ANL/EA/CP--84147

Conf-950216--103

ASSESSMENT OF TRANSPORTATION RISK FOR THE U.S. DEPARTMENT OF ENERGY ENVIRONMENTAL MANAGEMENT PROGRAMMATIC ENVIRONMENTAL IMPACT STATEMENT*

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for submission to

WM '95 Conference
February 26-March 2, 1995
Tucson, Arizona

sponsored by
WM Symposia, Inc.

* Work supported by the U.S. Department of Energy, Assistant Secretary for Environmental Management, under contract W-31-109-Eng-38.

DISCLAIMER

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ABSTRACT

In its Programmatic Environmental Impact Statement (PEIS), the Office of Environmental Management (EM) of the U.S. Department of Energy (DOE) is considering a broad range of alternatives for the future management of radioactive and hazardous waste at the facilities of the DOE complex. The alternatives involve facilities to be used for treatment, storage, and disposal of various wastes generated from DOE environmental restoration activities and waste management operations. The evaluation includes five types of waste (four types of radioactive waste plus hazardous waste), 49 sites, and numerous cases associated with each alternative for waste management. In general, the alternatives are evaluated independently for each type of waste and reflect decentralized, regionalized, and centralized approaches. Transportation of waste materials is an integral component of the EM PEIS alternatives for waste management. The estimated impact on human health that is associated with various waste transportation activities is an important component of a complete appraisal of the alternatives. The transportation risk assessment performed for the EM PEIS is designed to ensure through uniform and judicious selection of models, data, and assumptions that relative comparisons of risk among the various alternatives are meaningful and consistent. Among other tasks, Argonne National Laboratory is providing technical assistance to the EM PEIS on transportation risk assessment. The objective is to perform a human health risk assessment for each type of waste relative to the EM PEIS alternatives for waste management. The transportation risk assessed is part of the overall impacts being analyzed for the EM PEIS to determine the safest, most environmentally and economically sound manner in which to satisfy requirements for waste management in the coming decades.

INTRODUCTION

The U.S. Department of Energy (DOE) Office of Environmental Management (EM) is responsible for the treatment, storage, and disposal (TSD) of various wastes generated within the facilities of the DOE complex from environmental restoration activities and waste management operations. For the EM PEIS that is being prepared (1), alternatives are considered relative to the decentralized, regionalized, and centralized approaches. The types of radioactive waste being evaluated include high-level, transuranic, low-level, and low-level mixed. Hazardous waste is also being evaluated. The magnitude of the transportation activities varies with the alternative and ranges from minimal transportation for the

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decentralized alternative to significant transportation for the centralized alternative. Various aspects of the impact of transportation are radiological versus hazardous, rail versus truck, routine versus accident, worker versus public, population versus individual, and aggregate risk (i.e., probability times consequence) versus consequence. Because of complex-wide considerations, large amounts of waste in some alternatives are expected to result in unprecedented large-scale transportation activities for DOE or other federal agencies; the potential cumulative impacts of these activities may warrant special attention.

The magnitude and complexity of the scope of the EM PEIS present the following unique features regarding transportation risk assessment: (1) large amounts of waste requiring shipment result from programmatic considerations that are unprecedented for DOE and other federal agencies, (2) consistency exists between the radiological and hazardous risks, and (3) the magnitude and complexity of the routes for shipment require an integrated and expedient computational approach. The EM PEIS method represents a comprehensive and integrated approach to assessing risk regarding the transportation of radioactive, hazardous, and mixed waste.

TECHNICAL APPROACH

The technical approach for conducting the transportation risk assessment was developed following a thorough and critical review of the literature and existing documentation prepared for major federal actions under the National Environmental Policy Act (NEPA). Consideration was also given to recent commitments arising from public awareness and litigation. The approach has also received DOE internal review and external review outside of DOE.

The transportation of radioactive and hazardous wastes involves risk to both crew members and members of the public. Part of the risk results from the nature of the transportation operation itself, which is independent of the waste contents or characteristics of the cargo; for instance, traffic accidents during transportation may cause direct injuries or fatalities. Similarly, pollution from vehicle exhaust emissions may also affect human health. These risks are characterized as "vehicle-related." On the other hand, the transportation of waste may pose an additional risk because of the characteristics and potential hazards of the cargo (i.e., waste) itself. These risks are therefore considered "cargo-related."

