on and near the site, are listed in Tables 10 and 11, respectively. Sampling locations are shown in Fig. 6. Sampling locations were chosen at or near regions showing highest surface contamination in an attempt to determine maximum potential radon and radon daughter concentrations in air on and near the site. Except for the slightly elevated radon concentration measured at location R3 on the site, all measured radon and daughter concentrations were within the range of normal background for most areas of the country. Although short-term measurements of radon and radon daughter concentrations in outdoor air cannot be expected

to be conclusive. It appears from these results, together with the results concerning the relatively low average ^{226}Ra concentrations in surface and near-surface soil on the site, that there is no significant atmospheric transport of ^{222}Rn from the site.

SUMMARY

In 1956 and 1957, radioactive residues containing an estimated 5.8 tons of U_3O_8 (1.5 Ci of ^{238}U) were dumped on this site. A combination of analyses of subsurface soil samples and gamma scintillation probe "loggings" of 76 holes augered on this site to depths of up to 50 ft revealed the general location of residues containing an estimated total (above-background) ^{238}U activity of 1.3 Ci and an estimated total (above-background) ^{226}Ra activity of 4 Ci. The region in which subsurface contamination was found is indicated in Fig. 8. It appears that more than 75% of the residues lie at least 10 ft beneath the surface. Radioactive residues are also scattered on the surface in the area indicated by arrows in Fig. 5. No estimate of the total ^{238}U activity in these surface residues was obtained. At some points in the area indicated in Fig. 5., the surface soil shows ^{226}Ra concentrations of several thousand picocuries per gram, external gamma radiation levels at 1 m exceed 0.5 mR/hr, and beta-gamma dose rates at 1 cm from the surface exceed 5 mrad/hr. Such measurements are not representative for this area; at most sampling points radionuclide concentrations in surface soil and radiation levels at the surface and at 1 m above the surface are less than 10 times background levels.

Some surface and subsurface samples contain quantities of natural uranium requiring a license (that is, the samples are greater than 0.05% uranium by weight, corresponding to approximately 170 pCi $^{238}\text{U/g}$).

Analyses of sediment filtered from some water samples taken in drainage areas on and near the site revealed elevated concentrations of ^{210}Pb and in some cases, ^{230}Th . However, in all water samples taken on and near the site, concentrations of ^{226}Ra , ^{230}Th , ^{238}U , and ^{210}Pb (when measured) were below concentration guides as stated in 10 CFR 20, Appendix B.

It appears from limited data that there is no significant atmospheric transport of ^{222}Rn from the site.

An evaluation has been made of current radiation exposures at the Pennsylvania Railroad Landfill site and is presented in Appendix VI (page 95) of this report. The purpose of this evaluation is to present information which will permit the reader to compare current radiation exposures from the site to normal background exposures for that part of Pennsylvania, as well as to scientifically based guideline values established for the protection of radiation workers and members of the general public.

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Fig. 1. Aerial view of Pennsylvania Railroad Landfill Site and surrounding area.

Fig. 2. Scaled drawing showing 100 ft x 100 ft grid system used in survey.

Fig. 3. Scaled drawing showing 50 ft x 50 ft grid system used in survey of area with highest gamma radiation levels.

Fig. 4. Plan view of grid system for the site and numbered auger hole locations.

Fig. 5. Plan view of grid system for the site and numbered locations of surface soil samples on and off the site.

Fig. 6. Numbered sampling locations for radon and radon daughters on the site and numbered locations for water samples taken on and off the site.

Fig. 7. Profile of external gamma radiation level at 1 m in area showing highest surface contamination levels.

Fig. 8. Area of subsurface contamination.

Table 1. Directly measured beta-gamma contamination levels and external gamma radiation levels at grid points

Grid location shown in Fig. 2 ^a	External gamma radiation level at 1 m ($\mu\text{R/hr}$)	External gamma radiation level at surface ($\mu\text{R/hr}$)	Beta-gamma dose rate at 1 cm (mrad/hr)
0 + 0	34	25	0.03
0 + 50	31	31	0.04
1 + 0	34	39	0.05
1 + 50	45	31	0.05
2 + 0	21	19	0.03
2 + 50	10	16	0.02
3 + 0	10	10	0.01
3 + 50	10	10	0.01
4 + 0	10	9	0.01
4 + 50	10	10	0.01
5 + 0	10	13	0.02
5 + 50	7	5	0.01
6 + 0	5	5	0.01
7 + 0	7	6	0.01
8 + 0	8	9	0.01
9 + 0	6	5	0.01
10 + 0	6	6	0.01
11 + 0	5	5	0.01
12 + 0	8	8	0.01
13 + 0	6	5	0.01
14 + 0	5	6	0.01
15 + 0	6	8	0.01
0 - 50	7	5	0.01
0 - 100	7	7	0.01
0 - 150	9	9	0.01
0 - 200	10	9	0.01
0 + 0, 50L	9	8	0.01
0 + 50, 50L	26	16	0.02
1 + 0, 50L	120	140	0.14
1 + 50, 50L	190	220	0.25
2 + 0, 50L	48	47	0.07
2 + 50, 50L	22	19	0.03
3 + 0, 50L	28	31	0.04
3 + 50, 50L	17	19	0.03
4 + 0, 50L	17	19	0.03
4 + 50, 50L	14	13	0.02
5 + 0, 50L	17	19	0.03
0 - 50, 50L	7	5	0.01
0 - 100, 50L	9	10	0.01
0 - 150, 50L	11	16	0.02
5 + 50, 50L	17	25	0.03
6 + 0, 50L	12	16	0.02

Table 1 (cont.) Directly measured beta-gamma contamination levels
and external gamma radiation levels at grid points

Grid location shown in Fig. 2 ^a	External gamma radiation level at 1 m (μ R/hr)	External gamma radiation level at surface (μ R/hr)	Beta-gamma dose rate at 1 cm (mrad/hr)
6 + 50, 50L	7	6	0.01
0 + 0, 100L	9	10	0.01
0 + 50, 100L	7	7	0.01
1 + 0, 100L	8	9	0.01
1 + 50, 100L	83	19	0.02
2 + 0, 100L	41	16	0.09
2 + 50, 100L	34	47	0.05
3 + 0, 100L	15	19	0.03
3 + 50, 100L	23	31	0.04
4 + 0, 100L	26	25	0.03
4 + 50, 100L	27	31	0.03
5 + 0, 100L	24	31	0.03
5 + 50, 100L	45	47	0.05
6 + 0, 100L	6	6	0.01
7 + 0, 100L	10	16	0.02
8 + 0, 100L	11	16	0.03
9 + 0, 100L	6	6	0.01
10 + 0, 100L	5	5	0.01
11 + 0, 100L	5	5	0.01
12 + 0, 100L	5	5	0.01
13 + 0, 100L	5	5	0.01
14 + 0, 100L	5	5	0.01
15 + 0, 100L	6	6	0.01
0 + 0, 150L	12	13	0.01
0 + 50, 150L	12	13	0.01
1 + 0, 150L	12	19	0.02
1 + 50, 150L	11	13	0.01
2 + 0, 150L	8	8	0.01
2 + 50, 150L	8	8	0.01
3 + 0, 150L	12	10	0.01
3 + 50, 150L	12	16	0.02
4 + 0, 150L	11	16	0.02
4 + 50, 150L	14	19	0.02
5 + 0, 150L	13	13	0.02
5 + 50, 150L	8	9	0.01
1 + 0, 200L	10	8	0.01
1 + 50, 200L	10	9	0.01
2 + 0, 200L	9	10	0.01
2 + 50, 200L	8	8	0.01
3 + 0, 200L	6	6	0.01
3 + 50, 200L	5	5	0.01

Table 1 (cont.) Directly measured beta-gamma contamination levels
and external gamma radiation levels at grid points

Grid location shown in Fig. 2 ^a	External gamma radiation level at 1 m (μ R/hr)	External gamma radiation level at surface (μ R/hr)	Beta-gamma dose rate at 1 cm (mrad/hr)
4 + 0, 200L	5	5	0.01
4 + 50, 200L	7	7	0.01
5 + 0, 200L	7	7	0.01
6 + 0, 200L	8	8	0.01
7 + 0, 200L	7	8	0.01
8 + 0, 200L	7	7	0.01
9 + 0, 200L	9	9	0.01
10 + 0, 200L	7	8	0.01
11 + 0, 200L	6	6	0.01
12 + 0, 200L	6	6	0.01
13 + 0, 200L	6	6	0.01
14 + 0, 200L	6	6	0.01
15 + 0, 200L	7	7	0.01
1 + 50, 250L	8	7	0.01
2 + 0, 250L	8	9	0.01
2 + 50, 250L	6	6	0.01
3 + 0, 250L	8	8	0.01
3 + 50, 250L	6	6	0.01
4 + 0, 250L	5	5	0.01
4 + 50, 250L	5	5	0.01
5 + 0, 250L	6	6	0.01
2 + 50, 300L	8	8	0.01
3 + 0, 300L	6	7	0.01
3 + 50, 300L	8	8	0.01
4 + 0, 300L	8	8	0.01
4 + 50, 300L	9	8	0.01
5 + 0, 300L	8	8	0.01
6 + 0, 300L	5	5	0.01
7 + 0, 300L	5	5	0.01
8 + 0, 300L	5	5	0.01
9 + 0, 300L	5	5	0.01
10 + 0, 300L	5	5	0.01
11 + 0, 300L	5	5	0.01
12 + 0, 300L	5	5	0.01
13 + 0, 300L	5	5	0.01
14 + 0, 300L	5	5	0.01
15 + 0, 300L	6	6	0.01
3 + 0, 350L	6	6	0.01
3 + 50, 350L	7	7	0.01
4 + 0, 350L	8	9	0.01
4 + 50, 350L	8	8	0.01
5 + 0, 350L	8	8	0.01

Table 1 (cont.) Directly measured beta-gamma contamination levels
and external gamma radiation levels at grid points

