Environmental Impacts From Managing the U.S. Department of Energy's Spent Nuclear Fuel—A 40-Year Look Into the Future

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This paper summarizes the analysis of potential environmental impacts from managing the U.S. Department of Energy's (DOE) Spent Nuclear Fuel (SNF) for the next 40 years. Significant to this analysis are the multiple scenarios examined, each having major packaging and transportation operations components. This paper does not include activities of DOE's Civilian Nuclear Waste Management Program for disposing of nuclear power related SNF.

INTRODUCTION

During the previous 40 years, DOE and its predecessor agencies have packaged, transported, stored, and reprocessed about 100,000 metric tons of SNF. Today, DOE's SNF inventory is about 2,700 metric tons stored in locations across the U.S. This inventory also includes research reactor fuel in foreign countries which the U.S. may make future decisions to accept back. Most of the DOE-owned SNF is from defense-related activities to produce plutonium and tritium. A small amount of SNF is from U.S. Navy propulsion reactors and from domestic research reactors at government and university facilities. Managing SNF includes storage, conditioning, packaging, transportation, and all necessary actions to prepare for its final disposal in a geologic repository.

The scope of the recently completed Environmental Impact Statement (DOE 1995a) on the DOE program to manage the remaining and to-be-generated SNF included:

- Defining the purpose and need for a national effort;
- Examining the reasonable alternatives; and
- Determining the potential environmental impacts of each alternative.

DOE owned SNF is now located at 59 DOE, commercial, Navy, and university sites. The alternatives examined include as few as 200 intersite domestic shipments to over 7,000 shipments depending on the alternatives selected. Environmental impacts from managing SNF were examined from the perspective of three major DOE sites and several alternative sites. The final Environmental Impact Statement (EIS) was published in April 1995 with a Record of Decision (ROD) issued (DOE 1995b) in May 1995.

ALTERNATIVES

DOE examined five alternatives (DOE 1994) for managing SNF. These alternatives included variations in the number of storage locations, amount of SNF shipped, potential fuel stabilization methods, needed facilities, technology development requirements, and other parameters:

- **No Action**, which is taking the minimum actions required for safe and secure management of SNF at or close to the generation site or current storage location;

- **Decentralization**, which is storing most SNF at or close to the generation site or current storage location with limited shipments to DOE facilities;

- **1992/1993 Planning Basis**, which is transporting and storing newly generated SNF at Idaho National Engineering Laboratory or the Savannah River Site;

- **Regionalization**, which is distributing existing and projected SNF among DOE sites based primarily on fuel type or geographic location; and,

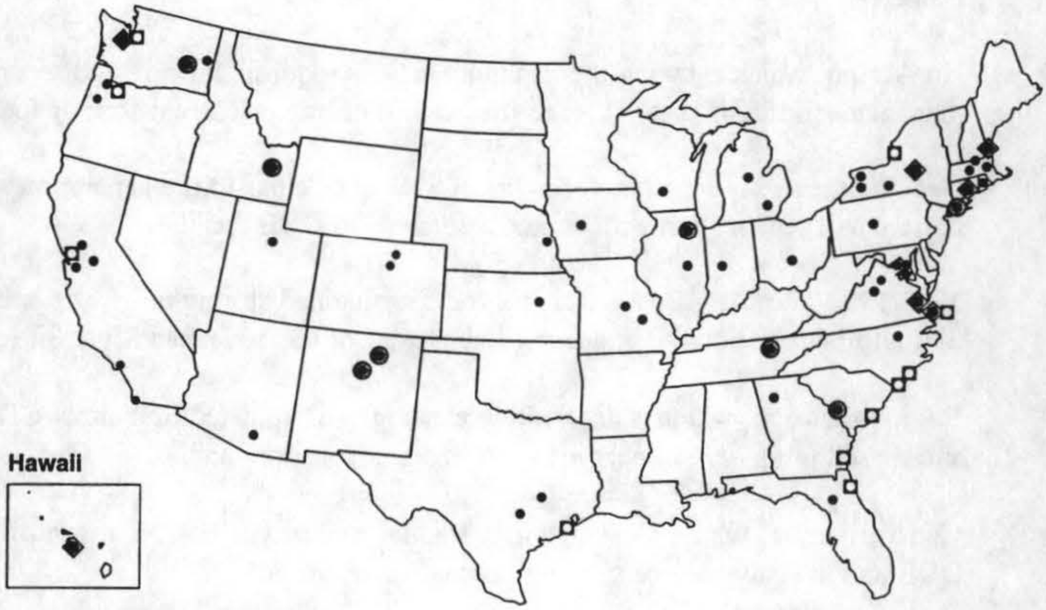
- **Centralization**, which is managing all existing and projected SNF inventories from DOE and the Navy at one site until ultimate disposition.

