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MEMORANDUM TO: Scott Moore, Chief
Special Projects Section
Decommissioning Branch
Division of Waste Management, NMSS

FROM: Sandra Wastler, Chief
Performance Assessment Section
Environmental & Performance Assessment Branch
Division of Waste Management, NMSS

SUBJECT: TECHNICAL ASSISTANCE REQUEST REGARDING THE RADIOLOGICAL ASSESSMENT FOR THE CABOT - REVERE, PENNSYLVANIA SITE

In response to a Technical Assistance Request (TAR), received on March 3, 2001, from the Decommissioning Branch, the Environmental and Performance Assessment Branch (EPAB) staff has completed its review of the radiological assessment for the Cabot-Revere site dated February 28, 2001. The radiological assessment is a revision of the previous radiological assessment (dated November 17, 1997) specifically to address concerns raised by staff with the earlier report.

Based upon the staff's review of the latest radiological assessment document, we believe that the licensee has provided an acceptable assessment to demonstrate that the site is acceptable for unrestricted release in accordance with 10 CFR 20.1402. Attached is the staff's technical evaluation report to document its findings.

Please feel free to contact Mark Thaggard or myself for any further assistance if you have any questions.

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Attachment: Technical Evaluation Report

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Radiological Assessment for Cabot Corporation Revere, PA Site

Technical Evaluation Report

Prepared by: Mark Thaggard, Sr. Systems Performance Analyst
Environmental and Performance Assessment Branch

Introduction

The Cabot Corporation Revere site encompasses roughly 40 hectares (100 acres) in Bucks County, Pennsylvania. The site is located about 60 kilometers (36 miles) north of Philadelphia and about 26 kilometers (16 miles) southeast of Allentown. Radioactively contaminated slag from a former niobium metal processing facility is present in four distinct areas at the site.

The purpose of the Cabot Corporation's Revere site radiological assessment is to demonstrate that doses from exposure to residual radioactivity at the site is sufficiently low to allow unrestricted release of the site in accordance with 10 CFR 20.1402 (i.e., unrestricted release of the site).

Staff reviewed the radiological assessment using guidance provided in NUREG-1727 (NRC, 2000) for conducting dose assessment to demonstrate compliance with the license termination rule. Specifically, the following aspects of the assessment were reviewed: the source term abstraction; the critical group, scenario, and pathways identification, the conceptual model development, and calculations and input parameter selections. Staff review of these aspects of the assessment is addressed separately below.

Source Term Abstraction

As previously stated, radioactively contaminated slag is present in four known areas at the site. A brief description of these areas is provided in Table 1. In addition, two small samples of radioactive slag have been found in the loading dock/warehouse area; however, these samples have been removed. Given that part of the loading dock/warehouse area is paved, the possibility of additional contamination in this area, cannot be completely ruled out. Gamma surveys would be inconclusive because of the shielding from the pavement. However, Cabot has provided statements from former employees that the area was paved prior to the use of radioactive material on the site. Further, Cabot has provided a 1970 aerial photo which shows the area as paved prior to the use of radioactive material in the early 1970's. Therefore, staff believes that it is unlikely that there is additional contamination in the loading dock/warehouse area.

For their radiological assessment, Cabot estimated radionuclide concentrations for slag by calculating a mass balance of the remaining activity on the site from process records and information on the amount of material removed from the site. Based on inventory records, Cabot estimates a maximum of 0.0065 Ci of thorium and 0.016 Ci of uranium remains on the site. Assuming a slag density of 2.0 g/cm^3 and a total volume of 820,000 ft^3 (2.3 x 10^4 m^3), a total mass of 4.64 x 10^7 kilograms of radioactive slag is believed to remain on the site. Based on the assumed activities of thorium and uranium remaining at the site, an estimated concentration of 0.14 pCi/g of thorium and 0.34 pCi/g of uranium was derived by Cabot.

Staff considers the concentrations used in the assessment to be appropriate because they are believed to be conservative. Cabot's estimate of the activity of uranium and thorium removed from the site is probably low in that they assumed the concentrations in the slag removed the site was only slightly above background. In reality, concentrations of uranium and thorium in the slag removed from the site were probably significantly above background as reflected by the concentrations in the recovered slag left on the site. Therefore, the total activity remaining at the site is probably significantly less than that assumed by Cabot in deriving their concentrations.

