OPERABLE UNIT 4 TREATABILITY STUDY WORK PLAN FOR THE VITRIFICATION OF RESIDUES FROM SILOS 1, 2, AND 3 APPENDIX D PROCEDURES AND METHODS REVISED APRIL 1992

4-24-92

ENCLOSURE
OPERABLE UNIT 4
TREATABILITY STUDY WORK PLAN
FOR THE VITRIFICATION OF RESIDUES
FROM SILOS 1, 2 AND 3

APPENDIX D

PROCEDURES AND METHODS

REVISED
APRIL 1992
I. INTRODUCTION

The following describes the procedures which will be used in support of the treatability study for the vitrification of operable unit 4 wastes. This information is provided to allow the quality of the data generated to be evaluated. The following sections discuss the test instruments and calibration, the test apparatus, and the procedures for measuring the physical properties of both untreated and treated waste, radon emanation of the treated and untreated wastes, radon emanation during vitrification, gamma dose rate from the vitrified material, and the modified TCLP for metals.

The determination of the physical properties (moisture content, density, specific gravity) will be carried out on three samples from each sample group received by PNL. A sample group is defined as the set of cans containing material from the same location (i.e., Silo 2 Zone B). The material from each sampling location was shipped in anywhere from 8 to 24 containers. Radon emanation and gamma dose rates will be monitored continuously and will not require replication. TCLP will be performed on a single sample from a given test run. All work performed in this study will be done in accordance with NQA-1 Impact Level 2 as detailed in the treatability study work plan.

II. TEST INSTRUMENTATION AND CALIBRATION

Following is a list of the instruments to be used for these tests:

- Mettler BB240 - Electronic balance with 240 g capacity, 0.001 g readability with ±0.002 g linearity.

- Mettler PJ6000 - Electronic balance with 6000 g capacity, 0.1 g readability with ±0.1 g linearity.

- Mettler LJ16 - Moisture analyzer with 300 g capacity, scale readability of 0.001 g, moisture analysis readability of 0.01% (0.1% for sample < 10g) and reproducibility of result of 0.03% (0.3% for sample < 10g).

- Eberline RGM-3 Radon Gas Monitor - Calibrated to an accuracy of ±5% from background up to a maximum concentration of 10^6 pCi/L.

- Pylon AB-5 Portable Radon Monitor with Pylon Model 300A Lucas Cell - The 300A cell has an accuracy of 0.3% at 50,000 cps (about 36,000 pCi/L), while the AB-5 monitor has an accuracy of 0.3% at 1,000,000 cps.

- Hanford Cutie Pie (CP) - A portable, air-filled ionization chamber ratemeter for measuring gamma dose rate. Four linear ranges of operation (0-5, 0-50, 0-500, 0-5000 mR/hr) with a linearity of ±5% of full-scale.

- Dwyer Ratemaster Rotameters - Various sizes, with a ±5% accuracy.
Calibration of the balances, moisture analyzer, rotameters, and Hanford CP are performed by the on-site Westinghouse or PNL calibration services, while the radon monitors were calibrated by the manufacturers at their calibration labs. Calibration is consistent with the QA/QC requirements of the project.

III. TEST APPARATUS

Physical properties measurements will be performed in a laboratory hood using standard laboratory glassware and the balances listed previously. Description of the procedures are provided below.

Vitrification and radon emanation measurements will be performed in the system shown in Figure 1. The control and electrical systems power silicon carbide heaters which heat the furnace to as high as 1500 °C, melting the sample in a refractory crucible. Radon from the waste is carried away by air which is continually drawn through the system by internal pumps in the radon monitors. The air is filtered to remove ambient radon before being drawn through the furnace. The off-gas (air sweep plus radon and other gases generated during vitrification) passes out of the furnace directly into a shell and tube heat exchanger where it is cooled, condensing out moisture present in the waste or generated during vitrification. The off-gas is then heated to a maximum of 50 °C before entering the radon monitors in order to prevent condensation in the monitoring cell. The off-gas passes through the monitors, through rotameters, and is vented to the hood.

Besides allowing monitoring of the off-gas during vitrification, the system also provides the ability to monitor the radon emanation from a sample of waste (treated or untreated). This monitoring system is isolated from the off-gas monitoring and can be carried out at any time, even during a vitrification run. The sample is placed inside the sealed, sample monitoring chamber and filtered air is again drawn into the vessel by the monitor's internal pump. Radon generated in the waste is carried away by the constant flow of air, the concentration is measured by the monitor, and the air stream is vented to the hood.
The moisture analysis is automatically carried out by the Mettler U16. The sample to be measured is placed in a tared, aluminum drying pan and heated by infrared radiation at a user-defined temperature (up to 160°C). The analyzer measures the weight loss and calculates and displays the percent moisture of the sample (mass lost divided by the original sample mass times 100%). It is believed, however, that some loss of moisture has occurred from the samples during shipping and storage. To quantify the loss previous to the moisture analysis, the original moisture content will be estimated based on the current total sample weight compared to the initial sample weight as recorded on the original container. This value will provide an upper bound for the moisture content, while the measured value from the moisture analyzer will give a lower bound. The sample size specified for this procedure (30 - 40 g) is fixed by the amount of dry material required for the bulk and apparent density measurements; the moisture analysis only requires a few grams or less.

**Procedure**

1. Turn on the moisture analyzer and verify that the appropriate settings have been made. These settings are infinite drying time, 160°C drying temperature, and the calculation mode set to percent moisture.

2. Measure and record the mass of a sample can, contents, and lid.

3. Tare the moisture analyzer. Place an aluminum drying pan in the moisture analyzer and record its mass. Re-tare the moisture analyzer.

