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ACCIDENT ANALYSIS FOR TRANSURANIC WASTE MANAGEMENT ALTERNATIVES IN THE U.S. DEPARTMENT OF ENERGY WASTE MANAGEMENT PROGRAM*

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ABSTRACT

Preliminary accident analyses and radiological source term evaluations have been conducted for transuranic waste (TRUW) as part of the U.S. Department of Energy (DOE) effort to manage storage, treatment, and disposal of radioactive wastes at its various sites. The approach to assessing radiological releases from facility accidents was developed in support of the Office of Environmental Management Programmatic Environmental Impact Statement (EM PEIS). The methodology developed in this work is in accordance with the latest DOE guidelines, which consider the spectrum of possible accident scenarios in the implementation of various actions evaluated in an EIS. The radiological releases from potential risk-dominant accidents in storage and treatment facilities considered in the EM PEIS TRUW alternatives are described in this paper. The results show that significant releases can be predicted for only the most severe and extremely improbable accidents sequences.

INTRODUCTION

Transuranic waste (TRUW) is waste contaminated with alpha-emitting transuranium radionuclides with half-lives greater than 20 years and concentrations greater than 100 nCi/g of waste at the time of assay (1). Packaged TRUW with surface dose rates less than 200 mrem/h is categorized as contact-handled (CH); that with surface doses greater than 200 mrem/h is categorized as remote-handled (RH). TRUW results from a variety of activities, including the processing and handling of plutonium and plutonium-contaminated materials. Principal sources are research and development, special nuclear materials recovery, weapons manufacturing, decontamination and decommissioning (D&D), and disposition of plutonium-bearing residues. Most residue is in solid form such as contaminated protective clothing, paper trash, glassware, tools, and machine parts. At the end of 1991, there were approximately 65,000 m^3 of CH TRUW and 4,300 m^3 of RH TRUW. Most TRUW is stored in 55-gal drums or standard waste boxes on asphalt pads within weather-protective structures, earthen berms, or concrete structures. Estimated inventory

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and generation rates for major storage sites, derived from data in the *Interim Mixed Waste Inventory Report* (2) and the *Integrated Data Base for 1992* (3), are provided in Hong et al. (4).

To support analyses for the U.S. Department of Energy (DOE) Office of Environmental Management Programmatic Environmental Impact Statement (EM PEIS), Argonne National Laboratory (ANL) has developed an integrated risk-based approach for evaluating the source terms from radiological releases from postulated facility accidents (5). The methodology has been developed in accordance with the latest DOE guidelines, which consider the spectrum of possible accident scenarios in the implementation of various actions evaluated in an EIS. This approach allows comparisons of facility accident impacts on EM PEIS strategies for consolidating the storage and treatment of TRUW at sites throughout the country. Accidents considered in this analysis include operational (scenarios such as handling accidents, facility fire, and facility explosion) and severe external events (such as earthquakes, tornadoes, and airplane impacts). This paper analyzes the radiological releases from potential risk-dominant accidents in storage and treatment facilities considered in the EM PEIS TRUW alternatives.

TRUW MANAGEMENT ALTERNATIVES OVERVIEW

Under DOE's current management program, retrievably stored and newly generated TRUW are to be prepared (characterized, segregated, packaged and/or certified for transport and disposal) and stored pending transport to the planned Waste Isolation Pilot Plant (WIPP) facility in New Mexico. The DOE has entered a WIPP test phase to evaluate long-term repository performance and subsequent acceptability for disposal. During this phase, limited quantities may also be located at the WIPP. Additional storage facilities may be required, depending on the timing of retrieval operations and the WIPP schedule. Other sites that generate TRUW, including that from D&D will have to store on-site, contract for commercial storage, or transport to one of the nine current storage sites. All sites are responsible for minimizing the quantities of waste generated. The current strategy is to treat TRUW to meet WIPP waste acceptance criteria (WAC) (6) and dispose of it at the WIPP under the Resource Conservation and Recovery Act (RCRA) "no migration" determination rule. However, treatment might be required, under RCRA, Title 40, Part 268 of the *Code of Federal Regulations* (CFR) (7), to remove or reduce the hazardous components to acceptable levels to meet the hazardous land disposal restriction (LDR), or to meet the radiological requirements of 40 CFR Part 191 (8), before WIPP disposal. These requirements depend on results of the test phase, a WIPP disposal performance assessment, and the establishment of U.S. Environmental Protection Agency (EPA) criteria for compliance certification.

