CONF-950216--139

Trade-offs Between Worker Risk and Public Risk During Remediation at DOE Sites

Presented by
Bethamy N. Beam
Oak Ridge National Laboratory*

At the
Waste Management 95 Conference
Pueblo Inn
Tucson, Arizona

February 27 through March 2, 1995

*Managed by Martin Marietta Energy Systems, Inc., under contract no. DE-AC05-84OR 21400 with the U. S. Department of Energy

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

TRADE-OFFS BETWEEN WORKER RISK AND PUBLIC RISK DURING REMEDIATION AT DOE SITES

Beth Beam (Oak Ridge National Laboratory), Jill Morris (Oak Ridge National Laboratory), Bonnie Blaylock (Oak Ridge National Laboratory), Curtis Travis (Oak Ridge National Laboratory)

ABSTRACT

Within the next 30 years, the U.S. Department of Energy (DOE) Environmental Restoration Program will be responsible for remediating thousands of waste sites across the DOE complex. A major concern during remediation will be the protection of thousands of workers engaged in the remediation. In addition to well know safety hazards associated with conventional construction operations, remedial workers at DOE will encounter radiation and chemical exposures from radioactive, hazardous, and mixed waste. Although historically represented as minimal due to a paucity of data related to worker exposures during remediation, potential worker health risk is an important factor that must be taken into account in the selection of remedial strategies, and the potential risk reduction offered by a remedial strategy must be weighed against the potential worker risk incurred during its implementation. Analysis has shown a trend that the worker risk incurred outweighs the benefits of risk reduction to the public.

INTRODUCTION

The U.S. Department of Energy (DOE) has generated and disposed of large quantities of wastes as a result of 50 years of nuclear weapons production. This waste has been disposed of in environmental locations such as burial pits, waste pits, holding ponds, and landfills. Many of these waste sites have begun to release contamination offsite and potentially pose risks to humans living or working in the vicinity of these sites. Over the next several decades, DOE's Environmental Restoration Program (ER) will be responsible for remediating the thousands of contaminated waste sites across the DOE Complex, an effort that will require more than $100 billion. A major concern during this cleanup effort will be the protection of thousands of remediation workers involved in a variety of remediation activities. In addition to the well-known safety hazards associated with conventional construction operations, remedial workers at DOE facilities will encounter chemical and radiation exposures from radioactive, hazardous and mixed wastes.

Historically, risks to workers has been represented as minimal due to a paucity of data related to worker exposures during remediation and the assumption that personal protective equipment is adequate. However, remediation workers also face safety risks associated with construction and transportation activities. These safety risks coupled with exposure risks must be well-characterized prior to the selection of remedial strategies, and occupational health and safety protection programs should be developed to mitigate such hazards. In addition, the potential risk reduction to members of the public associated with any particular remedial strategy must be weighed against the potential worker risk incurred during implementation of remedial activities.

In an effort to understand the nature and extent of remediation worker risk encountered during environmental restoration activities and the potential risk reduction to the public offered by a selected remedial strategy, we assessed the risk to remediation workers during remediation activities, the risk to a hypothetical farm family who moves on top of the site, the risk to the surrounding population, and the risk reduction to the public after remediation activities have been completed. Our analysis was conducted on a large number of DOE sites, but for the purposes of this paper, our discussion will be limited to five DOE case studies (contaminated soil site, burial ground, and three waste pits) that are representative of the trend we observed across the majority of the sites we analyzed: in general, worker risk incurred during remediation is higher than the risk reduction to the public after remediation has occurred.

RISK ASSESSMENT METHODOLOGY

The methodology for assessing risks to the public is based on the standard Environmental Protection Agency (EPA) Risk Assessment Guidance for Superfund (RAGS) methodology used for estimating baseline risks. For the baseline risk, we evaluated two receptor groups: a hypothetical onsite family of four that lives at the edge of the site and the existing offsite population surrounding the site within a 50-mile radius. The onsite family of four represents the typical conservative residential scenario that is included in all CERCLA Baseline Risk Assessments. This residential scenario, despite its hypothetical nature and unrealistic assumptions, usually drives the decision to remediate.