Grid location shown in Fig. 2 ^a	External gamma radiation level at 1 m (μ R/hr)	External gamma radiation level at surface (μ R/hr)	Beta-gamma dose rate at 1 cm (mrad/hr)
4 + 0, 400L	7	8	0.01
4 + 50, 400L	8	7	0.01
5 + 0, 400L	8	8	0.01
5 + 0, 450L	8	8	0.01
0 - 50, 50R	24	16	0.02
0 - 100, 30R	25	75	0.08
0 - 100, 50R	8	9	0.01
0 - 150, 50R	13	19	0.03
0 + 0, 50R	10	10	0.01
0 + 50, 50R	10	9	0.01
1 + 0, 50R	15	16	0.03
1 + 50, 50R	28	63	0.07
2 + 0, 50R	180	310	0.31
2 + 50, 50R	10	10	0.01
3 + 0, 50R	7	8	0.01
3 + 50, 50R	6	6	0.01
4 + 0, 50R	6	6	0.01
4 + 50, 50R	6	6	0.01
5 + 0, 50R	6	6	0.01
0 + 0, 100R	7	7	0.01
0 + 50, 100R - water, no readings			
1 + 0, 100R	5	5	0.01
1 + 50, 100R	6	5	0.01
2 + 0, 100R	5	5	0.01
2 + 50, 100R	6	6	0.01
3 + 0, 100R	5	5	0.01
3 + 50, 100R	5	5	0.01
4 + 0, 100R	5	5	0.01
4 + 50, 100R	5	5	0.01
5 + 0, 100R	5	5	0.01
6 + 0, 100R	7	7	0.01
7 + 0, 100R	8	7	0.01
8 + 0, 100R	7	7	0.01
9 + 0, 100R	6	6	0.01
10 + 0, 100R	5	5	0.01
11 + 0, 100R	6	6	0.01
12 + 0, 100R	7	8	0.01
13 + 0, 100R	5	5	0.01
14 + 0, 100R	5	5	0.01
15 + 0, 100R	5	5	0.01
0 + 0, 150R	5	6	0.01
0 + 0, 200R	6	7	0.01

Table 1 (cont.) Directly measured beta-gamma contamination levels
and external gamma radiation levels at grid points

Grid location shown in Fig. 2 ^a	External gamma radiation level at 1 m (μ R/hr)	External gamma radiation level at surface (μ R/hr)	Beta-gamma dose rate at 1 cm (mrad/hr)
2 + 50, 200R	5	5	0.01
3 + 0, 200R	5	5	0.01
3 + 50, 200R	6	6	0.01
4 + 0, 200R	6	6	0.01
4 + 50, 200R	5	6	0.01
5 + 0, 200R	6	6	0.01
5 + 50, 200R	6	6	0.01
6 + 0, 200R	6	6	0.01
7 + 0, 200R	5	5	0.01
10 + 0, 200R	8	10	0.01
11 + 0, 200R	5	5	0.01
12 + 0, 200R	6	6	0.01
13 + 0, 200R	5	6	0.01
14 + 0, 200R	6	7	0.01
15 + 0, 200R	5	5	0.01
0 + 0, 250R	6	7	0.01
1 + 0, 250R	5	5	0.01
1 + 50, 270R	19	310	0.31
2 + 0, 250R	5	5	0.01
3 + 0, 250R	5	5	0.01
4 + 0, 250R	7	8	0.01
5 + 0, 250R	6	7	0.01
6 + 0, 250R	6	7	0.01
0 - 100, 300R	7	8	0.01
0 - 200, 300R	7	7	0.01
0 + 0, 300R	5	7	0.01
1 + 0, 300R	5	6	0.01
2 + 0, 300R	6	6	0.01
3 + 0, 300R	6	6	0.01
4 + 0, 300R	6	6	0.01
5 + 0, 300R	6	6	0.01
6 + 0, 300R	6	6	0.01
7 + 0, 300R	6	6	0.01
8 + 0, 300R	5	6	0.01
11 + 0, 300R	7	8	0.01
12 + 0, 300R	8	8	0.01
13 + 0, 300R	5	6	0.01
14 + 0, 300R	7	8	0.01
15 + 0, 300R	7	7	0.01
0 + 0, 400R	8	8	0.01
1 + 0, 400R	5	5	0.01
2 + 0, 400R	6	6	0.01
3 + 0, 400R	5	5	0.01

Table 1 (cont.) Directly measured beta-gamma contamination levels and external gamma radiation levels at grid points

Grid location shown in Fig. 2 ^a	External gamma radiation level at 1 m ($\mu\text{R/hr}$)	External gamma radiation level at surface ($\mu\text{R/hr}$)	Beta-gamma dose rate at 1 cm (mrad/hr)
4 + 0, 400R	8	10	0.01
4 + 50, 400R	8	9	0.01
5 + 0, 400R	8	8	0.01
6 + 0, 400R	8	8	0.01
7 + 0, 400R	6	7	0.01
8 + 0, 400R	6	7	0.01
9 + 0, 400R	6	6	0.01
10 + 0, 400R	6	6	0.01
10 + 50, 400R	8	6	0.01
5 + 0, 500R	5	5	0.01
6 + 0, 500R	5	6	0.01
7 + 0, 500R	6	6	0.01
8 + 0, 500R	5	6	0.01
9 + 0, 500R	6	5	0.01
10 + 0, 500R	6	7	0.01
11 + 0, 500R	6	8	0.01
12 + 0, 500R	7	8	0.01
13 + 0, 500R	6	6	0.01
14 + 0, 500R	6	6	0.01
15 + 0, 500R	6	6	0.01
8 + 0, 600R	6	6	0.01
9 + 0, 600R	5	5	0.01
10 + 0, 600R	6	6	0.01
11 + 0, 600R	6	8	0.01
12 + 0, 600R	5	5	0.01
13 + 0, 600R	6	6	0.01
14 + 0, 600R	5	5	0.01
15 + 0, 600R	7	8	0.01
11 + 0, 700R	6	6	0.01
12 + 0, 700R	5	5	0.01
13 + 0, 700R	5	5	0.01
14 + 0, 700R	5	5	0.01
15 + 0, 700R	6	6	0.01

^aCoordinates are interpreted in the following way: 0 + 0 is the origin (Fig. 2), 0 + 50 is 50 ft east of the origin on the base line, 8 + 0 is 800 ft east of the origin on the baseline, and so forth. The point 11 + 0, 500R lies 1100 ft east of the origin (measured along the baseline) and 500 ft right (facing east) of the baseline. The point 0 - 150, 50L is 150 ft west of the origin (measured along the baseline) and 50 ft left (facing east) of the baseline.

Table 2. External gamma radiation levels and beta-gamma dose rates in survey blocks at points showing highest gamma radiation level

Survey block shown in Fig. 3	External gamma radiation level at 1 m ($\mu\text{R/hr}$)	External gamma radiation level at surface ($\mu\text{R/hr}$)	Beta-gamma dose rate at 1 cm (mrad/hr)
AA17	8	6	0.01
AA18	6	6	0.01
AA19	7	7	0.01
AA20	5	6	0.01
AA21	6	6	0.01
AA22	6	6	0.01
AA23	6	8	0.01
A13	6	8	0.01
A14	6	6	0.01
A15	8	8	0.01
A16	7	7	0.01
B10	7	8	0.01
B11	6	7	0.01
B12	6	8	0.01
B13	9	9	0.01
B14	9	10	0.01
B15	7	7	0.01
B16	10	10	0.01
AB17	30	66	0.07
AB18	9	10	0.01
AB19	7	8	0.01
AB20	9	9	0.01
AB21	6	8	0.01
AB22	6	6	0.01
AB23	9	9	0.01
C7	10	9	0.01
C8	10	9	0.01
C9	15	13	0.03
C10	18	38	0.04
C11	13	6	0.01
C12	10	10	0.01
C13	10	10	0.01
C14	11	9	0.01
C15	30	38	0.04
C16	18	19	0.06
D5	40	34	0.04
D6	43	59	0.06
D7	60	84	0.09
D8	60	280	0.31
D9	25	38	0.04
D10	30	41	0.04
D11	43	69	0.07
D12	38	59	0.06

Table 2. (cont.) External gamma radiation levels and beta-gamma dose rates in survey blocks at points showing highest gamma radiation levels

Survey block shown in Fig. 3	External gamma radiation level at 1 m (μ R/hr)	External gamma radiation level at surface (μ R/hr)	Beta-gamma dose rate at 1 cm (mrad/hr)
D13	23	34	0.04
D14	13	9	0.01
D15	17	16	0.02
D16	17	13	0.02
CD17	18	13	0.02
CD18	9	6	0.01
CD19	8	8	0.01
CD20	6	9	0.01
CD21	6	8	0.01
CD22	6	8	0.01
CD23	7	8	0.01
E3	180	310	0.40
E4	180	470	0.50
E5	88	88	0.09
E6	140	470	0.50
E7	26	50	0.06
E8	50	130	0.13
E9	31	72	0.08
E10	25	31	0.10
E11	59	110	0.13
E12	75	94	0.09
E13	34	63	0.06
E14	34	63	0.06
E15	15	16	0.02
E16	28	47	0.07
F1	41	47	0.15
F2	140	470	0.47
F3	310	2,500	3.3
F4	350	3,100	5.4
F5	170	630	1.1
F6	17	16	0.05
F7	31	31	0.05
F8	31	63	0.06
F9	52	63	0.10
F10	38	63	0.11
F11	16	16	0.02
F12	20	25	0.03
F13	16	19	0.02
F14	16	19	0.02
F15	16	16	0.02
F16	10	8	0.01
EF17	24	19	0.08
EF18	20	23	0.08

Table 2 (cont.) External gamma radiation levels and beta-gamma dose rates in survey blocks at points showing highest gamma radiation levels

Survey block shown in Fig. 3	External gamma radiation level at 1 m (μ R/hr)	External gamma radiation level at surface (μ R/hr)	Beta-gamma dose rate at 1 cm (mrad/hr)
EF19	30	28	0.04
EF20	20	38	0.04
EF21	11	19	0.02
EF22	9	9	0.01
EF23	8	9	0.01
G1	20	25	0.04
G2	20	25	0.04
G3	630	630	5.0
G4	630	630	5.0
G5	400	780	1.0
G6	400	780	1.0
G7-8	10	10	0.01
G9-10	13	88	0.09
G11-12	9	16	0.02
G13-14	12	25	0.03
G15-16	8	9	0.01
G17	8	8	0.01
G18	8	8	0.01
G19	9	7	0.01
G20	7	13	0.02
G21	11	25	0.03
G22	8	9	0.01
G23	11	13	0.02
H13-14	6	6	0.01
H15-16	6	8	0.01
H17	8	8	0.01
H18	6	7	0.01
H19	8	8	0.01
H20	9	22	0.03
H21	6	6	0.01
H22	6	8	0.01
H23	6	7	0.01
I1-2	7	7	0.01
I3-4	14	310	0.31
I5-6	7	8	0.01
I7-8	8	9	0.01
I9-10	8	8	0.01
I11-12	7	8	0.01
I13-14	6	8	0.01
I20	8	9	0.01
I21	8	8	0.01
I22	5	6	0.01
I23	6	8	0.01

Table 2 (cont.) External gamma radiation levels and beta-gamma dose rates in survey blocks at points showing highest gamma radiation levels

