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 MAY 24, 2001

1.0 Introduction

Cabot Performance Materials (Cabot) holds U.S. Nuclear Regulatory Commission (NRC) License SMC-1562, covering storage of radioactive materials at both its 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 rate constants, 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 1990s. A site decommissioning plan (DP) and risk assessment were submitted to NRC in April 1996 [Cabot and Cabot (b), 1996]. The DP and risk assessment were later replaced by a completely rewritten DP and Radiological Assessment (RA) in November 1997 [Cabot and Cabot (b) 1997]. In December 2000, NRC requested additional information [NRC, 2000] from Cabot, to complete the review of the proposed DP. In response, Cabot developed a revision to the 1997 DP and RA [Cabot and Cabot (b), 2001] which included information it had not previously submitted. Cabot also provided more information in an April 27, 2001, letter [Knapp, 2001].

This safety evaluation report (SER) has been prepared in response to the latter DP, RA and informational letter. If the latest DP 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 its source materials license, and requests 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 materials 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).

1.3 Release Criteria

The site release criteria are found in NRC's Final Rule "Radiological Criteria for License Termination" [License Termination Rule (LTR)] as 10 CFR Part 20, Subpart E (10 CFR 20.1402). This rule established a 0.25 millisieverts per year(mSv/yr) [25 millirem per year (25

mrem/yr)], plus As low as is reasonably achievable (ALARA) dose limit for license termination, without restrictions on future site use.

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 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 Buildings 4 and 5 Area. As reported by the licensee, these four areas vary in size from 1400 to 3200 square meters (m^2) [15,070 to 34,450 square feet (ft^2)], with at least 122 meters (m) [400 feet (ft)] separating them. The total property area is 405,000 m^2 (4.4 million ft^2).

Each of the above areas contain mixtures of building debris, slag, rock, and soil. The Old Pit Area is located near Rapp Creek, away from the manufacturing buildings. The Parking Area is next to the former sandblasting area, west of the principal manufacturing buildings. The Former Container Storage Area is located in the central portion of the property. The Buildings 4 and 5 area is behind Buildings 4 and 5, just north of the principal manufacturing buildings. See Table 1 for a brief description of volumes and areas of each location.

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 kilometers (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 1140 millimeters [45 inches (in)]. 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 0.00013 - 0.0016 cubic meters/second (m^3/s) [2-25 gallons per minute (gpm)]. The range of water yielded from the Brunswick Formation is 0.00013 -0.16 m^3/s (2-260 gpm), with an average of 0.0025 m^3/s (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. On 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 NRC to possess the waste slag containing greater than 0.05 percent 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 NRC and expressed its desire to obtain unrestricted release of the site and removal of it from the License [Cabot, 1991]. The Oak Ridge Institute for Science and Education (ORISE) performed a confirmatory survey in July 1991 [Berger and Smith, 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 [Cabot, 1994], which included a gamma survey at 1 m (3 ft) and 1 centimeter (0.4 in) above ground surface, establishment of background levels, and collection and analysis of surface samples. Additionally, Cabot developed a Radiological Subsurface Sampling Report [Craig, 1994] consisting of collection and analysis of subsurface slag, soil, and selected water samples. Subsurface slag samples were used to measure the readily available uranium (RAU) leach rate constant of uranium from slag. The leach rate constants of thorium and radium were also determined, along with an evaluation of the weathering rate of slag.

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

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 23,000 kilograms (kg) [50,000 pounds (lb)] of thorium- and uranium-bearing ore were delivered

and processed at the Revere site. Resulting slag waste was disposed of in four locations on site.

Buildings that were used for storage and processing of licensed materials have been completely demolished or removed and replaced, with the exception of three walls of the former blending building, located in the Old Pit Area.

