A Methodology for Estimating the Risk of Transporting Low-Level Radioactive Waste in the U.S.

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ABSTRACT

A simplified methodology for determining the population exposures due to the transportation of commercial low-level radioactive waste is described. The methodology consists of two components: (a) developing the shipping distances associated with LLW transportation and (b) developing the unit-consequence and unit-risk factors for the several classes of LLW materials that can be transported. The combination of these two components provides the population exposure estimate for LLW transportation. Since the shipping distances are usually not known with great accuracy the unit-factors can be applied to new or more accurate shipping estimates in the future in order to re-evaluate the LLW population exposures.

INTRODUCTION

The objective of this paper is to present a simplified methodology for estimating the risks associated with the transportation of radioactive low-level wastes (LLW) in the U.S. The methodology is used to calculate the consequences of normal (incident-free) transportation and the risks associated with transportation accidents. These consequences and risks are given in terms of population exposures (person-rem).

The methodology is divided into two parts, a LLW shipment analysis and the presentation of unit consequence and unit risk factors. The shipment analysis presented in Appendix A contains information about the estimated shipments to the present LLW disposal sites at Barnwell, SC, Beatty, NV, and Richland, WA. In addition, the shipping estimates for postulated regional LLW disposal sites are also given. The basis for the shipping analysis is given in Reference 1. The second part of the analysis provides the tabulation of the unit-consequence factors for LLW for normal transportation and the unit-risk factors for potential transportation accidents involving LLW. These unit-factors are given in terms of person-rem/kilometer, hence the determination of the consequences and risks of transporting LLW will involve the product of the shipment data and the unit-factors. The main thrust of this presentation is to describe how the consequences and risks associated with the transportation of low-level radioactive wastes can be estimated. One reason that the consequences and risks are estimates is because present and future shipping volumes and distances are not known with great certainty. The unit-factors used in this analysis are obtained from state-of-the-art calculational techniques. A secondary objective of this analysis is to emphasize that if other, or more accurate, LLW shipping scenarios become available in the future then the consequences and risks of LLW transportation can be re-evaluated using the methodology and the unit factors described in this report.

LOW-LEVEL WASTE SHIPMENT ANALYSIS

The low-level waste shipments used in this analysis were estimated in Reference 1 and are summarized and classified as shown in Table I. The shipments center about two principal options. That is, present practice with LLW shipments to the disposal facilities at Barnwell, SC, Beatty, NV, and Richland, WA; or the DOE suggested regional concepts as defined in Reference 1. A summary of the LLW shipments for the various categories of low-level waste from the reactor, industrial and institutional components is shown in Table II. In the next section of this paper, the shipment distance information in Table II will be combined with the unit consequence and unit risk information presented in Appendix A to produce the consequence and risk estimate for U.S. low-level waste transportation.

Table I

Typical Low-Level Waste Shipment Characteristics[1]

LLW Source	Waste Description	Typical DOT Packaging Type	Unit Consequence/Unit Risk Factors
Reactor LLW			
I	Low-activity dry compressible waste and contaminated equipment	LSA or Type A	Table A-I
II	Low-activity spent resins, filter sludges and evaporator bottoms	Type A or B	Table A-II
III	High-activity spent resins, filter sludges and evaporator bottoms	Type B	Table A-III
IV	High-activity irradiated components.	Type B	Table A-IV
Industrial LLW			
I	Low-activity wastes	LSA or Type A	Table A-I
II	High-activity wastes	Type A or B	Table A-III
Institutional LLW			
I	Low-activity wastes	LSA or Type A	Table A-I

Table II

Summary of Low-Level Waste Shipments
(1000's of shipment-km)

LLW Categories

	Reactor I	Reactor II	Reactor III	Reactor IV	Sub-Total
Reactor LLW					
Present Practice	1140	2070	370	1210	4790
Regional Concept	540	1000	170	310	2020
Industrial LLW	Ind.-I	Ind.-II			Sub-Total
Present Practice	680	450			1130
Regional Concept	440	260			700
Institutional LLW	Institutional				Sub-Total
Present Practice	980				980
Regional Concept	360				360
		Total -- Present Practice			6900
		Total -- Regional Concept			3080

