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INCREMENTAL RISKS OF TRANSPORTING NARM TO THE LLW DISPOSAL FACILITY AT HANFORD

Ruth F. Weiner
Sandia National Laboratories*

ABSTRACT

This study models the incremental radiological risk of transporting NARM to the Hanford commercial LLW facility, both for incident-free transportation and for possible transportation accidents, compared with the radiological risk of transporting LLW to that facility. Transportation routes are modeled using HIGHWAY 3.1 (2) and risks are modeled using RADTRAN 4 (1). Both annual population doses and risks, and annual average individual doses and risks are reported. Three routes to the Hanford site were modeled: from Albany, OR, from Coeur d'Alene, ID (called the Spokane route), and from Seattle, WA. Conservative estimates are used in the RADTRAN inputs, and RADTRAN itself is conservative.

INTRODUCTION

The commercial low-level radioactive waste (LLW) facility that is located at Hanford, WA is receiving shipments of naturally occurring radioactive material (NARM). All shipments of radioactive material pose some, albeit very small, radiological risk to the population along the transportation route, to crew riding in the transportation vehicle, and to occupants of vehicles sharing the route.

The radiological risks posed by shipments to the Hanford LLW facility, which have been going on for about 30 years, are negligible; no adverse effects attributable to these shipments have ever been documented. NARM has been shipped to the facility since 1993. This study models the incremental radiological risk of transporting NARM, both for incident-free transportation and for possible transportation accidents. The model is described below.

RADTRAN METHODS

Transportation risk is modeled using RADTRAN 4 (1). Although the basic equations of the model, presented in Neuhauser and Kanipe (1), are not repeated here, the main features of RADTRAN are worth noting.

Incident-free transportation model

RADTRAN models incident-free transportation as a separate module from transportation accidents. When radioactive materials are transported, an external dose, limited by regulation (10 CFR Part 71), is allowed. Figure 1 illustrates the RADTRAN model. Only external gamma radiation is considered, since external neutrons are absorbed by air before reaching a receptor. The radioactive cargo is modeled as a point source. Dose to the receptor is usually inversely proportional to the square of the distance from the receptor. Dose is also inversely proportional to vehicle velocity, and directly proportional to distance traveled and to the number of shipments.

DISCLAIMER

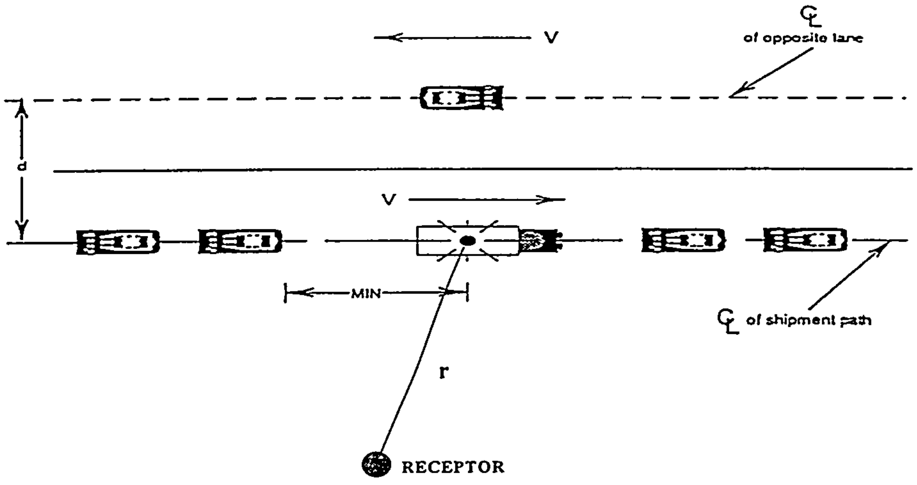

Figure 1. The RADTRAN incident-free module. V is the shipment speed. The distance between the shipment and the receptor is r; dose is calculated by integrating from r = -∞ to r = ∞.

