ENGINEERING CALCULATIONS AND ANALYSIS REPORT

ECAR No.: ECAR-786 ECAR Rev. No.: 0 Project File No.: ______ Date: 11/23/2009
Title: Bounding Dose Calculations for TRU Waste Drums Transportation

1. Index Codes
   Building/Type: Transportation SSC ID: NA Site Area: MFC

2. Quality Level: 2[1]

3. Objective/Purpose

The purpose of this engineering calculation and analysis report (ECAR) is to calculate the total effective dose (TED) to receptors downwind from an accident involving transportation of transuranic (TRU) waste material. This ECAR was prepared to support the dose consequence evaluation for the MFC TRU waste disposition plan accident analysis that addresses the handling and transportation of TRU waste from MFC to the Advanced Mixed Waste Treatment Plant (AMWTP) using a truck or tractor trailer.

The evaluated scenario involves transporting TRU waste loaded on a truck or tractor trailer on temporarily closed public roadways as an out-of-commerce shipment. The bounding postulated event is an accident which results in a pool fire in which fuel from the transport vehicle is spilled on the ground and ignited in a fire which engulfs the entire payload. The ensuing damage to the waste drums results in a release of TRU radiological material to the atmosphere. The TED to receptors downwind from a ground-level release of Pu-239 was determined for several distances ranging from 100 to 3,000 m. This ECAR supports the dose consequence analysis for the nuclear safety analysis and derived controls established for transport plan PLN-3243, "Transport Plan for the Transfer of Material Between MFC and AMWTP."

4. Conclusions/Recommendations

This ECAR assumes that the damage and material release of an engulfing fire on multiple waste drums represents a bounding credible accident for TRU transportation. Using the constants and conservative, yet reasonable, assumptions as listed in the analysis below, the calculations show the dose to the off-site public in terms of TED at various distances from the postulated accident.

Given the highly variable nature of contents of TRU waste containers, this evaluation was performed as a unit analysis on 1 curie of Pu-239 to determine resulting dose to the collocated worker at 100 m and to the public at various distances. These results can then be scaled up to any payload quantity up to the maximum of 1,400 plutonium equivalent curies (maximum of 35 PE-Ci in 40 drums[2]) to make decisions on appropriate controls for the transportation program. The analysis was performed on a single isotope – Pu-239, which is prevalent in the TRU waste streams. It is a common practice in TRU waste management to convert other isotopes to a Pu-239 curie equivalency (PE-Ci) using DOE/WIPP-02-3122, "Transuranic Waste Acceptance Criteria for the Waste Isolation Pilot Plant," Appendix B, "Pu-239 Equivalent Activity," or another equivalent document. This allows the user to efficiently relate dose from any TRU isotope – or mixed transuranic inventory, to that of Pu-239.

All analyses can be scaled up or down to approximate dose consequences from hypothetical events involving greater or smaller inventories, as needed, or from any isotopic composition.

ENGINEERING CALCULATIONS AND ANALYSIS REPORT

ECAR No.: ECAR-786 ECAR Rev. No.: 0 Project File No.: ______ Date: ~~11/3/2009~~ 11/23/09 LF.

Title: Bounding Dose Calculations for TRU Waste Drums Transportation

5. Review (R) and Approval (A) and Acceptance (Ac)[a]:			
		Typed Name/Organization	Signature/Date[b]
Performer/Author		B. D. Christensen	[signature] 11-3-09
Technical Checker	R	N. A. Stewart	Pages checked: All nastewart 11/11/09
Independent Peer Reviewer[c]	R	NA	
Performer's Manager	A	M. A. Lehto	[signature] 11/16/09
Requester	Ac	J. D. Atchison	NAS for J.D. Atchison per Telecom 11/19/09
Nuclear Safety[c]	Ac	C. L. Pope	BDC for C.L. Pope per Telecon 11-19-09

a. Review and Approval are required. See LWP-10200 for definitions and responsibilities.

b. An Electronic Change Request (ECR) indicating final review and concurrence by the listed individuals can be used in lieu of signatures.

c. If Required, per LWP-10200.