Three DOE site alternatives were selected: the Hanford Site, the Idaho National Engineering Laboratory, and the Savannah River Site. Also, four Naval shipyards and the DOE Kesselring Site (in upstate New York) were identified as having experience in handling Naval SNF; these shipyards are: Norfolk, in Portsmouth, VA; Portsmouth, in Kittery, ME; Pearl Harbor, in Honolulu, HI; and Pudget Sound, in Bremerton, WA.

In response to public comments generated in the scoping process, DOE decided to broaden the range of siting alternatives by considering other sites for future SNF management. DOE used a disciplined screening process, resulting in the addition of the Oak Ridge Reservation and the Nevada Test Site as reasonable alternative sites for regionalized or centralized SNF management. Figure 1 shows the location, approximate inventory, and SNF storage sites. Details on the SNF inventory site-by-site can be found in Volume I of the EIS (DOE 1995a) and in reference (DOE 1993).

METHODOLOGY

The EIS estimated the potential environmental consequences of SNF management alternatives based on conservative assumptions with a strong tendency to overestimate. Analytical approaches provided the maximum foreseeable consequences. Although a



1995 Inventory (Metric Tons Heavy Metal)[a]	
Hanford	2,133
Idaho National Engineering Laboratory	261
Savannah River Site	206
Oak Ridge Reservation	1
Other DOE Facilities	27
Universities	2
Other	16
Total	2,646

Legend

Source	No. of locations
U.S. Department of Energy Facilities	8
Naval Sites	7
Foreign Returns (potential points of entry)	11
Special-Case Commercial	3
Domestic Non-DOE	9
Universities	29

Figure 1. Existing spent nuclear fuel locations and quantities.

number of discriminators were examined to assist decisionmakers, the paper will focus on occupational health and safety factors:

Radiation Effects

Radiation exposure and its consequences are topics of intense public interest. Collective (population) dose to exposed populations was calculated by summing doses received by each member of the exposed population. Effects are calculated in terms of latent cancer fatalities. The factor (ICRP 1991) used to relate dose to effect is 0.0004 latent cancer fatalities per person-rem for workers and 0.0005 latent cancer fatalities per person-rem for people in the general population. The assumption for the later factor being higher is based on a possibly higher sensitivity to radiation for the public (vs radiation workers).

Risk

Annual risk is expressed in terms of the expected number of latent cancer fatalities per year, taking account of both the annual chance an accident might occur and the estimated consequences if it does occur.

Radiological Accidents

These are activities associated with transporting, receiving, handling, processing, and storing SNF involving substantial quantities of radioactive materials and limited quantities of toxic materials. Either routine SNF operations or accidents involving radioactive materials or toxic chemicals can result in exposure to workers or members of the public, or contamination of the surrounding environment. A number of existing accident analyses were evaluated to find a small group with relatively severe consequences or risks. These accidents included events such as small fires; severe accidents that a facility is designed to withstand; and beyond-design-basis events, which a facility is not designed to withstand. These accidents included those initiated by internal events, such as operational errors; those initiated by natural external phenomena, such as floods, tornados, and earthquakes; and those initiated by human-influenced external events, such as aircraft crashes and nearby explosions or toxic material releases. The accidents evaluated included those with an estimated probability ranging from 1 chance in 1,000,000 to 1 chance in 10,000,000 per year.