CONSEQUENCE AND RISK ANALYSIS

An estimate of the shipping distances required to transport low-level radioactive waste in the U.S. has been presented. The analysis presented in this section which uses the shipment information to estimate the population dose due to such transportation which can be used for other shipment scenarios when they are defined. This section will combine in a simple multiplication the shipment information, as summarized in Tables I and II, and the unit-consequence and unit-risk factors (UCF/URF) presented in Appendix A. The essence of the consequence and risk analysis presented here is the use of a state-of-the-art transportation risk analysis calculational tool, such as the code RADTRAN II, Reference A-1, to produce the radiological consequences and risks for incident-free transportation of LLW and for transportation accidents involved with the movement of LLW. The unit-factors were produced for a trip distance of one kilometer by using all the U.S. average input, NUREG-0170, such as accident probabilities, population densities and LLW source term definitions. Thus, the unit-factor approach provides all of the calculational relationships normally present in a code such as RADTRAN-II except for one final multiplication. That final multiplication is provided by multiplying the unit-factors by the shipment distances. Therefore, quick estimates of the consequences and risks of LLW transportation can be provided with a hand calculator, given that the shipping distances and unit factors are known. The consequences and risks of LLW transportation can be expressed by:

$$\begin{matrix} UCF_{LLW} \\ \text{or} \\ URF_{LLW} \end{matrix} \times \text{shipment distance} = \begin{matrix} \text{consequence}_{LLW} \\ \\ \text{risk}_{LLW} \end{matrix}$$

It is important to note that the unit factors tend to be rather constant in magnitude although they could change slightly as more accurate accident/incident data becomes available. The shipping distances are the real variables in the analysis because they tend to reflect uncertainties in governmental policies or uncertainties between hypothetical transportation alternatives or even the final location of LLW storage sites. The real thrust of this analysis is that the uncertainties in shipment information need not be a problem. When new or more accurate LLW shipment scenarios become defined they can be analyzed by the unit-factor method as described in this presentation. A summary of the consequences and risks of LLW transportation, as determined by the unit-factor method, is shown in Table III.

Table III

Population Dose Summary Transportation of Low-Level Waste

Present Practice	Population Dose (person-rem)	Regional Concepts	Population Dose (person-rem)
Reactor-LLW		Reactor-LLW	
Consequences	1915	Consequences	785
Risk	65	Risk	20
Industrial-LLW		Industrial-LLW	
Consequences	630	Consequences	405
Risk	25	Risk	15
Institutional-LLW		Institutional-LLW	
Consequences	680	Consequences	290
Risk	15	Risk	.5
Totals -- Present Practice		Totals -- Regional Concepts	
Consequences	3225	Consequences	1480
Risk	105	Risk	40
	3330		1520

policies, either state or federal, which require that approximations be made in number of LLW shipments or in the final destination of the LLW shipments (e.g., present shipping practice versus the proposed regional concepts).

The simplified methodology is referred to as either the unit-consequence or the unit-risk (UC/UR) methodology depending on whether the incident-free or accident conditions, respectively, are being considered. The analysis is presented in terms of consequence or risk per unit of distance travelled, hence, the term unit-consequence factor or unit-risk factor (UCF/URF).

The LLW unit factors calculated for this paper are presented in Tables A-I through A-IV. In each table the UCF/URF are found for the conditions of normal (accident-free) transport and for accident conditions associated with such transportation. The UCF/URF are calculated from the transportation risk analysis code RADTRAN-II (Reference A-1) assuming a population density distribution along the transportation route of 90 percent rural, 5 percent suburban, and 5 percent urban. Details of the unit-factor methodology can be found in Reference A-2. The unit-factors in this paper are presented in terms of population dose (person-rem/ km).

Table A-I. Unit Factors -- General Trash (Resins, Sludges, Concentrates)

BWR (Truck)

	Unit-Consequence (person-rem/km)
On-Link	6.4E-6
Off-Link	1.5E-5
Stops (person-rem/hour)	9.5E-3
Crew	5.4E-5

	Unit-Risk (person-rem/km)
Loss-of-Shielding	5.1E-11
Release-of-Contents	1.9E-6

PWR (Truck)

	Unit-Consequence (person-rem/km)
On-Link	5.2E-5
Off-Link	1.2E-4
Stops (person-rem/hour)	7.6E-2
Crew	4.4E-4

	Unit-Risk (person-rem/km)
Loss-of-Shielding	2.0E-10
Release-of-Contents	1.5E-5

Expected latent cancer fatalities (LCF) per 10^6 person-rem (whole body) = 121.6 (Reference 2).

