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**Facility Accident Considerations in the  
U.S. Department of Energy  
Waste Management Program\***

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FACILITY ACCIDENT CONSIDERATIONS IN THE  
U.S. DEPARTMENT OF ENERGY  
WASTE MANAGEMENT PROGRAM

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## ABSTRACT

A principal consideration in developing waste management strategies is the relative importance of potential radiological and hazardous releases to the environment during postulated facility accidents with respect to protection of human health and the environment. The Office of Environmental Management (EM) within the U.S. Department of Energy (DOE) is currently formulating an integrated national program to manage the treatment, storage, and disposal of existing and future wastes at DOE sites. As part of this process, a Programmatic Environmental Impact Statement (PEIS) is being prepared to evaluate different waste management alternatives. This paper reviews analyses that have been performed to characterize, screen, and develop source terms for accidents that may occur in facilities used to store and treat the waste streams considered in these alternatives. Preliminary results of these analyses are discussed with respect to the comparative potential for significant releases due to accidents affecting various treatment processes and facility configurations. Key assumptions and sensitivities are described.

## I. INTRODUCTION

The EM PEIS calls for separate evaluations of the cost and risk impacts for managing five different waste types: hazardous, high-level, low-level mixed, low-level, and transuranic. For each waste type, four categorical strategies have been devised for consolidating wastes for treatment and storage: (1) "no action," with existing sites generally storing and treating their own wastes consistent with approved plans; (2) decentralization; (3) regionalization; and (4) centralization.<sup>1</sup> The last three alternatives refer to the degree of consolidation and affect the number of sites that will be used to treat, store, and dispose of a given waste type. Each consolidation strategy

has associated siting options, and each option involves existing facilities, facilities in the design phase, and new facilities. Each siting option also implies unique inventories of waste to be stored and treated at each site and associated facilities. Finally, a number of treatment technologies and storage and disposal options for each waste type are to be evaluated for each alternative.

One of the major concerns with respect to the protection of human health is the threat of radioactive and toxicological releases resulting from accidents at waste management facilities. To facilitate relevant comparisons of the various EM PEIS strategies for consolidating and managing wastes with their attendant treatment technologies, facility descriptions, and different selected DOE sites throughout the country, an integrated accident analysis approach was developed in accordance with the latest National Environmental Policy Act (NEPA) compliance guidance from DOE.<sup>2</sup> This guidance calls for consideration of a spectrum of accident scenarios that could occur in implementing the various actions evaluated in an EIS. It also calls for a graded approach to direct attention to the issues expected to dominate risk.

The accident analysis methodology developed for the EM PEIS allows sufficient discrimination of the various options and alternatives to support the decision-making process. Although it allows reasonable estimates of the risk impacts associated with each alternative, its main goal is to allow reliable estimates of the relative risks among the alternatives. To accomplish these goals, the accident models approximate the key source term parameters as a function of the phenomenology and severity of the accident, the process parameters, the characteristics of the facility, and the properties of the waste types. Although developing all accidents in detail is not necessary, systematically applying the underlying approximate models is necessary. Many of the uncertainties in the data that are

reflected in estimates of absolute risk tend to be canceled in estimates of relative risk. Thus, systematic application of the models provides a sufficient and scrutable basis for discriminating among alternatives.

An overview of the accident analysis methodology and computational approach for the EM PEIS has been reported earlier.<sup>3,4</sup> In summary, the approach to accident analysis includes the following interrelated elements: (1) selection of potentially risk-important storage and treatment operations and related facility configurations across the DOE complex; (2) selection, development, and probabilistic evaluation of a uniform set of the most significant sequences of accidents; and (3) determination of the evolution and final compositions of source terms predicted to be released from these sequences. A personal-computer-based computational framework and database have been developed to automate these elements and provide source term input for the health effects analyses.<sup>5</sup>