6. Additional Distribution: (Name and Mail Stop)	Document Control: Charity Watkey 6156

Chad L Pope/POPECL/CC01/INEEL/US

11/19/2009 03:32 PM

To Boyd D Christensen/CHRIB/CC01/INEEL/US@INEL

cc

bcc

Subject Re: Fw: ECAR-786

Boyd,

I have reviewed ECAR-786. I do not have any comments and I concur with the ECAR.

Chad Pope, P.E.
MFC Technical Lead
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208-533-7745 office
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Boyd D Christensen/CHRIB/CC01/INEEL/US

Boyd D Christensen/CHRIB/CC01/INEEL/US

11/11/2009 04:04 PM

To Michael A Lehto/LEHTMA/CC01/INEEL/US@INEL, Chad L Pope/POPECL/CC01/INEEL/US@INEL, John D Atchison/ATCHJD/NON/INEEL/US@INEL

cc Nancy A Stewart/STEWNA/CC01/INEEL/US@INEL

Subject Fw: ECAR-786

The attachment below is ECAR-786, Bounding Dose Calculations for TRU Waste Drums Transportation, in support of the transportation plan for shipping TRU waste from MFC to AMWTP.

You have been identified for approval or acceptance. Please review the document accordingly.

If you have comments please respond to me. We will be getting signatures shortly to keep things on schedule.

[attachment "ECAR-786.pdf" deleted by Chad L Pope/POPECL/CC01/INEEL/US]

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Purpose

The purpose of this calculation is to predict the total effective dose (TED) to receptors downwind and to a collocated worker, from an accident involving transuranic (TRU) material being transported in Department of Transportation (DOT) drums. This engineering calculation and analysis report (ECAR) was prepared to support the dose consequence evaluation for a release accident involving the handling and transporting of TRU waste drums.

The scenario in this evaluation involves damage to waste containers resulting from a transportation accident. The accident results in an engulfing fire, which causes damage to the transport containers and a subsequent release of TRU material. The TED to receptors downwind from a ground-level release of Pu-239 was determined for workers and the public at various distances, from 100 to 3,000 m, representing collocated worker and the off-site public respectively. This ECAR supports the dose consequence analysis for transportation of TRU waste from various Materials and Fuels Complex (MFC) facilities to the Advanced Mixed Waste Treatment Project (AMWTP). From the results herein, shipment quantity limits and a public exclusion zone may be developed.

Scope and Brief Description

The postulated accident involves damaging multiple containers of TRU waste as it is being transported on public roadways. The mishap is assumed to occur as truck shipments of TRU waste packaged in 55-gallon drums are moved from MFC to the AMWTP as an out-of-commerce shipment. The quantities being shipped exceed the DOT certification limits for the material being shipped, so the shipments will occur on temporarily closed public highways.

The postulated scenario representing a bounding dose consequence and analyzed in this report involves multiple TRU waste drums being transported in an open-air vehicle such as flatbed truck or a tractor trailer. A non-specific accident results in ruptured fuel tanks on the transport vehicle and the loss of fuel into a pool surrounding up to 40 drums of 100% combustible waste material. Under the high temperatures of the engulfing fire, pressure within the drums will quickly rise causing some of the drum lids to eject, spewing contents, which in turn burn in the fire. It is assumed that for all drum lids that do not eject, lid seal failure will occur from the heat of the fire, further contributing to the source term analyzed.

Analysis of a liquid fuel fire such as this is important because of the possibility of the fuel forming a pool and igniting in a fire with a substantially higher temperature than other fire scenarios. With the higher temperature and rapid heating of relatively small containers, such as 55-gallon drums, a rapid increase in pressure is experienced, which results in lid failure and ejection of a fraction of the container contents, which then burn as unconfined material.

Dose calculations are provided for a worker assumed to be at 100 m distance from the accident and for the public located at various distances from 100 to 3,000 m.

