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Revision 1

REMOVAL OF HIGHLY RADIOACTIVE RADIONUCLIDES FOR TANK 16

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ACRONYMS/ABBREVIATIONS

DOE	U.S. Department of Energy
HRR	Highly Radioactive Radionuclide
HTF	H-Area Tank Farm
HHW	High-Heat Waste
HM	H-Modified
LHW	Low-Heat Waste
NRC	U.S. Nuclear Regulatory Commission
WCS	Waste Characterization System

1.0 PURPOSE

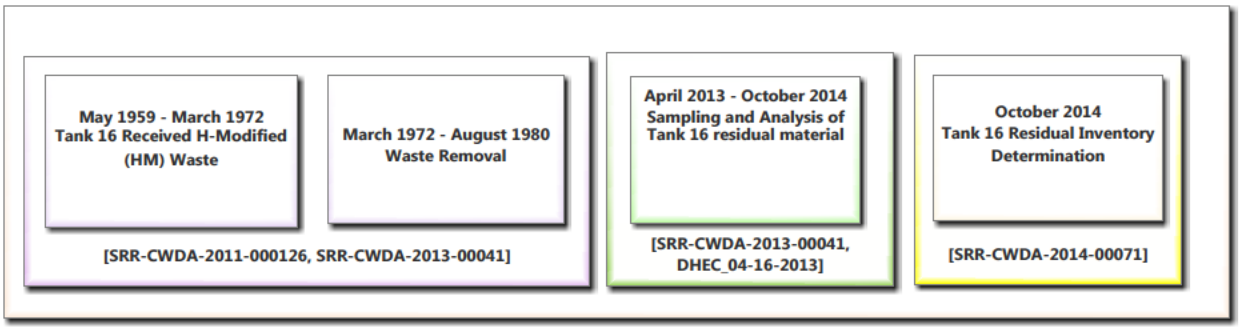
This document provides the percentage of the "highly radioactive radionuclide" (HRR) curies (i.e., inventory) removed from Tank 16 as part of waste removal efforts. This is based on a comparison between the Tank 16 HRR inventory prior to waste removal and the Tank 16 residual HRR inventory. The Tank 16 HRR inventory prior to waste removal is determined in this document along with a discussion on the methodology used for this determination. The Tank 16 residual HRR inventory is per the *Tank 16 Inventory Determination*, SRR-CWDA-2014-00071.

Based on consultation with the Nuclear Regulatory Commission (NRC), the U.S. Department of Energy (DOE) views HRRs to be those radionuclides that, using a risk-informed approach, contribute most significantly to radiological risk to workers, the public and the environment. For H-Area Tank Farm (HTF), a comprehensive HRR evaluation was performed resulting in the following list of potential HRRs: Sr-90, Tc-99, I-129, Cs-137, U-233, U-234, U-235, Np-237, Pu-238, Pu-239, Pu-240, Am-241, and Am-243. [DOE/SRS-WD-2014-001]

2.0 TANK 16 HISTORY

Tank 16 was placed into service in May 1959 to receive fresh H-Modified (HM) high-heat waste (HHW) and low-heat waste (LHW) from H-Canyon operations. In November 1959, leakage from the primary tank into the annulus was first identified. In May of 1960 Tank 16 reached its historical high volume of 1,060,000 gallons. Tank 16 operated until March 1972 when the use of Tank 16 for waste receipts ceased due to continued leaking. Waste removal efforts began to remove waste from both the Tank 16 primary tank and annulus. [SRR-CWDA-2011-00126] At the time when waste removal efforts began, there was an estimated 768,000 gallons of supernate, 77,000 gallons of insoluble solids (sludge), and 6,000 gallons of waste material in the annulus of Tank 16. [SRR-CWDA-2013-00041] In August 1980, the last waste was removed from Tank 16. In April 2013, Tank 16 entered into the sampling and analysis phase. [DHEC_04-16-2013, SRR-CWDA-2013-00041] After completion of sampling and analysis of the residual material in the Tank 16 primary tank and annulus, SRR-CWDA-2014-00071, *Tank 16 Inventory Determination* was issued in October 2014 and provided the residual inventory in Tank 16. This history is outlined in Figure 2.0-1 below.

