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Development of a Cumulative Risk Assessment for the Idaho National Engineering Laboratory's Waste Area Group 2

INTRODUCTION

In 1989, the Idaho National Engineering Laboratory (INEL) was added to the Environmental Protection Agency's (EPA) National Priorities List of Superfund sites. A Federal Facility Agreement and Consent Order (FFA/CO) for the INEL was signed by the Department of Energy, Idaho Operations Office (DOE-ID), EPA, and the State of Idaho in December 1991. The goal of this agreement is to ensure that potential or actual INEL releases of hazardous substances to the environment are thoroughly investigated in accordance with the National Contingency Plan (NCP) and that appropriate response actions are taken as necessary to protect human health and the environment. The Test Reactor Area (TRA) is included as Waste Area Group (WAG) 2 of ten INEL WAGs identified in the FFA/CO.

WAG 2 consists of 13 operable units (OUs) which include pits, tanks, rubble piles, ponds, cooling towers, wells, french drains, perched water and spill areas. OU 2-13 is the Comprehensive Remedial Investigation/Feasibility Study (RI/FS) for WAG 2. This RI/FS will bring together the results of studies that have been previously conducted for the WAG, and will investigate the WAG's release sites that have not yet been assessed in a comprehensive manner.

The study presented here is a preliminary evaluation of the comprehensive risk for WAG-2. This investigation will be used as the basis of the WAG-2 comprehensive baseline risk assessment (BRA), and it will serve as a model for other INEL comprehensive risk assessments.

The WAG-2 preliminary risk evaluation consisted of two broad phases. These phases were (1) a site and contaminant screening that was intended to support the identification of COPCs and risk assessment data gaps, and (2) an exposure pathway analysis that evaluated the comprehensive human health risks associated with WAG-2. The primary purposes of the investigation were to screen WAG-2 release sites and contaminants, and to identify risk assessment data gaps, so the investigation will be referred to as the WAG-2 Screening and Data Gap Analysis (SDGA) for the remainder of this report.

SITE AND CONTAMINANT SCREENING

Several dozen risk assessment investigations have been performed at WAG-2 since the FFA/CO was signed. The site and contaminant screening portion of the SDGA involved collection and analysis of all these previous risk investigations, so that information about all WAG-2 release sites and COPCs could be summarized.

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During the site and contaminant screening process, a total of 57 potential release sites and almost 100 COPCs were identified. To help focus the risk assessment on the release sites and contaminants that have the greatest potential for causing adverse human health effects, the following site and contaminant screening steps were applied to the identified release sites and COPCs. Table 1 lists the release sites that passed the SDGA site screening process.

Site screening:

1. Compile information for WAG 2 sites.
2. Identify newly identified and unevaluated sites.
3. Eliminate "No Action" sites and sites for which a source does not exist.
4. Eliminate sites for which no contamination was detected or the risk was determined to be less than $1E-06$ as a result of previous INEL risk evaluation activities.
5. Retain sites containing known contamination for further evaluation against the contaminant screening criteria.

Contaminant screening:

1. Contaminants with concentrations less than or equal to background concentrations were eliminated from the risk evaluation. INEL background concentrations were taken from (Rood, 1994a).
2. All contaminants that had a detection frequency of less than 5 percent, and were not expected to have been disposed of at a given site, were removed from further evaluation.
3. VOCs that were released at the surface or in de minimus amounts were assumed to have completely volatilized after 3 years. All VOCs that were released more than three years before the date of the assessment were removed from further evaluation.

CUMULATIVE RISK ASSESSMENT METHODOLOGY

The output of the site and contaminant screening processes was a list of sites and associated COPCs to be carried through the pathway analysis and cumulative risk calculations. The following sections describe how the SDGA cumulative risk assessment was performed.

Exposure Assessment

The SDGA evaluated two exposure scenarios: a current occupational scenario and a future residential scenario. The receptor considered for the current occupational scenario was a worker at WAG-2 who will be employed at the site for the next 25 years. The receptor considered for the future residential scenario

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was a hypothetical resident who moves to the site in 30 years, and lives there for the following 30 years.