The dose consequences have been calculated based on 1 curie of Pu-239. It is recognized that there is large variation in the isotopic makeup of TRU waste generated at MFC. From this dose calculation, it is expected that the results can be scaled up or down as needed based on any isotope mixture and adjusted for dose equivalency to Pu-239 and adjusted for the quantity of material in any proposed shipment. It is also shown that given the same source term, the dose decreases as distance from the source increases. Adjusting the variables of payload radionuclide inventory and distance from the source, any load configuration can be analyzed against the results of this report to determine the required exclusion zone for the public during the shipment.

Design Inputs and Sources

No specific design inputs were required in this analysis.

Results of Literature Search and Background Data

Results of literature searches are detailed in the body of this analysis. Documents searched are shown in the references section of this document.

Assumptions

Assumptions used in this report are found throughout the body of this document. In summary, the dose consequences calculated herein assume the following conditions:

- The analyzed event assumes bounding meteorological conditions for the INL.
- The postulated event occurs on or near public on the INL.
- The shipments of TRU waste discussed in the scope of this report are made on public roadways, which are closed to public travel at the time of the shipments.
- The shipments involve multiple drums of TRU waste - not a single drum.
- Damage ratios are consistent with those discussed in DOE-STD-5506-2007 and referenced in this document.
- The biokinetic models relating to radionuclide uptake, retention, and elimination used to develop DCFs in ICRP-68 and ICRP-72 are applicable to the conditions evaluated in this report.

Computer Code Validation

a) Computer type: Dell Optiplex 745 with Windows XP Operating System

b) Computer program name and revision: Radiological Safety Analysis Computer Program version 7.0.3

c) Inputs: See Appendix A

d) Outputs: See Appendix A

e) Evidence of computer program validation: PLN-2225, "Verification and Validation Plan for the Radiological Safety Analysis Computer (RSAC) Program Version 7.0," current revision

f) Bases supporting application of the computer program to the specific physical problem: NS-18104, "INL Guide to Safety Analysis Methodology," Rev. 5 recommends the use of RSAC 7 for calculating Chi/Q values consistent with this report

Methodology

As recommended in NS-18104, "INL Guide to Safety Analysis Methodology,"[3] the dispersion coefficients used for the radiological release from TRU waste in the postulated accident were taken from DOE-STD-5506-2007, "Preparation of Safety Basis Documents for Transuranic (TRU) Waste Facilities."[4] Also, following the methodology recommended in NS-18104, plume dispersion coefficients herein are obtained from the Radiological Safety Analysis Computer Program (RSAC). The computer calculated dispersion coefficients were performed on PC INL410677 using RSAC version 7.0.3[5]. RSAC software QA was performed in accordance with PLN-2225, "Verification and Validation Plan for the Radiological Safety Analysis Computer (RSAC) Program Version 7.0."[6] The dispersion coefficients were calculated for distances of

100 m (collocated worker) and various distances up to 3,000 m (off-site public). NS-18104 further states: "If facility-specific circumstances involve the potential release of actinides (e.g., Pu-239, Am-241, etc.), then it may be appropriate to estimate dose consequences using ICRP-60 and ICRP-68 methodology, rather than the ICRP-26 and ICRP-30 methodology. In this approach, dose conversion factors are taken from ICRP-68 for the collocated worker calculation and from ICRP-72 for the off-site public calculation." Given that Pu-239 is the principal isotope of concern in MFC TRU waste, ICRP 68/72 methodology is used to calculate dose to facility worker and public. ICRP 68/72 methods result in a committed effective dose (CED) rather than TED. The difference between CED and TED is deep dose equivalent, or pathways other than internal uptake. For this scenario and the distances involved, it is clear that direct radiation exposure is inconsequential compared to the inhalation dose, and so for all practical purposes, CED is equal to TED.

