SITE-SPECIFIC ANALYSIS OF A SPENT NUCLEAR FUEL TRANSPORTATION ACCIDENT *

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ABSTRACT

The number of spent nuclear fuel (SNF) shipments is expected to increase significantly during the time period that the United States’ inventory of SNF is sent to a final disposal site. Prior work estimated that the highest accident risks of a SNF shipping campaign to the proposed geologic repository at Yucca Mountain were in the corridor states, such as Illinois. The largest potential human health impacts would be expected to occur in areas with high population densities such as urban settings. Thus, our current study examined the human health impacts from the most plausible severe SNF transportation accidents in the Chicago metropolitan area. The RISKIND 2.0 program was used to model site-specific data for an area where the largest impacts might occur. The results have shown that the radiological human health consequences of a severe SNF rail transportation accident on average might be similar to one year of exposure to natural background radiation for those persons living and working in the most affected areas downwind of the actual accident location. For maximally exposed individuals, an exposure similar to about two years of exposure to natural background radiation was estimated. In addition to the accident probabilities being very low (approximately 1 chance in 10,000 or less during the entire shipping campaign), the actual human health impacts are expected to be lower if any of the accidents considered did occur, because the results are dependent on the specific location and weather conditions, such as wind speed and direction, that were selected to maximize the results. Also, comparison of the results of longer duration accident scenarios against U.S. Environmental Protection Agency guidelines was made to demonstrate the usefulness of this site-specific analysis for emergency planning purposes.

INTRODUCTION

With the recent approval by the United States Congress of a final geologic disposal repository for spent nuclear fuel (SNF) at Yucca Mountain in Nye County, Nevada, public interest is once again being directed towards the large national shipping campaign that will be necessary to transport the SNF to Yucca Mountain. The specter of a transportation accident releasing radioactive material into the nearby environment is one scenario that has been raised in public forums despite decades of safe SNF transport without a release. The likelihood of such a release remains extremely low because of stringent U.S. Nuclear Regulatory Commission (NRC) licensing requirements for SNF casks, as put forth in Title 10 of the Code of Federal Regulations Part 71 (*Packaging and Transportation of Radioactive Material*), and precautions taken by

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carriers. In the unlikely event that such a release might occur, this paper uses a site-specific analysis to examine the potential consequences of severe transportation accidents that might cause such a release.

INPUT ASSUMPTIONS AND ANALYSIS

Scenario Selection

The chosen accident scenario was designed to provide an estimate of human health impacts that are in the upper range of impacts that are plausible. Truck and rail shipment options are under consideration for shipment of the SNF (1). Because a rail cask can accommodate over five times more SNF than a truck cask, and because much more SNF could potentially be released to the environment, rail shipments were considered in this study. Under a mostly rail shipping option for the nation's SNF, Illinois and Connecticut were the states with the highest accident dose risk, as shown in Table I. The highest human health consequences from a potential SNF accident are expected to be in urban areas because of their higher population densities. The largest urban area in Illinois or Connecticut that would experience a significant volume of SNF traffic on the way to Yucca Mountain is the Chicago metropolitan area.

Under the mostly rail transportation option considered in the proposed action (1), approximately 7,000 SNF rail cask shipments could occur within Illinois, with about 860 shipments originating in-state. Of those shipments originating in-state, about 430 could originate in the Chicago metropolitan area. Another 470 shipments would originate nearby in Wisconsin and Michigan, resulting in at least 900 of the 7,000 SNF rail shipments expected in Illinois passing through the Chicago metropolitan area. More shipments through the Chicago area might be expected from reactors in the Northeastern U.S., but routing options are subject to change based on maintenance, weather, and traffic conditions. Thus, more than 900 SNF rail shipments through the Chicago area would be expected under the mostly rail transportation option. This large number of shipments near a highly populated area resulted in the consideration of an SNF rail accident scenario in the Chicago metropolitan area.