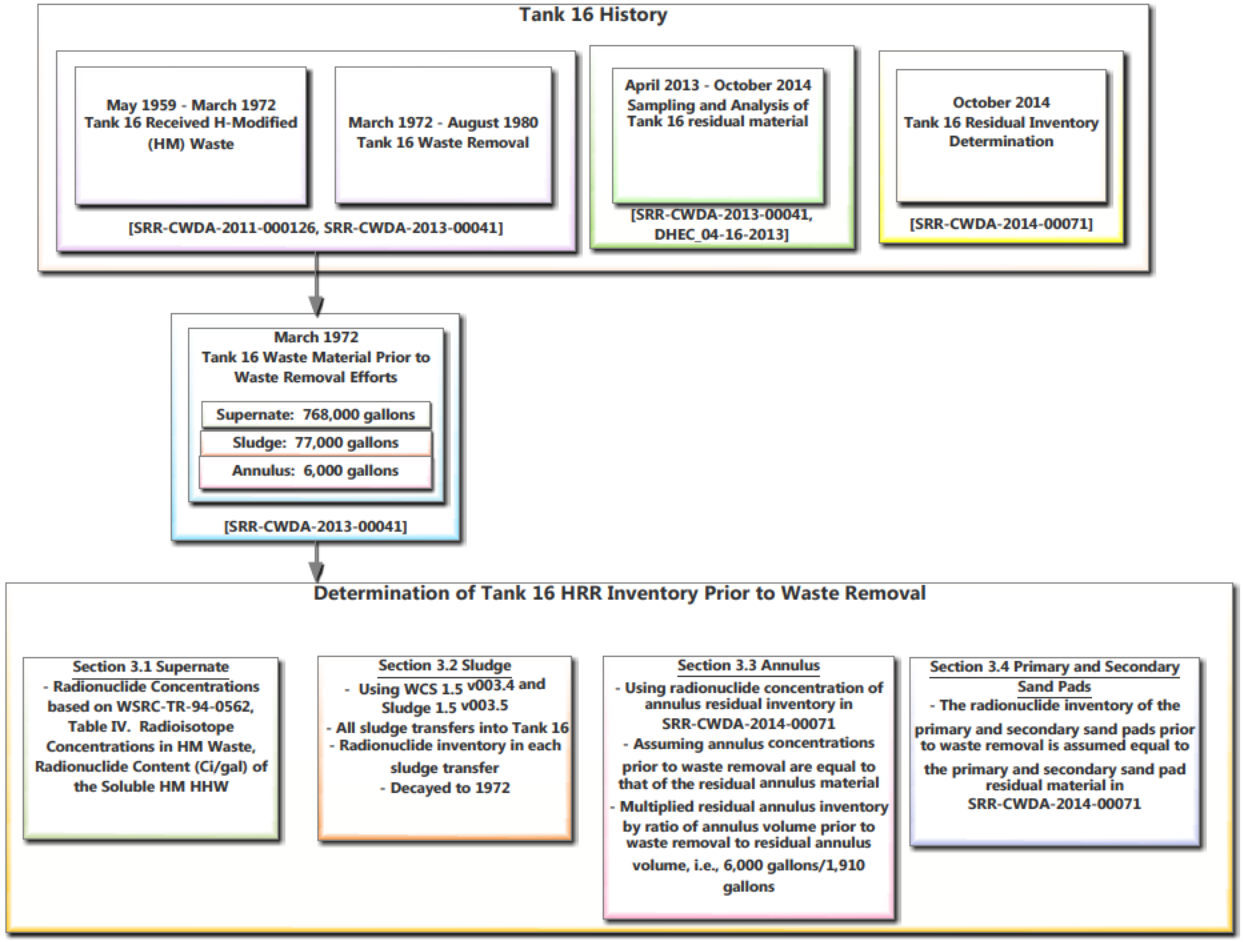
Figure 2.0-1: Tank 16 History



3.0 METHODOLOGY

This section describes the methodology used to determine the HRR inventory in Tank 16 prior to waste removal. The waste material in Tank 16 prior to waste removal is made up of the supernate and sludge within the primary tank as well as the waste material in the Tank 16 annulus. Based on Tank 16's operating history, waste material is also known to have overflowed from the annulus and is therefore assumed to be in the Tank 16 primary and secondary sand pads. The historical information and sample data that is used to determine inventory prior to waste removal vary between the Tank 16 supernate, sludge, annulus, and sand pads. Therefore, different methods are used to determine the inventory for each of these areas. The methodology for determining the Tank 16 HRR inventory prior to waste removal for each area of Tank 16 is given in the following sections. Figure 3.0-1 provides a summary of the methodologies used for each area of Tank 16 along with the corresponding section number that further discusses the methodology for each area. As seen in Figure 3.0-1, the demarcation point for the Tank 16 inventory prior to waste removal is March 1972. For conservatism, this date was selected as the point of the historical high inventory in Tank 16. The assumed volumes of supernate, sludge, and annulus waste at the time prior to waste removal are discussed in Section 2.0 and are also included in Figure 3.0-1.