χ/Q values were obtained from RSAC-7. Meteorological conditions were used for the bounding conditions for INL, such as 1.04 m/s wind velocity, stability class F weather conditions, and the Markee plume standard diffusion values which prevail with the INL sagebrush terrain. No plume fallout depletion or building wake correction was made in calculating diffusion coefficients. The release was assumed to be a ground release, and conservatism was added with no credit taken for plume rise associated with an exothermal event. Other variables are default in the RSAC-7 program and are standard for INL conditions. These can be seen on the RSAC attachment to this document (Appendix A).

The dose is calculated as an unmitigated analysis, meaning that no credit is taken for preventive or mitigative features or controls to reduce the consequences of the accident being evaluated. The scenario is intended to represent a reasonably conservative bounding analysis independent of the likelihood of the event.

Release Parameters

Material at Risk

The material at risk (MAR) is the total inventory of radioactive material that could be impacted for a given accident scenario and is expressed in terms of total quantity at risk. The release scenario for a bounding transportation accident is based on the contents of an entire shipment of TRU waste. Given the highly variable nature of TRU waste container shipments, this analysis assumes a MAR of 1 curie of Pu-239. It is recognized that shipments will contain other isotopes and often greater quantities than this; however, to provide program flexibility, this MAR is used in calculating dose consequence from a reference unit release. Other isotopes found to be present in waste can be equated to Pu-239 using DOE/WIPP-02-3122, "Transuranic Waste Acceptance Criteria for the Waste Isolation Pilot Plant," Appendix B, "Pu-239 Equivalent Activity,"[7] or similar method of equating consequence factors of other isotopes to that of Pu-239. Similarly, for determining dose consequences of any given known MAR quantity, the results from this analysis can be scaled up a corresponding amount since the relationship between dose and MAR quantity is linear.

The concept of establishing a Pu-239 equivalency is common throughout the DOE complex, especially for TRU waste destined for the Waste Isolation Pilot Plant (WIPP) repository. The premise is that by normalizing all radionuclides to a common radiotoxic hazard index, variations in individual waste streams or containers become irrelevant to results of analyses. Pu-239 is a common component of most TRU waste and is selected as the radionuclide to which the radiotoxic hazard of other TRU radionuclides can be indexed. By applying a weighting factor for each radionuclide, the dose consequence associated with the release of any known radionuclide distribution will be essentially identical to that of a release of material expressed in terms of a given quantity of Pu-239. The 50 year whole-body dose commitment for each radionuclide is correlated to that of Pu-239 to obtain the weighting factor.

Damage Ratio

The damage ratio (DR) represents the fraction of MAR that could be affected by the postulated accident and is a function of the accident initiator and the operational scenario being evaluated. The DR is typically estimated based on engineering analysis of the response of structural materials and materials-of-construction for containment to the type and level of stress/force generated by the event. For the accident being evaluated, multiple damage paths co-exist for the MAR in the waste drums. DOE-STD-5506-2007 describes the behavior of multiple stacked drums of TRU waste when involved in an engulfing fire, such as with the scenario being evaluated. The response of metal containers to fire can result in lid loss on some containers if certain conditions are met. DOE-STD-5506-2007 describes conditions under which a conservative estimate of 25% of metal drums in an engulfing fire will experience lid loss. Once the lid is expelled, some of the contents (67%) is expected to burn within the drum and burns as confined material. The other 33% of the container material is ejected from the drum and burns as unconfined material. Of the 33%, as the contents travel through the air from the drum to the landing spot, some radiological material is released as result of a flexing action and becomes an additional contributor to the source term. Upon landing, the rest of the material is burned unconfined. Of the 75% of the drums retaining their lids, it is conservatively assumed that all container lid seals fail, such that some leakage occurs from all drums.

Each drum action described above has associated DR, airborne release fraction (ARF), and respirable fraction (RF) appropriate for that particular condition of the container.

Airborne Release Fraction

The ARF is the coefficient used to estimate the amount of material suspended in the air as an aerosol and thus available for transport due to the physical stresses from a specific accident. For discrete events, the ARF is a fraction of the material affected. The ARF and RF values for the accident scenario were selected based on metal drums of TRU waste involved in an engulfing pool fire.