The radiation source is the external dose rate (in mrem/hr) measured at 1 meter from the cargo surface. RADTRAN models the regulatory limit of external dose for each type of shipment, although experience indicates that the external dose rate is well below the regulatory limit in the majority of shipments, and is undetectably low for many shipments. This conservatism is discussed in Weiner, et al (3). Because the regulatory limit is the modeled dose, the modeled incident-free dose is independent of the isotopic content or radioactivity of the material being shipped. Therefore, in the present study, the modeled incident-free doses for LLW and NARM shipments depend only on the external, measured dose rates.

Doses are calculated separately for the truck crew (crew dose), people by the side of the transportation corridor (off-link dose), occupants of vehicles that share the transportation corridor with the radioactive shipment (on-link dose), and people in the vicinity of the shipment when it is stopped (stop dose). The figures in this report reflect the off-link doses, as these are usually of most interest to the public. Other doses are tabulated in the report.

Because of similarities in highway vehicle speeds, vehicle densities, and vehicle accident rates, transportation routes may be categorized as rural, suburban, or urban, according to approximate population density. In this study, actual distances and population densities are used, but the rural, urban, suburban classifications are retained and results are reported accordingly.

Accident dose risks

The radioactive materials being shipped, and their activity, become important in the transportation accident module. RADTRAN models accidents as the risk from emission of fractions of the radioactive cargo into the air: this risk combines the probability of a breach of containment with the fraction of each isotope that would be leaked, aerosolized, and inhaled under a particular accident scenario. Dose to the receptor is then calculated from Health Physics Handbook dose conversion factors (4). In the model, the set of all possible accidents is divided into subsets (eight subsets in the present study), each with a particular probability of occurrence and aerosolized and respirable release fraction. The set of accidents always includes a subset for no release and no loss of shielding (by far the most probable case) and a subset for loss of shielding only (no actual release of material). A detailed description of the accident severity category approach may be found in Chapter 5 of USNRC (5). Essentially, the probability of occurrence of an accident depends on truck accident statistics and vehicle density, and indirectly on population density (e.g., a larger fraction of accidents in urban areas are minor). Releases and aerosol fractions depend on the physical and chemical nature of the isotope (e.g., volatility, particle size) and have been incorporated into the RADTRAN model (see Reference 1). The advantage of using the accident severity category approach is that particular accident scenarios need not be postulated and their probabilities speculated on. The universe of accidents is captured in the severity categories (the probabilities of the severity categories add to one for rural, urban, and suburban routes, respectively) and sensitivity studies may be performed by postulating different release, aerosol, and respirable fractions. Doses are modeled using a Gaussian dispersion model (e.g, Reference 6, Chapters 3 and 4).

Incident-free transportation has a probability of occurrence equal to ≈1 (100%): virtually all transportation is incident free. Transportation accidents involving vehicles carrying radioactive material have a probability of occurrence of much less than 1; the probability of an accident with a non-negligible release is less than 5%, as shown in Table 2. Therefore, instead of reporting doses as for incident-free transportation, dose *risks* are reported for potential accident scenarios. Risk is the product of probability and consequence; dose risks are the products of the probability of an accident happening times the dose to the receptor if the accident happens. The units of dose risk are Sv or mSv, like the units of dose. Routes and population densities are provided by the code HIGHWAY (2).

INPUT PARAMETERS

Routes

Three routes through Washington State were considered for this study

(1) The **Albany route**, from Albany, OR east along the Columbia Gorge to Umatilla and thence north on I-82 to I-182 to State Route 240 to the Hanford site.
(2) The **Spokane route**, from Coeur d'Alene, ID west on I-90 to Ritzville, WA, then south on US 395 to Pasco, WA, then north on I-182 to State Route 240 to the Hanford site.
(3) The **Seattle route**, east on I-90 to Ellensburg, WA, then south on I-82 through Yakima and east to I-182 to State Route 240 to the Hanford site.

Table I. Distances and population densities.

