SUPPLEMENTAL INFORMATION FOR
APPLICATION TO AMEND LICENSE NUMBER SMB-920 TO ALLOW FILTERCAKE DISPOSAL AT A CEMENT KILN

Prepared for:

CABOT SUPERMETALS

BOYERTOWN, PA

Prepared by:

WESTON SOLUTIONS, INC.

NOVEMBER 24, 2004

A/12

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1. PURPOSE OF APPLICATION

This document presents supplemental information to the attached NRC Form 313 signed by Tom Odle on November 18, 2004 requesting amendment of U.S. Nuclear Regulatory Commission (NRC) Source Material License Number SMB-920. . The section numbers in this document correspond to the item numbers on NRC Form 313.

Cabot Supermetals, Inc. (CSM) is requesting this amendment to allow filtercake that is generated by the plant's wastewater treatment process and that contains very low levels of naturally occurring radioactivity to be used as cement kiln feedstock. Under the current license filtercake is disposed by transportation to off-site sanitary landfills, as has been the practice for at least 10 years. If approved, the proposed use of the filtercake under the state of Pennsylvania co-product regulations will allow beneficial re-use of the material, reduce waste volumes in local landfills by 20,000 tons per year, and contribute to the cost-efficiency of CSM's operations. Specifically, CSM is requesting that condition 20 in the current license be revised to read as follows (revised language presented in *italics*):

> "The wastewater filtercake source material limit for release to a landfill *or cement kiln operation* is the sum of fractions as follows: uranium/10 pCi/g + thorium/3 pCi/g = 1. This limit applies to the monthly average filtercake released."

Dose models have been completed for three scenarios to assess the doses that might result from the use of filtercake as cement kiln feed material. The modeling input parameters included radionuclide concentrations in the filtercake that were at the release limits described above. The result for each of the three scenarios was less than a millirem. The dose modeling process is described in detail in Section 10.4 of this document.

2. NAME AND MAILING ADDRESS OF APPLICANT

The name and mailing address of the applicant are listed in item 2 on the attached Form 313 for which this document provides supplemental information.

3. ADDRESS WHERE LICENSED MATERIAL WILL BE USED OR POSSESSED

The address where licensed material will be used or possessed is listed in the attached Form 313 for which this document provides supplemental information. The facility covered under this license and the headquarters for CSM are located at the following address:

Cabot Supermetals
County Line Road
Boyertown, PA 19512

The parent corporation under which CSM operates is a $1.5 billion specialty chemical company. CSM is one of 14 business entities that compose Cabot Corporation. Each of those 14 businesses has responsibility for individual performance of operations. Neither CSM nor Cabot Corporation is a foreign-owned business.

4. NAME OF PERSON TO BE CONTACTED ABOUT THIS APPLICATION

The name of the person to be contacted about this application is listed in item 4 of the attached Form 313 for which this document provides supplemental information.

5. RADIOACTIVE MATERIALS

The facility is authorized under NRC License No. SMB-920 to possess a maximum of 360 metric tons (400 tons) of source material. Plant operation includes the receipt of feed material as ore, containing an average of 0.165% by weight of uranium oxide (U_3O_8), and an average of 0.057% by weight of thorium dioxide (ThO_2). The plant ore feed rate is approximately 9,600 pounds per day five days per week, or 1,200 tons per year. The feed material is processed for tantalum and niobium, two non-radioactive products that are used in the electronics industry.

This amendment request addresses only a waste stream that is produced from the treatment of process water and that contains only trace levels of licensed material. That material is described by the information below, and in subsequent text.

a. Element and mass number: Natural uranium and thorium.

b. Physical form: Solid filtercake containing between 25 and 50% moisture.

c. Maximum amount possessed at any time: The plant produces 20,000 tons of filtercake annually. However, because it is shipped offsite every 2 to 3 days, typically fewer than 165 tons of filtercake are maintained at the site.

This application addresses a proposed disposal option for the filtercake that will be used in addition to the current practice of landfill disposal. No revisions are required to the site Emergency Plan because it already addresses transportation accidents, which represent the only emergency response scenario that would be related to the proposed waste disposal option. Furthermore, potential impacts from transportation accidents and resulting emergency responses would be identical to those addressed in the Safety Evaluation Report that was developed in support of the license renewal process in March 2004. As described in that information and in Section 10.7 of this document, CSM has successfully avoided transportation accidents other than for one situation that was minor and was cleaned up without incident in accordance with CSM procedures.

Because filtercake contains such low radionuclide concentrations, the material did not have to be addressed in the current Decommissioning Funding Plan Cost Estimate for the site. Therefore, this amendment will not require any adjustments to that cost estimate.

6. PURPOSES FOR WHICH RADIOACTIVE MATERIAL WILL BE USED

Authorized uses of radioactive material under License No. SMB-920 include receipt, possession, and processing of radioactive material by CSM at the Boyertown, PA facility under the statements and conditions stated in the license. Statements, representations, and conditions specified in this application will apply only to the filtercake generated by the on-site wastewater treatment plant (WWTP). All other licensed materials at the site will continue to be received, handled, and disposed according to the commitments in CSM's current license that was granted by the NRC in May 2004. The following brief summary is provided to describe the general site operations as a basis for understanding the limited scope of this amendment request.

6.1 BASIS FOR LICENSE AMENDMENT REQUEST

Recycling of calcium-rich filtercake from semiconductor operations as cement kiln feed material is currently practiced by semiconductor manufacturers such as ROHM, Inc and STMicroelectronics in a manner similar to what is proposed in this application. An internet search on the names of those companies, and other semiconductor manufacturers will verify this fact. A local cement company has cooperated with CSM, conducted preliminary analyses of CSM's filtercake, and tentatively determined that it can use the filtercake as an alternative raw material feed source for their cement kiln. Site-specific details of that operation are considered to represent a typical cement kiln operations and have been used as the basis for calculations and evaluations provided in this application. However, the name of the cement kiln company and its specific location are not provided in part because CSM does not wish to limit this disposal option to any single location, just as the current disposal process is not limited to any single landfill location. This document describes the disposal process, quantifies the potential doses to the average members of critical groups, and establishes release limits for the filtercake that would maintain those potential doses at acceptable levels.

Calcium is the primary component in the feed sources for cement kilns, and the filtercake is primarily calcium fluoride and calcium sulfate (>70%). The cement company has determined that the high calcium content of the filtercake meets their criteria for feed material, and no obvious characteristics of the filtercake would cause adverse impacts to the quality of their cement. The filtercake would be added to the kiln at a 1% (by weight) feed ratio, resulting in a 100:1 dilution of CSM filtercake. The total raw material feed rate to the kiln is approximately 1.8 to 2.0 million tons per year; therefore, the quantity of filtercake that CSM would supply to that specific cement company in any year would be 20,000 tons. These values represent the current rate of filtercake production, but are not intended to be used as a limit for the annual rates or quantities of filtercake that would be disposed under the proposed amendment. CSM requests that the proposed filtercake disposal option be approved for any cement kiln operation as long as the 100:1 dilution ratio is maintained.

The filtercake would be transported from the Boyertown Plant using covered or contained vehicles similar to those used for landfill disposal and described in a prior dose assessment that was submitted with the recent CSM license renewal application. Approximately 62 truckloads carrying 20 cubic yards of material (assuming 90 pounds per cubic foot filtercake density) would be shipped each month if all of CSM's filtercake were disposed in this manner.

The cement company will receive the waste filtercake in bulk where it will be dumped and stored on a concrete pad. The pad is covered on three sides with a roof to protect it from the elements. To add the filtercake to the kiln feed, an operator will transport the material by front-end loader from the storage pad to the kiln feed chute. Once the material is dumped directly into the feed chute, there will be no further worker interaction with the filtercake. Material handling equipment (conveyors, scrapers, etc.) will move the filtercake material through the system to the blending and pre-heat areas, and to the kiln. After the blending stage, the radionuclide concentrations in the filtercake will have effectively been reduced by a factor of 100 by dilution with other feed materials. In other words, if the filtercake contained less than 10 picocuries per gram (pCi/g) of uranium, the blended material would now contain less than 0.1 pCi/g of the nuclide.

After the material is blended and processed, the cement clinker product will exit the kiln. The cement clinker product is a large (ping-pong ball size) solid material that presents very limited potential for airborne resuspension or radon emanation.

Evaluation of End Uses for Cement Product Material

The clinkers that emerge from the kiln will be ground into cement that is processed for bulk sale or packaged in individual bags for wholesale distribution and eventual mixing with aggregate and water to form concrete. It is expected that the clinkers and the cement will demonstrate gamma radiation levels that are indistinguishable from background using portable survey instruments.

End uses of concrete include a wide range of scenarios, such as roads, commercial and residential structures, and barriers. The final concrete matrix will be a non-distributable solid form that will not present an intake or uptake hazard and is expected to demonstrate external dose rates that are similar to those for concrete formed without the use of filtercake.

Regulatory Agency Coordination

CSM is working with the U.S. Environmental Protection Agency (EPA) Region III Team Leader for the Waste Minimization Program, Tad Radzinski, and EPA's consultant, David Friedman. During a conference call with them on July 8, 2004, Mr. Radzinski and Mr. Friedman verbally expressed support for the plan at this point, and provided their initial determination that this process is a good candidate for implementation under their program. They also indicated that they would initiate contact with the radiation protection program staff in their agency and would provide a letter to CSM by January 2005 documenting their support for this initiative.

In addition, CSM is working with the Pennsylvania Department of Environmental Protection (PADEP) Office of Solid Waste and the Bureau of Radiation Protection. A meeting was held on August 9, 2004 at the PADEP offices in Harrisburg, PA, with the following attendees:

David Allard, Director of the Bureau of Radiation Protection, PADEP

Bob Maiers, Chief of Decommissioning and Environmental Surveillance, PADEP

Ron Hassinger, Division of Municipal and Residual Waste, PADEP

Scott Walters, Division of Municipal and Residual Waste, PADEP

Tad Radzinski, EPA Team Leader, Waste Minimization

Dave Friedman, EPA

Pam Witmer, PA Chemical Industry Council

Brad Okonoewski, CSM

Tim Knapp, CSM

Jacqui Stewart, CSM

Bob Schoenfelder, CSM (Weston Solutions, Inc.)

Mr. Allard summarized the position of the PADEP after the meeting by saying that the proposed action presented no obvious obstacles based on current information, and that his office would like to stay involved in the NRC review and approval process. He expressed interest in seeing the results of the dose assessments to be performed in support of the license amendment request, and the amendment application.

The planned process will comply with the PADEP "co-product" determination of this material. The Co-Product Regulations contained in 25 PA Code 287.1 were established to reduce the amount of waste going to landfills by finding ways to beneficially re-use residual wastes such as this filtercake. If this disposal option is approved by the NRC, the Office of Solid Waste has concurred that it would be a positive approach from a solid waste regulation standpoint.

Factors Expected to Minimize Doses

In summary, the following factors support the minimal doses (see Section 10.4) that might result if this amendment is approved and filtercake is used as a cement kiln feedstock.

1. The concentrations of uranium and thorium in CSM's filtercake are extremely low and have remained consistent for a long period of time. The material has been released to local landfills in compliance with an NRC license condition that requires the total uranium and thorium levels in the material not to exceed 10 pCi/g and 3 pCi/g, respectively. The dose assessment submitted with the license renewal application in 2004 for this landfill disposal resulted in doses of less than a few millirem. CSM's process has not significantly changed in the recent past, and there are no plans to implement any significant change in the foreseeable future. CSM will continue to monitor the uranium/thorium content of its filtercake in accordance with commitments in its current NRC license
2. The filtercake is a fairly dense solid with a moisture content of about 40% when it is accumulated at the Boyertown plant. The physical nature of the material and the process for transporting and handling the filtercake minimizes the possibility of generating airborne particulates during handling and transportation or exposing individuals.
3. CSM has performed gamma surveys of trucks carrying the filtercake to landfills and found levels that are indistinguishable from background. Because several cement kiln operations are located within reasonable proximity to the CSM site, the distance to the cement company from the Boyertown site is expected to be short. The low dose rates and limited exposure period result in negligible doses to truck drivers and to individuals along the route.
4. The dilution factor for this process is 100:1, and the uranium and thorium content in the filtercake is typically less than 5 pCi/g, making the maximum expected contribution from the filtercake after dilution only 0.05 pCi/g. The uranium and thorium concentrations in the current feedstock are similar to those in background soils; therefore, the relative concentrations of the radionuclides in the feed material and the end product material should be in the range of natural background.
5. The process of mixing and handling the cement kiln feed material is automated, requires little direct worker interaction or close contact, and requires only a short period of time for completion.

7. INDIVIDUAL(S) RESPONSIBLE FOR RADIATION SAFETY PROGRAM AND THEIR TRAINING EXPERIENCE

The individual responsible for the execution of the radiation safety program at the Boyertown facility is the Radiation Safety Officer (RSO). Duties and responsibilities of the RSO are described in the current license and include disposing of the WWTP filtercake in compliance with the CSM's license conditions and state, local and federal regulations. This request for amendment does not alter or add to the roles, responsibilities, training and qualifications, or commitments of the RSO in the current license. The duties and responsibilities of the RSO include the following items that are applicable to the handling and disposal of the filtercake:

- Maintaining membership on the As Low As Reasonably Achievable (ALARA) committee
- Determining compliance with rules and regulations and license conditions

- Providing guidance on the proper shipping of all radioactive material from the CSM facility and ensuring compliance with applicable regulations of the U.S. Department of Transportation (DOT) and other appropriate agencies
- Ensuring that an accurate inventory of source material is maintained
- Managing the radioactive waste program
- Performing and arranging for calibration of instruments
- Training and supervising radiological technicians who conduct radiation monitoring program activities to ensure that procedures are followed and results are correct
- Maintaining files for records related to the Radiation Safety Program
- Maintaining radiological contingency plans and overseeing and coordinating the response to any radiological emergency related to the Boyertown operations.