The technical approach is conceptualized in Figure 1 for the EM PEIS transportation risk assessment. A more detailed description of the method has been provided by Monette et al. (2) for transportation of radioactive waste and by Hartmann et al. (3) for transportation of hazardous waste. Potential risks were estimated for the collective population, as well as for the maximally exposed individual, during routine transportation and accidents. For radioactive wastes, the cargo-related risks include exposure to external radiation from the waste package during routine operation and potential exposure to dispersed waste contents in accidents. The RADTRAN 4 (4) computer code was used to estimate the collective population risk. The approach of RADTRAN has been used extensively in previous NEPA assessments and has received wide acceptance. The collective population risk is a measure of the radiological risk posed to the society as a whole by the alternative being considered.

As such, the collective population risk is a reasonable primary measure for comparing different alternatives. Supplemental analyses were provided by using the RISKIND (5) computer code to address areas of specific concern to individuals or population subgroups. The supplemental analyses are primarily meant to address the "what if" scenarios frequently raised in public comments. Examples of such scenarios are "What if an accident happens near my community?" or "What is the risk to me if I live adjacent to the access road?"

FIGURE 1 HERE

The general methodology for characterizing risk from exposure to hazardous chemicals has many parallels to the methodology for characterizing risk for radioactive waste transportation; however, no standard computer code exists in the chemical area that is a direct counterpart to RADTRAN. One of the major tasks of the EM PEIS transportation risk analysis is to develop the details and coding of the general chemical risk methodology that parallels the steps in the RADTRAN method. Included in such details are a realistic treatment of the chemical accident itself, as well as development of a variety of appropriate chemical risk end points. The treatment of fires (leading to toxic gas releases) and water immersion is also to be included in the implementation of the general chemical risk methodology. Unique to this approach is the assessment of the impacts of water immersion.

Another unique feature of chemical risk assessment is that routine operations of hazardous chemical transportation do not lead to cargo-related risks. Chemical risks occur only from accident conditions because small spills or seepages of hazardous or chemical waste during routine operations are kept to a minimum by existing regulations and packaging of that waste. Consequence modeling of chemical spills during accidents is performed by using the Areal Locations of Hazardous Atmosphere (ALOHA™) (6) air dispersion code in conjunction with several end points for human health effects (discussed in the following paragraphs). The ALOHA™ code has been used extensively by the U.S. Environmental Protection Agency (EPA) for assisting emergency field personnel in planning for accident release consequences and in implementing emergency response measures.

DEVELOPMENT OF END POINTS FOR HEALTH EFFECTS

The potential exposures from transportation of radioactive materials, either from routine operations or from postulated accidents, are usually at a low dose, such that the primary adverse effect is the induction of latent cancer. The correlation of the radiation dose and human health effects for low doses has been traditionally based on what is termed the "linear, no-threshold hypothesis," as described by the International Commission on Radiological Protection (7).

In addition to latent cancer (which is assumed to be a linear, no-threshold effect), exposure to toxic chemicals may also cause threshold, nonlinear effects. These effects are often of an immediate nature (i.e., acute). The severity of the immediate health effects therefore depends strongly on the toxicity and exposure concentration of the specific chemical(s) released and can range from slight irritation to potential fatality for the exposed individuals. Thus, for the EM PEIS human health risk assessment, three end points were assessed: (1) potential for life-threatening effects, (2) potential for other adverse effects, and (3) increased cancer risk. The first two end points are acute. The potential life-threatening effects are specific only to toxic chemicals identified as "poison inhalation hazards" by the U.S. Department of Transportation (DOT) (Title 49, Parts 173.115 and 173.132-133 of the *Code of Federal Regulations* [CFR]). Estimates of these effects are derived from the 50% lethal concentration (LC_{50}) or other appropriate toxicity values. The toxicity values have been derived from the following sources: (1) the Registry of Toxic Effects of Chemical Substances (RTECS) database (8), and (2) *Dangerous Properties of Industrial Materials* (9). Estimates of other adverse effects are based on the inhalation reference dose values developed by the EPA, when available. Such data are derived from the EPA Integrated Risk Information System (IRIS) (10) database and the *Health Effects Assessment Summary Tables* (HEAST) (11). For the effects of latent cancer, assessment is performed for a carcinogenic risk of one in one million (10^{-6}) or higher. The concentration values corresponding to this risk level have also been derived from the IRIS and HEAST databases. A description of the derivation of the concentration values for these end points for health effects is provided in Hartmann et al (3).

PARAMETERS AND ASSUMPTIONS

Major input parameters and assumptions used in the EM PEIS transportation risk assessment are discussed in the following paragraphs.