Figure 3.0-1: Methodology for Determination of Tank 16 HRR Inventory Prior to Waste Removal



3.1 Supernate

The supernate inventory for Tank 16 prior to waste removal is calculated using the radionuclide concentrations provided in the waste characterization data from WSRC-TR-94-0562, *Characterization of Radionuclides in HLW Sludge Based on Isotopic Distributions in Irradiated Assemblies.* WSRC-TR-94-0562 provides the radionuclide content of the HM Waste which was sent to Tank 16. WSRC-TR-94-0562, Table IV. "Radioisotope Concentrations in HM Waste" gives the radionuclide concentrations in Ci/gal of the soluble material (i.e., supernate) in the HM HHW. Am-243 was not included in WSRC-TR-94-0562, but was added as a radionuclide of interest in 2005. CBU-PIT-2005-00034, *Compilation of Additional Radionuclide Data for SRS HLW Sludge to be included in Waste Characterization System (WCS II),* Table 5. "Radioisotope Concentrations for Four Waste Streams (t = 180 days)" provides the concentration of Am-243 in Ci/gal in the HM HHW waste stream. The Am-243 concentration given is that in the sludge, and is assumed to be the same concentration in the supernate. Table 3.1-1 below shows the HRR concentrations in the Tank 16 supernate per WSRC-TR-94-0562 and CBU-PIT-2005-00034.

Table 3.1-1: Tank 16 Supernate HRR Concentrations

HRR	Concentration (Ci/gal)
Sr-90	6.02E-03
Tc-99	9.00E-04
I-129	2.76E-06
Cs-137	1.17E+01
U-233	0.00E+00
U-234	1.33E-06
U-235	1.47E-08
Np-237	2.50E-07
Pu-238	2.81E-02
Pu-239	2.20E-04
Pu-240	1.54E-04
Am-241	9.09E-05
Am-243	9.36E-06

The supernate concentrations in Table 3.1-1 were multiplied by the supernate volume prior to waste removal (768,000 gallons per SRR-CWDA-2013-00041) to determine the supernate inventory for each HRR prior to waste removal. The HRR inventory in the supernate is given in Table 4.0-1.

3.2 Sludge

The sludge inventory for Tank 16 prior to waste removal is determined using the Waste Characterization System (WCS) 1.5 and the associated Sludge 1.5 computer programs. These programs reside on Work Group Server 17 and are maintained by the Concentration, Storage, and Transfer Facilities Process Safety and Regulatory Engineering group. WCS 1.5 and Sludge 1.5 are a system of Microsoft Excel® spreadsheets developed from 1995-2002. WCS 1.5 is the "parent" spreadsheet, linked to Sludge 1.5. These programs are updated periodically to reflect changes in the HTF waste composition based on waste tank sample results, solids measurements, and pre-transfer and post-transfer data. The version of WCS 1.5 used in this document is WCS 1.5 version 3.4. The version of Sludge 1.5 used in this document is Sludge 1.5 version 3.5. All changes to WCS 1.5 and Sludge 1.5 follow B-SQP-H-00041, *Closure Business Unit LWDP Waste Characterization System Software Quality Assurance Plan* and B-DMP-H-00002, *Waste Characterization System Data Management Plan*. Sludge 1.5 has a record of all sludge transfers into Tank 16 and the radionuclide concentrations in the waste streams for each transfer. The inventory for each radionuclide for each transfer date was calculated by multiplying the waste stream concentration for each radionuclide by the transfer volume.

Table 3.2-1 presents the Tank 16 sludge transfer information as found in Sludge 1.5. The top of Table 3.2-1 presents the HRR concentrations in the H-Canyon waste streams that were transferred to Tank 16. Per Sludge 1.5, Tank 16 processed two waste streams from H-Canyon. One stream was a LLW stream and the other a mixture of HHW and LHW. Table 3.2-1 also presents the sludge transfer dates, sludge transfer volume, and the type of waste stream for each transfer.

