RISKS IN TRANSPORTING RADIOACTIVE MATERIALS: COMPARISON OF DATA WITH NUREG-0170 PROJECTIONS

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ABSTRACT

Occupational and population doses from incident-free transportation of radioactive materials in the United States are calculated using 1982 shipment data and RADTRAN 4.0. The preliminary results obtained are compared with projections from the 1975 study (NUREG-0170) performed for the Nuclear Regulatory Commission.

Because of its preliminary nature, this paper has not been reviewed or approved by the Nuclear Regulatory Commission. It represents the views of the authors.

INTRODUCTION

NUREG-0170, the Environmental Statement on the Transportation of Radioactive Material by Air and Other Modes (1), has provided the basis for risk assessment for transportation of radioactive materials since its publication in 1977. NUREG-0170 surveyed several differently selected samples (1, Appendix C) of shippers and users of radioactive materials to compile statistics on amounts of radioactive materials shipped, origins and destinations of those materials, end uses, types of packages and sizes of shipments. The totals derived from this survey data were projected to 1985. A transportation risk study has been undertaken by the Center for Nuclear Waste Regulatory Analyses; using more recently collected data on radioactive materials transportation.

The first step in this study is calculation of doses using newer transportation data and a more recently developed algorithm. Moreover, representative shipments have been used instead of the "standard shipments model" of NUREG-0170. Some preliminary results of such calculations are presented here. In the present study, only incident-free ("normal") transportation is considered.

COMPARISON OF TRANSPORTATION PROJECTIONS

The most reliable data collection which deals only with transportation and which covers the period from the 1977 publication of NUREG-0170 to the present is found in the data collected for SAND84-7174 (2). The SAND84-7174 data files were compiled from a survey carried out between 1977 and 1982. The totals from 1982 were then compared with the 1985 projections from NUREG-0170, in order to calibrate those projections, and to provide a basis for projections to 1995 and 2005. Results are given in Table I.

It was found that the totals projected for 1985 by NUREG-0170 were high when compared to the 1982 figures; as much as two orders of magnitude high in some cases. The total annual numbers of packages and amount of radioactivity for some categories of radioactive materials transported between 1977 and 1982 were even lower than the 1975 totals. Projection to 1995 and 2005 using these data indicate that the amount of radioactive material shipped annually would remain the same, or would decrease slightly, unless there were some major shift which would add a new source of transported radioactive material or which would remove some source from the radioactive materials currently being shipped.

The opening of a high-level radioactive waste repository, or a major surface storage facility for radioactive waste, would clearly result in a change in total shipment projections. Such changes can be postulated, but they are independent of historical data. In other words, projections of high-level radioactive waste shipments, or shipments of defense wastes, can only be based on the total quantities of those wastes which are to be shipped, and the rates at which they may be shipped, and bear no direct relationship to current or past radioactive materials transportation.

Adequate projections of radioactive materials shipments depend on a well documented shipment data base for which data is collected periodically and regularly. Such a data base does not exist now. The projections which have been made depend essentially on two data points: 1975 shipment data and 1982 shipment data. Therefore, reliable conclusions regarding future transportation are difficult to draw from them.

PRELIMINARY COMPARISON OF DATA BASES

Several databases, including the Shipment Mobility and Accountability Collection (SM/AC)(3) and the U. S. Department of Energy 1988 Integrated Data Base (IDB)(4) were investigated in addition to SAND 84-7174. These data were found to have been developed inconsistently with SAND84-7174, because they were developed for different purposes. Moreover, there are overlaps among databases, and the overlapping records cannot be consistently iden-

TABLE I
COMPARISON OF RADIOACTIVE MATERIALS TRANSPORTATION WITH PROJECTIONS

	SHIPMENT TYPE					
DATA	LIMITED	MEDICAL	INDUSTRY	FUELCYCLE	WASTE	TOTAL
Packages/year ($x10^5$)						
1975	7.03	9.10	2.15	2.04	1.52	21.9
1985 (projected)[a]	18.3	17.1	5.63	83.6	6.27	131
1982 (SAND84-7174)	4.17	17.3	2.13	1.34	1.81	26.7
Curies/year ($x10^6$)						
1975	0.00211	5.78	9.39	532	0.268	548
1985 (projected)[a]	0.0055	15.0	24.7	8410	1.11	8450
1982 (SAND84-7174)	0.00105	3.08	5.70	34.7	0.137	43.6
TI/year ($x10^5$)						
1975	0.0774	6.43	3.43	5.69	29.8	45.4
1985 (projected)[a]	0.204	12.0	8.79	24.6	123	168

tified. Thus it was determined that SAND84-7174 would be the basis for the present study.