Figure 1 illustrates the integration of these elements into a systematic multiorganizational programmatic approach for performing risk impact analysis for the EM PEIS. Within the facility accident analysis, the source terms cited above were developed by Argonne National Laboratory and subsequently used by Oak Ridge National Laboratory for assessment of the radiological or toxicological health effects to the general public and to the work forces. The waste management alternatives included the identification of siting options for storing and treating each waste type before disposal. Storage inventories and treatment throughput for each site affected by a given alternative are then defined by the current inventories, existing and projected waste generation rates, and the disposition of the waste. The volume and radionuclide composition of each waste are tracked in a relational database<sup>6</sup> as the waste is processed to final disposal. Thus, the relative impacts of facility accidents in treating and storing waste are calculated as a function not only of the accident sequences but also of the waste inventories at each site, the treatment technologies chosen, the facilities that will house the operation, and, of course, the site demographics.

## II. SOURCE TERM CONSIDERATIONS IN RELATIVE IMPACT COMPARISONS

The relative differences in the impacts of facility accidents discussed in this paper are primarily derived from differences in the atmospheric release source terms, which are modeled according to:

$$\text{Radiological source term} = \text{MAR} \times \text{DF} \times \text{RARF} \times \text{LPF},$$

where

*MAR* is the quantity of material at risk,

*DF* is the damage fraction or fraction of *MAR* exposed to accident stresses capable of rendering the *MAR* airborne,

*RARF* is the respirable airborne release fraction or fraction of material subjected to accident stresses actually rendered airborne and respirable, and

*LPF* is the leak path factor or fraction of the respirable airborne inventory that escapes any containment or confinement barriers to reach the ambient atmosphere.

Figure 2 illustrates the evolution of radiological source terms, the factors of which are discussed in more detail in a paper by Mueller et al.<sup>7</sup> The chemical source term evolution is similar, with the evaporation or reaction rates of the toxic chemicals produced by the accident being analogous to the *RARF*.

In the discussions that follow, it will be seen that first-order comparisons among different accidents or among similar accidents affecting different facilities can often be readily obtained by disaggregating the potential accident source terms into the cited factors. Knowledge of the inventory amounts and compositions is generally sufficient to assess differences in the *MAR* among sites or facilities. However, inventory knowledge must be combined with knowledge of the waste packaging and the facility containment configuration and with a physical understanding of accident progression under varying conditions to properly assess the remaining source term factors.

### III. COMPARISON OF TREATMENT TECHNOLOGIES

For each of the waste types addressed in the EM PEIS, numerous treatment technologies are assessed. Each waste type is subdivided into treatability categories according to its physical, chemical, and radionuclide characteristics. For each waste type treatability category, the treatment process throughputs are derived and tracked based on current storage inventories, projected waste generation rates, and site consolidation assumptions defined by the alternative. The source terms in the treatment process accidents are of course proportional to the material at risk, which is derived from the above throughputs.

In reviewing the comparative importance of the potential source terms from treatment accidents, it was useful to focus on those technologies that (1) involved *MAR* with both high concentrations of radioactivity or radioactive materials and (2) required or used energy sources potentially capable of rendering large amounts of these materials airborne and respirable. This implied focusing on selected thermal treatment technologies. Energy sources included the presence of combustible materials or feedlines of natural gas or fuel as well as high temperatures or pressures inherent to the treatment process.

As a result of this review, nonthermal treatment operations such as repackaging, shredding, compaction, and grouting can generally be assessed as unimportant to radiological risk because of the lack of plausible mechanisms for promulgating large airborne source terms. Thermal treatment operations involving relatively dilute concentrations of radioactivity, such as wastewater evaporation, can also be assessed generally as unimportant to radiological risk. Of the various thermal treatment operations currently being evaluated in the EM PEIS, source term analyses were conducted for three technologies that appeared to be potentially important: incineration, vitrification, and wet-air oxidation.

Incineration in the EM PEIS is being considered for combustible solid waste and organic liquids and sludges. It involves high temperatures, combustible materials and fuel lines, and, because of a number of recorded incineration overpressurization accidents, a recognized potential for vessel rupture. Because the volume reduction

factor for this process is on the order of 100, the heavy metal radionuclide concentration of the ash by-product for the radioactive wastes is roughly two orders of magnitude greater than the input feed waste, providing a highly radioactive inventory of *MAR*. Moreover, the ash is highly dispersible under severe fire and explosion conditions, leading to potentially high *RARFs* under these conditions. As a result, considerable effort was spent in the EM PEIS facility accident analysis assessing potential incineration facility fires and explosions and developing radiological source terms.