Expected LCFs -- Present Practice = .40

Expected LCFs -- Regional Concept = .18

CONCLUDING REMARKS

The population dose due to the radiological effects of transporting radioactive low-level waste in the U.S. has been estimated by using a simplified methodology called the unit-factor method. This method consists of combining the results of a LLW shipment analysis, which is given in terms of shipment distances, and unit-factors representing unit-consequences (for normal, i.e., accident free transportation) and unit-risk (for accidents during transportation). The methodology consists of calculating the product of the shipment distances and unit-factors for each LLW contributing component and providing a bookkeeping system to add up all these radiological effects. The reference basis for the LLW shipment analysis is nominally the calendar year 1979 (Reference 1). The analysis calculates population exposures for LLW transportation under present practice to be 3330 person-rem (.40 latent cancer fatalities) compared to 1520 person-rem (.18 latent cancer fatalities) for the proposed regional locations of LLW disposal facilities. The regional concept reduces the population exposure for LLW transportation to 46 percent of the population exposure provided by present practice. These exposures are accurate only as far as because the shipment distances for LLW transportation are accurate. If in the future more accurate shipping analyses become available, then the unit-factors contained in this paper can be used to calculate new LLW consequence and risk estimates.

REFERENCES

1. Operational and Regulatory Impacts of Regional Management on Transportation of Commercial Low-Level Radioactive Waste, SAND81-1509, TTC-0228, C. G. Shirley, E. L. Wilmot, E. W. Shepherd, Sandia National Laboratories, September 1981.

2. Final Environmental Statement on the Transportation of Radioactive Material by Air and Other Modes, NUREG-0170, Office of Standards Development, U.S. Nuclear Regulatory Commission, December 1977.

APPENDIX A

UNIT-CONSEQUENCE AND UNIT-RISK FACTORS LOW-LEVEL RADIOACTIVE WASTE

The radiological impacts of the transportation of radioactive material can be calculated using a simplified methodology that allows the analysis in this report to be flexible. The flexibility aspect is necessary because there are uncertainties in governmental

Table A-IV. Unit Factors -- Irradiated Components

BWR (Truck)

	Unit-Consequence (person-rem/km)
On-Link	1.4E-5
Off-Link	3.2E-5
Stops (person-rem/hour)	2.1E-2
Crew	5.4E-5

	Unit-Risk (person-rem/km)
Loss-of-Shielding	2.8E-9
Release-of-Contents	8.7E-6

PWR (Truck)

	Unit-Consequence (person-rem/km)
On-Link	4.3E-5
Off-Link	9.9E-5
Stops (person-rem/hour)	6.5E-2
Crew	1.7E-4

	Unit-Risk (person-rem/km)
Loss-of-Shielding	8.7E-9
Release-of-Contents	2.7E-5

REFERENCES -- APPENDIX A

A-1. Taylor, J. M. and S. L. Daniel, "RADTRAN-II, A revised Computer Code to Analyze the Impacts of Transporting Radioactive Material," Sandia National Laboratories, SAND80-1943, Albuquerque, NM.

A-2. Appendix A, Unit-Consequence and Unit-Risk Factors, The Transportation of Radioactive Material (RAM) To and From U.S. Nuclear Power Plants: Draft Environmental Assessment, SAND81-0118, NUREG/CR-2325, prepared for Division of Risk Analysis, Office of Nuclear Regulatory Research, USNRC (to be published).

APPENDIX B

SAMPLE CALCULATION SHEET

Consequence-Risk Component Regional Concept / Institutional / LLW   Shipment Distance 3.6×10^5 km

Unit-Consequence/Unit-Risk Reference Table A-I

$$\text{Stops*} = \left(\frac{4 \text{ hours}}{1600 \text{ km}}\right)\left(3.60 \times 10^5 \text{ km}\right) = 900 \text{ hours}$$

Consequences (Incident-Consequences (Incident-Free Transportation)	UCF x Shipment Distance	Population Exposure (person-rem)
On-Link	$(5.2 \times 10^{-5}) \cdot (3.6 \times 10^5)$	18.7
Off-Link	$(1.2 \times 10^{-4}) \cdot (3.6 \times 10^5)$	43.2
Stops*	$(7.6 \times 10^{-2}) \cdot (900 \text{ hours})$	68.4
Crew	$(4.4 \times 10^{-4}) \cdot (3.6 \times 10^5)$	158.4
	Consequence Sub-Total	288.7

Risk (Transport Accidents)	URF x Shipment Distance	Population Exposure (person-rem)
Loss-of-Shielding	$(2.0 \times 10^{-10}) \cdot (3.6 \times 10^5)$	7.2E-5
Release-of-Contents	$(1.5 \times 10^{-5}) \cdot (3.6 \times 10^5)$	5.4
	Risk Sub-Total	
	Total Exposure for Consequence/Risk Component	294.1

*Stops: assumed to be 4 hours/1600 km (4 hours/1000 miles).