8. TRAINING FOR INDIVIDUALS WORKING IN OR FREQUENTING RESTRICTED AREAS

Training requirements in the current license are not changed by this request for amendment. If this amendment is granted, the proposed monitoring, handling, and loading of the material for transportation to the cement kiln will be essentially identical to the current methods used for disposal at local sanitary landfills. No additional or modified training will be required for CSM workers, and no training will be required for truck drivers or workers at the unlicensed cement kiln operation.

9. FACILITIES AND EQUIPMENT

The following description of facilities and equipment is consistent with CSM's current license requirements and is accurate and current as of the date of this application. A general description of the site is provided to assist the reviewer in understanding the overall licensed operations, and additional details are provided regarding the WWTP operations that are directly impacted by the proposed revision.

The Boyertown facility is sited on approximately 200 acres located along both sides of County Line Road in an industrial area about 1.5 miles northeast of Boyertown, PA. The site resides in two counties, Berks and Montgomery, with County Line Road essentially bisecting the site and marking the boundary between the two counties. The topography is relatively flat with a slightly elevated knoll just northeast of the main plant area. A stream runs along the western site boundary, and site drainage is generally south and west. Figure 9-1 presents the layout of the operations, and includes a legend to identify pertinent features, such as site buildings and structures, on-site roadways, points of vehicular and pedestrian access, and locations where licensed materials are present. The area that is impacted by this amendment request is the WWTP filterhouse, which is located in Building 62 and is shown as the teal-shaded area in the north central part of Figure 9-1.

Although CSM is licensed to handle source material under the NRC category for uranium mills, CSM's Boyertown plant is not a uranium operation and is of a much smaller scale than most uranium mills. Because the majority of the Boyertown plant is dedicated to chemical processing to produce tantalum and niobium, radioactive materials are handled in a very limited number of buildings and work areas. The quantities of licensed material that are received as feed material and processed or stored at the site are minimal compared with the massive quantities that are handled at uranium mills.

Radioactive constituents of the ore are not concentrated, unlike uranium mills that concentrate uranium as an end product. CSM's tantalum and niobium products do not contain any of the licensed radionuclides.

Insignificant trace levels of the radionuclides in the ores are found in the filtercake addressed by this amendment request; they are virtually all retained in recovered solids that are temporarily stored in bulk storage bins until they are ultimately disposed off-site. Liquid by-products and process waste water contain negligible levels of radioactive material and are processed through the WWTP on-site. The WWTP produces a damp filtercake that contains near-background radionuclide concentrations and is transported daily to nearby municipal landfills for disposal. Appendix G of CSM's license renewal application granted in May 2004 provided an assessment that showed maximum expected doses of a few millirem for landfill disposal of filtercake that contained concentrations of uranium (U) and thorium (Th) such that the sum of [U pCi/g]/10 and [Th pCi/g]/3 is less than unity.

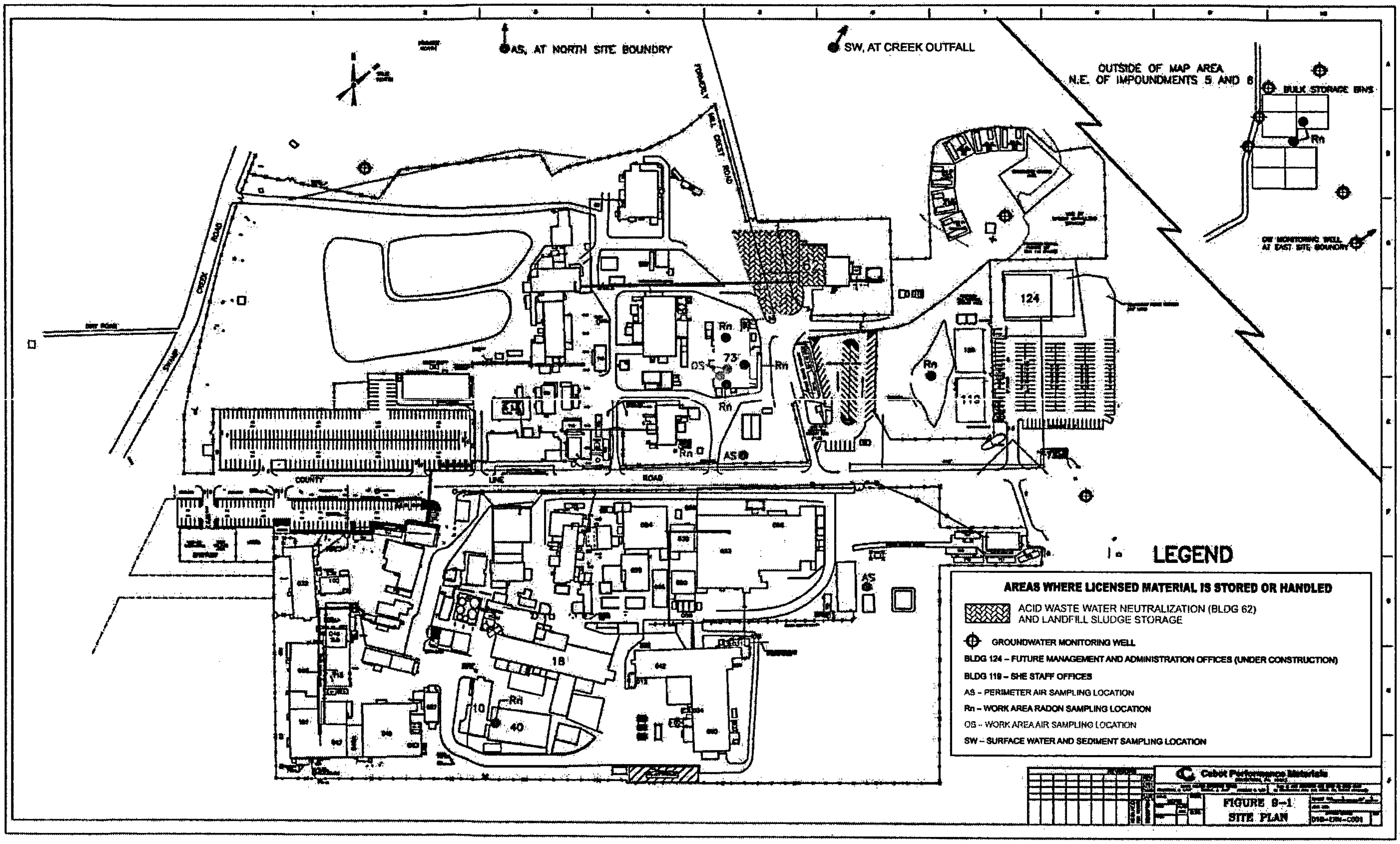

Figure 9-1. Site Plan

9.1 WWTP FACILITIES AND PROCESS DESCRIPTION

CSM operates the wastewater treatment system to treat its liquid effluent. The wastewater is treated with the addition of lime to adjust the pH then filtered and/or pressed to remove solids. The levels of radioactivity in the filtercake are marginally greater than background, and the lime that is added to treat the water contributes to that incremental radioactivity in excess of background. The filtercake, which contains about 50% moisture and has the consistency of moist clay, is released from the presses and placed onto conveyor belts that carry it outside, where it is deposited onto a concrete pad. It is then pushed by a front-end loader into one of three covered bins constructed along the end of the pad for sampling and short-term storage. Upon receipt of analytical data indicating compliance with the landfill release criteria (U less than 10 pCi/g and Th less than 3 pCi/g with the unity rule applied), the filtercake is loaded into trucks for transport to a local landfill. The trucks pass through the site's portal monitors upon exiting the site. Those monitors are designed to duplicate the monitors that are placed at the entrances to landfills that currently receive the filtercake. The sludge-like consistency of the filtercake and the short period that it remains at the site ensure that it remains wet enough to prevent the generation of airborne radioactive dust. CSM produces approximately 20,000 tons per year of filtercake that is currently shipped off-site to a landfill as a residual waste. The filtercake is composite sampled and analyzed for uranium and thorium to ensure that the total concentration remains below the approved release limit described in Section 6 of this document. Historically, the average concentrations of uranium and thorium residue released to a landfill have been 2.85 and 0.02 pCi/g, respectively. From 1999 through September 2002 the uranium and thorium content averaged 2.8 and 0.11 pCi/g, respectively , and in the period from 2002 to October 2004 they were 3.55 and 0.04, respectively. This material qualifies as unimportant quantities of source material under Title 10 Code of Federal Regulations (CFR) §40.13(a), and therefore is exempt from Part 40 regulations and is disposed of under §20.2002.

9.2 SITE ACCESS AND RESTRICTED AREAS

The perimeters of the Boyertown plant site are fenced into the two areas separated by County Line Road. The two primary access gates (pedestrian and vehicle access) are staffed with security guards to prevent inadvertent or unauthorized access. Secondary access gates are equipped with automatic identification card readers that release the magnetic locks when an authorized card is presented. These general site access procedures, signs posted in accordance with regulations, and training provided to employees, visitors, and contractors provide administrative controls to site access. However, within the primary perimeter fence the filterhouse is not a controlled work area and does not require additional control procedures.

9.3 PLANNED CHANGES TO THE WWTP

The only current project potentially affecting the WWTP is a proposed new wastewater treatment system, which is in the planning stages. Construction should begin in 2005, and the new process should be tested and brought online in 2007. This system will upgrade CSM's current treatment technology and minimize operational costs. Modifications to the system were approved by the NRC on August 27, 2002 and include the segregation of the raffinate wastewater stream from the plant's composite stream. Currently CSM combines the raffinate wastewater stream with other wastewater streams to precipitate fluoride by adding lime. CSM's wastewater treatability studies showed that this segregation and the combination of the lime and de-watered wastewater treatment sludge allows for effective treatment of both the remaining combined stream and the segregated raffinate stream. The resulting stream would contain 40 to 50% solids.

In addition, the treatability studies have shown that the resultant solids would not exhibit any hazardous waste characteristic, and the radiological constituents would be well below the filtercake release limit provided in the current license condition and justified by the dose assessment referenced in Section 11 of this document. Therefore, CSM believes that the solids generated would continue to qualify for ultimate disposal as a residual waste and as a feed material for cement kiln operations. Before construction commences, CSM will incorporate applicable review and permitting procedures as required by other federal, state and municipal authorities during the design and construction process.

CSM may change facilities and equipment as required to meet its business needs with the stipulation that any changes expected to impact the handling, control, or monitoring of licensed radioactive material will be made in accordance with the conditions of the existing license and all applicable federal, state, and local rules and regulations. The NRC will be informed in writing of any significant changes in facilities and operations.

10. RADIATION SAFETY PROGRAM

CSM has conducted operations at the Boyertown facility under License No. SMB-920 for more than 20 years, and has successfully completed renewals and amendments to that license on several occasions. The processes and facilities have not significantly changed other than to add capacity or improve the efficiency of the plant operations. In addition, license inspections have been completed at the facility on several occasions and resulted in only minor (Severity Level IV) violations. No violations have related to the WWTP process or the monitoring, handling, or disposal of the filtercake. This section of the application to amend the license summarizes the monitoring programs at the facility, including the latest improvements that have been designed to address input from the on-site inspection.

10.1 AUDIT PROGRAM

CSM is committed to establishing, implementing, and maintaining a Radiation Safety Program that meets or exceeds the regulatory requirements, including 10 CFR 20 Subpart B, and complies with accepted industry practices. The objective of the program is to ensure that exposures to employees and members of the general public from radioactive materials used by CSM are kept as low as reasonably achievable (ALARA). The Radiation Safety Program is currently maintained by CSM at the Boyertown facility in accordance with the conditions defined in License No. SMB-920.

CSM maintains an ALARA Committee to ensure that its operations are conducted in a manner that meets the ALARA commitment. The objective of the committee is to ensure that exposures to and releases of licensed radioactive materials are maintained at levels that are as low as reasonably achievable, that operations comply with license conditions, and that unexpected circumstances or changed conditions are appropriately considered and addressed. The ALARA Committee contracts an independent consultant to perform an annual review of the Radiation Safety Program and procedures.

CSM establishes and maintains written procedures to address the routine activities of its Radiation Safety Program. The current list of procedures includes the following topics that apply to the filterhouse operations that are impacted by this amendment request:

- Source material inventory
- Filtercake sampling and storage
- Filtercake sampling
- Incoming ore surveys
- Contamination surveys using wipe samples

The source material inventory and filtercake sampling procedures provide assurances that CSM knows what radionuclides to expect in its processes and in the filtercake. Incoming ore lots are assayed as part of the source material inventory and the results provide an early indication of material that may contain higher than normal concentrations of uranium or thorium. Filtercake is sampled to measure the uranium and thorium concentrations in filtercake before the material is released for disposal. That sampling is performed while the filtercake is in the bins and a monthly average concentration is determined in accordance with the requirements of condition 20 of license SMB-920. The proposed amendment will not require changes to any of these procedures, and the information that results from the implementation of these procedures will continue to ensure that CSM does not release filtercake that exceeds the release criteria. Official copies of procedures are maintained in electronic format, and the RSO keeps a current set of procedures for the Radiation Safety Program available for review during on-site inspections by the NRC.

