Pacific Northwest National Laboratory

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Organic Tank Safety Project: Equilibrium Moisture Determination Task FY 1998 Annual Progress Report

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Glossary

DESH	Duke Engineering and Services Hanford
DL	drainable liquid
HASQARD	Hanford Analytical Services Quality Assurance Requirements Document
P_{H_2O}	water partial pressure
PNNL	Pacific Northwest National Laboratory
PUREX	Plutonium Uranium Extraction
REDOX	Reduction-Oxidation (plant)
RH	relative humidity
RPD	relative percent difference
%RSD	percent relative standard deviation
TGA	thermogravimetric analysis
TIC	total inorganic carbon
TOC	total organic carbon

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1.0 Introduction

Twenty of the 177 underground storage tanks at the U. S. Department of Energy's Hanford Site that contain high-level radioactive wastes have been identified as tanks that contain wastes that originally included or are suspected of containing potentially reactive combinations of organics and oxidants. Because these potentially hazardous chemical reactions could release radioactive materials to the environment, the following 20 tanks have been placed on the Organic Tanks Watch List (Hanlon 1997) to ensure that special precautions and controls are used for all activities involving the tanks and the wastes stored in these tanks:

241-A-101	241-S-102	241-TX-105	241-U-106
241-AX-102	241-S-111	241-TX-118	241-U-107
241-B-103	241-SX-103	241-TY-104	241-U-111
241-C-102	241-SX-106	241-U-103	241-U-203
241-C-103	241-T-111	241-U-105	241-U-204

Note: Waste storage tanks will be referred to hereafter without the 241- prefix.

Several interrelated factors control the potential for and the consequences of hazardous chemical reactions between the organics and the oxidants nitrate and nitrite in the Hanford Site's stored radioactive wastes. These factors include the identities and concentrations of the organic fuel(s), the identities and concentrations of the oxidant(s), and the heat-absorption and heat-transfer properties of the waste, the tank, and its surrounding environment.

Water's heat-absorption and heat-transfer properties make it one of the primary common waste components that control whether hazardous self-sustaining reactions (Scheele et al. 1995) or propagating reactions (Fauske et al. 1995) can occur in an organic-bearing waste (Burger 1995; Fauske et al. 1995). Fauske et al. found that mixtures of organics and nitrate and/or nitrite would not support a propagating reaction if the water content exceeded 20 wt%. The lower the water content, the greater the potential that energetic and vigorous reactions can occur. Because of water's efficiency for preventing propagating reactions, Webb et al. (1995) used water content as one of the bases for the criteria used to assess the potential chemical reactivity hazard of a Hanford Site's stored waste. These criteria are based on 1) water content alone, 2) a combination of water content and total organic carbon (TOC), or 3) a combination of water content and reaction energetics.

Applying the Webb et al. criteria classifies wastes into the three waste safety categories of "Safe," "Conditionally Safe," and "Unsafe." For a waste to be classified as Safe, not even minimal control of tank configuration is required to maintain the water content at or above 20 wt% or to satisfy the energetics or TOC criteria (Webb et al. 1995). If minimal controls are required to maintain the waste in a condition that satisfies the criteria, then the waste is classified as Conditionally Safe. If the waste does not satisfy the criteria, the waste is classified as Unsafe in its current condition.

Because of water's importance in determining the hazard level of an organic-bearing waste (Webb et al. 1995; Hunter et al. 1997), it is important to understand the factors that control the water content in the waste and whether it is necessary to actively control any of these factors to continue to ensure safe storage

or to mitigate a future Unsafe situation. Several factors control the waste's water content, including the water partial pressure (P_{H_2O}) in the tank's headspace, the temperature of the waste, the temperature of the surrounding soil, the exchange rate of air within the tank with the outside air, the outside air's P_{H_2O} , and the strength of the chemical bond(s) between the waste and the retained water. For example, higher water contents will occur at higher water partial pressures and at lower waste temperatures. Lower water contents will occur at low water partial pressures and higher waste temperatures. In the long term, if the storage system is allowed to reach equilibrium with the ambient arid Hanford environment, the waste's water content will be determined by the P_{H_2O} in the tank's head space, which will be equivalent to the ambient Hanford P_{H_2O} shown in Figure 1.1.