Survey block shown in Fig. 3	External gamma radiation level at 1 m ($\mu\text{R/hr}$)	External gamma radiation level at surface ($\mu\text{R/hr}$)	Beta-gamma dose rate at 1 cm (mrad/hr)
J1-2	8	10	0.01
J3-4	8	8	0.01
J5-6	8	10	0.01
J7-8	8	6	0.01
J9-10	8	10	0.01
J11-12	6	8	0.01
J13-14	6	6	0.01
J15-16	6	8	0.01
J17	6	8	0.01
J18	5	6	0.01
J19	--	--	--
K5-6	6	6	0.01
K7-8	6	6	0.01
K9-10	6	8	0.01
K11-12	6	6	0.01
K13-14	6	6	0.01
K15-16	11	31	0.10
K17	6	6	0.01
K18	6	6	0.01
K19	5	6	0.01
K20	8	8	0.01
K21	8	8	0.01
K22	6	8	0.01
K23	6	8	0.01
L13-14	5	6	0.01
L15-16	5	6	0.01
L17	6	8	0.01
L18	8	9	0.01
L19	6	6	0.01
L20	6	8	0.01
L21	6	9	0.01
L22	5	6	0.01
L23	6	6	0.01
M17	5	5	0.01
M18	6	6	0.01
M19	7	8	0.01
M20	6	8	0.01
M21	5	6	0.01
M22	7	7	0.01
M23	8	8	0.01
N20	6	7	0.01
N21	6	5	0.01
N22	5	5	0.01
N23	7	7	0.01

Table 3. Concentrations of ^{226}Ra and ^{238}U in surface samples taken on the site

Location shown in Fig. 5	Radionuclide concentrations (pCi/g)	
	^{226}Ra	^{238}U
1	2.1	6.2
2	21	2.4
3	1.0	3.7
4	1.8	1.4
5	<1.0	1.5
6	260	28
7	2.7	1.6
8	7.2	2.0
9	2.7	2.7
10	1.5	1.5
11	8.6	5.7
12	5.3	3.5
13	1.8	1.7
14	1.9	2.1
15	2.4	1.9
16	5.8	4.9
17	4.4	2.9
18	5.1	3.2
19	23	15
20	45	30
21	9.0	3.9
22	28	10
23	17	3.8
24	2.9	12
25	6.0	2.2
26	3.9	1.8
27	3.9	2.7
28	3.5	1.9
29	5.3	2.4
30	2.8	2.3
31	2.2	1.9 ^a
35	14	ND ^a
36	16	5.8
37	10	8.4
38	5.2	2.6
39	7.9	4.1
40	7.5	3.9
41	17	8.7
42	26	8.8
43	1.6	1.7
44	4.5	4.1
45	4.9	3.0
46	6.6	3.3
47	4.7	2.7

Table 3. (cont.) Concentrations of ^{226}Ra and ^{238}U in surface samples taken on the site

Location shown in Fig. 5	Radionuclide concentrations (pCi/g)	
	^{226}Ra	^{238}U
48	1.3	1.2
49	<1.0	0.6
50	<1.0	1.2
51	<1.0	1.4
52	<1.0	0.8
53	<1.0	0.7
54	<1.0	1.2
55	1.1	0.8
56	3.7	2.1
57	<1.0	0.9
58	<1.0	0.9
59	<1.0	0.8
60	<1.0	0.6
61	<1.0	0.6
62	<1.0	0.9
63	<1.0	0.7
64	4.2	1.6
65	<1.0	0.7
66	1.6	1.0
67	1.8	1.2
68	1.1	1.0
69	1.7	1.0
70	1.9	1.0
71	4.8	2.0
72	5.0	3.1
73	2.8	2.5
74	1.5	1.3
75	2.0	1.3
76	7.2	2.6
77	2.4	1.6
78	3.6	0.3
79	<1.0	0.8
80	1.3	1.1
81	<1.0	0.8
82	1.1	0.9
83	1.4	1.1
84	1.2	1.0
85	<1.0	0.7
86	1.7	1.2
87	1.2	0.8
88	<1.0	0.8
89	1.3	1.2
90	<1.0	1.1

Table 3. (cont.) Concentrations of ^{226}Ra and ^{238}U in surface samples taken on the site

Location shown in Fig. 5	Radionuclide concentrations (pCi/g)	
	^{226}Ra	^{238}U
91	<1.0	0.8
92	1.2	1.3
93	<1.0	1.1
94	<1.0	0.8
95	<1.0	0.7
96	1.5	1.2
97	1.9	1.5
98	1.2	ND
99	1.4	1.2
100	<1.0	0.7
101	<1.0	1.1
102	1.4	1.1
103	<1.0	1.0
104	<1.0	0.9
105	<1.4	1.1
106	<1.0	ND
107	<1.0	0.9
108	<1.0	0.7
B1	2,000	95
B2	1,500	360
B3	150	16
B4	5,000	140
B5	1,300	170
B6	120	20
B7	2.4	0.9
B8	ND	6.2
B12	3,000	210
B13	140	170

^aND = not determined.

Table 4. Concentrations of ^{226}Ra and ^{238}U in composite soil samples taken from auger holes

Location shown in Fig. 4	Radionuclide concentrations (pCi/g)	
	^{226}Ra	^{238}U
1	3.6	2.2
2	20	7.1
3	130	17
4	50	47
5	18	16
6	15	5.5
7	12	2.9
8	1.8	2.0
9	4.9	2.5
10	2,100	56
11	3.9	3.6
12	3.5	3.0
13	2.9	1.5
14	No sample	No sample
15	30	8.8
16	38	9.7
17	3.1	1.8
18	2.1	2.8
19	120	42
20	1.9	1.4
21	1.7	1.3
22	1.1	1.1
23	1.0	1.1
24	130	43
25	1.9	1.5
26	1.7	1.2
27	<1.0	1.0
28	<1.0	0.6
29	1.6	1.4
30	1.1	1.0
31	12	4.5
32	14	6.0
33	20	13
34	2.5	1.6
35	<1.0	0.7
36	41	14
37	12	4.7
38	1.8	1.1
39	15	3.9
40	6.8	4.3
41	6.4	4.3
42	55	16
43	100	39
44	190	65
45	76	29

Table 4 (cont.). Concentrations of ^{226}Ra and ^{238}U in composite soil samples taken from auger holes

Location shown in Fig. 4	Radionuclide concentrations (pCi/g)	
	^{226}Ra	^{238}U
46	110	36
47	2.3	1.3
48	1.6	1.2
49	2.6	1.5
50	<1.0	0.7
51	1.6	1.3
52	<1.0	0.9
53	<1.0	1.0
54	<1.0	0.9
55	<1.0	1.1
56	No sample	No sample
57	1.5	1.2
58	<1.0	0.9
59	<1.0	1.0
60	No sample	No sample
61	ND ^a	0.4
62	<1.0	1.0
63	1.0	0.9
64	<1.0	1.0
65	<1.0	1.1
66	2.7	3.0
67	1.8	1.4
68	No sample	No sample
69	<1.0	1.0
70	1.0	1.0
71	<1.0	1.1
72	No sample	No sample
73	<1.0	ND

^aND = not determined.

Table 5. Concentrations of ^{226}Ra and ^{238}U in subsurface soil samples taken from core holes

Location shown in Fig. 4	Depth (ft)	Radionuclide concentrations (pCi/g)	
		^{226}Ra	^{238}U
74	0 - 0.5	9.4	2.8
74	0.5 - 1.5	110	43
74	1.5 - 3.0	24	22
74	3.5 - 4.6	3.7	2.9
74	6.5 - 8.0	1.4	1.0
75	0 - 1.0	1.9	1.2
75	16.5 - 18.0	<1.0	0.4
75	20.0 - 20.5	1.1	1.0
75	20.5 - 21.5	1.2	1.5
75	22.0 - 23.0	150	45
75	23.0 - 23.8	220	52
75	23.8 - 24.5	130	85
75	25.0 - 26.0	1.6	20
75	29.0 - 30.5	72	21
75	37.0 - 38.5	1.7	1.5
75	38.5 - 40.0	1.4	1.4
75	40.0 - 41.5	1.5	1.3
76	0 - 0.5	1.8	1.5
76	0.5 - 1.0	1.1	1.0
76	1.0 - 2.0	<1.0	0.5
76	2.0 - 3.0	<1.0	0.5
76	5.0 - 5.5	1.7	1.4
76	15.0 - 15.5	1.6	1.7
76	15.5 - 16.5	<1.0	0.9
76	22.5 - 23.5	1.8	1.3
76	25.5 - 26.5	3.2	2.0
76	26.5 - 27.0	190	54
76	29.0 - 29.5	960	240

Table 6. Estimates of subsurface ^{226}Ra contamination based on scintillation probe loggings

Location shown in Fig. 4	Estimated extent of contaminated soil (ft)	Depth of maximum contamination (ft)	Maximum reading with shielded scintillator (1000 cpm)	Estimated above-background ^{226}Ra concentration at point of maximum contamination - (pCi/g)	Estimated average above-background ^{226}Ra concentration in contaminated region (pCi/g)
1	0 - 1	1	2.2	1.4	1.0
2	0 - 3	1	14.2	89	29
3	0 - 6.5	3	143	1000	250
4	2 - 12	8	31.9	220	100
5	1 - 6	3	23.7	160	72
6	1 - 4.5	3	35.0	240	98
7	9 - 30	20	32.4	220	64
8	None	-	-	0	0
9	0.5 - 2.5	1.5	7.6	40	20
10	0 - 3.5	1.5	26.2	180	54
11	0.7 - 1.3	1.0	2.5	3.7	3.7
12	None	-	-	0	0
13	0.5 - 1.0	1.0	2.7	5.2	5.2
14	None	---	---	0	0
15	0 - 34	32	92.6	590	70
16	0 - 30	27	154	1100	140
17	None	---	---	0	0
18	None	---	---	0	0
19	0 - 4	0	4.4	18	5.6
20	0 - 1	1	3.0	7.6	5.4
	8 - 35	31	50.2	350	44
21	None	---	---	0	0
22	None	---	---	0	0
23	None	---	---	0	0
24	At Surface	---	3.6	8.8	8.8
25	2 - 2.5	2	4.0	14	14

Table 6 (cont.). Estimates of subsurface ^{226}Ra contamination based on scintillation probe loggings