Using the best available data, fate and transport models were used to simulate the contaminant migration through the environment to the population receptors. Five exposure pathways were assessed for both chemicals and radionuclides: ground water, surface water, air, direct soil ingestion, and direct radiation. Table 1 illustrates the exposure routes assessed for each receptor group and pathway. For all, risks represent current risks only, assuming institutional controls at the site are removed and unlimited site access is allowed.

No standardized risk assessment methodology for estimating risks to remedial workers exists. The methodology we developed and used for this study consists of two main elements: estimating exposure risks and estimating physical safety risks. The primary steps in the worker risk methodology are as follows:

- identify remedial alternative,
- identify specific activities and worker types,
- identify number of workers and person-hours for each activity,
- estimate exposures for each activity,
- estimate risks.

Insert Table 1.

Remedial Alternative Identification

For each site, the remedial alternative selected was remediation to Appropriate and Relevant and Acceptable Requirements (ARARs). To remediate to ARARs, the site must undergo the full range of remedial action. Complete cleanup of soil, ground water, surface water, and structures must be performed to ensure that individuals using the site are not exposed to hazardous substances. It is assumed that the land is used for residential and/or agricultural purposes. For example, technologies used to remediate the waste pits include ex-situ vitrification, excavation, drum removal, solidification, and packaging. For the contaminated soil site, the remediation technology selected was in-situ vitrification. For the burial ground, the technologies selected include excavation, solid classification, solidification, and packaging.

Identification of Activities and Worker Types

The next step in evaluating worker risk is to identify specific activities and worker types for each alternative. Each technology consists of several activities, for which different types of workers are needed. For this study, worker types are consolidated into three types: heavy equipment operator, laborer, and support personnel. Worker types are used to determine inhalation rates, which will affect the worker's exposure to contaminants during remediation.

Exposure to Contaminants

Once the remedial alternative for each site has been selected and site data have been gathered, potential exposures must be estimated. For chemicals, exposures are estimated using the standard EPA RAGS methodology. For radionuclides, dose estimation data need to include: (1) worker type involved in the remediation activity, (2) radionuclides to which workers may be exposed, (3) source-to-receptor distances, (4) exposure durations, and (5) shielding configurations. Direct radiation exposure rate estimates are calculated using MicroShield (version 3.0), a microcomputer adaptation of ISOCHILD (Grove Engineering 1988). The source-to-receptor distances and shielding configurations vary among the workers and remediation alternatives.

Worker risks are calculated for workers wearing personal protective equipment (PPE), when it is considered to be appropriate. The required level of respiratory protection is determined by comparing the estimated air concentrations to which workers are exposed to the regulatory and administrative limits. If exposures are above the limits, the level of protection is increased until air concentrations are less than the administrative limit. Although there is always a possibility that PPE can be ripped or is not sealed properly, good working practices are assumed under normal conditions.

Exposure Risk Estimates

For both the public and worker populations, the risk of fatal cancer from radionuclide exposures and the risk of cancer incidences from chemical and radionuclide exposures were estimated. Radiological risk factors were derived from ICRP documents (ICRP 1988, 1990). Cancer slope factors and toxicity factors are from EPA's HEAST and IRIS. Worker risks were estimated for injuries, illnesses, and fatalities associated with physical hazards. In order to compare the trade-offs associated with worker risk incurred during remediation with public risk reduction after remediation, a single endpoint was needed. For ease of comparison, worker fatalities were compared with cancer fatalities resulting from contaminant exposures. However, because there is no acceptable method for combining cancer incidences resulting from chemical exposures with cancer fatalities resulting from radionuclide exposures, we evaluated only the contribution of risk from exposure to radionuclides. This comparison may overlook the contribution of chemical risk to the overall risk estimate, but in many cases radiological risk drives the overall risk estimate.

