WESTINGHOUSE SAVANNAH RIVER COMPANY

SAVANNAH RIVER TECHNOLOGY CENTER

SRT-WED-97-0176

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April 24, 1997

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Evaluation of High-Level Tank Residuals versus NRC Class C Criteria

Summary

A study was conducted using the PATHRAE computer code to determine the intruder dose from the residual inventory in Tanks 25-28, 33-34, and 44-47. The study demonstrates that doses to hypothetical intruders from these tanks after closure and 100 years of institutional control will be well below the DOE performance objective of 100 mrem/year and the NRC performance objective of 500 mrem/year. This means that radionuclide concentrations higher that the published Class C limits are possible in a final configuration rather different than that used by the NRC in developing generic limits for near-surface, non-engineered disposal systems.

Introduction

The Savannah River Site has developed a plan to close the high-level waste tanks located in F- and H-Areas. This plan will result in some residual material being left in the tanks. This material consists largely of sludge from the processing of spent fuel and targets in the separations buildings at SRS, and is thus high-level waste, by definition:

> High-Level Waste. The highly radioactive waste material that results from the reprocessing of spent nuclear fuel, including liquid waste produced directly in reprocessing and any solid waste derived from the liquid, that contains a combination of transuranic waste and fission products in concentrations requiring permanent isolation (DOE Order 5820.2A, Definitions).

The purpose of this study was to determine if this small volume of high level waste would produce doses greater or less than the doses used to set the concentration limits set forth in the Nuclear Regulatory Commission's requirements for land disposal of radioactive waste, 10 CFR Part 61.

10 CFR Part 61 limits are concentration limits determined with a generic intruder analysis. This type of analysis was used because the Commission was writing requirements for disposal at a potentially large number of unknown sites expected because of the passage of the Nuclear Waste Policy Act. Intruder analyses are used to set concentration limits. The results depend almost entirely on the disposal technology used and very little on the specific site under investigation. This type of analysis suited the Commission's needs very well. The requirements of Part 61 also include a site specific analysis of the groundwater pathway. This type of analysis is very sensitive to the conditions at a given site, so generic groundwater-based limits were not included in the regulation. Rather, these were left for each applicant to develop for themselves.

Though based on a generic analysis, through time the upper limits for Class C have become a default boundary beyond which waste must be treated differently. The Commission did not intend for this to happen. In Part 61 they state:

> The Commission may, upon request or on its own initiative, authorize other provisions for the classification and characteristics of waste on a specific basis, if, after evaluation, or the specific characteristics of the waste, disposal site, and method of disposal, it finds reasonable assurance of compliance with the performance objective of subpart C of this part (10 CFR Part 61.58).

Part C is the section in the regulation dealing with performance objectives.

The Department of Energy has adopted the upper limits of Class C as a bound on near surface disposal, but also has a means for performance-based exemptions in the DOE Order on Radioactive Waste Management, 5820.2A. These are given below:

> Transuranic waste that the Department of Energy has determined, with the concurrence of the EPA Administrator, does not need the degree of isolation provided by a geologic repository or, transuranic waste that cannot be certified or otherwise approved for acceptance at the Waste Isolation Pilot Plant, shall be disposed of by alternative methods. Alternative disposal methods shall be approved by DOE Headquarters (DP-12 and EH-1) and shall comply with the National Environmental Policy Act requirements and EPA/State regulations (DOE Order 5820.2A - Chapter II - 2.b).
>
> Disposition of waste designated as greater-than-class C, as defined in 10 CFR 61.55, must be handled as special cases. Disposal systems for such waste must be justified by a specific performance assessment through the National Environmental Policy Act process and with the concurrence of DP-12 for all DP-1 disposal facilities and of NE-20 for those disposal facilities under the cognizance of NE-1 (DOE Order 5820.2A - Chapter III - 3.i.(4)).

SRTC has done a site specific intruder analysis of a closed tank system with the intent of demonstrating that the final configuration meets the performance objectives of Part 61, and thus meets the requirements for disposal of low-level waste. This analysis is discussed below.