10.2 RADIATION MONITORING INSTRUMENTS

The RSO maintains radiation-monitoring instruments to conduct surveys, collect measurements, and analyze samples. A qualified, licensed contractor calibrates the instruments on at least an annual frequency. Table 10-1 lists the types of instruments, or their functional equivalents, that are maintained at the site.

Table 10-1. List of Radiation Detection Instruments

Type	Purpose
Micro-R meter (NaI)	General area surveys
Geiger-Mueller tube	General area surveys
	Dose assessment, area monitoring
Geiger – Mueller pancake probe	Contamination surveys, fixed and removable
Dual scaler (alpha – beta)	Sample counting (air particulates, smears)
Alpha/beta surface probe	Contamination surveys (100 square centimeters.)

CSM will use instruments that meet the radiation monitoring instrument specifications in Appendix K to NUREG-1556, Vol. 12 (NRC, 2000a), and will upgrade survey instruments as necessary.

10.3 MATERIAL RECEIPT AND ACCOUNTABILITY

An inventory tracking system is currently in place using ore receipts, assay results, and calculations on spreadsheets to ensure that the license limit of 400 tons of elemental uranium is not exceeded and to determine the concentrations of uranium and thorium in ores received at the site. The uranium and thorium content of the filtercake is negligible compared with the quantities in the ores and solid wastes that are stored in the Bulk Storage Bins, and is not included in the inventory tracking calculations.

10.4 RESULTS OF DOSE ASESSMENTS USING FILTERCAKE RELEASE LIMITS

To assess the dose that results from using filtercake as cement kiln feed material, simulations were performed using RESRAD-BUILD 3.22 and RESRAD 6.22 (NRC 2000b and NRC 2002a) computer codes, parameter distributions from NUREG/CR-6697, and site-specific radionuclides and activity concentrations. The parameter distributions were used in order to run the computer codes in the probabilistic mode because this is a generic assessment that does not address a site-specific set of parameters, and because local or regional data are not available for some of the required input parameters. The following three exposure scenarios were explored for the simulations:

1. A worker in the bagging operation of the cement plant (an occupational setting that is not regulated under a license for the possession of radioactive materials), representing the average member of the occupationally exposed group

2. A resident of a building constructed using the cement from the plant, representing the member of the general public exposed to the concrete in its worst-case end-use scenario

3. A resident farmer who grazes livestock where the concrete building has been abandoned in-place, representing the member of the public exposed to the concrete in its final disposition scenario.

Details for dose assessment input parameters for each scenario and the results of the respective dose calculations are provided in the following sections.

Radionuclides of Concern

The principal radionuclides of interest are members of the uranium-238 and thorium-232 decay series. The relative concentrations of radionuclides in the filtercake are assumed based on the ratios established in the 2002 landfill sludge study conducted by CSM (See Attachment 4, "2002 Landfill Study"). Table 10-2 lists the activity concentrations in piC/g (wet weight) derived in the "Dose Assessment for Disposal of Wastewater Treatment Sludge from the Cabot Supermetals Facility in Boyertown, Pennsylvania" that was provided as Appendix G to the 2004 license renewal application. These are the input values used in the doses assessments for this amendment request. They were selected in order to maintain consistency with the current release criteria applied for landfill disposal of the filtercake.

Table 10-2. Activity Concentrations of CSM Filtercake Used in Dose Assessment

Radionuclide	Wet weight activity concentration (pCi/g) equivalent to landfill release limits	Wet weight activity concentration used in dose assessment (pCi/g)
U-238	5.0	0.05
U-234	5.0	0.05
Th-230	5.8	0.058
Ra-226	2.1	0.021
Pb-210	14.0	0.14
Th-232	1.0	0.01
Th-228	1.0	0.01
Ra-228	0.36	0.0036

Comparison of Activity Concentrations in CSM Filtercake, Typical U.S. Soil, and Current Feed Material

Table 10-3 lists the typical range of radionuclide concentrations in the United States soils taken from UNSCEAR (1993), and Table 10-4 lists the current activity concentrations in typical feed material based on a sample collected at the cement plant. These values are provided so that the reviewer can compare typical filtercake activity concentrations to similar values for background soils in the United States and for cement plant feed materials. It is important to note that the average concentrations of uranium and thorium in filtercake, based on monitoring results since 1999 are 3.18 and 0.08 pCi/g, respectively. The uranium values for filtercake are at the upper end of the range quoted for U.S. soils and about twice the level found in the cement plant feed material. The thorium values for filtercake are less than the lower end of the range for U.S soils and a fraction of the level found in the cement feed material.

Table 10-3. Typical Range of U and Th Concentrations in U.S. Soil*

Nuclide	Activity Concentration (pCi/g)
U-238	0.11 – 3.81
Th-230	0.11 – 3.81
Ra-226	0.11 – 3.81
Pb-210	0.11 – 3.81
Po-210	0.11 – 3.81
Th-232	0.11 – 3.54

*Taken from Table 5 in annex A, UNSCEAR (1993)

Table 10-4. U and Th Concentrations in Current Feed Material

Nuclide	Activity Concentration (pCi/g)
Uranium	1.6
Thorium	0.13

The data for the current feed material had no activity concentrations for the daughter products; therefore, equilibrium in the decay chains is assumed. Because the majority of feed material is not altered chemically from its natural state, equilibrium between parent and daughter is justified. Although the thorium content of CSM filtercake is consistently so low compared with current feed material that it could be ignored as a contributor to dose, it was not ignored in this dose assessment.

Physical / Chemical Form

CSM generates about 20,000 tons of filtercake annually. The filtercake is primarily calcium fluoride and calcium sulfate (>70%) and it will have a moisture content of 40% at the time of transfer to the cement plant. The total volume of raw feed material for a cement kiln is assumed to be 2.0 million tons per year. The filtercake will be added at a 1% (by weight) to the process, which would result in a dilution factor of 100.

Distribution of Radionuclides Throughout the Source Volumes

Filtercake is formed by filtration at the CSM wastewater treatment plant. It is further diluted with other feed materials at the cement plant. The formerly licensed material in the filtercake is expected to be uniformly mixed throughout the volume of Portland cement product.

Scenarios, Pathways and Critical Groups

The material flow through a typical cement kiln involves several steps. The cement plant receives the CSM filtercake and stores it on a covered, concrete pad. The filtercake is added to the manufacturing process by way of a front-end loader that dumps the material directly into the feed chute. Workers typically have no further interaction with the filtercake from this point until the material exits the kiln as a cement "clinker" product. The clinkers are a ping-pong ball size solid that has a low potential for the generation of airborne particulate. Portland cement product is obtained by milling the clinkers into a powder form. The product is then either sold in bulk or packaged into individual bags for distribution through retail outlets.

Based on available information, three critical groups were identified for dose assessment: a cement plant worker, a resident of a building constructed from the cement product, and a person who is exposed to demolition debris that is abandoned on pasture land.

The clinker milling and cement bagging personnel are expected to be the group of workers who will receive the most exposure. They will receive dose via ingestion, inhalation, and external exposure.

End uses of concrete include roads, commercial and residential structures as well as other items. The critical group for the end use was designated as a resident in a building having walls ceilings and floors made of concrete. In this scenario, exposure pathways include inhalation, ingestion, and external exposure.

The final scenario assumed that the structure was demolished and the debris was placed on pasture land. Gardening as an exposure pathway was excluded because soil with admixed construction debris is not practical to till. If the site were used for gardening, more than likely raised beds would be used. Therefore, the exposure pathways would be limited to consumption of milk and meat from livestock grazing on the site.

Each of these scenarios are developed in more detail in the following sections.

Concrete Worker Scenario

The first scenario is a cement plant worker evaluated using the industrial worker template in RESRAD 6.22 (NRC 2000b). After reviewing the process of cement product production, it was determined that the average member of this critical group works in the clinker crushing and bagging area of the plant and receives exposure through inhalation of airborne particulates, ingestion of particulate material, and external exposure from direct handling. The default values from the industrial worker template in the RESRAD 6.22 computer code and the input parameter distributions associated with probabilistic mode will effectively model typical cement plant conditions such as exposure duration, inhalation rate, fraction of time spent indoors, fraction of time spent outdoors and soil ingestion rate. Therefore, the only site-specific information is the radionuclides and activity concentrations (see Attachment 1 for details of input parameters). The computer code was run using the probabilistic mode, as described in NUREG/CR-6692 (NRC 2000b), in order to generate dose distribution curves with the final dose being assigned at the 90th percentile. The following assumptions and conditions were used in the model:

1. The average member of this critical group works in the bagging area of the plant and receives exposure through ingestion, inhalation including radon and external exposure.
2. Modeled using the Industrial Worker Template in RESRAD 6.21.
3. Since this is an industrial worker there is no consumption of food or water from the site. Therefore the pathways and parameters associated with the consumption of meat, milk, fish and water are not used.
4. A Certified Industrial Hygienist recommended modeling the mass loading as a uniform distribution. The upper bound was set at the American Council of Governmental Industrial Hygienists (ACGIH) Threshold Limit Value (TLV) for Portland cement. Respiratory protection

would be required if above this level. The lower bound for the distribution represented conditions that were visibly dusty per professional judgment.

5. The average building air exchange rate was set at 10 exchanges per hour from visible observation and professional judgment. The bagging area is expected to be a large high bay with large roll-up doors for access of heavy equipment during the hours of operation (24 hours per day, 7 days per week).

The RESRAD industrial worker template was used as a default scenario. Site-specific input parameters were used if available from telephone conversation on August 6, 2004 with Mr. Steve Kinback, a representative of the cement company that is cooperating with CSM. If an input parameter would significantly impact dose and no site-specific data were available the RESRAD default distribution was used. If a parameter would not significantly impact the dose and a distribution was available the mean value of the distribution was used. If the parameter would not significantly impact dose and no distribution or site-specific data were available the RESRAD industrial worker default value was assigned. Attachment 1 presents the input-parameter details in tabular form.

Sensitivity analyses indicated that the parameter with the most impact on dose was the mass loading of the breathing air. Assuming that the plant is compliant with OSHA regulations, it is conservative to use the professional judgment of the Certified Industrial Hygienist to establish a distribution. The use of this distribution is conservation and will in no way underestimate the dose to the worker.

The 90th percentile total dose over all pathways from bagging operations at the concrete factory is 0.339 millirem per year (mrem/yr).

End-User Scenario, Resident of Concrete Building

The second scenario evaluates the end use of the CSM concrete mixture using a building resident and the building occupancy data input template from RESRAD-BUILD 3.22 (NRC 2002a). The template represents a typical residential occupant outlined in NUREG/CR-5512 and this scenario models a structure with 6 sides consisting of four walls, a ceiling, and a floor made of concrete containing CSM filtercake. The assumption that all 6 sides of the structure are constructed of concrete is conservative because the ceilings or some of the walls are typically constructed of materials other than concrete in order to save material costs, and that would reduce the overall number of sources that contribute to the resident's dose. Default parameters were used with the exception of radionuclides and activity concentrations, which were specifically determined from CSM's historical data and past studies.

The following exposure pathways are available for consideration in the building occupancy template:

- External exposure to radiation emitted directly from the source
- External exposure to radiation emitted from radioactive particulates deposited on surfaces
- External exposure to radiation due to submersion in airborne radioactive particulates
- Inhalation of airborne radioactive particulates
- Inadvertent ingestion of radioactive material contained in removable material directly from the source
- Inadvertent ingestion of airborne radioactive particulates deposited on the surfaces of the building.

The RESRAD-BUILD 3.22 computer code was run using the probabilistic mode, as described in NUREG/CR-6692 (NRC 2000b) and NUREG/CR-6755 (NRC 2002a), in order to generate dose distribution curves and assign the 90th percentile dose. The following assumptions and conditions were used in the model for this scenario:

1. Modeled as a single room house using the Resident Building Occupant scenario Template from RESRAD-BUILD.
2. Six (6) sources in the room. Four walls and the floor and the ceiling are constructed of concrete.
3. Receptor is located at the center of the room.
4. Only exposure pathway considered is external exposure.
5. Doses from particulate inhalation or material ingestion are excluded because the radionuclides are bound in the solid concrete matrix, and covered with either paint, carpet or some type of floor covering. Radon inhalation is excluded because the standards for radiation protection for the general public in 10 CFR 20. ignore doses from indoor radon and its progeny.

The RESRAD-BUILD building occupancy template provided the default parameters. Site-specific input parameters were obtained from several telephone conversations with Mr. Steve Kinback, a representative from the cooperating cement plant, on August 6, 2004. If an input parameter significantly impacts dose and no site-specific data were available, the RESRAD default distribution was used. If a parameter would not significantly impact the dose and a distribution was available, the mean value of the distribution was used. If a parameter would not significantly impact dose and no distribution or site-specific data were available the RESRAD-BUILD building occupancy default value was assigned. Attachment 2 presents the input-parameter details in tabular form.

The result of the probabilistic dose analysis indicated that the dominant pathway was external exposure. The sensitive parameter is the amount of time the resident spends inside the building commonly referred to as the indoor fraction. No site-specific information is available for the indoor fraction because a hypothetical situation is being evaluated. With site-specific information unavailable, the distribution used for the residence indoor factor is derived from the EPA's Exposure Factors Handbook (EPA, 1996) and would not underestimate the dose to the resident.

The output of the building occupancy model includes individual results for each of the six sources (ceiling, floor and walls) that must be summed to provide the total dose. Table 10-5 provides those individual results and the summation value.

