OVERCOMING BARRIERS OF INSUFFICIENT SHIPMENT DATA TO FORECAST TRANSPORTATION RISKS FOR TRANSURANIC RADIOACTIVE WASTE SHIPMENTS

Steve L. Eagan
Steve C. Kline
Stoller Corporation
Albuquerque, NM 87107

Joe P. Harvill
Westinghouse-Waste Isolation Pilot Plant
Carlsbad, NM 88221

ABSTRACT

When there are gaps in required shipment related data for assessing the risk of radioactive waste shipments, methodologies for estimating such data must be developed. This paper will describe how such methodologies were developed to update forecasted annual average transportation risks for proposed transuranic radioactive waste shipments to the Waste Isolation Pilot Plant (WIPP).

The basic analytical tool used to assess transportation risk is a computer code developed for this purpose, called RADTRAN II. Input parameters to properly run RADTRAN II were difficult to determine for the following waste shipment characteristics: shipment transporter dimensions, container volume, shipment distance, radionuclide source term activity, transport index, transportation accident package release fractions, and intersite waste (non-WIPP destination) shipment volumes. Alternate methodologies were developed to more accurately determine each of these RADTRAN II input parameters, resulting in revised forecasts of transuranic radioactive waste transportation risks with greater confidence as to accuracy.

INTRODUCTION

When there are gaps in required shipment related data for assessing the risk of radioactive waste shipments, methodologies for estimating such data must be developed. This paper will describe how such methodologies were developed to update forecasted annual average transportation risks for proposed transuranic radioactive waste shipments to the Waste Isolation Pilot Plant (WIPP).

It is the task of the Defense Transuranic Waste Program (DTWP) of the U.S. Department of Energy (DOE) to ship all newly generated or retrievably stored transuranic radioactive waste from ten DOE sites to WIPP. The RADTRAN code has been utilized to assess the environmental impacts of such shipments. The code combines meteorological, demographic, health physics, transportation, packaging, and shipment material factors in order to evaluate incident-free and accident related radiological impacts.

Since transportation risk assessment work began in 1984 for proposed shipments to WIPP, there have been several changes to several components of the proposed transuranic (TRU) waste shipment system, requiring a reevaluation of transportation risk assessment previously performed.(1)

As a part of performing these revised forecasts of annual average transportation risks, it was discovered that several gaps in shipment data remained. However, with additional data becoming available, it was decided to revise the methodology used to estimate the values of certain analysis input parameters.

TRANSPORTATION RISK ANALYSIS DATA REQUIREMENTS

Overall Description of RADTRAN II

The RADTRAN II code is composed of seven submodels that together describe the broad scope of environmental impacts that might be generated from a radioactive material shipment. For incident-free impacts, four submodels materials, transportation, population distribution, and health effects are used. For accident related impacts, the above four submodels plus the following three submodels accident severity and package release, and meteorological dispersion. Version II of the RADTRAN code was used to perform the analysis. Version III was selectively used to assess potential impacts from ingestion pathways. Several input parameters, covering the entire sequence of a typical shipment of radioactive material, are required for running the RADTRAN II code. Because estimates of the values of many of these input parameters can have a wide variance, all versions of RADTRAN contain conservative default values for several input parameters to provide a baseline risk estimate.(2) Improper application of these default values can lead to a situation where the overall systemwide annual average transportation risks are being overestimated by an uncertain amount. Looking at the case of TRU waste shipments to WIPP, this problem of risk overestimization can be mitigated by developing appropriate methodologies to improve the accuracy of certain RADTRAN II input parameters.

Transporter Dimension Input Parameters

During early 1987, when the authors began this task of reassessing TRU waste shipment risks, the final designs of the contact-handled (CH) TRUPACT II container and the remote-handled RH-TRU cask were uncertain. Our methodology here was simply to continually revise the transporter dimension input as they were received, so that subsequent RADTRAN II runs will contain the revisions.

Projected WIPP shipment schedules were also revised frequently last year. For assessing impacts on a per shipment basis, the variance in total projected shipments was not relevant. However, cumulative risks for each given origin-destination set of shipments are dependent on total volume. The methodology developed to mitigate continuing fluctuations in schedule forecasts of TRU waste shipments was to sum the latest schedule forecast over the projected 25-year future life of WIPP as an operating repository, and then to divide by 25 to obtain annual average cumulative risk. This methodology had been adopted in the previous WIPP shipment risk assessment.(1)

Distance and Population Density Input Parameters

Although preferred routes for WIPP shipments have been established for all ten DOE TRU waste storage/generating sites, the carrier assigned to haul these shipments by either truck or rail modes will have the right under U.S. Department of Transportation regulations to take an alternate route, if safety factors warrant such a decision. The frequency of occurrence of these decisions to travel an alternate route is difficult to forecast.