4. Open the sample can and thoroughly mix the sample until the moisture content appears to be uniform. Evenly distribute about 30 to 40 g of sample into the aluminum pan. Record the mass of the sample portion added.

5. Close the lid of the moisture analyzer and press the START key.

6. Set the display to show weight loss. Allow the sample portion to dry until the observed change in mass is less than 0.001 g/min. Record the measured weight loss and the calculated percent moisture.

7. Set the dried sample portion aside for use in dry density measurements.

**Calculations**

\[
\text{% moisture in sample (calculated by the analyzer)} = 100\% \times \frac{\Delta m}{m_i} \quad (1)
\]

where:

- \( \Delta m \) = weight loss of sample portion
- \( m_i \) = initial mass of sample portion
% moisture loss in storage = 100% * (mtot - mtot) / mtot \[ (2) \]

where:

mtot = current mass of the sample (mass of can, contents, lid minus mass of can)

mtot, = mass of the sample measured when it was first packaged

% moisture actual (est.) = \[ \left( m_t - (m_t - s_t) \right) \times \left( 1 - \% \text{loss in storage}/100 \right) \] / m_t \[ (3) \]
The bulk density can be measured in several different ways for either the wet or dry material, i.e., uncompacted, compacted, or settled. This procedure will allow measurement of the bulk density for several conditions. The wet material is measured both in the uncompacted and compacted form. The uncompacted density is representative of the material after it is retrieved (i.e., the density as is in the sample container), while the compacted density is more representative of the material in the silos, with void spaces removed. The dry material density is measured as unsettled (uncompacted) or settled for the material both as is (with clumps) and with the clumps broken up. The density most representative of the dry material would depend on the drying method (if it produced a clumpy material or ground up the clumps) and the handling method (whether or not the material settles).

**Procedure**

1. Measure and record the mass of a 50 mL graduated cylinder.

2. Place between 45 and 50 mL of wet solid from the sample can into the graduated cylinder. Measure and record the mass of the cylinder and sample.

3. Tap the cylinder three times on the table top and record the observed volume of material.

4. Pack and compact the sample in the cylinder, breaking up clumps and voids in the material. A piece of metal rod is useful for this. When the sample is compacted and void spaces eliminated (as much as possible), measure and record the observed volume of compacted material.

5. Measure and record the mass of another 50 mL graduated cylinder.

6. Take the sample which was dried in the moisture analysis (about 20 - 30 g dry) and break up any large clumps so that the largest chunks are about 2 to 4 mm in diameter.

7. Place the sample in the cylinder and measure the mass of the cylinder with added sample.

8. Tap the cylinder three times and record the initial volume of material. Then, tap the cylinder on the table-top until no further settling is observed. Record the volume of settled material.

9. Remove the material from the cylinder and crush all clumps until the material is fairly powdery. Then repeat steps 7 and 8 for the crushed material. When finished, set the material aside for use in the determination of apparent density.
For all of the above measurements, the density is calculated as follows:

\[
\text{bulk density} = \frac{m}{V}
\]

where:

- \( m \) = mass of the sample (wet, dry, crushed dry) in the cylinder
- \( V \) = measured volume of the sample (initial, compacted, settled)
APPARENT DENSITY

The apparent density (or specific gravity) is the actual density of the particles of material. To measure the apparent density, the volume actually occupied by the solid material must be determined (as opposed to the interstitial volume between the particles). This method is different for the untreated waste (finely divided particles) versus the vitrified waste (large, solid pieces).

The apparent density of the untreated waste is measured by intimately mixing a portion of the solid with water in a flask whose volume is known very precisely. The mass of water can be measured through weighing and converted to a volume if the temperature of the water is known. Since the volume of the flask is known, the volume occupied by the solid can be obtained by difference. Knowing the mass of solid in the flask then allows calculation of the apparent density.

The apparent density of the vitrified waste is determined by measuring the buoyant force exerted on a sample of the vitrified residue. The buoyant force allows the mass, and thereby the volume, of water displaced to be calculated. The volume of water displaced is equal to the volume of the sample, and the density can then be calculated.

Procedure - Untreated

1. Measure and record the mass of an empty 100 mL volumetric flask (ASTM class A ±0.08 mL).

2. Add the dry sample which remains from the bulk density determinations (about 20 - 30 g dry) and measure and record the mass of the flask plus sample.

3. Fill the flask with water to the volumetric mark. This should be done by filling the flask partially with distilled water and swirling until the material is completely wet, then filling the remainder of the way. If a foam forms on top, then the foam must be removed and the mass of solids removed as part of the foam determined. The mass of solids is determined by drying the foam and determining the mass of the residue. After the foam is removed, add water to the volumetric mark if required. Measure and record the mass of the flask, sample, and water.

4. Measure and record the temperature of the water in the flask. Then discard the material.

Calculation - Untreated

\[
\text{apparent density} = \frac{m_{t} - m_{r} - m_{\text{int}}}{V_{f} - (m_{\text{flw}} - (m_{t} - m_{\text{int}}))/\text{density}}
\]  

(5)

where:

- \(m_{t}\) = mass of empty flask
- \(m_{r}\) = mass of flask and dry sample
- \(m_{\text{flw}}\) = mass of flask, sample, and water
\[ m_{\text{ref}} = \text{mass of sample removed with the foam} \]
\[ \rho = \text{density of water at the measured temperature} \]
\[ V_r = \text{volume of the volumetric flask} \]

**Procedure - Vitrified**

1. Place a 2000 mL beaker about three-fourths full of water on the electronic balance and tare. Suspend a stainless steel mesh basket from a fine wire (or fishing line) with a well defined mark to which the basket can be consistently submerged. Submerge the basket to this mark and tare the scale.