Figure 1.1. Average Hanford Monthly P_{H_2O} 1980 to 1995 (Data Provided by K. W. Burk of PNNL's Meteorological Group)

In 1996, we adapted and demonstrated a method to determine the effect of P_{H_2O} on the equilibrium water content of Hanford's stored radioactive wastes, providing a means to predict a waste's future safety status or category. We built on established methods to measure water potential in materials such as described by Campbell and Gee (1986) or used by Armstrong, Freeman, and Kovach (Postma et al. 1994). These studies were done as part of Pacific Northwest National Laboratory's (PNNL's) Organic Tank Safety Project. As a result of the early development and demonstration effort, we determined the effect of P_{H_2O} on selected potential waste components, surrogate waste mixtures made of those components, a simulated Hanford waste, and waste from T-111 (Scheele, Bredt, and Sell 1996). Studies continued in 1997 on wastes from BY-108, U-105, U-107, S-102, A-101, A-102, and BY-110 (Scheele, Bredt, and Sell 1997a; 1997b; 1997c).

Our earlier studies showed that the water content of Hanford wastes will depend on the individual waste components' identities and concentrations, temperature, and P_{H_2O} . Before these studies and the development effort, little was known about the response of actual Hanford wastes and their major components to P_{H_2O} , nor did the capability exist to measure accurately the effect of water partial pressures on the water content of radioactive Hanford wastes; Armstrong, Freeman, and Kovach (Postma et al. 1994) studied the response of simulated ferrocyanide wastes to different water vapor pressures at 25°C.

In continuing support of the Duke Engineering and Services Hanford (DESH) effort to ensure continued safe storage of Hanford's organic-bearing radioactive wastes, we at PNNL investigated the effect of P_{H_2O} on the equilibrium water content of waste samples obtained from Organic Watch List Tanks. We also included wastes suspected by D. A. Reynolds of Lockheed Martin Hanford of having significant organic content or wastes characteristic of organic-bearing wastes. This report provides the following data for A-101, A-102, AX-102, C-104, and U-106:

- historical information on the types of Hanford wastes present in the tanks
- the measured chemical compositions of the waste samples tested
- existing temperatures and water partial pressures in these tanks
- the effect of P_{H_2O} on the equilibrium water content of tested waste samples
- discussions on the effect of chemical compositions on the equilibrium water contents
- comparisons of the measured P_{H_2O} in the tanks' headspace and the expected P_{H_2O} based on our results.

2.0 Experimental Approach and Method

We used several experimental methods and procedures to measure selected physical properties and the effect of P_{H_2O} on the equilibrium water content of selected and available Hanford wastes. The physical properties were measured to support moisture-modeling studies of Hanford organic-bearing wastes (Simmons 1996; Simmons et al. 1997). This section describes the methods used to measure the equilibrium water content of these highly radioactive wastes and various physical properties related to water behavior, such as density. The studies to determine equilibrium moisture content and to measure selected physical properties were performed using a Work Plan,¹ satisfying requirements provided by the *Hanford Analytical Services Quality Assurance Requirements Document* (HASQARD) (DOE/RL 1997).

2.1 Determination of Equilibrium Moisture Content

We used the adapted experimental approach and procedure¹ described in an earlier report (Scheele, Bredt, and Sell 1996) to measure the equilibrium water content of Hanford waste samples when exposed to a range of water partial pressures. In this approach, waste samples were exposed to known water partial pressures at the tank's reported maximum surface temperature, and their mass was monitored until stabilized or appeared to be approaching a stable water content. The water partial pressures encompassed or were near the minimum P_{H_2O} observed at the Hanford Site between 1985 and 1995, 3.5 torr (see Figure 1.1), and the higher water partial pressures that may exist in the tank. The temperatures are from tank characterization reports, the tank characterization database, or from Hanlon's summary reports on the status of Hanford tank wastes (Hanlon 1996; 1997).

