Conf-950216--91

FEMP-2359
ABSTRACT / PAPER

STRATEGY UTILIZED FOR ASSESSING BASELINE RISKS TO HUMAN HEALTH FROM K-65 AND METAL OXIDE RESIDUES STORED AT THE FERNALD SITE

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FOR PRESENTATION AT THE
WASTE MANAGEMENT '95
TUCSON, ARIZONA

February 26, 1995 to March 2, 1995

*Fernald Environmental Restoration Management Corporation with the U.S. Department of Energy under Contract No. DE-AC-05-92OR21972

**U.S. Department of Energy - Fernald Field Office

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ABSTRACT

The U.S. Department of Energy (DOE) is responsible for cleanup activities at the Fernald Environmental Management Project (FEMP) site in southwestern Ohio. The 425-hectare (1050-acre) site consists of a former 55-hectare (136-acre) Production Area, an adjacent Waste Storage Area and various support facilities. From 1952 until 1989, the FEMP processed uranium into metallic "feed" materials for other DOE facilities in the nation's defense program. In accordance with the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), the FEMP site is currently listed on the National Priorities List (NPL). To facilitate an expeditious cleanup effort, environmental issues associated with site cleanup are being managed under five operable units.

This paper summarizes the risk assessment strategy employed to determine baseline human health risks associated with K-65 and metal oxide residues currently stored in Operable Unit 4. The K-65 and metal oxide residues were generated during the 1950s as a result of the extraction of uranium from uranium-bearing ores and concentrates. These residues are currently stored within Operable Unit 4 in concrete silos. Silos 1 and 2 contain approximately 6,120 cubic meters [m^3] (8,005 cubic yards [yd^3]) of K-65 residues, while silos 3 contains approximately 3890 m^3 (5,080 yd^3) of cold metal oxides. These concrete silos are beyond their design life and require remedial action. The risk assessment conducted for Operable Unit 4 constitutes the first detailed human health risk assessment to be approved by the Environmental Protection Agency (EPA) for the CERCLA clean-up effort at the FEMP Site. This paper discusses the FEMP's use of a Risk Information Quality Objective process in concert with the traditional risk assessment approach to determine baseline risk to human health and the environment posed by Operable Unit 4. A summary of the baseline risks to human health is also presented.

DESCRIPTION OF PROBLEM

As part of the process of developing remedial action objectives for Operable Unit 4, an assessment of the baseline risks posed to human health and the environment, by the contents of the silos and the contamination in the surrounding soil, was conducted. Given the concern about the stability of the silos, and the fact that Silos 1 and 2 contain radium-bearing residues (also referred to as K-65 residues), and Silo 3 contains thorium oxides, the evaluation of the potential risk, to human health and the environment associated with these materials was necessary. Extensive sampling conducted during the remedial investigation (RI) revealed that the major radionuclides in the K-65 residues in Silos 1 and 2 include in excess of 3,700 Curies (Ci) of Radium (Ra)-226, 600 Ci of Thorium (Th)-230, 1,800 Ci of Lead (Pb)-210, and more than 28 metric tons of uranium.[1] The K-65 residues also contain significant amounts of barium, lead, arsenic, and polychlorinated biphenyls (PCBs). The K-65 residues also generate several million picocuries per liter (pCi/l) of radon (Rn)-222. Silo 3 metal oxides contain significant concentrations of radionuclides from the uranium decay series with the predominant radionuclide being Th-230 in excess of 450 Ci. The metal oxides also contain several metals including arsenic, cadmium, chromium, and selenium. Radionuclide contamination, consistent with the contents of the silos, was also detected in the Operable Unit 4 surface soil, subsurface soil, and perched water.

BASELINE RISK ASSESSMENT APPROACH

The baseline risk assessment evaluates the risks to human health and the environment in the absence of remedial action. The Risk Assessment Work Plan Addendum established the Operable Unit 4 and the site-wide baseline risk assessment approach for establishing constituents of concern (COCs), developing exposure scenarios, and conducting toxicity assessments.[2] In order to define the level of quality for the required risk information and also to ensure that the risk information developed was sufficient to effectively evaluate a wide range of remedial alternatives, a Risk Information Quality Objective (RIQO) strategy was formulated by the Operable Unit 4 risk assessment project team. The RIQO process is a very structured approach similar to the data quality objective (DQO) process traditionally used for establishing data collection quality objectives for field sampling programs.[3] The RIQO approach enables the establishment of clear objectives, decisions, impacts, and uncertainties for the overall remedial investigation and baseline risk assessment. This process also helped to establish the bases for discussion and negotiation of key issues with the EPA. As a result,mutual agreement on the risk assessment approach was reach between the site and the EPA. This enabled Operable Unit 4 to effectively determine: 1) whether action is necessary (baseline risk assessment), 2) what action is necessary to reduce risks (feasibility study risk assessment), and 3) the contribution of the residual risk to the entire site (comprehensive response action risk evaluation [CRARE])[4].