2. Lift the basket out of the water. Keep it over the beaker so any water which drips off the basket remains in the beaker.

3. Place a known mass of vitrified sample (about 50 to 100 g) into the basket. The pieces must be large enough so as to be retained in the basket.

4. Submerge the basket to the same point as step 1. Record the mass; this is the buoyant force.

5. Measure the temperature of the water in the beaker.

**Calculation - Vitrified**

\[
\text{apparent density} = \frac{m_s}{(F_b / \rho)}
\]  

where:
\[ m_s = \text{mass of the vitrified sample submerged} \]
\[ F_b = \text{buoyant force (the mass measured in step 4)} \]
\[ \rho = \text{density of water at the measured temperature} \]

**D. Volume Reduction.**

The volume reduction is calculated from the bulk density of the waste and the apparent density of the glass so there is not a procedure by which it is determined, only a calculation using previously determined densities. The volume reduction can have several values, depending on the initial density on which it is based. The general formula is given below in terms of initial and final densities. The calculated value would be reported along with the specification of the original basis (i.e., wet uncompacted density, dry settled density, etc.)

**Calculation**

\[
\text{volume reduction\%} = 100\% \times (1 - \text{initial density} / \text{final density})
\]
GAMMA DOSE RATE OF VITRIFIED WASTE

The gamma dose rate will be measured directly from the crucible containing the vitrified waste using the Hanford CP. Measurements will be taken along the axis of the cylindrical block of vitrified waste at contact with the crucible bottom and 6", 12", and 24" from the bottom of the crucible. The CP instrument will be operated, and all appropriate corrections to the measured dose rate made, as detailed in PNL-MA-562 Section CP.

Procedure

1. Measure the background dose rate using the CP at the location where the measurements are to be made. This location should be away from the hood, sample storage, and other sources of radiation which would lead to a high background reading. The background reading should be taken just before each measurement on the vitrified waste.

2. When the crucible has cooled after vitrification (about 24 hrs), remove the crucible to the measurement location.

3. Place the window of the CP in contact with the bottom of the crucible with the axis of the crucible in line with the axis of the ionization chamber. Record the dose rate.

4. Repeat step 3 with the CP window at distances of 6", 12", and 24" from the bottom of the crucible and record the dose rates.

Calculation

The CP reads the dose rate directly (mR/hr). The only calculations required will be to multiply the measured dose rate by appropriate correction factors as detailed in PNL-MA-562. These may include corrections for photon energy dependence, temperature, and source-to-window distance.
RADON EMANATION FROM K-65 WASTE (TREATED AND UNTREATED)

The cross-sectional area of the material in the crucible (or measurement vessel) will be determined by measuring the inside diameter of the vessel at the glass or waste surface (using standard equipment like a ruler or inside micrometer).

Radon emanation from the untreated and vitrified wastes will be measured in the system shown in Figure 1. The sample to be measured will be placed in a can, and the can placed inside the sample monitoring chamber. The internal pump in the monitor will draw air through the sample chamber and into the monitor at a constant flow rate until a steady-state concentration is reached. The air inlet is filtered through a charcoal filter to remove ambient radon. Knowing the air flowrate and the concentration of radon in the gas stream the radon emanation rate can be calculated.

Radon emanation from the untreated waste will be measured using the Eberline RGM-3 radon monitor which operates at a flowrate of approximately 8 Lpm. The steady-state concentration under these conditions is estimated to be about 3,000 pCi/L. Since the vitrified residue has a much lower emanation rate, it is necessary to use a lower flowrate when monitoring the glass. This is accomplished with the Pylon AB-5 monitor which will operate at about 0.1 Lpm. The resulting steady-state radon concentration over the glass at this flow rate is estimated to be about 10 pCi/L. The vitrified residue will be monitored both 7 and 30 days after completion of vitrification.

Procedure

1. Open valves BV1 and BV7 and close valve BV2 and AV1. Flush the radon monitor with clean air and measure the background counts due to the plateout of radon daughters in the sample monitoring cell according to the manufacturer supplied operating instructions.

2. Place a known mass (100 to 200 g) of untreated or vitrified residue into a sample can of known diameter (hence, known cross-sectional area). Distribute the material evenly in the can.

3. Place the sample can into the sample monitoring chamber and seal the lid. Open valve BV2 and AV1 and close valve BV1.

4. Set the monitor so that the data collected is output to the printer as it is generated. Start the monitor and record the flow rate in the system. Monitor the radon levels until the concentration reaches a steady state.

5. Remove the sample from the monitoring chamber and measure the background again to verify that it has not shifted during the course of the measurements.
Calculations

radon emanation (pCi/m²/hr) = \( C \times \frac{Q}{A_{rx}} \)  
\( (8) \)

radon emanation (pCi/kg/hr) = \( C \times \frac{Q}{m_s} \)  
\( (9) \)

where:

\( C \) = measured concentration in pCi/L
\( Q \) = measured flowrate in L/hr
\( A_{rx} \) = cross sectional area or the sample can in m²
\( m_s \) = sample mass in kg
Radon emanation from the K-65 waste during vitrification will be measured using the system shown in Figure 1. The sample is placed in the furnace and heated to the vitrification temperature. During the entire process, ambient air is drawn through the furnace by the internal pumps of the radon monitors. Two monitors are used in parallel to provide redundancy in measurement. Additionally, the Eberline monitor is highly automated and can only provide a value for the average concentration over a one-hour time period; therefore, the Pylon is required to monitor for short duration changes in radon emanation.