Consequently, the solution to this uncertainty regarding routing and, therefore, the distance of each proposed TRU waste shipment to WIPP was to calculate an average route distance to use as input to the RADTRAN II code. See Table I.

These calculations were performed using an in-house Stoller Corporation statistical software code, called DTRUMAIN. Also, average fractions of rural, suburban, and urban population density zones were calculated, using DTRUMAIN, to be used as RADTRAN II input with the corresponding weighted average shipment distance values.

TABLE I
REPRESENTATIVE DISTANCES FOR SHIPMENTS TO WIPP (km)

Shipment Origin Site	Truck Average	Truck Range	Rail Average	Rail Range
ANLE	2,231	2,138-2,283	2,364	2,058-2,669
HANF	3,078	2,809-3,506	3,695	3,205-4,151
INEL	2,447	2,153-2,850	2,833	2,360-3,305
LANL	552	552		
LLNL	2,346	2,204-2,457	3,014	2,589-3,566
Mound	2,368	2,298-2,431	2,699	2,615-2,777
NTS	2,069	1,648-2,343		
ORNL	2,172	2,097-2,241	2,623	2,497-2,698
RFP	1,407	1,025-1,725	1,766	1,236-2,452
SRP	2,550	2,328-2,677	3,082	2,874-3,337

Radionuclide Source Term Data Adjustments

Recently, updated radionuclide source term data from the drums and boxes of retrievably stored and newly generated TRU waste at each of the DOE sites was difficult to collect. After the data was collected, it was noticed that the activity fractions shown for a given waste mix often did not sum to 1.0, as they should ideally. Therefore, we resolved this problem by normalizing all radionuclide activity fractions for any given homogeneous waste mix in a given package type at a given site. See Table II.

TABLE II
Contact-Handled TRU Waste
Radionuclide Source Term (3)

Site: Hanford
Package Type: Drums
Waste Status: Newly Generated
Distribution

Radionuclide	Weight Fraction	Measured Activity Fraction	Renormalized Activity Fraction
Pu-238	0.0003	0.0051	0.0047
Pu-239	0.9013	0.0561	0.0511
Pu-240	0.0875	0.0199	0.0182
Pu-241	0.0099	1.0155	0.9260
Pu-242	0.0012	0.0000	0.0000
Total	1.0000	1.0967	1.0000

Transport Index Input Parameters

The transport index (TI) is defined as the highest radiation dose rate (mrem/hr) at 3.3 feet (1 meter) from any accessible external surface of a package on a transport vehicle. For CH-TRU waste the shipment configuration consists of a trailer-load set of three TRUPACT-II packages. The RH-TRU waste shipment configuration is a trailer-load consisting of one RH-TRU cask.

In our initial assessment of transportation risk for WIPP shipments (1), there was insufficient site-specific waste data to accurately determine site-specific shipment origin TI values for input to RADTRAN II. To resolve this, the methodology adopted was to run RADTRAN II multiple times, using a range of TI values representing bounding estimates for the TI values. DOT regulatory maximum TI values were used for common use and exclusive-use shipments for RH-TRU shipments. This resulted in CH-TRU risk assessment results using a minimum TI of 0.1 and a maximum TI of 2.0. For RH-TRU shipments RADTRAN II risk assessment computer program runs were made using TI values of 5, 10, and 20.

The problem with this methodology of using ranges of TI values is that it is overly general and can lead to overestimates of actual radiological transportation impacts. A small change in the TI value yields a large change in incident-free, occupational and nonoccupational radiological transportation risks, measured in person-rems.

The achievement of relatively stable designs of the CH-TRU TRUPACT-II transporter and RH-TRU Cask transporter in 1988 had not been the case in the 1984-86 time period of the previous WIPP shipment risk assessment. Also, with the success in 1988 in collecting more detailed site-specific radionuclide source term data concerning the TRU waste to be shipped, it became possible for the first time to significantly change our methodology for calculating the TI input parameter for RADTRAN II.

Separate TI values were calculated for WIPP shipments from each generator/storage site, based on site specific data for average waste container radiation levels at the contact surface from the 1987 Integrated Data Base (IDB).(4) Two different computer codes were used to assist in the TI calculations by modeling the radiation shielding for the average trailer-load CH-TRU or RH-TRU shipment transporter from a given generator/storage site.

The computer code, SHIELDR, was used to calculate the CH-TRU TI values. SHIELDR is an interactive FORTRAN language code that is run on a CDC CYBER 170 computer and was written by Joseph P. Harvill of WIPP-Westinghouse.

The computer code, MICROSHIELD, Version 3.11 was used to calculate the RH-TRU TI values. MICROSHIELD is an IBM PC compatible code, written and owned by Grove Engineering, Incorporated.