Table I. Accident Dose Risk for Mostly Rail SNF Shipping Option to the Proposed Geologic Repository at Yucca Mountain[a]

Rank[b]	State	Dose Risk[c] (person-rem)
1	Illinois	0.16
1	Connecticut	0.16
3	Utah	0.090
4	Iowa	0.057
5	Pennsylvania	0.055
6	District of Columbia	0.050
7	New York	0.049
8	Nebraska	0.039
9	California	0.027
10	Ohio	0.026

[a] Source: Ref. 1, top 10 states.
[b] State rank according to accident dose risk in descending order.
[c] Average of 6 shipping options.

Methodology

A site-specific analysis at a particular location along a potential rail route in the southern Chicago area was conducted using the RISKIND 2.0 radiological transportation risk program

(2,3). RISKIND has been used extensively in U.S. Department of Energy (DOE) transportation risk assessments to analyze the consequences of radiological transportation accidents (4). Version 2.0 of RISKIND incorporates a geographical information system (GIS) module that allows users to locate the accident position in a map window and view the extent of contamination following a potential accident. In addition, the program can make use of spatial information, such as population data, in its calculations. These capabilities make RISKIND a powerful tool in analyzing radiological releases of any type, including facility accidents or terrorist-initiated events. RISKIND runs under the Windows® operating system and requires no additional licenses for the GIS software included with the program. Aside from the data listed below, the remaining input parameters used were RISKIND default values.

Geographic Information Data

For this study, TIGER/Line® data from the 2000 Census were imported directly into RISKIND to map the locations of streets, railroads, and waterways. Population densities at the census tract level from the 2000 Census were provided in a separate underlying layer in the GIS module. These data are readily available at the Census Bureau's website (www.census.gov). Population data were retrieved from the SF1 geographic header file for Illinois. To determine human health impacts, the number of affected persons was determined by RISKIND once the location of the contaminated area from an accidental release was calculated by the code.

Source Term

RISKIND contains a SNF database (5) created for the DOE. SNF inventory data are compiled according to reactor type, fuel burnup, and fuel cooling period. SNF from pressurized-water reactors was considered in this study. A typical rail cask might be expected to contain approximately 24 assemblies (1). Each assembly contains approximately 460 kilograms (kg) of uranium (1), resulting in approximately 11.0 metric tons of uranium (MTU) per cask for input into RISKIND. The average burnup used in the analysis was 41,200 megawatt-days per metric ton of heavy metal, an average value estimated to be received at the proposed geologic repository (1). The fuel cooling period, the amount of time since the fuel was removed from the reactor, was assumed to be 10 years to account for fresher SNF, which is in contrast to the average fuel cooling period estimated to be 23 years (1).

Release Fractions

Data on accident conditions and the amount of radioactive material releases were based on prior engineering studies. Limited full-scale testing of SNF transportation casks in the past showed them to be extremely robust under accident conditions. However, it is not practical to test them under all hypothetical accident conditions. Thus, engineering design studies were employed to estimate potential radioactive releases under various scenarios. These scenarios involved different levels and combinations of physical and/or thermal strain on the casks and their contents.

An in-depth study (6) (commonly referred to as the Modal Study) was conducted for the United States Nuclear Regulatory Commission (NRC) by Lawrence Livermore National Laboratory to assess the potential for radioactive material release following potential accidents involving SNF casks. In the Modal Study, 20 severity categories covering the range of accident conditions, ranging from minor to severe, were identified. For each severity category, potential release fractions were estimated for different classes of material. The Modal Study accident severity category scheme is incorporated into the RISKIND program. A more recent follow-up evaluation of SNF cask responses to accident conditions was conducted for the NRC (7). This reexamination of cask responses was based in part on the Modal Study and used an event-tree analysis to identify potential accidents for both truck and rail shipments. For rail accidents, 21 cases were identified.