Respirable Fraction

The RF is the fraction of airborne particles that can be transported through air and inhaled into the pulmonary region of the human respiratory system. RFs for particles made airborne under accident-induced stresses are dependent upon a variety of factors, such as the bulk density, the presence of moisture, how effectively the type and level of stress de-agglomerates the powder or subdivides the solid/liquid, the efficiency with which the stress suspends the powder/fragments of solid over varying size ranges, and the degree of immediate proximity of surfaces on which airborne particles may impact/settle. The RF includes particles having a 10-µm aerodynamic equivalent diameter or less. Values for RF for this analysis were taken from DOE-STD-5506-2007.

Leak Path Factor

The leak path factor (LPF) is the fraction of the radionuclides in aerosol transported through a confinement deposition or filtration mechanism. For purposes of this analysis, the LPF is assumed to be 1.0, consistent with an unmitigated analysis required per DOE-STD-3009[8].

Source Term

The five components of the following source term (ST) equation recommended by DOE-HDBK-3010-94[9] contain the basis for the accident parameters. The ST is the amount of radioactive material released during the postulated accident scenario. The ST is determined using the following equation and is calculated as:

ST = MAR × DR × ARF × RF × LPF

where:

ST	=	source term
MAR	=	material at risk (curies or grams)
DR	=	damage ratio
ARF	=	airborne release fraction
RF	=	respirable fraction
LPF	=	leak path factor

For this evaluation, an ST was selected based on the multiple damage paths as shown below. Values for DR, ARF, and RF for the postulated accident in this analysis were taken from testing and analysis and reported in DOE-STD-5506.

25% of drums experience lid loss

67% of the drum content remains inside drum and burns inside of drum

ST = MAR × DR (0.25 × 0.67) × ARF (5.0E-04) × RF (1.0) × LPF (1.0)

33% of the drum content is ejected from drum

ST = MAR × DR (0.25 × 0.33) × ARF (1.0E-03) × RF (0.1) × LPF (1.0)

Plus ST from unconfined burning of ejected contents outside of drum

ST = MAR × DR (0.25 × 0.33) × ARF (1.0E-02) × RF (1.0) × LPF (1.0)

75% of drums retain lids but experience lid seal failure

ST = MAR × DR (0.75) × ARF (5.0E-04) × RF (1.0) × LPF (1.0)

Table 1. Source term for the bounding TRU waste transportation accident scenario.

Radionuclide	Specific Activity (Ci/g)	MAR (g)	MAR (Ci)	DR	ARF	RF	LPF	Airborne ST (Ci)
Pu-239	0.0621	16.1	1.0	0.25 × 0.67	5.0E-04	1.0	1.0	8.37E-5
			1.0	0.25 × 0.33	1.0E-03	0.1	1.0	8.25E-6
			1.0	0.25 × 0.33	1.0E-02	1.0	1.0	8.25E-4
			1.0	0.75	5.0E-04	1.0	1.0	3.75E-4
							Total ST	1.29E-3

Figure 1 shows the basic material flow path and source term factors in the pool fire scenario as found in DOE-STD-5506.