	Albany Route	Spokane Route	Seattle Route	
			Seattle to Yakima	Yakima to Hanford site
Distances (km)	476.3	297.7	226.8	111
Rural	353.3	233.6	183.2	103.8
Suburban	95.5	58	37.4	7.2
Urban	27.5	6.1	6.2	0
People/sq. km				
Rural	7.6	5	6.3	3.7
Suburban	377.9	435.9	344.8	112.1

Urban	2193.8	2179.5	1853.5	--

Meteorology

Dispersion of released pollutants depends on the meteorology. RADTRAN allows selection of any desired combination of stability classes. In the interests of conservatism, dispersion of released materials was modeled using Class E stability -- a weak temperature inversion -- and a wind speed of 1 m/sec. Dispersion of released material was modeled out to 50 miles from the site of the hypothetical accident. Releases are modeled as a spherically symmetric puff ($\sigma_y = \sigma_z$) that is depleted by deposition.

Accident Scenarios

In this study, eight accident severity categories are used. Each category is characterized by probabilities of occurrence, fraction of material released at each severity, aerosolized fraction, and the fraction of aerosols that are respirable (less than 10 microns in diameter). Probabilities and released, aerosol, and respirable fractions are shown in Table II. It should be noted that the released fractions in Table 2 are conservative estimates.

Table II. Accident probabilities and released, aerosolized, and respirable fractions.

Severity category	Accident probability[a]			Released fraction	Aerosol fraction[b]	Respirable fraction[c]
	Rural	Suburban	Urban			
1	0.462	0.435	0.583	0	0	0
2	0.302	0.285	0.382	0.01	0.005	0.005
3	0.176	0.221	.0278	0.05	0.025	0.025
4	0.0403	0.0506	6.36E-3	0.075	0.0188	0.0188
5	0.0118	6.64E-3	7.92E-4	0.1	0.025	0.0125
6	6.47E-3	1.74E-3	1.46E-4	0.25	0.0675	0.0338
7	5.71E-4	6.76E-5	1.13E-5	0.5	0.075	0.019
8	1.13E-4	5.93E-6	9.94E-7	1.0	0.1	0.025

Notes:

a) The probability that an accident of this severity, given that an accident occurs.

b) The aerosolized fraction is the product (fraction released x fraction of released material aerosolized).

c) The respirable fraction is the product (aerosolized fraction x fraction of aerosolized material that is respirable).

In constructing these scenarios, it was assumed that the LLW and NARM disperse in the same way, and that, if only a small fraction of the cargo were released, it would contain a relatively large fraction of very small particles that would aerosolize. As the released fraction increases, it contains more material that is in pieces too large to aerosolize. The assumption that in the most severe accident category all of the cargo would be released is exceedingly conservative.

It should be noted that the most probable accidents release little or no cargo, that the probability of severe accidents is greater in rural than in urban areas, and that the probability of relatively much less severe accidents is greatest in urban areas.

RESULTS

Incident-free Transportation

Differences between population doses from incident-free transportation along the three routes considered depend primarily on the distance traveled and the populations along the route. Figure 2 shows the incident-free off-link population doses for the Albany route. The average incident-free off-link dose is the same for all three routes and is shown in Table III.

Table III. Average incident-free off-link dose for LLW transportation.

	Average dose (mSv)
RURAL	3.19E-9
SUBURBAN	3.32E-9
URBAN	4.47E-9
TOTAL ROUTE	3.81E-9