Four alternatives are considered in the EM PEIS: no action, decentralization, regionalization, and centralization. Decentralization and regionalization each have several cases that may result in distinct inventories for treatment at each site. In addition, three treatment options are considered. In the first, TRUW is treated to meet the minimum requirement for WIPP-WAC — namely, liquid absorption, compaction, immobilization, and repackaging. The second option considers an intermediate treatment level beyond WIPP-WAC that includes shredding, grouting, and changing containers to reduce gas generation. In the third option, TRUW is treated to meet LDRs. Detailed descriptions of TRUW treatment processes are provided in Hong et al. (9).

METHODOLOGY AND MODELING CONSIDERATIONS

The volumes, physical characteristics as defined by treatability categories, and radiological composition of the sites' TRUW inventories have been compiled in the ANL WASTE_MGMT computational model (10,11). Each site's facility throughput used for determining source term information was obtained directly from the ANL computational model. The data used included unique volumetric inventories and physical, radiological, and chemical compositions for each waste treatability category at each site for each alternative. Information on accident sequences, such as initiating frequencies, damage fractions (DFs), probabilities, respirable airborne release fractions (RARFs), and leak path factors (LPFs), are also compiled in the ANL accident analysis computational model (12).

The DF is defined as the fraction of the total inventory of waste in a facility or particular operation at risk involved in the accident sequence and actually susceptible to airborne release. The LPF is the fraction of the airborne inventory that passes through the containment barriers and filters to escape to the atmosphere. The RARF is the fraction of the potentially available inventory rendered airborne and having particulates with aerodynamic equivalent diameters below 10 micrometers at the point of the accident. The values of RARFs are a function of the physical form of the material rendered airborne, which varies by the treatability category of each waste stream, and are based on the work of Mishima (13).

Preliminary consequence factors from unit-radionuclide releases at all sites were obtained from ORNL and incorporated into the accident analysis computational model to screen the accident sequences on the basis of risk, defined here as the consequence times the frequency of the accident sequence. Chemical releases for mixed TRUW were considered in the EM PEIS but are not discussed in this paper.

Storage Facility Accidents

TRUW is typically packaged in drums or canisters and stored in concrete structures, weather-protective sheds, below-grade caissons, or earthen berms. Most TRUW is stored in facilities with minimal containment. Accordingly, in this analysis, the use of a generic storage structure was assumed to represent facilities with minimal confinement or with confinement that would likely fail under severe external challenges. To ensure conservatism, no credit was taken for filtration or containment integrity in the accidents postulated for storage, although DOE sites are increasingly moving toward development of qualified TRUW storage. Because special provisions have been made for storage of RH wastes that involve much more robust containment (e.g., underground caissons), the storage accidents investigated here cover only CH wastes.

Although the inventories, physical forms, and radiological and chemical compositions of waste stored at each site were characterized for the EM PEIS and the data then used in the ANL

WASTE_MGMT model, compilation of analogous information for individual facilities on each site is beyond the scope of the EM PEIS. A unit inventory approach was used to develop source terms on the basis of waste generation and inventory data at each site. All storage facility accidents reported here assume an inventory of 2,000 m^3 (10,000 drums) with a site-dependent radiological and physical composition derived by volume-weighting the inventories of the treatability categories within each waste type at that site. Scaling of these unit source terms will be required to account for actual facilities.

The storage accidents investigated include handling accidents, operation-induced facility fires, and external-event-induced fires and explosions. Representative handling accidents involve a single drum and assume that 25% of the drum inventory is affected and subject to stresses capable of rendering the contents airborne. The representative operation-induced fire scenario assumes that 10% of the facility inventory is affected. The earthquake was selected as a limiting surrogate for other natural phenomena because of its overriding damage potential. All external-event source term parameters vary according to the particular sequence. Aircraft (small or large) impacts were analyzed at selected sites, depending on their importance to risk.

Treatment Facility Accidents

In the minimal treatment (WIPP-WAC) option, retrieval drums and packages are opened and inspected in a glovebox (CH) or hot cell (RH). Absorbers are added for any free liquids, and compaction, immobilization, and/or repackaging are performed as required. The intermediate treatment option involves essentially the same operations except that all waste is treated and repackaged. The LDR treatment option includes incineration, evaporation, and various RCRA contaminant treatments.

Although several treatment operations may present potential exposure hazards, incineration was assessed to be the treatment technology most likely to dominate risk to facility and site staff and the surrounding general population. This is because incineration has key process characteristics affecting the potential for airborne release, including high temperature; the presence of fuel and fuel feed lines; the presence of combustible input feed waste (combustible solid waste, organic liquid waste, and organic sludge); the potential for overpressurization or explosion; and the high dispersibility of the ash by-product, which has radionuclide concentrations two orders of magnitude higher than the input feed waste. The focus here is on radiological accidents with sequences involving fires and explosions capable of producing large airborne releases of the ash present in storage or filtration systems.