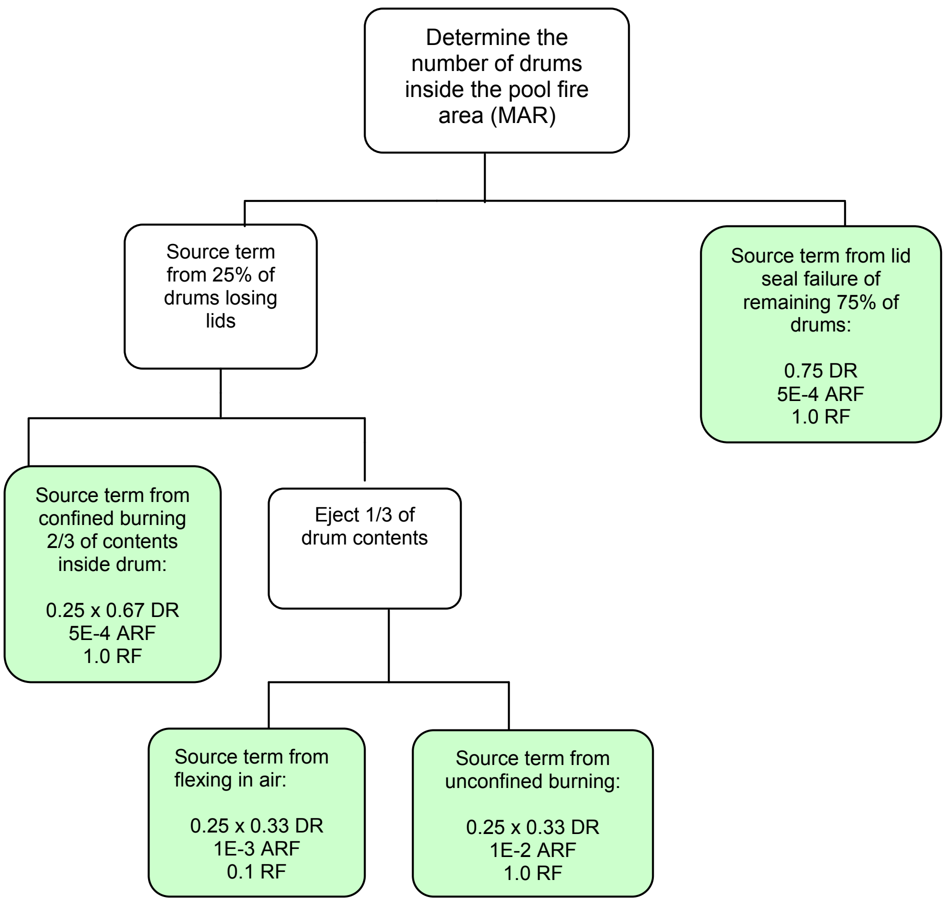

Figure 1. Pool fire source term factors.

Dose Calculations

The CED was determined by calculating the radiological doses using International Commission on Radiation Protection (ICRP)-68[10] and ICRP-72[11] dose conversion factors (DCFs). The DCF for the collocated worker is provided in ICRP-68, and the DCF for the off-site public is provided in ICRP-72. The ICRP-68/72 methodology results in a CED determination, whereas TED results are obtained by including other pathways in addition to inhalation. For this scenario, the inhalation dose dominates all other pathways, resulting in a CED roughly equivalent to a TED determination. The CED values and variables used for the drop scenario were determined using the following formula:

$$CED = \chi/Q \times BR \times ST \times DCF$$

where

χ/Q = plume dispersion coefficient (s/m^3)

BR = breathing rate (m^3/s)

ST = source term (Ci)

DCF = dose conversion factor (rem/Ci)

The dispersion coefficients for the collocated worker at 100 m and off-site public at various distance from 100 to 3,000 m, were obtained from RSAC-7 using meteorological conditions appropriate for use on the INL. Breathing rate is a standard and conservative rate provided in DOE-HDBK-3010 for the maximally exposed individual. Table 2 gives the RSAC input parameters for determining the dispersion coefficient.

Table 2. RSAC input parameters.

RSAC-7 Input Parameters	Input Values
Release elevation (m)	0
Meteorological stability class	F
Windspeed (m/second)	1.04
Diffusion coefficient	Markee
Downwind receptor distance (m)	100 m, 200 m, 400 m, 600 m, 800 m, 1000 m, 2000 m, 3000 m

Dose conversion factors were taken from ICRP-68 and -72, Table A.2, “Inhalation Dose Coefficients,” using the committed effective dose for adults. The most conservative DCF was used without respect for the different inhalation classes/types (slow, moderate, or fast), since information on solubility, aerosol particle size, reactivity, and retention factors are not known for TRU waste. ICRP DCF values are published in units of Sv/Bq. The following equations show the ICRP values and conversion to units of Rem/Ci for use in this evaluation.