In addition, external gamma measurements at the site suggest a U-238 concentration of less than 2 pCi/g and a Th-232 concentration essentially at background for the upper several inches of the contaminated areas. Even subsurface measurements in the container storage, parking, and old pit areas indicated near background conditions. Therefore, the concentrations used in the assessment are considered appropriate.

Table 1. Brief description of contaminated areas.

Contaminated Area	Area m^2 (ft^2)	Thickness m (ft)	Brief Description
Parking area	3259 (35,500)	1.8 (6)	Building rubble, slag, and soil
Container storage area	1744 (19,900)	1.22 (4)	Slag and soil
Building 4&5 area	1469 (16,000)	0.61 (2)	Slag, rock, and soil
Old pit area	5040 (54,900)	2.7 (9)	Building debris, slag, and soil

The radionuclide concentrations used in the radiological assessment are listed in Table 2. The isotopic ratios are based upon those commonly expected for natural thorium and natural uranium. All daughter radionuclides are assumed to be in secular equilibrium with their parents. By using the total estimated volume of radioactive slag (i.e., 23,000 m^3) in deriving radionuclide concentrations, Cabot is implicitly assuming that contamination is equally distributed among the four contaminated areas. This assumption could result in an underestimation of potential impacts if one or more of the areas are more heavily contaminated than the other areas.

To estimate releases of radioactivity from the slag[1], Cabot modeled releases of radionuclides as a surface process where the radionuclides are assumed to be adsorbed onto the surface of the contaminated media (i.e., slag). Because in reality the radioactivity is tightly bounded up into the slag matrix, modeling releases as a surface process requires an assumption of strong

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[1]In their radiological assessment, Cabot assumed that only slag is radioactively contaminated.

adsorption (i.e., represented by a high distribution coefficient) between the radionuclide and the solid media. Cabot calculated a distribution coefficient (K_d) using the readily available uranium (RAU) concentration measured in a leach test performed on a slag sample. A K_d value of 137,500 cm^3/g was used to calculate the leach rate of radionuclides from the source zone (i.e., slag). The same K_d value was also used for the U-238 progenies and Th-232 and its progenies. Although radionuclides are believed to leach incongruently from the slag, it is reasoned that using the uranium K_d value is appropriate because thorium and radium (the other key radionuclides) are believed, based on information from the literature, to leach at a slower rate.

Table 2. Radionuclide concentrations used in the Cabot assessment.

Radionuclide	Concentration (pCi/g)
Ac-227	0.0077
Pa-231	0.0077
Pb-210	0.17
Ra-226	0.17
Ra-228	0.083
Th-228	0.083
Th-230	0.17
Th-232	0.083
U-234	0.17
U-235	0.0077
U-238	0.17

Staff agrees that based upon the nature of the slag (i.e., its glass-like structure) and its low weathering rate (believed to be on the order of $2x10^{-6}$ to $1.5x10^{-5}$ mm/y) the leach rate of radionuclides from the source zone should be low (i.e., radionuclides should be fairly immobile). Based on the range of leach rates reported for uranium and thorium for slag (Felmy et al., in press), the leach rate for uranium and thorium at the Cabot site would be expected to be on the order of $1x10^{-12}$ to $1x10^{-10}$ yr^{-1} for thorium and $1x10^{-11}$ to $4x10^{-9}$ yr^{-1} for uranium. The leach rate assumed in the Cabot assessment is on the order of $1x10^{-6}$ to $1x10^{-5}$ yr^{-1}.

Critical Group, Scenario, and Pathways Identification and Selection

Scenarios represent possible realizations of the future state of the site. They are needed in a dose assessment to establish potential future conditions which might lead to human exposure to residual radioactivity at the site. The area surrounding the Cabot-Revere site is characterized as generally rural with land uses that include industrial, commercial, residential, and agriculture.

Two scenarios were considered by Cabot in their radiological assessment; specifically, a worker and resident scenario were considered. In addition, hybrids of the residential scenario were considered as a means of conducting a sensitivity analysis. Cabot's sensitivity analysis shows that the calculated dose is highly sensitive to the assumptions made about the future use of the site.

For its worker scenario, Cabot assumes that the site will continue to be used for industrial purposes. The industrial worker is assumed to be exposed by external gamma radiation and inhalation of re-suspended dust. The hypothetical worker is assumed to spend a very limited time in the contaminated area (40 hr/yr). No indoor exposure is assumed to occur because there are currently no buildings in the contaminated areas.