Transportation

In this EIS, one of the primary ways used to discriminate between alternatives is through the transportation impacts associated with each alternative. Some alternatives, such as the No Action alternative, would involve limited transportation of SNF and have few transportation impacts; while other alternatives such as the Centralization options, would involve extensive transportation of SNF and have greater transportation impacts.

Transportation impacts may be divided into two parts: (1) the impacts due to incident-free transportation and (2) the impacts due to transportation accidents. For incident-free transportation and transportation accidents, impacts may be further divided into two parts: (1) nonradiological impacts and (2) radiological impacts. The nonradiological impacts are composed of the vehicular impacts of transportation, such as vehicular emissions and traffic accidents, and are not related to the radioactivity present in the shipments.

In contrast to the nonradiological impacts, the radiological impacts are due to the radioactivity present in the SNF shipments. In the case of incident-free transportation, the radiological impacts result from the radiation field that surrounds the SNF shipping cask. These impacts are estimated for workers and the general population along the transportation route. In the case of transportation accidents, the radiological impacts would result from the radioactivity released from the SNF shipping cask during the accident. These impacts are also estimated for the general population along the transportation route. This EIS evaluated a full range of transportation accidents, up to and including accidents with very low probability, estimated to be on the order of one in 1 million years. In addition, the consequences of severe transportation accidents were evaluated. The probability of these severe accidents was estimated to be on the order of one in 10 million years.

Radiological impacts were determined for crew workers and the general population during normal, incident-free transportation. For truck shipments, the crew were the drivers of the transport vehicles. For rail shipments, the crew were workers in close proximity to the shipping containers during inspection or classification of railcars. The general population was persons within 800 m of the road or railway (off-link), persons sharing the road or railway (on-link), and persons at stops.

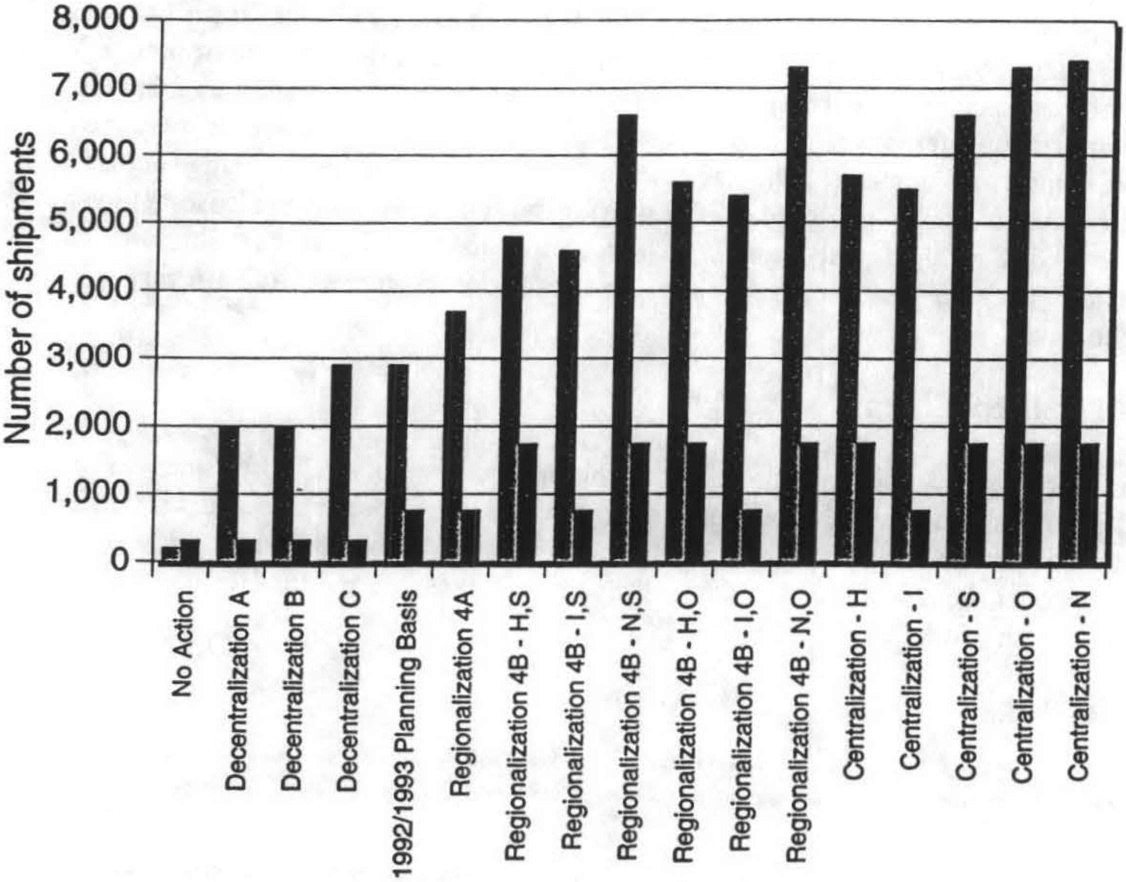
Collective does for the crew and general population were calculated using the RADTRAN 4 computer code (Nuehauser 1992). SNF was assigned a dose rate of 14 millirem per hour at 1 m from the shipping container. This dose rate yields a dose rate of 10 millirem per hour at 2 m from the vehicle, which is the regulatory maximum based on an exclusive use vehicle. A dose rate of 1 millirem per hour at 1 m was used for naval-type SNF shipments, based on measured dose rates from previous naval SNF shipments. Three population density zones (rural, suburban, and urban) were used. These zones correspond to mean population densities of 6,719 and 3, 861 persons per square kilometer, respectively.