The off-gas from the furnace passes through a heat exchanger which cools the gas to about 20°C and condenses moisture out of the gas stream. The off-gas is then preheated to about 37°C before entering the monitors to lower the humidity prior to entering the monitoring cells. The concentration is measured and flow rate is measured at the outlet of the monitors.

The total air flow through the system will be about 8.1 Lpm (8 Lpm through the Eberline and 0.1 Lpm through the Pylon). At this flow rate, the initial emanation from the untreated waste is estimated to yield an off-gas radon concentration of about 3,000 pCi/L. Since the instruments are linear to greater than 30,000 pCi/L, this allows a greater than 10-fold spike to be measured.

**Procedure**

1. Start with all valves closed. Open BV3, BV5, and BV6. Flush the radon monitor with clean air and measure the background counts due to the plateout of radon daughters in the sample monitoring cells. This is done following the operating instructions for the monitors which are supplied by the manufacturers.

2. The monitors should be configured for continuous mode measurements with output to a printer as detailed in the operation manuals for the instruments. The interval length for the Pylon should be set at 5 minutes, while for the Eberline it is fixed at 1 hour.

3. Load the sample into the furnace. Close BV3 and open BV4, AV2, and AV6. This allows filtered air to be drawn through the furnace and on to the monitors.

4. Record the flow rates at the outlet of each monitor and at the inlet to the furnace.

5. Allow the radon concentration in the off-gas to reach steady-state; then carry out the vitrification run according to the test plan.

6. Continue monitoring until the run is finished and the sample is removed from the furnace. Then measure the background again to verify that it has not shifted significantly during the course of the run.
Calculation

Radon emanation (pCi/hr) = concentration (pCi/L) * flow (L/hr)  

This value could also be reported based on some unit of measure as in equations 8 and 9 above.
The modified TCLP (or TCLP for metals only) will be performed by CEP Labs according to the attached procedure (Method 1311). The analysis will require about a 100 g sample of vitrified waste. Metals analyzed for will include arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver.
METHOD 3111
TOXICITY CHARACTERISTIC LEACHING PROCEDURE

1.0 SCOPE AND APPLICATION

1.1 The TCLP is designed to determine the mobility of both organic and inorganic analytes present in liquid, solid, and multiphasic wastes.

1.2 If a total analysis of the waste demonstrates that individual analytes are not present in the waste, or that they are present but at such low concentrations that the appropriate regulatory levels could not possibly be exceeded, the TCLP need not be run.

1.3 If an analysis of any one of the liquid fractions of the TCLP extract indicates that a regulated compound is present at such high concentrations that, even after accounting for dilution from the other fractions of the extract, the concentration would be above the regulatory level for that compound, then the waste is hazardous and it is not necessary to analyze the remaining fractions of the extract.

1.4 If an analysis of extract obtained using a bottle extractor shows that the concentration of any regulated volatile analyte exceeds the regulatory level for that compound, then the waste is hazardous and extraction using the ZHE is not necessary. However, extract from a bottle extractor cannot be used to demonstrate that the concentration of volatile compounds is below the regulatory level.

2.0 SUMMARY OF METHOD

2.1 For liquid wastes (i.e., those containing less than 0.5% dry solid material), the waste, after filtration through a 0.6 to 0.8 \( \mu \)m glass fiber filter, is defined as the TCLP extract.

2.2 For wastes containing greater than or equal to 0.5% solids, the liquid, if any, is separated from the solid phase and stored for later analysis; the particle size of the solid phase is reduced, if necessary. The solid phase is extracted with an amount of extraction fluid equal to 20 times the weight of the solid phase. The extraction fluid employed is a function of the alkalinity of the solid phase of the waste. A special extractor vessel is used when testing for volatile analytes (see Table 1 for a list of volatile compounds). Following extraction, the liquid extract is separated from the solid phase by filtration through a 0.6 to 0.8 \( \mu \)m glass fiber filter.

2.3 If compatible (i.e., multiple phases will not form on combination), the initial liquid phase of the waste is added to the liquid extract, and these are analyzed together. If incompatible, the liquids are analyzed separately and the results are mathematically combined to yield a volume-weighted average concentration.
3.0 INTERFERENCES

3.1 Potential interferences that may be encountered during analysis are discussed in the individual analytical methods.

4.0 APPARATUS AND MATERIALS

4.1 Agitation apparatus: The agitation apparatus must be capable of rotating the extraction vessel in an end-over-end fashion (see Figure 1) at 30 ± 2 rpm. Suitable devices known to EPA are identified in Table 2.

4.2 Extraction Vessels

4.2.1 Zero-Headspace Extraction Vessel (ZHE). This device is for use only when the waste is being tested for the mobility of volatile analytes (i.e., those listed in Table 1). The ZHE (depicted in Figure 2) allows for liquid/solid separation within the device, and effectively precludes headspace. This type of vessel allows for initial liquid/solid separation, extraction, and final extract filtration without opening the vessel (see Section 4.3.1). The vessels shall have an internal volume of 500-600 mL, and be equipped to accommodate a 90-110 mm filter. The devices contain VITON® O-rings which should be replaced frequently. Suitable ZHE devices known to EPA are identified in Table 3.

For the ZHE to be acceptable for use, the piston within the ZHE should be able to be moved with approximately 15 psi or less. If it takes more pressure to move the piston, the O-rings in the device should be replaced. If this does not solve the problem, the ZHE is unacceptable for TCLP analyses and the manufacturer should be contacted.

