DOCKET NO.	40-9027
LICENSE NO.	SMC-1562
LICENSEE:	CABOT PERFORMANCE MATERIALS, REVERE, PA
SUBJECT:	SAFETY EVALUATION REPORT, SITE DECOMMISSIONING PLAN AND RADIOLOGICAL ASSESSMENT DATED FEBRUARY 28, 2001

1.0 Introduction

Cabot Performance Materials (Cabot) holds NRC License SMC-1562, covering storage of radioactive materials at both their Revere and Reading sites in Pennsylvania. Former ore processing at the Revere facility generated waste slag contaminated with uranium and thorium. In 1988, Cabot began onsite decommissioning activities for the Revere facility, including site characterization, determination of slag leach rates, surface gamma measurements, and radiological analysis of surface and subsurface samples. Contaminated areas were remediated in a series of clean-up actions in the early 1990's. A site decommissioning plan (DP) was submitted to the NRC in August 1996. This DP was later replaced by a completely rewritten DP and radiological assessment in November 1997.

In December 2000, the NRC requested additional information from Cabot in order to complete the review of the proposed decommissioning plan. In reponse, Cabot developed a revision to the 1997 decommissioning plan and radiological assessment which included additional information not previously submitted. This safety evaluation report has been prepared in response to the latter decommissioning plan. If the latest decommissioning plan and supporting materials are approved, the Revere site will be removed from the license and released for unrestricted use.

1.1 Description of Proposed Action

Cabot proposes to remove the Revere, Pennsylvania site from their source materials license and that NRC release the site for unrestricted use without further onsite decommissioning.

1.2 Purpose and Need for the Proposed Action

The purpose of this action is to remove the site, which no longer uses source materials, from a source material license. Furthermore, the intent is to allow unrestricted release of the site, thereby removing limitations on the future use of the property. This action is required by the Decommissioning Timeliness Rule (10 CFR 40.42).

2.0 Facility Description/Operating History

2.1 Description of Revere Site

The Cabot facility is located in Revere, Bucks County, Pennsylvania. Slag materials containing uranium and thorium were generated from niobium (columbium) and tantalum metal processing in the 1970s. These materials were deposited in four areas on the site: (1) the Old Pit Area, (2) the Parking Area, (3) the Former Container Storage Area, and (4) the Building 4&5 Area.

These four areas vary in size from $1.5x10^3$ to $5.1x10^3$ m^2 (0.4 to 1.3 acres), with at least 122 m (400 ft) separating them. The total property area is $4x10^5$ m^2 (100 acres).

Each of the above areas contain mixtures of building debris, slag, rock, and soil. The Old Pit Area is a 5,110 m^2 (55,000 ft^2) area, away from the manufacturing buildings, which extends to a depth of 2.7 meters (9 feet) below the ground surface. The Parking Area is a 3,298 m^2 (35,500 ft^2) area, extending to a depth of 1.8 meters (6 feet), located west of the principal manufacturing buildings. The slag area in the Former Container Storage Area is 1,858 m^2 (20,000 ft^2), extending to a depth of 1.22 meters (4 feet), located in the central portion of the property. The Building 4&5 area is behind buildings 4 & 5 and is a 1,486 m^2 (16,000 ft^2) area, extending to a depth of 0.61 meters (2 feet) below the ground surface.

The area surrounding the site is generally rural with land uses including industrial, commercial, residential, and agricultural. The facility is located between the Rapp Creek and Beaver Creek Drainage Basins. Rapp Creek originates near Lake Warren, 3.2 km (2 miles) north of the site, and flows through the northwestern portion of the site. The creek then flows southward to the confluence with Beaver Creek, where it becomes Tinicum Creek. Tinicum Creek flows generally north-east from the basin into the Delaware River. The Delaware River is 5.6 km (3.5 miles) north of the site, flowing eastward and eventually southward.

