PROJECTED ENVIRONMENTAL IMPACTS OF RADIOACTIVE MATERIAL TRANSPORTATION TO THE FIRST US REPOSITORY SITE*

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Abstract

PROJECTED ENVIRONMENTAL IMPACTS OF RADIOACTIVE MATERIAL TRANSPORTATION TO THE FIRST US REPOSITORY SITE.

The relative national environmental impacts of transporting spent fuel and other nuclear wastes to each of nine candidate repository sites in the United States of America were analysed. Two scenarios were examined for each repository: (1) shipment of 5 year old spent fuel and defence high level waste (DHLW) directly from their points of origin to a repository (Reference Case); (2) shipment of 5 year old spent fuel to a Monitored Retrievable Storage (MRS) facility and shipment (by dedicated rail) of 10 year old consolidated spent fuel from the MRS to a repository. Transport by either all truck or all rail from the points of origin were analysed as bounding cases. The computational system used to analyse these impacts included the WASTES II logistics code and the RADTRAN III risks analysis code. The radiological risks for the Reference Case increased as the total shipment miles to a repository increased for truck; the risks also increased with mileage for rail but at a lower rate. For the MRS scenario the differences between repository sites were less pronounced for both modal options because of the reduction in total shipment miles possible with the large dedicated rail casks. All the risks reported are small in comparison to 'natural background'.

Introduction

Spent fuel from commercial nuclear power reactors in the United States will be permanently disposed of in mined geologic repositories. The Nuclear Waste Policy Act (NWPA) of 1982 outlined the implementation of this approach by the US Department of

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Energy (DOE). The DOE has begun selection of a site for a first repository from among nine sites in three geologic media - salt, tuff, and basalt. A Monitored Retrievable Storage (MRS) facility may be included in the system; spent fuel would be stored for up to 5 years at an MRS, which would also consolidate the fuel before shipping it to the repository. This paper discusses the relative national environmental impacts of transporting nuclear wastes to each of the nine candidate repository sites in the United States (Reference 1). Several of the potential sites are closely clustered and, for the purpose of distance and routing calculations, are treated as a single location. These are: Cypress Creek Dome and Richton Dome in Mississippi (Gulf Interior Region), Deaf Smith County and Swisher County sites in Texas (Permian Basin), and Davis Canyon and Lavender Canyon sites in Utah (Paradox Basin). The remaining sites are: Vacherie Dome, Louisiana; Yucca Mountain, Nevada; and Hanford Reservation, Washington.

For compatibility with both the repository system authorized by the NWPA and with the MRS option, two separate scenarios were analyzed. In brief, they are (1) shipment of spent fuel and high level waste (HLW) directly from waste generators to a repository (Reference Case) and (2) shipment of spent fuel to a Monitored Retrievable Storage (MRS) facility and then to a repository.

Problem Definition

In order to perform cost and risk analyses of the impacts of transportation for a future US nuclear waste management system, a large array of data is required. These data include information on the transport links and surrounding populations, routing information (e.g. distances traveled), the packaging (e.g. cask capacity), transport mode characteristics (e.g. train speeds), radionuclide inventory, and pertinent operational characteristics of the system such as accident rates. These data are used as inputs for two major computational tools, the WASTES II logistics code and the RADTRAN III risk analysis code. This complex computational system is described more fully in Reference 2.

For the Reference Case, the primary waste stream is spent nuclear fuel (SF) from reactors. Secondary waste streams considered for this case include defense high level wastes (DHLW) from the Savannah River Plant in South Carolina, the Hanford Reservation in Washington, and the Idaho National Engineering Laboratory in Idaho, and commercially-generated high level waste from West Valley, New York (WVHLW). Acceptance of DHLW in a commercial repository was endorsed by the President of the United States in 1985 (Reference 3). In this case, all reactors will ship 5-year-old or older unconsolidated spent fuel directly to a candidate repository site. High level commercial and defense wastes will also be shipped directly to the repository. Two primary modal options are examined for the Reference Case: all truck and all rail from reactors and HLW generators. The resultant costs and risks will bound the transportation impacts. No attempt has been made to forecast the actual fractions of truck and rail transport that might be used. The shipping system ultimately used for transportation of spent fuel and HLW will be a combination of modes determined by considerations such as the capabilities of handling facilities at the origins, freight rates, and operational constraints of the system.