ICRP-68 DCF for worker = 3.20E-5 Sv/Bq

(3.20E-5 Sv/Bq) (100 Rem/Sv) (3.70E+10 Bq/Ci) = 1.18E+8 Rem/Ci

ICRP-72 DCF for adult public = 1.20E-4 Sv/Bq

(1.20E-4 Sv/Bq) (100 Rem/Sv) (3.70E+10 Bq/Ci) = 4.44E+8 Rem/Ci

The resulting radiological consequence is estimated using the χ/Q values described above for the airborne release, a standard breathing rate, source term as calculated in a previous section of this document and DCFs from appropriate ICRP publications. The results of a release from a 1 curie Pu-239 multiple drum shipment involved in an engulfing pool fire as described above and using the assumptions noted above gives the following dose consequence to a collocated worker at 100 m and to the public at the distances shown below in Table 3.

Table 3. Dose calculations for the bounding transportation accident scenario.

Airborne Source Term (CI)	Breathing Rate (m^3/s)	Distance (m)	χ/Q (s/m^3)	Inhaled DCF (rem/Ci)	Dose (rem)	Receptor
1.29E-03	3.33E-04	100	4.08E-03	1.18E+08	2.08E-01	worker
1.29E-03	3.33E-04	100	4.08E-03	4.44E+08	7.80E-01	public
1.29E-03	3.33E-04	200	1.93E-03	4.44E+08	3.69E-01	public
1.29E-03	3.33E-04	400	8.57E-04	4.44E+08	1.64E-01	public
1.29E-03	3.33E-04	600	5.25E-04	4.44E+08	1.00E-01	public
1.29E-03	3.33E-04	800	3.69E-04	4.44E+08	7.05E-02	public
1.29E-03	3.33E-04	1000	2.81E-04	4.44E+08	5.36E-02	public
1.29E-03	3.33E-04	2000	1.21E-04	4.44E+08	2.31E-02	public
1.29E-03	3.33E-04	3000	7.45E-05	4.44E+08	1.42E-02	public

Plotting the doses at distance from 200 to 1,000 m gives a trend line shown in Figure 2. The general shape of this graphic would be typical of any source term used at these distances and parameters and shows a rapid decrease in dose at distances close to the source with a leveling out effect at greater distances.

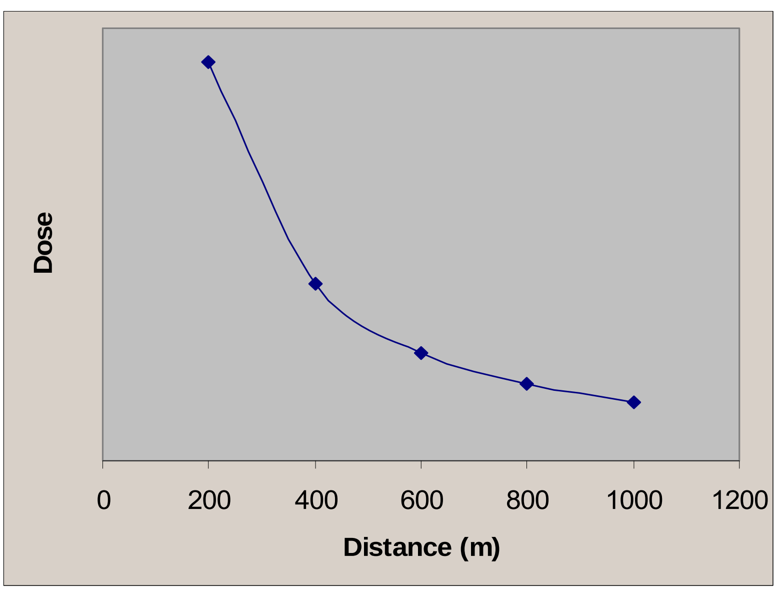

Figure 2. Dose trends for the analyzed conditions.

