RADON MONITORING AT THE WASTE ISOLATION PILOT PLANT*

L. S. Pendlebury
U.S. Department of Energy

R. D. Boyer
Westinghouse Electric Corporation
Waste Isolation Division
WIPP Project
P.O. Box 2078
Carlsbad, NM 88221

ABSTRACT

In memory of Ormand Cordes

A year-long radon monitoring program began in July 1990 at the Waste Isolation Pilot Plant (WIPP) to determine the background concentrations of radon (222Rn) in specific areas of interest. Electret-passive radon monitors (E-PERMs) were the primary measurement instruments used in one configuration to measure radon concentrations and in another configuration to measure the location-by-location gamma background radiation. Time-integrated radon concentrations for the first quarter of monitoring indicated that both surface and underground radon concentrations were less than 1.0 pCi/liter and that concrete liners of the Air Intake Shaft and Waste Shaft do not appear to increase the radon concentrations underground.

INTRODUCTION

The WIPP is a United States (U.S.) Department of Energy (DOE) facility which was designed and constructed to provide a research and development facility to demonstrate the safe disposal of transuranic (TRU) waste generated by the defense activities of the U.S. government. The WIPP is located 40 km from Carlsbad, in southeast New Mexico, and the waste horizon is 855 m underground in a 600-m-thick bedded salt deposit. Four shafts connect the waste horizon with the surface.

Fans in the Exhaust Filter Building draw ventilation air into the underground via three air-intake shafts and out the Exhaust Shaft. Underground fans distribute the air underground. Normal ventilation is 6792 m^3/min., but if radioactive contamination above the set point is detected in the exhaust air, certain fans in the Exhaust Filter Building automatically stop operating, decreasing ventilation to 3396 m^3/min. and diverting it through a bank of high-efficiency particulate air filters.

On July 13, 1990, a year-long radon monitoring program began at the WIPP to determine the background concentrations of radon (222Rn) gas at specific areas of interest. Outdoor air was monitored near the intake shafts, and air was monitored underground near the base of the four shafts. Other locations were monitored for general area radon concentrations.

Radon concentrations were expected to be low, based on the limited radon monitoring conducted previously. In 1983, Sandia National Laboratories (SNL) reported that "Radon and working levels were at or below detection levels at all locations, and the radon concentration was estimated to be about 0.01 pCi/l on the surface based on spectral measurements." (Minnema and Brewer 1983). Furthermore, a recent DOE study of radon concentrations in DOE-owned buildings showed radon concentrations ranging from 0.4-1.0 pCi/l on the surface at the WIPP and a 0.6 and 0.7 pCi/l underground (Pearson 1990).

EQUIPMENT AND MATERIALS

The current radon monitoring program uses the electret-passive environmental radon monitor (E-PERM) system, which consists of E-PERMsTM (Rad Elec, Inc.), gamma flasks, and an electret voltage reader. The E-PERM is comprised of an electret ion chamber and an electret. An E-PERM and a Harshaw 8805 thermoluminescent dosimeter (TLD) are co-deployed in each gamma flask for intercomparison of gamma background measurements.

E-PERM System

The electret ion chamber is a 200-ml, electrically conductive, plastic chamber that can be opened and closed to make a series of measurements. The chamber was designed to allow radon gas to enter by diffusion. Baffles in the ion chamber slow the diffusion of air to the extent that 90 percent of any thoron (220Rn) which is present decays before it reaches the interior of the chamber. The air inlet pathway contains a filter which traps radon progeny and other particulate matter, preventing them from entering the ion chamber. The electret is a charged wafer of Teflon TM (Du Pont) which acts as a voltage source and ion collector.

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The electret voltage reader reads the electrostatic voltage potential on the surface of the electret.

Four sensitivities of electrets were available at the beginning of this program. The short-term electret has a lower limit of detection of 0.30-0.33 pCi/l for a 14-day exposure (Dempsey and Kotrappa 1989), and the new ultra-short-term electret has 1.7 times the sensitivity of the short-term electret. These electrets were selected because of the low radon concentrations anticipated at the WIPP and the anticipated frequency of reading electrets.

The gamma flask is a polyethylene volumetric flask with a lid, ring, and hose clamp to seal the flask. A TLD and an open E-PERM are placed in the gamma flask, and the flask is sealed to exclude air. Gamma radiation penetrates the flask and electret ion chamber. Both gamma and alpha particles cause ionization, when in the electret ion chamber, and the ions collect on the electret, causing a voltage drop. The voltage drop and gamma dose rate are calculated for the electret in the gamma flask. Then the experimentally derived conversion factor converts the gamma dose rate to the equivalent radon concentration that would be required to cause the same voltage drop. This equivalent background (in pCi/l) is subtracted from the radon concentration at a given location (Dempsey and Kotrappa 1989).

For convenience, the gamma correction factor often used is based on the average gamma background for the state. However, an area TLD study (monitoring two underground and 22 surface locations at the WIPP) indicated that WIPP surface locations ranged from 11-25 mrem/quarter; underground was below the lower limit of detection (ten mrem/quarter) for the Harshaw 8805 TLD. Using the state average would result in over-correcting for such a low gamma background underground. Consequently, the gamma background at each monitoring location is being measured.