MRS input data and scenarios are compatible with those being used by the MRS program. Final MRS documentation to be presented to Congress will, however, include additional alternatives not discussed here.

For the MRS cases, as in the reference case, reactors will ship 5-year-old or older unconsolidated spent fuel, but to an MRS rather than a repository. All spent fuel leaving the MRS will be consolidated and at least 10 years old. Additional secondary wastes would be generated at an MRS by the proposed spent fuel consolidation and possible overpacking operations. These MRS-related secondary wastes would consist of assembly hardware, high activity waste (HAW), and transuranic waste (TRU), which would also be shipped to the repository. Transport from an MRS would be by one of two possible shipping options: (1) 100-ton (100T) dedicated rail shipments of overpacked consolidated spent fuel and waste byproducts generated in the consolidation process and (2) 150-ton (150T) dedicated rail shipments of nonoverpacked consolidated spent fuel and byproducts. As in the Reference Case, high level commercial and defense wastes are shipped directly to the repository. For shipments from the MRS bounding values for total cask weight and payload characteristics were used either to minimize or to maximize cask capacity and, hence, to put upper and lower limits on the number of shipments from the MRS to the repository.

Results

Results of the analysis performed for the Reference Case are summarized in Tables 1-3, below. The differences in cost and impacts among the various repository sites are related primarily to the total shipping distances (Table 1). As can be noted from the table, spent fuel shipments account for the largest fraction of the total shipping distance for both modal options, comprising from 70-80 percent of the total truck travel and from 62-75 percent of the total rail travel. In either case the largest percentages are associated with travel to the westernmost site (Hanford, Washington). The fraction of total travel attributable to spent fuel transport increases as the potential repository site is shifted to the west because most of the spent fuel inventory projected to require shipment to the first repository is from reactors in the eastern United States. The relative contribution of high level wastes requiring shipment to the repository is between 19 and 29 percent for truck and 25 and 37 percent for rail. Although the projected mileage increases as the more western repository options are analyzed, the relative influence of high

TABLE 1. TOTAL SHIPMENT-MILES (millions of miles*)
REFERENCE CASE-Direct to Repository

Mode/Waste Type	Repository Location GIR	Vacherie	Permian	Paradox	Yucca Mt	Hanford
100% Truck						
SF	67.4	71.7	94.4	115.1	141.8	149.7
DHLW	28.0	28.0	26.0	28.0	33.0	35.0
WVHLW	1.0	1.0	1.0	2.0	2.0	2.0
TOTAL	96.4	100.7	121.4	145.1	176.8	186.7
100% Rail						
SF	11.0	11.7	15.4	18.8	23.2	24.6
DHLW	6.5	6.5	6.1	6.5	7.6	8.4
WVHLW	0.2	0.2	0.2	0.2	0.3	0.3
TOTAL	17.7	21.2	21.7	25.5	31.1	33.3

* 1 mile = 1.608 km

TABLE 2. TOTAL TRANSPORTATION COSTS ($M)
REFERENCE CASE-Direct to Repository

Mode/Waste Type	Repository Location GIR	Vacherie	Permian	Paradox	Yucca Mt	Hanford
100% Truck						
CAPITAL	227.2	234.2	261.2	290.1	325.1	337.2
OPERATING	708.9	730.0	866.0	1015.1	1213.6	1277.8
TOTAL	936.1	964.2	1127.2	1305.2	1538.7	1615.0
100% Rail						
CAPITAL	267.3	277.7	300.9	322.5	354.2	362.8
OPERATING	714.7	734.9	821.6	885.3	991.0	1013.8
TOTAL	982.0	1012.6	1122.5	1207.8	1345.2	1376.6

level wastes on the results decreases. Data in Table 1 indicate that miles traveled to the westernmost sites (Yucca Mt, Nevada, and Hanford, Washington) are almost double the total shipment miles required for transport to the easternmost sites in the Gulf Interior Region.