WCS 1.5 and Sludge 1.5 were used to total all of the sludge curies transferred into Tank 16 prior to March 1, 1972 (the assumed starting date for Tank 16 waste removal efforts). The sludge curies transferred into Tank 16 are insoluble solids and can be reasonably assumed to remain in the tank even as liquid was decanted from the tank. Using a built in decay capability in Sludge 1.5, the radionuclide inventory of the sludge in Tank 16 was decayed to March 1, 1972. Am-243 was added to WCS 1.5 as a radionuclide of interest in 2005. Sludge 1.5 was not updated to include Am-243 as a radionuclide in Tank 16. CBU-PIT-2005-00034, *Compilation of Additional Radionuclide Data for SRS HLW Sludge to be included in Waste Characterization System (WCS II),* Table 5. "Radioisotope Concentrations for Four Waste Streams (t = 180 days)" provides the concentration of Am-243 in Ci/gal in the HM HHW waste stream and is shown as the Am-243 concentration in the LHW and mixed HHW and LHW waste streams at the top of Table 3.2-1. The Am-243 concentration was multiplied by each sludge transfer volume to give the total Am-243 inventory added to Tank 16. The inventory calculated for each transfer was then decayed to March 1, 1972. Table 3.2-1 shows the Tank 16 inventory for each HRR in each sludge transfer as calculated in Sludge 1.5 (using the waste stream concentrations and transfer volume) with the exception of Am-243 which was calculated as previously stated. The summation of the decayed radionuclide inventory from all the sludge transfers to Tank 16 for each HRR gives the total sludge inventory for each HRR in Tank 16 prior to waste removal. This total inventory for each HRR is given at the bottom of Table 3.2-1.

The HRR inventory in the Tank 16 sludge is equal to the total presented in Table 3.2-1 and is also summarized in Table 4.0-1. However, the value for Am-241 in Table 4.0-1 is the summation of the Am-241 ingrowth and Am-241 total values presented in Table 3.2-1.

Table 3.2-1: Per Sludge 1.5 - Tank 16 HRR Historical Sludge Transfer Data with Decay to March 1, 1972

		Sr-90	Tc-99	I-129	Cs-137	U-233	U-234	U-235	Np-237	Pu-238	Pu-239	Pu-240	Ingrowth Am-241	Am-241	Am-243
Waste Stream Concentration	LHW Stream (Ci/gal)	4.47E-01	5.92E-05	2.05E-10	2.34E-02	0.00E+00	0.00E+00	0.00E+00	2.39E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.07E-04	2.93E-06
	Mixed HLW and LHW Stream (Ci/gal)	4.33E+00	7.96E-04	1.99E-09	2.28E-01	0.00E+00	0.00E+00	0.00E+00	2.29E-06	2.65E-01	2.08E-03	1.46E-03	0.00E+00	2.81E-03	2.93E-06

