CONF-900210--47

RADIOLOGICAL RISK ASSESSMENT OF A RADIOACTIVELY CONTAMINATED SITE*

CONF-900210--47

DE90 010622

Jas S. Devgun, Ph.D.
Environmental Systems Engineer

Argonne National Laboratory
9700 South Cass Avenue
Argonne, Illinois 60439

ABSTRACT

A limited-scope preliminary assessment of radiological risk has been conducted at a radioactively contaminated site under current site use conditions and based on the available preliminary radiological characterization data for the site. The assessment provides useful input to the remedial action planning for the site.

SITE BACKGROUND

The site considered in this paper is known as the Elza Gate site and is located in the southeastern part of the city of Oak Ridge, Tennessee, near the intersection of Melton Lake Drive and Oak Ridge Turnpike. It covers an area of about 8 ha (20 acres) and was used by the Manhattan Engineer District (MED) in the early 1940s as a storage area for pitchblende (a high-grade uranium ore from Africa) and ore-processing residues. Five warehouses (with concrete pad floors) were used for storing such materials. In 1946, the Atomic Energy Commission (AEC) assumed ownership of the site and used it as a storage area for the Y-12 plant. The AEC used the site until 1972, at which time it was vacated, and, subsequent to a decontamination performed under the guidelines and criteria current at that time, the title to the property was transferred to the city of Oak Ridge. The property was then sold to Jet Aire, Inc., in 1972 and used for operation of a metal plating facility. The ownership of the site passed on to Meco, a development company, in January 1988, and it is currently being developed for use as an industrial park. None of the original structures remain, but the concrete pads upon which the warehouses were built are still in place. The site is divided into nine parcels. The five concrete pads are found on Parcels 1 through 4. Figure 1 shows a plan view of the Elza Gate site and areas of radioactive contamination at the site, as well as the radon and gamma measurement locations. Currently, the only existing building on site was erected on an existing concrete pad in Parcel 1. The building is leased by Electro-Panel and is used for fabricating metal containers.

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

*Work supported by U.S. Department of Energy, Assistant Secretary for Nuclear Energy under Contract W-31-109-Eng-38.

MASTER

The submitted manuscript has been authored by a contractor of the U. S. Government under contract No. W-31-109-ENG-38. Accordingly, the U. S. Government retains a nonexclusive, royalty-free license to publish or reproduce the published form of this contribution, or allow others to do so, for U. S. Government purposes.