This study evaluated railcar accidents with a probability greater than 1×10^{-8}, taking into account all of the SNF railcar shipments considered in the proposed action for Yucca Mountain (1). Accidents with smaller probabilities cannot be assumed to be credible events. Given that the U.S. average for the probability that a railcar will be involved in an accident is approximately 5.39×10^{-8} per railcar kilometer of travel (4), about 4.3 SNF railcar accidents are expected on a statistical basis during the entire shipping campaign, assuming approximately 3.5 million railcar-km traveled per year for 23 years (1). The reexamination report (7) estimates that 99.996% of all SNF railcar accidents will not result in a release (Case 21). Of the 20 accident cases involving potential releases considered in the reexamination report, four cases were identified that had an estimated probability greater than 1×10^{-8} and involved train speeds less than 60 miles per hour (mph). The probabilities and estimated release fractions for these four accidents are listed in Table II. Cases 4, 5, and 6 involved railcar impact speeds of 30 to 60 mph followed by an engulfing fire, with the final temperature of the cask contents increasing in each case, from Case 4 to Case 6, as the result of a longer duration fire. Case 20 represents an accidental release solely due to a fire. Cases 2 and 7 were within the range of probability, but were not considered because these two cases involved train speeds greater than 60 mph. Such train speeds are not currently encountered in the Chicago urban setting, in part because of the hazards posed by the number of road/rail crossings in the area. However, the potential releases from these two cases are bounded by the four accidents considered.

Table II. Fraction of Material Released and Dispersed to the Environment[a]

		Radionuclide Class			
Case Number	Probability[b]	Kr	Cs	Ru	Particulates
4 (impact + cask temperature < 350°C)	1.3×10^{-4}	1.4×10^{-1}	4.1×10^{-9}	1.0×10^{-7}	1.0×10^{-7}
5 (impact + cask temperature < 750°C)	5.1×10^{-6}	1.8×10^{-1}	5.4×10^{-9}	1.3×10^{-7}	1.3×10^{-7}
6 (impact + cask temperature < 1,000°C)	6.5×10^{-8}	8.4×10^{-1}	3.6×10^{-5}	1.4×10^{-5}	1.4×10^{-5}
20 (fire only, cask temperature < 1,000°C)	2.7×10^{-5}	8.4×10^{-1}	1.7×10^{-5}	2.5×10^{-7}	2.5×10^{-7}

[a] Data from Ref. 7.
[b] Estimated probability of accident occurring during SNF shipping campaign to the proposed geologic repository.

Weather Conditions

The effect of weather plays an important role in assessing the potential impacts of a material release accident. Input to RISKIND includes stability class, wind speed, and wind direction. The predominant weather stability class in the Chicago area, as well as most areas of the country, is stability class D. In Chicago, the average annual wind speed is 10.3 mph (4.6 meters/second [m/s]) (8). However, higher impacts can be encountered under weather conditions that do not disperse a release as widely, thereby causing higher air and subsequent ground concentrations to which people could be potentially exposed. Such conditions could occur at nighttime under stable air conditions (stability class F) at lower wind speeds. For this analysis, impacts were assessed under D stability conditions with a wind speed of 4.6 m/s. For perspective, impacts were also assessed for F stability conditions with a wind speed of 1.5 m/s.

Impacts are highly dependent on the wind direction at the time of an accidental release. On an annual basis, the Chicago metropolitan area experiences wind primarily from the southwestern direction. Thus, such conditions have a higher probability of occurring during a potential accident. Since SNF rail shipments could enter the area from the north, the south, and the southwest and exit to the west (1), a preliminary analysis was conducted to ascertain the hypothetical accident location most likely to affect the largest number of people. The preliminary results indicated that the largest effects would result from a hypothetical accident towards the southern part of Chicago with the wind blowing from the south-southeast (SSE). Although not as common, a wind from this direction was assumed for this analysis to maximize potential impacts.