References

1. QLD-MFC-000812, Materials and Fuels Complex (MFC) Nuclear Facility Safety Basis Related Shielding and Radiological Consequence Calculation and Analysis Reports.

2. FRM-435.83, "Idaho National Laboratory Contact-Handled Transuranic Waste Disposal (Checklist – Requirements – Certification)," October 2008.

3. NS-18104, "INL Guide to Safety Analysis Methodology," Rev. 5.

4. DOE-STD-5506-2007, "Preparation of Safety Basis Documents for Transuranic (TRU) Waste Facilities," April 2007.

5. Radiological Safety Analysis Computer Program, Version 7.0.3.

6. PLN-2225, "Verification and Validation Plan for the Radiological Safety Analysis Computer (RSAC) Program Version 7.0," current revision.

7. DOE/WIPP-02-3122, "Transuranic Waste Acceptance Criteria for the Waste Isolation Pilot Plant," February 2009.

8. DOE-STD-3009-94, "Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Documented Safety Analysis," July 1994; with Change Notice No. 1 January 2000, Change Notice No. 2 April 2002, and Change Notice No. 3 March 2006.

9. DOE-HDBK-3010-94, "Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities," December 1994.

10. ICRP-68, "Dose Coefficients for Intakes of Radionuclides by Workers, International Commission on Radiation Protection," July 1995.

11. ICRP-72, "Age-Dependent Doses to Members of the Public from Intake of Radionuclides, International Commission on Radiation Protection," September 1996.

Appendix A: RSAC χ/Q Values

Radiological Safety Analysis Computer Program (RSAC 7.0.3)

Name: Boyd Christensen **Company:** INL **Serial:** J4127-C4RH4-D6H6H-STA3B-OBECE
Computer: INL410677 **Run Date:** 11/03/2009 **Run Time:** 09:38:55
File: InputFile1.rsac

Input

```
* CH-TRU Chi/Q Values
# ECAR-786 Meteorological Condition Input
#
#
# Bounding meteorological conditions for transportation event
5000,0
5001,1.04,0.,400.,1.099E3,0.,0
5101,100.,200.,400.,600.,800.,1000.,2000.,3000.
5201,1.,0.
5400,2,0.,0.
5410,2,6,0,0.
5999
10000
```

Meteorological Data

```
        MEAN WIND SPEED = 1.040E+00 (m/s) STACK HEIGHT = 0.000E+00 (m)

    MIXING LAYER HEIGHT = 4.000E+02 (m)   AIR DENSITY = 1.099E+03 (g/cu m)

    WET DEPOSITION SCAVENGING COEFFICIENT = 0.000E+00 (1/s)

    THERE IS 1 SET OF LEAKAGE CONSTANTS (K1,K2)
          1.000E+00       0.000E+00

    PLUME MEANDER FACTOR = 1.00E+00

    PASQUILL CLASS F METEOROLOGY, MARKEE SIGMA VALUES

    NO BUILDING WAKE CORRECTION MADE
```

DOWNWIND DISTANCE	STACK HEIGHT (m)	SIGY (m)	SIGZ (m)	CHI/Q (s/m^3)
1.000E+02	0.000E+00	2.069E+01	3.625E+00	4.081E-03
2.000E+02	0.000E+00	3.730E+01	4.253E+00	1.930E-03
4.000E+02	0.000E+00	6.978E+01	5.118E+00	8.570E-04
6.000E+02	0.000E+00	1.015E+02	5.750E+00	5.245E-04
8.000E+02	0.000E+00	1.325E+02	6.261E+00	3.689E-04
1.000E+03	0.000E+00	1.629E+02	6.695E+00	2.807E-04
2.000E+03	0.000E+00	3.062E+02	8.279E+00	1.207E-04
3.000E+03	0.000E+00	4.380E+02	9.386E+00	7.445E-05