Discussion

The intruder analysis used the intruder-agriculture scenario and a performance objective of 100 mrem/year. The dose objective used by the NRC was 500 mrem/year, but the 100 mrem/year is the current limit used in DOE performance assessments. The choice of the lower dose limit is appropriate for this study. The four radionuclides that are common to the Tables 1 and 2 in 10 CFR 61.55 and the inventory in Tanks 17-20 were included, ^{90}Sr, ^{99}Tc, ^{137}Cs and ^{239}Pu.

The configuration modeled by HNUS for the closure plan was used. Tanks 34 and 47 have been identified as potentially containing the highest levels of residual material, so the inventories from all of the tanks in the group 25-28, 33-34, and 44-47 was assumed to be in the area occupied by the Tanks 17-20 system. This places a higher inventory in a smaller area than will be actually found and is thus conservative. The final configuration of the tank systems after closure will be a thin layer of residual waste located at least 10 meters below the ground surface. This depth precludes the intrusion into the waste while excavating a standard basement with a depth of 3 meters. In this case, the intruder-agriculture scenario becomes the post-drilling scenario, where exposure is from drill cuttings containing waste materials brought to the surface and water used for irrigation. This material is then used to grow food in a home garden, can produce contaminated dust that is inhaled, and produces direct exposure to gamma radiation. This scenario was analyzed with the PATHRAE computer code for a number of time periods. The results of this intruder analysis for a 100 year institutional control period are given in Table 1. The PATHRAE output file for this analysis is included as Attachment I.

Table 1. Intruder doses from post-drilling scenario after 100 years of institutional control with upper bound inventory.

Pathway	Total Dose (mrem/year)	Major Radionuclide
Food Grown on Site	1.2	^{90}Sr
Direct Gamma Exposure	8.1×10^{-5}	^{137}Cs
Dust Inhalation	1.0×10^{-2}	^{239}Pu

The relatively low doses for the closed tank system are due to several factors. The most important is the depth of the residual material below the ground surface. Ten meters of soil provides enough shielding so that dose from direct gamma radiation is extremely small. The intruder scenario includes digging a basement over the facility, but the depth of the basement excavation is 3 meters. In the case of the tank system, no radioactive material is brought to the surface by this activity.

The only way that the intruder is exposed to the radioactivity is through well drilling. In the case of the tank system, the thickness of the contaminated layer is so small compared to the depth from the surface, that very little radioactivity reaches the surface. The PATHRAE code

calculates that amount of radioactive material, then calculates doses due to direct gamma radiation, ingestion of food grown in the material, and inhalation of dust produced by the material.

Conclusions

This study demonstrates that doses to hypothetical intruders from the Tank Farm after closure and 100 years of institutional control will be well below the DOE performance objective of 100 mrem/year and the NRC performance objective of 500 mrem/year. The study also shows that radionuclide concentrations higher that the published Class C limits are possible in a final configuration that is different than that used by the NRC in developing generic limits for near-surface, non-engineered disposal systems.

ATTACHMENT I

PATHRAE OUTPUT FOR CONCENTRATION LIMITS FOR HIGH LEVEL WASTE TANK CLOSURE

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PATHRAE-RAD(PC)  Version 2.2d  February 1995
  Date:  4-24-1997
  Time: 11:51:27

 HLW TANK STUDY - CHRONIC INTRUDER  - Tanks 25-28, 33-34, 44-47


********** PATHRAE INPUT SUMMARY **********

THERE ARE 80 ISOTOPES IN THE DOSE FACTOR LIBRARY
NUMBER OF TIMES FOR CALCULATION IS  4
YEARS TO BE CALCULATED ARE ...

      .00   100.00   300.00   500.00

THERE ARE  11 ISOTOPES IN THE INVENTORY FILE
THE VALUE OF IFLAG IS 0
NUMBER OF PATHWAYS IS  3

           PATHWAY            TYPE OF USAGE
                            FOR UPTAKE FACTORS
   5  FOOD GROWN ON SITE          0
   7  DIRECT GAMMA                0
   8  DUST INHALATION             0

TIME OF OPERATION OF WASTE FACILITY IN YEARS                    0.
LENGTH OF REPOSITORY (M)                                       52.
WIDTH OF REPOSITORY (M)                                        52.
RIVER FLOW RATE (M**3/YR)                                       1.60E+07
STREAM FLOW RATE (M**3/YR)                                      1.60E+07
DISTANCE TO RIVER (M)                                        1000.

