Radioactive Waste Management Associates

Memo

To: Bob Halstead

From: RWMA

Date: 02/14/00

Re: RADTRAN IV Economic Analysis

This memo discusses the inputs, methodology, and results of a RADTRAN IV economic analysis of a severe accident involving a rail cask of spent nuclear fuel in an urban area. It is divided into two rough sections. The first section discusses the equations used by RADTRAN to estimate economic impacts. The second section discusses our results obtained from running the RADTRAN IV economic code.

I. RADTRAN equations used in the economic analysis of spent fuel accidents

We will only be discussing urban costs, as these are the relevant inputs needed for our analysis.

RADTRAN II and RADTRAN III User's Guides assume the following land use distribution for an urban area:

RADTRAN Default Land use Assumptions: Urban Environment

Description	% of land
High-density residences $\leq$ 6 floors	10
High-density residences $\geq$ 6 floors	10
Single family residences	20
Public Land	20
Commercial Land	20
Parks, Cemeteries	10
Undeveloped/Vacant Land	10

The parameter which controls the choice of equations for determining the economic impact of transportation accidents is the Decontamination Factor, or $DECON_n$. $DECON_n$ is described as follows:

$$DECON_n = \frac{n \cdot PPS \cdot RF \cdot AER \cdot \overline{x}_n \cdot V_d}{CULVL}$$

n = number of curies per package
PPS = packages per shipment (1)
RF = release fraction of spent fuel inventory for each family of radionuclides
AER = fraction of released fuel in aerosol form
$\bar{X}_n$ = atmospheric dilution factor in area n
V_d = deposition velocity
CULVL = Cleanup Level following an accident

In the RADTRAN IV User's Guide, chapter 3, the following discussion on the CULVL value is given:

> Clean-Up Level (CULVL). This factor describes the required level to which contaminated surfaces must be cleaned up (EPA, 1977). The default value is set to the proposed guideline of 0.2 μCi/m^2. Note that this value applies to the sum of deposited activity over all isotopes of a multi-isotope material and that the default cleanup value is not widely accepted.

In our analysis of economic costs, the default CULVL was retained. For a sensitivity analysis, a RADTRAN IV run was also performed using a CULVL value of 1μCi/m^2, the maximum value allowed as input.

The Decontamination factor (DECON) is the ration of the contamination level before cleanup to the eventual cleanup level. In determining equations for cleanup costs, the DECON values are grouped into clusters based on the following divisions. Note that the variable names DECON and DF are the same, and are used interchangeably in the RADTRAN User's Guides.

DF_1 = 0.1 = minimum level of detectability.
DF_2 = 1.0 = criteria level for cleanup. This value corresponds to a contamination level equal to CULVL.
DF_3 = 20 = maximum contamination level for low to moderate range
DF_4 = 40 = max level for which cleanup criterion level is feasible

RADTRAN IV uses the CULVL value and the other data for the radionuclide inventory to assign a decontamination factor for a given area of contamination. The atmospheric dilution factor, deposition velocity, and release fraction are radionuclide-specific. Then, RADTRAN assigns economic consequence equations for the following divisions:

$DECON<DF_2$:

For areas in which the Decontamination Factor is less than the criteria level for cleanup, there is no cleanup cost outside of the initial fixed costs.

$DF_2<DECON<DF_3$:

For areas in which the Decontamination Factor is greater than the criteria level for cleanup, but less than twenty times this level, the RADTRAN II and RADTRAN III User's Guides specify values and equations for economic consequences. These values are derived from per-capita values, then multiplied by the percentage of land occupied by each division. Thus, for example, it is assumed that cleanup of High-Density Residences having $\geq$ 6 floors is \$40 per capita. Since it is assumed that 10% of a city is covered by these buildings, the cost of cleanup is \$40 *.1 or \$4 per person.

