

RISK ASSESSMENT FOR SAMPLE WIPP AND YUCCA MOUNTAIN SHIPMENTS

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ABSTRACT

Large transcontinental shipping campaigns like those bound for the Waste Isolation Pilot Plant (WIPP) and Yucca Mountain require cooperation among regulators, shippers, and government agencies at all levels. Public acceptance, in addition to cooperation, influences the ability of a large-scale transportation program to remain on schedule, within budget, and operating safely over the course of the entire shipping campaign. Thus, public perception should play an important role in the planning and operational stages of any large shipping campaign.

Radiological risk assessment plays an invaluable role for scientists, engineers, and managers, but is often very difficult for members of the public to understand or trust. In an effort to help interested members of the public understand some of the intricacies of transportation operations the National Transportation Program (NTP) is preparing an INTERNET web site. One topic to be discussed on this web site is radiological risk assessment. This paper will provide the background for a discussion of transportation risk analysis methods and results in an effort to help facilitate public trust and improve understanding. Ten representative transportation scenarios involving commercial spent nuclear fuel (SNF), DOE-managed SNF, and vitrified high-level waste (HLW) bound for Yucca Mountain and transuranic (TRU) wastes bound for WIPP are evaluated to quantify potential consequences and risks for both routine and accident transportation environments. The RADTRAN code, now in the RADTRAN 4 and RADTRAN 5 versions, developed at Sandia National Laboratories (SNL) is used to quantify route-specific incident-free dose consequences and accident-related dose risks (1,2). The RISKIND code, version 1.11, developed at Argonne National Laboratory (ANL) is used for site-specific risk analysis (3).

INTRODUCTION

Risk analysis is an important analytical tool that has come into extensive use over the past few decades because it provides a basis for consistent, defensible decision making. In terms of transportation risk, this tool is especially useful for determining the safest transport route, estimating worst case risk bounds, aiding in emergency planning procedures, demonstrating compliance with regulatory requirements, estimating overall risk, and evaluating risk reduction options (4). In recent years, risk analysis has also played a vital role in public communications efforts, both laying minds at ease as well as creating new questions.

One of the ways the U.S. Department of Energy (DOE) plans to improve public communications is through the use of the INTERNET. The DOE sponsored National Transportation Program (NTP) has set up a world wide web (WWW) home page at <http://www.ntp.doe.gov> to aid in the

public dissemination of information related to non-classified DOE shipments of radioactive materials. The web page will provide public access to the prospective shipments reporting system; historical transportation records and maps; operation and package specific pictures and fact sheets; terminology definitions; and links to federal regulatory agencies and national laboratory based transportation research programs. In addition, the web page will contain information about the risks associated with the transport of radioactive materials. This report provides supporting documentation for the representative consequence and risk estimates that will eventually be presented on the NTP home page and touches upon how these estimates should be presented in a public forum such as the INTERNET.

CALCULATION OF RISK ESTIMATES

A total of ten representative transportation scenarios are modeled to provide an estimate of the expected radiological consequences and risks resulting from individual shipments of radioactive material traveling to either the Yucca Mountain facility or the WIPP site. Population-averaged dose consequence and risk estimates over an entire shipment route are calculated using RADTRAN 4. An excerpt of the RADTRAN input is then used in the Transportation Individual Center-Line Dose (TICLD) code to provide distance and time-integrated individual accident dose risk estimates. RISKIND 1.11 is used to assess site-specific individual and population subgroup consequences and risks.

Quantities and Assumptions Used

Transportation risk analysis necessarily involves a large number of parameters, most, of which lack readily available case-specific supporting data. Instead, the analyst must make assumptions based on previous analyses or attempt to make an educated guess that can be reasonably supported for parameters lacking sufficient real-life data. In the representative cases studied here, we attempt to use only previously published referenced data for our parameters. The following sections will discuss the various input parameters and assumptions used for the ten scenarios studied here.

GENERAL SHIPMENT DESCRIPTION

All ten representative scenarios assume that the transport package will be transported using either a tractor-trailer combination or locomotive railcar. This is a reasonable assumption considering the size and weight of the packages, in addition to the fact that both Yucca Mountain and WIPP are land-locked. A basic overview of each representative shipment scenario is given in Table I.