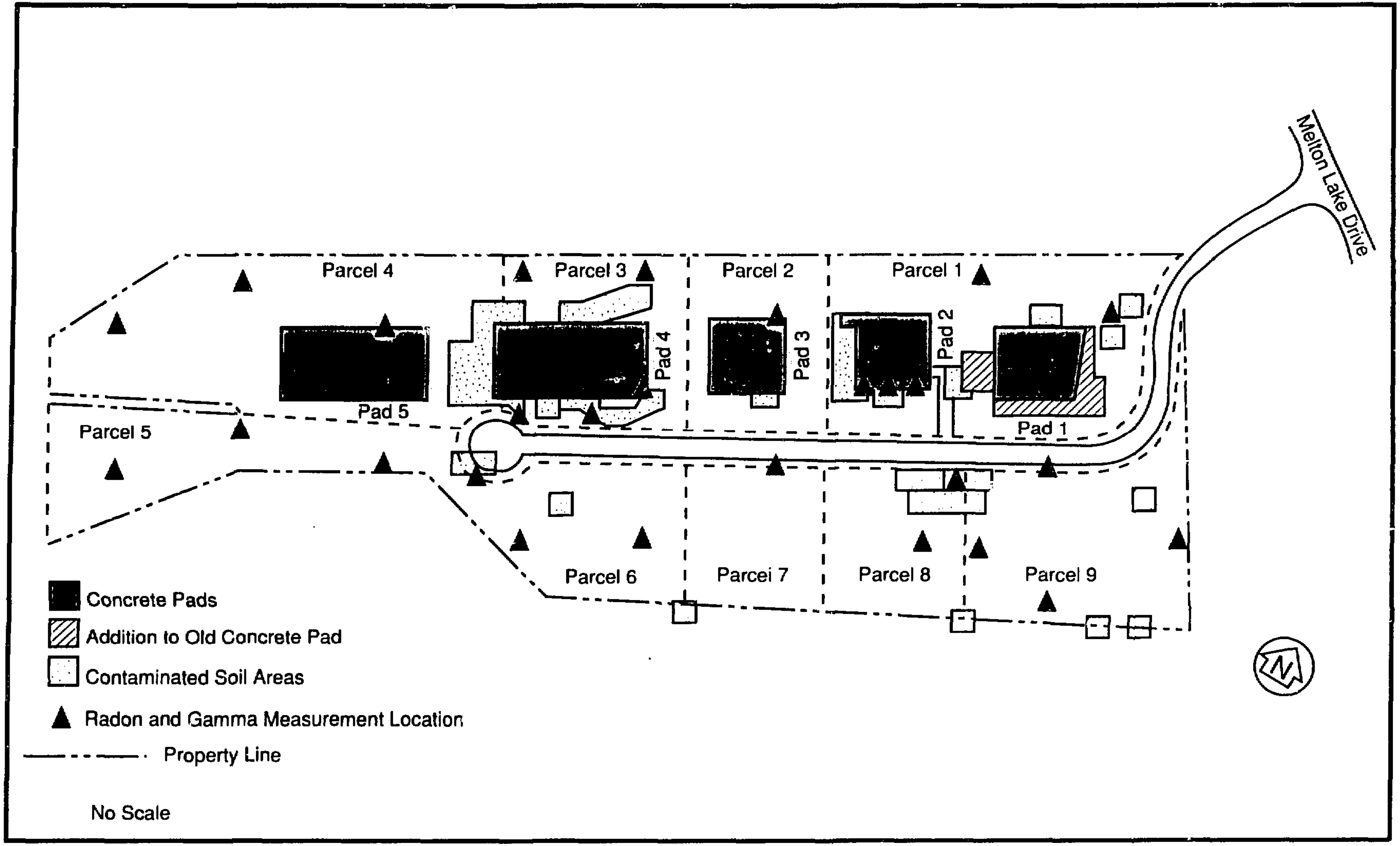

FIGURE 1 Plan View of the Elza Gate Site Showing Areas of Radioactive Contamination and Radon and Gamma Measurement Locations.

Remedial action at the site is currently being planned under the Formerly Utilized Sites Remedial Action Program (FUSRAP).

ANALYSIS OF RADIOLOGICAL CONDITIONS

Oak Ridge Associated Universities (ORAU) conducted a survey of the site in 1987 at the request of the Tennessee Department of Health and Environment because of the possibility of contamination from the metal plating facility (1). A radiological survey of the site was conducted in October 1988 by the Oak Ridge National Laboratory (ORNL) (2). Both surveys confirmed the presence of elevated levels of naturally occurring radionuclides (mainly from U-238 decay series) in soils in the northern portion of the site and on the existing concrete pads. Most of the contamination is present at and around the concrete pads, around the cul-de-sac and at several small areas on the site. The site was authorized for inclusion in the FUSRAP in November 1988 (3).

Bechtel National Inc. (BNI) has recently conducted preliminary characterization activities to determine the extent of radioactive and chemical contamination at the site (4). Further characterization is currently in progress. The analysis in this paper is based on the preliminary radiological data in the ORNL and BNI reports (2,4).

The gamma exposure rates across the site were found to range from 7 to 571.4 μR/h. The maximum gamma exposure rate occurred just north of the cul-de-sac, coinciding with an area where high concentrations of U-238 and Ra-226 were found. The radon flux measurements at the site ranged from 3 to 9, 512 pCi/m^2/min; the highest measurement coincided with the location (just north of the cul-de-sac) of highest gamma exposure rate and the highest concentrations of U-238 and Ra-226.