Calculating the collective doses was based on developing unit risk factors. Unit risk factors provide an estimate of the impact from transporting one shipment of radioactive material over a unit distance of travel in a given population density zone. The unit risk factors are combined with routing information, such as the transport distances in various population density zones, to determine the risk for a single shipment (a shipment risk factor) between a given origin and destination. Maximum individual doses were calculated using the RISKIND computer code (Yuan 1993). The maximum individual doses for the routine transport offsite were estimated for transportation workers as well as members of the general population.

Incident-free nonradiological fatalities were also estimated using unit risk factors. These unit risk factors account for the fatalities associated with the exhaust emissions, but the distances used to estimate the impacts must be doubled to reflect the round trip distance because these impacts occur whether or not the shipment contains radioactive material.

Number of Shipments

Figure 2 graphically displays the number of shipments of SNF elements and SNF test specimens for the five primary alternatives and the subalternatives. Navy Fuel is shipped by rail. All other fuels and test specimens are shipped by truck.



Key:

Decentralization A: No examination of naval fuels
Decentralization B: Limited examination of naval fuels at Puget Sound Naval Shipyard
Decentralization C: Full examination of naval fuels at Idaho National Engineering Laboratory with spent nuclear fuel stored at naval sites
Regionalization 4A: Regionalization by fuel type
Regionalization 4B: Regionalization by geography

Site initials:
H: Hanford Site
I: Idaho National Engineering Laboratory
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■ Spent fuel
■ Test specimens[a]

a. Test specimens are small quantity fuel samples shipped for laboratory analysis

Figure 2. Number of spent fuel shipments.

RESULTS

Chapter 5 of the EIS presents the results of environmental consequence analysis. Data are presented for the five major alternatives and their sub-alternatives (21 total alternatives in all). Under all alternatives, over a 40-year period, the estimated number of latent cancer fatalities to the public from normal SNF management activities (facility operations plus transportation) would range from approximately zero to about two latent cancer fatalities, or about 0.05 per year (Figure 3) In general, the greatest radiation exposure from operations and incident-free transportation is associated with regionalization by fuel type and centralization alternatives. This is not surprising since these alternatives involve the greatest number of shipments. The risk associated with facility accidents is small across the alternatives as shown in Figure 4. The risk for transportation accidents poses a lower risk than facility accidents; see Figure 5. The risks associated with traffic fatalities (nonradiological) are greater than the risks due to radiation exposure. Both are very small, however.