Table I. Basic Parameters for Representative Yucca Mountain and WIPP Shipment Scenarios

Shipment Origin (Site, State) ¹	Source Term	Transport Mode	Total Distance (km)	Shipment Container Type
<i>Shipments Bound for Yucca Mountain Repository, NV</i>				
Connecticut Yankee NPP ³ , CT	PWR SNF	Truck	4420.7	GA-4
Washington Nuclear NPP, WA	BWR SNF	Rail	2107.1	MPC
Maine Yankee NPP, ME	PWR SNF	Rail	5270.8	MPC
Big Rock Point NPP, MI	BWR SNF	Truck	3767.4	GA-9
Hanford Repository, WA	HLW	Rail	2140.9	HLW Cask ²
Hanford Repository, WA	HLW	Truck	1907	HLW Cask ²
Hanford Repository, WA	SNF	Rail	2140.9	Unknown ²
<i>Shipments Bound for WIPP, NM</i>				
INEEL, ID	TRU	Truck	2238.5	TRUPACT -II
Rocky Flats, CO	TRU	Truck	1132.9	TRUPACT -II
LANL, NM	TRU	Truck	550.2	TRUPACT -II

¹ Origin nodes listed specifically as named in the HIGHWAY and INTERLINE routing codes. ² Cask data from the Transportation Technology Center (TTC) files available on TRANSNET. The characteristic package dimensions were 4.60 m for the HLW Cask and 2.0 m for the unknown cask. ³ NPP stands for nuclear power plant.

SHIPMENT INVENTORY TERMS

RADTRAN, TICLD, and RISKIND require an isotopic description of the material being transported. The user must provide the curie amounts of each isotope present as well as information to distinguish the chemical-physical and dispersion group parameters. Three basic types of shipment materials are modeled in this study -- contact-handled transuranic waste (CH-TRU), spent nuclear fuel (SNF), and vitrified high-level waste (HLW). Identical isotopic distributions are used in all calculations regardless of the code being used. Since TICLD uses a subset of the RADTRAN input data, the chemical-physical and dispersion group terms are also identical. RISKIND, however, is limited to no more than five chemical-physical groups and uses slightly different dispersion parameters; thus, some parameter adjustment is necessary.

TRU Source Term

The CH-TRU waste source terms are derived from the site-wide isotope activity tables available in the Transuranic Waste Baseline Inventory Report (5). The activity per unit volume of waste is calculated by assuming a uniform isotope distribution throughout the total site-specific waste volume. Then the shipment source term is estimated based on a TRUPACT-II inner container

volume of 2.912 m^3 . Only isotopes defined in the RADTRAN isotope library and present at a concentration greater than $1.0\text{E-}7$ curies per shipment are included in the source term model. An external gamma radiation field measuring 0.1 mrem/hr at 1 meter from the outside of the TRUPACT-II package is used for all three WIPP shipment scenarios.

Commercial SNF Source Term

The commercial SNF source terms are derived from the RISKIND defaults for light water reactor fuel (LWR), which experienced 35,000 MWd/MTU burnup and 10 years of decay cooling. Table II shows the cask specific parameters used to determine the source terms for both pressurized water reactor (PWR) and boiling water reactor (BWR) fuels (3). All commercial SNF calculations assume an external radiation field, composed of 83% gamma and 17% neutron radiation, measuring 14 mrem/hr at 1 meter from the cask surface.

Table II. Parameters Used in RISKIND to Determine Commercial SNF Source Terms

Cask Type	Fuel Type	Number of Assemblies	Initial Uranium Weight (MTU/cask)	Cask Length (m)	Cask Radius (cm)
GA-4 LWT	PWR	4	1.69	4.77	50.48
GA-9 LWT	BWR	9	1.59	5.03	50.48
MPC	PWR	21	10.3	5.29	108.6
MPC	BWR	40	8.0	5.29	108.6

Other Source Terms

The source terms for the Hanford shipments were taken directly from Transportation Technology Center (TTC) developed sample files publicly available on the TRANSNET system. Table III outlines the source terms taken from the TTC files for both DOE-managed SNF and vitrified HLW from the Hanford Site in Washington. No changes were made to the package or material parameters in the TTC files.