RESULTS AND DISCUSSION

The human population affected by an accidental release of radioactivity could be exposed through a variety of environmental pathways. A short description of these exposure pathways is given below. The impacts of exposure to this radioactivity is measured in terms of dose and the potential resulting human health effects are given in terms of latent cancer fatalities (LCFs). A short description of these terms is also given below. As discussed above, impacts were assessed for hypothetical accidents involving impact/fire or fire alone occurring on the south side of the Chicago metropolitan area during average weather conditions (D stability class, wind speed of 4.6 m/s) with the wind blowing from the SSE. Release fractions from the NRC's reexamination report (7) were assumed. Comparisons were also made with weather conditions that would maximize exposure (F stability class, wind speed of 1.5 m/s).

Exposure Pathways

After an accidental release to the environment from a SNF shipment, wind will carry the radioactive gases and particulate matter (radioactive plume) downwind of the accident location, where it could be inhaled by individuals or settle on the ground. Radioactivity in the plume and on the ground could cause direct radiation exposures of individuals if they are immersed in the plume or located near the contaminated ground. Ground contamination may also be resuspended into the air by the wind or mechanical action and then inhaled further downwind.

Human receptors were considered potentially exposed to radioactivity released from the accident via four major pathways. These pathways were the inhalation of radioactive gases and particulate matter downwind of the accident as the plume passes overhead, the immersion in the radioactive plume (cloudshine), the resuspension and inhalation of contaminated soil, and the direct exposure to the contaminated ground (groundshine).

Human Health Effects

The effects of radiation exposure on humans depend on the kind of radiation received, the total amount absorbed by the body, and the tissues involved. A rem is a unit of radiation dose that is calculated by a formula that takes these three factors into account. Background radiation levels result in a national annual average individual exposure of approximately 0.30 rem, with an additional 0.060 rem from other man-made sources (9). Background radiation comes from natural sources, such as cosmic radiation and naturally occurring radioactive material, and from man-made sources that cannot be controlled, such as global fallout from nuclear testing or nuclear accidents. Other man-made sources, including consumer products and medical procedures, account for additional exposure.

The primary adverse health effect from the potential radiation doses received from the accident scenarios analyzed would be the possible induction of latent cancer fatalities (LCFs). LCFs are a measure of the expected number of additional cancer deaths in a population (or people dying of cancer) as a result of exposure to radiation. Death from cancer induced by exposure to radiation may occur at any time after the exposure takes place. However, latent cancers would be expected to occur in a population from one year to many years after the exposure takes place.

A conversion factor suggested by the International Commission on Radiological Protection (10) estimates that for every person-rem of collective dose, approximately 0.0005 individual from the public would ultimately develop a radiologically induced cancer. If this conversion factor is multiplied by an individual’s dose, the result is the individual’s increased lifetime probability of developing an LCF. If this factor is multiplied by the collective (population) dose, the result is the number of excess LCFs.

Impacts

Under conditions expected to maximize human exposure, approximately 21,300 people (Case 4) were estimated to receive an exposure exceeding 1% of the annual exposure to background radiation over the short term following the accidents analyzed. Table III presents the results assuming no mitigative actions were taken for the four hypothetical accidents evaluated. It can be seen that Case 6, 30-60 mph impact and long-term (hours) fire, results in the highest impacts.

Table III. Collective Population Human Health Impacts from Hypothetical Severe SNF Rail Accidents in Chicago[a]

	Short-Term Exposure		1-Year Exposure[b]	
	Dose (person-rem)	LCFs[c]	Dose (person-rem)	LCFs
Case 4	386	0.19	467	0.23
Case 5	490	0.25	507	0.25
Case 6	46,000	23	19,900	10
Case 20	1,040	0.52	1,340	0.67

[a] No mitigative actions are assumed. Case 4 best represents the immediate danger to the public.
[b] Does not include the short-term exposure.
[c] Excess latent cancer fatalities among the total exposed population over their lifetimes.

