Post-Accident Cleanup Analysis for Transportation of Radioactive Materials*

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INTRODUCTION

Approximately 5 to 10 million packages of radioactive material and wastes are shipped annually in the United States.[1] Most of these shipments consist of small quantities of medical and research isotopes. However, larger quantities of radioactive wastes are shipped by the U.S. Department of Energy (DOE) via commercial truck or rail service. The number of shipments of radioactive waste is expected to increase over the next several years as efforts to dispose of waste stored and generated at DOE sites progress.[2] The potential for a severe accident involving these anticipated waste shipments is small, but not insignificant. The probability of a severe accident resulting in the largest credible release of material has been estimated to range from approximately 0.01 to 0.1 over the 20-year time period considered for permanent disposal of each of the low-level, transuranic, and high-level radioactive waste types (LLW, TRUW, and HLW).[2] The potential radiological consequences of the most severe credible accident involving each of these waste types could adversely affect the community in which it occurred. These consequences are considered below. Accidents involving spent nuclear fuel (SNF) shipments are of concern to the public and are also considered.

Exposure of individuals to radionuclides can occur through many exposure pathways if an accident results in a radioactive release to the environment. The Federal Radiological Emergency Response Plan establishes a coordinated response by Federal agencies when requested by State, tribal, or local government officials during a peacetime radiological emergency.[1] In case of such an emergency, DOE has primary responsibility for providing assistance unless the radioactive source is unknown, unidentified, or from a foreign country, then the U.S. Environmental Protection Agency (EPA) becomes the primary coordinating Federal agency. The EPA has issued a set of protective action guides[3] (PAGs) to aid public officials in responding to an accident involving radioactive materials. Under emergency conditions, maximum individual dose limits are suggested when practicable. Limits are set for the early phase of an accident, lasting up to four days from the time of the initial radioactive release, and for the intermediate phase of an accident, taken to represent up to one year after the accident.

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In this paper, a pathway analysis code, the RISKIND computer program,[4] has been used as a screening tool to help develop an example action plan for both the early and intermediate phases of an accident involving the release of radioactive materials. RISKIND was developed for the analysis of radiological consequences and health risks to individuals and the collective population from exposures associated with the transport of SNF or other radioactive materials. RISKIND was developed by Argonne National Laboratory under the support of the DOE Office of Civilian Radioactive Waste Management.

Projection of individual doses at the start of the early phase following an accident is difficult because quantitative data on contamination levels in the vicinity of a transportation accident are not immediately available to response officials. However, RISKIND can be used to estimate potential doses to members of the public in specific locations downwind of the accident. The following discussions illustrate the application of RISKIND to the most severe, credible transportation accidents involving the different radioactive waste types.

DISCUSSION

Transportation Accidents

The primary regulatory approach used to ensure safety during transport of radioactive materials is to specify standards for the proper packaging of such materials. Primary regulatory authority is provided by the U.S. Department of Transportation (DOT), as set forth in 49 CFR Part 173 ("Shippers — General Requirements for Shipments and Packaging"). Packaging for transporting radioactive materials must be designed, constructed, and maintained to ensure that it will contain and shield the contents during normal transportation. Type A packaging provides such protection for less radioactive material, such as low-level waste (LLW). Type B packaging is required for more highly radioactive material, such as high-level waste (HLW), transuranic waste (TRUW), and SNF. Type B packaging is designed to contain and shield its contents in all but the most severe accidents

In general, accident severity is characterized by the potential release fraction of the shipment contents. That is, for the same type of packaging, more severe events result in a larger quantity of material released [5,6] The more severe cases, however, are associated with lower probabilities of occurrence. In its recent programmatic environmental impact statements, DOE has evaluated various options for managing its radioactive wastes and SNF. Because of the large number of DOE shipments and total estimated mileage, transportation accidents leading to the highest potential releases have been estimated to have overall probabilities that range from 1 in 10 to 1 in 100 for all waste types (i.e., HLW, LLW, and TRUW). Possible SNF accidents within this probability range are not the most severe but could result in a potential release. In this study, only three waste types are included (and the cases are so designated): LLW, TRUW, and SNF. No analysis is performed for HLW because of the low release in its vitrified form. Because of the large variability of accident release fractions, the study also includes a very improbable event, a second SNF case involving the highest potential release. Such accidents have a probability of about 3 in 100,000 (case designated as SNF1).

Early Phase

Doses to individuals downwind during the early phase of an accident are primarily from inhalation during the passing of the contaminated plume. In the case of a transportation accident, protective actions such as sheltering or evacuation to mitigate exposure may not be feasible in the near vicinity of the accident because there may be only a matter of minutes or less before the plume arrives. Figure 1 shows the relative time-integrated ground-level air concentrations within the first 1 km downwind of an accident as determined by RISKIND. The results are based on a ground-level release under neutral weather conditions. It can be seen that the ground-level air concentrations are highest near the accident for this ground-level release. Working downwind from the area with the highest concentration, every second isopleth in Figure 1 represents a factor of 10 decrease in concentration. In an accident involving fire, which can be modeled with RISKIND, the highest concentrations would be at the downwind location where the buoyant plume descends back to the ground.