DEVELOPMENT OF RISK INFORMATION QUALITY OBJECTIVES (RIQOs)

Based on the established end use for the risk information, the RIQOs helped to define the level of quality required through the following process:

Step 1.
Problem statement — A clear statement of the area of concern (e.g., human health risk, compliance with Applicable Relevant and Appropriate Requirements [ARARs], nature and extent of contamination, contaminant fate and transport, etc.) and an evaluation of the practical limitations imposed by the data collection process was first established.

Step 2.
Identification of a decision that addressed the problem — Once the stated concern was established, a decision/question was formulated which enabled the development of a list of alternative actions that addressed the problem. Examples of the types of decision/questions formulated include:

- What contaminants are present both in the silos and within the environmental media and at what concentrations?
- Where are the contaminants located within the soils surrounding the silos?
- What is the migration potential of the various contaminants?
- What are the pathways of exposure to people and the environment from these contaminants?

Step 3.
Identification of inputs that affect the decision — The next step involved the identification of the specific variables or characteristics to be measured or investigated.in addition to any other information needed to make the decision (e.g. aquifer flow characteristics, or wind speed frequency and direction).

Step 4.
Specification of the domain of the decision — This part of the process required a detailed description of the boundaries of the decision including spatial and temporal considerations and in particular those critical to ascertaining the impact of contaminant fate and transport on future land use scenarios.

Step 5.
Development of logic statement — The logic statement discussed how the risk information was to be used in the decision process. For the Operable Unit 4 the end use of the risk estimates

were used to determine the magnitude of the risk to sensitive receptors and also as a basis for evaluating the optimum approach to risk reduction. The logic statements included those used to screen COCs and to evaluate the upper end of the risk estimates for determining when action is needed and within what media.

Step 6.
Establishment of constraints on uncertainty — This step involved placing constraints on uncertainty. Objectives for controlling decision errors were stated as limits on the acceptable probability of making an incorrect decision on the basis of the study findings. The limits on uncertainty were based on careful consideration of the consequences of incorrect conclusions.

Step 7.
Optimize design for obtaining risk information — This step addressed mechanisms for optimizing the evaluation, collection, and presentation of the risk information by identifying the most efficient way one can be expected to achieve the desired results given the constraints on uncertainty.

RESULTS OF ASSESSMENT OF OPERABLE UNIT 4 BASELINE RISKS TO HUMAN HEALTH

Determination of Constituents of Concern

The primary source terms for Operable Unit 4 were the contents of Silos 1, 2 and 3, and the contamination in the surrounding surface soil, subsurface soil, and the earthen berms surrounding Silos 1 and 2. The RIQO process was used to first identify constituents of interest. Two statistical tests were then used in sequence to identify COCs: a "location" test (student's t-test to compare the mean of site-related data with the mean of the background data, or a Wilcoxon Rank Sum [WRS] test or Mann-Whitney U-test, a direct corollary to the WRS, to compare the two distributions of rank ordered data), followed by a "95th Percentile Test." The 95th Percentile Test was used to determine if any sample measurement (not the mean, upper confidence limit [UCL], or any other statistical parameters) for a given constituent exceeded the upper 95th percentile for the background concentrations. If so, the test indicated that the site has at least one relatively high concentration and that the constituent should be considered a COC. If either test rejected the null hypothesis, i.e., the distribution of measurements at the site appears to be shifted to the right (to higher measurements) of background, the constituent was considered to be a COC. The constituent was not included as a COC only if both tests indicated that there was not a "significant difference" between the two distributions. Constituents were omitted from the list of COCs if they were: 1) common laboratory contaminants found in concentrations less than 10 times the blank concentrations; 2) essential elements (eg. sodium, magnesium, iron etc.) and known to be non-toxic; 3) chemicals that are ubiquitous in nature (eg. silicon, chloride, etc.) and were inappropriate for hazard analysis; 4) chemicals found at very low concentrations (< 1 part per million [ppm]) and known to be non-toxic; 5) chemicals that are identified only as a chemical group (eg. total organic carbon, chlorinated hydrocarbons, etc.) and cannot be properly addressed in a risk assessment; or 6) chemicals that are from off-site anthropogenic sources (autos, local factories, etc.) unless they presented a significant risk.