For its resident scenario, Cabot assumes that the residence is constructed entirely in the contaminated area and that the resident spends 78% of his time in the area (85% indoors and 15% outdoors). Exposure is assumed to occur through direct gamma radiation, inhalation, soil ingestion, and drinking water. A six-inch layer of topsoil is assumed to be permanently maintained over the slag to support grass, but would not be deep enough to support growing edible vegetables. It should be noted that the assumption of a permanent soil layer, even one as thin as 0.15 meters (6 inches), obviates the need for considering doses from the inhalation pathway; that is, the hypothetical future resident will not receive any doses through inhalation of dust as long as a soil layer is kept over the slag. Given that the current surrounding land-use around the site includes residences and agriculture, staff believes that some type of future residential use of the site is highly credible. However, staff does not believe that it is appropriate to assume that a cover will be permanently maintained over the slag without active maintenance.

As a hybrid of the resident scenario, Cabot also looked at a resident scenario assuming that there is no six-inch soil layer. The results of this sensitivity analysis give a calculated dose significantly below the release limit, but roughly six times higher than the dose calculated for the base-case resident scenario. This reflects the importance of the assumption that a six-inch soil layer will be permanently maintained over the whole area.

As another hybrid of the resident scenario, Cabot assumed that the resident maintains a garden in the contaminated area and thus is exposed through ingestion of plants grown in the contaminated slag. For this assessment, Cabot conservatively assumed that the plants are grown directly in the slag without an intervening soil layer. Again, the calculated dose was significantly below the release limit.

Staff believes that the resident garden scenario appropriately bounds the potential exposure pathways for future use of the site. Cabot also evaluated an excavation scenario, where it is assumed that some of the slag is excavated and used as foundation fill in the construction of a house. However, staff believes that exposure times assumed in the resident gardener scenario appropriately bounds this scenario.

Staff supports the exclusion of the aquatic pathway in the Cabot resident scenario. Because of the relative immobile nature of the radionuclides it is unlikely that any contaminants will reach nearby surface waters. Further, the depth of the ground water (approximately 20 meters) would likely make it rather expensive to maintain a fish pond.

Because the surficial layer of the contaminated areas is composed principally of slag which do not readily support the growth of vegetation (as evident by current site conditions), staff believes that it is unlikely that the contaminated areas will be used for growing commodity crops or raising livestock. Because of the cost, it is difficult to envision someone purchasing enough topsoil to cover an area large enough to grow commodity crops or raise livestock. Further, because soilless gardening require more management than more traditional gardening methods and given that the presence of slag in the area would not lend itself to mechanized agriculture, staff believes that it is unlikely that the contaminated areas will be used to grow commodity items such as grains or livestock fodder. Therefore, staff believes that it is appropriate to exclude these pathways in the assessment. In addition, the relative small size of the container storage and former building 4&5 areas, which are both less than the default area assumed in the NRC's screening approach for the residential farmer scenario (i.e., 2400 m^2), would also tend to support an argument that these areas will not be used for growing commodity items.

Conceptual Model Development

Analyzing the release and migration of radionuclides through the environment is an essential part of assessing potential doses someone might receive from exposure to various concentrations of the radionuclides in the accessible environment. Dose assessment analyses require an interpretation of site conditions and processes that are likely to affect the transport of radionuclides through the environment to receptors. The interpretation of site conditions and processes as reflected in the dose assessment forms the conceptual model.

The predefined conceptual model in RESRAD was used in the Cabot-Revere radiological assessment with a limited number of input parameters tailored to model the site conditions and features. The predefined conceptual model in RESRAD is described in the RESRAD User's Manual (Yu et al., 1993). Specifically, the predefined conceptual model assumes that the individual resides immediately atop the contaminated media. Further, the individual is assumed to have a well located either in the center of the contaminated area or immediately down-gradient from the contaminated area. For the Cabot-Revere assessment it was assumed that the well is located in the center of the contaminated area. As stated in NUREG-1727 (NRC, 2000), no justification is required for making this assumption as it will generally give greater estimates of ground-water impacts than assuming that the well is located down-gradient of the contaminated area.

Figure 1 shows a schematic of the general conceptual model used in the Cabot-Revere radiological assessment, based upon staff's interpretation of the information presented in the report.