Transportation costs for the repository location options are summarized in Table 2. These costs increase with the total number of shipment-miles; however, because of the tariff structures of the transport modes, they do not increase in a linear manner. Truck costs increase by approximately 75 percent between the most eastern site in the Gulf Interior Region and the Hanford site in the West. Consistent with the rail rate structure, total rail costs for these sites vary by only about 40 percent. Truck costs are lower than rail for the easternmost sites and higher than rail for the western sites. The contribution of spent fuel cost to the total is consistent with the fraction of shipment mileage at-

TABLE 3. SUMMARY OF THE TOTAL RISKS OF TRANSPORTATION
REFERENCE CASE - Direct to Repository

	Repository					
MODE	GIR	VACHERIE	PERMIAN	PARADOX	YUCCA MT	HANFORD
100% Truck from origin						
SF						
Radiological[1]	4.6	5.0	6.2	7.7	9.2	10
Nonradiological[2]	13	14	18	24	29	31
HLW						
Radiological	1.8	1.7	1.7	1.8	2.1	2.1
Nonradiological	6.2	5.8	6.2	6.1	7.4	7.4
100% Rail from origin						
SF						
Radiological	.16	.17	.18	.21	.24	.25
Nonradiological	.81	.85	1.0	1.3	1.6	1.6
HLW						
Radiological	.062	.067	.063	.066	.079	.074
Nonradiological	.63	.69	.64	.66	.84	.79
TOTALS						
Truck from origin:						
Radiological	6.4	6.7	7.9	9.5	11	12
Nonradiological	19	20	24	30	36	38
Rail from origin:						
Radiological	.22	.24	.24	.28	.32	.32
Nonradiological	1.4	1.5	1.6	2.0	2.4	2.4

[1] Radiological health effects include latent cancer fatalities and genetic effects in all generations.
[2] Nonradiological fatalities

tributable to spent fuel transport for truck; it is somewhat less than the fraction of total mileage for rail.

Because the points of origin of most shipments (i.e. reactors) are primarily in the eastern United States, the average fractions of total travel in rural, suburban, and urban population-density zones are about the same for spent fuel transport to each candidate repository site. Consequently, total travel distance becomes the major discriminator of risk between sites for a given shipment scenario. Table 3 shows that the Gulf Interior Region (GIR) and Vacherie, Louisiana, sites, which are closest to the origin points, have the lowest overall risks associated with them; while those sites farthest from the majority of the country's reactors have the highest associated risks. However, the total risks associated with the closest repository sites only differ from those for the most distant site by about a factor of 1.9 to 2.1 for truck and by about a factor of 1.5 to 1.8 for rail. These factors generally parallel increases in shipment-miles except for the radiological risk of rail transport, which increases at a significantly lower rate than the mileage. A component of radiological risk for rail transport, but not for truck transport, is associated with required endpoint classification and

TABLE 4. TOTAL SHIPMENT-MILES (millions of miles)
MRS CASE - MRS at Oak Ridge

	Repository Location					
Mode/Waste Type	GIR	Vacherie	Permian	Paradox	Yucca Mt	Hanford
Truck from Origin						
SF to MRS	48.8	48.8	48.8	48.8	48.8	48.8
DHLW to Repos.	28.0	28.0	26.0	28.0	33.0	35.0
WVHLW to Repos.	1.0	1.0	1.0	2.0	2.0	2.0
Rail from Origin						
SF to MRS	8.0	8.0	8.0	8.0	8.0	8.0
DHLW to Repos.	6.5	6.5	6.1	6.5	7.6	8.4
WVHLW to Repos.	0.2	0.2	0.2	0.2	0.3	0.3
Rail from MRS to Repository (150T, nonoverpacked SF)						
0.2	0.3	0.6	0.8	1.5	1.0	
TOTALS						
Truck from Origin						
150T from MRS	78.0	78.1	76.4	78.6	85.3	86.8
Rail from Origin						
150T from MRS	14.9	15.0	14.9	15.5	17.4	17.7

TABLE 5. TOTAL TRANSPORTATION COSTS ($M)[1]
MRS CASE - MRS at Oak Ridge

	Repository Location					
Mode/Waste Type	GIR	Vacherie	Permian	Paradox	Yucca Mt	Hanford
Truck from Reactors, HLW Sites						
CAPITAL	201.0	202.1	204.3	209.8	214.2	217.5
OPERATING	613.7	608.1	601.1	615.8	639.0	652.9
Rail from Reactors, HLW Sites						
CAPITAL	232.3	237.7	235.9	239.5	246.7	250.3
OPERATING	643.7	646.1	647.5	644.2	667.9	664.4
Rail from MRS to Repository (150T, nonoverpacked)						
CAPITAL	78.6	78.6	78.6	78.6	100.6	84.1
OPERATING	172.7	199.0	265.3	306.8	468.7	346.8
TOTALS						
Truck from Origin						
150T from MRS	1066.0	1087.8	1149.3	1211.0	1422.5	1301.3
Rail from Origin						
150T from MRS	1127.3	1161.4	1227.3	1269.1	1483.9	1345.6

[1] The totals presented in this table are for the case in which all spent fuel and HLW wastes are shipped by the mode indicated; dedicated rail shipments from the MRS to the repository are added.