The ZHE should be checked for leaks after every extraction. If the device contains a built-in pressure gauge, pressurize the device to 50 psi, allow it to stand unattended for 1 hour, and recheck the pressure. If the device does not have a built-in pressure gauge, pressurize the device to 50 psi, submerge it in water, and check for the presence of air bubbles escaping from any of the fittings. If pressure is lost, check all fittings and inspect and replace O-rings, if necessary. Retest the device. If leakage problems cannot be solved, the manufacturer should be contacted.

Some ZHEs use gas pressure to actuate the ZHE piston, while others use mechanical pressure (see Table 3). Whereas the volatiles procedure (see Section 7.3) refers to pounds per square inch (psi), for the mechanically actuated piston, the pressure applied is measured in torque-inch-pounds. Refer to the manufacturer's instructions as to the proper conversion.

4.2.2 Bottle Extraction Vessel. When the waste is being evaluated using the nonvolatile extraction, a jar with sufficient capacity

1 VITON® is a trademark of Du Pont.
to hold the sample and the extraction fluid is needed. Headspace is allowed in this vessel.

The extraction bottles may be constructed from various materials, depending on the analytes to be analyzed and the nature of the waste (see Section 4.3.3). It is recommended that borosilicate glass bottles be used instead of other types of glass, especially when inorganics are of concern. Plastic bottles, other than polytetrafluoroethylene, shall not be used if organics are to be investigated. Bottles are available from a number of laboratory suppliers. When this type of extraction vessel is used, the filtration device discussed in Section 4.3.2 is used for initial liquid/solid separation and final extract filtration.

4.3 Filtration Devices: It is recommended that all filtrations be performed in a hood.

4.3.1 Zero-Headspace Extractor Vessel (ZHE): When the waste is evaluated for volatiles, the zero-headspace extraction vessel described in Section 4.2.1 is used for filtration. The device shall be capable of supporting and keeping in place the glass fiber filter and be able to withstand the pressure needed to accomplish separation (50 psi).

Note: When it is suspected that the glass fiber filter has been ruptured, an in-line glass fiber filter may be used to filter the material within the ZHE.

4.3.2 Filter Holder: When the waste is evaluated for other than volatile analytes, any filter holder capable of supporting a glass fiber filter and able to withstand the pressure needed to accomplish separation may be used. Suitable filter holders range from simple vacuum units to relatively complex systems capable of exerting pressures of up to 50 psi or more. The type of filter holder used depends on the properties of the material to be filtered (see Section 4.3.3). These devices shall have a minimum internal volume of 300 mL and be equipped to accommodate a minimum filter size of 47 mm (filter holders having an internal capacity of 1.5 L or greater, and equipped to accommodate a 142 mm diameter filter, are recommended). Vacuum filtration can only be used for wastes with low solids content (<10%) and for highly granular, liquid-containing wastes. All other types of wastes should be filtered using positive pressure filtration. Suitable filter holders known to EPA are shown in Table 4.

4.3.3 Materials of Construction: Extraction vessels and filtration devices shall be made of inert materials which will not leach or absorb waste components. Glass, polytetrafluoroethylene (PTFE), or type 316 stainless steel equipment may be used when evaluating the mobility of both organic and inorganic components. Devices made of high density polyethylene (HDPE), polypropylene (PP), or polyvinyl chloride (PVC) may be used only when evaluating the mobility of metals. Borosilicate glass bottles are recommended for use over other types of glass bottles, especially when inorganics are analytes of concern.

4.4 Filters: Filters shall be made of borosilicate glass fiber, shall contain no binder materials, and shall have an effective pore size of 0.5 to
0.3 μm, or equivalent. Filters known to EPA which meet these specifications are identified in Table 5. Pre-filters must not be used. When evaluating the mobility of metals, filters shall be acid-washed prior to use by rinsing with 1N nitric acid followed by three consecutive rinses with deionized distilled water (a minimum of 1 L per rinse is recommended). Glass fiber filters are fragile and should be handled with care.

4.5 pH Meters: The meter should be accurate to ± 0.05 units at 25°C.

4.6 ZHE Extract Collection Devices: TEDLAR® bags or glass, stainless steel or PTFE gas-tight syringes are used to collect the initial liquid phase and the final extract of the waste when using the ZHE device. The devices listed are recommended for use under the following conditions:

4.6.1 If a waste contains an aqueous liquid phase or if a waste does not contain a significant amount of nonaqueous liquid (i.e., <1% of total waste), the TEDLAR® bag or a 600 mL syringe should be used to collect and combine the initial liquid and solid extract.

4.6.2 If a waste contains a significant amount of nonaqueous liquid in the initial liquid phase (i.e., >1% of total waste), the syringe or the TEDLAR® bag may be used for both the initial solid/liquid separation and the final extract filtration. However, analysts should use one or the other, not both.

4.6.3 If the waste contains no initial liquid phase (is 100% solid) or has no significant solid phase (is 100% liquid), either the TEDLAR® bag or the syringe may be used. If the syringe is used, discard the first 5 mL of liquid expressed from the device. The remaining aliquots are used for analysis.

4.7 ZHE Extraction Fluid Transfer Devices: Any device capable of transferring the extraction fluid into the ZHE without changing the nature of the extraction fluid is acceptable (e.g., a positive displacement or peristaltic pump, a gas tight syringe, pressure filtration unit (see Section 4.3.2), or other ZHE device).

4.8 Laboratory Balance: Any laboratory balance accurate to within ± 0.01 grams may be used (all weight measurements are to be within ± 0.1 grams).