OPERATIONAL SPILLAGE FRACTION                                   0.00E+00
DENSITY OF AQUIFER (KG/M**3)                                 1600.
LONGITUDINAL DISPERSIVITY (M)                                   2.50E+02
LATERAL DISPERSION COEFFICIENT -- Y AXIS (M**2/YR)              1.70E+01
NUMBER OF MESH POINTS FOR DISPERSION CALCULATION               20
FLAG FOR GAMMA PATHWAY OPTIONS                                  2
FLAG FOR GAMMA BUILDUP CALCULATION                              1
FLAG FOR ATMOSPHERIC PATHWAY                                    0

COVER THICKNESS OVER WASTE (M)                                  9.92
THICKNESS OF WASTE IN PITS (M)                                   .08
TOTAL WASTE VOLUME (M**3)                                       1.700E+02
DISTANCE TO WELL -- X COORDINATE (M)                         1550.
DISTANCE TO WELL -- Y COORDINATE (M)                            0.
DENSITY OF WASTE (KG/M**3)                                   2000.

FRACTION OF FOOD CONSUMED THAT IS GROWN ON SITE                  .500
FRACTION OF YEAR SPENT IN DIRECT RADIATION FIELD                 .500
DEPTH OF PLANT ROOT ZONE (M)                                    1.000
AREAL DENSITY OF PLANTS (KG/M**2)                               1.000
AVERAGE DUST LOADING IN AIR (KG/M**3)                           1.00E-07
ANNUAL ADULT BREATHING RATE (M**3/YR)                        8000.

FRACTION OF YEAR EXPOSED TO DUST                                 .250
CANISTER LIFETIME (YEARS)                                    1000.
INVENTORY SCALING FACTOR                                        1.00E+00
HEIGHT OF ROOMS IN RECLAIMER HOUSE (CM)                       240.
AIR CHANGE RATE IN RECLAIMER HOUSE (CHANGES/SEC)                5.56E-04
RADON EMANATING POWER OF THE WASTE                              3.00E-01

DIFFUSION COEFF. OF RADON IN WASTE (CM**2/SEC)                  2.00E-02
DIFFUSION COEFF. OF RN IN CONCRETE (CM**2/SEC)                  3.00E-04
THICKNESS OF CONCRETE SLAB FLOOR (CM)                          20.0
DIFFUSION COEFF. OF RADON IN COVER (CM**2/SEC)                  1.00E-02
ATMOSPHERIC STABILITY CLASS                                     4
AVERAGE WIND SPEED (M/S)                                        3.00
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FRACTION OF TIME WIND BLOWS TOWARD RECEPTOR		1.0000
RECEPTOR DISTANCE FOR ATMOSPHERIC PATHWAY (M)		11000.0
DUST RESUSPENSION RATE FOR OFFSITE TRANSPORT (M**3/S)		1.00E-07
DEPOSITION VELOCITY (M/S)		.0100
STACK HEIGHT (M)		.0
STACK INSIDE DIAMETER (M)		.00
STACK GAS VELOCITY (M/S)		.0
HEAT EMISSION RATE FROM BURNING (CAL/S)		0.00E+00
DECAY CHAIN FLAGS	0 0 0 0 0 0	0
FLAG FOR INPUT SUMMARY PRINTOUT		1
FLAG FOR DIRECTION OF TRENCH FILLING		1
FLAG FOR GROUNDWATER PATHWAY OPTIONS		0
AMOUNT OF WATER PERCOLATING THROUGH WASTE ANNUALLY (M)		4.00E-01
DEGREE OF SOIL SATURATION		.200
RESIDUAL SOIL SATURATION		.100
PERMEABILITY OF VERTICAL ZONE (M/YR)		400.00
SOIL NUMBER		.250
POROSITY OF AQUIFER		.30
POROSITY OF UNSATURATED ZONE		.30
DISTANCE FROM AQUIFER TO WASTE (M)		1.0
AVERAGE VERTICAL GROUNDWATER VELOCITY (M/YR)		6.67E+00
HORIZONTAL VELOCITY OF AQUIFER (M/YR)		2.0
LENGTH OF PERFORATED WELL CASING (M)		4.570
SURFACE EROSION RATE (M/YR)		5.100E-05
LEACH RATE SCALING FACTOR		1.000E+00
ANNUAL RUNOFF OF PRECIPITATION (M)		4.00E-01