TABLE 6. SUMMARY OF THE RISKS OF TRANSPORTATION OF SPENT FUEL AND HIGH LEVEL WASTES: MRS CASE - (All SF to MRS, 150T cask)

Mode	Repository GIR	VACHERIE	PERMIAN	PARADOX	YUCCA MT	HANFORD
100% Truck from Origin						
SF						
Radiological[1]	3.6	3.6	3.6	3.6	3.6	3.6
Nonradiological[2]	9.1	9.1	9.1	9.1	9.1	9.1
HLW						
Radiological	1.8	1.7	1.7	1.8	2.1	2.1
Nonradiological	6.2	5.8	6.2	6.1	7.4	7.4
100% Rail from Origin						
SF						
Radiological	.14	.14	.14	.14	.14	.14
Nonradiological	.92	.92	.92	.92	.92	.92
HLW						
Radiological	.062	.067	.063	.066	.079	.074
Nonradiological	.63	.69	.64	.66	.84	.79
150T Rail from MRS						
Radiological	.017	.035	.035	.038	.054	.042
Nonradiological	1.4	2.6	3.8	5.3	1.0	6.1
TOTALS						
Truck from Origin						
150T from MRS						
Radiological	5.4	5.3	5.3	5.4	5.8	5.7
Nonradiological	17	18	19	20	26	22
Rail from Origin						
150T from MRS						
Radiological	.22	.25	.24	.25	.27	.26
Nonradiological	2.9	4.2	5.3	6.9	12	7.7

[1] Radiological health effects include latent cancer fatalities and genetic effects in all generations.
[2] Nonradiological fatalities

inspection stops. Because this component is distance-independent (i.e. the same for all trips, short or long), the influence of distance traveled on total radiological risk for rail is less pronounced than for truck.

Insertion of an MRS into the system tends to reduce the variation in cost and risk between the potential repository sites because of the reduction in shipment-miles possible with the large dedicated rail casks. The 100T cask can carry between 18 and 45 consolidated, canistered spent fuel assemblies; the 150T cask capacity is between 48 and 171 assemblies. The actual payload depends on the fuel type (BWR or PWR) and the geologic medium of the repository because the consolidated fuel is packaged differently according to whether the repository is developed in salt, tuff, or basalt. Further, the MRS also reduces the difference in costs and risks between modal options from the reactors and high-level-waste sites, which dominate the total impacts. The 150T rail cask in particular reduces the impacts of transportation from the MRS to the repository because of its large payload per shipment.

Use of repository-specific canisters and overpacks for the MRS cases influences the relative ranking of the Yucca Mountain (tuff) and the Hanford (basalt) repository sites because the canister and overpack for tuff are lower in capacity than the canister and overpack for basalt (all of the other sites use the canister and overpack for salt). In addition, the projected rail routings between the MRS locations and Yucca Mountain are more circuitous than the rail routings between the MRS locations and Hanford. The combination of increased shipment-miles and reduced canister and overpack capacities causes Yucca Mountain to rank higher in cost and risk than the Hanford repository site. Tables 4-6 summarize the shipment-miles, costs, and risks for the MRS case for an MRS located in Oak Ridge, Tennessee, with 150T dedicated rail casks between the MRS and the repository.

Summary

To summarize, between 17 and 38 truck accident fatalities, between 1.4 and 7.7 rail accident fatalities, and between 0.22 and 12 radiological health effects can be expected to occur as a result of radioactive material transportation during the 26-year operating period of the first repository. During the same period in the United States, about 65,000 total deaths from truck accidents and about 32,000 total deaths from rail accidents would occur; also an estimated 58,300 cancer fatalities are predicted to occur in the United States during a 26-year period from exposure to background radiation alone (not including medical and other manmade sources) (Reference 4). The risks reported here are upper limits and are small by comparison with the "natural background" of risks of the same type.

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