Table III. Hanford Site Source Terms Taken from TTC Files on TRANSNET

Nuclide	Ci/pkg. SNF	Ci/pkg. HLW	Nuclide	Ci/pkg. SNF	Ci/pkg. HLW	Nuclide	Ci/pkg. SNF	Ci/pkg. HLW
$^3\text{H}_2\text{O}$	1.55E-1		^{106}Ru	1.20E+4	1.23E+4	^{151}Sm	3.21E+1	
Org ^{14}C	1.25E-2		^{125}Sb	4.46E+2		^{154}Eu	6.29E+1	2.81E+3
^{60}Co	2.55E-2	7.70E+2	$^{125\text{m}}\text{Te}$	1.04E+2		^{155}Eu	4.36E+1	
^{85}Kr	3.13E+2		^{127}Te	3.27E+2		^{238}Pu	1.17E+1	4.58E+3
^{89}Sr	8.99E+3		^{129}I	9.02E-4		^{239}Pu	3.66E+1	4.32E+1
^{90}Sr	2.41E+3	1.97E+5	^{131}I	1.96E-2		^{240}Pu	1.94E+3	2.74E+1
^{91}Y	1.56E+4		^{134}Cs	1.04E+3	1.71E+3	^{241}Pu	2.34E+3	5.20E+3
^{95}Zr	2.28E+4		^{137}Cs	3.02E+3	1.65E+5	^{241}Am	2.36	4.86E+1
^{95}Nb	4.46E+4		^{141}Ce	3.70E+3		^{243}Am		2.58E-2
^{99}Tc	4.20E-1		^{144}Ce	4.43E+4	4.42E+4	^{244}Cm		7.30E-1
^{103}Ru	5.56E+3		^{147}Pm	8.03E+3				

SHIPMENTS ROUTES AND TRAVEL RELATED PARAMETERS

All of the shipment routes are determined using the HIGHWAY and INTERLINE routing codes developed at Oak Ridge National Laboratory (6,7). The truck routes for both SNF and HLW use the HM-164 highway route-controlled materials option, which favors Interstate highways as the predominant road type. All of the WIPP bound truck shipment routes use the WIPP routing option, which forces the use of designated highways within New Mexico.

All of the routes are described in RADTRAN using the LINK option. By using the LINK option, the local and state roads used to access the origin and destination sites can be distinctly modeled. All local roads are modeled as city streets with a 40.2-kph (25-mph) speed limit and a 235 vehicle per hour traffic count. Since most of the sites are in reasonably remote areas, rural accident rates are used. All of the interstate travel is modeled in an aggregate manner using the three population zone data supplied in the RADTRAN output section of HIGHWAY and INTERLINE. The accident rates and vehicle densities are applied on a population zone basis. Table IV describes the values used in each population zone for both highway and rail transport modes. The only exceptions to the values in Table IV are for the local site access roads as previously described.

Table IV. Accident Rates and One-Way Vehicle Densities

	Rural	Suburban	Urban
<i>-----Truck Transport-----</i>			
Accident Rate (accident/km)	1.37E-7	3.0E-6	1.60E-5
Vehicle Density (vehicle/hr)	470	780	2800
<i>-----Rail Transport-----</i>			
Accident Rate (accident/km)	1.0E-7	1.90E-6	1.5E-5
Vehicle Density (vehicle/hr)	1	5	5

The maximum population zone specific truck velocities are modified from the RADTRAN 4 default values. Table V gives the default RADTRAN 4 data as well as the values used in this study for interstate, state highway, and local road travel. The default rural, suburban, and urban velocities of 64.4-kph (kilometers per hour), 40.2-kph, and 24.2-kph for rail travel are used for each of the rail transport cases studied in this report.

Table V. Maximum Permitted Travel Velocities by Road Type and Population Zone

Road Type	Population Zone	Default Velocity (km/hr)	Assumed Velocity (km/hr)
Interstate	Rural	88.49	104.65
Interstate	Suburban	40.25	88.49
Interstate	Urban	24.16	80.50
State	Rural/Suburban	24.16/40.25	104.65
State	Urban	24.16	80.50
Local	Rural	NA	40.25

ACCIDENT-SEVERITY CATEGORY SCHEMES

All representative scenarios involving SNF, both commercial and DOE-managed, use the six-category transportation accident-severity category scheme developed by Wilmot (8). The remaining scenarios use the normalized eight-category accident-severity scheme outlined in NUREG-0170 (9).