Thermoluminescent Dosimeter

A Harshaw TLD assembly 8805 is co-deployed in each gamma flask. When E-PERMs in gamma flasks are read, the TLD assemblies are retrieved and an new set deployed. The TLDs are read by the WIPP Dosimetry Section under a program that is accredited by the DOE Laboratory Accreditation Program (DOELAP). The gamma dose (deep dose) is reported for each TLD assembly for subsequent comparison with the gamma dose calculated from the E-PERM in the gamma flask.

TEST PLAN

E-PERM Deployment Configuration

E-PERMs are deployed in 24 clusters of four each as described in Table I below. All E-PERMs are deployed in the open configuration (i.e., lid unscrewed and spring extended).

Schedule for Reading Electrets and TLDs

The frequencies for reading the E-PERMs in gamma flasks and those exposed to the air were determined primarily by the lower limits of detection of the instruments. Because the short-term electret has a lower limit of detection of 0.30-0.33 pCi/l for a 14-day air-exposure period, that frequency was deemed adequate for concentrations above four pCi/l, which was the lowest concentration at the WIPP based on the 1988-1989 study of radon concentrations in DOE-owned buildings (Pearson 1990). Instruments in gamma flasks will be read quarterly. Due to the very low concentrations at the first two post-deployment readings, all instruments will be read quarterly. However, reading frequency and deployment locations must be reassessed prior to receipt of TRU waste because the increased gamma dose near waste containers will cause electrets to discharge

TABLE I

E-Perm Cluster Configuration

Instrument	Number	Configuration	To Monitor
E-PERM			
Short-term	1	open to air	222Rn + gamma
Ultra-short-term	1	open to air	222Rn + gamma
Short-term	1	open in flask	gamma
Ultra-short-term	1	open in flask	gamma
TLD			
Harshaw 8805	2	1 per flask	gamma

sooner, resulting in the loss of data if electrets discharge to significantly less than 200 V before.

E-PERM Deployment Locations

Twenty-four E-PERM clusters are deployed in 22 locations, two with duplicates, as recommended by Dempsey and Kotrappa (1989). Fifteen clusters (including the two duplicates) are deployed on the surface and nine are underground. Some locations were selected to investigate an early hypothesis that radium-bearing sand in the concrete liners of the Waste Shaft and Air Intake Shaft was contributing to the radon concentrations underground. Those clusters were deployed on the surface near the air intakes and underground near the discharges of those shafts. The Salt Handling Shaft, which has a steel liner, was monitored similarly. Most other clusters were deployed to monitor the Waste Handling Building and air underground.

Deployment locations could not interfere with routine operation of the facility and or expose the clusters to undue risk of damage and consequent loss of data.

DISCUSSION

Although both short-term and ultra-short-term electrets were deployed and read for both radon and gamma background measurement, ultra-short-term electrets will be disregarded at the manufacturer's suggestion. The short-term electrets have proven reliable in the U.S. Environmental Protection Agency (EPA) Round 6 Cumulative Radon Measurement Proficiency testing program; but the ultra-short-term electrets were new, with the first commercially available set being used at the WIPP.

The time-integrated average radon concentration and gamma background from July 13 to September 28, 1990 were calculated for each E-PERM cluster, and the TLDs were read by the WIPP Dosimetry Section.

RESULTS

Surface Results

When calculated for the entire quarter, the highest radon concentration on the surface was 0.34 pCi/l measured in the shielded storage room in the Waste Handling Building. The lowest positive surface concentration was 0.11 pCi/l at the Waste Shaft collar (top) in the Waste Handling Building. Hence, the highest and lowest positive surface concentrations were found in the Waste Handling Building; the mean concentration in the building was 0.17 pCi/l. Gamma background in the Waste Handling Building ranged from a 9-13 mrem/quarter calculated for E-PERMs and 8.5-12 mrem/quarter from the TLD mean, with means of 9.9 and 10.1 mrem/quarter respectively.

The outdoor surface radon concentrations (including Station A) ranged from a high of 0.24 pCi/l in the north door of the air intake to the Waste Shaft to a low of -0.33 pCi/l measured by the duplicate at Station A. The outdoor mean concentration was less than 0.2 pCi/l for the quarter. Gamma background outdoors ranged from 10-11 mrem/quarter from E-PERMs and 9-13 from TLD mean values, with means of 10.6 and 11.7 mrem/quarter respectively.

Air Intake Results

Table II presents comparisons of radon concentrations at the bottom and top of air intake shafts, however, it should be noted that the radon concentrations in all cases are very low. These data are of special interest in determining whether or not radium-bearing sand in the shaft liners of the Air Intake Shaft and Waste Shaft was contributing to the radon concentration in ventilation air. Comparable data are also presented for the steel-lined Salt Handling Shaft.