CONCLUSIONS

To transportation practitioners, the results of this analysis are not at all surprising. Even on a department-wide and 40-year scale, the transportation of spent nuclear fuel is a safe and environmentally benign activity. Risks are not only low in this analysis, worldwide experience over the last 40 years confirms the safety of transport and the efficacy of the regulatory framework.

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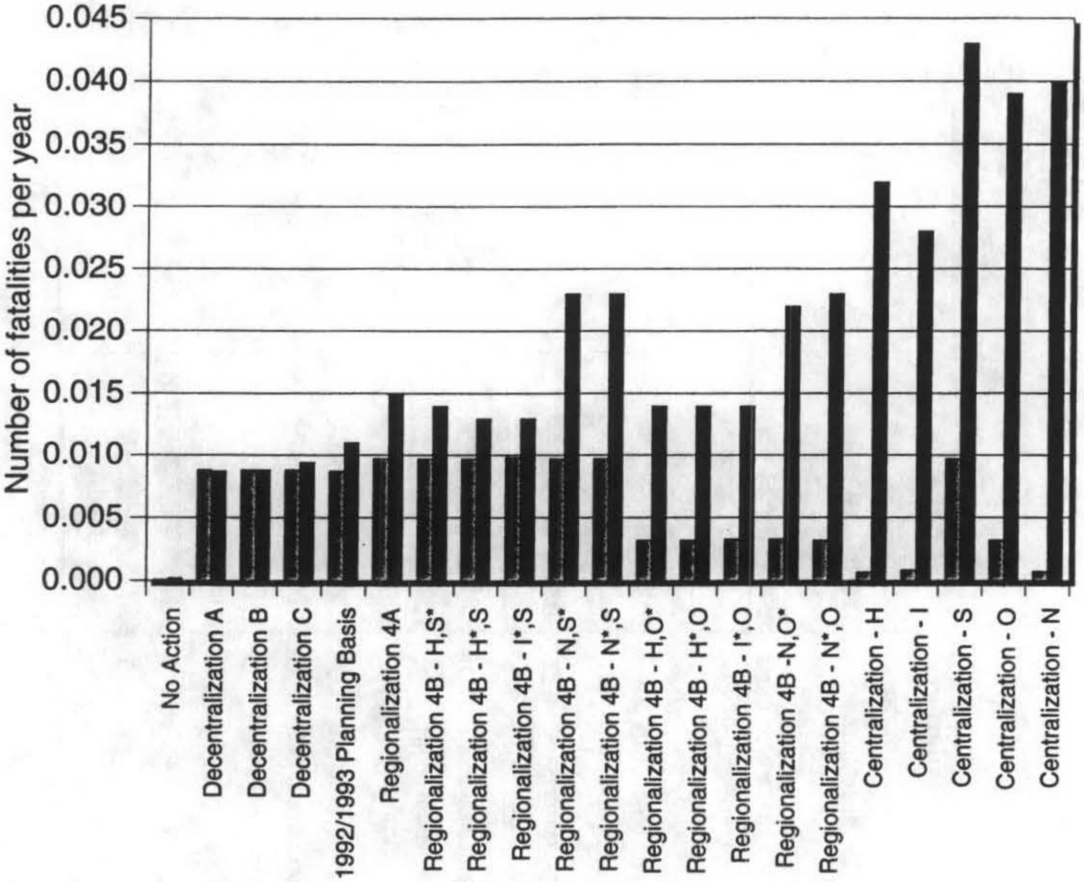
Yuan, Y.C., S.Y. Chen, D.J. LePoire, R. Rothman, *RISKIND - A Computer Program for Calculating Radiological Consequences and Health Risks from Transportation of Spent Nuclear Fuel*, ANL/EAIS-6, Rev. 0, Argonne National Laboratory, Argonne, Illinois, (Yuan 1993).