To determine the equilibrium water content of a waste, nominal 1-g aliquots of waste were exposed to a P_{H_2O} controlled by a saturated salt solution, and the samples' masses were monitored until they stabilized. The water content was determined by drying the samples at 105°C to a stable mass as well as using thermogravimetric analysis (TGA) for selected samples. The procedure is as follows:

1. Duplicate 1-g samples are placed in 20-mL glass vials and then placed in 500-mL sealed plastic jar (desiccator sans desiccant) containing saturated solutions to control the P_{H_2O} at particular levels. They are then placed in a constant-temperature oven. The salts selectively used in the saturated solutions to control P_{H_2O} were reagent grade KOH, NaOH, $CaCl_2$, $CaBr_2$, $MgCl_2$, NaBr, NaI, KCl, KNO_3 , and/or $NaNO_3$. A schematic of this system is shown in Figure 2.1.
2. The samples' masses are monitored frequently at first, with the frequency lessening to weekly intervals until the mass appears to be stabilizing. The experiment concludes when the mass change is less than 3 mg for a 3-day interval.
3. Once the masses have stabilized, samples exposed to the highest P_{H_2O} and the lowest P_{H_2O} are exchanged to investigate the reversibility of the water absorption and desorption. The samples' masses are monitored again until they stabilize, based on the same criteria used before. Subsamples are then taken from the highest P_{H_2O} and the lowest P_{H_2O} for TGA.

¹ Scheele, R. D. 1997. *Organic Tank Safety Project: Equilibrium Moisture Determination Subtask Fiscal Year 1998 Work Plan*, TWS98.10.

4. The final equilibrium water contents are determined gravimetrically by drying at 105°C to a stable mass, and TGA is repeated on 105°C dried subsamples taken from the highest P_{H_2O} and the lowest P_{H_2O} .

The temperatures and the water partial pressures used for the different waste samples are presented in Table 2.1. Saturated salt solutions of NaOH, $CaCl_2$, NaBr, KCl, and KNO_3 controlled the water partial pressures for the A-101, A-102, and BY-110 experiments. $MgCl_2$ was used instead of KCl for the U-106 testing and was added for the C-104 testing to improve low P_{H_2O} data. Scheele, Bredt, and Sell (1996) or Lide (1993) provide P_{H_2O} as a function of temperature for these saturated salt solutions. For the AX-102 experiments, we used KOH, $CaCl_2$, $CaBr_2$, NaI, KNO_3 , and $NaNO_3$ solutions. The water partial pressures for KOH, $CaBr_2$, NaI, and $NaNO_3$ at 26°C were measured using the same method provided by Scheele, Bredt, and Sell (1996), and the water partial pressures at 23°C are based on Lide (1993). The temperatures in the experiments ranged from 26 to 41°C (PNNL 1997). In some tanks, the maximum temperature in some locations within the waste is significantly higher than the surface waste's temperature; e.g., A-101 has a maximum waste temperature of 65°C deep in the waste. With time, the tank waste temperatures will decline because the heat-producing radionuclides are decaying, causing increasing equilibrium moisture contents at equivalent water vapor pressures.

Figure 2.1. Constant Humidity Experimental Apparatus

Table 2.1. Experimental Test Conditions

Tank	Temperature, °C	Water Partial Pressures, torr	Temperature, °C	Water Partial Pressures, torr
A-101	41	3.5, 11, 30, 44, 48	23	6, 12, 18
A-102	32	2, 8, 20, 30, 32	23	6, 12, 18
AX-102	30	2, 4, 7, 9, 14, 18, 20	23	6, 12, 18
BY-110	35	3, 9, 23, 34, 37	23	6, 12, 18
C-104	36	3.5, 11, 30, 44, 48	23	6, 7, 12
U-106	27	2, 7.5, 8, 16, 24	23	6, 7, 12

The effect of declining waste temperatures and the corresponding effect of P_{H_2O} on the equilibrium water content can be estimated using the results of our testing and the Clausius–Clapeyron relationship presented in Equation 2.1. In the equation, ΔH_v is the heat of vaporization, P_1° is the equilibrium vapor pressure at temperature 1, P_2° is the equilibrium vapor pressure at temperature 2, R is the gas constant, and T is temperature in Kelvin.

$$\ln \frac{P_2^\circ}{P_1^\circ} = \frac{\Delta H_v}{R} \left(\frac{1}{T_1} - \frac{1}{T_2} \right) \quad (2.1)$$

To provide some information on temperature effects, when the waste samples exposed to the intermediate water partial pressures reached equilibrium, we removed them from the elevated temperature oven and continued the experiments at room temperature (nominally 23°C). We did not monitor these samples' masses until the hysteresis experiments neared completion. Then we began monitoring their masses to ensure that they had reached equilibrium. The test conditions for these supplemental experiments are provided in Table 2.1. These experiments provide a limited data set to estimate the effects of temperature and P_{H_2O} on the equilibrium water content of these tested wastes.