Risks for the occupational scenario were evaluated for the present day. The potentially complete human exposure routes considered for the occupational scenario were:

- Inhalation of particulates
- Soil ingestion
- External radiation exposure

Risks for the future residential scenario were evaluated at 30 years, 100 years, and 1,000 years. These times were selected for the following reasons. In accordance with INEL Track 2 guidance (DOE, 1994), there is a potential that residents could move to the site in as little as 30 years. One hundred years was selected because the WAG-2 institutional control period is currently expected to last for one century, and 1,000 years was selected because a reasonable time limit for predicting future contaminant exposure concentrations is one millennium.

The potentially complete human exposure routes for the future residential scenario were:

- Inhalation of particulates
- Ingestion of groundwater
- Soil ingestion
- External radiation exposure
- Consumption of homegrown produce

As indicated by the exposure routes described above, the transport media considered in the SDGA were air, groundwater, and soil. Table 2 presents a matrix of scenarios, pathways and exposure routes that were analyzed in the SDGA. The following paragraphs discuss specific assumptions associated with each of the SDGA exposure pathways.

Air Pathway Analysis

Sites with a contaminant source in the top 15 cm (6 in.) of soil were evaluated as part of the air pathway analysis. Health impacts were assessed cumulatively for this pathway using the following assumptions:

- Each contaminant was assumed to have the same airborne concentration at every point above the WAG.
- The concentration of each contaminant in the airborne respirable particulate matter above the WAG was assumed to equal the average concentration of the contaminant in the WAG's soil.

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- The receptor was assumed to spend the entire exposure duration (25 years at 250 days per year of exposure for current occupational workers, and 30 years at 350 days per year of exposure for future residents) within the boundaries of the WAG.
- All VOCs were assumed to have completely volatilized because all VOC releases occurred at least three years from the date of the SDGA.

Groundwater Pathway Analysis

All retained contaminants, regardless of the depth of contamination, were evaluated in the SDGA groundwater analysis. The groundwater analysis relied on the computer code GWSCREEN (Rood, 1994b) to estimate future contaminant groundwater concentrations. GWSCREEN is a screening code that uses a plug flow model (steady state, one-dimensional flow) for contaminant transport through the unsaturated zone and a semi-analytical solution to the advection dispersion equation (Codell and Duguid, 1983) in the saturated zone.

Health impacts from the ingestion of contaminated groundwater were cumulatively assessed using the following assumptions:

- Contaminant masses were assumed to be homogenized into a soil volume that was determined by connecting the outermost edges of all the retained release sites, and multiplying this area by the average depth of surficial sediments at WAG-2 (15 m).
- The receptor was assumed to draw all drinking water for the 30 year exposure duration from a well completed at the center of the downgradient edge of the area encompassing all of the retained sites.
- Advection, sorption, and radioactive decay with select ingrowth were assumed to be the predominant processes affecting transport through the unsaturated zone.
- Contaminant sorption was assumed to be a linear process controlled by a contaminant's soil to water partition coefficient.
- Only radioactive contaminants were assumed to have the potential for decay during groundwater transport. No decay was assumed for nonradionuclide contaminants.
- Transport modeling of volatile organics was not conducted. As with the air pathway, all volatile organic contaminants were assumed to have completely volatilized at the surface.
- Institutional controls were assumed to be protective enough that WAG-2 workers would not be allowed to drink contaminated groundwater.

Soil Pathway Analysis

The soil pathway and associated exposure routes were evaluated on a site-by-site basis. This pathway was not evaluated cumulatively because the probability of a receptor receiving contaminant exposures from

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more than one release site through the soil pathway was considered to be negligible.

The following routes of exposure routes, and associated assumptions, were considered in the SDGA:

- Soil Ingestion – The exposure concentrations for soil COPCs was assumed to equal the 95% upper confidence level concentrations for each contaminant.
- External Radiation Exposure – Standard EPA protocols were used to estimate intakes and risks for each of the WAG-2 sites of concern.
- Ingestion of Homegrown Produce – Ingestion of produce grown in the soil at each retained site was assessed for only the future residential scenario. Institutional controls were assumed to be protective enough that workers at WAG-2 would not be ingest contaminated produce.