Transfer Date	Waste Stream*	Transfer Volume (gal)	Sr-90 (Ci)	Tc-99 (Ci)	I-129 (Ci)	Cs-137 (Ci)	U-233 (Ci)	U-234 (Ci)	U-235 (Ci)	Np-237 (Ci)	Pu-238 (Ci)	Pu-239 (Ci)	Pu-240 (Ci)	Ingrowth Am-241** (Ci)	Am-241 (Ci)	Am-243 (Ci)
06/01/59	M	88,975	282,798	51	0.00018	15,152	0	0.132	0.002	0.208	589	44	17	37	245	0.260
07/01/59	M	111,550	355,261	64	0.00022	19,032	0	0.120	0.003	0.332	945	67	27	58	307	0.326
08/01/59	M	119,223	380,483	69	0.00024	20,381	0	0.117	0.003	0.400	1,131	80	33	65	328	0.349
09/01/59	M	121,275	387,831	70	0.00024	20,772	0	0.124	0.003	0.347	1,286	70	28	57	334	0.355
10/01/59	M	186,343	597,108	107	0.00037	31,977	0	0.095	0.002	0.567	1,611	111	47	92	513	0.545
11/01/59	M	135,658	435,594	78	0.00027	23,325	0	0.047	0.001	0.292	821	59	24	50	373	0.397
12/01/59	M	83,226	267,770	48	0.00017	14,337	0	0.040	0.001	0.178	496	38	15	28	229	0.244
01/01/60	M	52,212	168,333	30	0.00010	9,012	0	0.088	0.002	0.354	1,203	47	36	58	144	0.153
02/01/60	M	61,854	199,831	36	0.00012	10,697	0	0.076	0.002	0.364	1,249	48	37	57	170	0.181
03/01/60	M	64,521	208,850	37	0.00013	11,178	0	0.113	0.003	0.389	1,327	52	40	57	178	0.189
04/01/60	M	39,321	127,543	23	0.00008	6,826	0	0.040	0.001	0.140	484	21	14	21	108	0.115
05/01/60	M	24,025	78,084	14	0.00005	4,178	0	0.048	0.001	0.133	459	19	14	21	66	0.070
01/01/61	M	99,343	328,187	57	0.00020	17,546	0	0.140	0.003	0.155	2,676	84	48	104	274	0.291
11/01/67	L	24,402	9,806	1	0.00001	518	0	0.015	0.0003	0.070	0	0	0	0	5	0.071
12/01/67	L	36,832	14,831	2	0.00001	783	0	0.005	0.0001	0.096	5	0	0	0	8	0.108
01/01/68	L	49,588	20,008	3	0.00001	1,056	0	0.007	0.0001	0.023	158	0	0	0	10	0.145
02/01/68	L	69,913	28,268	4	0.00001	1,492	0	0.014	0.0002	0.040	115	0	0	0	14	0.205
03/01/68	L	57,606	23,337	3	0.00001	1,231	0	0.012	0.0001	0.067	95	0	0	0	12	0.169
04/01/68	L	68,200	27,686	4	0.00001	1,461	0	0.013	0.0001	0.026	62	0	0	0	14	0.200
05/01/68	L	26,000	10,576	2	0.00001	558	0.0836	0.001	0.00001	0.001	15	0	0	0	5	0.076
01/01/70	L	7,800	3,304	0.5	0.0000016	174	0	0.003	0.00003	0.002	3	0	0	0	2	0.023
02/01/70	L	5,000	2,122	0.3	0.0000010	112	0	0.002	0.00002	0.002	1	0	0	0	1	0.015
Total			3.96E+06	7.05E+02	2.44E-03	2.12E+05	8.36E-02	1 25E+00	2.87E-02	4.19E+00	1.47E+04	7.41E+02	3.81E+02	7.05E+02	3.34E+03	4.49E+00

*Note – An "L" in this column indicates a waste stream with only LHW, an "M" indicates a waste stream with a mix of LHW and HHW.

**Note – Sludge 1.5 accounts for the Am-241 ingrowth curies based on the Pu-241 inventory.

3.3 Annulus

Due to the leaking of waste material from the Tank 16 primary tank into the annulus, numerous samples were taken of the Tank 16 annulus material, but not all HRRs were characterized during these sampling efforts. During the residual inventory determination, sample analysis was done for all the Tank 16 HRRs. The characterization of annulus residual material in the residual inventory determination is assumed to be applicable to the annulus material prior to waste removal. The annulus residual material characterization is found in SRR-CWDA-2014-00071, *Tank 16 Inventory Determination.* SRR-CWDA-2014-00071, Table 5.5-1 gives the annulus residual inventory in 2014 for the 1,910 gallons of annulus residual material. The residual inventory for each HRR is multiplied by the ratio of the annulus waste material volume prior to waste removal (6,000 gallons per SRR-CWDA-2013-00041) to the annulus residual material volume (1,910 gallons per SRR-CWDA-2014-00071) to give the annulus inventory prior to waste removal. The HRR inventory in the annulus is given in Table 4.0-1.

3.4 Primary and Secondary Sand Pads

Based on Tank 16's operating history, waste material is also known to have overflowed from the Tank 16 annulus and it is assumed to be in the Tank 16 primary and secondary sand pads. SRR-CWDA-2014-00071, *Tank 16 Inventory Determination* has determined the residual inventory for the Tank 16 primary and secondary sand pads. SRR-CWDA-2014-00071 assumes that the primary sand pad was saturated with waste material and that some material went into the secondary sand pad. The primary and secondary sand pad inventory prior to waste removal is not expected to differ from the residual material since waste removal from the sand pads was not possible. Therefore the primary and secondary sand pad HRR inventories prior to waste removal have been set equal to the primary and secondary sand pad residual inventories found in SRR-CWDA-2014-00071, Table 5.7-1. The HRR inventory in the sand pads is given in Table 4.0-1.

4.0 TANK 16 HRR INVENTORY PRIOR TO WASTE REMOVAL

Using the methodologies presented in Section 3.0, the Tank 16 HRR inventories for the supernate, sludge, annulus, and primary and secondary sand pads was determined. Table 4.0-1 presents the HRR inventory in each area and the total HRR inventory for Tank 16 prior to waste removal.