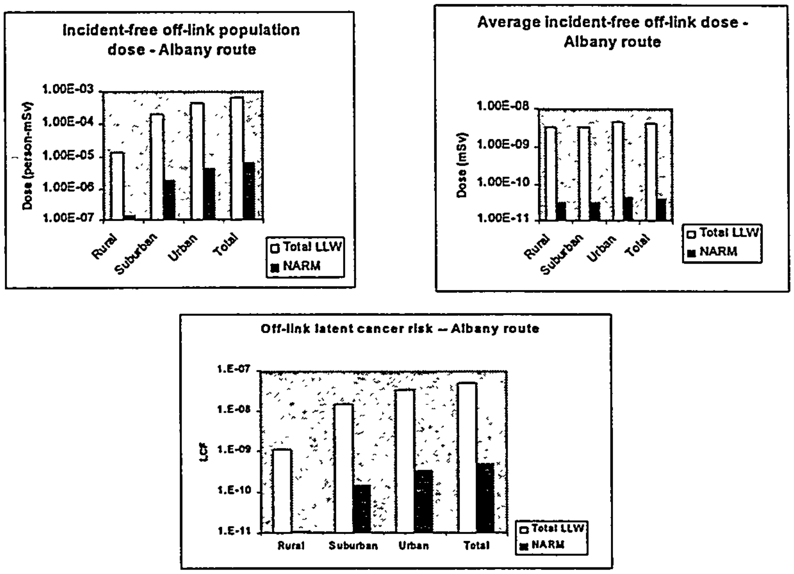

Figure 2. Annual off-link population doses, average individual doses, and LCF for incident-free LLW and NARM transportation on the Albany route.

Table IV presents the incident-free population doses to truck crew, occupants of other vehicles (on-link), and people at stops.

Table IV. Crew, on-link, and stop annual population doses: incident-free LLW transportation. Doses are in person-mSv; 1 x 10^{-2} mSv = 1 mrem.

	Albany			Spokane			Seattle		
	CREW	ON LINK	STOPS	CREW	ON LINK	STOPS	CREW	ON LINK	STOPS
RURAL	1.36E-03	3.69E-04	7.58E-02	8.99E-04	2.44E-04	5.02E-02	1.10E-03	3.00E-04	6.16E-02
SUBURB	4.38E-04	2.37E-04	2.05E-02	2.66E-04	1.44E-04	1.25E-02	2.04E-04	1.11E-04	9.58E-03
URBAN	1.68E-04	1.20E-03	5.90E-03	3.73E-05	2.67E-04	1.31E-03	3.79E-05	2.71E-04	1.33E-03
TOTALS:	1.96E-03	1.81E-03	1.02E-01	1.20E-03	6.55E-04	6.40E-02	1.34E-03	6.82E-04	7.25E-02

The differences in these doses depend on route length, and therefore on travel time. The highest population dose is the total stop dose on the Albany, OR, route, and is 0.102 person mSv (10.2 person - mrem). With 50 persons exposed per stop, this would give an average annual individual dose of 0.00204 mSv (0.204 mrem).

Table V shows the annual individual doses from incident–free LLW transportation. Crew and stop doses were calculated by dividing the appropriate population doses by 2 and 50, respectively. The average individual on-link doses were calculated by Equation 1.

Equation 1. $$On-link\_individual\_dose = \frac{On-link\_population\_dose}{2 * vehicle\_density * km}$$

"Total" individual on-link dose is meaningless because of different populations, distances, etc. Table V demonstrates that, although the population on-link doses may appear to be non-negligible, the average individual doses are very small – of the order of nanosieverts or fractions of microrems.

TableV. Crew, on-link, and stop annual average individual doses: incident-free LLW transportation. Doses are in mSv; 1 x 10^{-2} mSv = 1 mrem.

	Albany			Spokane			Seattle		
	CREW	ON LINK	STOPS	CREW	ON LINK	STOPS	CREW	ON LINK	STOPS
RURAL	6.80E-04	1.11E-09	1.52E-03	4.50E-04	1.11E-09	1.00E-03	5.50E-04	1.11E-09	1.23E-03
SUBURB	2.19E-04	1.59E-09	4.10E-04	1.33E-04	1.59E-09	2.50E-04	1.02E-04	1.60E-09	1.92E-04
URBAN	8.40E-05	7.79E-09	1.18E-04	1.87E-05	7.82E-09	2.62E-05	1.90E-05	7.81E-09	2.66E-05
TOTALS:	9.83E-04		2.05E-03	6.02E-04		1.28E-03	6.71E-04		1.45E-03

Figure 2 shows the annual population and average individual off-link doses for LLW and NARM transportation for the Albany, OR, route; the results for the other two routes are similar. RADTRAN parameters are the same for NARM as for LLW except for the transport index (TI), which is 0.5 for NARM. Because the TI is modeled the same for all NARM shipments, the incident-free off-link dose is the same for all NARM shipments. Latent cancer fatalities (LCF) may be calculated by multiplying by a risk factor; the risk factor used (Schleien, et al, 1996, page 15-19) is 7.9 LCF per 10^5 persons per mSv.