Contaminant Concentration Estimates

Contaminant concentrations for each retained site were calculated for both surface and subsurface soils. The surface soil concentration estimates were derived from all sampling results within the top 15 cm (6 in.) of soil at each retained site, while the subsurface soil concentration estimates were derived from all sampling results at each retained site, regardless of sampling depth. The concentration estimates were used either directly or indirectly to calculate chemical intakes as follows:

- Surface concentration estimates were used directly for calculation of intakes for the soil ingestion, ingestion of homegrown produce, and external radiation exposure routes, and as input to the calculation of contaminant concentration for the air pathway.
- Subsurface concentration estimates were used as input to the calculation of contaminant mass for the groundwater pathway.
- The parent radionuclide COPC concentration estimates in soil were adjusted for radioactive decay. Radionuclide concentration estimates were calculated at 30, 100, and 1,000 years. Radioactive progeny were not considered in the study unless the daughter was identified as a COPC originally (i.e., in the contaminant screening process). For those daughters originally identified, the concentrations used in the risk calculation for each retained site represented the concentration of the daughter in addition to the concentration of the decayed parent.

A WAG-wide average soil concentration was calculated for each retained contaminant for use in the air pathway analysis. The equation used to calculate the WAG-wide average soil concentrations was:

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$$C_{\text{soil}} = \frac{C_1 A_1 + C_2 A_2 + C_3 A_3 + C_n A_n}{A_T} \quad (1)$$

where:

C_{soil} = WAG-wide area weighted average soil concentration (mg/kg or pCi/g)
 C_n = Contaminant soil concentration at release site n (mg/kg or pCi/g)
 A_n = Surface area of release site n (m^2)
 A_T = Total area of retained release sites (m^2).

The average soil concentration of each retained contaminant was used to derive each contaminant's average airborne concentration using the following equation:

$$C_{\text{air}} = 1\text{E-}06 R C_{\text{soil}} \quad (2)$$

where:

C_{air} = Contaminant concentration in the air (mg/m^3)
 $1\text{E-}06$ = Conversion from kg to mg
 R = WAG-2 respirable particulate matter concentration ($11 \mu\text{g}/\text{m}^3$ [Hoff 1993])
 C_{soil} = WAG-wide area weighted average soil concentration (mg/kg or pCi/g).

For the groundwater pathway analysis, the GWSCREEN source model was used to estimate the release of contaminants from the source volume. This source model required an input of the mass (or activity) of each COPC. The COPC mass at each retained site was calculated using the following equation:

$$M = A \times D \times \rho \times C \quad (3)$$

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where:

M	=	Mass (or activity) of each COPC (mg or Ci)
A	=	Surface area of the release site (m ²)
D	=	Depth of contamination at the release site (ft)
ρ	=	Bulk density of soil (1.5 g/cm ³)
C	=	Subsurface soil concentration of each COPC (mg/kg or pCi/g)

The total mass of each COPC was then calculated by summing the COPC mass from each retained site.

For the future residential scenario, contaminant concentrations in crops were assessed by estimating contaminant uptake and accumulation through crop roots. Contaminant concentrations in WAG-2 crops was estimated using the following equation:

$$C_{\text{crop}} = \text{PUF} \times C_{\text{soil}} \quad (4)$$

where:

C_{crop}	=	Contaminant concentration in crop (mg/kg or pCi/g)
PUF	=	Dry weight soil to plant transfer coefficient (unitless ratio)
C_{soil}	=	Surface soil contaminant concentration (mg/Kg or pCi/g)

Plant uptake factor values were taken from Baes and Sharp (1984).

Toxicity Assessment

Toxicity information was gathered and summarized for both carcinogenic and noncarcinogenic health effects. The toxicity constants used in the study were obtained from several sources. The primary sources of information were EPA's Integrated Risk Information System (IRIS) and EPA's Health Effects Assessment Summary Tables (HEAST).

After toxicity information was compiled, the health risks from each COPC were calculated in two parts: first to determine potential carcinogenic effects and second to determine noncarcinogenic effects. The calculated risk associated with carcinogenic effects was interpreted in terms of the target risk range (1E-04

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to 1E-06) established by the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). The calculated hazard quotient associated with noncarcinogenic health effects of each COPC was interpreted through comparison to an acceptable hazard quotient of 1.0.

Risk Characterization

To obtain an estimate of total carcinogenic risk resulting from modeled exposures to carcinogens at each retained site, cancer risks were summed across all exposure routes. Cancer risks from exposure to multiple carcinogens across multiple pathways were also assumed to be additive, based on EPA carcinogen risk assessment guidelines (EPA, 1986). For this study, cancer risk from radionuclides and chemical carcinogens were also summed.

