SAND99-2138C

Projected Consequence for Potential Sabotage Events Related to Spent Fuel Shipments

Lih-Jenn Shyr, Sieglinde Neuhauser, Scott Mills, Charles Massey
Transportation Safety and Security Analysis
Sandia National Laboratories
P.O. Box 5800
Albuquerque, NM 87185-0718 U.S.A.
505-845-7774
lshyr@sandia.gov

RECEIVED
AUG 23 1999
OSTI

SUMMARY

There is a growing interest in understanding the potential consequences of malevolent acts against shipments of nuclear waste and/or material. Recently, Sandia National Laboratories (SNL) conducted a study[1] to evaluate the potential source terms available for release in a sabotage event for spent fuel shipments. Using these source terms, we developed an approach to assess the potential radiological consequences of the hypothesized events and to compare them to consequences of transportation accidents involving the same types of shipments.

Our analysis showed that there could be orders of magnitude differences in consequence for urban, suburban, and rural events. Sabotage consequences could be orders of magnitude higher than those of transportation accidents with a probability of 10^{-12} or higher and be similar to events with a probability less than 10^{-12}. Also, explosive-induced buoyancy would disperse the source further out than a non-buoyant release in a transportation accident, which, therefore, would have a higher dose near the release point.

I. BACKGROUND

Two major studies, one sponsored by the U.S. Department of Energy and the other by the U.S. Nuclear Regulatory Commission, were conducted in the late 1970s and early 1980s to provide information and source terms for an optimally successful act of sabotage on spent fuel casks. Recently, Sandia National Laboratories (SNL) conducted additional analyses to derive potential source terms for certain classes of sabotage events on spent fuel casks typical of those that could be shipped in the early decades of the 21st century[1]. Based on that recent study, we evaluated the potential radiological consequences from two sabotage events and investigated the dose pathway, distribution, and factors that could have large impacts on the projected consequences.

II. APPROACH

We chose to use a baseline route for Spent Fuel Repository Site Selection Study to perform the consequence analysis. Given the route and the meteorological data, dispersion of radioactive material by two types of explosive devices was modeled using the Explosive Release Atmospheric Dispersion (ERAD) model[2]. Based on the population density along the route and the amounts of isotopes released, we estimated the total population dose and examined the dose pathway and distribution. To facilitate the interpretation of the projected consequences, we compared them to those of transportation accidents involving the same types of shipments. The route-specific accident rates were used to evaluate the probabilities of various transportation accidents, and the same inventory with different release, airborne and respirable fractions was used to assess the accident consequence.

Figure 1 Truck route for Consequence Analysis and Comparison

III. Method and Analysis

In the following section, we will discuss the scenario, source term, dispersion modeling, and

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, make any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

the model input parameters for both sabotage events and transportation accidents.

A. Scenario

Figure 1 shows the truck route generated by the HIGHWAY routing code. The distance-weighted average population densities for urban, suburban, and rural areas were 2191, 328, and 7 per sq. km, respectively. A rail route generated by the INTERLINE routing code (not shown) had distance-weighted average population densities of 2063, 360, and 8 per sq. km for urban, suburban, and rural areas, respectively. These population densities were used to estimate the population doses along the route. It was assumed that four PWR spent fuel assemblies are transported by truck and 26 by rail.

Two types of high energy density devices, HEDD1 and HEDD2, are considered in this study and their characteristics are shown in Table 1.

Table 1. HEDD1 and HEDD2 Characteristics

Features	HEDD1	HEDD2
Availability	Yes	Yes
Portability	Less	More
Penetration in Steel	Less	More
Swept Volume	Larger	Smaller
Remote Delivery	No	Yes

Table 2. Inventory for truck and rail transport

Material	Isotope	Truck (Ci)	Rail (Ci)
CRUD	Co-60	4.E+02	2.E+03
Matrix	Sr-90	2.E+05	2.E+06
	Ru-106	6.E+04	4.E+05
	Ce-144	5.E+04	3.E+05
	Eu-154	3.E+04	2.E+05
	Pu-238	1.E+04	8.E+04
	Pu-239	2.E+03	1.E+04
	Pu-240	2.E+03	1.E+04
	Pu-241	5.E+05	3.E+06
	Am-241	5.E+03	3.E+04
	Am-243	8.E+01	5.E+02
	Cm-244	7.E+03	5.E+04
Volatile	Cs-134	1.E+05	7.E+05
	Cs-137	4.E+05	2.E+06
Noble gas	Kr-85	2.E+04	2.E+05

B. Source Terms

The inventory for truck and rail transports includes four different forms of sources (Table 2). CRUD (Chalk River Unidentified Deposits) consists of deposited metal-bearing compounds on the outer surface of fuel rods. Table 3 shows the release fraction, aerosolized fraction, respirable fraction, and the product of these three factors. The release fraction and the total fraction were measured in a recent study[1]. The respirable fraction for matrix, CRUD, and volatile was assumed to be about 11% based on the Operation Roller Coaster studies conducted in the 1960s and 70s. This fraction is considered to be conservative because an explosion, such as a malevolent act, tends to produce larger particles than the implosion scenario evaluated in the Operation Roller Coaster studies. The aerosolized fractions were calculated given the three known variables.