The radon concentrations decreased from top to bottom of both shafts with concrete liners. The radon concentration decreased by 0.03 pCi/l from the top of the Air Intake Shaft to its base.The air intake configuration for the Waste Shaft is more complicated, and the air is also in contact with concrete in the intake tunnel which joins the Waste Shaft a short distance underground. The radon concentration at the collar area in the Waste Handling Building was disregarded, being a minimal contributor of air. From the surface air to the junction of the shaft and intake tunnel, radon concentration decreased by 0.07 pCi/l; from the junction to the base, it increased by 0.01 pCi/l; and overall from surface air to the base, it decreased by 0.07 pCi/l. Conversely, the radon concentration increased from top to bottom of the steel lined Salt Handling Shaft. The concentration increased by 0.02 pCi/l.

The radon concentration in effluent air, measured near the base of the Exhaust Shaft, indicated a higher radon concentration than the underground mean concentration, and the surface air intake mean. Effluent air radon concentration was 0.65 pCi/l higher than the underground mean concentration and 0.73 pCi/l higher than the surface air intake mean.

Underground Results

When calculated for the quarter, the underground radon concentrations ranged from a high of 0.85 pCi/l near the Exhaust Shaft to a low of -0.01 pCi/l in Room D at the extreme northeast end of the underground facility. The mean radon concentration was 0.20 pCi/l. Underground gamma background ranged from 1-5 mrem/quarter from E-PERMs and 5.0-8.5 mrem/quarter from mean TLD values, with means of 2.3 and 5.8 mrem/quarter respectively.

TABLE II

Summary of Changes in Radon and Gamma in Ventilation System

Area of Interest (Cluster Number)	Radon Concentration (pCi/1)	Change in Gamma Background (mrem/quarter) TLD Mean	E-PERM Gamma
Air Intake Shaft			
Surface (11)	0.23	12.0	11.0
Underground (4)	0.20	5.0	2.0
Change	-0.03	-7.0	-9.0
Waste Shaft			
Surface (13)*	0.24	18.0	16.0
Junction w/shaft (14)	0.16	9.0	10.0
Change**	-0.07	-9.0	-6.0
Junction w/shaft (14)	0.16	9.0	10.0
Underground (5)	0.17	5.5	2.0
Change	0.01	-3.5	-8.0
Surface (13)	0.24	18.0	16.0
Underground (5)	0.17	5.5	2.0
Change	-0.07	-12.5	-14.0
Salt Handling Shaft			
Surface (10)	0.12	13.0	11.0
Underground (9)	0.14	8.5	2.0
Change	0.02	-4.5	-9.0
Effluent Changes			
Underground mean (1,3,4,5,6,8,9)	0.20	5.8	2.3
Exhaust Shaft (7)	0.85	5.5	2.0
Change	0.65	-0.3	-0.3
Air Intakes Mean (10,11,13)	0.12	11.7	12.5
Exhaust Shaft (7)	0.85	5.5	2.0
Change	0.72	-6.2	-10.5

*Main Waste Shaft air intake is Building 465
**Discrepancies are due to roundoff

Coefficients of Variation for Duplicates

Coefficients of variation for the quarter's radon concentration were calculated for the two pairs of E-PERMs co-deployed for duplicate testing. The radon concentration (before background subtraction) calculated for the short-term electret in each E-PERM was used. The coefficient of variation was 0.03 at Station A, and 0.03 in the site-generated waste room in the Waste Handling Building.

SUMMARY AND CONCLUSIONS

The first quarter of a year-long radon monitoring program at the WIPP has been completed. The radon concentrations and gamma backgrounds were quite low, as had been anticipated. From July 13 through September 28, radon concentrations on the surface and underground were less than 1.0 pCi/l. These concentrations are below the four pCi/l level at which the U.S. EPA recommends further testing of indoor radon concentrations. Furthermore, the radon concentration does not appear to increase as air passes through concrete-lined shafts en route to the underground. As a result, no changes in operations or construction materials (i.e., specifying low radium content in sand used in concrete) are justified based on these concentrations.

Gamma background was also quite low, and calculating the gamma background on a location-by-location proved to be essential, especially since the underground gamma background appears to be a factor of ten lower than on the surface. Continuing to monitor gamma background on a location-by-location basis will continue for the duration of the program.

Short-term electrets will replace ultra-short-term electrets in January. This will ensure an increase in the number of reliable measurements in each cluster and location, and permit a statistical analysis of the data in the future.

The frequency of readings and the locations of E-PERM clusters must be reassessed before TRU waste is received at the WIPP to minimize the likelihood of losing data. In the area of quality assurance, two types of quality assurance tests recommended by Dempsey and Kotrappa (1989) have not been conducted. Quarterly blind spike calibrations and an annual calibration are recommended for a randomly selected group of electrets. The electrets were selected when first received in July, but blind-spike calibration data are unavailable.

Overall, the radon monitoring program at the WIPP has been successful. It provides supportable results that show that the radon concentrations at the WIPP are low and do not require any change in operations. Continuation for the year will confirm early results and may show some seasonal variation.

REFERENCES

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