If projected doses are expected to be near the PAG values, protective actions should be taken to mitigate exposure, providing the risk involved in implementing the protective actions is not comparable to or greater than the risk posed by the accidental release itself. Protective actions include such measures as sheltering and evacuation in the early phase following an accident if the projected dose is expected to exceed 1 rem. As estimated by using RISKIND, individual doses could reach 6 6, 32, 1.9, or 2.1 rem from the LLW, TRUW, SNF, and SNF1 accidents, respectively. If the release occurs over a short period (seconds), there may not be time for protective actions. However, if the release occurs over a longer period (minutes or hours), such as in a transportation accident involving a fire, there might be time to implement sheltering or evacuation to mitigate dose.

RISKIND can be used to estimate the area that might require protective actions in the early phase of an accident. Figure 2 shows the total area near the accident in which RISKIND projects the 1-rem PAG to be exceeded for each waste type accident. Although the accident conditions used in the RISKIND calculations were the same for each waste type (except for the SNF1 accident, which involves fire), areas of different sizes are affected because of the different radioactive isotope mixes typically found in each waste type.

Intermediate Phase

For the intermediate phase of an accident, RISKIND can estimate both the need for protective actions and the amount of cleanup necessary to achieve proposed dose limits. Intermediate-phase exposures occur through inhalation of resuspended contamination and external exposure to contaminated surfaces and resuspended contamination. RISKIND estimates contaminated ground concentration isopleths similar to those calculated for contaminant air concentrations.

These contours match those for air concentrations under most conditions. The exposure time and dose limit can be input independently The doses estimated for this illustration take into account the average daily indoor/outdoor activity patterns of people and the shielding normally afforded by different types of structures.

The PAGs suggest relocation as a protective action if the first-year dose to a single individual would exceed 2 rem. Figure 2 shows the amount of contaminated area where this PAG is projected by RISKIND to be exceeded. Without mitigation, a person might be expected to receive a dose in the first year as high as 70, 13, 7, and 3.5 rem from accidents involving LLW, TRUW, SNF, and SNF1, respectively.

For doses expected to be less than 2 rem, the PAGs suggest that surface contamination be reduced to levels as low as reasonably achievable and recommend initial efforts to be concentrated in areas where the projected doses are expected to exceed 0.5 rem in the first year. Again, Figure 2 displays the amount of area in each case where this PAG would be exceeded.

Longer-Term Objectives

The stated objective of the PAGs regarding deposited radioactivity for the intermediate phase is that doses to an individual in any single year after the first year not exceed 0.5 rem and that the cumulative dose over 50 years (including the first and second years) not exceed 5 rem. RISKIND shows (Figure 2) that in the case of the LLW, SNF, and SNF1 accidents, the 50-year 5-rem value is more limiting than the first-year guide of 2 rem. Without cleanup, an individual might receive up to 416, 13, 71, and 54 rem from a LLW, TRUW, SNF, or SNF1 accident, respectively, over a 50-year period following the accident. (Note that the LLW, TRUW, and SNF1 examples have different limiting PAG values, as shown in Figure 2).

CONCLUSION

RISKIND has been shown to be a useful emergency response planning tool for shipment of radioactive waste and spent nuclear fuel. The code has been used to project individual and population doses for the early and intermediate phases following an accident involving the release of radioactive material. In the process, the decontamination factors for deposited radioactivity to achieve a specific PAG, as input to RISKIND, were provided on an isopleth-by-isopleth basis downwind of the accident. RISKIND can also be used to determine the most restrictive PAG, in large part on the basis of the type of radioactive material released, as demonstrated in the examples provided. However, the quantity of material involved can also be a major factor. For example, severe accidents involving LLW shipped in Type A packaging can have consequences similar to or worse than those from TRUW, SNF, and HLW accidents involving material shipped in Type B packaging, because more radioactive material is released.

REFERENCES

1. Federal Emergency Management Agency, 1998, *Guidance for Developing State, Tribal, and Local Radiological Emergency Response Planning and Preparedness for Transportation Accidents*, FEMA REP-5, Rev. 2, Draft 3, March 31.

2. U.S. Department of Energy, 1997, *Final Waste Management Programmatic Environmental Impact Statement for Managing Treatment, Storage, and Disposal of Radioactive and Hazardous Waste*, DOE/EIS-0200-F, Office of Environmental Management, Washington, D.C., May.

3. U.S Environmental Protection Agency, 1992, *Manual of Protective Action Guides and Protective Actions for Nuclear Incidents*, EPA 400-R-92-001, Office of Radiation Programs, Washington, D.C., May.