NUCLIDE	INGESTION DOSE FACTORS (MREM/PCI)	INHALATION DOSE FACTORS (MREM/PCI)	DIRECT GAMMA DOSE FACTORS (MREM-M2/PCI-YR)	HALF LIFE (YR)
Cs-135	7.100E-06	4.500E-06	0.000E+00	2.300E+06
Cs-137	5.000E-05	3.200E-05	3.100E-09	3.010E+01
Eu-154	9.100E-06	2.600E-04	6.100E-09	8.500E+00
Se-79	8.300E-06	8.900E-06	0.000E+00	6.500E+04
Sn-126	1.700E-05	8.600E-05	3.800E-09	1.000E+05
Tc-99	1.300E-06	7.500E-06	2.900E-15	2.130E+05
U-238	2.300E-04	1.200E-01	2.600E-12	4.470E+09
Pu-239	4.300E-03	5.100E-01	1.600E-12	2.420E+04
Sr-90	1.300E-04	1.300E-03	0.000E+00	2.860E+01

NUCLIDE	VOLATILITY FRACTION	GAMMA ENERGY (MEV)	GAMMA ATTENUATION (1/M)
Cs-135	0.000E+00	0.000E+00	0.000E+00
Cs-137	0.000E+00	6.600E-01	1.200E+01
Eu-154	0.000E+00	1.000E+00	1.000E+01
Se-79	0.000E+00	0.000E+00	0.000E+00
Sn-126	0.000E+00	6.600E-01	1.200E+01
Tc-99	0.000E+00	0.000E+00	0.000E+00
U-238	0.000E+00	5.000E-02	5.000E+01
Pu-239	0.000E+00	1.000E-01	2.700E+01
Sr-90	0.000E+00	0.000E+00	0.000E+00

NUCLIDE	INPUT LEACH RATE (1/YR)	FINAL LEACH RATE (1/YR)	SOLUBILITY (MOLE/L)	INPUT INVENTORY (CI)
Cs-135	9.330E-02	9.330E-02	0.000E+00	4.390E-03
Cs-137	9.330E-02	9.330E-02	0.000E+00	2.030E+03
Eu-154	1.440E-03	1.440E-03	0.000E+00	3.030E+02
Se-79	1.070E+01	1.070E+01	0.000E+00	3.840E-01
Sn-126	1.870E-03	1.870E-03	0.000E+00	7.140E-01
Tc-99	1.870E-03	1.870E-03	0.000E+00	6.650E+00
U-238	4.000E-05	2.316E-07	3.000E-10	1.120E-01
Pu-239	3.740E-04	3.740E-04	0.000E+00	1.130E+02
Sr-90	1.740E+00	1.740E+00	0.000E+00	3.000E+04

NUCLIDE	AQUIFER SORPTION	AQUIFER RETARDATION	VERTICAL SORPTION	VERTICAL RETARDATION
Cs-135	1.000E+02	5.343E+02	1.000E+02	2.668E+03
Cs-137	1.000E+02	5.343E+02	1.000E+02	2.668E+03
Eu-154	8.000E+02	4.268E+03	8.000E+02	2.133E+04
Se-79	5.000E+00	2.767E+01	5.000E+00	1.343E+02
Sn-126	1.300E+02	6.943E+02	1.300E+02	3.468E+03
Tc-99	3.600E-01	2.920E+00	3.600E-01	1.060E+01
U-238	5.000E+01	2.677E+02	5.000E+01	1.334E+03
Pu-239	1.000E+02	5.343E+02	1.000E+02	2.668E+03
Sr-90	1.000E+01	5.433E+01	1.000E+01	2.677E+02