Figure 3. Maximum estimated latent cancer fatalities per year in the general population from normal spent nuclear fuel site operations and total fatalities from incident-free transportation.



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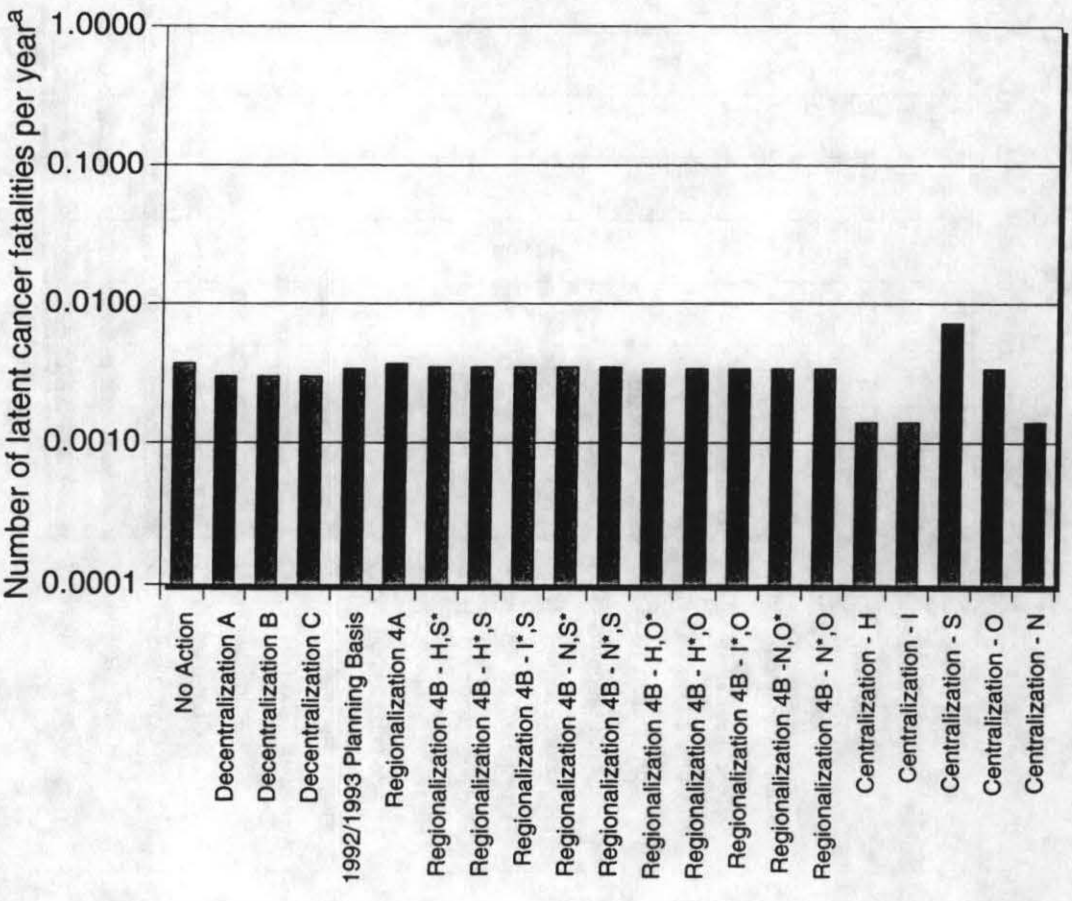
Operations
Transportation[a]

* Location of Expended Core Facility

a. Total fatalities are the sum of the estimated number of radiation-related latent cancer fatalities for workers and the general population and the estimated number of nonradiological fatalities from vehicular emissions. Average annual risk for incident free transportation was determined by dividing the cumulative risks over the entire transportation campaign by the estimated duration of the transportation compaign. Cumulative risks are presented in Chapter 5 of EIS Volume 1.