Location shown in Fig. 4	Estimated extent of contaminated soil (ft)	Depth of maximum contamination (ft)	Maximum reading with shielded scintillator (1000 cpm)	Estimated above-background ^{226}Ra concentration at point of maximum contamination (pCi/g)	Estimated average above-background ^{226}Ra concentration in contaminated region (pCi/g)
26	4 - 4.5	4	4.4	17	17
27	None	---	---	0	0
28	None	---	---	0	0
29	None	---	---	0	0
30	None	---	---	0	0
31	3 - 9	6	54.4	380	130
32	21 - 27	25	48.5	340	100
33	10 - 18.5	16	26.5	180	67
34	5 - 7	6	8.3	46	18
35	23.5 - 24.5	24	2.6	4.2	4.2
36	At Surface	---	2.2	1.6	1.6
	10 - 23	20	65.0	460	140
37	23 - 25	24	11.1	66	30
38	1 - 1.5	1	3.2	9	9
39	1 - 3.5	2	29.4	200	63
40	0 - 4	2	25.0	170	56
41	0 - 3.5	2	17.7	120	41
42	0 - 10	4	38.3	270	110
43	0 - 16	10	70.6	500	170
44	0 - 33	27	88.7	630	100
45	17 - 33	33	34.3	290	68
46	At Surface	---	3.3	9.7	9.7
	10 - 34	26	39.0	270	120
47	None	---	---	0	0
48	None	---	---	0	0
49	None	---	---	0	0
50	None	---	---	0	0

Table 6 (cont.). Estimates of subsurface ^{226}Ra contamination based on scintillation probe loggings

Location shown in Fig. 4	Estimated extent of contaminated soil (ft)	Depth of maximum contamination (ft)	Maximum reading with shielded scintillator (1000 cpm)	Estimated above-background ^{226}Ra concentration at point of maximum contamination (pCi/g)	Estimated average above-background ^{226}Ra concentration in contaminated region (pCi/g)
51	None	---	---	0	0
52	None	---	---	0	0
53	None	---	---	0	0
54	None	---	---	0	0
55	None	---	---	0	0
56	None	---	---	0	0
57	None	---	---	0	0
58	None	---	---	0	0
59	None	---	---	0	0
60	No Log	---	---	0	0
61	None	---	---	0	0
62	None	---	---	0	0
63	None	---	---	0	0
64	None	---	---	0	0
65	None	---	---	0	0
66	6.5 - 7.0	6.5	3.9	14	13
67	None	---	---	0	0
68	None	---	---	0	0
69	None	---	---	0	0
70	None	---	---	0	0
71	None	---	---	0	0
72	None	---	---	0	0
73	None	---	---	0	0
74	0 - 3.0	2.0	22.0	150	51
75	At Surface	---	2.4	2.7	2.7
	20 - 26	23	34.0	230	87
76	0 - 1.5	0(surface)	4.0	14	9
	7 - 27	27	130.0	930	120

Table 7. Analyses of water samples taken from auger holes

Location shown in Fig. 4	Radionuclide concentration (pCi/ml)		
	^{230}Th	^{226}Ra	^{238}U
3	$0.37 \pm 2\%$	<0.0005	0.0044
5	NA ^a	NA	0.0055
6	NA	NA	0.0092
9	NA	NA	0.0025
10	NA	NA	0.095
11	NA	NA	0.0072
12	NA	NA	0.0047
13	NA	NA	0.0025
16	NA	NA	0.0105
17	NA	NA	0.0058
18	$0.008 \pm 6\%$	$0.003 \pm 50\%$	0.036
19	NA	NA	0.0137
20	NA	NA	0.0050
21	NA	NA	0.0043
22	NA	NA	0.0039
23	NA	NA	0.0032
24	NA	NA	0.0103
27	NA	NA	0.0021
31	NA	NA	0.0060
35	NA	NA	0.0055
36	NA	NA	0.0036
37	NA	NA	0.0062
39	NA	NA	0.059
44	NA	NA	0.403
45	$0.30 \pm 2\%$	$0.01 \pm 31\%$	0.021
46	NA	NA	0.214
47	$0.007 \pm 6\%$	$0.003 \pm 57\%$	0.014
48	NA	NA	0.0044
58	$0.0009 \pm 16\%$	$0.001 \pm 67\%$	0.0025
66	NA	NA	0.028
67	NA	NA	0.0112
68	$0.001 \pm 17\%$	$0.004 \pm 50\%$	0.019
70	NA	NA	0.026
CG _w ^b	2	0.03	40

^aNA = Not yet available.

^bConcentration guide for water, 10 CFR 20.

Table 8. Analyses of water samples taken from drainage pathways from the site to the Conemaugh River

Sample designation ^a	Radionuclides in water (pCi/ml)				Radionuclides in water sediment (pCi/g)		
	²¹⁰ Pb	²³⁰ Th	²²⁶ Ra	²³⁸ U	²¹⁰ Pb	²³⁰ Th	²²⁶ Ra
OW1	0.010 ± 32%	0.0002 ± 50%	0.001 ± 33%	0.0032	590 ± 46%	1.4 ± 270%	2.7 ± 150%
OW2	0.006 ± 46%	0.00009 ± 50%	0.0005 ± 100%	0.0010	210 ± 120%	9.0 ± 120%	1.8 ± 250%
OW3	0.0005 ± 400%	0.00009 ± 250%	0.0005 ± 100%	0.0039	1800 ± 100%	135 ± 67%	<1.4
OW4	<0.001	0.00005 ± 300%	0.0005 ± 100%	0.0007	<36	5 ± 90%	0.18 ± 250%
CG _w ^b	0.1	2	0.03	40			

^aSee Fig. 6 for sample locations.

^bConcentration guide for water as stated in 10 CFR 20, Appendix B, and ERDAM 0524, Annex A.

Table 9. Analyses of water samples taken from the east and west lagoons on the site

Sample designation	Radionuclides in water (pCi/ml)				Radionuclides in water sediment (pCi/g)		
	^{210}Pb	^{230}Th	^{226}Ra	^{238}U	^{210}Pb	^{230}Th	^{226}Ra
W1 ^a	0.003 ± 67%	0.0002 ± 200%	0.0009 ± 50%	0.0035	86 ± 35%	2.7 ± 10%	1.1 ± 80%
W2 ^b	0.005 ± 42%	0.0009 ± 100%	0.0009 ± 50%	0.0019	11 ± 39%	0.43 ± 10%	1.4 ± 31%
CG _w ^c	0.1	2	0.03	40			

^aSample taken from the east lagoon (Fig. 6).

^bSample taken from the west lagoon (Fig. 6).

^cConcentration guide for water as stated in 10 CFR 20, Appendix B, and ERDAM 0524, Annex A.

Table 10. Radon concentrations measured outdoors on the site

Location shown in Fig. 6	Sampling interval (hr)	Average ^{222}Rn concentration (pCi/liter)	Maximum ^{222}Rn concentration (pCi/liter)
R1	4.4	0.24	0.35
R1	7.0	0.26	0.35
R2	4.4	0.48	9.67
R2	7.0	0.28	0.43
R3	4.5	1.82	2.65
R4	4.5	0.49	0.63
R5	8.0	0.30	0.47
R6	8.0	0.28	0.43

Table 11. Radon-222 daughter concentrations measured outdoors on the site

Location shown in Fig. 6	Radionuclide concentrations in air (pCi/liter)			Working levels
	$^{218}\text{Po}(\text{RaA})$	$^{214}\text{Pb}(\text{RaB})$	$^{214}\text{Bi}(\text{RaC})$	
D1	0.13	0.11	0.16	0.001
D1	0.05	0.13	0.15	0.001
D2	0.20	0.07	0.14	0.001
D3	0.12	0.11	0.08	0.001
D4	0.09	0.10	0.12	0.001
D5	0.03	0.06	0.06	0.0006
D5	0.07	0.10	0.03	0.0006
D5	0.10	0.17	0.03	0.001
D6	0.17	0.22	0.12	0.001
D6	0.008	0.05	0.09	0.0006
D7	0.13	0.10	0.02	0.0007
D8	0.15	0.01	0.09	0.0005

APPENDIX I

DESCRIPTION OF RADIATION SURVEY METERS, WRENN CHAMBERS, AND TECHNIQUE FOR THE MEASUREMENT OF RADON DAUGHTER CONCENTRATIONS

RADIATION SURVEY METERS

Beta-Gamma Survey Meter

A portable Geiger-Muller (G-M) survey meter is the primary instrument for measuring beta-gamma radioactivity. The G-M tube is a halogen-quenched stainless steel tube having a 30 mg/cm^2 wall thickness and presenting a cross-sectional area of approximately 10 cm^2 . Since the G-M tube is sensitive to both beta and gamma radiation, measurements are taken in both an open-window and a closed-window configuration. Beta radiation cannot penetrate the closed window, and thus the beta reading can be determined by taking the difference between the open- and closed-window readings. This meter is shown in Fig. I-A.

The G-M survey meters were calibrated by comparison with a pre-calibrated Victoreen Model 440 ionization chamber (Fig. I-B). The open-window calibration factor was found to be 2000 cpm per mR/hr for surfaces contaminated with ^{226}Ra in equilibrium with ^{238}U and 2300 cpm per mR/hr for surfaces contaminated with initially pure uranium. The closed-window (gamma) calibration factor, determined by use of a NBS standard ^{226}Ra source, was 3200 cpm per mR/hr.

Gamma Scintillation Survey Meter

A portable survey meter using a NaI scintillation probe is used to measure low-level gamma radiation exposure. The scintillation probe is a $3.2 \times 3.8\text{-cm}$ NaI crystal coupled to a photomultiplier tube. This probe is connected to a Victoreen Model Thyac III ratemeter (see Fig. I-C). This unit is capable of measuring radiation levels from a few $\mu\text{R/hr}$ to several hundred $\mu\text{R/hr}$. This instrument is calibrated at ORNL with an NBS standard ^{226}Ra source. Typical calibration factors are of the order of 300 cpm/ μR per hr.

TECHNIQUES FOR THE MEASUREMENT OF RADON AND RADON DAUGHTERS IN AIR

Continuous Radon Monitor

Concentrations of radon are measured using a detector developed by Wrenn et al.^{I-1} This detector operates on the principle that most of the RaA ions are positively charged. Radon is allowed to diffuse through a foam rubber covered hemispherically shaped metal screen, which filters radon daughters. As radon in the chamber decays, after diffusing into the cavity, RaA ions are attracted to a thin aluminized mylar film which is stretched over a zinc sulfide scintillation detector. The potential between this aluminized mylar film and the hemispherically shaped wire screen creates a strong electric field which serves to attract the charged ions. The ions thus attracted remain on the surface of the mylar film and continue their radioactive decay to other radon daughters. The principal radiation detected by a radon monitor of this type is the alpha particles from RaA and RaC'. Alpha pulses are counted and integrated for a fixed period of time, usually 30 min. At the end of each timed counting period, the total count for each channel is printed automatically and the system is reset and counting for the next period is initiated.