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 240 megaBecquerel (MBq) [0.0065 curies (Ci)] of thorium and 590 MBq (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 grams per cubic centimeter (g/cm^3) for the slag/debris and a total volume of 23,000 cubic meters (m^3) [820,000 cubic feet (ft^3)], a total mass of 46.4×10^6 kg (102 million lb) of affected material remains at the four locations on the site [Cabot (b), 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 57,000 kg (125,000 lb), from normal processing, which exceeds the original ore mass of 23,000 kg (50,000 lb) 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 11.4 becquerels per gram (Bq/g) [309 picocuries per gram (pCi/g)] thorium and 26.9 Bq/g (726 pCi/g) uranium, to represent the radionuclide concentrations in the 23,000 kg (50,000 lb) 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 [Craig, 1994] determined that radioactivity is limited to the slag and no detectable concentrations had leached into the soil. The ORISE report [Berger and Smith, 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 caused by slag fragments deposited in the area.

3.3 Radiological Status of Surface Water and Ground Water

Monitoring of ground water and surface water is not required by License SMC-1562. However, there is some information on the status of water on the Revere site contained in the Radiological Subsurface Sampling Report submitted in August 1994 [Craig, 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 ground water [Cabot, 2001]. Based on leach-rate test results, Cabot reports the total available uranium to be 0.82 microgram 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 medium (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 medium. Cabot calculated a distribution coefficient (K_d) of 137,500 milliliters per gram (ml/g) 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 a pH of 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 cubic centimeters per gram (cm^3/g) [3.8 million cubic inches per pound (in^3/lb)] was used to calculate the leach rate constant of radionuclides from the source zone (i.e., slag). The same K_d value was also used for the uranium-238 progenies and thorium-232 and its progenies, consistent with the approach described in Appendix A of the DP, since thorium and radium (the other key radionuclides) have been shown to leach at a slower rate. The leach rate constant assumed in Cabot's 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" (LTR) as Part 20, Subpart E, established a 0.25 mSv/yr (25 mrem/yr) total effective dose equivalent (TEDE) limit plus ALARA for license termination without restrictions on future site use. Cabot's ALARA analysis [Cabot (b), 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 0.25 mSv/yr (25 mrem/yr) (that is 100 percent cleanup of radioactive material); a dose time of 1000 years, a population density of 0.001 persons per square meter (man/m^2) [4 persons per acre (man/ac)], and a dose value of $200,000 per man-sievert ($2000 per man-rem), discounted at 3 percent 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 $8.8 million.

Cabot estimates a dose benefit of between $0.04- $2.00 per m^2 ($160 - $8,000/ac) of remediated contamination, and a remediation cost of $312 per m^2 ($1.3 million/ac).

4.0 Evaluations

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[1]In its RA, Cabot assumed that only slag is radioactively contaminated.

4.1 Decommissioning Program

No site decommissioning activities are proposed or anticipated in the DP, which concludes that the site meets the 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 LTR requirements for unrestricted release. Specifically, there would be no need for a management program, radiation protection program, radiological accident analysis, radioactive waste management program, quality assurance/quality control program, or emergency plan.

4.2 Radiological Assessment

Staff reviewed the RA using guidance provided in NUREG-1727 [NRC, 2000] for conducting dose assessments, to demonstrate compliance with the LTR. Specifically, the following aspects of the assessment were reviewed: site characterization and 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, followed by staff conclusions regarding the RA.

4.2.1 Site Characterization and Source Term-Abstraction

As previously stated, radioactively contaminated slag is present in four known areas at the site. A summary of the licensee's description of these areas is provided in Table 1.

NRC staff had concerns regarding not including the loading dock/warehouse area as a contaminated area. This was in part because of two small samples of radioactive slag found during the 1991 ORISE survey in the loading dock/warehouse area [Berger and Smith, 1993]. The licensee confirmed that these samples have been removed and NRC inspection reports have verified that no elevated direct radiation remains in the loading dock/warehouse area. However, given that part of the loading dock/warehouse area is paved, the possibility of additional subsurface contamination in this area cannot be completely ruled out. Gamma surveys would be inconclusive because of the shielding from the pavement. In response to this concern, Cabot has provided statements from former employees that the area was paved before the use of radioactive material on the site. Further, Cabot has provided a 1970 aerial photo that shows the area as paved before the use of radioactive material in the early 1970s. Therefore, staff believes that it is unlikely that there is additional contamination in the loading dock/warehouse area.