Vitrification is being considered in the EM PEIS for immobilizing incineration ash, sludges and resins, and other partitioned wastes. It involves high temperatures, electrically heated melters, and concentrated feed wastes that are converted into a glass by-product. It is potentially comparable to incineration in terms of the high temperature, the potential for pressurization, and the combustible material hazards. The key accident in vitrification is a steam explosion from the interaction of molten glass with water from the cooling or drain system with rupture of the vessel. This accident could affect the integrity of the hot cell in which the melter is located. However, because the dispersibility of the feedstock is at most equivalent to that of the feedstock for incineration and because the forms of the vitrification material (molten and solidified borosilicate glass) are less dispersible (i.e., the *RARF* is lower) by several orders of magnitude than ash from a kiln or from a secondary combustion chamber, incineration accidents produced more significant radiological source terms.

Wet-air oxidation in the EM PEIS is being considered for the aqueous phase treatment of suspended organic substances. In this process, water catalyzes oxidation so that reactions proceed at much lower temperatures than would be required if the same materials were oxidized in open flame combustion, such as in incineration. Because the pressures are higher than those in other thermal treatment processes, rupture of the oxidation vessel followed by pressurized releases is considered plausible. However, the *MAR* is more dilute and is in an aqueous noncombustible liquid form. As a result, accidents affecting wet-air oxidation produced source terms that were generally enveloped by incineration.

As a result of the relative potential accident frequency and associated source term parameter comparisons for a number of thermal treatment technologies, incineration was identified as the treatment process with the highest potential radiological risk. These calculations assumed the same generic containment characteristics (DOE Hazard Category 2) for all thermal treatment facilities. The final radiological risk associated with accidents affecting any specific treatment facility will of course be a function of the actual process parameters and final containment design characteristics that affect the source term parameters, as well the site location and demographics.

#### IV. COMPARISON OF ACCIDENT TYPES

In addition to treatment-process-related accidents, a spectrum of radiological release scenarios was reviewed for the potential to affect workers at or in the immediate vicinity of accidents, other on-site workers, and off-site populations. General handling accidents involving waste package breach are expected to dominate the radiological risks to workers because of the relatively high frequency of such accidents and the proximity of the workers to any release. Standard operations considered include handling in storage and staging areas, packaging and unpackaging, movement of waste within treatment facilities, and some treatment operations. Handling accidents include container breaches caused by package drops, forklift or other vehicular impacts, crane drops or crushing, and overpressurization. Exposures to radiation from operational incidents such as puncture wounds during waste sorting, minor contamination from glove failures, and minor spreads of contamination from the events of treatment equipment pressurization were judged to be enveloped by this class of accidents.

Severe accidents involving storage facilities were also considered. Because of their large MAR inventories, large centralized storage facilities were specifically analyzed, with accidents involving fires generally dominating the source terms capable of producing off-site health effects. Fully developed facility fires arising from either operational fires or from natural phenomena such as earthquakes generally tended to be the most significant. Although they generally affected greater inventories, aircraft crashes were assessed to be much less important (depending on the site) because of their low frequencies.

#### V. SUMMARY AND CONCLUSIONS

This paper discusses the screening methods used to determine relative importance and the illustrative comparisons of the potential airborne release source terms from facility accidents for various treatment technologies considered in the EM PEIS. These comparisons were based primarily on considerations of the material at risk and other source terms factors for categorical classes of potential accidents affecting the various storage and treatment options for the various waste types. Cross comparisons of different types of accidents as determined by reviewing the frequencies and potential magnitudes of the related source terms have also been made.

Uncertainties in the inventories, source term development, and frequencies of accidents imply that the absolute source terms and subsequently derived radioactive or hazardous releases analyzed for facility accidents are highly uncertain. To the extent that uniform methods can be systematically applied to facility accident analysis, as discussed herein, the relative importance of accidents can be calculated much more accurately and is judged to provide a useful measure for discrimination among EM PEIS alternatives.