TRANSPORT PACKAGE CHOICES

Although the GA-9 legal weight truck (LWT) shipping cask has not completed the licensing process it is assumed to be the cask of choice for truck transport of commercial BWR fuel at the time when the Yucca Mountain repository begins accepting SNF. This is a reasonable

assumption based on the fact that the GA-4 LWT cask for commercial PWR fuel was certified by the Nuclear Regulatory Commission (NRC) in 1998. Although DOE dropped the multi-purpose canister (MPC) from supported development in 1996, it is assumed that a similar rail cask will be available when Yucca Mountain opens. According to the TTC file documentation on TRANSNET, the casks for the Hanford shipments were designed specifically for transporting Hanford waste, thus, they are not expected to change before off-site waste shipment begins. All of the WIPP shipments use the TRUPACT-II truck-trailer combination. This is the only package design currently licensed for acceptance at the WIPP site.

PARAMETERS USING DEFAULT VALUES

Since this work involves representative scenarios, there are several parameters for which specific real-life data is not available. With the exception of the assumptions previously listed, code-specific default values are used when real-life data is not available. Some specific examples of accepted default values include the use of RADTRAN 4 zone specific shielding, breathing rate, and cultivation values (1). In addition, all of the RADTRAN 4 calculations conservatively use the default evacuation period of one day although there have been published studies showing that accident site evacuation times are on the order of several hours (10). Since RISKIND involves calculating site-specific consequences and risks, it requires a more detailed description of the particular site of an accident. Considering the nature of this study, it is not feasible to create detailed descriptions for all the possible accident sites along the transport route. Instead, we model the same specific situation for each waste type and transport mode combination. The data used in the RISKIND analyses closely mimic the data used in the RADTRAN analyses. Since default values between the two codes are not identical, we use RADTRAN 4 defaults for the common parameters. In general, all of the default values are well documented in their respective code manual, so a concerned reader should look there for more information. For an actual shipment, site-specific data would be obtained for most of the parameters, thus avoiding the heavy reliance on default parameter values.

Risk Estimation Results

Several types of population and individual dose consequence and dose risk values are estimated using the input parameters and assumptions previously discussed in the RADTRAN, RISKIND, and TICLD risk analysis codes. The calculated results are described in the following sections.

RADTRAN RESULTS

RADTRAN 4 is used to estimate the incident-free population-averaged dose consequence to persons sharing the transportation route (on-link population), persons residing near the transportation route (off-link population), persons exposed during stops, and the maximally exposed individual (MEI). In addition, RADTRAN 4 is used to estimate population and route-averaged accident dose risks. Table VI describes these population dose estimates for each of the ten representative cases modeled.

Table VI. RADTRAN Estimated Dose Consequences and Risks for Representative Shipments

Shipment Origin (Site, State)	Source Term	Transpo rt Mode	Incident-Free Dose Consequences (person-rem)				Total Accident Dose Risk (person-rem)
			Off- Link	On- Link	Stop Dose	Max. Ind.	
Shipments Bound for Yucca Mountain, NV							
Connecticut Yankee NPP, CT	PWR SNF	Truck	5.9E-3	3.4E-2	8.6E-1	5.6E-7	6.2E-4
Washington Nuclear NPP, WA	BWR SNF	Rail	3.3E-3	4.7E-4	5.3E-4	6.1E-7	1.6E-2
Maine Yankee NPP, ME	PWR SNF	Rail	2.3E-2	2.5E-3	3.8E-3	6.1E-7	2.1E-1
Big Rock Point NPP, MI	BWR SNF	Truck	4.4E-3	3.1E-2	7.6E-1	5.8E-7	3.3E-4
Hanford Repository, WA	HLW	Rail	3.2E-3	4.2E-4	4.8E-4	5.4E-7	1.5E-4
Hanford Repository, WA	HLW	Truck	2.7E-3	1.7E-2	3.5E-1	5.4E-7	5.1E-4
Hanford Repository, WA	SNF	Rail	1.5E-3	1.9E-4	2.2E-4	6.4E-7	6.1E-4
Shipments Bound for WIPP, NM							
INEEL, ID	TRU	Truck	7.3E-5	7.3E-5	1.5E-2	1.8E-8	3.1E-5
Rocky Flats, CO	TRU	Truck	7.4E-5	5.1E-4	7.4E-3	1.8E-8	2.8E-4
LANL, NM	TRU	Truck	3.7E-5	3.6E-4	3.6E-3	1.8E-8	4.4E-5

RISKIND RESULTS

The RISKIND computer code has been designed primarily for site-specific accident dose risk calculations, although it does contain options to calculate some site-specific routine consequence values. RISKIND is used in this evaluation to estimate routine transport dose consequences to four potentially exposed individuals exposed to both stationary and passing waste shipments. Additionally, RISKIND is used to evaluate routine dose consequences and accident dose risks to a specified sub-population along a small segment of the transport route.