The five concrete pads total about 7,800 m^2 in area and are primarily contaminated with U-238, Th-232, Th-230, and Ra-226. Rings of rust-colored stains crusted over with a yellow residue are visible in scattered areas on the pads where 55-gallon metal drums had apparently been stored in the past. Direct Measurements of alpha activity and beta-gamma activity on the concrete pads showed that all pads had areas of contamination exceeding the DOE guidelines (5); the highest measurements were observed on Pad 2. On Pad 1, alpha activity ranged from 14 to 17,000 dpm/100 cm^2 with an average of 2,700 dpm/100 cm^2. Pad 1 was decontaminated during a demonstration of the abrasive blasting technique in the summer of 1989 (6). The measurements after the decontamination showed alpha activity to be 750 dpm/100 cm^2 and beta-gamma activity to be 4,600 dpm/100 cm^2.

On Pad 2, the alpha measurements were found to range from 390 to 242, 870 dpm/100 cm^2 for an average of 30, 270 dpm/100 cm^2. The beta-gamma activity ranged from 1,590 to 1,643,050 dpm/100 cm^2 for an average of 227, 250 dpm/100 cm^2. On Pads 3, 4, and 5, the alpha measurements ranged (dpm/100 cm^2), respectively, 20 to 6,130; 17 to 6,530; and 20 to 5,370; with an average of 120; 350; and 70 dpm/100 cm^2, respectively. The beta-gamma activity on Pads 3, 4, and 5 ranged (dpm/100 cm^2), respectively, 550 to 97,630; 560 to 57,510; and 550 to 4,900; with an average of 4,340; 3,280; and 970 dpm/100 cm^2, respectively. However, analyses of smear samples showed that the contamination is not readily transferable. The radiological contamination at the concrete pads is estimated to extend to a depth of about 2 cm. As the characterization activities have proceeded, soil beneath Pad 1 has been found to be contaminated. The average concentrations of various radionuclides in the contaminated soil on the property, the contaminated soil beneath Pad 1, and the concrete pads are shown in Table 1.

In the current analysis, only four pads (Pads 2 to 5) are considered (Pad 1 is assumed to be clean for this analysis following decontamination with an abrasive blasting technique. The analysis of radiological risk was performed with the RESRAD computer code (7). Separate calculations were done for contaminated soil beneath Pad 1.

Several hundred surface and subsurface samples from the contaminated soil areas of the site were taken and analyzed by BNI for determining the radionuclide concentrations. From the data provided for individual samples in the BNI report (4), the average radionuclide concentrations were determined for the site, excluding the "hot spot" area (just north of the cul-de-sac) where the concentrations are much higher than the rest of the site. These average concentrations are shown in Table 1. The individual sample results indicated that in most contaminated soil areas at the site (except for the hot spot and a few other areas) the concentration Ra-226 and Th-230 were below the DOE guideline of 5 pCi/g averaged over the first 15 cm of soil below the surface and 15 pCi/g averaged over any 15 cm thick soil layers beneath the first layer (5). The concentration of Th-232 was below the DOE guidelines (same as for Th-230) in all contaminated soil areas except the hot spot area and one measurement of 7 pCi/g in a surface soil sample at one location (east of the cul-de-sac) in the rest of the area. The highest concentrations in the soils across the site (except the hot spot) were found to be: 110 pCi/g U-238, 360 pCi/g Ra-226, 7.0 pCi/g Th-232, and 370 pCi/g Th-230. In the hot spot area, the highest concentrations were 12,000 pCi/g U-238, 12,000 pCi/g Ra-226, 82 pCi/g Th-232, and 15,000 pCi/g Th-230.

RADIOLOGICAL RISK ASSESSMENT

Radiological risk to an individual at the Elza Gate site was estimated in three ways: (1) the gamma exposure rates across the site were analyzed and potential dose to an individual was estimated; (2) the radionuclide concentration data for the concrete pads and the contaminated soil were analyzed and calculations were performed with the RESRAD code to estimate the dose to an individual under different scenarios; and (3) the radon flux data at the site were analyzed and the radon excess exposure to an individual was estimated.