Description	Cleanup Costs ($)
Survey Costs (fixed)	200,000 * Area
Evacuation Costs (fixed)	180 * Pop. Density * Area
Income Loss	230 * Pop. Density * Area
Cleanup Costs:	
High-Density Residences ≥ 6 floors	2 * Pop. Density * Area
High-Density Residences ≤ 6 floors	4 * Pop. Density * Area
Single-family Homes	73.1 * Pop. Density * Area
Public Land	10.6 * Pop. Density * Area
Commercial Land	5.6 * Pop. Density * Area
Parks, Cemeteries	3.9 * Pop. Density * Area
Undeveloped/Vacant Land	22,000 * Area

The above criteria is then combined into a single equation, given below:

Cost of Cleanup ($DF_2 < DECON < DF_3$)
= [2.2e5 + (509.2*Pop. Density)]*Area

$DF_3 < DECON < DF_4$:

Similarly, for areas in which the Decontamination Factor is greater than twenty times the criteria level for cleanup, but less than forty times this level, the RADTRAN II and RADTRAN III User's Guides specify values and equations for economic consequences. These values are derived from per-capita values, then multiplied by the percentage of land occupied by each division. Thus, for example, it is assumed that cleanup of High-Density Residences having ≥ 6 floors is $40 per capita. Since it is assumed that 10% of a city is covered by these buildings, the cost of cleanup is $40 *.1 or $4 per person.

Description	Cleanup Costs ($)
Survey Costs (fixed)	200,000 * Area
Evacuation Costs (fixed)	180 * Pop. Density * Area
Income Loss	230 * Pop. Density * Area
Cleanup Costs:	
High-Density Residences ≥ 6 floors	18.7 * Pop. Density * Area
High-Density Residences ≤ 6 floors	37.4* Pop. Density * Area
Single-family Homes	235 * Pop. Density * Area
Public Land	112 * Pop. Density * Area
Commercial Land	284 * Pop. Density * Area
Parks, Cemeteries	5.1 * Pop. Density * Area
Undeveloped/Vacant Land	22,000 * Area

The above criteria is then combined into a single equation, given below:

Cost of Cleanup ($DF_3 < DECON < DF_4$)
= [2.2e5 + (1102*Pop. Density)]*Area

$DECON > DF_4$:

For areas where the contamination level is greater than 40 times the criterion cleanup level, it is assumed that the land will be permanently interdicted, and economic costs stem from relocation and opportunity costs.

Description	Cleanup Costs ($)
Survey Costs (fixed)	100,000 * Area
Evacuation Costs (fixed)	180 * Pop. Density * Area
Personal Income Loss	5880 * Pop. Density * Area
Corporate Income Loss	2470 * Pop. Density * Area
Land Value Loss	23,000 * Pop. Density * Area
Permanent Relocation Cost	3874 * Pop. Density * Area
Relocation of Government Operations	67 * Pop. Density * Area
Security Cost	1,200,000 * Area

The above criteria is then combined into a single equation, given below:

Cost of Cleanup (DECON > DF_4)
= [1.3e6 + (35470*Pop. Density)]*Area

II. RWMA Economic Analysis using RADTRAN IV

This section highlights the inputs needed for the economic analysis in addition to the CULVL value discussed in the previous section.

Keywords used in Economic Analysis:

<u>ECONF:</u>

This parameter is the discount factor used to account for inflation. Since the RADTRAN 4 economic model gives results in 1980 dollars, this has to be updated to present value using an interest rate. One way to approximate this is to use the Consumer Price Index:

Cost (2000) = Cost (1980) * (CPI (2000)/CPI (1980))

According to the Federal Reserve Bank of Minneapolis, the CPI in 1980 was 82.4, and the CPI in 2000 is projected to be 171, based on the change from 4^{th} quarter 1998 to 4^{th} quarter 1999. Thus, the ECONF factor used as input for RADTRAN will be the ratio of the two consumer price indexes, or 2.08.

<u>ONSCST:</u>

This parameter specifies the estimated on-scene costs for cleanup of a spent fuel accident of a given severity. The severity of the accident is determined by the release fraction for the fuel. There are four values inputted into the ONSCST array. The first value is a basic cost for determining that there was no release. This cost corresponds to a release fraction (RF) of 0.0. the second value is a cost estimate for accidents with overall release fractions $0<RF\leq .01$; the third for $.01<RF\leq .10$; and the fourth for RF>.10. Each species category (eg, NOBLE, PARTICULATE, VOLATILE, RUTHENIUM) has a release fraction for each accident severity category. The overall release fraction is determined from the fraction of the total inventory released.

In the RADTRAN 4 User's Manual, example output file 3 includes economic impacts of transportation by rail in rural areas. This analysis uses the following values for ONSCST:

ONSCST 250 2400 2400 5000

These numbers correspond to the values given in the RADTRAN III User's Manual for spent fuel particulate releases. As an initial estimate, our analysis of a severe train accident in an urban area used these values.