All that remains of buildings within the four contaminated areas is three walls of the old blender building in the Old Pit Area. In 1991, ORISE performed alpha and beta surface scans of the three walls and did not identify any areas of elevated direct radiation. NRC staff considers that the building remains do not contain embedded residual radioactivity that is distinguishable from background.

In its RA, 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 240 MBq (0.0065 Ci) of thorium and 590 MBq (0.016 Ci) of uranium remains on the site. The total volume of contaminated material (slag, rubble, and soil for each location, as described in

Table 1) from all four areas was initially estimated as 23,000 m^3 (820,000 ft^3) [Cabot, 2001]. Assuming a contaminated material density of 2.0 g/cm^3, a total mass of 46.4 x 10^6 kg (102 million lb) of contaminated material is believed to remain on the site. Based on the assumed activities of thorium and uranium remaining at the site, and uniform dispersion among the four areas, an estimated concentration of 0.0052 Bq/g (0.14 pCi/g) of thorium (thorium-232 plus thorium-228) and 0.013 Bq/g (0.34 pCi/g) of uranium (uranium-234 plus uranium-238) was derived by Cabot. Cabot's RA analysis used 0.0063 Bq/g (0.17 pCi/g) of thorium and 0.013 Bq/g (0.34 pCi/g) of uranium in the RESRAD analyses (see Table 2).

Table 2. Radionuclide concentrations used in the Cabot Radiological Assessment.

Radionuclide	**Concentration** Bq/g (pCi/g)
Actinium-227	0.00028 (0.0077)
Protactinium-231	0.00028 (0.0077)
Lead -210	0.0063 (0.17)
Radium-226	0.0063 (0.17)
Radium-228	0.0031 (0.083)
Thorium-228	0.0031 (0.083)
Thorium-230	0.0063 (0.17)
Thorium-232	0.0031 (0.083)
Uranium-234	0.0063 (0.17)
Uranium-235	0.00028 (0.0077)
Uranium-238	0.0063 (0.17)

Note: Bq/g = Bequerels per gram, pCi/g = picocuries per gram

In an April 27, 2001, letter, Cabot revised the volume estimate for each area by reviewing site characterization reports and using the minimum reported area, and thus volume, for each of the four contaminated locations. This resulted in a contaminated volume of 15,180 m^3 (536,010 ft^3), which is a 35 percent reduction in volume from the RA estimate. This results in a radionuclide concentration and dose increase of approximately 50 percent, which is still an order of magnitude below the LTR limit. [Knapp, 2001].

Staff considers the radionuclide activities 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 it 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.

The radionuclide concentrations used by Cabot in the RA are listed in Table 2. The isotopic ratios are based on those commonly expected for natural thorium and natural uranium. All daughter radionuclides are assumed to be in secular equilibrium with their parents. In addition, external gamma measurements at the site suggest a uranium-238 concentration of less than 0.074 Bq/g (2 pCi/g) and a thorium-232 concentration essentially at background for the upper several inches of the contaminated areas. Subsurface measurements in the Container Storage, Parking, and Old Pit Areas indicated near-background conditions. Therefore, the concentrations used by Cabot are consistent with exposure rate measurements.

By using the total estimated volume of radioactive slag [i.e., 23,000 m^3 (820,000 ft^3) in the RA, or 15,180 m^3 (536,000 ft^3) in the April 2001 letter] 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 4.2.4).

Staff agrees that, based on 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/yr ($8x10^{-8}$ to $6x10^{-7}$ in/yr)] 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 rate constants reported for uranium and thorium for slag [Felmy, et al., 1999], the leach rate constant 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 constant assumed in the Cabot assessment is on the order of $1x10^{-6}$ to $1x10^{-5}$ yr.

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

4.2.2 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 that 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 agricultural.

Cabot considered two scenarios in its RA; specifically, both worker and resident scenarios 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 to external gamma radiation from the slag and inhalation of re-suspended dust. The hypothetical worker is assumed to spend a very limited time in the contaminated area [40 hours per year (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 bounded by the previous analysis, the additional sensitivity analysis is not required.