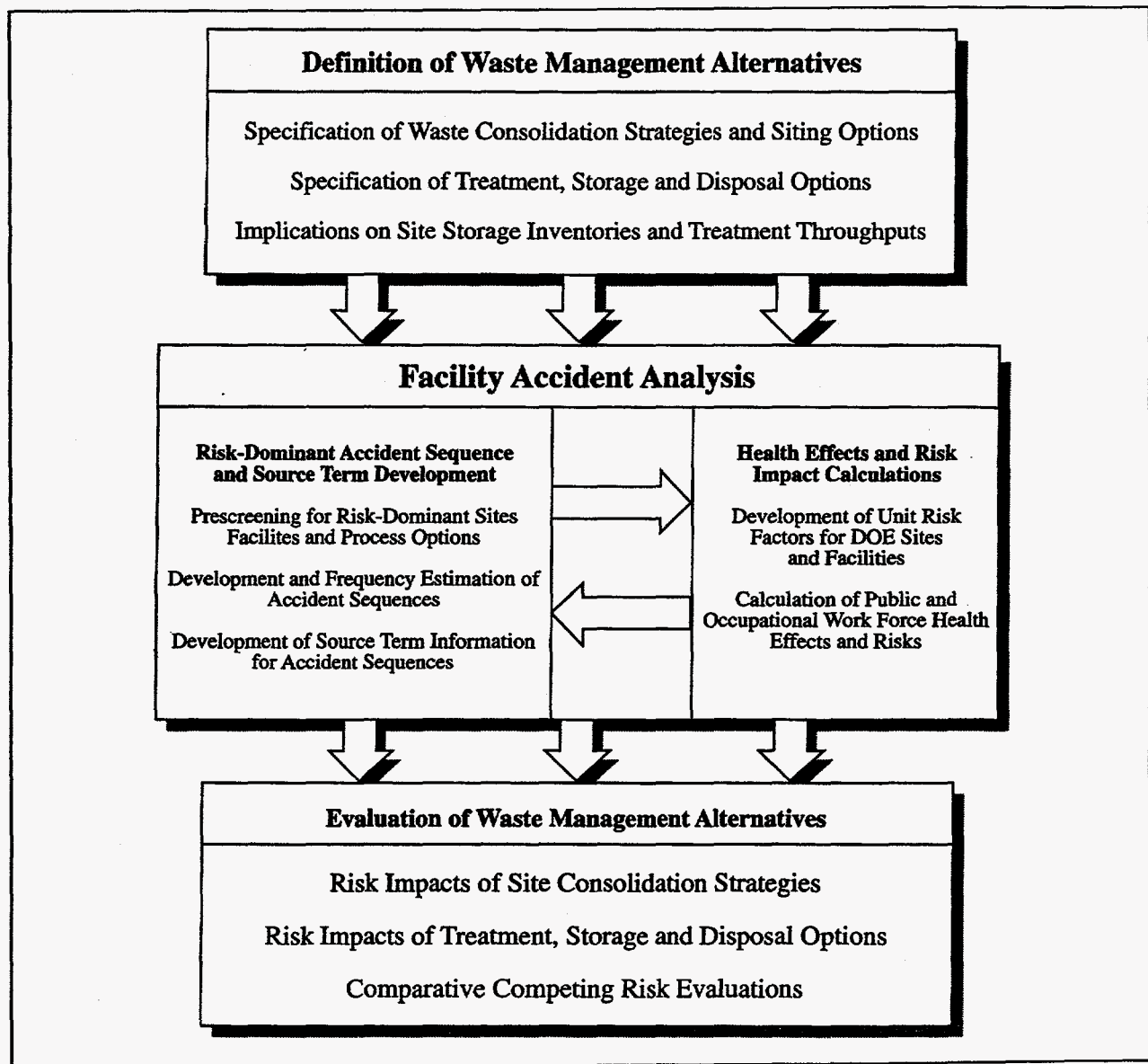
#### ACKNOWLEDGMENTS

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**FIGURE 1 Overview of Facility Accident Analysis Interactions for the EM PEIS**