Table 10-5. Building Occupancy Scenario Using CSM Activity Concentration Limits For Filtercake Release To Landfills

Radionuclide	Activity Conc. (pCi/g)	All Pathways		
U-238	5	Source	Location	Dose 90%(mrem)
U-234	5	1	Floor	0.254
Th-230	5.8	2	Ceiling	0.185
Ra-226	2.1	3	Wall	0.0492
Pb-210	14	4	Wall	0.0492
Th-232	1	5	Wall	0.0492
Ra-228	0.36	6	Wall	0.0492
Th-228	1		Summation	0.6358

The 90th percentile total dose estimates for an occupant of a building constructed of concrete with CSM filtercake is 0.636 mrem/yr.

Final Disposition Scenario

The third and final scenario evaluated was described as a demolished abandoned building with the debris remaining on site. The site was released and used as open range for grazing livestock. The resident farmer template provided by RESRAD 6.22 was used along with default parameters associated with ingestion of milk from livestock raised grazing at the site and ingestion of meat from livestock raised grazing at the site. All other pathways were disabled (see Table 10-6 for disabled pathways and Attachment 3 for details of input parameters). Radionuclides and activity concentrations were input as site-specific values. The computer code was run in the probabilistic mode, as described in NUREG/CR-6692 (NRC 2000), in order to generate dose distribution curves and to assign the 90th percentile dose.

Table 10-6. Description of Model Pathways

Pathway	Description
Direct exposure from source	Minimal amount of time spent in grazing area.
Inhalation of resuspended dust	Vegetation prevents resuspension
Inhalation of radon and decay product	Outside environment
Ingestion of crops	Not possible to till area if debris is present
Ingestion of fish	Debris is limited to grazing area
Ingestion of water	Grazing livestock only
Ingestion of soil	Material bound by concrete or vegetation

The following assumptions and conditions were used in the model:

1. Modeled as a building demolished and the rubble remained on site for the entire evaluation period.
2. The site was released for unrestricted use and eventually was used as free range for grazing livestock.
3. Due to the fact that the building debris remained on site it is not suitable for growing produce or aquatic animals.
4. A residential well is feasible so groundwater consumption is enabled.
5. The exposure pathways are therefore limited to consumption of milk and meat from livestock grazing on the site.

The RESRAD Resident Farmer Template was used as a default scenario. Site-specific input parameters were used if available from telephone conversations with Mr. Steve Kinback on August 6, 2004. If the input parameter significantly impacted dose and no site-specific data were available the RESRAD default distribution was used. If the parameter would not significantly impact the dose and a distribution was available the mean value of the distribution was used. If the parameter would not significantly impact dose and no distribution or site-specific data were available the RESRAD Resident Farmer default value was assigned. Attachment 3 presents the input-parameter details in tabular form.

The parameters with the greatest impact on dose are: meat transfer factors for lead and polonium, milk transfer factors for polonium, milk consumption rate, and distribution coefficients for uranium-234 and uranium-238. The distributions provided by RESRAD were used to conservatively represent the site in the exposure scenario because it presents a hypothetical situation so no site-specific information is available to replace the distribution.

The 90th percentile total dose over all pathways from consumption of milk and meat from livestock grazing at the site is 0.289 mrem/yr.

ALARA Consideration

Appendix N of NUREG 1757 (NRC 2002b) states that an ALARA evaluation is not required if radioactivity is not distinguishable from background. After dilution of the filter cake with other feed materials the radionuclide activity concentration is within the range of soil and current feed material and an ALARA evaluation is not required.

10.5 SAFE USE OF RADIONUCLIDES AND EMERGENCY PROCEDURES

CSM maintains emergency response procedures, equipment, and plans as approved by the NRC during the recent license renewal. These procedures and plans address transportation accidents and spills and are adequate, without revision, to address any likely emergency associate with this proposed license revision.

CSM has established routine work practices and procedures designed to minimize exposures to radioactive materials for employees and members of the general public. Detailed procedures are available for review as described in Section 10.1, and a general description of methods used at the site is provided in the following subsections.

10.5.1 Administrative Controls

CSM employs administrative controls such as designating restricted access areas, requiring training courses for workers, prohibiting undesirable activities in designated work areas, and displaying signs, postings, and labeling as required. Workers are prohibited from eating, drinking, smoking, or chewing in the plant processing areas, and they are informed of these restrictions during training sessions and by signs in the work areas. Work areas are posted with signs and informational postings as required by the regulations and consistent with their conditions.

10.5.2 Engineering Controls

Liquid effluents are retained in on-site lagoons to control their release from the site. They are discharged when conditions are adequate to ensure compliance with regulatory limits. Although no additional control of the effluent is required at this time, CSM monitors the effluent to detect conditions that might indicate a need for additional control. Alternate methods of disposal in compliance with regulatory requirements may be implemented. CSM will ensure that liquid effluents are released from the site only in a manner that complies with regulatory release limits.

10.5.3 Personal Protective Equipment

Respirators are used in work areas where airborne concentrations are expected to exceed the occupational derived air concentration specified in 10 CFR Part 20, Appendix B, Table 1 for the radionuclides of concern. The Safety, Health and Environment (SH&E) Department maintains a respiratory protection program in compliance with Occupational Safety and Health Administration (OSHA) and NRC requirements. Protective clothing, such as disposable or washable coveralls, gloves, and shoe covers may also be used to minimize the potential for surface contamination of clothing and skin surfaces where transferable contamination may be present. Personal protective equipment will not be required for any of the operations covered by this proposed amendment.

10.6 SURVEYS

CSM will survey its facilities and maintain contamination levels in accordance with the survey frequencies and contamination levels in Appendix P to NUREG-1556, Vol. 12, *Consolidated Guidance about Materials Licenses: Program-Specific Guidance about Possession Licenses for Manufacturing and Distribution.*(2000a)

10.6.1 Occupational Monitoring

Occupational monitoring programs are designed in compliance with the requirements of 10 CFR 20 to measure concentrations of radioactive material and radiation levels in the work environment, and evaluate personnel dose equivalents when those concentrations or levels exceed administrative limits. The RSO is responsible for the technical oversight and implementation of the monitoring programs. He oversees activities performed by technicians, reviews the data, evaluates potential changes in the programs or procedures, determines if follow-up actions are required, and maintains files of the results.

The following subsections describe, in general, the types of measurements that are performed. Monitoring program details are provided in site-specific procedures and documents that are maintained by the RSO at the plant and have been reviewed by NRC personnel during past inspections.

10.6.1.1 Exposure to External Radiation

Personal or area dosimeters are used to track levels of radiation exposure in the work areas where ores and residues are handled. Area dosimeters are considered an acceptable alternative to personal dosimeters in some areas of the plant because of the low levels of radioactivity in the materials, the small quantities of materials that are handled, and the short periods of time that workers are close to the material. Area dosimeters are placed in locations where highest dose rates are found as determined by the RSO.

10.6.1.2 Monitoring Airborne Radionuclides

The radionuclide concentrations in the filtercake are very close to background levels, and the filtercake has such high moisture content that the potential to generate airborne radionuclides is negligible. For this reason, the existing radiation safety programs at the plant do not include air particulate monitoring at the filterhouse.

10.6.1.3 Surface Contamination Surveys

Ores and residues are not handled in a manner or in quantities that are likely to result in significant surface contamination. However, wipe samples are routinely collected each month from locations where surface contamination would most likely accumulate or would present the greatest potential for transfer to personnel. Samples are counted for alpha activity, and corrective actions are implemented to clean surfaces if levels are increasing or above administrative limits.

10.6.1.4 Miscellaneous Radiological Surveys

Additional instrument surveys are performed as directed by the RSO to check incoming ore shipments or other site conditions to ensure that radiological conditions are not significantly changed. Ore shipments typically present external dose rates of less than 2 milliroentgen (mR)/hr. Any shipment that exceeds this dose rate will be segregated in a fenced or barricaded area and labeled as appropriate. This procedure is intended to detect ores that may contain higher than usual concentrations of uranium and thorium so that

CSM can implement special procedures to segregate that material during processing and closely monitor its impacts to the resulting products and waste streams.

10.6.2 Environmental Programs

In addition to its NRC license, CSM acquires all necessary permits and licenses required by local, state, regional, and other federal agencies for its on-site activities. CSM maintains contact with those agencies and complies with the permit requirements, and with regulations that apply to the ongoing operations.

The Environmental Monitoring Program measures radiological conditions in air, water, and wastes at the Boyertown facility, along its site boundaries, or at effluent release points. Surface waters, sediments, ground water, and air samples are collected on a regular frequency not less than quarterly. Samples are analyzed for pertinent radionuclide concentrations, and the results compared with administrative and regulatory limits, as well as with past results to identify potential trends. Sampling locations have been selected to monitor background conditions near the facility and conditions along the site boundary at points of expected maximum potential releases to the environment, such as downwind, down gradient, and downstream from the plant. Other significant locations, such as the nearest occupied residence, may also be designated for sampling if there is potential impact from the site. Sampling frequency and analyses have been selected to determine if CSM is in compliance with license or permit conditions, and to identify trends that could eventually result in non-compliance if not corrected.

The individual components of the environmental monitoring program for the existing license are considered adequate to address the impacts of this license amendment. Monitoring locations are indicated on Figure 9-1, Site Plan.

10.6.3 Environmental Impacts

Environmental impacts from the CSM operations in Boyertown, PA were evaluated and addressed in the license renewal application and Environmental Assessment related to the current license issued in 2004. The proposed license amendment applies only to filtercake disposal and does not change any conditions at the CSM site in a manner that would require revision of the environmental sections of either of those documents. However, the environment around the cement kiln operations is not addressed in those documents and will therefore be evaluated here.

The principal source of emissions at the cement kiln operation is the exhaust stack from the kiln itself. Typically sulfur dioxide (SO2) and particulate emissions monitored and controlled under an air permit at the cement kiln, but radionuclides are neither measured not permitted for the kiln. The proposed mixing of filtercake into the kiln feed materials will not alter the SO2 or particulate emissions, so the site air permit will require no modifications. Although radionuclide emissions are not monitored or controlled at cement kiln operations, they must be evaluated for this license amendment.

Environmental impacts from radioactive effluents at a cement kiln can be evaluated using dispersion models and dose assessment models if significant source terms are involved. However, the radionuclide concentrations in the filtercake are too small to make either method worthwhile. As described in Section 9.2 of this document, the average concentrations of uranium and thorium in the filtercake from 1999 to 2002 were 2.85 and 0.02 pCi/g, respectively. When the filtercake is diluted at a 100:1 ratio with standard kiln feed material, those concentrations are reduced to 0.03 and 0.0002 pCi/g, respectively. Those values are lower by factors of 4 and 500, respectively, than the typical concentrations of uranium and thorium in background soils as listed in Table 10-3. That makes the diluted feed filtercake indistinguishable from background soils and makes air emission modeling unnecessary.

Another way to quantify the air emission source term impacts when filtercake is added to the feed material is to evaluate the fractional increase from the filtercake. The kiln feed material that excludes filtercake contains uranium and thorium at concentrations of 1.6 and 0.13 pCi/g, respectively, as listed in Table 10-4. The addition of filtercake at a 100:1 ratio raises the uranium concentration to 1.61 and actually lowers the thorium concentration because the filtercake contains less thorium than does the standard feed material. The increase in the uranium concentration as an input value for dispersion or dose modeling is in the range of rounding errors. Therefore, it would not make a measurable contribution to environmental impact evaluations and modeling is not required.

10.7 TRANSPORTATION

CSM has been transporting filtercake to local landfills for decades and has experienced one spill incident in that time. That spill was detected, evaluated, and cleaned up by the transporter's response team, with CSM oversight, within 30 minutes of the incident. CSM and its transporters maintain incident response procedures and resources that will be in effect for the cement kiln operation, as well.

11. WASTE MANAGEMENT

CSM manages filtercake as a wastestream at the Boyertown plant, as described in the following text.

11.1 PAST PRACTICES AND DISPOSAL HISTORY

The filtercake that is generated from the onsite treatment of acidic wastewaters has historically been released for disposal at nearby landfills as non-radioactive material. CSM produces approximately 20,000 tons of filtercake each year, which has been composite sampled at least quarterly and analyzed for uranium and thorium to ensure that the total concentration remains below the release limit stated in CSM's license condition. In addition, CSM uses ore assay data to track uranium and thorium concentrations in individual ore batches and to isolate occasional batches that may contain higher concentrations than normal. Those batches are either rejected or are isolated during processing so that the related filtercake can be monitored closely to detect materials that exceed the landfill release limits.

11.2 WASTE DISPOSAL PLANS FOR ONGOING OPERATIONS

CSM will employ disposal options that have been approved for the existing license by the NRC. If this amendment is approved, cement kiln disposal of filtercake will be added to the list of options.

12. LICENSE FEES

- Fee category: 2.a.1
- Amount assessed: Full cost, payable upon notification from the NRC.

REFERENCES

10 Code of Federal Regulations (CFR) §40.13(a) and §20.2002.

10 CFR 20 Subpart B

Environmental Protection Agency (EPA), 1996. *Exposure Factors Handbook*, Office of Research and Development, National Center for Environmental Assessment, Washington, DC 20460, Draft, August 1996.

NRC 2000a. *Consolidated Guidance about Materials Licenses: Program-Specific Guidance About Possession Licenses for Manufacturing and Distribution,* NUREG-1556, Vol. 12, Appendices K and Appendix P.

NRC 2000b. *Probabilistic Modules for the RESRAD and RESRAD-BUILD Computer Codes*, NUREG/CR-6692.