In the absence of empirical information on the effects of temperature and P_{H_2O} for a particular waste on ΔH_v , a first estimate of temperature effects for a particular waste-moisture could be calculated using the results of single temperature studies, the Clausius–Clapeyron equation, and the ΔH_v for pure water, 43.6 kJ/mole. It must be assumed that ΔH_v is constant as a function of temperature for all combinations of waste and moisture. This assumption is probably not true since the number of phases could change as both the temperature and the nature of water's interaction with the waste and other water in the waste change. Alternatively, Moyers and Baldwin (Perry and Green 1997) report that between 15°C and 50°C equilibrium water content remains constant at constant relative humidity (RH).

2.2 Determination of Physical Properties

We measured selected physical properties of these wastes using PNNL's analytical chemistry laboratory's procedure *PNNL-ALO-501, Laboratory Procedure for Measurement of Physical and Rheological Properties of Solutions, Slurries, and Sludges* consistent with our HASQARD-compliant work plan¹. To determine the density of the as-received material, centrifuged solids density, supernate density, the wt% and vol% centrifuged solids, the wt% solids in the as-received material, the wt% solids in the centrifuged solids, and the wt% dissolved solids in the supernate, a nominal 1-g sample was first centrifuged 1 h at about 1900 gravities in a graduated centrifuge cone. The mass and volume of the

centrifuged solids and supernate were determined by weighing duplicate samples before and after the supernate was decanted. The centrifuged solids and the supernate were air dried at room temperature until sufficient water had evaporated to prevent splattering and loss of sample during drying at 105°C. The wt% and vol% interstitial solution are calculated values based on the assumption that the water in the sample is an interstitial solution having the composition of the recovered supernate or the supernate in the tank.

All of the waste's physical properties are calculated from measured masses and volumes. The density of the as-received sample equals the total mass divided by the total volume after centrifuging; in all cases, the volumes did not change measurably when centrifuged. The densities of the centrifuged solids and centrifuged supernate equals the respective masses of the centrifuged solids or centrifuged supernate divided by their respective volumes. We calculated the vol% and wt% centrifuged solids by dividing the respective volume or mass of the centrifuged solids by the total volume or mass of the centrifuged sample. The wt% solids (dry basis) or wt% dissolved solids in the centrifuged solids and supernate is the mass of the dried solids divided by the mass of the undried centrifuged solids or supernate, respectively. Because we had a very limited amount of sample, we calculated the wt% solids in the as-received material by multiplying the wt% solids in the centrifuged solids by the wt% centrifuged solids and added the product of the wt% centrifuged supernate and wt% dissolved solids. The physical properties were determined consistent with HASQARD.

The wt% and vol% of interstitial solution are derived properties calculated using the measured water content, the dissolved solids content in the supernate, and the densities of the as-received solids and the supernates. The wt% interstitial solution is calculated by adding the wt% water in the as-received material to the wt% solids associated with that water, assuming the water is in the as-received solids as interstitial solution. The vol% interstitial solution is calculated by multiplying the wt% interstitial solution by the ratio of the solids density and supernate (interstitial solution) density. These two properties are provided to provide the reader with some insight into the nature of the liquid and solids in the waste and were not derived using HASQARD-compliant procedures.

3.0 Background Information on Tanks and Their Wastes

The equilibrium water content of Hanford's organic-bearing wastes at a particular P_{H_2O} will be controlled by temperature, the chemical composition, and several physical factors, such as the ability of water to migrate through waste and other factors beyond the scope of this work. Our work focused on empirically determining the response of selected Hanford wastes to the range of water partial pressures that the organic-bearing wastes may be exposed to during storage and supplying physical properties for C.S. Simmons efforts to model water behavior in wastes.

Fauske et al. (1995) and this laboratory (Scheele, Bredt, and Sell 1996) demonstrated the importance of chemical composition and temperature. These studies demonstrated that the equilibrium water content of a waste or compound-water mixture at different water partial pressures depends on the chemical composition. Both Fauske et al. and our laboratory found sodium hydroxide to be quite hydrophilic and sodium nitrate and/or nitrite to sorb water only at very high (>70%) relative humidities. Mixtures of potential waste constituents exhibited the qualitative behavior of the primary constituent; however, the mixture behaved as a blend of the ingredients, as would be expected. The chemical composition of the stored wastes depends on the processes that produced the wastes and any additional processing that the waste encountered during its lifetime. As Scheele, Sobolik, Sell, and Burger (1995) and Agnew (1997) discuss, strontium removal from Plutonium Uranium Extraction (PUREX) wastes produced most of the Hanford organic-bearing wastes.