Table 3. Release, Airborne, and Respirable Fractions for Sabotage Events

		HEDD1		HEDD2	
		Truck	Rail	Truck	Rail
Matrix	Rel. F	3.E-03	4.E-04	6.E-04	5.E-05
	AF	4.E-01	7.E-02	2.E-01	4.E-02
	RF	1.E-01	1.E-01	1.E-01	1.E-01
	Tot F	1.E-04	3.E-06	2.E-05	2.E-07
CRUD	Rel. F	3.E-02	4.E-03	6.E-03	5.E-04
	AF	2.E-02	3.E-03	1.E-02	8.E-04
	RF	1.E-01	1.E-01	1.E-01	1.E-01
	Tot F	8.E-05	1.E-06	9.E-06	5.E-08
Noble	Rel. F	2.E-02	4.E-04	6.E-03	4.E-05
	AF	1.E+00	1.E+00	1.E+00	1.E+00
	RF	1.E+00	1.E+00	1.E+00	1.E+00
	Tot F	2.E-02	4.E-04	6.E-03	4.E-05
Volatile	Rel. F	5.E-03	6.E-04	1.E-03	8.E-05
	AF	2.E+00	2.E-01	8.E-01	7.E-02
	RF	1.E-01	1.E-01	1.E-01	1.E-01
	Tot F	1.E-03	2.E-05	1.E-04	7.E-07

C. Dispersion Modeling

We used ERAD to model the buoyant release of an explosive event. ERAD performs a 3-D numerical simulation of particle dispersion by considering cloud dynamics, buoyancy effects, and turbulent diffusion. The required input parameters include mass of explosives, meteorological profiles, particle size distribution, aerosolized

mass, etc. It then calculates dose/deposition contour levels and the population dose.

We used the radiosonde data collected by the National Climatic Data Centers located across the continental United States to characterize the meteorology. Specifically, a representative meteorological profile, including height, wind speed, wind direction, temperature, etc., was derived for each Pasqill-Gifford stability class. Each explosive scenario was modeled for all six stability classes. Then, the consequence was weighted by the relative frequency of each stability class.

D. Transportation Accidents

Table 4 shows the scenarios for transportation accidents analyzed for consequence comparison. There were seven scenarios with the probabilities ranging from 10^{-5} to 10^{-15}. The first six scenarios are variations of those stated in NUREG-0170 and the last scenario is a severe accident considered in a recent SNL study using a scheme similar to that used in the "Modal Study." The same inventory shown in Table 1 was used and the release, airborne, and respirable fractions are shown in Table 5.

Table 4. Transportation Accident Scenario

Transportation Accident	Prob.
Conditions do not exceed those of Type A package	1x10-5
Conditions do not exceed those for Type B package	8x10-6
Seal damage for CRUD release, fuel undamaged	8x10-9
Fuel damage, particulate and gases release	8x10-12
Fuel damage + fire, particulate. Gases, volatile release	5x10-12
Fuel damage + fire, greater release	3x10-12
Fuel damage + prolonged fire, more release	1x10-15

IV. RESULTS AND ANALYSIS

Table 6 shows the total population dose and the Latent Cancer Fatality (LCF) for the sabotage events by two types of explosive devices and the comparison to one of the most severe transportation accidents (the 6th scenario in Table 4.) Urban events had a much higher consequence due to a much higher population density. HEDD1 truck scenario and severe rail accident had similar consequences. HEDD1 rail, HEDD2 truck, and the severe truck accident also were similar. The HEDD2 rail was relatively lower and HEDD2 was less severe than HEDD1. While rail sabotage events were less severe than truck events, this was not the case for transportation accidents, primarily because of the change in release fractions. The LCF values were obtained using a risk conversion factor of $5x10^{-4}$ LCF/person-rem.

Table 5. Release, Airborne, and Respirable Fractions for Transportation Accidents

Scenario	Matrix	CRUD	Noble	Volatile
1	0.E+00	0.E+00	0.E+00	0.E+00
2	0.E+00	0.E+00	0.E+00	0.E+00
3	0.E+00	6.E-04	0.E+00	0.E+00
4	5.E-10	6.E-04	1.E-02	1.E-08
5	3.E-09	6.E-04	1.E-01	2.E-04
6	3.E-09	6.E-04	1.E-01	3.E-04
7	2.E-05	6.E-03	8.E-01	1.E-04

Figure 2 shows the comparison of sabotage events and the transportation accidents in the context of "risk." The consequences and associated probabilities for the transportation accidents (Table 4) were plotted along with the consequences of two sabotage events, which do not have corresponding probabilities. This comparison showes that sabotage consequences could be orders of magnitude higher than those of transportation accidents with a probability of 10^{-12} or higher and they were similar to events with a probability less than 10^{-12}.