A generic treatment facility was defined for all options for assessing a range of radiological releases from treatment process accidents. Each generic facility consists of a series of linked process modules that provide a specific treatment process. A DOE Hazards Category of 2 and concomitant performance requirements were assumed for the generic facilities. Double high-efficiency particulate air (HEPA) filtration systems are assumed to be in place.

Treatment facility accidents analyzed include (1) a fire in the baghouse area of the incineration facility, failing the filtration systems completely (LPF = 1.0) and affecting 3% of the total amount of ash existing in the facility (DF = 0.03); (2) an incinerator ash explosion caused by combustible gas buildup that affects the existing ash in the rotary kiln (12% of the total in the facility [i.e., DF = 0.12]) and partially degrades the filtration system of the facility (LPF = 0.001); and (3) external events leading to a fire. Aircraft (small or large) impacts were analyzed at selected sites, depending on their importance to risk. The earthquake was selected as a limiting surrogate for other natural phenomena because of its overriding damage potential. All external-event source term parameters vary according to the particular sequence.

RESULTS AND CONCLUSIONS

Preliminary results of the accident sequences for various site consolidation cases for each EM PEIS alternative were reviewed for risk importance in terms of the frequency-weighted dose (risk) to the maximally exposed individual. These sequences were then grouped into four annual frequency categories: anticipated (greater than 1.0E−02), unlikely (between 1.0E−02 and 1.0E−04), very unlikely (between 1.0E−04 and 1.0E−06), and extremely unlikely (less than 1.0E−06). Representative source terms for the important sequences were then selected as the bases for health effects calculations, which are now being considered as part of the risk impact calculations performed for the EM PEIS. Generic CH TRUW storage facilities were analyzed at the nine major sites. Representative estimated total releases for each accident and its frequency group are provided in Table I for selected storage facility accidents. These accidents assume a generic 10,000 drum facility with site-specific waste composition.

Incineration facility accidents were analyzed for three cases under regionalization: treatment at five sites (ANL-E, Hanford, INEL, LANL, RFETS, and SRS), treatment at three sites (Hanford, INEL, and SRS), and treatment of RH waste at two sites (Hanford and ORNL); and one case under centralization: treatment at one site (WIPP). Representative estimated total releases for each accident and its frequency group are provided in Table II for selected incineration facility accidents. Detailed radionuclide release data for all accidents can be found in Mueller et al. (14). These accidents assume the generic source term parameters discussed above, with facility inventories defined by the EM PEIS alternative.

Uncertainties in the inventories, source term parameters, and frequencies of accidents imply that absolute source terms are highly uncertain and should be used cautiously. In addition, the results presented here are based on the unit storage facility size or treatment throughput inventories. Nevertheless, with appropriate weighting by the ultimate inventories to be stored or treated at the various sites, these results allow the relative importance of accident source terms to be calculated with sufficient accuracy to provide a measure of comparison among the EM PEIS alternatives.

PLACE TABLES I AND II HERE.

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TABLE I. Summary of Unit Source Terms and Frequencies of Storage Facility Accidents at Selected Sites

Site	Accident	Frequency Bin (per year)				Release (Ci)
		>1.0E-02	1.0E-04 - 1.0E-02	1.0E-06 - 1.0E-04	<1.0E-06	
Hanford	Drum handling	X				2.4E-03
Hanford	Facility fire		X			6.3E+01
Hanford	Earthquake followed by fire				X	6.8E+01
Hanford	Large aircraft impact with fire and explosion				X	1.2E+03
INEL	Drum handling	X				5.1E-03
INEL	Facility fire		X			2.5E+01
INEL	Earthquake followed by fire				X	2.7E+01
INEL	Large aircraft impact with fire and explosion				X	4.4E+02
LANL	Drum handling	X				3.3E-02
LANL	Facility fire		X			1.1E+02
LANL	Earthquake followed by fire				X	1.3E+02
LANL	Small aircraft impact with fire and explosion				X	2.5E+03
LLNL	Drum handling	X				6.0E-04
LLNL	Facility fire		X			7.0E+01
LLNL	Earthquake followed by fire		X			7.2E+01
LLNL	Small aircraft impact with fire and explosion				X	3.0E+02
ORNL	Drum handling	X				7.8E-03
ORNL	Facility fire		X			1.9E+00
ORNL	Earthquake/Tornado followed by fire				X	3.1E+01
ORNL	Small aircraft impact with fire and explosion				X	3.1E+03
RFETS	Drum handling	X				4.5E-03
RFETS	Facility fire		X			1.5E+01
RFETS	Earthquake followed by fire				X	1.8E+01
RFETS	Small aircraft impact with fire and explosion				X	2.9E+02
SRS	Drum handling	X				3.6E-03
SRS	Facility fire		X			5.8E+03
SRS	Earthquake/Tornado followed by fire				X	5.8E+03
SRS	Large aircraft impact with fire and explosion				X	1.2E+04