Physical Safety Risk Estimates

In addition to hazards from exposure to contaminants, remedial workers face safety risks from implementation of remediation activities. Two primary safety risks that workers encounter are fatalities from construction accidents and heat stress. The Department of Labor's (DOL) Bureau of Labor Statistics publishes fatality rates for major industrial classifications. Those remediation workers who are involved in demolition activities, the use of earth-moving equipment, electrical work, and building activities, can be classified as construction workers. Construction industry fatality rates can be used to estimate fatality risks for remedial workers that were classified as construction workers (NSC 1990). The 1990 fatality rate for the construction industry is ~1.65E-7 fatalities/person-hr. However, these fatality data are representative of establishments in the private sector with 11 employees or more and may not be representative of remediation workers. In this study, the fatality rate is multiplied by the total number of construction-related person-hrs to yield the risk attributed to a given construction activity.

Heat stress occurs as a result of personal protective equipment (PPE) and working conditions. The heat stress fatality rate used for this methodology is 1.6E-9 fatalities/person-hr (Ellis 1972; Roberts 1987). This assumes 2000 full-time person-hrs/yr and deaths per 100,000 workers.

0.32

Risk Reduction

To calculate the reduction in risk posed to the onsite family of four, the sites were modeled based on the new conditions of the site once remediation has occurred.

RESULTS

PUBLIC RISK RESULTS

This methodology was used to estimate public and worker risks for a large number of contaminated DOE sites and for a variety of remedial alternatives. For this paper, five of those sites were selected to illustrate trends observed in this analysis. Table 2 contains the risk estimates for the onsite family of four (risk of cancer fatality to the maximally exposed individual) and the average risk to the offsite populations (number of predicted cancer fatalities) before any remediation occurs. The risk estimate for the onsite farm family is included in this analysis because of its inclusion in typical CERCLA Baseline Risk Assessments as an indicator of risk and, thus, the driver for whether remedial action is necessary. However, this scenario is highly unrealistic since DOE expects it will be able to maintain institutional controls and thereby prohibit unauthorized access to the site.

For a more realistic scenario and one that would be comparable to a comparison with risks posed to workers involved in remediation, we also estimated the risks to the surrounding population (measured in cancer fatalities). While risk to the onsite farm family is generally considered high (above the EPA acceptable risk range), ranging from 5E-6 to one predicted cancer fatality for the maximally exposed individual (MEI), the risk to the offsite populations is low (less than one predicted cancer fatality).

Insert Table 2.

WORKER RISK RESULTS

The activities that comprise the remedial strategy (remediate to ARARs) are included in Table 3. Table 3 also presents a summary of the number of workers required during implementation of the remedial strategy and the number of worker fatalities within that population predicted as a result of radionuclide exposures as well as construction accidents and physical safety risks. We assumed that workers would wear an appropriate level of protection and that the exposure of an individual worker could not exceed the allowable DOE exposure limits. The predicted number of worker fatalities provides an indication of the cumulative risk to all workers required to implement the remedial strategy.

The number of worker fatalities ranges from one predicted fatality for three of the sites to 17 predicted fatalities for the contaminated soil site. In each case, the proportion of the predicted fatalities due to construction and physical safety risks far outweighs the proportion attributed to contaminant exposure. In each of these five sites, the excavation and packaging activities drive the risk posed to the workers because of the time required to implement these activities.

Insert Table 3.

DISCUSSION

Analysis of these results indicated the following trend: at sites where extensive removal and remediation activities will be performed, the risks to remediation workers during remediation activities far exceeds the benefit to the public once remediation has occurred. Table 4 contains the results for the five sites selected as illustrative examples of this trend.

In each of these five cases, the current risk posed to the existing offsite populations (expressed as the number of predicted fatalities) prior to any remediation is less than 1E-6. However, remediation decisions are usually based on the potential risk posed to a hypothetical farm family for a residential scenario, when in reality, the risk posed to the offsite populations is extremely low. Thus, decisions to remediate are being made in an attempt to reduce risk to a hypothetical farm family. For each of these five cases, risk reduction to a level of 1E-6 was achieved. In other cases, however, such as for ground water sites, it may not be technically feasible to achieve a 1E-6 risk level.

The issue of concern here is the risk that will be posed to remediation workers during the implementation of remediation activities. Our analysis has shown that for these five cases, and in many others included in our analysis, worker risks far exceed the risk to the offsite populations, and in many cases exceed the risk to the onsite family of four MEI.