Bucks County has a temperate humid, maritime climate. The average annual precipitation is approximately 1100 mm (45 inches). Bedrock beneath the site is reported to be the Triassic age Lockatong formation in the eastern portion of the site and the Triassic age Brunswick formation in the western portion of the site. These formations result in a rolling terrain of low hills, dictated by the occurrence of argillite and sandstone, which are more resistant to weathering. The gray/black argillite of the Lockatong formation grades into the red shales and sandstones of the Brunswick formation. The Lockatong formation at the site was metamorphosed by the intrusive diabase occurring near the eastern edge of the site. Around the diabase intrusives, common copper-bearing minerals such as azurite and malachite occur. In some areas near the site, the argillite gradually becomes a black hornfels. The highest topographic points near the site occur as a result of the highly resistant diabase.

The Lockatong formation is generally a poor source of water and its ability to transmit water is low, with reported yields of wells ranging from 2-25 gpm. The range of water yielded from the Brunswick formation is 2-260 gpm, with an average of 40 gpm.

2.2 Facility Operating History

Cabot's predecessor, Kawecki Chemical Company, used a thermite reduction process to produce steel-grade niobium metal. This process involved the use of pyrochlore, containing natural uranium and thorium. Upon completion of the processing, uranium and thorium remained in the form of a waste silica slag.

In the early 1970s, Kawecki Chemical obtained a source materials license from the NRC to possess the waste slag containing greater than 0.05% by weight uranium and thorium. The processing of pyrochlore was discontinued in 1976. Cabot now holds license SMC-1562 allowing the company to possess the slag material produced by the Kawecki Chemical Company. Currently, there are no source materials being used on site and no activities occurring in the four areas where the slag was deposited.

Cabot began performing decommissioning activities at the site in 1988. In 1991, Cabot Corporation submitted a final survey of the Revere site to the NRC and expressed their desire to obtain unrestricted release of the site and removal from their license. The Oak Ridge Institute for Science and Education performed a confirmatory survey in July 1991 (final report issued in 1993), and found that although the average concentrations of natural uranium and thorium met NRC limits, individual fragments of slag exceeded NRC guidelines.

Cabot performed a Radiological Characterization Survey Report (1994) which included a gamma survey at 1 m and 1 cm above ground surface, establishment of background levels, and collection and analysis of surface samples. This data was then used to prepare a Radiological Assessment Report (1997). Additionally, Cabot developed a Radiological Subsurface Sampling Report (1994) consisting of collection and analysis of subsurface slag, soil, and select water samples. Subsurface slag samples were used to measure the readily available uranium (RAU) leach rate of uranium from slag. The leach rates of thorium and radium were also determined along with an evaluation of the weathering rate of slag.

Subsequently, Cabot prepared a site decommissioning plan (SDP) in April 1996 using the Interim Radiological Cleanup Criteria for Decommissioning, specifically the concentration based limits given in NMSS Policy and Guidance Directive FC 83-23. This SDP included an ALARA analysis, and Risk Assessment for the Revere Site. This plan was later replaced by an SDP and Radiological Assessment (RA) submitted November 1997, using the dose based limits, in 10 CFR 20 Subpart E. In December 2000, NRC requested additional information regarding the SDP and RA. Cabot responded to NRC's request in March 2001, with revision 1 to the 1997 SDP and RA.

3.0 Radiological Status of the Facility

3.1 Radiological Status of Uranium/Thorium Contaminated Slag

According to Cabot, based on inventory records and site assessment reports, approximately 50,000 pounds of thorium and uranium bearing ore were delivered and processed at the Revere site. Resulting slag waste was disposed in four locations on site.

The residual radionuclide concentrations for slag are estimated by calculating a mass balance of the remaining activity on the site from process records and information on the amount of material removed during prior decommissioning activities. Based on inventory records, it is estimated that a maximum of 0.0065 Ci of thorium and 0.016 Ci of uranium remain on the site. The thorium and uranium are contained in slag fragments which are distributed with building debris and uncontaminated slag in the four areas. Assuming a density of 2.0 g/cm^3 for the slag/debris and a total volume of 23,000 m^3 (820,000 ft^3), a total mass of 46.4 x 10^6 kilograms of affected material remains at the four locations on the site. (Radiological Assessment, 2001).