NRC 2002a. *Technical Basis for Calculating Radiation Doses for the Building Occupancy Scenario Using the Probabilistic RESRAD-BUILD 3.0 Code*, NUREG/CR-6755.

NRC 2002b. *Consolidated NMSS Decommissioning Guidance: Characterization, Survey, and Determination of Radiological Criteria*, NUREG-1757, Volume 2, Draft.

UNSCEAR (1993). *Sources and Effects of Ionizing Radiation. United Nations Scientific Committee on the Effects of Atomic Radiation, UNSCEAR Report to the General Assembly with Scientific Annexes.* United Nations, New York, 1993.

ATTACHMENT 1
INPUT PARAMETERS FOR CEMENT PLANT WORKER

RESRAD Parameter	Units	Concrete plant worker	Source of parameter
Area of contamination	m^2	100	Site-specific information from telephone conversation with Local cement company on august 6, 2004.
Thickness of contaminated zone	m	1	Site-specific information from telephone conversation with Local cement company on august 6, 2004.
Length parallel to aquifer flow	m	100	RESRAD Industrial worker template default (ANL/EAD-4)
Time since placement of material	yr	0	RESRAD Industrial worker template default (ANL/EAD-4)
Cover depth	m	0	RESRAD Industrial worker template default (ANL/EAD-4) – No cover material
Density of cover depth	g/m3	Not used	No cover material
Cover depth erosion rate	m/yr	Not used	No cover material
Density of contaminated zone	g/m3	2.54	Site-specific – density of portland cement
Contaminated zone erosion rate	m/yr	5.14E-02	Mean value from default distribution (NUREG-6697)
Contaminated zone total porosity	unitless	0.425	Mean Value from default distribution (NUREG/CR6565)
Contaminated zone field capacity	unitless	0.2	RESRAD Industrial Worker template (ANL/EAD-4)
Contaminated zone hydraulic conductivity	m/yr	2.3	Mean Value from default distribution (NUREG/CR6565)
Contaminated zone "b" parameter	unitless	1.06	Mean value from default distribution (NUREG/CR6565)
Humidity in air	g/m3	Not used in pathways evaluated	Tritium model
Average annual wind speed	m/sec	6.0	Annual average for the region
Evapotranspiration coefficient	unitless	0.625	Mean value from default distribution (NUREG 6697)
Precipitation	m/yr	1.01	Site-specific from regional average
Irrigation	m/yr	0.2	Default RESRAD Industrial Worker Template (ANL/EAD-4)
Irrigation mode	unitless	Overhead	Default RESRAD Industrial Worker Template (ANL/EAD-4)
Runoff coefficient	unitless	0.45	Mean Value from default distribution (NUREG/CR 6565)
Watershed area for nearby stream or pond	m^2	1.0E+06	Default RESRAD Industrial Worker Template (ANL/EAD-4)
Accuracy for water/soil computations	unitless	0.001	Default RESRAD Industrial Worker Template (ANL/EAD-4)
Saturated zone density	g/m3	1.52	Mean Value from default distribution (NUREG/CR 6565)
Saturated zone total porosity	unitless	0.425	Mean Value from default distribution (NUREG/CR 6565)
Saturated zone effective porosity	unitless	0.355	Mean Value from default distribution (NUREG/CR 6565)
Saturated zone field capacity	unitless	0.2	Default RESRAD Industrial Worker Template (ANL/EAD-4)
Saturated zone hydraulic conductivity	m/yr	2.3	Mean Value from default distribution (NUREG/CR 6565)

RESRAD Parameter	Units	Concrete plant worker	Source of parameter
Saturated zone hydraulic gradient	unitless	0.25	Mean value from default distribution (NUREG 6697)
Saturated zone "b" parameter	unitless	1.06	Mean Value from default distribution (NUREG/CR 6565)
Water table drop rate	m/yr	0.001	Default RESRAD Industrial Worker Template (ANL/EAD-4)
Well pump intake depth	m	10	Default RESRAD Industrial Worker Template (ANL/EAD-4)
Model	unitless	nondispersion	Default RESRAD Industrial Worker Template (ANL/EAD-4)
Well pumping rate	m3/yr	250	Default RESRAD Industrial Worker Template (ANL/EAD-4)
Number of unsaturated zone strata	unitless	1	Default RESRAD Industrial Worker Template (ANL/EAD-4)
Unsaturated zone thickness	m	2.296	Mean value from default distribution (NUREG 6697)
Unsaturated zone soil density	g/m3	1.52	Mean Value from default distribution (NUREG/CR 6565)
Unsaturated zone total porosity	unitless	0.425	Mean Value from default distribution (NUREG/CR 6565)
Unsaturated zone effective porosity	unitless	0.355	Mean Value from default distribution (NUREG/CR 6565)
Unsaturated zone field capacity	unitless	0.2	Default RESRAD Industrial Worker Template (ANL/EAD-4)
Unsaturated zone 'b'parameter	unitless	1.06	Mean Value from default distribution (NUREG/CR 6565)
Unsaturated zone hydraulic conductivity	m/yr	0.25	Mean Value from default distribution (NUREG/CR 6565)
Distribution coefficient - actinium	cm3/g	Not used	Not a radionuclide of concern
Distribution coefficient - protactinium	cm3/g	Not used	Not a radionuclide of concern
Distribution coefficient - lead	cm3/g	7.78	Mean Value from default distribution (NUREG 6697)
Distribution coefficient - polonium	cm3/g	5.20	Mean Value from default distribution (NUREG 6697)
Distribution coefficient - radium	cm3/g	8.17	Mean Value from default distribution (NUREG 6697)
Distribution coefficient - thorium	cm3/g	8.68	Mean Value from default distribution (NUREG 6697)
Distribution coefficient - uranium	cm3/g	4.84	Mean Value from default distribution (NUREG 6697)
Inhalation rate	m3/yr	Probabilistic analysis	Mean Value from default distribution (NUREG 6697)
Mass loading for inhalation	g/m3	Probabilistic analysis	Site-specific from CIH consultant
Exposure duration	yr	25	Default RESRAD Industrial Worker Template (ANL/EAD-4)
Shielding factor, inhalation	unitless	1	Site-specific no filtration present
Shielding factor external gamma	unitless	1	Site-specific no shielding material
Fraction of time spent indoors	unitless	0.6575	Mean Value from default distribution (NUREG 6697)
Fraction of time spent outdoors (on site)	unitless	0.06	Default RESRAD Industrial Worker Template (ANL/EAD-4)
Shape factor flag, external gamma	Unitless	circular	Default RESRAD Industrial Worker Template (ANL/EAD-4)
Fruits, vegetables and grain consumption	kg/yr	Pathway not evaluated	Worker does not consume produced grown on site - industrial complex.

RESRAD Parameter	Units	Concrete plant worker	Source of parameter
Leafy vegetable consumption	kg/yr	Pathway not evaluated	Worker does not consume produced grown on site - industrial complex.
Milk consumption	L/yr	Pathway not evaluated	Worker does not consume products from livestock on site - industrial complex.
Meat and poultry consumption	kg/yr	Pathway not evaluated	Worker does not consume products from livestock on site - industrial complex.
Fish consumption	kg/yr	Pathway not evaluated	Worker does not consume fish from site - industrial complex.
Other seafood consumption	kg/yr	Pathway not evaluated	Worker does not consume seafood from site – industrial complex.
Soil ingestion rate	g/yr	Probabilistic analysis	Default distribution (NUREG 6697)
Drinking water intake	L/yr	Pathway not evaluated	Worker does not consume drinking water from site – bottled water no pumping of groundwater.
Contamination fraction of drinking water	unitless	Pathway not evaluated	Not from site
Contamination fraction of household water	unitless	Pathway not evaluated	Not from site
Contamination fraction of livestock water	unitless	Pathway not evaluated	Not from site
Contamination fraction of irrigation water	unitless	Pathway not evaluated	Not from site
Contamination fraction of aquatic food	unitless	Pathway not evaluated	Not from site
Contamination fraction of plant food	unitless	Pathway not evaluated	Not from site
Contamination fraction of meat	unitless	Pathway not evaluated	Not from site
Contamination fraction of milk	unitless	Pathway not evaluated	Not from site
Livestock fodder intake for meat	kg/yr	Pathway not evaluated	Not from site
Livestock fodder intake for milk	kg/yr	Pathway not evaluated	Not from site
Livestock water intake for meat	L/day	Pathway not evaluated	Not from site

RESRAD Parameter	Units	Concrete plant worker	Source of parameter
Livestock water intake for milk	L/day	Pathway not evaluated	Not from site
Livestock soil intake	kg/day	Pathway not evaluated	Not from site
Mass loading for foliar deposition	g/m3	Pathway not evaluated	Not from site
Depth of soil mixing layer	m	0.3	Mean value from default distribution (NUREG 6697)
Depth of roots	m	Pathway not evaluated	Not from site
Drinking water fraction from ground water	unitless	Pathway not evaluated	Not from site
Household water fraction from ground water	unitless	Pathway not evaluated	Not from site
Livestock water fraction from ground water	unitless	Pathway not evaluated	Not from site
Irrigation fraction from ground water	unitless	Pathway not evaluated	Not from site
Wet weight crop yield for non-leafy	kg/m2	Pathway not evaluated	Not from site
Wet weight crop yield for leafy	kg/m2	Pathway not evaluated	Not from site
Wet weight crop yield for fodder	kg/m2	Pathway not evaluated	Not from site
Growing season for non-leafy	years	Pathway not evaluated	Not from site
Growing season for leafy	years	Pathway not evaluated	Not from site
Growing season for fodder	years	Pathway not evaluated	Not from site
Translocation factor for non-leafy	unitless	Pathway not evaluated	Not from site
Translocation factor for leafy	unitless	Pathway not evaluated	Not from site
Translocation factor for fodder	unitless	Pathway not evaluated	Not from site
Dry foliar interception fraction for non-leafy	unitless	Pathway not evaluated	Not from site

RESRAD Parameter	Units	Concrete plant worker	Source of parameter
Dry foliar interception fraction for leafy	unitless	Pathway not evaluated	Not from site
Dry foliar interception fraction for fodder	unitless	Pathway not evaluated	Not from site
Wet foliar interception fraction for non-leafy	unitless	Pathway not evaluated	Not from site
Wet foliar interception fraction for leafy	unitless	Pathway not evaluated	Not from site
Wet foliar interception fraction for fodder	unitless	Pathway not evaluated	Not from site
Weathering removal constant for vegetation	unitless	Pathway not evaluated	Not from site
Storage time: fruits, non-leafy vegetables, and grain	days	Pathway not evaluated	Not from site
Storage time: leafy vegetables	days	Pathway not evaluated	Not from site
Storage time: milk	days	Pathway not evaluated	Not from site
Storage time: meat and poultry	days	Pathway not evaluated	Not from site
Storage time: fish	days	Pathway not evaluated	Not from site
Storage time: crustacean and mollusks	days	Pathway not evaluated	Not from site
Storage time: well water	days	Pathway not evaluated	Not from site
Storage time: surface water	days	Pathway not evaluated	Not from site
Storage time: livestock fodder	days	Pathway not evaluated	Not from site
Thickness of building foundation	m	0	Site-specific - material on top of foundation
Bulk density of building foundation	g/cm3	0	Site-specific - material on top of foundation
Total porosity of the cover material	unitless	0	Site-specific – no cover material
Total porosity of building foundation	unitless	0	Site-specific - material on top of foundation
Volumetric water constant of the cover material	unitless	0	Site-specific – no cover material

RESRAD Parameter	Units	Concrete plant worker	Source of parameter
Volumetric water constant of the foundation	unitless	0	Site-specific - material on top of foundation
Diffusion coeff. For radon gas in cover material	m/sec	0	Site-specific – no cover material
Diffusion coeff. For radon gas in foundation material	m/sec	0	Site-specific - material on top of foundation
Diffusion coeff. For radon gas in contaminated zone soil	m/sec	Probabilistic Log uniform	Default distribution (NUREG 6697)
Radon vertical dimension of mixing	m	2	Default RESRAD Industrial Worker Template (ANL/EAD-4)
Average building air exchange rate	1/hour	10	Site-specific large open manufacturing area
Height of building room	m	2.5	Default RESRAD Industrial Worker Template (ANL/EAD-4)
Building interior area factor	unitless	1	Site-specific – ratio of finite to infinite source
Building depth below ground surface	m	0	Site-specific - material on top of foundation
Emanating power of Rn-222 gas	unitless	Probabilistic	Default distribution (NUREG 6697)
Emanating power of Rn-220 gas	unitless	Probabilistic	Default distribution (NUREG 6697)
Pathway – external gamma	unitless	Active	Default RESRAD Industrial Worker Template (ANL/EAD-4)
Pathway – inhalation (w/o radon)	unitless	Active	Default RESRAD Industrial Worker Template (ANL/EAD-4)
Pathway – plant ingestion	unitless	Inactive	No plants grown on site for consumption
Pathway – meat ingestion	unitless	Inactive	No livestock grazing on site
Pathway – milk ingestion	unitless	Inactive	No livestock grazing on site
Pathway – aquatic foods	unitless	Inactive	None on site for consumption
Pathway – drinking water	unitless	Inactive	Not from site
Pathway – soil ingestion	unitless	Active	Default RESRAD Industrial Worker Template (ANL/EAD-4)
Pathway – radon	unitless	Active	Radon parents present

1. Site-specific parameter obtained from phone interview with Mr. Steve Kinback on August 6, 2004.
2. If parameter significantly impacts dose and no site-specific data is available RESRAD default distribution is used.
3. If parameter does not significantly impact dose and a distribution is available the mean value of the distribution is used.
4. If parameter does not significantly impact dose and no distribution is available the RESRAD Industrial worker template is used.