EMRCST:

This parameter estimates the immediate cost for a given severity category for emergency response. Since we are only concerned with one accident severity category here (the maximum reasonably foreseeable accident scenario), there will be one estimate here.

In the RADTRAN 4 User's Manual, example output file 3 includes economic impacts of transportation by rail in rural areas. This analysis uses the following values for EMRCST:

EMRCST 20 400 500 600 1500 1700 2100 2500

These EMRCST values correspond to values for each of 8 severity categories. Since our analysis is only considering one category, we use the cost estimate for the most severe category. I will also use the EMRCST value for severity category 6, because I am unclear whether the most severe accident considered by the YMEIS falls into category 6 or category 8.

Since the current analysis is for an accident requiring cleanup costs, the cost involved with initial emergency response will be a relatively small component of the overall costs. For this reason, we are using the values suggested in the RADTRAN IV example problem, keeping in mind that this is likely to result in an underestimate of the true cost of an accident.

Results:

The first step in using RADTRAN IV is to ensure it calculates similar health consequences to those calculated using RADTRAN 5. This is done to check our inputs as well as to check the program itself. We took the inputs from the RADTRAN 5 calculation of impacts from 10-year cooled, 4μCi/cm^2 CRUD density, spent nuclear fuel transported in a rail cask containing 26 PWR assemblies. We assumed the same population density (4932.5 persons/km^2) and release fractions for maximum accidents. The comparison is given below.

Comparison between RADTRAN 5 and RADTRAN 4

Program used	Population Density persons/km^2	Spent Fuel Age years	Crud Density μCi/cm2	Crud Inventory* Ci	Population Dose person-rem	Expected LCFs
RADTRAN 5	4932.5	10	4	4.36	915000	457.5
RADTRAN 4	4932.5	10	4	4.36	857000	428.5

The table shows that RADTRAN 4 computes consequences that are reasonably close to those given by RADTRAN 5. The conservative nature of the calculated consequences using RADTRAN 4 when compared to the consequences calculated using RADTRAN 5 suggest that the economic impacts could be greater than those calculated and reported here.

The following table shows the results of all RADTRAN 4 calculations performed by RWMA. It shows the economic consequences of a severe spent fuel accident to be crippling.

RADTRAN 4: Calculations of Economic Impacts of Max. Reasonably Foreseeable Rail Accident

File Name	Spent Fuel Age	CRUD Inventory*	ECONF	ONSCST				EMRCST	Pop. Dose	Expected LCFs	Economic Cost
	years	Ci	*	RF = 0	0<RF<.01	.01<RF<.1	RF>.1	$	person-rem		$
one.in4	10	4.36	1	250	2400	2400	5000	2500	857000	428.5	4.53E+09
two.in4	10	4.36	2.08	250	2400	2400	5000	2500	857000	428.5	9.42E+09
three.in4	10	56.03	1	250	2400	2400	5000	2500	864000	432	4.53E+09
four.in4	10	56.03	2.08	250	2400	2400	5000	2500	864000	432	9.42E+09
five.in4	10	4.36	1	250	2400	2400	5000	1700	857000	428.5	4.53E+09
six.in4	10	4.36	2.08	250	2400	2400	5000	1700	857000	428.5	9.42E+09
seven.in4	25.9	0.55	1	250	2400	2400	5000	2500	852000	426	4.53E+09
eight.in4	25.9	0.55	2.08	250	2400	2400	5000	2500	852000	426	9.42E+09
nine.in4	25.9	7.09	1	250	2400	2400	5000	2500	853000	426.5	4.53E+09
ten.in4	25.9	7.09	2.08	250	2400	2400	5000	2500	853000	426.5	9.42E+09
eleven.in4	25.9	0.55	1	250	2400	2400	5000	1700	852000	426	4.53E+09
twelve.in4	25.9	0.55	2.08	250	2400	2400	5000	1700	852000	426	9.42E+09

One more analysis was done to perform a sensitivity analysis on the impact of the cleanup level on economic costs. For this scenario, we reran file "eight.in4," which corresponds to 25.9-year cooled fuel, corrected to 2000 dollars, this time using a CULVL value of 1.0 $\mu Ci/m^2$, the maximum level allowed by RADTRAN IV. In this case, the calculated economic cleanup cost was $3,180,000,000, about 1/3 the cost of the 0.2$\mu Ci/m^2$ cleanup level case.

It is important to note that the economic figures obtained through the RADTRAN IV code are extremely conservative. Regardless, the estimated consequences are crippling.