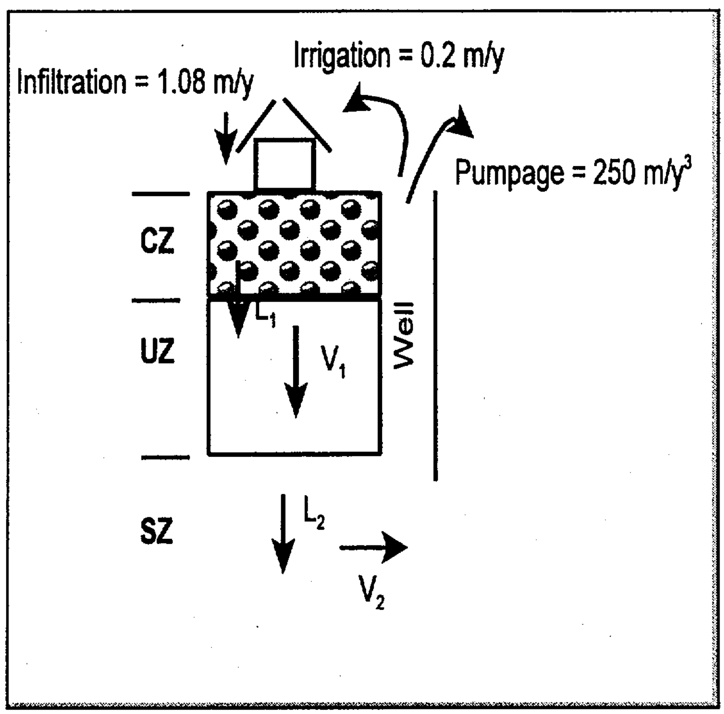

Figure 1. Generalized conceptual model used in the Cabot-Revere assessment.

It should be noted that a default irrigation rate of 0.2 m/y was used in the analysis although the licensee only assumed irrigation as part of their residential gardener scenario.

Based on regional information, the unsaturated zone is believed to be roughly 20 meters thick; however, for the assessment nominal credit is taken for the possible hold-up of contaminants migrating through the unsaturated zone. This is reflected by the small unsaturated zone thickness (0.01 m) assumed for the analysis. Staff believes that this adds conservatism to the calculated doses for the water-dependent pathways.

Calculations and Input Parameters

RESRAD Version 6.0 was used to calculate doses for the two base-case scenarios, and the residential and residential gardener sensitivity scenarios. In addition, RESRAD-Build Version 3.0 was used to calculate doses for the excavation scenario. As previously noted, staff believes that potential impacts from future exposure to residual radioactivity at the site are appropriately bound by the residential gardener scenario.

As previously stated, for its assessment, Cabot assumes that the radioactivity is uniformly distributed in the total volume of radioactive slag remaining on the site. Thus for the residential gardener scenario, Cabot assumes that the total 23,000 cubic meters of radioactive slag are uniformly spread out over an area of 23,000 square meters to a depth of one meter. However, because the slag is currently located in four distinct areas; this assumption would appear to be unrealistic. In addition, as previously stated, assuming that the radioactivity is uniformly distributed in the total volume of slag could be nonconservative if one or more of the contaminated areas are more contaminated than the others. To address this concern, staff performed its own independent assessment by assuming that the residual radioactivity is limited to just two of the four areas. For the staff assessment, the total activity of uranium and thorium

Table 2. Values of parameters reflected in the schematic in Figure 1.

Parameter	Contaminated Area Section				
	Parking Area	Container Storage	Bldg. 4&5	Old Pit	Combo
CZ≡ cont. zone thickness (m)	1.8	1.22	0.61	2.7	1.0
UZ≡unsat. zone thickness (m)	0.01	0.01	0.01	0.01	0.01
L_1≡leach rate from CZ (pCi/y)	1.9e-5	2.7e-5	5.5e-5	1.2e-5	4.1e-6
V_1≡ velocity in UZ (m/y)	6.4	6.4	6.4	6.4	0.02
V_2≡ velocity in SZ (m/y)	0.2	0.2	0.2	0.2	0.2

Note: L_2≡leach rate from the unsaturated zone = L_1- radioactive decay.
The reported V_1 is uranium, for thorium the value is 1.7e-5.

conservatively estimated by Cabot as remaining at the site was equally proportioned between the slag remaining in the Old Pit and Building 4&5 areas. Information on remediation activities at the site suggests that less remediation may have occurred in these two areas than in the Container Storage and Parking areas.