4. Yuan, Y.C., S.Y. Chen, B.M. Biwer, and D.J. LePoire, 1995, *RISKIND — A Computer Program for Calculating Radiological Consequences and Health Risks from Transportation of Spent Nuclear Fuel*, ANL/EAD-1, Argonne National Laboratory, Argonne, Ill., Nov.

5. U.S. Nuclear Regulatory Commission, 1977, *Final Environmental Impact Statement on the Transportation of Radioactive Material by Air and Other Modes*, NUREG-0170, Office of Standards Development, Washington, D.C., Dec.

6. Fischer, L.E et al., 1987, *Shipping Container response to Severe Highway and Railway Accident Conditions*, NUREG/CR-4829, UCID-20733, prepared by Lawrence Livermore National Laboratory, Livermore, Calif., for the U.S. Nuclear Regulatory Commission, Office of Nuclear Regulatory Research, Division of Reactor System Safety, Washington, D.C., Feb.

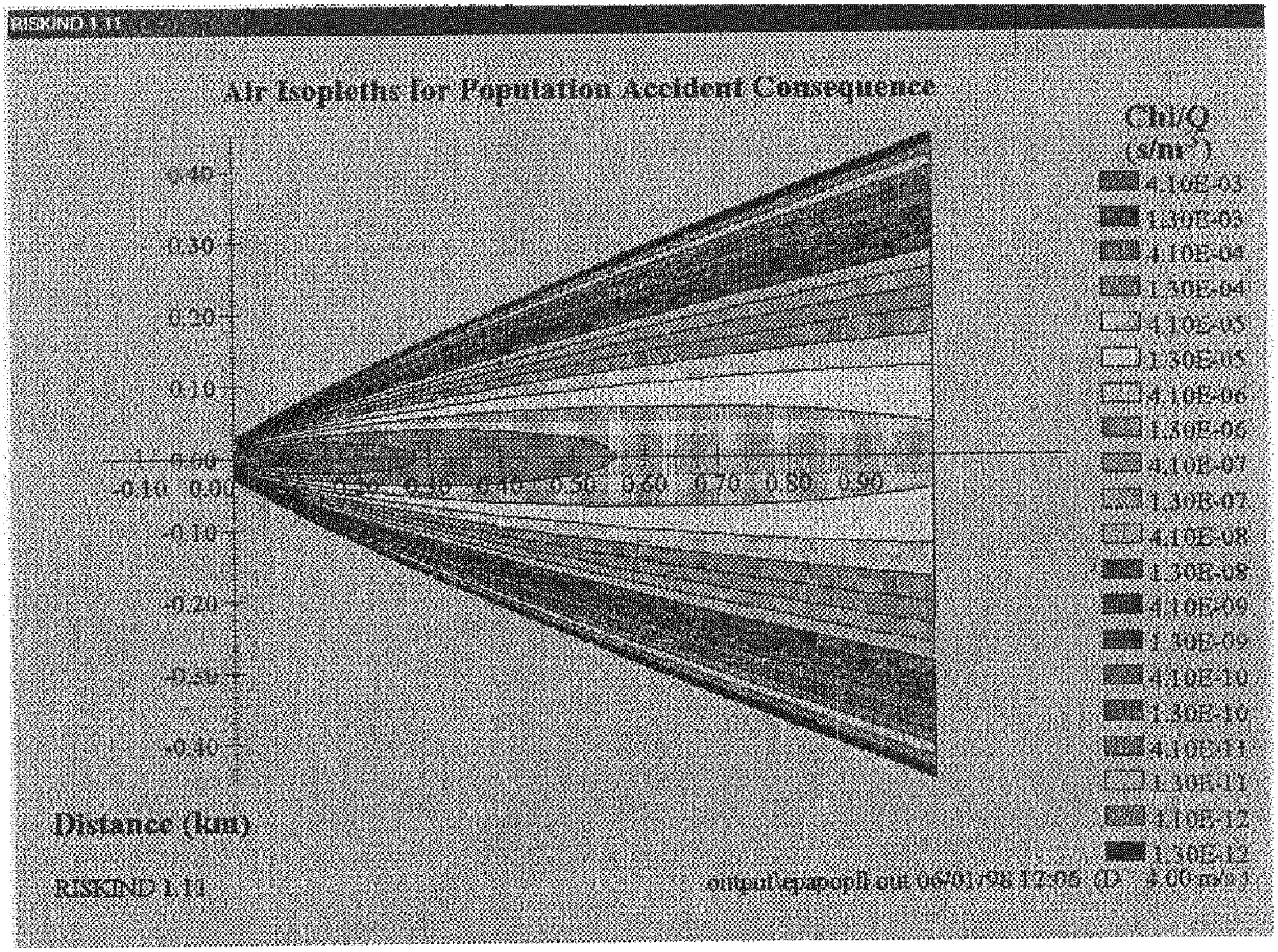

Figure 1. Isopleths of time-integrated air concentrations following an accidental release of radioactive material under neutral stability weather conditions (ground-level release, Pasquill stability class D, 4 m/s windspeed).