The radon monitor in use by ORNL is similar to that developed by Wrenn. However, the scintillation detector is larger (2 in. in diam), and a provision has been made to utilize an alpha source in order to standardize the chamber before putting it into service (see Fig. I-D). The alpha standard is inserted through a hole in the top of the chamber and rests in a fixed and repeatable position. During use of the monitor, the source access hole is plugged with a rubber stopper. An overall view of the ORNL radon monitor is shown in Fig. I-E.

Radon Progeny Monitor

An alpha spectrometry technique has been refined by Kerr^{I-2, I-3} for the measurement of ^{222}Rn progeny concentrations in air. From one integral count of the ^{218}Po alpha activity and two integral counts of the ^{214}Po alpha activity, the concentrations in air of ^{218}Po , ^{214}Bi and ^{214}Pb may be calculated.

Particulate ^{222}Rn daughters attached to airborne dust are collected on a membrane filter with a pore size of 0.4 microns. A sampling time of 5 min and a flow rate of 12 liters/min are used. This filter sample is then placed under a silicon surface barrier detector and counted. The detector and counting system used for radon daughter measurements are shown in Fig. I-F. Usually, counting of this kind is performed with a vacuum between the sample and the detector which requires a complicated sample holder and time-consuming sample changing methods. Experiments at this laboratory have shown that ease in sample handling is obtained with little loss in resolution when helium is used as a chamber fill gas.^{I-4} In this counter, helium is flowed between the diode and the filter sample, which are separated by a distance of 0.5 cm. One integral count of the ^{218}Po alpha activity is obtained from 2 to 12 min, and two integral counts of the ^{214}Po activity are obtained from 2 to 12 min and 15 to 30 min, respectively. All counting intervals are referenced to $t = 0$ at the end of sampling.

The equations describing the ^{222}Rn progeny atoms collection rates on the filter are of the form

$$\frac{dn_i(t)}{dt} = C_i v + \lambda_{i-1} n_{i-1}(t) - \lambda_i n_i(t), \quad (1)$$

where

n_i = number of the i^{th} species of atom on the filter as a function of time,

λ_i = radioactive decay constant of the i^{th} species (min^{-1}),

C_i = concentration of the i^{th} species (atoms liters^{-1}), and

v = air sampling flow rate (liters min^{-1}).

From the general form of Eq. 1, specific equations can be obtained describing the number of each ^{222}Rn decay product collected on the filter as a function of time. Also, by letting $v = 0$ in Eq. 1, a set of equations describing the decay on the filter of each ^{222}Rn progeny can be obtained. The equations describing the decay of ^{222}Rn progeny on the filter can be integrated and related to the integral counts obtained experimentally. Values for the total activities of ^{218}Po , ^{214}Pb , and ^{214}Bi on the filter at the end of sampling are obtained. The airborne concentrations are obtained by solving the equations describing the atom collection rates on the filter. A computer program has been written to perform these matrix operations, to calculate the air concentrations of the radon progeny, and to estimate the accuracy of the calculated concentrations.

REFERENCES FOR APPENDIX I

- I-1. M. E. Wrenn, H. Spitz, and N. Cohen, IEEE Trans. Nucl. Sci., 22, 645 (1975).
- I-2. G. D. Kerr, Measurement of Radon Progeny Concentrations in Air by Alpha-Particle Spectrometry, ORNL/TM-4924 (July 1975).
- I-3. G. D. Kerr, "Measurement of Radon Progeny Concentrations in Air," Trans. Am. Nuc. Soc. 17, 541 (1973).
- I-4. P. T. Perdue, W. H. Shinpaugh, J. H. Thorngate and J. A. Auxier, "A Convenient Counter for Measuring Alpha Activity of Smear and Air Samples," Health Phys. 26, 114 (1974).

Fig. I-A. G-M survey meter

Fig. I-B. Victoreen 440 ionization chamber.

Fig. I-C. Gamma scintillation survey meter.

Fig. I-D. View of ionization chamber utilized in ORNL radon monitor. Shown in the photo-multiplier housing, screen mesh hemisphere housing, and aluminized mylar covered ZnS scintillator.

Fig. I-E. Overall view of ORNL continuous radon monitor.

Fig. I-F. Counting system for radon daughter measurements.

APPENDIX II

DESCRIPTION OF GE(LI) DETECTOR AND SOIL COUNTING PROCEDURES

DESCRIPTION OF Ge(Li) DETECTOR SYSTEM

A holder for twelve 30-cm³ polyethylene bottles (standard containers for liquid scintillation samples) and a background shield have been designed for use with a 50-cm³ Ge(Li) detector system (see Figs. II-A, II-B). During counting of the samples, the holder is used to position ten of the sample bottles around the cylindrical surface of the detector, parallel to and symmetric about its axis, and two additional bottles across the end surface of the detector, perpendicular to and symmetric with its axis. With a 300-cm³ sample and a graded shield developed for use with the system, it is possible to measure 1 pCi/g of ²³²Th or ²²⁶Ra with an error of $\pm 10\%$ or less.

Pulses are sorted by a 4096-channel analyzer (see Fig. II-C), stored on magnetic tape, and subsequently entered into a computer program which uses an iterative least squares method to identify radio-nuclides corresponding to those gamma-ray lines found in the sample. The program, which is accessible through a remote terminal, relies on a library of radioisotopes which contains approximately 700 isotopes and 2500 gamma-rays and which runs continuously on the IBM-360 system at ORNL. In identifying and quantifying ²²⁶Ra, six principal gamma-ray lines are analyzed. Most of these are from ²¹⁴Pb and correspond to 295, 352, 609, 1120, 1765, and 2204 KeV. An estimate of the concentration of ²³⁸U is obtained from an analysis of the 93 KeV line from its daughter ²³⁴Th.

Fig. II-A. Holder for Ge(Li) detector system.

Fig. II-B. Ge(Li) detector system.

Fig. II-C. 4096-channel analyzer.

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APPENDIX III

PROCEDURE FOR ESTIMATING THE TOTAL ^{226}Ra

CONTAMINATION FROM SCINTILLATION

PROBE LOGGINGS

Since the gamma radiation intensity of subsurface soil contaminated with ^{226}Ra and other radionuclides from the ^{238}U chain depends chiefly on the concentrations of ^{226}Ra and daughters present, gamma scintillation probe loggings in auger holes can be used to estimate ^{226}Ra concentrations in subsurface soil. In the case of the Blairsville site, 75 auger holes were logged. At three of these holes, soil samples were extracted at intervals of approximately 1 ft. By comparison with scintillation probe readings at corresponding depths, a "best fitting" curve, $y = (7.3)(x - 2)$, was obtained, where y is the ^{226}Ra concentration in pCi/g and x is the meter reading in thousand cpm.

Using this conversion, the average ^{226}Ra concentration and depth of contamination were estimated for each auger hole. These values were then averaged over the portions of the survey blocks contained within the shaded area shown in Fig. 8. In order to obtain an estimate of the total contamination in a block, a process of integration was used, whereby the product of the average concentration of ^{226}Ra and the depth of contamination was determined for each hole within the block. These products were averaged over the entire survey block, then multiplied by a constant factor to convert to curies of ^{226}Ra . This method yielded an estimate of 4 curies of ^{226}Ra .

In estimating the ^{238}U content, the ^{226}Ra value was divided by a factor of 3. Twenty-one composite samples taken from auger holes and showing contamination were analyzed and the ^{226}Ra to ^{238}U ratio was obtained. An average value of 2.99 was determined with a standard deviation of the mean of 0.26.

APPENDIX IV

PERTINENT RADIOLOGICAL REGULATIONS, STANDARDS AND GUIDELINES

GUIDELINES FOR DECONTAMINATION OF FACILITIES AND EQUIPMENT

PRIOR TO RELEASE FOR UNRESTRICTED USE

OR TERMINATION OF LICENSES FOR BYPRODUCT, SOURCE,

OR SPECIAL NUCLEAR MATERIAL

U. S. Nuclear Regulatory Commission
Division of Fuel Cycle
and Material Safety
Washington, D. C. 20555

November 1976 .

The instructions in this guide in conjunction with Table IV-1 specify the radioactivity and radiation exposure rate limits which should be used in accomplishing the decontamination and survey of surfaces or premises and equipment prior to abandonment or release for unrestricted use. The limits in Table IV-1 do not apply to premises, equipment, or scrap containing induced radioactivity for which the radiological considerations pertinent to their use may be different. The release of such facilities or items from regulatory control will be considered on a case-by-case basis.

1. The licensee shall make a reasonable effort to eliminate residual contamination.
2. Radioactivity on equipment or surfaces shall not be covered by paint, plating, or other covering material unless contamination levels, as determined by a survey and documented, are below the limits specified in Table IV-1 prior to applying the covering. A reasonable effort must be made to minimize the contamination prior to use of any covering.
3. The radioactivity on the interior surfaces of pipes, drain lines, or ductwork shall be determined by making measurements at all traps, and other appropriate access points, provided that contamination at these locations is likely to be representative of contamination on the interior of the pipes, drain lines, or ductwork. Surfaces of premises, equipment, or scrap which are likely to be contaminated but are of such size, construction, or location as to make the surface inaccessible for purposes of measurement shall be presumed to be contaminated in excess of the limits.
4. Upon request, the Commission may authorize a licensee to relinquish possession or control of premises, equipment, or scrap having surfaces contaminated with materials in excess of the limits specified. This may include, but would not be limited to, special circumstances such as razing of buildings, transfer of premises to another organization continuing work with radioactive materials, or conversion of facilities to a long-term storage or standby status. Such request must:
 - a. Provide detailed, specific information describing the premises, equipment or scrap, radioactive contaminants, and the nature, extent, and degree of residual surface contamination.
 - b. Provide a detailed health and safety analysis which reflects that the residual amounts of materials on surface areas, together with other considerations such as prospective use of the premises, equipment or scrap, are unlikely to result in an unreasonable risk to the health and safety of the public.

5. Prior to release of premises for unrestricted use, the licensee shall make a comprehensive radiation survey which establishes that contamination is within the limits specified in Table IV-1. A copy of the survey report shall be filed with the Division of Fuel Cycle and Material Safety, USNRC, Washington, D.C. 20555, and also the Director of the Regional Office of the Office of Inspection and Enforcement, USNRC, having jurisdiction. The report should be filed at least 30 days prior to the planned date of abandonment. The survey report shall:
 - a. Identify the premises.
 - b. Show that reasonable effort has been made to eliminate residual contamination.
 - c. Describe the scope of the survey and general procedures followed.
 - d. State the findings of the survey in units specified in the instruction.

Following review of the report, the NRC will consider visiting the facilities to confirm the survey.