ATTACHMENT 2
INPUT PARAMETERS FOR RESIDENTIAL BUILDING OCCUPANT

RESRAD Parameter	Units	Residential occupant	Source of parameter
External dose conversion factor	(mrem/yr) /(pCi/g)	Nuclide specific	Values are from FGR-12.
Inhalation dose conversion factor	mrem/pCi	Nuclide specific	Values are from FGR-11.
Ingestion dose conversion factor	mrem/pCi	Nuclide specific	Values are from FGR-11.
Air submersion dose conversion factor	(mrem/yr) /(pCi/m^3)	Nuclide specific	Values are from FGR-12.
Exposure duration	d	365.25	To match the occupancy period of 365.25 days in NUREG/CR-6565.
Indoor fraction	unitless	Probabilistic analysis	Residential Building Occupant distribution NUREG/CR 6697.
Number of evaluation times	unitless	1	RESRAD-BUILD default from building occupant template ANL/EAD-03
Number of rooms	unitless	1	RESRAD-BUILD default from building occupant template ANL/EAD-03
Deposition velocity	m/s	0	Site-specific radionuclides are contained in concrete matrix no potential to become airborne.
Resuspension	1/s	0	Site-specific radionuclides are contained in concrete matrix no potential to become airborne.
Room height	m	3	RESRAD-BUILD default from building occupant template ANL/EAD-03
Room area	m^2	64	RESRAD-BUILD default from building occupant template ANL/EAD-03
Air exchange rate for building and room	1/h	Probabilistic analysis	Default distribution NUREG/CR 6697.
Net flow.	m^3/h	Not used	One room model this parameter is not required. RESRAD-BUILD default from building occupant template ANL/EAD-03
Outdoor inflow	m^3/h	Not used	One room model this parameter is not required. RESRAD-BUILD default from building occupant template ANL/EAD-03
Number of receptors	unitless	1	RESRAD-BUILD default from building occupant template ANL/EAD-03
Receptor room	unitless	1	RESRAD-BUILD default from building occupant template ANL/EAD-03
Receptor location	M	4,4,1	RESRAD-BUILD default from building occupant template ANL/EAD-03
Receptor time fraction	unitless	1	RESRAD-BUILD default from building occupant template ANL/EAD-03
Receptor inhalation rate	m^3/d	Probabilistic analysis	RESRAD-BUILD distribution default. NUREG/CR 6697
Receptor indirect ingestion rate	m2/h	0	Site-specific radioactive material in contained within the concrete matrix no potential for ingestion from deposition
Number of sources	unitless	6	Site-specific floor, ceiling, and 4 walls of the room are volume contaminated
Source1 type	unitless	Volume	Site-specific volume sources are considered uniformly contaminated throughout

RESRAD Parameter	Units	Residential occupant	Source of parameter
Source 1 room or primary room	unitless	1	RESRAD-BUILD default from building occupant template ANL/EAD-03
Source 1 direction	unitless	z	The direction perpendicular to the exposed area (floor). RESRAD-BUILD default from building occupant template ANL/EAD-03
Source 1 location -	m	4,4,0	Source center location. RESRAD-BUILD default from building occupant template ANL/EAD-03
Source 1 length or area	m or m2	64	Floor is contaminated. RESRAD-BUILD default from building occupant template ANL/EAD-03
Source 2 type	unitless	Volume	Site-specific volume sources are considered uniformly contaminated throughout
Source 2 room or primary room.	unitless	1	Site-specific source is part of the primary room one room model.
Source 2 direction	unitless	z	The direction perpendicular to the exposed area (ceiling). RESRAD-BUILD default from building occupant template ANL/EAD-03
Source 2 location	m	4,4,3	Source center location. RESRAD-BUILD default from building occupant template ANL/EAD-03
Source 2 length or area	m or m2	64	Ceiling is contaminated. RESRAD-BUILD default from building occupant template ANL/EAD-03
Source 3 type	unitless	Volume	Site-specific volume sources are considered uniformly contaminated throughout
Source 3 room or primary room	unitless	1	Site-specific source is part of the primary room one room model.
Source 3 direction	unitless	x	The direction perpendicular to the exposed area (wall). RESRAD-BUILD default from building occupant template ANL/EAD-03
Source 3 location	m	0,4,1.5	Source center location. RESRAD-BUILD default from building occupant template ANL/EAD-03
Source 3 length or area	m or m2	24	Wall is contaminated. RESRAD-BUILD default from building occupant template ANL/EAD-03
Source 4 type	unitless	Volume	Site-specific volume sources are considered uniformly contaminated throughout
Source 4 room or primary room	unitless	1	Site-specific source is part of the primary room one room model.
Source 4 direction	unitless	x	The direction perpendicular to the exposed area (wall). RESRAD-BUILD default from building occupant template ANL/EAD-03
Source 4 location	m	8,4,1.5	Source center location. RESRAD-BUILD default from building occupant template ANL/EAD-03
Source 4 length or area	m or m2	24	Wall is contaminated. RESRAD-BUILD default from building occupant template ANL/EAD-03
Source 5 type	unitless	Volume	Site-specific volume sources are considered uniformly contaminated throughout
Source 5 room or primary room	unitless	1	Site-specific source is part of the primary room one room model.
Source 5 direction	unitless	y	The direction perpendicular to the exposed area (wall). RESRAD-BUILD default from building occupant template ANL/EAD-03
Source 5 location	m	4,01.5	Source center location. RESRAD-BUILD default from building occupant template ANL/EAD-03

RESRAD Parameter	Units	Residential occupant	Source of parameter
Source 5 length or area	m or m2	24	Wall is contaminated. RESRAD-BUILD default from building occupant template ANL/EAD-03
Source 6 type	unitless	Volume	Site-specific volume sources are considered uniformly contaminated throughout
Source 6 room or primary room	unitless	1	Site-specific source is part of the primary room one room model.
Source 6 direction	unitless	y	The direction perpendicular to the exposed area (wall). RESRAD-BUILD default from building occupant template ANL/EAD-03
Source 6location	m	4,8,1.5	Source center location. RESRAD-BUILD default from building occupant template ANL/EAD-03
Source 6 length or area	m or m2	24	Wall is contaminated. RESRAD-BUILD default from building occupant template ANL/EAD-03
Air release fraction for all sources	unitless	0	Site-specific contamination is contained within the concrete matrix no potential for release
Direct ingestion rate for all sources	g/h (volume)	0	Site-specific contamination is contained within the concrete matrix no potential for release
Radon release fraction	unitless	0	Radon inhalation pathway is not required to be evaluated in a residential scenario.
Radionuclide concentration	pCi/g	Site-specific	For all six sources activity concentration is the same
Number of regions in volume Source	unitless	1	Site-specific volume source uniformly contaminated
Contaminated region-volume source	unitless	1	Site-specific volume source uniformly contaminated
Source thickness, volume source	cm	16.25	Mean Value of RESRAD-BUILD default distribution NUREG/CR 6697.
Source density, volume source	g/cm3	2.4	Mean value of RESRAD-BUILD default distribution. NUREG/CR 6697
Source erosion rate, volume source	cm/d	0	Site-specific contamination is contained within the concrete matrix
Source porosity	unitless	0	Site-specific contamination is contained within the concrete matrix
Radon effective diffusion coefficient	m2/s	0	Radon inhalation pathway is not required to be evaluated in a residential scenario.
Radon emanation coefficient	unitless	0	Radon inhalation pathway is not required to be evaluated in a residential scenario.
Shielding thickness.	cm	0	Site-specific no shielding in place only air between the source and the receptor.
Shielding density	g/cm3	Not used	Site-specific no shielding in place only air between the source and the receptor.
Shielding material	unitless	Not used	Site-specific no shielding in place only air between the source and the receptor.

ATTACHMENT 3
INPUT PARAMETERS FOR ABANDONED BUILDING RESIDENT FARMER

RESRAD Parameter	Units	Abandoned debris on site	Source of parameter
Area of contamination	m^2	10,000	No distribution therefore - RESRAD Resident Farmer Template. (ANL/EAD-04).
Thickness of contaminated zone	m	2	No distribution therefore - RESRAD Resident Farmer Template. (ANL/EAD-04).
Length parallel to aquifer flow	m	100	No distribution therefore - RESRAD Resident Farmer Template. (ANL/EAD-04).
Time since placement of material	yr	0	No distribution therefore - RESRAD Resident Farmer Template. (ANL/EAD-04).
Cover depth	m	0	No distribution therefore - RESRAD Resident Farmer Template. (ANL/EAD-04).
Density of cover depth	g/m3	Not used	No cover material
Cover depth erosion rate	m/yr	Not used	No cover material
Density of contaminated zone	g/m3	2.4	Density of concrete from RESRAD-BUILD. (ANL/EAD-03)
Contaminated zone erosion rate	m/yr	6.0E-05	Attachment C of NUREG 6697
Contaminated zone total porosity	unitless	0.425	Mean value from default distribution (NUREG/CR 6565).
Contaminated zone field capacity	unitless	0.2	No distribution therefore - RESRAD Resident Farmer Template. (ANL/EAD-04).
Contaminated zone hydraulic conductivity	m/yr	2.3	Mean value from default distribution (NUREG/CR 6565).
Contaminated zone "b" parameter	unitless	1.06	Mean value from default distribution (NUREG/CR 6565).
Humidity in air	g/m3	Not used	This parameter is only used when Tritium (H-3) is a principal radionuclide.
Average annual wind speed	m/sec	6 m/sec	Site-specific – determined from regional weather information.
Evapotranspiration coefficient	unitless	0.625	Mean value from default distribution (NUREG 6697).
Precipitation	m/yr	1.01	Site-specific – Determined from regional weather information.
Irrigation	m/yr	0	Site-specific – free range grazing of livestock no irrigation.
Irrigation mode	unitless	Overhead	Site-specific – free range grazing of livestock no irrigation.
Runoff coefficient	unitless	0.45	Mean value from default distribution (NUREG/CR 6565).
Watershed area for nearby stream or pond	m^2	1.0E+06	No distribution therefore - RESRAD Resident Farmer Template. (ANL/EAD-04)
Accuracy for water/soil computations	unitless	0.001	No distribution therefore - RESRAD Resident Farmer Template. (ANL/EAD-04)
Saturated zone density	g/m3	1.52	Mean value of default distribution. (NUREG/CR 6565)
Saturated zone total porosity	unitless	0.425	Mean value of default distribution. (NUREG/CR 6565)
Saturated zone effective porosity	unitless	0.355	Mean value of default distribution. (NUREG/CR 6565)
Saturated zone field capacity	unitless	0.2	No distribution therefore – RESRAD Resident Farmer Template. (ANL/EAD-04).
Saturated zone hydraulic conductivity	m/yr	2.3	Mean value of default distribution. (NUREG/CR 6565)
Saturated zone hydraulic gradient	unitless	0.25	Mean value of default distribution. (NUREG 6697)
Saturated zone "b" parameter	unitless	1.06	Mean value of default distribution. (NUREG/CR 6565)

RESRAD Parameter	Units	Abandoned debris on site	Source of parameter
Water table drop rate	m/yr	0.001	No distribution therefore – RESRAD Resident Farmer Template. (ANL/EAD-04).
Well pump intake depth	m	10	No distribution therefore – RESRAD Resident Farmer Template. (ANL/EAD-04).
Model	unitless	nondispersion	No distribution therefore – RESRAD Resident Farmer Template. (ANL/EAD-04).
Well pumping rate	m3/yr	250	No distribution therefore – RESRAD Resident Farmer Template. (ANL/EAD-04).
Number of unsaturated zone strata	unitless	1	No distribution therefore – RESRAD Resident Farmer Template. (ANL/EAD-04).
Unsaturated zone thickness	m	2.296	Mean value of default distribution. (NUREG 6697)
Unsaturated zone soil density	g/m3	1.52	Mean value of default distribution. (NUREG/CR 6565)
Unsaturated zone total porosity	unitless	0.425	Mean value of default distribution. (NUREG/CR 6565)
Unsaturated zone effective porosity	unitless	0.355	Mean value of default distribution. (NUREG/CR 6565)
Unsaturated zone field capacity	unitless	0.2	No distribution therefore – RESRAD Resident Farmer Template. (ANL/EAD-04).
Unsaturated zone 'b'parameter	unitless	1.06	Mean value of default distribution. (NUREG/CR 6565)
Unsaturated zone hydraulic conductivity	m/yr	2.3	Mean value of default distribution. (NUREG/CR 6565)
Distribution coefficient – actinium	cm3/g	Not used	Not a radionuclide of concern
Distribution coefficient – protactinium	cm3/g	Not used	Not a radionuclide of concern
Distribution coefficient – lead	cm3/g	Probabilistic analysis	Default distribution. (NUREG 6697)
Distribution coefficient - radium	cm3/g	Probabilistic analysis	Default distribution. (NUREG 6697)
Distribution coefficient - thorium	cm^3/g	Probabilistic analysis	Default distribution. (NUREG 6697)
Distribution coefficient - uranium	cm^3/g	Probabilistic analysis	Default distribution. (NUREG 6697)
Inhalation rate	m^3/yr	Not used	Not a potential pathway of exposure. Site is used as a free range for grazing livestock.
Mass loading for inhalation	g/m^3	Not used	Not a potential pathway of exposure. Site is used as a free range for grazing livestock.
Exposure duration	yr	30	USEPA standard default exposure factor.
Shielding factor, inhalation	unitless	Not used	Does not contribute to pathways of concern.
Shielding factor external gamma	unitless	Not used	Does not contribute to pathways of concern.
Fraction of time spent indoors	unitless	Not used	Does not contribute to pathways of concern.
Fraction of time spent outdoors (on site)	unitless	Not used	Does not contribute to pathways of concern.
Shape factor flag, external gamma	Unitless	Not used	Does not contribute to pathways of concern.
Fruits, vegetables and grain consumption	kg/yr	Not used	Does not contribute to pathways of concern. Site is used only as free range grazing for livestock.