PRELIMINARY COMPARISON OF CALCULATED DOSES

In addition to projections of shipments of radioactive material, occupational doses and doses to the public from transportation of radioactive materials have been calculated for a number of the radionuclides considered. Representative shipments for each radionuclide were extracted from the data, scenarios for these representative shipments have been formulated, and doses to transportation workers and to the general public were calculated using RADTRAN III and RADTRAN 4.0 (5, 6, 7), accessed through TRANSNET. Although the last document for RADTRAN published in final form is the documentation for RADTRAN III, RADTRAN 4.0 is now the code available through TRANSNET (6).

Only incident-free transportation (sometimes referred to as normal transportation) is considered here. Any dose to crew and to the public from incident-free transportation depends on the external radiation from the shipment itself. Dose to handlers of radioactive material depends on the external radiation from the package, if the package is not breached. This external radiation is characterized by the transport index (TI); both RADTRAN III and 4.0 incorporate a factor for TI (5,6,7).

NUREG-0170 lists doses to crew and the public by radionuclide (Tables 4-16, 4-17 and 4-18 of Ref. 1). Since NUREG-0170 has become a generally used reference document for risks due to radioactive materials transportation, the calculation of dose by radionuclide is retained in order to compare results of the present study to NUREG-0170. This presentation is generally not appropriate, however, for two reasons.

1. An apparent overestimate occurs because a package or shipment can contain more than one radionuclide, and sometimes contains many radionuclides. All radionuclides contained in a package contribute to the package TI, just as all radionuclides contained in a single shipment contribute to the shipment TI. The dose for incident-free transportation is TI-dependent, but when that dose is listed for each radionuclide, the package TI and or shipment TI will be counted separately for each radionuclide in the package or shipment.
2. The NUREG-0170 calculations were made from projections of "standard shipments," which were extrapolated from a combination of samples of shippers' responses to detailed questionnaires and summary questionnaires extrapolated to the entire shipper population (Appendix A, Ref. 1). The calculations for the present study used a survey of shippers described in Ref. 2, independent of the NUREG-0170 surveys. Some data in the data set of Ref. 2 were found to contain evident entry errors and were not used. Both the survey used in NUREG-0170 and that used in SAND84-7174 were shipment-based, rather than radionuclide-based.

It is recommended that future calculations of incident-free radioactive materials transportation risk be shipment-based, or at least package-based, and that the concept of risk associated with transporting a particular radionuclide be discontinued once comparison with NUREG-0170 no longer serves a purpose.

Incident-free transportation of radioactive materials appears to pose a greater risk to the public than transportation accidents do (1). However, the relationship may only be an apparent one because of the presentation of dose as a function of radionuclide rather than of shipment. As noted above, listing doses by radionuclide counts some doses several times; i.e., each time radionuclides share a package or shipment. Doses from incident-free transportation are also properly related to transportation mode and end use. Since the dose from incident-free transportation depends on TI while the accident dose depends on the radionuclide and the source strength, comparison of incident-free and accident doses cannot be direct.

All versions of RADTRAN used in transportation risk assessment impose regulatory limits on shipments, assuming that all shipments are made in accord with 10 CFR Part 71 and 49 CFR Parts 170-178. Since the transport indices in RADTRAN 4.0 do not apply to exclusive use shipments, this limits the scenarios which may be used as input to RADTRAN and does not allow scenarios involving very large shipments of any radionuclides. Thus, some doses cannot be calculated using RADTRAN as it can presently be accessed.

Other assumptions made in performing the RADTRAN III and 4.0 calculations are given below:

1. NUREG-0170 information for distances of shipments were used since none were available from the SAND84-7174 data.
2. All package activity is assumed to be gamma.
3. The source to crew distance for truck transportation was 3.3 m.
4. RADTRAN 4.0 default data was used when available. When a nuclide was not in the internal RADTRAN library, data from the RADTRAN III NUREG-0170 conversion factors from ICRP 30 were used to calculate the necessary parameters.
5. NUREG-0170 standard shipment data was used to allocate packages between modal categories.