TABLE IV-1

ACCEPTABLE SURFACE CONTAMINATION LEVELS

NUCLIDES ^a	AVERAGE ^{b c f}	MAXIMUM ^{b d f}	REMOVABLE ^{b e f}
U-nat, U-235, U-238, and associated decay products	5,000 dpm $\alpha/100 \text{ cm}^2$	15,000 dpm $\alpha/100 \text{ cm}^2$	1,000 dpm $\alpha/100 \text{ cm}^2$
Transuranics, Ra-226, Ra-228, Th-230, Th-228, Pa-231, Ac-227, I-125, I-129	100 dpm/100 cm^2	300 dpm/100 cm^2	20 dpm/100 cm^2
Th-nat, Th-232, Sr-90, Ra-223, Ra-224, U-232, I-126, I-131, I-133	1,000 dpm/100 cm^2	3,000 dpm/100 cm^2	200 dpm/100 cm^2
Beta-gamma emitters (nuclides with decay modes other than alpha emission or spontaneous fission) except SR-90 and other noted above.	5,000 dpm $\beta\gamma/100 \text{ cm}^2$	15,000 dpm $\beta\gamma/100 \text{ cm}^2$	1,000 dpm $\beta\gamma/100 \text{ cm}^2$

^aWhere surface contamination by both alpha- and beta-gamma-emitting nuclides exists, the limits established for alpha- and beta-gamma-emitting nuclides should apply independently.

^bAs used in this table, dpm (disintegrations per minute) means the rate of emission by radioactive material as determined by correcting the counts per minute observed by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.

^cMeasurements of average contaminant should not be averaged over more than 1 square meter. For objects of less surface area, the average should be derived for each such object.

^dThe maximum contamination level applies to an area of not more than 100 cm^2 .

^eThe amount of removable radioactive material per 100 cm^2 of surface area should be determined by wiping that area with dry filter or soft absorbent paper, applying moderate pressure, and assessing the amount of radioactive material on the wipe with an appropriate instrument of known efficiency. When removable contamination on objects of less surface area is determined, the pertinent levels should be reduced proportionally and the entire surface should be wiped.

^fThe average and maximum radiation levels associated with surface contamination resulting from beta-gamma emitters should not exceed 0.2 mrad/hr at 1 cm and 1.0 mrad/hr at 1 cm, respectively, measured through not more than 7 milligrams per square centimeter of total absorber.

Excerpts from
Proposed

ANSI N328-197

Proposed American National Standard

Control of Radioactive Surface Contamination
on Materials, Equipment, and Facilities to be
Released for Uncontrolled Use

Secretariat

Health Physics Society

Property shall not be released for uncontrolled use unless documented measurements show the total and removable contamination levels to be no greater than the values in Table IV-2 or Table IV-3. (Table IV-3 is easier to apply when the contaminants cannot be individually identified.)

Where potentially contaminated surfaces are not accessible for measurement (as in some pipes, drains, and ductwork), such property shall not be released pursuant to this standard, but made the subject of case-by-case evaluation. Credit shall not be taken for coatings over contamination.

TABLE IV-2

SURFACE CONTAMINATION LIMITS

The levels may be averaged* over the 1 m^2 provided the maximum activity in any area of 100 cm^2 is less than 3 times the limit value.

<u>Nuclide</u>	<u>Limit (Activity)</u> <u>dpm/100 cm^2</u>	
	Total	Removable
Group 1: Nuclides for which the nonoccupational MPC [†] is $2 \times 10^{-13} \text{ Ci/m}^3$ or less, or for which the nonoccupational MPC [‡] is $2 \times 10^{-7} \text{ Ci/m}^3$ or less; includes Ac-227; Am-241; -242m, -243; Cf-249; -250, -251, -252; Cm-243, -244, -245, -246, -247, -248; I-125, -129; Np-237; Pa-231; Pb-210; Pu-238, -239 -240, -242, -244; Ra-226, -228; Th-228, -230. [§]	100	20
Group 2: Those nuclides not in Group 1 for which the nonoccupational MPC [†] is $1 \times 10^{-12} \text{ Ci/m}^3$ or less or for which the nonoccupational MPC [‡] is $1 \times 10^{-6} \text{ Ci/m}^3$ or less; includes Es-254; Fm-256; I-126, -131, -133; Po-210; Ra-223; Sr-90; Th-232; U-232. [§]	1,000	200
Group 3: Those nuclides not in Group 1 or Group 2.	5,000	1,000

*See note following Table 2 on application of limits.

[†]MPC: Maximum Permissible Concentration in Air applicable to continuous exposure of members of the public as published by or derived from an authoritative source such as NCRP, ICRP or NRC (10 CFR Part 20, Appendix B, Table 2, Column 1).

[‡]MPC: Maximum Permissible Concentration in Water applicable to members of the public.

[§]Values presented here are obtained from 10 CFR Part 20. The most limiting of all given MPC values (e.g. soluble vs. insoluble) are to be used. In the event of the occurrence of mixture of radionuclides, the fraction contributed by each constituent of its own limit shall be determined and the sum of the fractions must be less than 1.

TABLE IV-3

ALTERNATE SURFACE CONTAMINATION LIMITS

(All alpha emitters, except U-nat and Th-nat are considered as a group)

The levels may be averaged over 1 m^2 * provided the maximum activity in any area of 100 cm^2 is less than 3 times the limit value.

Nuclide	Limit (Activity)	
	dpm/100 cm^2	
	Total	Removable
If the contaminant cannot be identified; or if alpha emitters other than U-nat and Th-nat are present; or if the beta emitters comprise Ac-227, Ra-226, Ra-228, I-125 and I-129.	100	20
If it is known that all alpha emitters are generated from U-nat and Th-nat; and beta emitters are present which, while not identified, do not include Ac-227, I-125, I-129, Ra-226 and Ra-228.	1,000	200
If it is known that alpha emitters are generated only from U-nat and Th-nat; and the beta emitters, while not identified, do not include Ac-227, I-125, I-129, Sr-90, Ra-223, Ra-228, I-126, I-131 and I-133.	5,000	1,000

*NOTE ON APPLICATION OF TABLES 1 AND 2 TO ISOLATED SPOTS OR ACTIVITY:

For purposes of averaging, any m^2 of surface shall be considered to be contaminated above the limit, L, applicable to 100 cm^2 if:

- From measurements of a representative number, n, of sections, it is determined that $1/n \sum_{i=1}^n S_i > L$, where S_i is the dpm/100 cm^2 determined from measurement of section i; or
- On surfaces less than 1 m^2 , it is determined that $1/n \sum_{i=1}^n S_i > AL$, where A is the area of the surface in units of m^2 ; or
- It is determined that the activity of all isolated spots or particles in any area less than 100 cm^2 exceeds $3L$.

SURGEON GENERAL'S GUIDELINES
Part 712
Grand Junction Remedial Action Criteria

Federal Register, Vol. 41, No. 253, pp. 56777-8, Thursday, December 30, 1976

PART 712 - GRAND JUNCTION
REMEDIAL ACTION CRITERIA

712. 1 Purpose

(a) The regulations in this part establish the criteria for determination by ERDA of the need for, priority of and selection of appropriate remedial action to limit the exposure of individuals in the area of Grand Junction, Colo., to radiation emanating from uranium mill tailing which have been used as construction-related material.

(b) The regulations in this part are issued pursuant to Publ. L. 92-314 (86 Stat. 222) of June 16, 1972.

713.2 Scope

The regulations in this part apply to all structures in the area of Grand Junction, Colo., under or adjacent to which uranium mill tailings have been used as a construction-related material between January 1, 1951, and June 16, 1972, inclusive.

712.3 Definitions

As used in this part:

(a) "Administrator" means the Administrator of Energy Research and Development or his duly authorized representative.

(b) "Area of Grand Junction, Colo.," means Mesa County, Colo.

(c) "Background" means radiation arising from cosmic rays and radioactive material other than uranium mill tailings.

(d) "ERDA" means the U.S. Energy Research and Development Administration or any duly authorized representative thereof.

(e) "Construction-related material" means any material used in the construction of a structure.

(f) "External gamma radiation level" means the average gamma radiation exposure rate for the habitable area of a structure as measured near floor level.

(g) "Indoor radon daughter concentration level" means that concentration of radon daughters determined by: (1) Averaging the results of 6 air samples, each of at least 100 hours duration, and taken at a minimum of 4-week intervals throughout the year in a habitable area of a structure, or (2) utilizing some other procedure approved by the Commission.

(h) "Milliroentgen (mR) means a unit equal to one-thousandth (1/1000) of a roentgen which roentgen is defined as an exposure dose of X or gamma radiation such that the associated corpuscular emission per 0.001293 gram of air produces, in air, ions carrying one electrostatic unit of quantity of electricity of either sign.

(i) "Radiation" means the electromagnetic energy (gamma) and the particulate radiation (alpha and beta) which emanate from the radioactive decay of radium and its daughter products.

(j) "Radon daughters" means the consecutive decay products of radon-222. Generally, these include Radium A (polonium-218), Radium B (lead-218), Radium C (bismuth-214), and Radium C (polonium-214).

(k) "Remedial action" means any action taken with a reasonable expectation of reducing the radiation exposure resulting from uranium mill tailings which have been used as construction-related material in and around structures in the area of Grand Junction, Colo.

(l) "Surgeon General's guidelines" means radiation guidelines related to uranium mill tailings prepared and released by the Office of the U.S. Surgeon General, Department of Health, Education and Welfare on July 27, 1970.

(m) "Uranium mill tailings" means tailings from a uranium mill operation involved in the Federal uranium procurement program.

(n) "Working Level" (WL) means any combination of short-lived radon daughter products in 1 liter of air that will result in the ultimate emission of 1.3×10^5 MeV of potential alpha energy.

712.4 Interpretations

Except as specifically authorized by the Administrator in writing, no interpretation of the meaning of the regulations in this part by an officer or employee of ERDA other than a written interpretation by the General Counsel will be recognized to be binding upon ERDA.

712.5 Communications

Except where otherwise specified in this part, all communications concerning the regulations in this part should be addressed to the Director, Division of Safety, Standards, and Compliance, U.S. Energy Research and Development Administration, Washington, D.C. 20545.

712.6 General radiation exposure level criteria for remedial action

The basis for undertaking remedial action shall be the applicable

guidelines published by the Surgeon General of the United States. These guidelines recommend the following graded action levels for remedial action in terms of external gamma radiation level (EGR) and indoor radon daughter concentration level (RDC) above background found within dwellings constructed on or with uranium mill tailings:

EGR	RDC	Recommendation
Greater than 0.1 mR/hr.	Greater than 0.05 WL.	Remedial action indicated
From 0.05 to 0.1 mR/hr.	From 0.01 to 0.05 WL.	Remedial action may be suggested.
Less than 0.05 mR/hr.	Less than 0.01 WL.	No remedial action in- dicated.