Exposure Assessment Scenarios

Three land-use scenarios and two source-term scenarios were developed. The land-use scenarios established (1) current land-use without access controls, (2) current land-use with access controls, and (3) future land-use without access controls. No remedial actions were assumed to have been taken, and no members of the public establish residence within the boundaries of Operable Unit 4 for the first land-use scenario. Potential receptors included an off-property resident farmer, a trespassing child, an on-property worker (groundskeeper), and an off-property user of surface water.

The second land-use scenario is similar to the first, except that, it was assumed that the site access restrictions currently provided by DOE are maintained. This scenario further assumed that DOE maintains a site-specific health and safety program to ensure that workers and visitors are properly protected. Potential receptors under this scenario included an off-property resident farmer, a trespassing child, and an off-property user of surface water.

The third land-use scenario included exposure routes that require development time, such as establishing a home and farm where members of the public were assumed to have established residence within the Operable Unit 4 boundaries. Access controls were assumed to be absent and again, no remedial actions have been taken. Hypothetical receptors under this scenario were a reasonable maximum exposure (RME) on-property resident farmer, a central tendency (CT) on-property resident farmer, an on-property resident child, an off-property resident farmer, and an off-property user of surface water.

In addition to the three land-use scenarios, two source-term scenarios were established: the current source-term scenario and the future source-term scenario. The current source-term scenario considered the silos as they exist today. The future source-term scenario assumed complete structural failure of Silo 3, resulting in the spread of its contents to Operable Unit 4 surface soil, and the collapse of the Silo 1 and 2 domes, consequently exposing their contents to the elements and increasing the leaching of their contents by precipitation.

Under the current land-use scenario without access control and under the future land-use scenario, risks were calculated using both the current source-term and the future source-term. Under the current land-use with access control scenario, the future source-term does not apply; the assumption was made that under institutional control of DOE, measures would be undertaken to maintain the current configuration of the silos and implement mitigative action in the event of silo failure. Thus, under the current land-use with access control scenario, risk was calculated only for the current source-term.

These land-use/source-term/receptor scenarios provided the framework for conducting fate and transport modeling using the exposure pathways and transport mechanisms mentioned above. Exposure point concentrations for all of the COCs were then established. These exposure point concentrations established the amount of each COC to which human receptors could potentially be exposed. Figure 1 illustrates the conceptual model developed to represent the potential exposure pathways and routes for human contact with Operable Unit 4 Silo material. A similar conceptual model was developed for soils, berms, and other environmental media.

Toxicity Assessment

Intakes calculated in the exposure assessment were used in conjunction with EPA cancer slope factors to determine the incremental lifetime cancer risk (ILCR). Table 1 provides a summary of the cancer risks for Operable Unit 4. In accordance with CERCLA guidance, risks greater than $1x10^{-4}$ to $1x10^{-6}$ were considered unacceptable. Toxicity data were taken from the Integrated Risk Information System (IRIS)[5] and the updated Health Effects Assessment Summary Table (HEAST).[6] For chemical toxicants, risk was characterized using dose thresholds or reference doses (R^fDs). These values are also developed by the EPA to indicate the potential for adverse health effects from exposure to chemicals exhibiting non-carcinogenic effects. To determine if the exposure levels of Operable Unit 4 constituents may cause adverse health effects, the estimated intake of a particular constituent (calculated from the exposure