This section provides the reader with some of the key background information necessary to understand the response of the tested Hanford wastes to different water partial pressures. The background information provided in this section includes 1) a brief history of the wastes stored in the tanks, 2) the temperatures and water partial pressures found in the tanks, 3) the history of the sampling event that yielded the samples studied, and 4) the major measured chemical constituents found in the wastes studied. It should be noted that for all but one waste studied, the hydroxide content was unmeasured.

3.1 Background Information on A-101 and its Wastes

The single-shell Tank A-101 is listed on both the "Hydrogen Tank" and the "Organic Tank" Watch Lists. Tank A-101 was added first to the Hydrogen Tank Watch List in January 1991 and later to the Organic Watch List Tanks in May 1994 (Hanlon 1997). The waste has been partially interim stabilized. The tank is passively ventilated (Field, Place, and Cromar 1997).

Tank A-101, which was constructed during 1954 and 1955, is a concrete tank with a primary mild steel liner. Tank A-101 has a 3785-kL capacity, a diameter of 23 m, and an operating depth of 9.5 m. The tank has a flat bottom. Tank A-101 was the first tank in a cascade of four tanks where overflow wastes from A-101 could flow into A-102, then A-103, and then A-106. The overflow line is approximately 4.9 m from the bottom of the tank. The tank was designed to store self-boiling waste with a maximum temperature of 121°C (250°F) (Field, Place, and Cromar 1997). See Field, Place, and Cromar's report (1997) for detailed drawings of A-101's configuration.

Tank A-101 became operational in the first quarter of 1956 when it received PUREX organic wash waste and was used until November 1980 when it last received residual waste from the 81-1 evaporator

campaign and was removed from service. Tank A-101 contains 3607 kL of waste. Two types of solid wastes are stored in A-101. The uppermost waste consists of 3596 kL of 242-A evaporator waste, and the bottom waste is a layer of 10 kL PUREX high-level waste. Hanlon (1997) reports that A-101 contains no supernate in the tank; however, it does contain 1560 kL of drainable (interstitial) liquid. Agnew (1997) provides compositions and descriptions of these waste types. During its lifetime, A-101 received PUREX organic wash waste, PUREX high-level and low-level wastes, evaporator flush water and dilute feed for the evaporators, flush water from miscellaneous sources, strontium recovery waste, and evaporator wastes.

3.1.1 A-101 Temperatures and P_{H_2O}

The one operable thermocouple tree of the three thermocouple trees in A-101 is located in Riser 12 and measures temperatures at 18 different heights (Field, Place, and Cromar 1997). Riser 12 is located approximately 4 m north of the southernmost edge of the tank. Based on the surface data provided in the supporting documents provided by Consort et al. (1996a), thermocouples 1 through 16 should be in the waste and thermocouples 17 and 18 in the tank's headspace. Thermocouple 15 is at 803 cm, and thermocouple 16 is at 863 cm, about 6 cm below the reported surface of the waste.

Between June 1987 and June 1997, temperatures in Tank A-101 waste solids ranged from 70 to 26°C, depending on depth and season. Temperatures varied seasonally with maximum temperatures occurring in October to November and the minimum temperatures occurring in March and April. The variability in temperature is less at the lower depths. Thermocouple 16, the uppermost thermocouple in the waste, measured temperatures ranging from 26 to 42°C.

The temperatures in A-101's vapor space ranged from 30 to 40°C between March 1988 and June 1997 with temperatures again depending on the season, but in general independent of location. Tank A-101 is passively ventilated with no active circulation of vapor.

The observed P_{H_2O} in A-101's headspace on June 8, 1995, was 25 torr at a headspace temperature of 35°C (Huckaby and Bratzel 1995). This P_{H_2O} corresponds to an RH of 60% at 35°C.