Table II compares the occupational doses and non-occupational population doses projected to 1985 in NUREG-0170 with the doses calculated from 1982 data in this study. The scenarios used as input into RADTRAN 4.0 for the shipments shown in the table were approximately 68% highway, 30% air and 2% rail. Occupational doses include doses to crew, handlers, and warehouse workers; non-occupational population doses include on-link and off-link doses, doses during stops and doses to airline passengers.

Although most of the doses calculated in the present study were of the same order of magnitude as those reported in NUREG-0170, there are substantial differences between the two sets of results. Potential differences between RADTRAN I (used in NUREG-0170) and RADTRAN 4.0 in calculating individual doses were investigated to determine if such differences were the source of the divergence. There were essentially no differences between the results from the two codes. A given scenario will result in essentially the same annual individual dose for a particular transportation mode when calculated by RADTRAN 4.0 as when calculated by the methods of NUREG-0170.

From Table I, the 1985 projection of total TI/year shipped is about 10 times the 1982 total TI from SAND84-7174. This difference ought to have an order of magnitude greater effect on dose than differences in population projections, differences in route breakdowns, transfer of some types of shipments from air to highway, etc. Sensitivity analysis of population doses from incident-free transportation indicates that the parameters of RADTRAN which have the greatest influence on dose are TI, numbers of packages shipped per year, number of shipments per year and the distance traveled. The sensitivity to a given parameter is a function of the particular radionuclide, but the ratio of sensitivities to different parameters remains within the same order of magnitude. The sensitivities for each radionuclide are given in RADTRAN, and may also be calculated from Ref. 5 or the equations in Appendix D of Ref. 1.

Because the sensitivity of the dose calculation to TI, number of packages shipped, etc. is different for each radionuclide, one would not expect the calculated doses for the 1982 data to differ from the 1985 projected doses by a common factor. However, using the largest "importance" factors for each radionuclide also does not explain the difference between the 1985 projected doses and the 1982 calculated doses.

A reasonable explanation for the variations observed was found by comparing the 1985 projected TI with the 1982 TI for each end use. This comparison is given in Table III.

The analysis to date has not included enough limited shipments or waste shipments to compare with the 1985 projections in any meaningful way. However, if the remainder of the data are compared by end use, an approximate relationship emerges. This relationship is shown in Table IV, below.

Calculation of both occupational and population doses using RADTRAN depends most heavily on the number of packages shipped, the number of shipments, the TI, and the distance traveled. Occupational doses are also sensitive to the distance between the source and the crew, and on the stop time, though the dependence is less than on TI, number of shipments and distance traveled. Dependence of national total doses on population densities, fractions of travel in various population-density zones and traffic counts is much

TABLE II
TOTAL POPULATION DOSES (PERSON-SV) COMPARING 1985 PROJECTIONS FROM NUREG-0170 WITH THE PRESENT STUDY

		DOSE TO CREW		DOSE TO PUBLIC	
MATERIAL	PKG	NUREG-0170	STUDY	NUREG-0170	STUDY
Am-241	A	5.66	1.84	0.81	0.97
Am-241	B	0.037	1.44	0.012	0.68
Au-198	A	0.45	0.033	0.21	0.018
Co-57	A	0.15	0.35	0.18	0.25
Co-60	LSA	4.40	11.72	0.57	4.30
Co-60	B	0.36	0.11	0.032	0.052
Cs-137	A	7.89	0.68	1.30	0.34
Cs-137	B	0.023	0.022	0.003	0.008
Ga-67	A	0.23	0.83	0.28	0.64
H-3	LSA	0.013	0.19	0.010	0.10
H-3	A	0.008	0.011	0.009	0.006
I-131	A	9.87	3.64	11.18	3.94
Ir-192	A	0.82	0.30	0.10	0.15
Ir-192	B	10.13	9.06	1.15	3.90
Kr-85	A	0.86	0.024	0.34	0.033
Mo-99	A	30.43	34.80	25.99	24.66
P-32	A	0.31	0.11	0.32	0.10
Ra-226	A	0.93	0.12	0.12	0.064
Ra-226	B	0.032	0.056	0.006	0.015
Tc-99m	A	2.96	6.10	0.62	2.95
UF_6-nat	B	1.08	0.056	0.17	0.024
UF_6-enr	B	0.14	0.36	0.019	0.14