Table 3 shows the concentrations used in the staff assessment. Table 4 shows parameter values used in the staff assessment that were different from those used by Cabot. For both areas, the staff assessment give calculated doses that are less than the 25 mrem/year limit for unrestricted release of the site[2].

The calculated doses derived by both the staff and Cabot primarily result from direct exposure to the gamma radiation from thorium and radium. This is expected because the very low leachability of the slag will result in very little of the radionuclides being transported through the environment during the next thousand years. Although no sensitivity or uncertainty analysis was performed by Cabot to identify key parameters, it is known that calculated doses from direct exposure to gamma radiation are largely dependent upon the assumed exposure time. For both the Cabot and staff assessments, the default exposure times recommended by the NRC for doing screening analyses for a residential farmer scenario were used. Therefore, the parameter value used is considered appropriate.

Conclusion

Based upon a review of specific aspects of the Cabot radiological assessment, staff considers the assessment appropriately demonstrates that the residual radioactivity at the site will not result in a dose exceeding the requirements under 10 CFR 20.1402. Accordingly, the site should be acceptable for unrestricted release.

References

Amonette, J.E., G.R. Holdren, K.M. Krupa, and C.W. Lindenmeier, "Assessing the Environmental Availability of Uranium in Soils and Sediments," U.S. Nuclear Regulatory Commission, NUREG/CR-6232, June 1994.

Felmy, A.R., D. Raj, and V.L. LeGore, "Solubility and Leaching Controls on Radionuclides in SDMP Wastes," U.S. Nuclear Regulatory Commission, Washington, DC, NUREG/CR-6632, in press.

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[2]The concentration of radionuclides in food is dependent upon their availability for uptake by plants, which is dependent upon their solubility. Because the slag is fairly insoluble, the uptake of radionuclides by plants is expected to be small. In NUREG/CR-6232 (Amonette et al., 1994) it is suggested that doses from the ingestion pathway for uranium in slag be calculated on the basis of the total available uranium derived from leaching experiments. Therefore, for the staff assessment the dose from the plant ingestion pathways is calculated as a fraction reflecting the fraction of the total available uranium obtained in the leaching experiment to the total uranium in the sample.

Meyer, P.D., M.L. Rockhold, and G.W. Gee, "Uncertainty Analyses of Infiltration and Subsurface Flow and Transport for SDMP Sites," U.S. Nuclear Regulatory Commission, NUREG/CR-6565, September 1997.

NRC, "NMSS Decommissioning Standard Review Plan," U.S. Nuclear Regulatory Commission, Washington, DC, NUREG-1727, September 2000.

NRC, "Policy and Guidance Directive PG-8-08 - Scenarios for Assessing Potential Doses Associated with Residual Radioactivity," U.S. Nuclear Regulatory Commission, Office of Nuclear Material Safety and Safeguards, May 1994.

Yu, C., et al., "Manual for Implementing Residual Radioactive Material Guidelines Using RESRAD, Version 5.0," ANL/EAD/LD-2, Argonne National Laboratory, Argonne, IL, September 1993.

Table 3. Radionuclide concentrations used in the staff assessment.

	Concentration (pCi/g)	
Radionuclide	**Old Pit Area**	**Building 4&5 Area**
Ac-227	0.0066	0.1
Pa-231	0.0066	0.1
Pb-210	0.147	2.23
Ra-226	0.147	2.23
Ra-228	0.06	0.9075
Th-228	0.06	0.9075
Th-230	0.147	2.23
Th-232	0.06	0.9075
U-234	0.147	2.23
U-235	0.0066	0.1
U-238	0.147	2.23

Table 4. Parameter values used in the staff assessment.

Parameter	Staff's value	Cabot's value	Comment
Well pumping rate (m^3/y)	118	250	Screening value used by staff
Unsaturated zone K_d (cm^3/g)	0	RESRAD defaults	No basis provided for the licensee's value
Saturated zone K_d (cm^3/g)	0	10	No basis provided for the licensee's value
Inhalation rate (m^3/y)	11690	8400	Screening value used by staff
Mass loading (g/m^3)	3.14e-6	3.4e-5	Screening value used by staff
Shielding factor	0.5512	0.59	Screening value used by staff