The derived average radionuclide concentrations for natural uranium and thorium (assumed to be in equilibrium) are based on an analysis of process slag samples and recovered slag or waste samples. The residual contaminated slag mass is estimated at 125,000 pounds, from normal processing which exceeds the original ore mass of 50,000 pounds due to other added materials. Thus, the average slag concentration would be expected to be less than the average ore concentration. Five of nine thorium process slag samples were from test melts conducted in 1970, with lower amounts of added materials, which concentrated the radionuclides in the ore by a factor of 1.6. To ensure the activity used for the dose assessment did not underestimate the potential dose, the highest average activities for thorium and uranium bearing slag (i.e., with the 1.6 concentration factor) were used to represent the activity in the original ore. This resulted in using measured radionuclide concentrations (in slag) of 309 pCi/g thorium and 726 pCi/g uranium to represent the radionuclide concentrations in the 50,000 pounds of ore.

3.2 Radiological Status of Soils

Cabot reports there is little soil in the slag areas; it is mostly clean slag and rubble. Furthermore, the Radiological Subsurface Sampling Report submitted in 1994 determined that radioactivity is limited to the slag and no detectable concentrations had leached into the soil. The ORISE report (ORISE 1993) indicated that other than two soil samples that may have contained small pieces of slag, the average concentrations of total uranium and thorium in the soil were well below the guideline levels and less than twice background levels. The elevated direct readings in the four areas were due to slag fragments deposited in the area.

3.3 Radiological Status of Surface Water and Groundwater

Monitoring of groundwater and surface water is not required by license SMC-1562. However, there is some information regarding the status of water on the Revere site contained in the Radiological Subsurface Sampling report submitted in August 1994. Analysis of water flowing through the container storage area showed total uranium and thorium concentrations in the range of typical background values for the site.

In addition, the licensee conducted leach rate tests to demonstrate that contamination would not extend to surface and groundwater. Based on leach test results, Cabot reports the total available uranium to be 0.82 µg, per gram of slag.

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 the radioactivity is actually tightly bound in the slag matrix, modeling releases as a surface process requires an assumption of strong 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. The RAU was determined using a modified Toxicity Characteristic Leaching Procedure leach in water adjusted to pH 2.9 (10 - 100 times more acidic than the natural environment) using acetic acid and performed four times sequentially on the same sample aliquot. The sample aliquot was ground before the procedure, greatly increasing the available contact surface area.

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, consistent with the approach described in Appendix A of the SDP, since thorium and radium (the other key radionuclides) have been shown to leach at a slower rate. The leach rate assumed in the Cabot assessment is on the order of $1x10^{-6}$ to $1x10^{-5}$ yr^{-1}.

3.4 ALARA

The July 21, 1997 Final Rule "Radiological Criteria for License Termination" (License Termination Rule) as 10 CFR Part 20, Subpart E established a 0.25 Sv/y (25 mrem/y) total effective dose equivalent limit plus ALARA[2] for license termination without restrictions on future site use. Cabot's ALARA analysis (RA 2001) used a simplified approach by assuming a conservatively high dose savings and a conservatively low remediation cost estimate. For calculating the dose savings, Cabot assumed a dose of 25 mrem/man-y (that is 100% cleanup of radioactive material), dose time of 1000 years, and population density of 4 per acre and a dose value of $2000/ man-rem, discounted at 3% per year. For calculating disposal costs, Cabot estimated approximately (all in 1996 dollars) $4.2 million for planning, mobilization and site cleanup, and $4.6 million for waste disposal for a total remediation cost of $8,825,000.

Cabot estimates a dose benefit of between \$0.04- \$2.00 /m^2 of remediated contamination and a remediation cost of \$312/m^2.

4.0 Evaluations

4.1 Decommissioning Program

No site decommissioning activities are proposed or anticipated in the SDP, which concludes that the site meets criteria for unrestricted release without further cleanup. Staff agrees that a Decommissioning Program is not necessary if it is found that the site meets the License

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

[2] As Low As is Reasonably Achievable.

Termination Rule requirements for unrestricted release. Specifically, there would be no need for a management program, radiation protection program, radiological accident analysis, radioactive waste management program, QA/QC program, or emergency plan.