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FIGURE I

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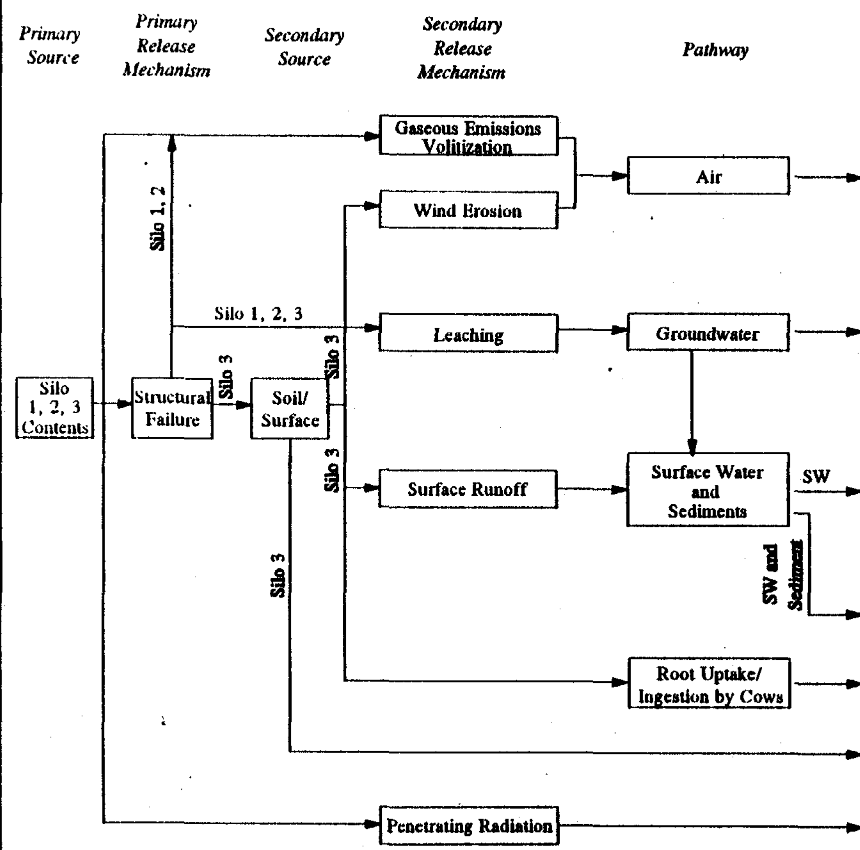
Cross-hatched boxes indicate receptor exposure routes that are included in the quantiatove risk assessment

CT – Central Tendency
RME – Reasonable Maximum Exposure



Exposure Routes	Current Land Use without Access Controls: Trespassing Child	Groundskeeper Worker	Off-Property Farmer	Off-Property User of Surface Water	Current Land Use with Access Controls: Trespassing Child	Off-Property Farmer	Off-Property User of Surface Water	Future Land Use: Typical On-Property Farmer	RME On-Property Farmer	On-Property Resident Child	Off-Property Farmer	Off-Property User of Surface Water
Inhalation	X	X	X	1	X	X	1	X	X	X	X	1
Dermal Contact	2	2	2	1	2	2	1	2	2	2	2	1
Direct Radiation	2,3	2,3	2,3	1	2,3	2,3	1	2,3	2,3	2,3	2,3	1
Food Stuffs	4	4	X	1	4	X	1	X	X	X	X	1
Ingest Drinking Water	4	4	X	1	4	X	1	X	X	X	X	1
Inhalation VOCs	4	4	X	1	4	X	1	X	X 8	X	X	1
Dermal Contact	4	4	X	1	4	X	1	X	X	X	X	1
Food Stuffs	4	4	X	1	4	X	1	X	X	X	X	1
Ingest Drinking Water	4	4	7	X	4	7	X	7	7	7	7	X
Inhalation VOCs	4	4	7	X	4	7	X	7	7	7	7	X
Dermal Contact	4	4	7	X	4	7	X	7	7	7	7	X
Food Stuffs	4	4	7	X	4	7	X	7	7	7	7	X
Incidental Ingestion	X 9	8	2	2	X 9	2	2	2	2	X 9	2	2
Dermal Contact	X 9	8	2	2	X 9	2	2	2	2	X 9	2	2
Food Stuffs	4	4	6	1	4	6	1	X	X	X	6	1
Incidental Ingestion	X	X	6	1	X	6	1	X	X	X	6	1
Dermal Contact	X	X	6	1	X	6	1	X	X	X	6	1
Direct Radiation	X	X	2	1	X	2	1	X	X	X	2	1

