RAE-8339/12-1

EXPOSURES AND HEALTH EFFECTS FROM SPENT FUEL TRANSPORTATION

November 29, 1985

G.M. Sandquist
V.C. Rogers
A.A. Sutherland
G.B. Merrell

Prepared for

U.S. Department of Energy
Office of Civilian Radioactive Waste Management
Washington, D.C.

Rogers and Associates Engineering Corporation
P.O. Box 330
Salt Lake City, Utah 84110

It is important to recall the conservative assumptions made in arriving at these estimates for the maximum consequences of severe but credible rail accidents that result in significant water contamination. The probability of a rail cask accident with radionuclide release is no greater than 2 occurences per millcon rail transport accidents. Futhermore, the probability that such an accident would occur near a major reservoir and that prevailing weather conditions would combine to result in significant reservoir water contamination is extremely small. In the very unlikely event that a water reservoir were actually contaminated by a spent fuel accident release it is reasonable to assume that normal water treatment processes, combined with monitoring and emergency actions, would significantly reduce doses received by the affected population to levels well below those predicted by this maximum consequence analysis.

It is also helpful to put the impacts in Table 3-5 into perspective. Assuming an annual water ingestion of 400 quarts per year by each person, for the water consumption assumed in the calculations (one percent of one billion gallons), this water quantity would service about 37 million people. In a single year, using the same cancer risk factor as used in Section 3.3 (Ref 19), those people would experience about 72,000 cancer fatalities from other causes. Again, even using very conservative calculations of accident effects, the worst case rail cask accident that could contaminate a water supply does not pose a significant health impact.

3.4 CLEANUP TIME AND COST ESTIMATES FOR SPENT FUEL RAIL CASK ACCIDENTS

The risk of injuries and fatalities resulting from releases of radioactive material as a consequence of a severe but credible rail cask accident can be reduced if a cleanup of the more highly contaminated areas is carried out. However, the total economic costs associated with cleanup and reclamation for a substantial radionuclide release could be very high and the net reduction in associated health effects relatively low (see Section 3.3).

Detailed estimates of the costs incurred for cleanup and recovery from a shipping cask accident in a highly developed urban environment have previously been made in several studies (Refs 20 and 21). Total cost estimates of about 2 billion dollars have been projected following the atmospheric release of about a 1000 curies in a city. The bulk of these costs are attributed to the denial of public access to contaminated areas while cleanup occurs.

The economic costs for cleanup and recovery will be strongly dependent on the amount and type of radioactive material released, the particular setting (rural, urban, plain, mountainous, sea shore, etc.) and the level of cleanup (i.e., the minimum residual activity level that is permitted to remain after cleanup).

In this analysis the cost and manpower estimates for cleanup and recovery from worst case rail cask accidents are for a contaminated rural setting. The three classes of rail cask accidents described previously were considered.

Table 3-6 provides the ground areas calculated by the PATHRAE-T code as being contaminated after a spent fuel rail cask accident. The areas are shown for contamination above various levels of surface activity. For example, a level of 10 $\mu Ci/m^2$ for the 1380 curie release from an impact, burst and oxidation class accident is associated with a contaminated area of 2.16 km^2. The characteristics for other contamination levels and accident classes are similarly defined.

TABLE 3-6

CONTAMINATED AREAS FROM SPENT FUEL RAIL CASK ACCIDENTS

Accident Class	Radiation Release (Ci)	Level of Contamination ($\mu Ci/m^2$)	Contaminated Area (km^2)
Impact	8.1	10	0.013
		5	0.025
		1 (≈250 mrem/yr)	0.13
		0.5	0.26
		0.2	0.67
Impact and Burst	153	10	0.24
		5 (≈500 mrem/yr)	0.48
		1	2.4
		0.5	4.9
		0.2	13
Impact, Burst and Oxidation	1380	10	2.2
		5 (≈500 mrem/yr)	4.3
		1	22
		0.5	45
		0.2	110

* Activity for Kr-85 (and all other radioactive noble gases) is omitted. All other nuclides are eventually assumed to be deposited in the soil.