4.2 Site Characterization

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. Staff review of the source term abstraction follows:

4.2.1 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

Table 1. Brief description of contaminated areas.

Contaminated Area	**Area m^2 (ft^2)**	**Thickness m (ft)**	**Brief Description**
Parking area	3,259 (35,500)	1.8 (6)	Building rubble, slag, and soil
Container storage area	1,744 (19,900)	1.22 (4)	Slag and soil
Building 4&5 area	1,469 (16,000)	0.61 (2)	Slag, rock, and soil
Old pit area	5,040 (54,900)	2.7 (9)	Building debris, slag, and soil

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 (0.17 pCi/g Th-232 plus Th-228) used in RESRAD calculations, see Table 2) and 0.34 pCi/g of uranium (U-234 plus U-238) 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 previously removed from 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.

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. This assumption is satisfactorily addressed by the staff's analysis (see section 4.3.3).

Staff agrees that based upon the glass-like structure of the slag 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

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

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.

Additionally, Cabot assumes that the leach rate of thorium, radium, and all other radionuclides are the same as leach rate of uranium, based on evidence which indicates that other radionuclides would leach at a slower rate.

4.3 Radiological Assessment

Staff reviewed the radiological assessment using guidance provided in NUREG-1727 (NRC, 2000) for conducting dose assessments 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. Review of the source term is addressed in 4.2.1.

4.3.1 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. The residential gardener scenario was shown to be the most restrictive analysis in the RA, when compared with other plausible land-use scenarios for the site.

For its worker scenario, Cabot assumed 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. A more realistic worker scenario was conducted in the sensitivity analysis portion of Revision 0 of the RA, but was omitted in Revision 1. The Revision 0 analysis used higher radionuclide concentrations and evaluated the case of a worker spending 1920 hr/yr in a building constructed in a contaminated area, along with 80 hr/yr outdoors; and a second case with 1600 hr/yr indoors and 400 hr/yr outdoors. Dose estimates from these scenarios demonstrated that the dose limit would not be exceeded, even though the estimated dose increased by slightly more than order of magnitude than the base scenario evaluated in Revision 1. Since, a similar analysis done using the lower radionuclide concentration values presented in Revision 1 of the RA is bound by the previous analysis, the additional sensitivity analysis is not required. Additionally, staff analysis of the Revision 1 shows that the resident gardener scenario (see below) would bound a realistic worker scenario.

For its resident scenario, Cabot assumed 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 finds 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 finds that exposure times assumed in the resident gardener scenario appropriately bounds this scenario. Additionally, in the 1997 SDP and RA, Cabot completed a sensitivity analysis of worker scenarios that included acceptable estimates of worker exposure times. Staff finds these earlier, more appropriate worker scenarios are also bounded by the resident gardener scenario provided in the March 2001 RA.

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 does 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 requires 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. 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. Therefore, staff believes that it is appropriate to exclude these pathways in the assessment.

4.3.2 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.

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.