RESRAD Parameter	Units	Abandoned debris on site	Source of parameter
Leafy vegetable consumption	kg/yr	Not used	Does not contribute to pathways of concern. Site is used only as free range grazing for livestock.
Milk consumption	L/yr	Probabilistic analysis	Default distribution. (USEPA 1997)
Meat and poultry consumption	kg/yr	63	No distribution therefore – RESRAD Resident Farmer Template. (ANL/EAD-04).
Fish consumption	kg/yr	Not used	Does not contribute to pathways of concern. Site is used only as free range grazing for livestock.
Other seafood consumption	kg/yr	Not used	Does not contribute to pathways of concern. Site is used only as free range grazing for livestock.
Soil ingestion rate	g/yr	Not used	Does not contribute to pathways of concern. Site is used only as free range grazing for livestock.
Drinking water intake	L/yr	Probabilistic analysis	Default distribution. (NUREG 6697)
Contamination fraction of drinking water	unitless	1	No distribution therefore – RESRAD Resident Farmer Template. (ANL/EAD-04).
Contamination fraction of household water	unitless	Not used	Does not contribute to pathways of concern. Site is used only as free range grazing for livestock.
Contamination fraction of livestock water	unitless	1	No distribution therefore – RESRAD Resident Farmer Template. (ANL/EAD-04).
Contamination fraction of irrigation water	unitless	0	Does not contribute to pathways of concern. Site is used only as free range grazing for livestock.
Contamination fraction of aquatic food	unitless	Not used	Does not contribute to pathways of concern. Site is used only as free range grazing for livestock.
Contamination fraction of plant food	unitless	Not used	Does not contribute to pathways of concern. Site is used only as free range grazing for livestock.
Contamination fraction of meat	unitless	1	No distribution therefore – RESRAD Resident Farmer Template. (ANL/EAD-04).
Contamination fraction of milk	unitless	1	No distribution therefore – RESRAD Resident Farmer Template. (ANL/EAD-04).
Livestock fodder intake for meat	kg/yr	68	No distribution therefore – RESRAD Resident Farmer Template. (ANL/EAD-04).
Livestock fodder intake for milk	kg/yr	55	No distribution therefore – RESRAD Resident Farmer Template. (ANL/EAD-04).
Livestock water intake for meat	L/day	50	No distribution therefore – RESRAD Resident Farmer Template. (ANL/EAD-04).
Livestock water intake for milk	L/day	160	No distribution therefore – RESRAD Resident Farmer Template. (ANL/EAD-04).
Livestock soil intake	kg/day	0.5	No distribution therefore – RESRAD Resident Farmer Template. (ANL/EAD-04).
Mass loading for foliar deposition	g/m3	0.0001	No distribution therefore – RESRAD Resident Farmer Template. (ANL/EAD-04).
Depth of soil mixing layer	m	Probabilistic analysis	Default distribution. (NUREG 6697)
Depth of roots	m	Probabilistic analysis	Default distribution. (NUREG 6697))

RESRAD Parameter	Units	Abandoned debris on site	Source of parameter
Drinking water fraction from ground water	unitless	1	No distribution therefore – RESRAD Resident Farmer Template. (ANL/EAD-04).
Household water fraction from ground water	unitless	Not used	Does not contribute to pathways of concern. Site is used only as free range grazing for livestock.
Livestock water fraction from ground water	unitless	1	No distribution therefore – RESRAD Resident Farmer Template. (ANL/EAD-04).
Irrigation fraction from ground water	unitless	0	Does not contribute to pathways of concern. Site is used only as free range grazing for livestock.
Wet weight crop yield for non-leafy	kg/m2	Not used	Does not contribute to pathways of concern. Site is used only as free range grazing for livestock.
Wet weight crop yield for leafy	kg/m2	Not used	Does not contribute to pathways of concern. Site is used only as free range grazing for livestock.
Wet weight crop yield for fodder	kg/m2	1.1	No distribution therefore – RESRAD Resident Farmer Template. (ANL/EAD-04).
Growing season for non-leafy	years	Not used	Does not contribute to pathways of concern. Site is used only as free range grazing for livestock.
Growing season for leafy	years	Not used	Does not contribute to pathways of concern. Site is used only as free range grazing for livestock.
Growing season for fodder	years	0.08	No distribution therefore – RESRAD Resident Farmer Template. (ANL/EAD-04).
Translocation factor for non-leafy	unitless	Not used	Does not contribute to pathways of concern. Site is used only as free range grazing for livestock.
Translocation factor for leafy	unitless	Not used	Does not contribute to pathways of concern. Site is used only as free range grazing for livestock.
Translocation factor for fodder	unitless	1	No distribution therefore – RESRAD Resident Farmer Template. (ANL/EAD-04).
Dry foliar interception fraction for non-leafy	unitless	Not used	Does not contribute to pathways of concern. Site is used only as free range grazing for livestock.
Dry foliar interception fraction for leafy	unitless	Not used	Does not contribute to pathways of concern. Site is used only as free range grazing for livestock.
Dry foliar interception fraction for fodder	unitless	0.25	No distribution therefore – RESRAD Resident Farmer Template. (ANL/EAD-04).
Wet foliar interception fraction for non-leafy	unitless	Not used	Does not contribute to pathways of concern. Site is used only as free range grazing for livestock.
Wet foliar interception fraction for leafy	unitless	Not used	Does not contribute to pathways of concern. Site is used only as free range grazing for livestock.
Wet foliar interception fraction for fodder	unitless	0.25	No distribution therefore – RESRAD Resident Farmer Template. (ANL/EAD-04).
Weathering removal constant for vegetation	unitless	20	No distribution therefore – RESRAD Resident Farmer Template. (ANL/EAD-04).

RESRAD Parameter	Units	Abandoned debris on site	Source of parameter
Storage time: fruits, non-leafy vegetables, and grain	days	Not used	Does not contribute to pathways of concern. Site is used only as free range grazing for livestock.
Storage time: leafy vegetables	days	Not used	Does not contribute to pathways of concern. Site is used only as free range grazing for livestock.
Storage time: milk	days	1	No distribution therefore – RESRAD Resident Farmer Template. (ANL/EAD-04).
Storage time: meat and poultry	days	20	No distribution therefore – RESRAD Resident Farmer Template. (ANL/EAD-04).
Storage time: fish	days	Not used	Does not contribute to pathways of concern. Site is used only as free range grazing for livestock.
Storage time: crustacean and mollusks	days	Not used	Does not contribute to pathways of concern. Site is used only as free range grazing for livestock.
Storage time: well water	days	1	No distribution therefore – RESRAD Resident Farmer Template. (ANL/EAD-04).
Storage time: surface water	days	1	No distribution therefore – RESRAD Resident Farmer Template. (ANL/EAD-04).
Storage time: livestock fodder	days	45	No distribution therefore – RESRAD Resident Farmer Template. (ANL/EAD-04).
Meat Transfer Factor for Pb	Unitless	Probabilistic analysis	Default distribution. (NUREG 6697))
Milk Transfer Factor for Pb	Unitless	Probabilistic analysis	Default distribution. (NUREG 6697))
Meat Transfer Factor for Po	Unitless	Probabilistic analysis	Default distribution. (NUREG 6697))
Milk Transfer Factor for Po	Unitless	Probabilistic analysis	Default distribution. (NUREG 6697))
Meat Transfer Factor for Ra	Unitless	Probabilistic analysis	Default distribution. (NUREG 6697))
Milk Transfer Factor for Ra	Unitless	Probabilistic analysis	Default distribution. (NUREG 6697))
Meat Transfer Factor for Th	Unitless	Probabilistic analysis	Default distribution. (NUREG 6697))
Milk Transfer Factor for Th	Unitless	Probabilistic analysis	Default distribution. (NUREG 6697))
Meat Transfer Factor for U	Unitless	Probabilistic analysis	Default distribution. (NUREG 6697))
Milk Transfer Factor for U	Unitless	Probabilistic analysis	Default distribution. (NUREG 6697))
Thickness of building foundation	m	Not used	Does not contribute to pathways of concern. Site is used only as free range grazing for livestock.
Bulk density of building foundation	g/cm3	Not used	Does not contribute to pathways of concern. Site is used only as free range grazing for livestock.

RESRAD Parameter	Units	Abandoned debris on site	Source of parameter
Total porosity of the cover material	unitless	Not used	Does not contribute to pathways of concern. Site is used only as free range grazing for livestock.
Total porosity of building foundation	unitless	Not used	Does not contribute to pathways of concern. Site is used only as free range grazing for livestock.
Volumetric water constant of the cover material	unitless	Not used	Does not contribute to pathways of concern. Site is used only as free range grazing for livestock.
Volumetric water constant of the foundation	unitless	Not used	Does not contribute to pathways of concern. Site is used only as free range grazing for livestock.
Diffusion coeff. For radon gas in cover material	m/sec	Not used	Does not contribute to pathways of concern. Site is used only as free range grazing for livestock.
Diffusion coeff. For radon gas in foundation material	m/sec	Not used	Does not contribute to pathways of concern. Site is used only as free range grazing for livestock.
Diffusion coef. For radon gas in contaminated zone soil	m/sec	Not used	Does not contribute to pathways of concern. Site is used only as free range grazing for livestock.
Radon vertical dimension of mixing	m	Not used	Does not contribute to pathways of concern. Site is used only as free range grazing for livestock.
Average building air exchange rate	1/hour	Not used	Does not contribute to pathways of concern. Site is used only as free range grazing for livestock.
Height of building room	m	Not used	Does not contribute to pathways of concern. Site is used only as free range grazing for livestock.
Building interior area factor	unitless	Not used	Does not contribute to pathways of concern. Site is used only as free range grazing for livestock.
Building depth below ground surface	m	Not used	Does not contribute to pathways of concern. Site is used only as free range grazing for livestock.
Emanating power of Rn-222 gas	unitless	Not used	Does not contribute to pathways of concern. Site is used only as free range grazing for livestock.
Emanating power of Rn-220 gas	unitless	Not used	Does not contribute to pathways of concern. Site is used only as free range grazing for livestock.
Pathway – external gamma	unitless	Inactive	Site is used for free range grazing of livestock. Therefore, Insufficient occupancy time
Pathway – inhalation (w/o radon)	unitless	Inactive	Site is used for free range grazing of livestock. Therefore, Insufficient occupancy time
Pathway – plant ingestion	unitless	Inactive	Site is used for free range grazing of livestock. Therefore, not appropriate for tilling and gardening.
Pathway – meat ingestion	unitless	Active	Pathway for potential exposure. Therefore, pathway is active.
Pathway – milk ingestion	unitless	Active	Pathway for potential exposure. Therefore, pathway is active.

RESRAD Parameter	Units	Abandoned debris on site	Source of parameter
Pathway – aquatic foods	unitless	Inactive	Site is used for free range grazing of livestock. Therefore, no aquatic foods collected for consumption.
Pathway – drinking water	unitless	Active	Pathway for potential exposure. Therefore, pathway is active.
Pathway – soil ingestion	unitless	Inactive	Site is used for free range grazing of livestock. Therefore, Insufficient occupancy time
Pathway – radon	unitless	Inactive	Site is used for free range grazing of livestock. Therefore, Insufficient occupancy time

1. Site-specific parameter obtained from phone interview with Mr. Steve Kinback on August 6, 2004.
2. If parameter significantly impacts dose and no site-specific data is available RESRAD default distribution is used.
3. If parameter does not significantly impact dose and a distribution is available the mean value of the distribution is used.
4. If parameter does not significantly impact dose and no distribution is available the RESRAD Resident Farmer default is used.

ATTACHMENT 4
2002 LANDFILL SLUDGE STUDY

Table 1 provides analytical data from the 2002 landfill sludge study. Only values that were above analytical detection limits are included in Table 1.

Table 1. Detected Radionuclide Concentrations in pCi/g on a dry weight basis.