As shown in Table 6, the consequences for HEDD1 rail, HEDD2 truck, and a truck transportation accident were similar. However, the contours (not shown) indicated that a non-buoyant release from an accident produced a much higher dose near the release point. This could have significant implications when local population is considered in a real event.

Some of the input parameters to the dispersion model could have significant impacts on the projected consequences. For example, different meteorological data representing different stability classes could significantly affect the distance and the distribution of the radiological doses (not shown).

Table 6 Total Population Dose and Latent Cancer Fatalities

	HEDD1		HEDD2		Severe Accident	
	Truck	Rail	Truck	Rail	Truck	Rail
	Consequence (person-rem)					
Urban	1.6E+04	1.4E+03	2.4E+03	4.8E+01	1.2E+03	1.7E+04
Suburban	2.3E+03	2.5E+02	3.5E+02	8.3E+00	1.8E+02	3.0E+03
Rural	5.3E+01	5.5E+00	8.0E+00	1.8E-01	4.0E+00	6.5E+01
	Consequence (LCF)					
Urban	7.8E+00	7.2E-01	1.2E+00	2.4E-02	5.9E-01	8.5E+00
Suburban	1.2E+00	1.2E-01	1.8E-01	4.2E-03	8.8E-02	1.5E+00
Rural	2.6E-02	2.7E-03	4.0E-03	9.1E-05	2.0E-03	3.3E-02

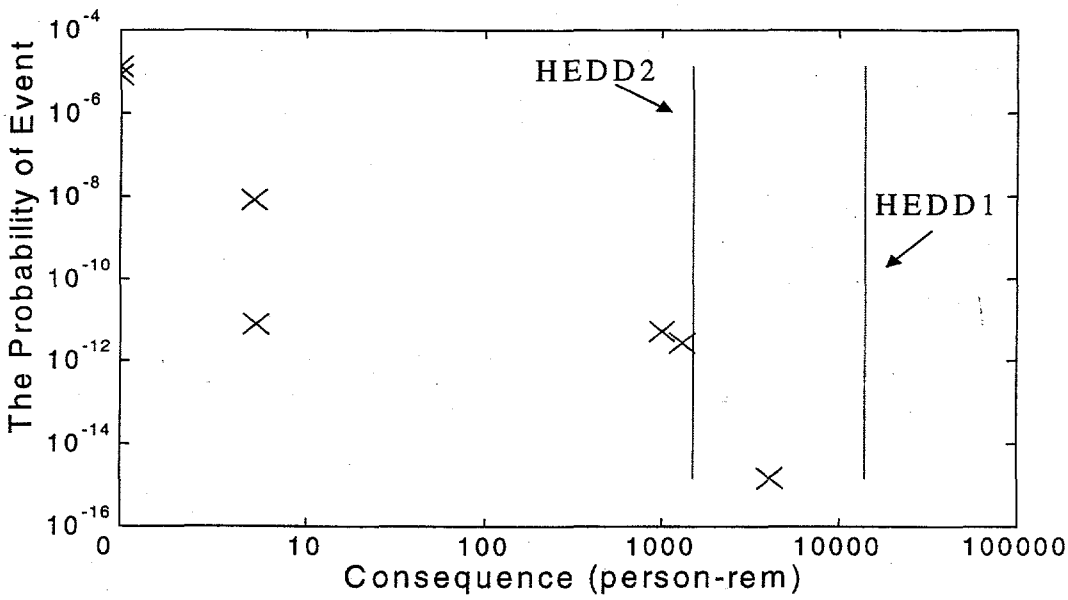

Figure 2 Probability and Consequence for Sabotage and Transportation Accidents (four PWR spent fuel assemblies)

V. CONCLUSIONS

In this study, we developed an approach for evaluating the potential consequences of malevolent acts against spent fuel shipments. Further, the consequences were compared to transportation accidents in a risk context to allow a meaningful interpretation of the results. In addition to the source terms, the meteorological profiles were found to be a sensitive parameter with regard to the predicted consequence. Use of a probabilistic development of meteorological data and census population block input data would further refine this study and provide a more complete picture of the potential consequences.

REFERENCES

1. R.E. Luna, K.S. Neuhauser, and M.G. Vigil "Projected Source Terms for Potential Sabotage Events Related to Spent Fuel Shipments," *SAND99-0963*, Sandia National Laboratories, Albuquerque, NM (1999).
2. B. Boughton and J. M. DeLaurentis, "Description and Validation of ERAD: An Atmospheric Dispersion Model for High Explosive Detonations," SAND92-2069, Sandia National Laboratories, Albuquerque, NM (1992).

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under contract DE-AC04-94AL85000.