4.9 Beaker or Erlenmeyer flask, glass, 500 mL.

4.10 Watchglass, appropriate diameter to cover beaker or Erlenmeyer flask.

4.11 Magnetic stirrer.

2 TEDLAR® is a registered trademark of Du Pont.
5.0 REAGENTS

5.1 Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available. Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

5.2 Reagent water. All references to reagent water in this method refer to one of the following, as appropriate:

5.2.1 Inorganic Analytes: Water which is generated by any method which would achieve the performance standards for ASTM Type II water. The analyte(s) of concern must be no higher than the highest of either (1) the detection limit, or (2) five percent of the regulatory level for that analyte, or (3) five percent of the measured concentration in the sample.

5.2.2 Volatile Analytes: Water in which an interferant is not observed at the method detection limit of the compounds of interest. Organic-free water can be generated by passing tap water through a carbon filter bed containing about 1 lb. of activated carbon. A water purification system may be used to generate organic-free deionized water. Organic-free water may also be prepared by boiling water for 15 minutes. Subsequently, while maintaining the temperature at 90°C, bubble a contaminant-free inert gas through the water for 1 hour. The analyte(s) of concern must be no higher than the highest of either (1) the detection limit, or (2) five percent of the regulatory level for that analyte, or (3) five percent of the measured concentration in the sample.

5.2.3 Semivolatile Analytes: Water in which an interferant is not observed at the method detection limit of the compounds of interest. Organic-free water can be generated by passing tap water through a carbon filter bed containing about 1 lb. of activated carbon. A water purification system may be used to generate organic-free deionized water. The analyte(s) of concern must be no higher than the highest of either (1) the detection limit, or (2) five percent of the regulatory level for that analyte, or (3) five percent of the measured concentration in the sample.

5.3 Hydrochloric acid (1N), HCl, made from ACS reagent grade.

5.4 Nitric acid (1N), HNO₃, made from ACS reagent grade.

5.5 Sodium hydroxide (1N), NaOH, made from ACS reagent grade.

5.6 Glacial acetic acid, CH₃CH₂OOH, ACS reagent grade.

5.7 Extraction fluid.

5.7.1 Extraction fluid # 1: Add 5.7 mL glacial CH₃CH₂OOH to 500 mL of reagent water (See Section 5.2), add 64.3 mL of 1N NaOH, and...
dilute to a volume of 1 liter. When correctly prepared, the pH of this fluid will be $4.93 \pm 0.05$.

5.7.2 Extraction fluid #2: Dilute 5.7 mL glacial CH$_3$COOH with reagent water (see Section 5.2) to a volume of 1 liter. When correctly prepared, the pH of this fluid will be $2.28 \pm 0.05$.

Note: These extraction fluids should be monitored frequently for impurities. The pH should be checked prior to use to ensure that these fluids are made up accurately. If impurities are found or the pH is not within the above specifications, the fluid shall be discarded and fresh extraction fluid prepared.

5.8 Analytical standards shall be prepared according to the appropriate analytical method.

6.0 SAMPLE COLLECTION, PRESERVATION, AND HANDLING

6.1 All samples shall be collected using an appropriate sampling plan.

5.2 The TCLP may place requirements on the minimal size of the field sample, depending upon the physical state or states of the waste and the analytes of concern. An aliquot is needed for preliminary evaluation of which extraction fluid is to be used for the nonvolatile analyte extraction procedure. Another aliquot may be needed to actually conduct the nonvolatile extraction (see Section 1.4 concerning the use of this extract for volatile organics). If volatile organics are of concern, another aliquot may be needed. Quality control measures may require additional aliquots. Further, it is always wise to collect more sample just in case something goes wrong with the initial attempt to conduct the test.

6.3 Preservatives shall not be added to samples before extraction.

6.4 Samples may be refrigerated unless refrigeration results in irreversible physical change to the waste. If precipitation occurs, the entire sample (including precipitate) should be extracted.

6.5 When the waste is to be evaluated for volatile analytes, care shall be taken to minimize the loss of volatiles. Samples shall be collected and stored in a manner intended to prevent the loss of volatile analytes (e.g., samples should be collected in Teflon-lined septum capped vials and stored at 4°C. Samples should be opened only immediately prior to extraction).

6.6 TCLP extracts should be prepared for analysis and analyzed as soon as possible following extraction. Extracts or portions of extracts for metallic analyte determinations must be acidified with nitric acid to a pH $< 2$, unless precipitation occurs (see Section 7.2.14 if precipitation occurs). Extracts should be preserved for other analytes according to the guidance given in the individual analysis methods. Extracts or portions of extracts for organic analyte determinations shall not be allowed to come into contact with the atmosphere (i.e., no headspace) to prevent losses. See Section 8.0 (QA requirements) for acceptable sample and extract holding times.
7.0 PROCEDURE

7.1 Preliminary Evaluations

Perform preliminary TCLP evaluations on a minimum 100 gram aliquot of waste. This aliquot may not actually undergo TCLP extraction. These preliminary evaluations include: (1) determination of the percent solids (Section 7.1.1); (2) determination of whether the waste contains insignificant solids and is, therefore, its own extract after filtration (Section 7.1.2); (3) determination of whether the solid portion of the waste requires particle size reduction (Section 7.1.3); and (4) determination of which of the two extraction fluids are to be used for the nonvolatile TCLP extraction of the waste (Section 7.1.4).

7.1.1 Preliminary determination of percent solids: Percent solids is defined as that fraction of a waste sample (as a percentage of the total sample) from which no liquid may be forced out by an applied pressure, as described below.

7.1.1.1 If the waste will obviously yield no liquid when subjected to pressure filtration (i.e., is 100% solids) proceed to Section 7.1.3.