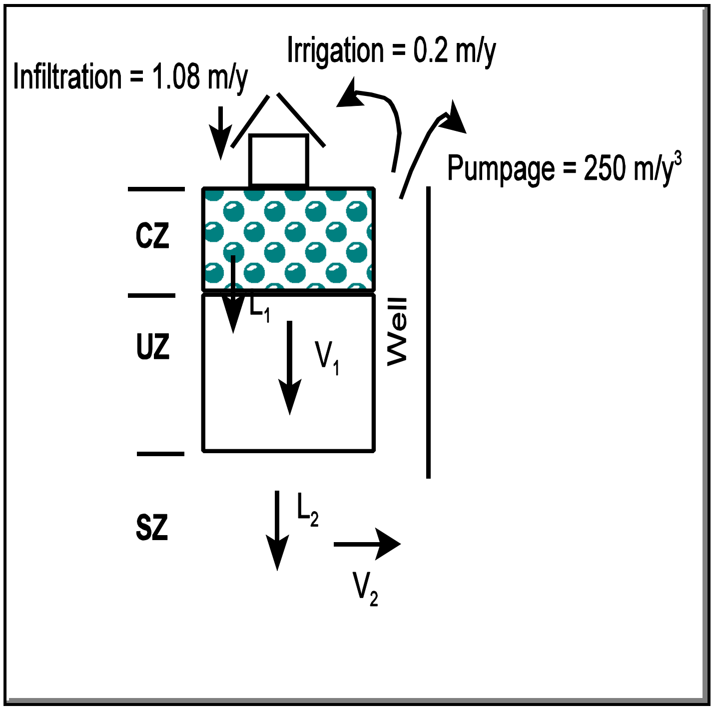

Figure 1. Generalized conceptual model used in the Cabot-Revere assessment.

4.3.3 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

Table 3. 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.

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 non-conservative 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 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 4 shows the concentrations used in the staff assessment. Table 5 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/y limit for unrestricted release of the site[3].

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[3]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

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.

Table 4. 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

experiment to the total uranium in the sample.

Table 5. 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

4.3.5 Conclusion of Radiological Assessment

The most bounding scenario analyzed by staff is of the Building 4&5 area containing ½ of the total volume of contaminated slag in a residential gardener scenario, with no cover. In this scenario, the maximum calculated annual TEDE dose over 1000 years was calculated to be 20 mrem/y.

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.

Staff has found the existing survey data to be sufficient to demonstrate with reasonable assurance that the dose criterion of 10 CFR 20.1402 has been met. Since no further decommissioning activities are planned, staff concludes that no further survey is needed, and the existing surveys, with Cabot's radiological assessment, adequately demonstrate compliance with 10 CFR 20.1402 requirements.

4.4 ALARA Analysis Evaluation

Staff has reviewed the information submitted by Cabot to demonstrate that the preferred decommissioning option is ALARA, as required in 10 CFR Part 20, Subpart E, in accordance with the criteria in the NMSS Decommissioning Standard Review Plan, (NUREG-1727) Section 7.0 ("ALARA Analysis"). Cabot's dose savings estimate used a lower population density of 4 persons per acre than the NUREG-provided value of 0.0004 person/m^2. This results in an overestimate of the dose benefit from further remediation. However, this overestimate (a factor of 2.5) while not insignificant does not invalidate Cabot's ALARA analysis, since there is considerable margin in their findings.

The remediation cost estimate estimates the total volume at 17,000 cubic meters while other sources estimate the volume to range from 23,222 cubic meters (1996, NES) to 31,319 cubic meters (1994, NES). The estimate is considered conservatively low. Cabot did not provide detailed information about unit cost factors, contingency factors, salvage credits, and details of site activities; although staff did not need this information to satisfactorily analyze Cabot's ALARA evaluation.

In accordance with section 1.5 of appendix D of the Standard Review Plan, "For residual radioactivity in soil at sites that will have unrestricted release, generic analyses show that shipping soil to a low-level waste disposal facility is unlikely to be cost effective, largely because of the high costs of waste disposal. Therefore, shipping soil to a low-level waste disposal facility generally does not have to be evaluated for unrestricted release." For purposes of the cost analysis for remediation work, the contaminated slag/soil/debris mixture at the four contaminated areas would be excavated and disposed of in the same way as soil. Therefore, staff concludes that the preferred option provides reasonable assurance that the sites current residual radioactivity levels are ALARA.

4.5 Release Criteria

The site release criteria are found in NRC's Final Rule "Radiological Criteria for License Termination" (License Termination Rule) as 10 CFR Part 20, Subpart E (10 CFR 20.1402). This rule established a 0.25 Sv/y (25 mrem/y) plus ALARA dose limit for license termination without restrictions on future site use.

5.0 Summary and Conclusion of Safety Evaluation

Staff finds that the site meets both the dose limitation and ALARA requirements of the License Termination Rule, (10 CFR 20.1402), and the site is acceptable for unrestricted release with no further action.

6.0 Recommendations

Staff recommends the Cabot Revere site be released for unrestricted release, and license amendments and SDMP delisting actions proceed accordingly.

7.0 License Conditions

Revere site to be removed from license, Reading site will remain on license.

8.0 References

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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.