Additionally, staff analysis of 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 percent of his time in the area (85 percent indoors and 15 percent outdoors). Exposure is assumed to occur through direct gamma radiation, inhalation, soil ingestion, and drinking water. A 0.15 m (6 in) 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 m (6 in), 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 0.15 m (6 in) soil layer. The results of this sensitivity analysis give a calculated dose significantly below the release limit, but roughly 6 times higher than the dose calculated for the base-case resident scenario. This reflects the importance of the assumption that a 0.15 m (6 in) 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, including an excavation scenario evaluated by Cabot. In the excavation scenario, it is assumed that some of the slag is excavated and used as foundation fill in the construction of a house. Staff finds that the resident gardener scenario appropriately bounds the excavation scenario, because of the higher exposure times. Additionally, in the 1997 DP 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 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 m (66 ft)] 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 Buildings 4 and 5 areas, which are both less than the default area assumed in NRC's screening approach for the residential farmer scenario [i.e., 2400 m^2 (26,000 ft^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.

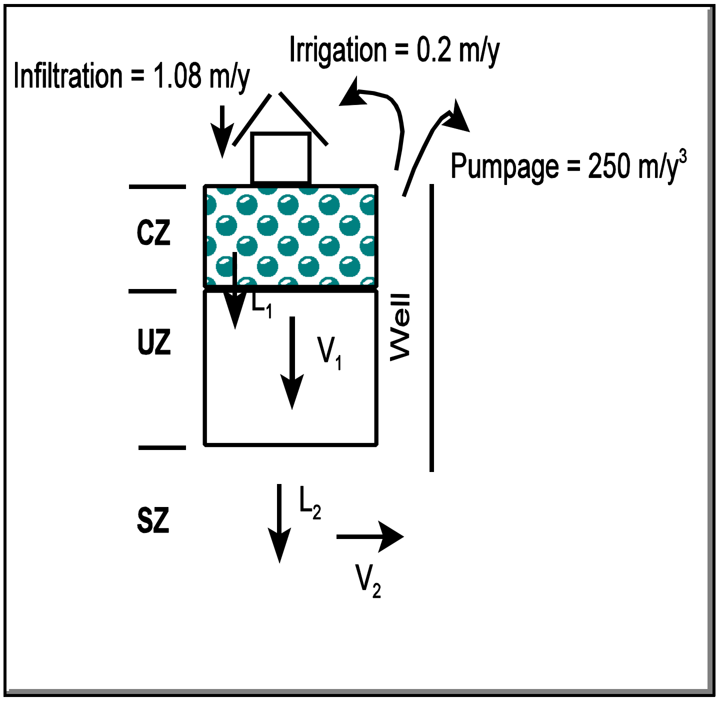

Figure 1. Generalized conceptual model used in the Cabot-Revere assessment.
Note: CZ-Contaminated Zone; UZ-Uncontaminated Zone, SZ-Saturated Zone; L1-Leach Rate from the CZ; L2- Leach Rate from the UZ; V1-Velocity in UZ V2- Velocity in SZ

4.2.3 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 RA 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 RA, based on the staff's interpretation of the information presented in the report.

It should be noted that a default irrigation rate of 0.2 m/yr (0.7 ft/yr) was used in the analysis, although the licensee only assumed irrigation as part of its residential gardener scenario.

Based on regional information, the unsaturated zone is believed to be roughly 20 m (66 ft) 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 (0.03 ft)] assumed for the analysis. Staff believes that this adds conservatism to the calculated doses for the water-dependent pathways.

4.2.4 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 bounded 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 m^3 (820,000 ft^3) of contaminated material are uniformly spread out over an area of 23,000 m^2 (250,000 ft^2) to a depth of 1 m (3.3 ft). (See the “Combo” column in Table 3.)

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 these concerns, 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 and 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. Values of parameters reflected in the schematic in Figure 1

Parameter	Contaminated Area Section				
	Parking Area	**Container Storage**	**Bldgs 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/yr)	1.9e-5	2.7e-5	5.5e-5	1.2e-5	4.1e-6
V_1≡ velocity in UZ (m/yr)	6.4	6.4	6.4	6.4	0.02
V_2≡ velocity in SZ (m/yr)	0.2	0.2	0.2	0.2	0.2
Note: SZ≡ saturated zone, L_2≡leach rate from the UZ = L_1- radioactive decay. The reported V_1 is uranium; for thorium the value is 1.7e-5.					