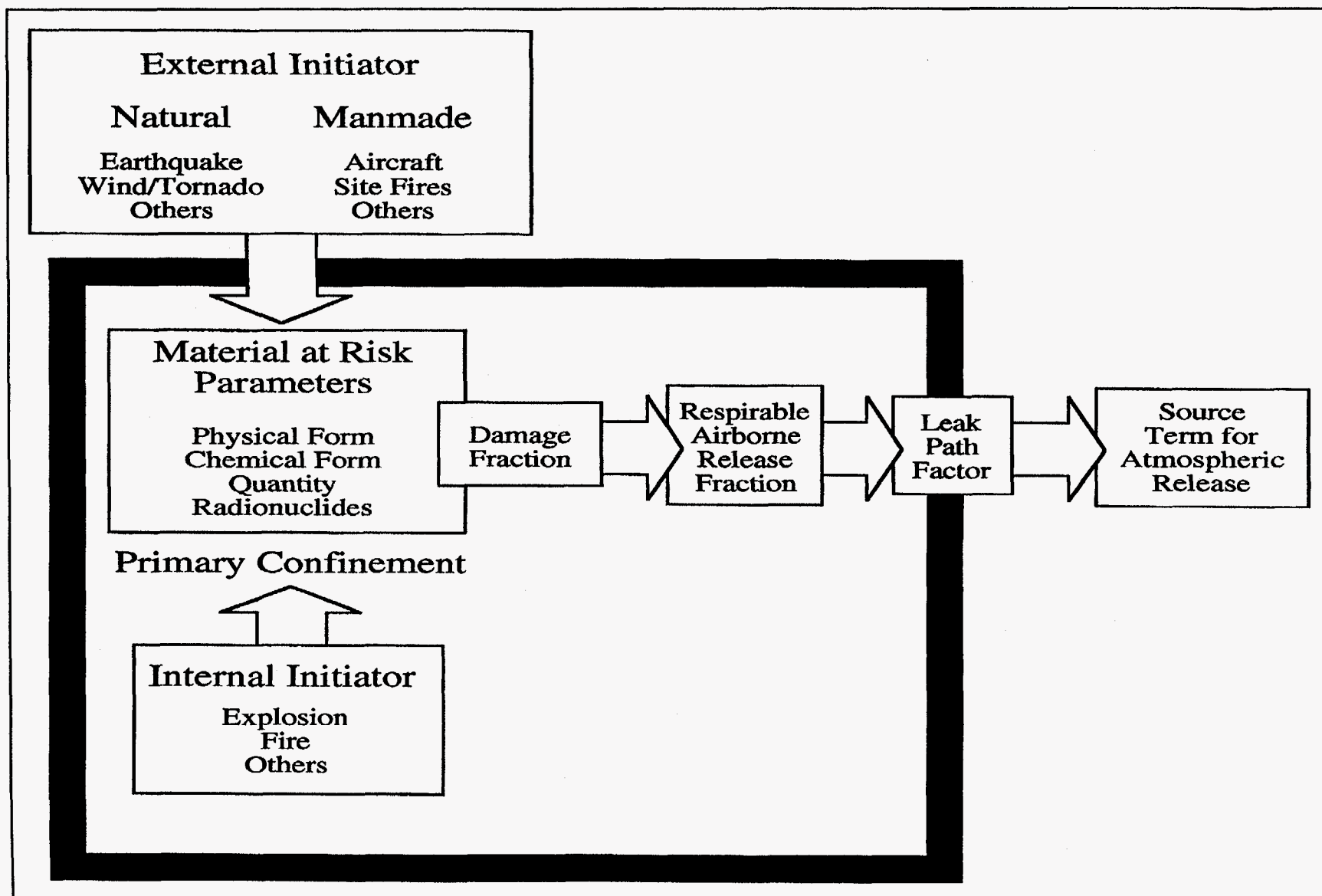


FIGURE 2 Conceptual Flow Diagram for Source Term Development