3.1.2 A-101 Core Sampling Events

Two nineteen-segment core samples were collected from A-101 in July 1996 using the push mode sampling truck (Field, Place, and Cromar 1997). These core samples are referred to as Core 154 and Core 156. Core 154 was taken from Riser 15 located in the SE quadrant of the tank, nominally 8 m from the center of the tank and 3.5 m from the outside wall, assuming that Field, Place, and Cromar's (1997) tank schematic is roughly to scale. Core 156 was taken through Riser 24 located an estimated 1.5 m from the westernmost wall and 9 m from the center of the tank. The 222-S laboratory analyzed both cores.

As Field, Place, and Cromar (1997) report, both core samples obtained nineteen segments, recovering 94% of the expected recovery. A full segment is 48 cm in length. Segments are numbered starting from the top of the waste, so Segment 1 will contain material from the uppermost layer of the waste.

Segment 1 of Core 154 recovered 28 cm of yellowish-brown solids. The upper half (U) of Core 154 Segment 1 recovered 13 cm resembling a dry salt. The lower half (L) of Segment 1 was 15 cm of a moist

salt. Segments 2 through 9 were dark-gray moist solids. Segment 10 yielded a light-gray salt slurry and about 5 mL of a yellow liquid. Segment 11 contained only the hydraulic head fluid. Segments 13 through 16 and Segments 18 and 19 yielded principally an opaque yellow liquid and small amounts of a white salt slurry. Segment 17 was primarily an opaque white liquid with a very small amount of white solids. PNNL studied the behavior of the Segment 1U and Segment 1L.

The uppermost sample obtained by Core 156, Segment 1L, recovered 3 cm of green-brown solids and 5 mL of a green-brown opaque liquid. Segments 2 through 8 recovered moist dark gray salt solids. Segment 10 yielded 18 cm of a white-to-gray salt slurry and 110 mL of a yellow opaque liquid. Segments 11 and 14 contained a white salt slurry and a yellow opaque liquid. Segments 12, 13, and 15 through 19 recovered white solids and an opaque green liquid. PNNL studied the drainable liquid from Segment 14.

3.1.3 Composition of Tested A-101 Waste

Table 3.1 provides the concentrations on a weight and molar basis of the major chemical constituents measured as reported by the Hanford Tank Waste Characterization Program for the wet samples that we tested (Field, Place, and Cromar 1997). Table 3.2 provides the concentrations on a dry basis. Sodium hydroxide, a significant hydrophilic typical waste constituent, was not measured.

As shown in Table 3.1 and Table 3.2, the principle ($>1000 \mu\text{mol/g dry}$) elements, anions, and other measured constituents, excluding water, in the supernate sample are aluminum, sodium, hydroxide, nitrate, and nitrite. Minor constituents include potassium, chloride, sulfur primarily as sulfate, organic carbon including oxalate, and inorganic carbon (likely carbonate assuming a $\text{pH} > 10$); the nearly identical phosphate and phosphorous concentrations indicate that in the supernate, phosphorous is present as phosphate. The supernate is 53 wt% water (Jo 1996).

Table 3.1 and Table 3.2 show that the principle ($>1000 \mu\text{mol/g dry}$) elements, anions, and other measured constituents, excluding water, in the two Segment 1 solid samples tested are sodium, nitrate, nitrite, aluminum, and total inorganic carbon (TIC); significant potassium is also in the 1L sample. Other analytes above $100 \mu\text{mol/g dry}$ are potassium for the 1U sample, sulfate, chloride, and TOC, including oxalate. The Segment 1U and 1L solids contained 29 and 32 wt% water, respectively (Field, Place, and Cromar 1997).

The principle waste constituents in the drainable liquid (DL) sample obtained by Core 156 Segment 14 are similar to those found in the two solid samples with the exception of TIC. The lesser constituents are nearly the same with the exception that no oxalate was found in the DL. The water content in the Core 156 Segment 14DL was 53 wt%.

3.2 Background Information on A-102 and its Wastes

The single-shell tank A-102 is not listed on any watch list; however, D. A. Reynolds of Lockheed Martin Hanford identified A-102 as a tank likely to contain a high concentration of organics. D. A. Reynolds' evaluation is borne out by the 2.2 wt% TOC measured on a dry basis for the auger sample (Jo 1996). A-102 has been interim stabilized with the drainable liquid removed from the waste (Jo 1996). The tank is passively ventilated (Jo 1996).