7.1.1.2 If the sample is liquid or multiphasic, liquid/solid separation to make a preliminary determination of percent solids is required. This involves the filtration device described in Section 4.3.2 and is outlined in Sections 7.1.1.3 through 7.1.1.9.

7.1.1.3 Pre-weigh the filter and the container that will receive the filtrate.

7.1.1.4 Assemble the filter holder and filter following the manufacturer's instructions. Place the filter on the support screen and secure.

7.1.1.5 Weigh out a subsample of the waste (100 gram minimum) and record the weight.

7.1.1.6 Allow slurries to stand to permit the solid phase to settle. Wastes that settle slowly may be centrifuged prior to filtration. Centrifugation is to be used only as an aid to filtration. If used, the liquid should be decanted and filtered followed by filtration of the solid portion of the waste through the same filtration system.

7.1.1.7 Quantitatively transfer the waste sample to the filter holder (liquid and solid phases). Spread the waste sample evenly over the surface of the filter. If filtration of the waste at 4°C reduces the amount of expressed liquid over what would be expressed at room temperature then allow the sample to warm up to room temperature in the device before filtering.

Note: If waste material (>1% of original sample weight) has obviously adhered to the container used to transfer the sample to the filtration apparatus,
determine the weight of this residue and subtract it from the sample weight determined in Section 7.1.1.5 to determine the weight of the waste sample that will be filtered.

Gradually apply vacuum or gentle pressure of 1-10 psi, until air or pressurizing gas moves through the filter. If this point is not reached under 10 psi, and if no additional liquid has passed through the filter in any 2 minute interval, slowly increase the pressure in 10 psi increments to a maximum of 50 psi. After each incremental increase of 10 psi, if the pressurizing gas has not moved through the filter, and if no additional liquid has passed through the filter in any 2 minute interval, proceed to the next 10 psi increment. When the pressurizing gas begins to move through the filter, or when liquid flow has ceased at 50 psi (i.e., filtration does not result in any additional filtrate within any 2 minute period), stop the filtration.

Note: Instantaneous application of high pressure can degrade the glass fiber filter and may cause premature plugging.

7.1.1.8 The material in the filter holder is defined as the solid phase of the waste, and the filtrate is defined as the liquid phase.

Note: Some wastes, such as oily wastes and some paint wastes, will obviously contain some material that appears to be a liquid. Even after applying vacuum or pressure filtration, as outlined in Section 7.1.1.7, this material may not filter. If this is the case, the material within the filtration device is defined as a solid. Do not replace the original filter with a fresh filter under any circumstances. Use only one filter.

7.1.1.9 Determine the weight of the liquid phase by subtracting the weight of the filtrate container (see Section 7.1.1.3) from the total weight of the filtrate-filled container. Determine the weight of the solid phase of the waste sample by subtracting the weight of the liquid phase from the weight of the total waste sample, as determined in Section 7.1.1.5 or 7.1.1.7.

Record the weight of the liquid and solid phases. Calculate the percent solids as follows:

\[
\text{Percent solids} = \frac{\text{Weight of solid (Section 7.1.1.9)}}{\text{Total weight of waste (Section 7.1.1.5 or 7.1.1.7)}} \times 100
\]

7.1.2 If the percent solids determined in Section 7.1.1.9 is equal to or greater than 0.5%, then proceed either to Section 7.1.3 to determine whether the solid material requires particle size reduction or to Section 7.1.2.1 if it is noticed that a small amount of the filtrate is entrained in wetting of the filter. If the percent solids determined in Section 7.1.1.9 is less than 0.5%, then proceed to Section 7.2.9 if the nonvolatile TCLP is to be performed and to Section 7.3 with a fresh portion of the waste if the volatile TCLP is to be performed.
7.1.2.1 Remove the solid phase and filter from the filtration apparatus.

7.1.2.2 Dry the filter and solid phase at 100 ± 20°C until two successive weighing yield the same value within ± 1%. Record the final weight.

Note: Caution should be taken to ensure that the subject solid will not flash upon heating. It is recommended that the drying oven be vented to a hood or other appropriate device.

7.1.2.3 Calculate the percent dry solids as follows:

\[
\text{Percent dry solids} = \frac{\text{Initial wt. of waste (Section 7.1.1.5 or 7.1.1.7)} - \text{tared wt. of filter}}{\text{wt. of dry waste + filter}} \times 100
\]

7.1.2.4 If the percent dry solids is less than 0.5%, then proceed to Section 7.2.3 if the nonvolatile TCLP is to be performed, and to Section 7.3 if the volatile TCLP is to be performed. If the percent dry solids is greater than or equal to 0.5%, and if the nonvolatile TCLP is to be performed, return to the beginning of this Section (7.1) and, with a fresh portion of waste, determine whether particle size reduction is necessary (Section 7.1.3) and determine the appropriate extraction fluid (Section 7.1.4). If only the volatile TCLP is to be performed, see the note in Section 7.1.4.

7.1.3 Determination of whether the waste requires particle size reduction (particle size is reduced during this step): Using the solid portion of the waste, evaluate the solid for particle size. Particle size reduction is required, unless the solid has a surface area per gram of material equal to or greater than 3.1 cm², or is smaller than 1 cm in its narrowest dimension (i.e., is capable of passing through a 9.5 mm (0.375 inch) standard sieve). If the surface area is smaller or the particle size larger than described above, prepare the solid portion of the waste for extraction by crushing, cutting, or grinding the waste to a surface area or particle size as described above. If the solids are prepared for organic volatiles extraction, special precautions must be taken (see Section 7.3.6).