Chemical-specific hazard quotients were summed across exposure routes to calculate a hazard index. Individual pathway hazard index values were then summed to determine a cumulative hazard index value for all exposure pathways and COPCs.

SUMMARY OF SDGA RESULTS

The SDGA site and contaminant screening analysis identified 18 release sites and approximately 50 COPCs that deserved further analysis in the WAG-2 comprehensive BRA. A total of 11 risk assessment data gaps associated with these retained sites and COPCs were also identified. Investigations that are designed to fill these data gaps are currently being planned.

The risk assessment portion of the SDGA indicated that the most influential pathway for both the occupational and residential exposure scenarios is the soil pathway. For the occupational scenario, risks greater than 1E-04 were calculated for both the ingestion of soil and external radiation exposure routes. For the residential scenario, risks greater than 1E-04 were calculated for the ingestion of soil, external radiation exposure, and ingestion of homegrown produce exposure routes. Hazard indices greater than unity were only calculated for the future residential scenario through the ingestion of homegrown produce exposure route.

Table 1. Summary of WAG 2 retained sites.

OU	Subunit	Site description	Potential data gaps?
2-04	TRA-34	North storage area	Yes
2-04	TRA-619	PCB spills	Yes
2-04	TRA-626	PCB spills	Yes
2-04	TRA-653	PCB spills	Yes
2-05	TRA-15	Soil surrounding hot waste tanks 2, 3, and 4 at TRA-713	Yes
2-05	TRA-16	Soil surrounding inactive radionuclide contaminated tank at TRA-614	No
2-05	TRA-19	Soil surrounding rad tanks 1 and 2 near TRA-630, replaced by catch tanks 1, 2, 3, and 4	Yes
2-09	TRA-08	Cold waste pond	No
2-09	TRA-13	Sewage Leach Pond	No
2-10	TRA-03B	Warm waste pond, cells 52, 57, 64	Yes
2-11	TRA-04/-05	Retention basin, cold waste sampling pit and cold waste sump pit (sediments only) (excludes disposal well)	Yes
2-12	None	Perched water system	No
2-13	TRA-06	Chemical Waste Pond	Yes
2-13	TRA-13	Sewage Leach Pond wind blown contamination	Yes
2-13	TRA-41	French drain associated with TRA-653 mechanical shop	Yes
2-13	Hot Tree	Radionuclide contaminated tree	Yes
2-13	Brass cap	Brass cap	No
2-13	TRA-42	Diesel Unloading Pit near TRA-627	Yes

Table 2. Matrix of scenarios, pathways, and exposure routes.

OU	Subunit	Current worker			Future resident				
		Air		Soil	Air	Groundwater	Soil		
		Inhalation ^a	Ingestion ^a	External radiation exposure ^b	Inhalation ^a	Ingestion ^c	Ingestion ^a of soil	External radiation exposure ^b	Ingestion ^a of homegrown produce
2-04	TRA-34	•	•	•	•	•	•	•	•
2-04	TRA-619					•			
2-04	TRA-626					•			
2-05	TRA-653	•	•		•	•	•		•
2-05	TRA-15	•	•	•	•	•	•	•	•
2-05	TRA-16					•			
2-05	TRA-19	•	•	•	•	•	•	•	•
2-09	TRA-08	•	•	•	•	•	•	•	•
2-09	TRA-13	•	•	•	•	•	•	•	•
2-10	TRA-03B					•			
2-11	TRA-04/05	•	•	•	•	•	•	•	•
2-12	Perched water					•			
2-13	TRA-06	•	•	•	•	•	•	•	•
2-13	TRA-13	•	•	•	•	•	•	•	•
2-13	TRA-41					•			
2-13	Hot Tree	•	•	•	•	•	•	•	•
2-13	Brass Cap	•	•	•	•	•	•	•	•
2-13	TRA-42	•	•	•	•	•	•	•	•
None	Unevaluated Site	•	•	•	•	•	•	•	•

a. To be considered a complete exposure route, contamination must be present in the top 15 cm (6 in).

b. To be considered a complete exposure route, surface radionuclide contamination must be present.

c. All COPCs, regardless of depth, were considered available for transport to assess the groundwater ingestion exposure route.

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