Both software codes model waste packages in containers and transporters. TABLE III displays the resultant transport index values. The results show tremendous variance in TI values between sites, which generates a large variance in resultant radiological transportation risks. Also, TABLE III shows that the previous TI range estimates for CH-TRU shipments of 0.1 to 2.0 are no longer valid estimates of potential minimum and maximum TI values.

TABLE III
TRANSPORT INDEX VALUES
(mrem/hr at 1 Meter from transporter surface)

Site	CHTRU Waste	RHTRU Waste
ANLE	7.5	*
HANF	0.7	16.04
INEL	1.0	4.98
LANL	4.1	8.86
LLNL	0.4	*
MOUND	0.41	*
NTS	1.2	*
ORNL	11.0	3.21
RFP	1.5	*
SRP	2.7	*

Transportation Accident Input Parameters

There are three RADTRAN II input parameters that have a significant effect on the resultant accident related component of risk for any given set of TRU waste shipments. They are the radionuclide release fraction, the aerosolization fraction, and the respirable fraction. These parameters strongly influence the consequence of radiological impacts under accident conditions. The release fraction is defined as the fraction of package contents that escapes for a given accident severity. The aerosolization fraction is defined as the fraction of escaped material that aerosolizes. The respirable fraction is defined as the fraction of aerosolized material that is small enough to be inhaled directly and retained in the lungs(5).

The Type B container CH-TRU TRUPACT II and RH-TRU Cask are designed in accordance with 10 CFR 71 requirements and will endure 99.6% of all credible potential accidents without breeching. Of interest was to determine the potential radiological consequences of the remaining 0.4% of forecasted accidents, where, theoretically, a radioactive material release to the environment could occur. Therefore, extensive review of the literature of material release mechanisms following severe accidents was performed.

The literature on this topic, including packaging test data, is very limited. Therefore, a parametric evaluation of the accident input parameters (release fractions, aerosolization fractions, and respirable fraction) was performed. Because of RADTRAN II code limitations involving the Material Dispersion Factor input parameter, it was concluded that the best solution to estimating the three interacting transportation accident release input parameters, was to set the respirable fraction and aerosolization fraction values for all accident severity levels at the worst case maximum of 1.0 or 100%, and then, develop an algorithm to accurately estimate the total respirable release fraction.

There are multiple release mechanisms and pathways that determine the amount of airborne radioactive material that may be released to the environment following a severe accident. Release mechanisms may be evaluated on the basis of the initiating accident event impact event, thermal event, or a combination of both. Specific impact release mechanisms include waste container failure, fragmentation of solid waste, particulate suspension, and aerodynamic entrainment of particles to the environment upon failure of packaging containment. Thermal release mechanisms include thermally induced failures of the waste container; aerosolization of particulates by combustion, gas generation, or heating of contaminated surfaces; potential volatilization of selected radionuclides; and subsequent aerodynamic entrainment of particles and aerosols to the environment upon loss of containment.

The following assumptions were utilized in order to estimate release fractions:

- All waste is packaged in Type A drums.
- A major breech of the Type B packaging system is not

credible, limiting external air/oxygen sources.

- Loss of packaging containment will result in a 100% release to the environment of airborne particulates and aerosols present in the packaging cavity.
- Radioactive contamination is evenly distributed throughout the waste volume.

The third bullet listed above adds conservatism to the analysis and recognizes the accident specific nature of mitigating factors such as particulate settling, plateout, and filtration effects.

Table IV summarizes the algorithm used to estimate the total respirable release fraction (TRRF) for impact and thermal events. The algorithm assumes that accidents involving a fire will always have an associated impact event and that the releases associated with both event types are additive.

TABLE IV
ESTIMATE OF POTENTIAL ACCIDENT RELEASE FRACTIONS FOR CH AND RH-TRU WASTE SHIPMENTS

Total Respirable Release Fraction (TRRF) = Impact Release Fraction (IRF) + Thermal Release Fraction (TRF)

Impact Release Fraction = (FFC x FMRC) x (FMAI + FMEI) x FMRPI

Thermal Release Fraction = FAT x ((FMC x FMAC) + FMAT) x FMRPT

Where:

FFC =	Fraction of Failed Waste Containers
FMRC =	Fraction of Material Released from Failed Containers into Package Cavity
FMAI =	Fraction of Material Aerosolized from Impact
FMEI =	Fraction of Material Entrained During Impact Event
FMRPI =	Fraction of Material Released from Packaging During Impact Event
FAT =	Fraction of Accidents Involving a Thermal Event
FMC =	Fraction of Material Consumed by Combustion
FMAC =	Fraction of Material Aerosolized by Combustion
FMAT =	Fraction of Material Aerosolized by Thermal Event
FMRPT =	Fraction of Material Released from Packaging During Thermal Event

Intersite Shipments

In the DTWP, projections of intersite shipments of TRU waste are highly variable. Several of the sites have potential problems with processing and certifying their TRU waste that might be alleviated with future intersite shipments of the problematic TRU waste. However, the most likely needs for future intersite shipments are for RH-TRU or special case TRU waste that cannot be processed at their origin site to meet the WIPP Waste Acceptance Criteria and will have to be shipped to another site for final processing prior to shipment to WIPP.