1) The objective of quantifying exposure routes to the off-property user of surface water is to isolate and evaluate the impact of contamination from the Great Miami River through water pathways.
2) Potential impact of exposure route is minor compared to other exposure routes .
3) EPA Risk assessment methodology for radionuclides dos not address this exposure route.
4) Exposure route is not applicable to a transient, non-resident receptor.
5) Evaluated using two different exposure point concentrations: modeled aquifer concentration and modeled sand lens concentration.
6) Off-property soils is within the scope of OU5. Impact on food stuff exposure routes from air deposition is included in the air exposure routes.
7) Receptor is assumed to obtain water for all needs from groundwater.
8) Receptor is assumed to restrict activities to work at OU4 and not contact surface water via these exposure routes.
9) Evaluated for sediment ingestion and dermal contact with sediment using modeled concentration impacted by sand lens.

FIGURE 1 OU4 CONCEPTUAL MODEL – SILO CONTENTS

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INCREMENTAL LIFETIME CANCER RISK SUMMARY ALL SOURCES/ALL PATHWAYS

Land Use/ Source Term Scenario	Type of Risk	Trespassing Child	Grounds Keeper	Off-Property Resident Farmer	Off-Property User of Surface Water	CT On-Property Resident Farmer	RME On-Property Resident Farmer[a]	On-Property Resident Child
Current Land Use without Access Control/Current Source Term Scenario	Radiological-Nuclide Specific[b]	3.0×10^{-5}	8.0×10^{-5}	1.0×10^{-5}	1.0×10^{-7}	NA[c]	NA	NA
	Radiological-External[d]	5×10^{-3}	1×10^{-4}	NA	NA	NA	NA	NA
	Chemical Risk	1.0×10^{-5}	2.0×10^{-5}	1.0×10^{-4}	1.0×10^{-7}	NA	NA	NA
	Total Risk	5.0×10^{-3}	2.0×10^{-4}	1.0×10^{-4}	2.0×10^{-7}	NA	NA	NA
Current Land Use without Access Control/Future Source Term Scenario	Radiological-Nuclide Specific	1.0×10^{-2}	3.0×10^{-2}	2.0×10^{-5}	1.0×10^{-6}	NA	NA	NA
	Chemical Risk	4.0×10^{-4}	6.0×10^{-4}	2.0×10^{-4}	7.0×10^{-7}	NA	NA	NA
	Total Risk	1.0×10^{-2}	3.0×10^{-2}	2.0×10^{-3}	2.0×10^{-6}	NA	NA	NA
Current Land Use with Access Control/Current Source Term Scenario	Radiological-Nuclide Specific	3.0×10^{-5}	NA	1.0×10^{-5}	1.0×10^{-7}	NA	NA	NA
	Radiological-External	5.0×10^{-3}	NA	NA	NA	NA	NA	NA
	Chemical Risk	1.0×10^{-5}	NA	1.0×10^{-4}	1.0×10^{-7}	NA	NA	NA
	Total Risk	5.0×10^{-3}	NA	1.0×10^{-4}	2.0×10^{-7}	NA	NA	NA
Future Land Use/Current Source Term Scenario	Radiological-Nuclide Specific	NA	NA	1.0×10^{-5}	1.0×10^{-7}	2.0×10^{-4}	3.0×10^{-3}	3.0×10^{-4}
	Radiological-External	NA	NA	NA	NA	2.0×10^{-4}	2.0×10^{-3}	9.0×10^{-3}
	Chemical Risk	NA	NA	1.0×10^{-4}	1.0×10^{-7}	5.0×10^{-3}	8.0×10^{-2}	5.0×10^{-2}
	Total Risk	NA	NA	1.0×10^{-4}	2.0×10^{-7}	5.0×10^{-3}	9.0×10^{-2}	6.0×10^{-2}
Future Land Use/ Future Source Term Scenario	Radiological-Nuclide Specific	NA	NA	2.0×10^{-3}	1.0×10^{-6}	1.0×10^{-1}	1.0×10^{0}	1.0×10^{-1}
	Chemical Risk	NA	NA	2.0×10^{-4}	7.0×10^{-7}	1.0×10^{-2}	2.0×10^{-1}	9.0×10^{-2}
	Total Risk	NA	NA	2.0×10^{-3}	2.0×10^{-6}	1.0×10^{-1}	>1.0	2.0×10^{-1}