Waste Inventory and Characterization

A radioactive waste inventory computational model (WASTE_MGMT) (12,13) has been developed by Argonne National Laboratory to support the EM PEIS analysis of risk and cost. The model combines information on the waste inventory and characterization of waste across the DOE complex, on characterization of the TSD modules, and on definitions of the EM PEIS alternatives. Waste properties are provided in terms of isotope- or chemical-specific concentrations. Physical forms of waste are generally classified into a small number of categories such as vitrified waste, liquid waste, metal waste, and heterogeneous solid waste. Hazardous waste is inventoried and characterized with a separate database of shipping manifests collected from the entire DOE complex for the year 1992. From those manifests and associated data, physical and chemical characterizations were obtained, from which data on treatment and disposal could be obtained or estimated.

Packaging And Shipping Configurations

For the transportation of radioactive materials, the basic types of packaging required by the regulations are designated as Type A, Type B, or "strong and tight." The regulatory requirements are those specified by the DOT and the U.S. Nuclear Regulatory Commission (NRC) (49 CFR 173 and 10 CFR 71). For the EM PEIS, all transportation of radioactive waste has been assumed to take place in certified containers and exclusive-use vehicles. Low-level waste and low-level mixed waste are assumed to be transported in Type A packages. The high-level and transuranic wastes require the use of Type B packaging. The transuranic waste will essentially consist of Type A waste containers within reusable, certified Type B shipping containers, such as TRUPACT-II for contact-handled waste and

NuPac 72B for remote-handled waste. For hazardous waste, packaging is assumed to follow the DOT specifications for containers (49 CFR 173).

Shipping Routes

Representative shipping routes have been determined for all possible pairs of DOE sites that generate or store wastes. For each origin-destination pair, representative highway and rail routes were generated and analyzed by using the routing models HIGHWAY (14) and INTERLINE (15), respectively. The routing models are updated periodically to reflect current road and track conditions and have been benchmarked against the reported shipping distances and the observations of commercial truck and rail firms. The routes calculated conform to current routing practices and all applicable routing regulations and guidelines; however, the routes do not necessarily represent the actual routes that will be used to transport waste in the future. For risk analysis, the important routing characteristics include total shipping distance and the fractions of travel in rural, suburban, and urban zones of population density. The hazardous waste methodology uses only HIGHWAY because no such waste is currently or is planned to be sent by rail.

External Dose Rate

Because all shipments are assumed to take place on exclusive-use vehicles, the maximum external dose rate from a radioactive waste package is limited by the regulatory value of 10 mrem/h measured at 2 m from the lateral surfaces of the conveyance. Because of the complex nature of the EM PEIS alternatives and the different types of waste, a representative external dose rate appropriate for each type of waste was determined for the EM PEIS analysis. This dose rate was based on the average of the entire waste inventory appropriate for the EM PEIS analysis and, therefore, was not intended to represent site-specific values. External dose rate concepts are not applicable to hazardous waste.

Traffic Accident Rates

For calculation of the accident-related risk, accident rates for truck and rail transportation were taken from a compilation by Saricks and Kvitek (16). Data include the accident rate, injury rate, and fatality rate. State-specific accident rates for truck shipment were based on statistics compiled by the DOT Office of Motor Carriers for 1986-1988, specifically for heavy combination trucks involved in interstate commerce. These data were benchmarked against the existing nuclear commercial carriers. State-specific rates for rail accidents were based on statistics compiled by the Federal Railroad Administration for 1985-1988. Rail accident rates include both accidents on main lines and those occurring in rail yards. For hazardous materials, data on accidents were based on 1979-1983 California highway accident data for shipment of hazardous waste.

Accident Severity Categories

A range of potential severities for radioactive waste transportation-related accidents has been described by the NRC (17). The NRC scheme for classifying accidents categorizes accidents as a function of the magnitudes of the mechanical forces (impact) and thermal forces (fire) to which transported packages may be subjected. For each category of severity, a conditional probability is also assigned. The RADTRAN accident risk assessment considers the entire range of accident categories as defined by the NRC, including accidents with low probability but high consequences and those with high probability but low consequences. On the other hand, for consequences to maximally exposed individuals and to population subgroups, scenarios analyzed by the RISKIND code include those representing the accident scenarios with the highest release of waste. Hazardous waste accident scenarios were based on accident release data compiled from the DOT Hazardous Materials Incident Reporting System (HMIRS) (18) database. The contents of each DOE shipment were assumed to have a "breach fraction" (expected fraction of containers ruptured) and a "release fraction" (expected amount of each chemical released from those breached containers) during a transportation-related accident. The amounts of the chemicals released were used in the consequence modeling.