The various levels of soil contamination listed in Table 3-6 can be re... ed approximately to average annual radiation exposure that would be incurred by individuals living in the contaminated area immediately after cleanup. The three principal nuclides that account for over 99.5 percent of the activity deposited on the ground are Co-60, Cs-134 and Cs-137. Healy (Ref 22) estimates that a uniform soil activity of 80 pCi/g of Cs-137 or Cs-134 will result in a total annual individual dose from all pathways combined (inhalation, ingestion, and external radiation) of about 500 mrem per year to an individual living on the contaminated site and consuming food from a home garden. A soil activity of 80 pCi/g (Cs-134 or Cs-137) is conservatively associated with a surface contamination of about 5 $\mu Ci/m^2$.

For Co-60, which is the dominant nuclide for the impact class spent fuel accident, a soil activity of about 20 pCi/g, or 2 $\mu Ci/m^2$ is a... ciated with the equivalent 500 mrem per year dose to an individual living on the contaminated site. In view of Federal policy (both EPA and NRC) to minimize doses to both individuals and population groups, it is difficult to predict the actual cleanup levels that would be required. The EPA (Ref 23) has recommended a cleanup level of 0.2 $\mu Ci/m^2$ for transuranic elements in the general environment.

Using the data from Table 3-6 it was possible to project a set of cost and time requirements for different cleanup levels in a rural setting. Knowing the ground area of contamination and assuming an acceptable depth of soil removal, the volume of contaminated soil was estimated.

Rough estimates of cleanup costs and recovery time requirements are given in Table 3-7, for cleanup to a level that limits individual dose rates from radionuclides to 500 mrem/yr. For a given rail cask accident ... ss, the volume of contaminated soil that was removed was estimated by

TABLE 3-7

CLEANUP COSTS AND RECOVERY TIME ESTIMATES FOR RURAL SPENT FUEL RAIL CASK ACCIDENTS*

Accident Class	Contaminated Land Area (m^2)	Total Cost Range ($) Low	High	Cleanup and Recovery Time (Calendar Days)
I - Impact	6.3E+4	2.0E+5	9.5E+6	25
II - Impact and Burst	4.8E+5	1.4E+6	7.0E+7	68
III - Impact, Burst and Oxidation	4.3E+5	1.3E+7	6.2E+8	460

* Cleanup is to a level that reduces individual dose rates from deposited radionuclides down to a maximum value of 500 mrem/yr.

assuming a 10 cm excavation depth. Costs per cubic meter of soil removed were then assessed for the four categories:

- Monitoring, excavating, loading and packaging. These costs vary with terrain, equipment accessibility and packaging (if necessary) requirements.
- Transportation costs to the nearest acceptable disposal site. These costs vary with travel distance and transportation routes.
- Disposal costs. This varies with the disposal site selected and necessary site preparations to accomodate the given waste form.
- Site restoration costs. This includes costs for fill material, hauling, spreading, and seeding. Also, erosion protection and replacement of existing improvements and utilities may be required.

Estimates for cleanup and restoration costs range from $10/m^3 for simple monitoring, excavation and loading of contaminated soil in open trucks to $430/m^3 for extensive monitoring, packaging the contaminated soil in sealed drums and loading the drums in trucks. Similar ranges of extremes exist for transportation ($15/m^3 to $530/m^3) and disposal ($5/m^3 to $510/m^3) costs depending upon the specific cleanup scenario projected. The low cost estimates are based on costs projected for cleanup of the Vitro uranium mill tailings in Salt Lake City, Utah (Ref 24). The Vitro cleanup represents rail transportation over about 100 miles. The high cost estimates are based on transportation and waste preparation cost estimates for low-level radioactive wastes from Reference 25 and disposal costs for the Barnwell, South Carolina low-level waste facility (Ref 26). For the latter, a highway transportation distance of about 400 miles was assumed. All cost estimates are adjusted to 1985 dollars.

Estimated cleanup and recovery times in calendar days are also provided for each scenario shown in Table 3-7. These time estimates assume about 4 to 7 calendar days for emergency response, radiation monitoring, and evaluation of the contaminated area. The remaining time is devoted to actual cleanup and removal of contaminated materials. The mathematical relationship assumed for the cleanup and recovery time is approximately linearly dependent upon the contaminated land area, with a correction applied for economy of scale for large areas.