	BIOACCUMULATION FACTORS			
NUCLIDE	SOIL-PLANT Bv	SOIL-PLANT Br	FORAGE-MILK Fm (D/L)	FORAGE-MEAT Ff (D/KG)
Cs-135	1.000E-02	3.000E-02	1.200E-02	4.000E-03
Cs-137	1.000E-02	3.000E-02	1.200E-02	4.000E-03
Eu-154	2.500E-03	2.500E-04	5.000E-06	4.800E-03
Se-79	1.300E+00	1.300E-01	4.500E-02	1.500E-02
Sn-126	7.500E-03	4.000E-03	5.000E-04	3.400E-04
Tc-99	2.500E-01	1.500E+00	2.500E-02	4.000E-01
U-238	2.500E-03	4.000E-03	5.000E-04	3.400E-04
Pu-239	2.500E-04	4.500E-05	2.000E-06	1.400E-05
Sr-90	1.700E-02	2.500E-01	8.000E-04	6.000E-04

PATHWAY 5
FOOD GROWN ON SITE

********* NUCLIDE DOSES (mrem/yr) ********

NUCLIDE/TIME	0.	100.	300.	500.
Cs-135	1.8E-08	1.8E-08	1.8E-08	1.8E-08
Cs-137	5.8E-02	5.8E-03	5.8E-05	5.8E-07
Eu-154	2.9E-05	8.5E-09	7.0E-16	5.8E-23
Se-79	1.6E-04	1.6E-04	1.6E-04	1.6E-04
Sn-126	7.7E-07	7.7E-07	7.7E-07	7.7E-07
Tc-99	1.1E-03	1.1E-03	1.1E-03	1.1E-03
U-238	1.5E-06	1.5E-06	1.5E-06	1.5E-06
Pu-239	3.7E-04	3.7E-04	3.7E-04	3.6E-04
Sr-90	1.4E+01	1.2E+00	9.6E-03	7.5E-05

******* SUM OF NUCLIDE DOSES FOR GIVEN TIMES ******

1.4E+01	1.2E+00	1.1E-02	1.7E-03

******* SUM OF NUCLIDE RISKS FOR GIVEN TIMES ******

6.9E-06	6.2E-07	5.6E-09	8.5E-10

FRACTIONAL MIXING OF WASTE IN SOIL IN TRENCH IS .786
FRACTION OF FOOD CONSUMED WHICH IS GROWN AT THE WASTE SITE (FG) IS .500
FRACTIONAL MIXING OF TRENCH MATERIAL IN SURFACE SOIL IS 3.68E-07

PATHWAY 7
DIRECT GAMMA

********* NUCLIDE DOSES (mrem/yr) ******** WITH BUILDUP

NUCLIDE/TIME	0.	100.	300.	500.
Cs-135	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Cs-137	8.0E-04	8.0E-05	8.0E-07	8.0E-09
Eu-154	2.4E-04	6.8E-08	5.6E-15	4.6E-22
Se-79	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Sn-126	3.5E-07	3.5E-07	3.5E-07	3.4E-07
Tc-99	0.0E+00	0.0E+00	0.0E+00	0.0E+00
U-238	3.7E-11	3.7E-11	3.7E-11	3.7E-11
Pu-239	2.3E-08	2.3E-08	2.3E-08	2.3E-08
Sr-90	0.0E+00	0.0E+00	0.0E+00	0.0E+00

******* SUM OF NUCLIDE DOSES FOR GIVEN TIMES ******

1.0E-03	8.1E-05	1.2E-06	3.8E-07

******* SUM OF NUCLIDE RISKS FOR GIVEN TIMES ******

5.2E-10	4.0E-11	5.9E-13	1.9E-13

EROSION STOPS AFTER COVER IS ALL ERODED IN 194509.8 YEARS
FRACTIONAL MIXING OF TRENCH MATERIAL IN SURFACE SOIL IS 3.68E-07