Note: nonmetric conversions omitted for brevity

Table 4 shows the concentrations used in the staff's independent dose assessment.

In addition, staff questioned the volume estimate for the Old Pit Area provided by Cabot in both the RA and the April 2001 Cabot letter. A conservative NRC staff estimate of the volume for the Old Pit Area, based on direct observation, would be still be greater than the volume of the Buildings 4 and 5 Area, resulting in a higher calculated concentration in the Buildings 4 and 5 Area. Therefore, NRC staff considers that the dose estimated is bounded by the above NRC staff analysis for the Buildings 4 and 5 area. Additionally, the April 2001 Cabot letter provided a slightly reduced volume for the Building 4 and 5 Area. This reduction in volume is minimal (5 percent) and would not affect the results of staff's 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 0.25 mSv/yr (25 mrem/yr) limit for unrestricted release of the site[2].

Table 4. Radionuclide concentrations used in the staff assessment

	Concentration Bq/g (pCi/g)	
Radionuclide	**Old Pit Area**	**Buildings 4&5 Area**
Actinium-227	0.00024 (0.0066)	0.0037 (0.1)
Protactinium-231	0.00024 (0.0066)	0.0037 (0.1)
Lead -210	0.00544 (0.147)	0.0825 (2.23)
Radium-226	0.00544 (0.147)	0.0825 (2.23)
Radium-228	0.0022 (0.06)	0.00336 (0.9075)
Thorium-228	0.0022 (0.06)	0.00336 (0.9075)
Thorium-230	0.00544 (0.147)	0.0825 (2.23)
Thorium-232	0.0022 (0.06)	0.00336 (0.9075)
Uranium-234	0.00544 (0.147)	0.0825 (2.23)
Uranium-235	0.00024 (0.0066)	0.0037 (0.1)
Uranium-238	0.00544 (0.147)	0.0825 (2.23)

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 Cabot performed no sensitivity nor uncertainty analysis to identify key parameters, it is known that calculated doses from direct exposure to gamma radiation are largely dependent on the assumed exposure time. For both the Cabot and staff assessments, the default exposure times recommended by NRC for doing screening analyses for a residential farmer scenario were used. Therefore, the parameter value used is considered appropriate.

[2]The concentration of radionuclides in food is dependent on 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 the fraction of the total available uranium obtained in the leaching 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/yr)	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/yr)	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

4.2.5 Conclusion of Radiological Assessment

The most bounding scenario analyzed by staff is of the Buildings 4 and 5 Area containing one-half of the total volume of contaminated slag in a residential gardener scenario, with no cover. In this scenario, the maximum calculated annual TEDE dose within 1000 years was calculated to be 0.2 mSv/yr (20 mrem/yr).

Based on a review of specific aspects of the Cabot RA, staff considers that the RA 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 RA, adequately demonstrate compliance with 10 CFR 20.1402 requirements.

4.3 ALARA Analysis Evaluation

Staff has reviewed the information submitted by Cabot to demonstrate that the preferred decommissioning option is ALARA, as required in 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 higher population density of 0.001 man/m^2 (4 man/ac). than the NUREG-provided value of 0.0004 man/m^2 (1.6 man/ac). This results in an overestimate of the dose benefit from further remediation, which is conservative. The remediation cost estimate estimates the total volume at 17,000 m^3 (600,000 ft^3). This estimate may be non-conservative (too high), based on a Cabot revised estimate of the

minimum volume of 15,178 m^3 (536,010 ft^3) [Cabot, 2001]. However, this overestimate, although not insignificant, does not invalidate Cabot's ALARA analysis, since there is considerable margin in its findings. 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.

5.0 Summary and Conclusion of Safety Evaluation

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

6.0 Recommendations

Staff recommends that the Cabot Revere site be released for unrestricted release, and license amendments and Site Decommissioning Management Plan 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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