GAMMA EXPOSURE RATES

The eight measurements of gamma exposure rate inside the only building on site provide an average rate of 10.4 μR/h comparable to the background of 10 μR/h reported for the Oak Ridge area (2). Thus, dose to an individual inside the building is indistinguishable from the background. All of the measurements taken inside the building are also below the DOE criteria of 20 μR/h average above background level for a habitable structure (5). The average site-wide gamma exposure rate outside the building

TABLE 1 Radionuclide Concentration Data for Soils and Pads Used In This Analysis

	U-238[a] (pCi/g)	Ra-226 (pCi/g)	Th-232 (pCi/g)	Th-230 (pCi/g)
Average concentrations in surface and subsurface soils for contaminated soil areas, excluding the hot spot (average depth of contamination is 0.6 m)[b]	6.6	3.3	1.6	4.8
Average concentrations in surface and subsurface soils (to a depth of 2.1 m) in the hot spot area[b]	2160	2241	11.7	2593
Average concentrations in soil beneath Pad 1 (to a depth of 1 m beneath the pad)[b]	146	8.9	1.9	59.4
Estimated average concentrations for concrete pads (Pads 2, 3, 4, and 5)[c]	884	18	6	366

[a]Secular equilibrium was assumed (i.e., U-238: U-234: U-235 1:1:0.046) and calculated concentrations of U-234 and U-235 were also used in the analysis.

[b]Average data derived from individual sample analysis results listed in BNI report (4).

[c]Based on the radionuclide concentration analysis of 11 chip samples (to approximately 2 cm depth) taken from Pads 2, 3, 4, and 5 (8). For the purpose of this analysis, the average radionuclide concentrations in each pad were determined and, then, assuming the pads to be contiguous, the estimated average concentrations were uniformly applied.

is 32.8 μR/h above the average background level of 10 μR/h. Potential dose to an industrial worker (the current use of the site is industrial) was estimated assuming that the worker spends 8 h/d, 5 d/wk, and 50 wk/yr at the site with half of this time spent inside the building and half outside the building. Because the average gamma exposure rate inside the building is at background level, additional dose (above background) to the worker results only from the above-background average exposure rate during the time spent outside the building. This dose is estimated to be 31 mrem/yr and is below the DOE guideline of 100 mrem/yr for an individual member of the public (5).

RESRAD ANALYSIS

For calculations with the RESRAD code, two types of scenarios (an industrial use scenario and a recreational use scenario) were considered for estimating potential dose to an individual from contamination at the site.

Industrial Worker Scenario

The most realistic scenario considering current site use is the industrial (but non-radiation) worker scenario. A worker is generally assumed to spend 2000 h/yr (8 h/d, 5 d/wk, 50 wk/yr) at the site, with 50% (1,000 h) spent outside and 50% (1,000 h) spent inside. At the Elza Gate site, however, the only presently existing building and the pad on which it is located are assumed to have been decontaminated and thus do not contribute to the radiation dose to the worker. Thus, the radiation dose to the worker occurs from the contamination outside the building and during the time spent outdoors. The worker does not drink any water from the site or ingest any foods (plants, meat, or milk) grown or raised on the site. The only exposure pathways considered are direct exposure to external radiation from the contaminated material and internal radiation from inhalation of dust. For the purpose of this analysis, the contaminated area is assumed to be uniform and contiguous; therefore, since the data input for the contaminated pads varies greatly from that of the contaminated soil areas, the pads were analyzed separately. The direct exposure doses to the worker spending time on the pads (Pads 2, 3, 4, and 5) were predicted with the RESRAD code using estimated average radionuclide concentrations in concrete pads (Table 1) and other site-specific parameters. In the absence of some site-specific parameters (such as porosity and hydraulic conductivity), parameter values from literature were used. For estimating total doses, the dust inhalation pathway doses were calculated separately using the area-weighted average radionuclide concentrations for the contaminated soil (including the hot spot). It is assumed that, while the pads do not contribute any dust, an individual on the pads is exposed to windblown dust from the nearby contaminated soil areas. For this analysis, several possible cases were considered:

(a) the worker is assumed to spend all of his/her outside hours on the concrete pads;

(b) the worker is assumed to spend 50% of the outside hours on the concrete pads and 50% on the rest of the open property (assuming uniform work activity on all property excluding the concrete pads);

(c) the worker is assumed to spend all of the outside hours on the contaminated soil, excluding the hot spot (assuming that access to the hot spot is restricted);

(d) same as case (c), except that the worker is an outside area worker and spends 2000 h/yr working outside (1000 h on the concrete pads and 1000 h on rest of the property including contaminated soil areas and the hot spot).