However, Case 4, which considers the same 30-60 mph impact but a short-term fire, results in a significantly lower dose to the exposed population. In each case, the physical impact in the accident is the same and is not considered to be solely responsible for the release, but merely compromising the SNF cask, making it more susceptible to damage by the ensuing fire (7). Thus, any immediate danger to the public is best represented by the short-term dose from Case 4, 386 person-rem. A long-term fire (hours) is necessary for the release in Case 20, as well as Cases 5 and 6, giving responders in an urban area such as Chicago ample time to evacuate the immediate vicinity or extinguish the fire. Of the 386 person-rem estimated for the short-term exposure in Case 4, 385 person-rem occurred through the inhalation pathway. Cloudshine accounted for the remainder of that dose. If the contaminated ground was left unmitigated for an additional year of exposure in Case 4, an additional 467 person-rem would be received, 324 person-rem from groundshine and 143 person-rem from inhalation of resuspended contamination. Cloudshine made a very minor contribution (<0.03%) to either the short-term or one-year exposures. The immediate concern is the short-term exposure of those persons living or working nearest the hypothetical accident location.

Figure 1 presents a map of the area analyzed with the estimated contaminant concentration isopleth areas overlaid to show the region most affected by a potential accident. Information on the isopleth areas for Case 4 is given in Table IV, which includes the actual areas and number of people impacted as well as the estimated individual short-term and long-term (one-year exposure) doses. It can be seen in Table IV that the average person immediately downwind of the hypothetical accident, in Area 1, could receive an estimated short-term dose of 0.42 rem. Over 99.99% of the dose was estimated to come from inhalation. Although the intake occurred within a period of seconds, the inhalation exposure is an internal exposure calculated over a 50-year period from the material remaining in the body. Thus, no immediate health effects might be expected. In the longer term, such an exposure might result in a chance of 1 in 4,800 of contracting a latent fatal cancer over the individual's lifetime. To put the magnitude of this exposure into perspective, the average individual is assumed to receive about 0.360 rem/year from various natural and man-made sources (9). Thus, the average accident dose received by an individual living in the area most affected by this accident is about the same as the dose received from the average annual exposure to natural and man-made background radiation. However,

Table IV. Hypothetical Case 4 Accident Exposures under Average Weather Conditions[a]

						Average Individual Dose	
Area Number	Near Distance (km)	Far Distance (km)	Area (km^2)	Number of People Affected	Area Dose (person-rem)	Short-Term (rem)	1-Year[b] (rem)
1	0.050	0.33	0.0091	24	22	0.418	0.506
2	0.050	0.69	0.035	89	26	0.132	0.16
3	0.050	1.4	0.13	712	66	0.0418	0.0506
4	0.050	2.9	0.51	3,890	114	0.0132	0.016
5	0.050	6.0	2.0	16,600	153	0.00418	0.00506
6	0.050	12	8.1	44,200	129	0.00132	0.0016
7	0.050	25	32	124,000	115	0.000418	0.000506
8	0.050	51	120	598,000	175	0.000132	0.00016
9	0.050	80	340	518,000	48	0.0000418	0.0000506
10	0.050	80	220	215,000	6.0	0.0000132	0.000016

[a] Case 4 release fractions used from Ref. 7.
[b] Does not include short-term dose.