[a]The ILCR values were identical for the future land use/future source term scenario evaluated for either the Great Miami Aquifer or for perched water.
[b]The ILCR result from exposure to radionuclides from air, water, (ground and surface), soil and sediment as detailed in Attachment II of Appendix D and summarized in tables within Section D.5.
[c]NA signifies not applicable.
[d]*This risk results from exposure to direct external radiation from large sources (Silos 1, 2, and 3) and are presented in Table D.5-2. It does not include exposure to external radiation emanating from radionuclides in surface soils. These later risk are accounted for in the nuclide-specific ILCR.*

assessment) is compared to the RfD. If the ratio of estimated intake to the acceptable intake is greater than 1, the site-related intake may cause toxic effects. This ratio is called the Hazard Quotient (HQ). When HQs for multiple COCs are summed, the resultant value is the Hazard Index (HI). Table 2 summarizes the hazard indices for Operable Unit 4.

Assessment of Uncertainty

Recognizing that uncertainty is a factor throughout the exposure and toxicity assessment process, a qualitative assessment of the uncertainty was done. The sources of uncertainty examined included the analytical data, the values of input variables for the models, the accuracy with which the models represent the actual environment or biological processes, the manner in which the exposure scenarios were developed, and the high-to-low dose and interspecies extrapolations for the dose-response relationships. Table 3 presents a summary of this qualitative uncertainty assessment and the potential impact and resultant bias imposed on the Operable Unit 4 baseline risk assessment.

CONCLUSIONS

Given the RIQO logic process and the uncertainty in the risk information developed, the results were found to be valuable in supporting the risk management decisions for Operable Unit 4. The risk information was then carried forward to support the development and evaluation of alternatives in the feasibility study. The RIQO logic process provided the basis for ensuring that the risk information carried forward was sufficient to enable site-wide risk management decisions. The methods, models, and cross-communication between operated units on risk information, set the stage for developing cleanup priorities for the site as a whole.

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TABLE II

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TABLE II

HAZARD INDEX SUMMARY ALL SOURCES/ALL PATHWAYS

Land Use/ Source Term Scenario	Type of Risk	Trespassing Child	Grounds Keeper	Off-Property Resident Farmer	Off-Property User of Surface Water	CT On-Property Resident Farmer	RME On-Property Resident Farmer[a]	On-Property Resident Child
Current Land Use without Access Control/Current Source Term Scenario	Chemical Hazard Index	0.3	0.1	0.05	0.0004	NA[b]	NA	NA
Current Land Use without Access Control/Future Source Term Scenario	Chemical Hazard Index	20	20	5	0.002	NA	NA	NA
Current Land Use with Access Control/Current Source Term Scenario	Chemical Hazard Index	0.3	NA	0.05	0.0004	NA	NA	NA
Future Land Use/Current Source Term Scenario	Chemical Hazard Index	NA	NA	0.05	0.0004	8	20	100
Future Land Use/Future Source Term Scenario	Chemical Hazard Index	NA	NA	5	0.002	300	500	2000

[a]The HI (500) was identical for the future land use/future source-term scenario.
[b]NA signifies not applicable.

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TABLE III

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TABLE III

UNCERTAINTIES ASSOCIATED WITH ESTIMATED RISKS FOR OPERABLE UNIT 4

Source of Uncertainty	Potential Impact on Estimated Risks	Direction of Bias
The applicability of the future resident farmer scenario.	High	Increases conservatism
Bias in silo waste sampling	High for radionuclides	Increases conservatism
Assumptions in geochemical and groundwater and air transport modeling	Moderate to high	Increases conservatism
Impact of sand lens beneath Operable Unit 4 on groundwater model	Moderate to high	Increases conservatism
Estimated volume of air released from silo head spaces	Moderate to high	Increases conservatism
Environmental transfer factors for contaminants	Moderate to high	Increases conservatism
Contaminant toxicity information	Moderate to high	Increases conservatism
The applicability of the trespassing child scenario under current land use	Moderate	Increases conservatism
Determination of the Operable Unit 4 RME from all media and exposure routes simultaneously	Moderate	Increases conservatism
Silo headspace radon concentration measurement data	Low	Neutral
High sample quantitation limits (SQLs) for "D"-qualified radiological analytical results in silo waste samples	Low for radionuclides	Decreases conservatism
Subsurface soils were not included as a source-term in groundwater fate and transport modeling due to their expected small contribution to risk in comparison to the potential for migration from the waste in the silos	Low	Decreases conservatism

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