PATHWAY 8
DUST INHALATION

********* NUCLIDE DOSES (mrem/yr) ********

NUCLIDE/TIME	0.	100.	300.	500.
Cs-135	3.4E-12	3.4E-12	3.4E-12	3.4E-12
Cs-137	1.1E-05	1.1E-06	1.1E-08	1.1E-10
Eu-154	1.3E-05	3.9E-09	3.2E-16	2.6E-23
Se-79	5.8E-10	5.8E-10	5.8E-10	5.8E-10
Sn-126	1.0E-08	1.0E-08	1.0E-08	1.0E-08
Tc-99	8.5E-09	8.5E-09	8.5E-09	8.5E-09
U-238	2.3E-06	2.3E-06	2.3E-06	2.3E-06
Pu-239	9.8E-03	9.8E-03	9.7E-03	9.7E-03
Sr-90	6.6E-03	5.9E-04	4.6E-06	3.6E-08

******* SUM OF NUCLIDE DOSES FOR GIVEN TIMES ******

1.6E-02	1.0E-02	9.7E-03	9.7E-03

******* SUM OF NUCLIDE RISKS FOR GIVEN TIMES ******

8.2E-09	5.2E-09	4.9E-09	4.8E-09

FRACTIONAL MIXING OF TRENCH MATERIAL IN SURFACE SOIL IS 3.68E-07

********** CUMULATIVE TOTAL DOSES PER YEAR FOR GIVEN TIMES **********

3	1.39E+01	1.24E+00	2.10E-02	1.14E-02

********** CUMULATIVE TOTAL RISKS PER YEAR FOR GIVEN TIMES **********

3	3.89E-06	3.48E-07	5.88E-09	3.18E-09

NUCLIDE HALFLIFE AND INVENTORY (CI) ASSUMING NO TRANSPORT FROM THE FACILITY

(TIMES IN YEARS)	HALFLIFE	0.	100.	300.	500.
Cs-135	2.30E+06	4.39E-03	4.39E-03	4.39E-03	4.39E-03
Cs-137	3.01E+01	2.03E+03	2.03E+02	2.03E+00	2.03E-02
Eu-154	8.50E+00	3.03E+02	8.71E-02	7.19E-09	5.94E-16
Se-79	6.50E+04	3.84E-01	3.84E-01	3.83E-01	3.82E-01
Sn-126	1.00E+05	7.14E-01	7.14E-01	7.13E-01	7.12E-01
Tc-99	2.13E+05	6.65E+00	6.65E+00	6.64E+00	6.64E+00
U-238	4.47E+09	1.12E-01	1.12E-01	1.12E-01	1.12E-01
Pu-239	2.42E+04	1.13E+02	1.13E+02	1.12E+02	1.11E+02
Sr-90	2.86E+01	3.00E+04	2.66E+03	2.09E+01	1.64E-01

NUCLIDE HALFLIFE AND INVENTORY (CI) REMAINING IN THE FACILITY

(TIMES IN YEARS)	HALFLIFE	0.	100.	300.	500.
Cs-135	2.30E+06	4.39E-03	4.39E-03	4.39E-03	4.39E-03
Cs-137	3.01E+01	2.03E+03	2.03E+02	2.03E+00	2.03E-02
Eu-154	8.50E+00	3.03E+02	8.71E-02	7.19E-09	5.94E-16
Se-79	6.50E+04	3.84E-01	3.84E-01	3.83E-01	3.82E-01
Sn-126	1.00E+05	7.14E-01	7.14E-01	7.13E-01	7.12E-01
Tc-99	2.13E+05	6.65E+00	6.65E+00	6.64E+00	6.64E+00
U-238	4.47E+09	1.12E-01	1.12E-01	1.12E-01	1.12E-01
Pu-239	2.42E+04	1.13E+02	1.13E+02	1.12E+02	1.11E+02
Sr-90	2.86E+01	3.00E+04	2.66E+03	2.09E+01	1.64E-01

********** MAXIMUM DOSES & DOMINANT NUCLIDES BY PATHWAY **********

HLW TANK STUDY - CHRONIC INTRUDER - Tanks 25-28, 33-34, 44-47

PATHWAY	DUST	ATMOSPHERIC	GAMMA	WELL	FOOD
ANNUAL DOSE	1.65E-02	0.00E+00	1.04E-03	0.00E+00	1.69E-03
YEAR	0	0	0	0	500
DOMINANT NUCLIDE	Pu-239		Cs-137		Tc-99