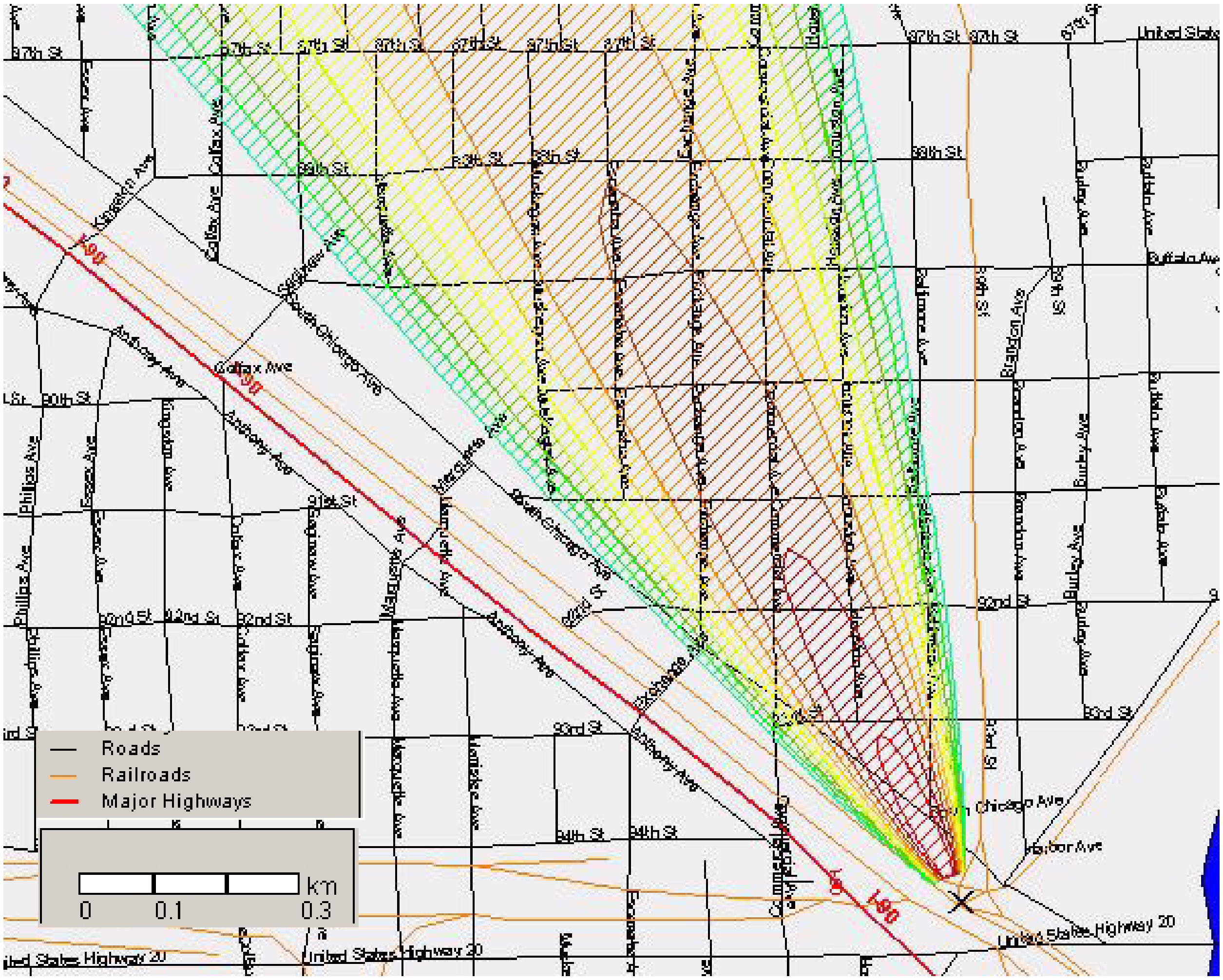

Fig. 1. Local Chicago area of hypothetical SNF accident with radioactive concentration isopleth areas outlined for average weather conditions. Figure exported from RISKIND.

the maximally exposed individual short-term dose estimated for this accident scenario was 0.74 rem, which is less than double the average dose and approximately equal to two years exposure to background radiation.

For illustrative planning purposes, Table V presents a break down of the results for Case 6 (the worst case accident evaluated) assuming no mitigative actions were taken. In an emergency situation, it would be prudent for people living downwind of such an accident to evacuate or seek shelter. Under U.S. Environmental Protection Agency guidelines (11), evacuation or sheltering is recommended for those persons projected to receive a short-term dose greater than 1 rem. In this case, such action for the 4,715 people located within Areas 1 through 4 would be suggested. The U.S. Environmental Protection Agency guidelines (11) also recommend the relocation of individuals if the projected dose after the first year is 2 rem or greater from external radiation and inhalation. Thus, following such an accident, relocation might be required of the 825 people estimated to reside within the 0.18 km^2 area bounded by Area 3.