Accident Dose Risks

As discussed briefly above, accident dose risk is the product of the accident probability and the consequences of release, so that although the units are the same (mSv), they express a risk rather than only a dose. LCF may be calculated by multiplying the same risk factor as used for the LFC calculation for incident-free transportation. Figure 3 shows the accident dose risks and LCF for the Albany route.

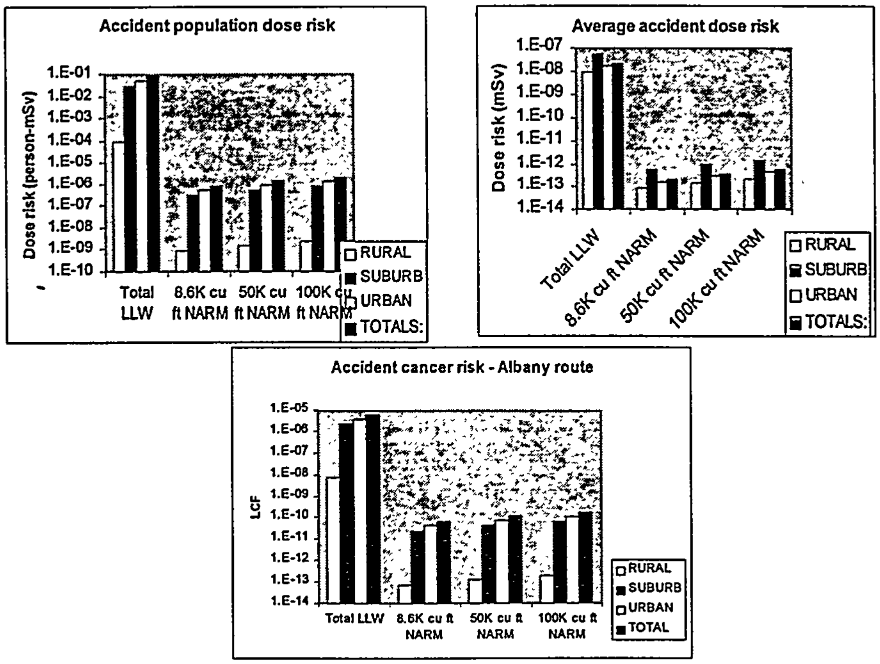

Figure 3. Annual population dose risks, average individual dose risks, and LCF for LLW and NARM transportation on the Albany route.

As anticipated, accident population dose risks are somewhat smaller than incident-free off-link population doses because the probability of incident-free transportation is essentially 100% and more than 94% of truck accidents involve no release of cargo. It should be remembered that the exposed populations differ in the two cases, and that conservative meteorology was used in modeling the dispersion of released material. Table VI compares the receptor populations for accidents and incident-free transportation. Incident-free doses are also a direct function of the TI (the external gamma dose).

TableVI. Total modeled receptor populations

	Albany	Spokane	Seattle
Incident-free transportation (off-link)	1.58 E+5	6.37 E+4	4.27E+4
Population under accident plume	3.61E+6	3.69E+6	3.23E+6

As further anticipated, the risks from NARM transportation are four or more orders of magnitude less than the risks from transporting LLW. A combination of factors explain this result: fewer and different isotopes are present in NARM, the total activity and the activity of most isotopes are much lower, and the TI was 5% of the LLW TI. Predictably, the annual doses and dose risks are slightly larger for larger amounts of transported NARM, but in all cases the doses are so much lower than for LLW transportation that there appear to be no significant differences among the three NARM quantities.