TABLE III
Comparison By End Use of Projected 1985 TI Shipped With 1982 TI Shipped

	1985 TI/1982 TI
LIMITED	0.3
MEDICAL	1.3
INDUSTRIAL	5.7
FUEL CYCLE	32
WASTE	52

less, because the geographic extent of high-density population zones is very limited. Since the NUREG-0170 1985 projections and the present study using SAND84-7174 data differ in all of the parameters which affect dose strongly, there is no single factor that can account consistently for the difference in calculated doses. The discrepancies appear to reflect primarily the use of different data bases.

CONCLUSIONS

If consistent projections of risks of radioactive materials transportation are to be made, and new types of transportation included in these by constructing scenarios, a consistent data base which has some year-to-year continuity is needed. In the absence of such a data base, the cumulative comparable and combinable data from the base for NUREG-0170 should be combined with SAND84-7174 and any more recent comparable data for newer refined dose projections.

RADTRAN models doses in a manner consistent with present understanding of the physics of ionizing radiation. However, doses from incident-free transportation depend on TI rather than on the amount of activity or the specific radionuclides transported. The dependence on TI suggests that calculating population or occupational doses for the

TABLE IV

Correlation Between Ratio of Doses Calculated for NUREG-0170 and for the Study, Nuclide and End Use

END USE	NUREG-O170 DOSE/STUDY DOSE	NUCLIDES EXHIBITING THE GIVEN DOSE RATIO CREW	POPULATION
Medical	Less than 1.0	Co-57 Type A Pkg.	Co-57 Type A Pkg.
		Co-60 - Type LSA Pkg.	Co-60 - Type LSA Pkg.
		H-3 - Type A Pkg.	H-3 - Type A Pkg.
		H-3 - Type LSA Pkg.	H-3 - Type LSA Pkg.
		Ga-67 - Type A Pkg.	Ga-67 - Type A Pkg.
		Tc-99m - Type A Pkg.	Tc-99m - Type A Pkg.
			Ir-192 - Type B Pkg.
Medical	1 - 3	Co-60 - Type B Pkg.	Co-60 - Type B Pkg.
		I-131 - Type A Pkg	I-131 - Type A Pkg.
		Ir-192 - Type A Pkg.	Ir-192 - Type A Pkg.
		Mo-99 - Type A Pkg.	Mo-99 - Type A Pkg.
		P-32 - Type A Pkg.	P-32 - Type A Pkg.
		Ir-192 - Type B Pkg.	
Industry	8 - 10	Cs-137 - Type A Pkg	Au-198 - Type A Pkg.
		Cs-137 - Type B Pkg.	Kr-85 - Type A Pkg.
		Au-198 - Type A Pkg.	Ra-226 - Type A Pkg.
		Kr-85 - Type A Pkg	
		Rr-226 - Type A Pkg.	
Fuel Cycle	20 - 30	UF_6 nat - Type B Pkg.	UO_2 enr - Type A Pkg
		UO_2 enr - Type A Pkg	
<u>Anomalous</u> The radionuclides listed below do not exhibit the correlation characteristic of the end use.		Anomalous The radionuclides listed below do not exhibit the correlation characteristic of the end	
Less than 1		Am-241 - Type B Pkg.	Am-241 - Type B Pkg.
		UF_6 enr - Type B Pkg.	UF_6 enr - Type B Pkg.
		Ra-226 - Type B Pkg.	Ra-226 - Type B Pkg.
			Cs-137 - Type B Pkg.
1 - 3		Am-241 - Type A Pkg.	Am-241 - Type A Pkg.
		I-131 - Type A Pkg.	Cs-137 - Type A Pkg.
8 - 10			UF_6 nat - Type B Pkg.

total amount of each radionuclide transported is less meaningful than dose calculations based on shipments or packages.

The final report from the present study will present incident-free doses by shipment, and thus allow determination of which shipments pose the greatest risk to the general public.

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