Recreational Use Scenario

A second plausible scenario for the site is the recreational use scenario. If access to the site were uncontrolled, an individual could enter occasionally or regularly. For instance, a worker from a nearby industrial site (the current use of the nearby areas is industrial; there are no residences near the site) might spend lunch hours at the site eating or engaging in recreational activities. The individual is assumed to spend 250 h/yr (1 h/d, 5 d/wk, 50 wk/yr) at the site. The individual does not drink any water from the site or ingest any foods (plants, meat, or milk) grown or raised on the site. Thus, the only radiation pathways to consider are direct exposure to external radiation from the contaminated material and internal radiation from inhalation of dust.

Three possible cases were considered:

(e) the individual is assumed to spend all of his/her time at the site (250 h/yr) on the concrete pads;

(f) the individual is assumed to spend 50% of his/her time on the concrete pads and 50% on contaminated soil (except the hot spot);

(g) the individual is assumed to spend all of his/her time on the contaminated soil;

In this analysis, the calculations of the doses were done separately for: (i) the pads; (ii) the "hot spot"; and (iii) the remainder of the contaminated soil area. In those cases where a worker is assumed to spend time on the rest of the property (excluding concrete pads), the calculations were done separately for the time the worker may spend (area-weighted) at the hot spot, the contaminated soil area excluding the hot spot, and the uncontaminated area. This approach is justified because either an industrial worker working outdoors or an individual engaging in recreational activity would be unlikely to spend all the time at one spot; rather, uniform work/recreation activity is more likely over the entire area.

Table 2 shows the doses predicted with the RESRAD code for various cases under an industrial worker scenario and a recreational use scenario. In the industrial worker scenario, because of the potential use of the concrete pads as a storage site, Case (a) is more likely to be a realistic case. For this case, the external radiation from the pads contributes 19 mrem/yr to the worker, while the windblown dust inhalation from the

TABLE 2 Predicted Doses for Various Cases Analyzed with RESRAD Code

Scenario	Case	Effective Dose Equivalent (mrem/yr)
Industrial worker	(a)	33
	(b)	25
	(c)	21
	(d)	49
Recreational use	(e)	8
	(f)	7
	(g)	41

nearby contaminated soil areas contributes 14 mrem/yr. On the pads, Ra-226 contributes 71% to the external exposure pathway dose, followed by U-238 (19%) and U-235 (9%). The primary contributor to the dust-inhalation pathway is Th-230 (56%), followed by U-234 (19%), U-238 (18%), and Th-232 (4%).

The predicted dose to a worker for each of the Cases (a) to (d) is below DOE's 100 mrem/yr dose criteria for an individual member of the public.

In the recreational use scenario, for the more likely Case (e), the predicted dose is 8 mrem/yr. The predicted dose for each of the Cases (e) to (g) is below DOE's 100 mrem/yr dose criteria. Because all radiological surveys conducted at the site confirmed the elevated gamma exposure rate and high concentrations of radionuclides in the small hot spot area, calculations were also done for an extreme case where an individual is assumed to spend 250 h/yr at the location of the hot spot. The predicated dose to such an individual could be approximately 700 mrem/yr, exceeding the DOE criteria of 100 mrem/yr.

Results of these simulations show that, for various cases that are more likely, the potential dose to an individual at the site is within the DOE criteria. However, for extreme or worst-case scenarios the dose to an individual may exceed DOE's radiation protection criteria. Given the current use of the site, the probability of occurrence of such extreme cases is very small.