Figure 4. Estimate of risk of latent cancer fatalities in general population from facility accidents for spent nuclear fuel management activities.



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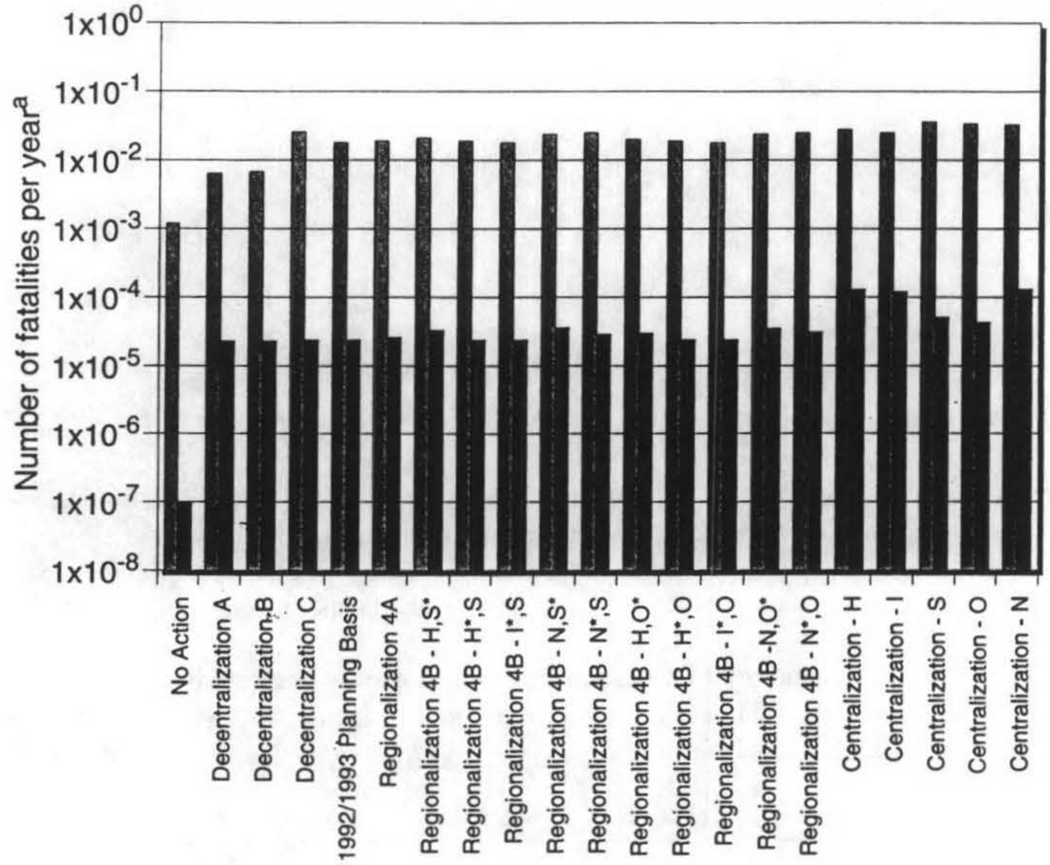
a. Facility risks are based on the product of the probability and consequences of the respective maximum foreseeable facility accident for each alternative and expressed in latent cancer fatalities per year.

Figure 5. Estimate of average annual risk from transportation accidents for spent nuclear fuel management activities.



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Traffic fatality risk
Radiological risk

* Location of Expended Core Facility

a. Radiological risk is in terms of latent cancer fatalities per year from spent nuclear fuel shipments; traffic fatality risk is in terms of estimated nonradiological traffic accident fatalities per year from spent nuclear fuel shipments.

b. Average annual risk was determined by dividing the cumulative accident risks over the entire transportation campaign by the estimated duration of the transportation campaign. Cumulative transportation accident risks are presented in Chapter 5 of EIS Volume 1.