Table V. Hypothetical Case 6 Accident Exposures under Average Weather Conditions[a]

						Average Individual Dose	
Area Number	Near Distance (km)	Far Distance (km)	Area (km^2)	Number of People Affected	Area Dose (person-rem)	Short-Term (rem)	1-Year[b] (rem)
1	0.050	0.33	0.0091	24	1,730	49.9	21.6
2	0.050	0.69	0.035	89	2,010	15.8	6.83
3	0.050	1.4	0.13	712	5,090	4.99	2.16
4	0.050	2.9	0.51	3,890	8,800	1.58	0.683
5	0.050	6.0	2.0	16,600	11,900	0.499	0.216
6	0.050	12	8.1	44,200	10,000	0.158	0.0683
7	0.050	25	32	124,000	8,880	0.0499	0.0216
8	0.050	51	120	598,000	13,500	0.0158	0.00683
9	0.050	80	340	518,000	3,710	0.00499	0.00216
10	0.050	80	220	215,000	487	0.00158	0.000683

[a] Case 6 release fractions used from Ref. 7. Results if mitigative actions not taken. Illustrates areas that may require evacuation or relocation.
[b] Does not include short-term dose.

If more stable weather conditions were present during the postulated accident, such as nighttime conditions (F stability class) with a wind speed of 1.5 m/s, the number of people affected would be smaller but the average individual exposures would be higher because of reduced dispersion and dilution of the emitted radioactive plume. For Case 4, a short-term collective dose and 1-year collective dose of 431 person-rem and 521 person-rem, respectively, were estimated. These values represent an increase of approximately 12% over those for more average weather conditions.

Discussion

From the results presented in Tables IV and V, it is shown that the location of highest impact is less than a square kilometer area downwind of the hypothetical accidents. The estimated short-term exposure (depending on weather conditions, the amount of radioactivity released, and mitigative actions) suggests that no LCFs might be expected for any of the accidents evaluated. In addition, a conservative assumption used in the analysis was that all persons downwind were totally exposed during passage of the radioactive plume in the minutes following an accident. Case 4 was the only accident where those persons immediately downwind would have no warning before passage of the radioactive plume, but many would be indoors where the inhalation dose could have been much less, depending on building ventilation and time of year (e.g., whether windows were open or closed). Thus, the actual impacts might be expected to be lower in the short term. As discussed above, mitigative measures would be taken to reduce the long-term exposures if warranted for any of the accident cases.

The accident location was selected to maximize human health impacts from a worst-case type of accident. Also used was the largest population center (Chicago) in a state with the highest estimated dose risk from future SNF rail shipments to a geologic repository. The site-specific nature of this analysis allowed us to determine a location along a potential rail shipment route that would, when combined with the wind blowing from a particular direction, provide maximum impacts. Combinations of different locations along potential rail routes (1) and wind directions in the Chicago metropolitan area were not found to provide higher impacts. In addition, the latest census figures were used to determine the number of persons affected. However, depending on the time of day and the daily routines of these individuals, the number of persons affected could be lower or higher.

It is important to note that the results presented in this paper are intended to give the reader an idea of the potential human impacts in a heavily populated urban area if such a severe SNF accident were actually to occur. As discussed in the section on release fractions, the likelihood of such an accident occurring is extremely low. The most likely of the four accidents evaluated, Case 4, was estimated to have a probability of 1.3×10^{-4} (1 chance in 7,700) over the entire 23-year shipping campaign proposed for the geologic repository. The chance of such an accident occurring in the Chicago area is even lower, but if it occurred in Chicago, the highest estimated short-term dose to an individual would be similar to two years of exposure to natural background radiation and no LCFs were estimated. The other severe accidents that might be considered credible involved a longer duration fire to cause a release of radioactive material from the SNF cask (Cases 5, 6, and 20). Under these conditions, there is sufficient time to evacuate or shelter those in the immediate vicinity of the accident. Use of the RISKIND code enabled the prediction of those areas most affected in the short term and long term and allowed comparisons with EPA's recommended guidelines with respect to evacuation and sheltering for short-term exposures and relocation for one-year exposures following an accident.