The contaminated soil beneath Pad 1 poses no radiological hazard under present conditions. However, calculations were done with the RESRAD code to estimate potential dose to workers if future remedial actions required excavation of this contaminated soil. It was assumed that only the workers implementing the excavation and packaging of the contaminated soil will be exposed to the radionuclides in the soil. For this dose assessment, the only pathways considered were the external exposure and the inhalation of radioactive contaminants. Radionuclide concentrations given in Table 1 were used and a crew of 14 workers was assumed to complete the work in 170 hours (for a total 2,380 worker-hours). The predicted dose to each worker is 4.5 mrem with the external exposure pathway accounting for 63% of the total dose and the dust inhalation pathway accounting for the remaining 27%.

RADON EXPOSURE

Excess exposure due to radon flux measured at the site was also estimated for an individual who works outside in the open area near the on-site building. An average radon flux of 464 $pCi/m^2/min$, calculated from 27 measurements across the site, was used, along with other generally conservative assumptions (exposure time of 2,000 h/yr, stable, Class F, atmospheric conditions for a year, outdoor equilibrium factor of 10%, and a slow wind [2 m/s] blowing from southwest toward the individual). The excess dose to an individual from radon flux at the site and under the above conditions is estimated to be 0.1 mrem/yr. This excess exposure is indistinguishable from the background levels.

CONCLUSIONS

Preliminary assessment of the radiological risks at the Elza Gate site under current site conditions has been made. From the analysis of radiological conditions at the site, a small area just north of the cul-de-sac has been delineated as the hot spot area, where gamma exposure rates and the radionuclide concentrations are much higher than those in the rest of the contaminated areas. Estimates of potential dose to an individual have been made for various cases under two different scenarios; the predicted doses are within DOE's radiation protection criteria. The predicted dose to an individual may exceed the DOE criteria for the extreme or worst-case scenarios. The estimated excess exposure to an individual due to radon flux at the site is indistinguishable from the background.

REFERENCES

1. R.L. EGLI (DOE-OR), "Sampling Data for Land Parcel 228," letter dated April 25, 1988, to K. Cole (Oak Ridge, Tenn.). [Copy available from U.S. Department of Energy, Oak Ridge Operations, Technical Services Division, Oak Ridge, Tennessee.]

2. W.D. COTTRELL, J.L. QUILLEN, and R.F. CARRIER, "Preliminary Site Survey Report for the Former Elza Gate Warehouse Area, Oak Ridge, Tennessee," Draft Report ORNL/RASA-89A, Oak Ridge National Laboratory, June 1989.

3. J.J. FIORE (DOE-NE), "Authorization for Remedial Action at the Melton Lake Industrial Park (Former Elza Gate Area Warehouses), Oak Ridge, Tennessee," memorandum dated November 30, 1988, to P. Gross (DOE-OR). [Copy available from U.S. Department of Energy, Oak Ridge Operations, Technical Services Division, Oak Ridge, Tennessee.]

4. BECHTEL NATIONAL, INC., "Preliminary Characterization Activities at the Elza Gate Site," Draft report CCN #064103, Bechtel National, Inc., Oak Ridge, Tennessee, October 1989.

5. U.S. DEPARTMENT OF ENERGY, "U.S. Department of Energy Guidelines for Residual Radioactive Material at Formerly Utilized Sites Remedial Action Program and Remote Surplus Facilities Management Program Sites," Revision 2, U.S. Department of Energy, Washington, D.C., March 1987.

6. J.S. DEVGUN, R.R. LAND, and R.W. DOANE, "Demonstration Experience with an Abrasive Blasting Technique for Decontaminating Concrete Pads," Waste Management '90, Tucson, Arizona, February 25-March 1, 1990, These Proceedings.

7. T.L. GILBERT, C. YU, Y.C. YUAN, A.J. ZIELEN, M.J. JUSKO, and A. WALLO III, "A Manual for Implementing Residual Radioactive Material Guidelines," ANL/ES-160 (DOE/CH/8901), Argonne National Laboratory, Argonne, Illinois, June 1989.

8. M.E. KAYE (Bechtel National, Inc., Oak Ridge, Tenn.), personal communication to J.S. Devgun (Argonne National Laboratory, Argonne, Ill.), July 18, 1989.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.