RISKIND is used to estimate the individual dose to three people exposed to a stationary shipment for one hour. IND #1 is a person shopping in a mall 200 m away from the transport route. IND #2 is a customer at a gas station by a local interstate on-ramp 40 m away from the transport route. IND #3 is a child playing in a nearby school yard 500 m away from the transport route. The same three individuals are also used to evaluate the dose due to a passing shipment. The passing shipment analyses assume a suburban interstate velocity of 105-kph (65-mph) or a train velocity of 40.2-kph (25-mph) through a suburban area. In addition, a fourth individual is modeled for the moving shipment case. This modeled individual is a motorist following 20 m behind the waste truck for 15 minutes. Since a car cannot follow directly behind a train, there

are no motorist values reported for origins using rail transportation. Parameters used in the RISKIND calculations are identical to their RADTRAN counterparts unless the code prohibits their use. The adult breathing rate is assumed to be the RADTRAN 4 default value of $1.04\text{E}4 \text{ m}^3/\text{yr}$. The breathing rate for a child is assumed to be $8000 \text{ m}^3/\text{yr}$. The results of these calculations for each representative shipment scenario are shown in Table VII.

Table VII. RISKIND Calculated Individual Dose Consequences

Origin	Stationary Shipment Dose (rem)			Passing Shipment Dose (rem)			Motorist Dose (rem)
	IND #1	IND #2	IND #3	IND #1	IND #2	IND #3	
Connecticut Yankee NPP ²	1.1E-8	2.8E-5	1.7E-8	3.6E-11	2.7E-8	1.0E-10	3.0E-5
Maine Yankee NPP	1.7E-8	4.3E-5	2.6E-8	1.5E-10	1.1E-7	4.1E-10	NA
Washington Nuclear NPP	1.7E-8	4.3E-5	2.6E-8	1.5E-10	1.1E-7	4.1E-10	NA
Big Rock Point NPP	1.1E-8	2.9E-5	1.7E-8	3.8E-11	2.8E-8	1.0E-10	3.1E-5
Hanford SNF	5.5E-9	1.5E-5	8.7E-9	4.8E-11	3.8E-8	1.4E-10	NA
Hanford HLW Truck	1.0E-8	2.7E-5	1.6E-8	3.4E-11	2.6E-8	9.9E-11	2.9E-5
Hanford HLW Rail	1.0E-8	2.7E-5	1.6E-8	8.8E-11	6.8E-8	2.6E-10	NA
WIPP	8.9E-11	2.4E-7	1.4E-10	3.0E-13	2.3E-10	8.7E-13	2.6E-7

¹ IND #1: a mall shopper, IND #2: gas station customer, IND #3: a child in a school yard

² NPP stands for nuclear power plant.

In addition, RISKIND is used to evaluate the collective dose to a population subgroup for a single representative accident environment for each origin-destination pair studied with RADTRAN. The modeled accident conditions come from example problem 2 in the RISKIND manual (3). The population is assumed to extend uniformly between 200 and 400 m from the potential accident site with an average shielded population density of $600 \text{ adult persons}/\text{km}^2$. The weather is modeled using Pasquill category D with a 4 m/s wind blowing towards the exposed population. Only short-term exposure from plume passage is considered. The results of this calculation are tabulated in Table VIII.

Table VIII. Sub-population Accident Dose Risk Calculations Using RISKIND

Waste Origin	Off-Link Consequence (person-rem)	On-Link Consequence (person-rem)	Acute Accident Dose Risk (person-rem)
Connecticut Yankee NPP	3.20E-8	1.39E-5	3.88E-4
Maine Yankee NPP	1.31E-7	5.23E-5	6.75E-7
Washington Nuclear NPP	1.31E-7	5.23E-5	2.03E-5
Big Rock Point NPP	3.31E-8	1.42E-5	5.05E-4
Hanford SNF	4.24E-8	2.17E-5	1.03E-3
Hanford HLW – Truck	2.97E-8	1.34E-5	1.55E-9
Hanford HLW – Rail	7.77E-8	3.75E-5	1.17E-9
INEEL	2.62E-10	1.13E-7	1.52E-10
LANL	2.62E-10	1.13E-7	3.89E-10
Rocky Flats	2.62E-10	1.13E-7	8.91E-10