It was estimated that a worst case scenario of shipments over the 25 year life cycle of WIPP will involve eight average annual truck RH-TRU cask shipments or four rail shipments of average systemwide trip length. Likewise, it was estimated over this same 25-year time period that there will be one average annual truck CH-TRU shipment or one average annual rail CH-TRU shipment of average systemwide trip length.

By assuming in each case that the projected annual average intersite shipments will be of average systemwide trip length, the cumulative radiological risk for each type of annual intersite shipment was calculated as the ratio of the intersite 25-year average annual shipments (stated in the previous paragraph), over the WIPP-bound 25-year average annual shipment projection, times the combined systemwide cumulative risk. The results are shown in Table V. It was concluded that intersite shipments add an extremely small amount of radiological exposure risk to the TRU waste shipment system.

TABLE VI
Cumulative Radiological Risk For Annual Intersite CH-TRU and RH-TRU Shipments (Person-Rems)

Formula = (Avg. Annual Intersite Shipments)/(WIPP Bound Total Shipments/25 Years) x Combined Systemwide Cumulative Risk

CH-TRU
Truck: 1/(15497/25) x 52.387 = 0.084
Rail: 1/(7751/25) x 68.858 = 0.222

RH-TRU
Truck: 8/(4934/25) x 53.101 = 2.152
Rail: 4/(2468/25) x 17.524 = 0.710

CONCLUSION

The results of the revised transportation risk assessment for TRU waste shipments to WIPP, which incorporated the methodologies discussed above, were documented in a forthcoming report,(6) and referred to here as the Addendum. A summary of the 25-year annual average systemwide risk results for the truck mode are shown in TABLE VI. Comparisons with the original risk assessment document, referred to here as the Transportation Assessment Guidance Report (TAGR) show the following:

- For both truck and rail shipment modes, 25-year Systemwide Combined (occupational & nonoccupational population) Annual Average Cumulative Radiological Risk Assessment is lower than the 1984 TAGR estimate.
- The recent changes to the TRU Waste Shipment Plans have further lowered the already very low

transportation risks of TRU waste shipments to WIPP.

TABLE VI
25-Year Annual Average Systemwide Transportation Risk
100% Truck Mode

Radiological Risk (Person-rems)

	TAGR	Addendum	Dif.
CH-TRU Shipments			
Occupational, Incident free	90.293	32.538	-57.71
Nonoccupational, Incident f ree	67.574	16.236	-51.338
Nonoccupational, Accident Related	0.080	3.568	+3.488
Combined Total	157.947	52.387	-105.560
RHTRU Shipments			
Occupational, Incident free	34.88	20.638	-14.242
Nonoccupational, Incident free	77.224	28.4322	-48.7918
Nonoccupational, Accident Related	0.092	4.03	+3.93
Combined Total	112.196	53.101	-59.095

By utilizing the methodologies discussed above, we were able to resolve the data gaps that we discovered while performing this updated transportation risk assessment task. As a result, we obtained more accurate transuranic radioactive waste transportation risks estimates.

REFERENCES

1. U.S. DOE, February 1986. Transuranic Waste Transportation Assessment and Guidance Report, DOE/JIO-002, Rev.1.
2. P.C. Reardon, K.S. Neuhauser, Sandia National Laboratories, March 1987. "A Demonstration Sensitivity Analysis for RADTRAN III," Waste Management '87: Proceedings of the Symposium on Waste Management.
3. Westinghouse-WIPP, (forthcoming). Radionuclide Source Term for the Waste Isolation Pilot Plant.
4. Madsen, M.M., E.L. Wilmont, and J.M. Taylor, 1983. RADTRAN II User Guide, SAND82-2681, TTC-0399, Albuquerque, NM: Sandia National Laboratories.
5. US DOE, September 1987. Integrated Data Base from 1987: Spent Fuel and Radioactive Waste Inventories, Projections, and Characteristics, DOE/RW-0006, Rev. 3.
6. Eagan, Steve L., Kline, Steve C., Stoller Corp., and Harvill, Joseph P., Westinghouse-WIPP, November, 1988. Draft Addendum to Transuranic Waste Transportation Assessment and Guidance Report.