Accident Release Fractions

The release fractions relevant to the risk assessment include three major components: the fraction of the waste contents that could be released to the environment for a given severity of accident, the fraction of the released material that can be dispersed to the atmosphere, and the fraction of the dispersed portion that is respirable. Most solid materials are difficult to release in particulate form and, therefore, are nondispersible even if they are released. Gaseous materials, on the other hand, are relatively easy to release when the container is breached. Release fractions under accident conditions have been estimated by the NRC (17) for Type A and Type B containers under various categories of accident severity. The dispersible fractions and respirable fractions have been suggested by RADTRAN (4) for various forms of materials. Breach and release fractions for hazardous waste are based on analysis of thousands of accidents in the HMIRS database (18).

Atmospheric Conditions

Because predicting the specific location of a transportation-related accident is impossible, generic weather conditions were used for transportation risk assessment. For accident risk analysis, neutral weather conditions (represented by Pasquill stability class D) were assumed. Because neutral meteorologic conditions constitute the most frequently occurring atmospheric stability conditions in the United States, these conditions are most likely to be present during an accident. For maximally exposed individuals, however, both neutral (represented by Pasquill stability class D) and stable (represented by class F) conditions were considered; the stable condition was used to represent a conservative condition intended to maximize the consequence.

Scenarios For Maximally Exposed Individuals

For routine transportation, risks to maximally exposed individuals were estimated for a number of hypothetical exposure scenarios. The receptors include transportation crew members, inspectors, and members of the public exposed during traffic delays, while working at a service station, or while living near a waste site. Parameters typical of such scenarios have been described in previous DOE documents (19, 20). For accidents, the maximally exposed individuals are assumed to be downwind. The accident severity category with the highest release was used to represent "worst-case" scenarios for the accident analysis.

For hazardous waste, worst-case accidents were evaluated in a similar manner and were chosen on the basis of the shipments with the maximum quantity, toxicity, and volatility of the hazardous waste within those shipments.

DEVELOPMENT OF AUTOMATED COMPUTATIONAL SYSTEM

Because of the magnitude and complexity of the EM PEIS transportation risk analysis, an automated computational system was developed by Biwer et al. (21) to facilitate the computation of risk for radioactive waste. The system uses the unit-risk factor concept; that is, unit-risk factors derived from the RADTRAN 4 calculations form the basis of the system. Key parameters providing a foundation for the unit-risk factors include transport mode, external dose rates from waste packages, transport speeds, and radionuclide-specific information. Shipment risks are estimated by the combination of the unit-risk factors with state-specific population zone distances and accident rates, package release characteristics, and other relevant factors. For the purpose of the EM PEIS analysis for DOE facilities, the system also incorporated routing information derived from HIGHWAY (14) and INTERLINE (15). The system is designed to incorporate such routing information and unit-risk factors to produce risks for a particular alternative. The system is now equipped with a menu-driven feature for analyzing transportation-related risks for large and complex shipping campaigns required by the EM PEIS. For hazardous waste, a semiautomated system has been set up that links the hazardous waste database, the ALOHA™ model, and a spreadsheet program that computes risk.

ASSESSMENT OF ALTERNATIVES

On the basis of the technical approach and the assumptions discussed previously, the transportation risk assessment was performed for the EM PEIS. Potential transportation-related health risks were calculated for both all-truck transportation (radioactive and hazardous wastes) and all-rail transportation (radioactive wastes only). For shipments between each origin-destination pair, the collective risks to workers and the public for incident-free conditions and for accidents were assessed. For each alternative, the total collective risks represent the aggregate of risks from the set of origin-destination pairs. For comparison, the vehicle-related impacts (i.e., the total number of traffic accident fatalities) from collisions were also estimated and are presented along with the cargo-related (waste-related) impacts.

CONCLUSIONS

The transportation risk assessment conducted for the EM PEIS is a comprehensive and integrated approach that can be applied to all types of radioactive waste, as well as to hazardous waste, generated within the DOE complex. By combining a traditional method (for radiological risk assessment) with some developmental components (for hazardous risk assessment), the magnitude and complexity of the analysis are addressed. The results of the assessment constitute an important component of the overall evaluation of waste management alternatives of the EM PEIS.

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