The severe rail accident modeled is one of a particular class of accidents that might produce the type of release assumed for this study. However, the particular details of the accident itself are not known, including the initiating event(s), the time of day, and the persons in the immediate vicinity, along with their downwind proximity to the release point from the cask. Thus, it is not possible to model the impacts to onlookers or first responders at the accident location, but if such persons are not able to evade the radioactive release in the resulting fire plume, they could possibly receive substantially higher doses than those persons evaluated as living or working downwind.

Factors that will have a marked effect on the expected impacts should such a severe accident occur, include source term parameters such as fuel burnup and cooling times for the SNF before shipment. The expected average cooling time for shipments to the repository was estimated to be 23 years (1), which is more than double that used in this study. In such a case, the impacts will be lower, since the shorter-lived radionuclides will have had more time to decay. On the other hand, if intermediate storage options are considered before shipment to a final repository, shorter cooling times may be more likely. The average fuel burnup discharged from reactors has been increasing slightly over time as more experience is gained and reactors are upgraded (12). This study used the expected average (1). Thus, higher burnup fuel would result in larger impacts, but ultimately fewer shipments.

This study focused on human health impacts from a SNF railcar shipment in an urban environment. Also of concern to the public are the political and psychological impacts as well as economic losses from the standpoints of cleanup, lost business, and disrupted human occupation. The human health impacts in a rural setting would be much lower due to lower population densities. Rural densities are typically 100 to 1000 times lower than those in Chicago as derived from the data in Table IV (4), indicating a similar decrease in exposure. However, the loss or remediation of farmland in these rural areas must be taken into account in this latter case.

Many future SNF shipments might also be made using truck transport (1). The impacts from a similar truck accident would be expected to be less because of a smaller payload than a railcar cask. On the other hand, in deciding on the future needs and direction of SNF transport, decision-makers must take a wide range of variables into account when comparing truck versus rail transport. Such variables include, but are not limited to, the following. Truck shipments may have less SNF per shipment involved in an accidental release, but more shipments would be necessary to transport the same amount of fuel. Truck shipments are more readily routed around large population centers, but many beltways are near large suburban populations and have high traffic densities. Rail shipments are more likely to be routed directly through large cities because of the fixed nature of railroads, but these tracks are on private rights-of-way that keep the public at a further distance than truck shipments that share the road with the public.

The focus of this paper was to assess what might be the largest potential human health impacts from a transportation accident involving a SNF shipment in the United States, if such an accident were to occur during shipment of SNF to a final geologic repository. As discussed above, such an accident is extremely unlikely. In addition, no radioactive release from an accident involving SNF has occurred during the decades of SNF transport on the nation's highways and railroads (13). Thus, although the type of accident modeled in this study might be the most plausible severe accident, such an accident is not expected. However, there is also public concern over the possibility of a terrorist attack on SNF shipments. The excellent safety record of SNF shipments is due in large part to the NRC packaging regulations for transport of SNF. As a result of these requirements, the SNF transportation casks are able to withstand extreme conditions. Any attack would have to compromise the integrity of such casks before any type of release could occur.

SUMMARY

The number of SNF shipments is expected to increase significantly during the time period that the United States' inventory of SNF is sent to the Yucca Mountain repository. This study examined the human health impacts from the most plausible severe SNF transportation accidents in an urban area. The RISKIND 2.0 program was used to model site-specific data for an area where the largest impacts might occur in the Chicago metropolitan area. The results have shown that the radiological human health consequences of a severe SNF rail transportation accident might be similar to one-year's exposure to natural background radiation for those persons living downwind in the most affected areas. In addition to the accident probabilities being very low, the actual human health impacts are expected to be lower if any of the accidents considered did occur because the results are dependent on the specific location and weather conditions, such as wind speed and direction, that were selected to maximize the results.

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