For the burial ground, the risk of cancer fatality to the MEI of the onsite family of four before remediation is 5E-6 due to direct radiation exposure. The number of predicted fatalities predicted for the offsite populations is less than 1E-6. The risk reduction to the onsite family of four after remediation is less that 1E-6. Yet the worker risk incurred during remediation is four fatalities due to construction and/or physical hazards and one fatality due to direct radiation exposure.

For the contaminated soil site, the risk of cancer fatality to the MEI of the onsite family of four before remediation is 5E-3 due to direct radiation exposure. The number of predicted fatalities predicted for the offsite populations is less than 1E-6. The risk reduction to the onsite family of four after remediation is less that 1E-6. Yet the worker risk incurred during remediation is 17 fatalities due to construction and/or physical hazards.

For the waste pits, the risk of cancer fatality to the MEI of the onsite family of four before remediation ranges from 3E-1 to 1 due to direct radiation exposure. The number of predicted fatalities predicted for the offsite populations for all three pits is less than 1E-6. The risk reduction to the onsite family of four after remediation for all three pits is less that 1E-6. Yet the worker risk incurred during remediation ranges from two to five fatalities due to construction and/or physical hazards.

Insert Table 4.

REFERENCES

1. Ellis FP. 1972. Mortality from Heat Stress Aggravated Illness in the United States. Environmental Research. 5:1-58.

2. EPA. 1991. Risk Assessment Guidance for Superfund: Volume 1 -- Human Health Evaluation Manual, Part C, Office of Emergency and Remedial Response, Publication 9285.7-01C, Washington, D.C.

3. Grove Engineering, 1988. Microshield, Version 3, Grove Engineering, Inc., Rockville, MD.

4. ICRP (International Commission on Radiological Protection). 1988. Publication 51. Data for Use in Protection Against External Radiation, Annals of the ICRP, Pergamon Press.

5. ICRP. 1990. Publication 60. 1990 Recommendations of the International Commission on Radiological Protection, ICRP, Pergamon Press.

6. National Safety Council. (NSC). 1991. Accident Facts, 1991 Edition. Chicago, Illinois.

7. Roberts DL. 1987. "Heat Stress." Occupational Health and Safety. June.

Table 1. Exposure Routes Evaluated for Each Receptor Group.

Exposure Pathway/ Exposure Route	Onsite Family of Four	Offsite Population
Groundwater:		
Ingestion of water	●	●
Irrigation of crops	●	●
Ingestion of crops	●	●
Ingestion of crops by animals	●	●
Ingestion of water by animals	●	●
Surface water:		
Ingestion of water	●	●
Fishing/shellfishing	●	●
Recreational	●	●
Air:		
Inhalation of vapors	●	●
Inhalation of particulates	●	●
Food:		
Ingestion of contaminated crops	●	●
Ingestion of animals	●	●
Soil:		
Incidental ingestion of soil	●	--
Direct radiation	●	--

Table 2. Public Risk Before Remediation.

Site	Onsite Family of Four (MEI)	Offsite Population Risk (Number of fatalities)
Burial Ground	5E-6	<1E-6
Soil	5E-3	<1E-6
Pit 1	3E-1	<1E-6
Pit 2	1	<1E-6
Pit 3	1	<1E-6

Table 3. Worker Risk During Remediation.

Site Type	Activities	No. of Workers	Worker Fatalities
Burial Ground	Excavation Soil Classification Solidification Packaging	74	1 Direct Radiation 4 Construction
Contaminated Soil	In-situ Vitrification	230	17 Construction
Pit 1	Excavation Drum Removal Solidification Packaging	63	4 Construction
Pit 2	Excavation Drum Removal Solidification Packaging	63	5 Construction
Pit 3	Excavation Drum Removal Solidification Packaging	65	2 Construction

Table 4. Public Risk and Risk Reduction Compared With Worker Risk Incurred.

Site	Onsite Family of Four (MEI)	Offsite Public (Number of Fatalities)	Risk Reduction to Onsite Family of Four	Worker Fatalities
Burial Ground	5E-6	<1E-6	<1E-6	5
Soil	5E-3	<1E-6	<1E-6	17
Pit 1	3E-1	<1E-6	<1E-6	4
Pit 2	1	<1E-6	<1E-6	5
Pit 3	1	<1E-6	<1E-6	2