712.7 Criteria for determination of possible need for remedial action

Once it is determined that a possible need for remedial action exists, the record owner of a structure shall be notified of that structure's eligibility for an engineering assessment to confirm the need for remedial action and to ascertain the most appropriate remedial measure, if any. A determination of possible need will be made if as a result of the presence of uranium mill tailings under or adjacent to the structure, one of the following criteria is met:

(a) Where ERDA approved data on indoor radon daughter concentration levels are available:

(1) For dwellings and schoolrooms: An indoor radon daughter concentration level of 0.01 WL or greater above background.

(2) For other structures: An indoor radon daughter concentration level of 0.03 WL or greater above background.

(b) Where ERDA approved data on indoor radon daughter concentration levels are not available:

(1) For dwellings and schoolrooms:

(i) An external gamma radiation level of 0.05 mR/hr. or greater above background.

(ii) An indoor radon daughter concentration level of 0.01 WL or greater above background (presumed).

(A) It may be presumed that if the external gamma radiation level is equal to or exceeds 0.02 mR/hr. above background, the indoor radon daughter concentration level equals or exceeds 0.01 WL above background.

(B) It should be presumed that if the external gamma radiation level is less than 0.001 mR/hr. above background, the indoor radon daughter concentration level is less than 0.01 WL above background and no possible need for remedial action exists.

(C) If the external gamma radiation level is equal to or greater than 0.001 mR/hr. above background but is less than 0.02 mR/hr. above background, measurements will be required to ascertain the indoor radon daughter concentration level.

(2) For other structures: (i) An external gamma radiation level of 0.15 mR/hr. above background averaged on a room-by-room basis.

(ii) No presumptions shall be made on the external gamma radiation level/indoor radon daughter concentration level relationship. Decisions will be made in individual cases based upon the results of actual measurements.

712.8 Determination of possible need for remedial action where criteria have not been met

The possible need for remedial action may be determined where the criteria in 712.7 have not been met if various other factors are present. Such factors include, but are not necessarily limited to, size of the affected area, distribution of radiation levels in the affected area, amount of tailings, age of individuals occupying affected area, occupancy time, and use of the affected area.

712.9 Factors to be considered in determination of order or priority for remedial action

In determining the order or priority for execution of remedial action, consideration shall be given, but not necessarily limited to, the following factors:

(a) Classification of structure. Dwellings and schools shall be considered first.

(b) Availability of data. Those structures for which data on indoor radon daughter concentration levels and/or external gamma radiation levels are available when the program starts and which meet the criteria in 712.7 will be considered first.

(c) Order of application. Insofar as feasible remedial action will be taken in the order which the application is received.

(d) Magnitude of radiation level. In general, those structures with the highest radiation levels will be given primary consideration.

(e) Geographical location of structures. A group of structures located in the same immediate geographical vicinity may be given priority consideration particularly where they involve similar remedial efforts.

(f) Availability of structures. An attempt will be made to schedule remedial action during those periods when remedial action can be taken with minimum interference.

(g) Climatic conditions. Climatic conditions or other seasonable considerations may affect the scheduling of certain remedial measures.

712.10 Selection of appropriate remedial action

(a) Tailings will be removed from those structures where the appropriately averaged external gamma radiation level is equal to or greater than 0.05 mR/hr. above background in the case of dwellings and schools and 0.15 mR/hr. above background in the case of other structures.

(b) Where the criterion in paragraph (a) of this section is not met, other remedial action techniques, including but not limited to sealants, ventilation, and shielding may be considered in addition to that of tailings removal. ERDA shall select the remedial action technique or combination of techniques, which it determines to be the most appropriate under the circumstances.

ENVIRONMENTAL PROTECTION AGENCY

Title 40-Part 141

Drinking Water Regulations-Radionuclides

Interim Primary Drinking Water Regulations
Promulgation of Regulations on Radionuclides

Federal Register, Vol. 41, No. 133, pp. 28402-9 Friday, July 9, 1976

Part 141.15 Federal Register

Vol 41, No. 133, p 28404, Friday, July 9, 1976

Maximum contaminant levels for ^{226}Ra , ^{228}Ra , and gross alpha particle radioactivity.

- (a) Combined ^{226}Ra and ^{228}Ra - 5 pCi/liter.
- (b) Gross alpha particle activity (including ^{226}Ra but excluding radon and uranium) - 15 pCi/liter.

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APPENDIX V

PHOTOGRAPHS SHOWING THE LANDFILL SITE AND
UNLOADING OPERATIONS AT APPROXIMATELY
THE TIME THE RESIDUES WERE DUMPED

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DISPOSAL AREA LOOKING EAST

Fig. V-I. View from the top of the foothills looking east showing the general layout of the disposal site.

Fig. V-II. Looking east showing unloading operations from the north siding of the pit.

Fig. V-III. Looking west from the extreme eastern end of the fill.

Fig. V-IV. Looking northwest showing dozing of Vitro waste into the pit.

APPENDIX VI

EVALUATION OF RADIATION EXPOSURES

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EVALUATION OF RADIATION EXPOSURES AT THE PENNSYLVANIA RAILROAD
LANDFILL SITE, BURRELL TOWNSHIP, PENNSYLVANIA

The U. S. Department of Energy has determined that the Pennsylvania Railroad Landfill Site, Burrell Township, Pennsylvania, is presently contaminated with radioactive residues. The site was used for the dumping of radioactive residues generated by the Vitro Corporation's uranium processing plant in Canonsburg, Pennsylvania, while under contract with the Manhattan Engineer District. Approximately 11,000 tons of this material were dumped on the site between October 1955 and January 1957. The residues contained approximately 6 tons of uranium (U_3O_8) by weight. Dumping occurred in a portion of the former bed of the Conemaugh River, which had been diverted several years earlier. There are no thoroughfares through the site, with the exception of the railroad. The entire site comprises approximately 60 acres and is located one mile southeast of Blairsville, Pennsylvania. The nearest dwelling is approximately 500 ft from the site. There are a few persons, railroad workers or hunters, for example, who may be on the site occasionally.

Contamination at the disposal site is due to buried deposits of naturally occurring uranium-238 and radium-226. This contamination will yield slight exposures to persons at the site. Most exposures result from beta and gamma emitting radionuclides located in surface and subsurface soil at the site. In addition to these direct radiation exposures, radium deposits in the soil will lead to exposures through the inhalation of radon and its short-lived daughters. Exposures received by ingestion (e.g., eating or drinking on the site) are relatively small compared with external radiation and the inhalation of radon and its short-lived daughters. A summary of radiation exposures at the

Burrell Township site is provided in Table VI-1 along with appropriate guidelines and background values.

The naturally occurring radionuclides present at the Burrell Township site are also present in minute quantities throughout our environment. Concentrations of these radionuclides in normal soils, air, water, food, etc., are referred to as background concentrations. Radiation exposures resulting from this environmental radioactivity are referred to as background exposures. These background exposures are not caused by any human activity and, to a large extent, can be controlled only through man's moving to areas with lower background exposures. Each and every human receives some background exposure daily.

The use of radioactive materials for scientific, industrial, or medical purposes may cause radiation exposures above the background level to be received by workers in the industry and, to a lesser extent, by members of the general public. Scientifically based guidelines have been developed to place an upper limit on these additional exposures. Limits established for exposures to the general public are much lower than the limits established for workers in the nuclear industry.

Uranium-238 is believed to have been created when the earth was formed. It is still present today because it takes a very long time to decay. The half-life is a measure of the time required for radioactive decay; for uranium-238 it is 4.5 billion years. Thus, if 4.5 billion years ago you had a curie^a of uranium-238, today you would have one-half

^aThe curie is a unit used to measure the amount of radioactivity in a substance; one curie represents 37 billion radioactive disintegrations per second.

curie; 4.5 billion years hence, this would only be one-fourth curie. As the uranium-238 decays, it changes into another substance, thorium-234. Thorium-234 is called the "daughter" of uranium-238. In turn, thorium-234 is the "parent" of protactinium-234. Radioactive decay started by uranium-238 continues as shown in Table VI-2 until stable lead-206 is formed. The "decay product" listed in Table VI-2 is the radiation produced as the parent decays.

Direct Beta and Gamma Ray Exposures

Nuclear Regulatory Commission (NRC) guidelines state that the combined dose from weakly penetrating beta particles and from gamma rays, measured at a distance of one centimeter from any surface, should not exceed 0.2 millirad^b per hour when averaged over an area of one square meter. The combined dose rate should not exceed 1.0 millirad per hour in small areas of 100 cm². These guidelines are exceeded at 7 locations at the site, with individual measurements ranging up to 5.4 millirads per hour along the western half of the baseline used to establish a measurement grid for the radiological survey. Most of the contamination appears to be confined to the northwestern quadrant of the site. Beta-gamma exposure rates in this area averaged 0.16 millirad per hour, with several areas exceeding the guideline value of 0.2 millirad per hour when averaged over one square meter or greater.

Thus, handling the surface soil from this area for a period of ten hours would produce a beta-gamma dose of 1.6 millirads to the skin. For

^bThe millirad is a unit for measuring radiation dose to tissue and is one-thousandth of a rad.

comparison, the skin dose which would be expected from a normal year's watching of color television by an adult is 1.6 millirads; for a child less than 15 years of age, the comparable dose is 3.6 millirads per year (according to the United Nations Scientific Committee on the Effects of Atomic Radiation).

As may be seen in Table VI-2, several of the daughters of uranium-238 and of radium-226 emit gamma radiation (gamma rays are penetrating radiation like X-rays). Hence, the residues on this site are sources of external gamma radiation exposure. External gamma exposures measured at one meter above the ground at the Burrell Township site ranged from 5 to 630 microRoentgens^c per hour, with the highest readings being obtained in the northwestern quadrant of the site. The average exposure rate for the site was 11 microRoentgens per hour. The average exposure rate in the northwest quadrant was 36 microRoentgens per hour. Exposure to this level for 2000 hours per year, a typical work year, would lead to an exposure of 72,000 microRoentgens. For comparison, a typical chest X-ray (according to Department of Health, Education, and Welfare data) might yield an exposure of 27,000 microRoentgens. Background levels in the disposal site area range from 5 to 9 microRoentgens per hour.