TICLD RESULTS

TICLD calculates the maximum individual dose risk from inhalation, cloudshine, and the first day of groundshine for an individual that is either outdoors or inside a building during a potential accident and subsequent cleanup activities. TICLD allows the estimation of the distance away from the accident site at which an individual will receive a negligible individual dose (NID) of 0.01 mSv (1 mrem) (11). In addition, TICLD results can be used to determine the radial distance within which the 1 mSv (100 mrem) recommended annual dose limit for a member of the public is exceeded (12). Table IX gives the radial distances from the accident site for these regulatory limits for both unshielded outdoor and shielded indoor individuals. The values reported in Table IX are for an accident falling into the highest accident severity category modeled. In general, this category represents accidents involving severe thermal and impact environments that lead to a significant release of the package contents. These accidents have very low probabilities of actually occurring, so the values in Table IX are not representative of what is considered to be a typical accident.

Table IX. TICLD Estimated Radial Distances at Which the Annual NCRP and IRCP Dose Limits Are Exceeded for an Accident in the Worst Severity Category Modeled

Shipment Origin (Site, State)	Outdoor Distance from Accident Site (m)		Indoor Distance from Accident Site (m)	
	0.01 mSv limit	1 mSv limit	0.01 mSv limit	1 mSv limit
<i>Shipments Bound for Yucca Mountain</i>				
Connecticut Yankee NPP, CT	3.7E3	2.3E2	2.1E2	1.3E1
Washington Nuclear NPP, WA	8.2E3	5.2E2	4.7E2	3.0E1
Maine Yankee NPP, ME	1.1E4	6.8E2	6.2E2	3.9E1
Big Rock Point NPP, MI	3.1E3	1.9E2	1.8E2	1.2E1
HLW Hanford Repository, WA	4.5E6	2.8E5	2.6E5	1.6E4
SNF Hanford Repository, WA	1.2E4	7.6E2	6.9E2	4.4E1
<i>Shipments Bound for WIPP</i>				
INEEL, ID	1.3E4	7.8E2	7.2E2	4.5E1
Rocky Flats, CO	3.6E4	2.3E3	2.3E3	1.3E2
LANL, NM	1.6E3	1.0E2	2.8E4	1.7E3

INTERNET PRESENTATION OF THE RESULTS

To someone familiar with very small and very large quantities, the results presented in the previous section do not cause much alarm; however, to a member of the public who is not familiar with the notation, it is difficult to gauge the magnitude of danger associated with the reported results. That is to say, it is difficult to put the discussed analyses into perspective. Additionally, it is hard for a non-technical person to understand why several computer codes are necessary to calculate what appear to be similar terms and why the different values presented cannot be directly compared. It is these types of difficulties, which we hope to alleviate through the information available on the NTP web site.

There are two main goals associated with the presentation of these representative cases on the INTERNET. First, we would like to be able to give members of the public a background in risk analysis. Thus, we must first and foremost explain what risk analysis is and why it is so vital to the planning and operation of safe shipping campaigns. Secondly, we want to be able to help people put these risk analysis values into perspective. The representative shipments studied in this report provide risk values spanning 10 orders of magnitude. In addition, these representative shipments do not reflect the same assumptions that were used in the WIPP and Yucca Mountain Environmental Impact Statements (EISs) risk evaluations. Thus, the other goal of this project will be to help a member of the public put the calculated risk values from this report and other reports into some sort of perspective with respect to the risks they might encounter in their daily lives.

Choosing the Presentation Format

One of the most important and probably most difficult tasks of presenting the results of these representative risk analyses on the INTERNET will be deciding on the proper notation of the numerical results. Since most non-technical people do not deal with scientific notation on a regular basis, we plan to present the numbers in a general format including all of the preceding and placeholder zeros. In addition, a graphical comparison of scenarios which only differ in a single parameter, such as transport mode, travel distance, velocity, or source term model, will be provided to help interested non-technical people understand how parameter variations effect the risk analysis results.