[a] Abbreviations: ANL-E = Argonne National Laboratory-East, INEL = Idaho National Engineering Laboratory, LANL = Los Alamos National Laboratory, LLNL = Lawrence Livermore National Laboratory, NTS = Nevada Test Site, ORNL = Oak Ridge National Laboratory, RFETS = Rocky Flats Environmental Technology Site, and SRS = Savannah River Site.

TABLE II. Summary of Source Terms and Frequencies of Treatment Facility Accidents

EM PEIS Alternative	Site	Accident	Frequency Bin (per year)				Release (Ci)
			>1.0E-02	1.0E-04 - 1.0E-02	1.0E-06 - 1.0E-04	<1.0E-06	
Regionalization (treatment at 5 Sites)	Hanford	Incinerator ash explosion	X				4.5E-05
	Hanford	Baghouse area facility fire		X			1.1E-03
	Hanford	Earthquake followed by fire and explosion			X		7.5E-02
	Hanford	Large aircraft impact with fire and explosion				X	1.1E-01
	INEL	Incinerator ash explosion	X				5.2E-04
	INEL	Baghouse area facility fire		X			1.3E-02
	INEL	Earthquake followed by fire and explosion			X		8.7E-01
	INEL	Large aircraft impact with fire and explosion				X	1.3E+00
	LANL	Incinerator ash explosion	X				3.6E-03
	LANL	Baghouse area facility fire		X			9.0E-02
	LANL	Earthquake followed by fire and explosion			X		6.0E+00
	LANL	Small aircraft impact with fire and explosion				X	1.5E+00
	RFETS	Incinerator ash explosion	X				1.1E-04
	RFETS	Baghouse area facility fire		X			2.9E-03
	RFETS	Earthquake followed by fire and explosion			X		1.9E-01
	RFETS	Small aircraft impact with fire and explosion				X	4.8E-02
	SRS	Incinerator ash explosion	X				1.3E-02
	SRS	Baghouse area facility fire		X			3.2E-01
	SRS	Earthquake followed by fire and explosion			X		2.1E+01
	SRS	Large aircraft impact with fire and explosion				X	3.2E+01
Regionalization (treatment at 3 sites)	Hanford	Incinerator ash explosion	X				4.5E-05
	Hanford	Baghouse area facility fire		X			1.1E-03
	Hanford	Earthquake followed by fire and explosion			X		7.5E-02
	Hanford	Large aircraft impact with fire and explosion				X	1.1E-01
	INEL	Incinerator ash explosion	X				4.2E-03
	INEL	Baghouse area facility fire		X			1.1E-01

TABLE II. (Cont.)

EM PEIS Alternative	Site	Accident	Frequency Bin (per year) >1.0E-02	1.0E-04 - 1.0E-02	1.0E-06 - 1.0E-04	<1.0E-06	Release (Ci)
	INEL	Earthquake followed by fire and explosion			X		7.0E+00
	SRS	Incinerator ash explosion	X				1.3E-02
	SRS	Baghouse area facility fire		X			3.2E-01
	SRS	Earthquake followed by fire and explosion			X		2.1E+01
	SRS	Large aircraft impact with fire and explosion				X	3.2E+01
Centralization (treatment at 1 site)	WIPP	Incinerator ash explosion	X				1.3E-02
	WIPP	Baghouse area facility fire		X			3.2E-01
	WIPP	Earthquake followed by fire and explosion			X		2.1E+01
	WIPP	Small aircraft impact with fire and explosion				X	5.3E+00
Regionalization (RH-treatment at 2 sites)	Hanford	Incinerator ash explosion	X				6.8E-03
	Hanford	Baghouse area facility fire		X			1.7E-01
	Hanford	Earthquake followed by fire and explosion			X		1.1E+01
	Hanford	Large aircraft impact with fire and explosion				X	1.7E+01
	ORNL	Incinerator ash explosion	X				2.8E-03
	ORNL	Baghouse area facility fire		X			7.1E-02
	ORNL	Earthquake followed by fire and explosion			X		4.7E+00
	ORNL	Small aircraft impact with fire and explosion				X	1.2E+00