The National Council on Radiation Protection and Measurement (NCRP) has recommended a maximum annual whole-body exposure rate of 500,000 microRoentgens per year to an individual continually exposed in the general public. This value corresponds to 250 microRoentgens per hour for 2000 exposure hours (40 hours per week and 50 weeks per year) or to approximately 60 microRoentgens per hour for continuous exposure. The

^cThe Roentgen is a unit which was defined for radiation protection purposes for people exposed to penetrating gamma radiation. A micro-Roentgen is one-millionth of a Roentgen.

guideline of 250 microRoentgens per hour was exceeded at six locations at the site.

At the present time, the disposal site is not occupied (nearest residence is approximately 500 feet to the north). However, it is used during hunting season since it is populated with wild game (fowl, rabbits, deer, etc.). There is also frequent short-time occupancy along the northern edge of the site by railroad maintenance crews, and by local residents who use a small dirt road for riding trail bikes and for access to an area used to dump refuse. It is unlikely that a single person occupies any part of the site for more than a few hours per month.

Inhalation of Radionuclides

Radon-222, the daughter of radium-226, is an inert gas which may leave the soil and enter the atmosphere. Measurements of the concentration of radon at the site range from 0.24 to 9.67 picocuries^d per liter and average approximately 0.52 picocuries per liter over the northwestern quadrant of the site. Several of these readings exceed the guideline value of 3.0 picocuries per liter for exposure of the general public as set forth in 10 CFR 20.^e At the present, no structures exist on the site. However, if buildings were to be constructed over contaminated soil, radon concentrations higher than those measured on site could exist in the buildings. Estimates indicate that the radon concentration in structures built over the most contaminated soil could exceed 50 picocuries per liter.

As may be seen in Table VI-2, the decay of radon-222 produces a series of short-lived daughters. The unit which has been developed to measure

^dOne picocurie is one million-millionth of a curie, previously defined.

^eTitle 10, Code of Federal Regulations, Part 20, is a regulatory document published by the Nuclear Regulatory Commission and may be found in the Federal Register.

the concentration of daughters is the working level.^f Measurements at the Burrell Township site ranged from 0.0006 to 0.001 working level. These measurements are well below the guideline value of 0.03 working level suggested in 10 CFR 20. However, it is estimated that this guideline value could be exceeded in structures built over the most contaminated soil.

Studies of uranium and other hard rock miners have established that inhalation of large quantities of daughters of radon-222 over long periods of time increases an individual's risk of contracting lung cancer. The present federal guide value for uranium mine workers (given by the Environmental Protection Agency), when translated to the units discussed here, would limit mine workers to an exposure of 0.33 working levels, assuming exposure for 2000 hours per year, a typical work year. This level is significantly lower than the exposures received by most of the miners included in the studies.

Other Considerations of Exposure

The concentration of radionuclides in grab water samples taken at the site were all below the concentration guide for water (CG_w) set forth in 10 CFR 20. Additional water samples were taken on the site from water standing in the east and west lagoons and from the point where the drainage path from the west lagoon joins the Conemaugh River. The concentration of radionuclides in all samples was well below the concentration guide values.

While no crops are currently grown on this site, use of the contaminated soil for such purposes could produce additional human

^fThe working level is a unit which was defined for radiation protection purposes for uranium miners. It represents a specific level of energy emitted by the short-lived daughters of radon.

exposure through consumption of crops which have incorporated radium-226. Soil at this site contains high levels of radium-226. In addition, actions which involve considerable scraping or tilling of dry soil, particularly in the areas showing high concentrations of radium in surface soil, could lead to human exposures through inhalation of airborne radioactive dust.

Risk and Radiation Exposures

Risks resulting from radiation exposures should be considered within the context of other risks incurred in normal living. For simplicity, risks to health may be classified in four categories:

1. Unacceptable — problems with risk so high as to require immediate action, such as severe diseases where medical treatment is required to save a life.
2. Concerned — problems where people are willing to spend time and money to reduce potential hazards. Examples of this include the maintenance of public highways and signs, signals, fire departments, and rescue squads.
3. Recognized — problems where people may accept some inconvenience to avoid certain activities such as flying in airplanes, swimming alone, etc.
4. No great concern — problems with a low frequency of occurrence. There is an awareness of potential hazard, but an accompanying feeling that these problems occur only to other people.

An individual may be exposed to risks over which he can exercise some control (voluntary), and risks over which he feels he has no personal control or choice (involuntary).

Daily, an individual is confronted with decisions about risk which have an associated benefit -- for example, driving a car. This can serve as an illustration that a voluntary, concerned risk may be deemed appropriate due to the desirable perceived benefit. As another example, an individual who smokes cigarettes has subjected himself to a risk of lung cancer which is about ten times higher than that for a nonsmoker.

For purposes of radiation protection, all radiation exposures are assumed to be capable of increasing an individual's risk of contracting cancer. A precise numerical value cannot be assigned with any certainty to a given individual's increase in risk attributable to radiation exposure. The reasons for this are numerous; they include the individual's age at onset of exposure, variability in latency period (time between exposure and physical evidence of disease), the individual's personal habits and state of health, previous or concurrent exposure to other cancer-causing agents, and the individual's family medical history. Because of these variables, large uncertainties would exist in any estimates of the number of increased cancers in the relatively small population exposed at the Burrell Township site.

The normal annual death rate from lung cancer for all population groups in Indiana County (as of 1970) was 14.8 deaths per 100,000 population. At the same time, the annual death rates from lung cancer for all population groups in the United States and the state of Pennsylvania were 21.1 and 21.5 deaths per 100,000 population, respectively. A one-year exposure to the guideline value for uranium miners (0.33 working level for 2000 hours) might increase the risk of death due to lung cancer by approximately four percent.

The annual death rate from all types of cancer among all population groups in Indiana County (as of 1970) was 136 deaths per 100,000 population. At the same time, the death rates from all types of cancer for all population groups in the United States and in the state of Pennsylvania were 151 and 160 per 100,000 population, respectively. A one-year exposure to penetrating gamma radiation of 500,000 microRoentgen might increase the risk of death due to all types of cancer by about one-tenth of a percent. Exposures in excess of these guideline values would be expected to result in proportionately higher increases in risk. Consequently, any action taken to reduce either the rate or the duration of radiation exposures would also reduce the risk attendant to that exposure.

There are no data at present which give evidence of a relationship between low-level exposure of the skin and the development of skin cancers. This does not mean that skin cancer cannot be produced by low-level exposures. This does mean that the risk associated with guideline level exposures of the skin is so small that it cannot be quantified.

Remedial Measures

The radiation exposures at the Burrell Township site are attributable to the presence of uranium-238 and radium-226 deposits in soil at the site. This contamination leads to exposures due to external beta and gamma radiation and from the inhalation of radon which is produced by deposits of radium-226 in the soil. Each of these exposures would be eliminated by the removal of contaminated soil followed by backfill with uncontaminated soil. Due to the depth to which radium is deposited, it would

be necessary to remove the top ten feet of soil in the northwestern quadrant of the site. In some areas, it would be necessary to excavate to depths exceeding 30 feet. Current exposures from the pathways discussed here could be reduced to below guideline values by placing additional fill dirt over the areas containing the uranium and radium bearing residues. Periodic surveillance of the area would be required to insure that the additional fill remained intact and that use of the site did not change. The Department of Energy is now actively evaluating these and other alternatives under a priority program designed to assure public protection.

Summary

The Pennsylvania Railroad Landfill Site in Burrell Township is contaminated with residues resulting from the use of this site to dispose of radioactive residues containing naturally occurring uranium-238 and radium-226. This contamination is leading to exposures resulting from beta and gamma radiation and from the inhalation of radon and its short-lived daughters. Measurements made at the site indicate that, in several cases, such exposures exceed pertinent guidelines. In addition, construction of buildings on the site could produce exposures to radon and its daughters which greatly exceed guidelines. Consequently, some remedial measures are in order. The Department of Energy has developed a coordinated plan which addresses the specific problems at this landfill site and other formerly utilized MED/AEC sites. Currently, work is underway to implement the elements of this plan.

TABLE VI-1

SUMMARY OF EXPOSURE DATA AT THE PENNSYLVANIA RAILROAD LANDFILL SITE
BURRELL TOWNSHIP, PENNSYLVANIA

Exposure Source	Background Levels	Guideline Value for General Public	Guideline Value for Radiation Workers	Average Levels at Burrell Township site
Radon in air	Less than one picocurie ^a per liter of air	Continuous exposure to 3 picocuries per liter of air	Exposure for 40 hours per week and 50 weeks per year to 30 picocuries per liter of air	Average daytime concentration ranged from 0.24 to 2.4 picocuries per liter of air
Radon daughters in air	Less than 0.01 working level ^b	0.01 working level for residences and school rooms, and 0.03 working level for other structures	0.33 working level for uranium miners exposed for 40 hours per week and 50 weeks per year	Average daytime concentration ranged from 0.0006 working level to 0.001 working level
Gamma radiation from daughters of radium and uranium contamination	8 micro-Roentgens ^c per hour in the landfill site area	250 microRoentgens per hour above natural background for 40 hours per week and 50 weeks per year for an individual in the general public. This is equivalent to 0.5 Roentgen per year	2500 microRoentgens per hour for 40 hours per week and 50 weeks per year. This is equivalent to 5 Roentgens per year	Gamma radiation levels one meter above the ground ranged from 5 to 630 microRoentgens per hour. Exposure rate averaged 36 microRoentgens per hour in the northwest quadrant of the site

^aThe picocurie is a unit which was defined for expressing the amount of radioactivity present in a substance.

^bThe working level is a unit which was defined for radiation protection purposes for uranium miners. It represents a specific level of energy emitted by the short-lived daughters of radon.

^cThe Roentgen is a unit which was defined for radiation protection purposes for people exposed to penetrating gamma radiation. A microRoentgen is one-millionth of a Roentgen.

Table VI-2

Uranium-238 decay series

Parent	Half-life	Decay products	Daughter
uranium-238	4.5 billion years	alpha	thorium-234
thorium-234	24 days	beta, gamma	protactinium-234
protactinium-234	1.2 minutes	beta, gamma	uranium-234
uranium-234	250 thousand years	alpha	thorium-230
thorium-230	80 thousand years	alpha	radium-226
radium-226	1600 years	alpha	radon-222
radon-222	3.8 days	alpha	polonium-218
polonium-218*	3 minutes	alpha	lead-214
lead-214*	27 minutes	beta, gamma	bismuth-214
bismuth-214*	20 minutes	beta, gamma	polonium-214
polonium-214*	$\frac{2}{10,000}$ second	alpha	lead-210
lead-210	22 years	beta	bismuth-210
bismuth-210	5 days	beta	polonium-210
polonium-210	140 days	alpha	lead-206
lead-206	stable	none	none

*Short-lived radon daughters.