Table 4.0-1: Tank 16 HRR Inventory Prior to Initiation of Waste Removal (1972)

Radionuclide	HRR Supernate Inventory (Ci)	HRR Sludge Inventory (Ci)	HRR Annulus Inventory (Ci)	HRR Primary Sand Pad Inventory (Ci)	HRR Secondary Sand Pad Inventory (Ci)	HRR Total Inventory (Ci)
Sr-90	4.62E+03	3.96E+06	5.03E+04	1.10E+04	2.20E+02	4.02E+06
Tc-99	6.91E+02	7.05E+02	5.97E+00	1.30E+00	2.60E-02	1.40E+03
I-129	2.12E+00	2.44E-03	2.48E-02	5.40E-03	1.10E-04	2.15E+00
Cs-137	8.99E+06	2.12E+05	1.79E+04	3.90E+03	7.80E+01	9.22E+06
U-233	0.00E+00	8.36E-02	3.46E-02	7.70E-03	1.50E-04	1.26E-01
U-234	1.02E+00	1.25E+00	3.77E-02	8.50E-03	1.70E-04	2.32E+00
U-235	1.13E-02	2.87E-02	5.65E-04	1.20E-04	2.40E-06	4.07E-02
Np-237	1.92E-01	4.19E+00	6.28E-02	1.40E-02	2.80E-04	4.46E+00
Pu-238	2.16E+04	1.47E+04	1.10E+02	2.40E+01	4.70E-01	3.64E+04
Pu-239	1.69E+02	7.41E+02	1.48E+01	3.20E+00	6.40E-02	9.28E+02
Pu-240	1.18E+02	3.81E+02	6.60E+00	1.50E+00	2.90E-02	5.08E+02
Am-241	6.98E+01	4.04E+03	2.42E+01	5.20E+00	1.00E-01	4.14E+03
Am-243	2.25E+00	4.49E+00	2.51E-02	5.40E-03	1.10E-04	6.77E+00
TOTAL	**9.01E+06**	**4.19E+06**	**6.83E+04**	**1.49E+04**	**2.99E+02**	**1.33E+07**

5.0 PERCENT OF HIGHLY RADIOACTIVE RADIONUCLIDES REMOVED

To quantitatively address how effective the waste removal techniques have been, the percentages are determined by comparing the inventory of the radioactivity (Ci) that was present prior to waste removal to the current estimated residual waste inventory. The percentages of HRRs for individual radionuclides, as well as overall removal, are provided.

For Tank 16, the percent removed for each radionuclide was determined by comparing the HRR original inventory shown in Table 4.0-1 to the HRR residual inventory in 2014 found in SRR-CWDA-2014-00071, *Tank 16 Inventory Determination*. The residual inventories for the primary tank (which includes the residual equipment inventory), the annulus, and the primary and secondary sand pads were taken from SRR-CWDA-2014-00071, Tables 5.1-1, 5.4-1, 5.5-1, and 5.7-1, respectively. The percentages of HRRs removed from Tank 16 for individual HRRs, as well as overall removal percentage, are shown in Table 5.0-1.

Table 5.0-1: Tank 16 HRRs Percent Removed

Radionuclide	Tank 16 HRR Inventory Prior to Waste Removal (1972) (Ci)	Tank 16 HRR Residual Inventory (2014) (Ci)	Percent Removed (%)
Sr-90	4.02E+06	4.23E+04	98.9%
Tc-99	1.40E+03	4.95E+00	99.6%
I-129	2.15E+00	1.47E-02	99.3%
Cs-137	9.22E+06	9.68E+03	99.9%
U-233	1.26E-01	3.83E-02	69.7%
U-234	2.32E+00	3.26E-02	98.6%
U-235	4.07E-02	3.06E-04	99.2%
Np-237	4.46E+00	3.58E-02	99.2%
Pu-238	3.64E+04	6.48E+01	99.8%
Pu-239	9.28E+02	8.18E+00	99.1%
Pu-240	5.08E+02	3.72E+00	99.3%
Am-241	4.14E+03	1.46E+01	99.6%
Am-243	6.77E+00	1.37E-02	99.8%
Total	**1.33E+07**	**5.21E+04**	**99.6%**

Based on the results shown Table 5.0-1, more than 99% of the total inventory for Tank 16 has been removed.

6.0 REFERENCES

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