Explaining Why RADTRAN and RISKIND Cannot be Directly Compared

It is usually difficult to explain why different codes have been developed to calculate what seem to be similar dose effects. One of the goals of the web presentation will be to explain the difference between population-averaged route-specific risk calculations, for which RADTRAN was designed to handle, and individual site-specific risk calculations, for which RISKIND was specifically designed. In addition, it will be important to explain the particular differences between the two codes, which prevent them from being directly compared. Some examples of these differences include the fact that RISKIND models all stops as a uniform distribution of people between to concentric circles. In RADTRAN this method is used for rail stops, but truck stops are modeled as a population of x people at a distance, r , from the shipment. Other examples that might be used include RISKIND parameter limits, which are more restricted than those in RADTRAN. These restrictive limits include a 5000 km limit on the shipment distance and a one-way traffic density limit of 2200 vehicles per hour.

Analyzing the Results

The simplest way to help a non-technical person surmount the overwhelming complexity of risk assessment is through the use of comparative examples which demonstrate how variations in parameter values effect the calculated outcome. There are several ways that the representative cases presented in this paper could be used to demonstrate expected trends. A few examples are outlined below.

Incident-free dose consequences are determined predominantly by the external radiation field and the total distance traveled by a shipment. Based on these two parameters, several expected trends can be observed in the RADTRAN results displayed in Table VI. Looking at only the incident-free dose consequences we see that the estimated dose consequence increases with increasing distance traveled. Two behind the scene aspects account for this trend. First, the number of potentially exposed people increases the longer the distance traveled. Second, the longer one travels, especially by truck, the more stops that are necessary; again increasing the number of potentially exposed people. One can also see that the off-link results differ by about two orders of magnitude between Yucca Mountain and WIPP bound shipments. This trend makes sense when one considers that the transportation index (TI) for a single shipment bound for each destination is 14 and 0.1, respectively.

Another important comparison in the RADTRAN data would be between the truck and rail shipments of the Hanford Site HLW. Comparing the results of these two analyses would allow

us to discuss some of the aspects affecting transport mode decisions such as on-site rail availability, cask capacity, average population distributions along roads versus train tracks, and the overall number of shipments necessary to complete a shipping campaign. This comparison and explanation would allow us to hammer the importance of looking at campaign level rather than shipment level consequences and risks.

The individual dose consequences and risks calculated for the specified individuals and population subgroups range from 10^{-5} to 10^{-13} . From a scientific standpoint, all of the calculated risk values are insignificant and well below the background radiation dose experienced by everyone, but to someone outside the field, any extra radiation appears detrimental, especially when many times people do not even realize that they are exposed to radiation everyday of their life. Thus, we must make specific communication efforts to help people understand radiation sources and quantities so that non-technical people can put transportation risk results into perspective with the other risks in our lives.

Explaining the Usefulness of Such Seemingly Arbitrary Calculations

In addition to focusing on understanding the magnitude of risk, it is also important to demonstrate what will be done to protect the public from danger. It is important that people know that several measures are in place to ensure that the radiation hazard that they will personally experience is being minimized. It is important to communicate how the transport packages are tested to insure safety and how DOE plans to insure that packages are inspected and constantly monitored. In addition, we must show that we can be prepared for an accident should something actually occur during a transport operation. The TICLD output could be used to demonstrate how emergency response personnel could benefit from the availability of radial dose distributions for an accident situation. Information like that obtained in Table IX would be helpful to emergency response teams, since knowing where to control accident site boundaries and proper evacuation distances prior to an accident will allow for confident and quick emergency response should an accident occur. Additionally, data like this might also help to ease fears about the possibility of "contaminating the nation" should some type of accident occur in the future.

CONCLUSIONS

The results of the RADTRAN, RISKIND, and TICLD calculations show that risk analysis and communication efforts must focus on a wide variety of situations. The scientific consequences and risks from the transportation of radioactive materials are low, but the public has difficulty accepting that which they do not fully understand or even trust. Analysts need to be familiar with current risk evaluation codes and input parameters so that they can fully evaluate potential credible situations to the best of their ability. However, they must also be open to the concerns of the public so that interactive communication can actually occur. Without trying to understand their point of view, we will never gain public trust or acceptance for any large-scale transportation campaign. Without public acceptance, it will be impossible to maximize transport safety and effectively make use of disposal sites like WIPP and Yucca Mountain.

The NTP web site is dedicated to empowering the public with respect to radioactive materials transportation issues. It is hoped that these representative shipments will provide concerned

individuals with enough information to create interest in risk analysis and prompt them to get involved with community and government organizations to insure that all radioactive materials are handled, transported, and disposed of in the safest manner possible.

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