Sample ID	Po-210	Th-228	Th-230	Th-232	U-234	U-238	Ac-228	Pb-214	Pb-210
71235049	5.81		1.71		0.705	0.623		0.183	8.06
71235050	8.21		1.1		0.807	1.41		0.353	19.4
71235051	8.79		1.14		0.908	0.657		0.339	17.8
71235052	8.87		0.699		0.841	0.768		0.33	21.2
71235053	5.16		3.7	0.624	1.53	1.26		0.692	8.88
71235054	4.99		1.84		0.927	1.36		0.621	11.4
71235055	11.8		1.42	0.478	1.32	1.94		0.496	22.2
71235056	3.37		0.833		1.22	0.705		0.317	19.3
71235057	5.17		1.03		0.903	0.688		0.308	18.6
71235058	4.62		1.19		0.984	1.27		0.516	6.86
71235059	1.69		1.5	0.679	0.922	0.554	0.709	0.721	3.32
71235060	5.4		3.23		1.96	1.82		1.05	8.7
71235061	5.72		1.81		0.678	1.22		0.367	22.7
71235062	4.37		2.32		1.5	1.08		0.121	10
71235063	5.93		2.46		1.88	1.26		0.846	11.2
71235064	12.3				2.07	2.32		0.483	23.5
71235065	8.51		0.883		2.32	2.26		0.584	24.1
71235066	8.7				2.14	2.05		0.65	26.4
71235067	4.97		0.934	0.181	1.42	1.25		0.389	21.1
71235068	4.67	0.294	1.16		0.726	1.37		0.348	20.8
71235069	4.03		0.91	0.167	0.881	0.863		0.39	20.9
71235070	4.68		1.75		2.42	1.97		0.295	28
71235071	8		0.535		0.983	1.45		0.323	15

Sample ID	Po-210	Th-228	Th-230	Th-232	U-234	U-238	Ac-228	Pb-214	Pb-210
71235072	4.39		2.19	0.253	0.991	1.4		0.765	7.29
71235074	4.45		1.92		2.09	1.74		0.757	7.91
71235075	4.54		1.25		1.52	1.72		0.569	9.73
71235076	4.53		2.12	0.225	1.6	1.46	0.195	0.755	8.6
71235078	3.89		0.938	0.157	1.29	0.897		0.303	18.5
71235079	4.62		0.921		1.79	1.04			20.3
71235080	6.1		1.12		1.24	1.11		0.21	33.8
71235081	5.36		0.836	0.181	3.24	2.5		0.376	27
71235082	6.27		1.02		2.99	1.75		0.169	22.3
71235083	2.31		1.16		1.09	0.579		0.203	8.11
71235084	6.09		0.625		0.982	1.55		0.285	30.4
71235085	25.3		3.89	0.328	9.68	9.61		0.369	10.7
71235086	13.9		1.12	0.13	1.41	1.16		2.87	34
71235087	20		18.4		8.89	8.58	0.741	7.22	16.5
71235088	9.03		2.15		3.09	3.24		0.76	14
71235089	19.7		4.51		5.1	5.36		1.88	31.5
71235090	19.6		6.74		5.33	6.11	0.794	6.51	20.3
71235091	17.2		13.8		7.64	9.97		6.54	19.8
71235092	14.7		15.9		7.07	8.03	0.57	6.13	16.5

Figure 1 illustrates that there is no appreciable correlation between the concentrations of uranium-238 and thorium-232. In a similar fashion, Figure 2 demonstrates that there is no appreciable correlation between lead-210 and uranium-238 activity.

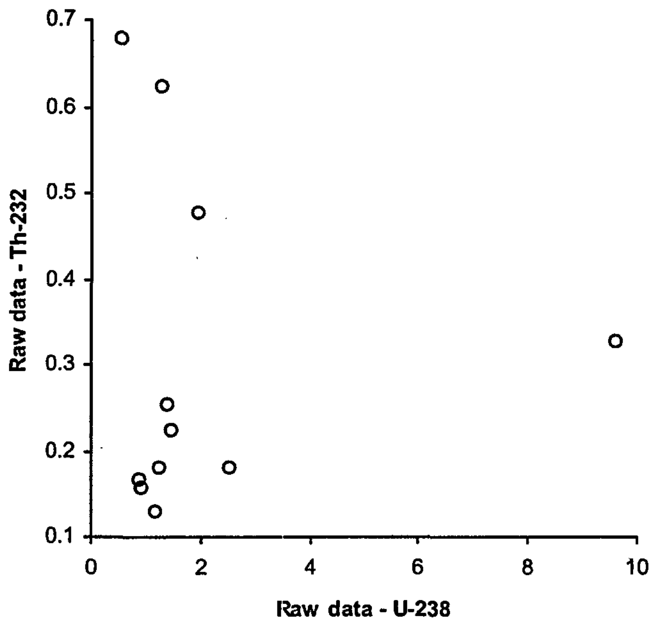

Figure 1. Plot of thorium-232 and uranium-238 activity for landfill sludge samples.

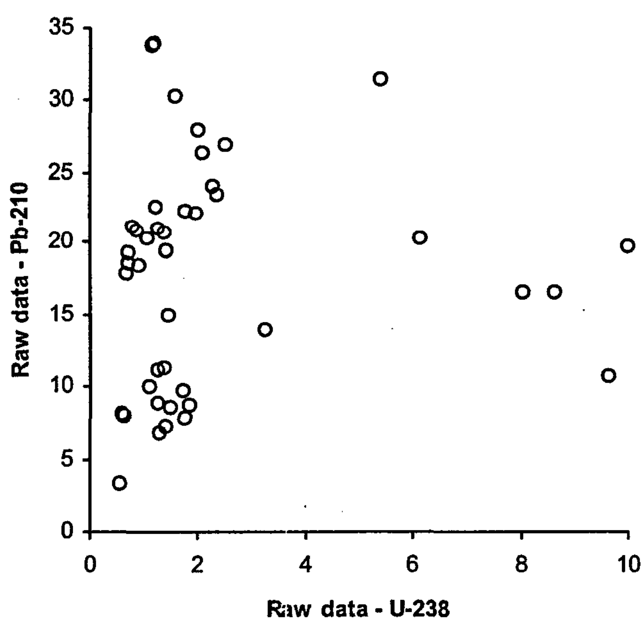

Figure 2. Plot of lead-210 and uranium-238 activity for landfill sludge samples.

Figures 3, 4, 5, and 6 indicate that the concentrations of pollonium-210, lead-214 (and hence radium-226), thorium-230 and uranium-234 are positively correlated with uranium-238 concentrations in landfill sludge.

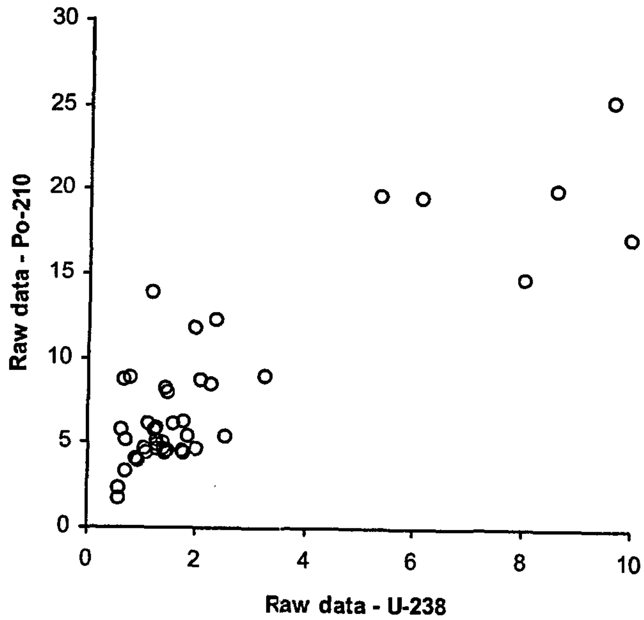

Figure 3. Plot of polonium-210 and uranium-238 activity for landfill sludge samples.

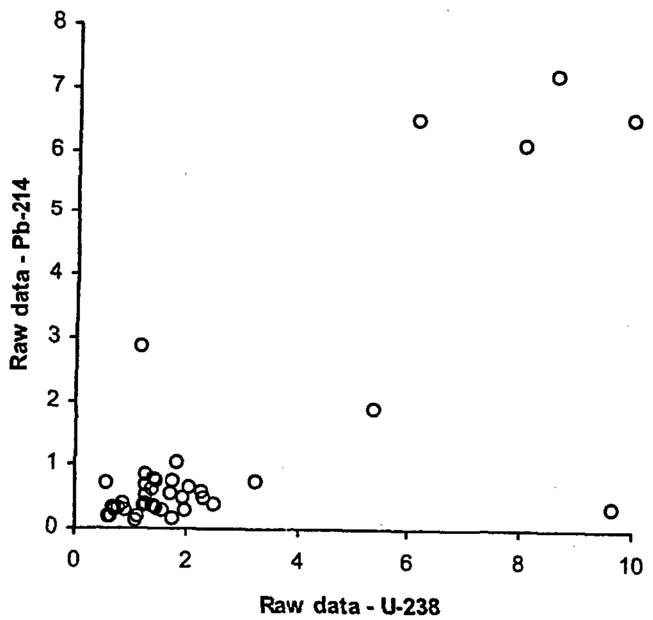

Figure 4. Plot of lead-214 and uranium-238 activity for landfill sludge samples.

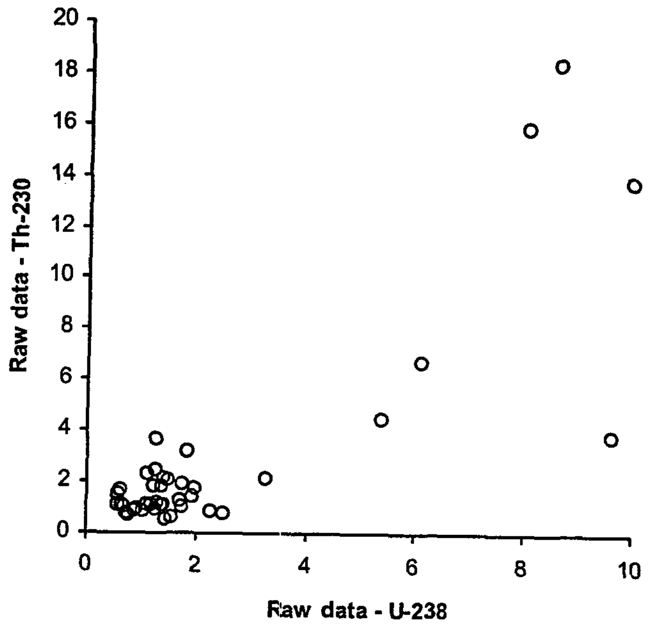

Figure 5. Plot of thorium-230 and uranium-238 activity for landfill sludge samples.

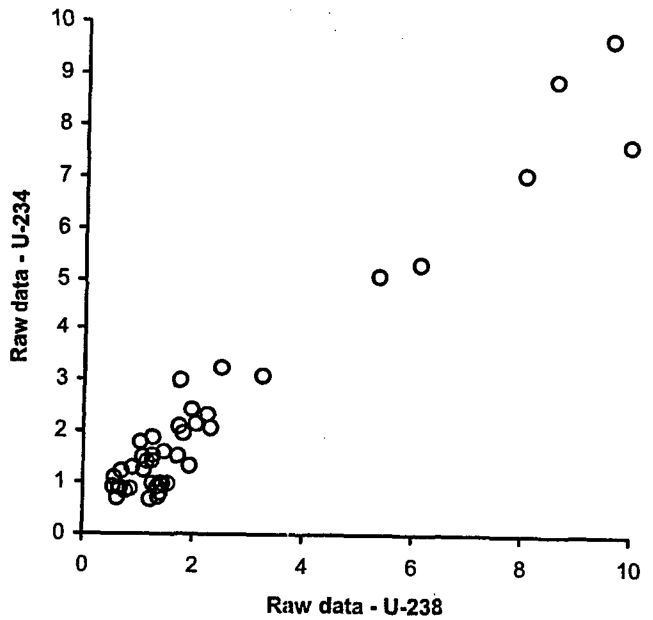

Figure 6. Plot of uranium-234 and uranium-238 activity for landfill sludge samples.

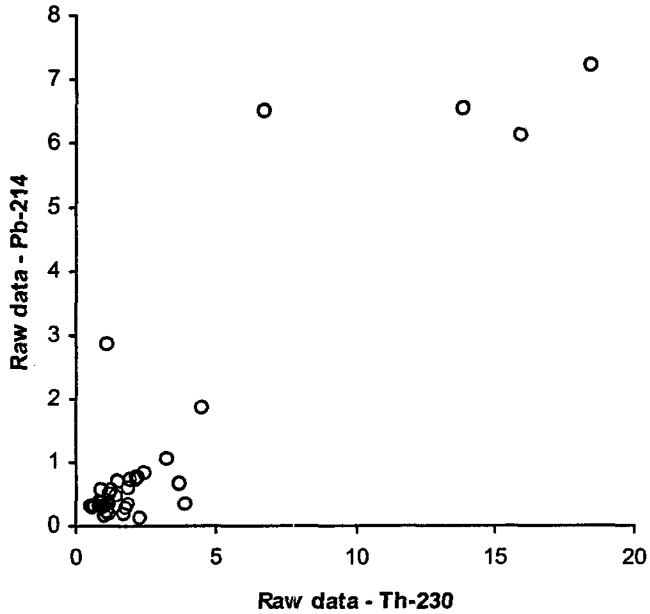

Figure 7. Plot of lead-214 and thorium-230 activity for landfill sludge samples.

Because the processing of ores at the CSM Boyertown plant is not expected to result in significant fractionation of uranium isotopes, the uranium-234/uranium-238 activity ratio was taken to be one. This assumption is consistent with the data presented in Figure 6.

Based on Figure 2, the concentration of lead-210 was modeled as independent of uranium-238.

Figures 3 through 5 show that the concentrations of polonium-210, lead-214, and thorium-230 were correlated with uranium-238. Therefore, the dose contributions of these radionuclides were included with the uranium-238 dose estimates.

It is notable that thorium-228, thorium-232, or actinium-228 were detected in only a small number of samples, and always at low concentrations. The ratio of radium-228 to thorium-232 is apt to be the same as the ratio of lead-214 to thorium-230. This is reasonable since (1) lead-214 would be in equilibrium with radium-226 in the samples, and (2) there is no reason to expect the isotopic ratio of radium-228 to thorium-232 to be different than the ratio of radium-226 to thorium-230, because any chemical separation that selectively reduced either the radium or the thorium would impact all the isotopes of that element in the same sample.