Figure 4 shows annual transportation accident dose risks and latent cancer fatalities (LCF) for transportation until 2056. Only accident results are shown, because the annual incident-free doses would be the same as for 1998 closure, because they depend only on TI. The relative risks for the three routes depend on the exposed population, route length (since accident rates are per km) and the fraction of the route that is more heavily populated. 5.6% of the Albany route is urban, while only 1.8% of the Seattle route is urban.

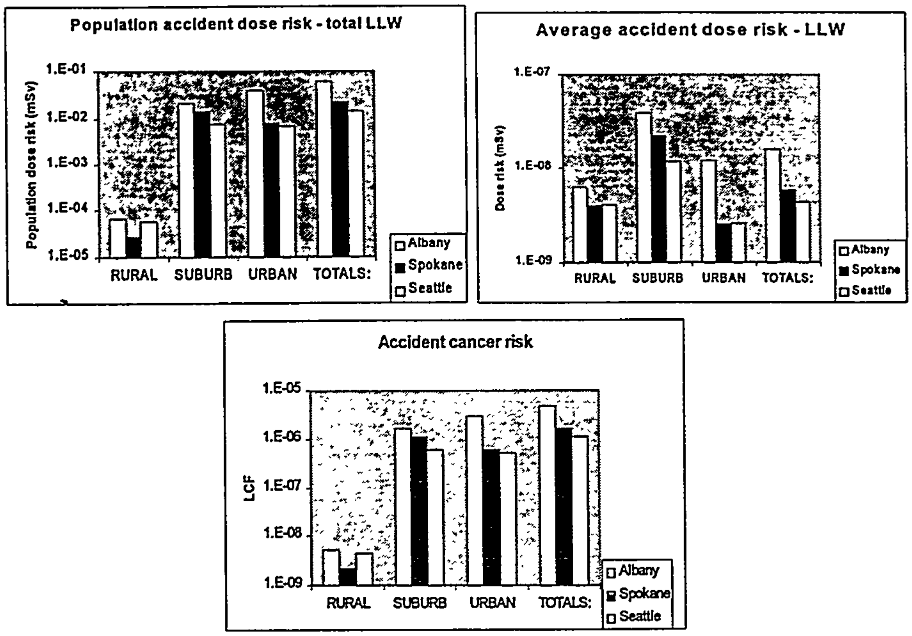

Figure 4. Accident population dose risks, average individual dose risks, and LCF for LLW transportation for site closure in 2056.

The total average individual accident risk is less than the suburban average individual accident risk because these averages are obtained by dividing the population dose risks by the affected population, and the total is considerably larger than the suburban affected population.

Throughout this report, annual doses are reported; cumulative doses may be determined by multiplying the annual dose or dose risk or LCF by the desired number of years. Annual amounts are reported because it is virtually impossible to project a stable receptor population until 2056 or site closure, and the 1998 results provide the annual existing risk figures.

Conclusions

These results may be summarized as follows:

- Transporting NARM does not significantly increase the potential accident dose risk over the potential accident dose risk of transporting LLW.
- Transporting NARM at the rate of 100,000 cu. ft. per year increases the annual incremental accident dose risk more than transporting 50,000 cu. ft. per year, which in turn increases the annual risk more than transporting 8,600 cu ft. per year. The total incremental risk, however, would depend on the total amount of NARM transported.
- Transporting NARM does not increase the incident-free dose at all; the incident-free dose is the same for transporting NARM with LLW as for transporting LLW only.
- Conservative estimates are used in these models, and the absolute values of the doses and dose risks are not significant. The point of the study is comparison of transportation of NARM with LLW to LLW transportation.

- The total incremental dose risk (person-mSv) is largest for the Albany, OR, route and smallest for the Seattle route, but there is only about half an order of magnitude difference between the largest and smallest dose risks.
- All of these risks are exceedingly small and, even so, are conservative estimates.

References

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FOOTNOTES

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