Note: Surface area criteria are meant for filamentous (e.g., paper, cloth, and similar) waste materials. Actual measurement of surface area is not required, nor is it recommended. For materials that do not obviously meet the criteria, sample specific methods would need to be developed and employed to measure the surface area. Such methodology is currently not available.

7.1.4 Determination of appropriate extraction fluid: If the solid content of the waste is greater than or equal to 0.5% and if the sample will be extracted for nonvolatile constituents (Section 7.2),
determine the appropriate fluid (Section 5.7) for the nonvolatiles extraction as follows:

Note: TCLP extraction for volatile constituents uses only extraction fluid #1 (Section 5.7.1). Therefore, if TCLP extraction for nonvolatiles is not required, proceed to Section 7.3.

7.1.4.1 Weigh out a small subsample of the solid phase of the waste, reduce the solid (if necessary) to a particle size of approximately 1 mm in diameter or less, and transfer 5.0 grams of the solid phase of the waste to a 500 mL beaker or Erlenmeyer flask.

7.1.4.2 Add 96.5 mL of reagent water to the beaker, cover with a watchglass, and stir vigorously for 5 minutes using a magnetic stirrer. Measure and record the pH. If the pH is <5.0, use extraction fluid #1. Proceed to Section 7.2.

7.1.4.3 If the pH from Section 7.1.4.2 is >5.0, add 3.5 mL 1N HCl, slurry briefly, cover with a watchglass, heat to 50°C, and hold at 50°C for 10 minutes.

7.1.4.4 Let the solution cool to room temperature and record the pH. If the pH is <5.0, use extraction fluid #1. If the pH is >5.0, use extraction fluid #2. Proceed to Section 7.2.

7.1.5 If the aliquot of the waste used for the preliminary evaluation (Sections 7.1.1 - 7.1.4) was determined to be 100% solid at Section 7.1.1.1, then it can be used for the Section 7.2 extraction (assuming at least 100 grams remain), and the Section 7.3 extraction (assuming at least 25 grams remain). If the aliquot was subjected to the procedure in Section 7.1.1.7, then another aliquot shall be used for the volatile extraction procedure in Section 7.3. The aliquot of the waste subjected to the procedure in Section 7.1.1.7 might be appropriate for use for the Section 7.2 extraction if an adequate amount of solid (as determined by Section 7.1.1.9) was obtained. The amount of solid necessary is dependent upon whether a sufficient amount of extract will be produced to support the analyses. If an adequate amount of solid remains, proceed to Section 7.2.10 of the nonvolatile TCLP extraction.

7.2 Procedure When Volatiles are not Involved

A minimum sample size of 100 grams (solid and liquid phases) is recommended. In some cases, a larger sample size may be appropriate, depending on the solids content of the waste sample (percent solids, See Section 7.1.1), whether the initial liquid phase of the waste will be miscible with the aqueous extract of the solid, and whether inorganics, semivolatile organics, pesticides, and herbicides are all analytes of concern. Enough solids should be generated for extraction such that the volume of TCLP extract will be sufficient to support all of the analyses required. If the amount of extract generated by a single TCLP extraction will not be sufficient to perform all of the analyses, more than one extraction may be performed and the extracts from each combined and aliquoted for analysis.
7.2.1 If the waste will obviously yield no liquid when subjected to pressure filtration (i.e., is 100% solid, see Section 7.1.1), weigh out a subsample of the waste (100 gram minimum) and proceed to Section 7.2.3.

7.2.2 If the sample is liquid or multiphasic, liquid/solid separation is required. This involves the filtration device described in Section 4.3.2 and is outlined in Sections 7.2.3 to 7.2.8.

7.2.3 Pre-weigh the container that will receive the filtrate.

7.2.4 Assemble the filter holder and filter following the manufacturer's instructions. Place the filter on the support screen and secure. Acid wash the filter if evaluating the mobility of metals (see Section 4.4).

Note: Acid washed filters may be used for all nonvolatile extractions even when metals are not of concern.

7.2.5 Weigh out a subsample of the waste (100 gram minimum) and record the weight. If the waste contains <0.5% dry solids (Section 7.1.2), the liquid portion of the waste, after filtration, is defined as the TCLP extract. Therefore, enough of the sample should be filtered so that the amount of filtered liquid will support all of the analyses required of the TCLP extract. For wastes containing >0.5% dry solids (Sections 7.1.1 or 7.1.2), use the percent solids information obtained in Section 7.1.1 to determine the optimum sample size (100 gram minimum) for filtration. Enough solids should be generated by filtration to support the analyses to be performed on the TCLP extract.

7.2.6 Allow slurries to stand to permit the solid phase to settle. Wastes that settle slowly may be centrifuged prior to filtration. Use centrifugation only as an aid to filtration. If the waste is centrifuged, the liquid should be decanted and filtered followed by filtration of the solid portion of the waste through the same filtration system.

7.2.7 Quantitatively transfer the waste sample (liquid and solid phases) to the filter holder (see Section 4.3.2). Spread the waste sample evenly over the surface of the filter. If filtration of the waste at 4°C reduces the amount of expressed liquid over what would be expressed at room temperature, then allow the sample to warm up to room temperature in the device before filtering.

Note: If waste material (>1% of the original sample weight) has obviously adhered to the container used to transfer the sample to the filtration apparatus, determine the weight of this residue and subtract it from the sample weight determined in Section 7.2.5, to determine the weight of the waste sample that will be filtered.

Gradually apply vacuum or gentle pressure of 1-10 psi, until air or pressurizing gas moves through the filter. If this point is not reached under 10 psi, and if no additional liquid has passed through the filter in any 2 minute interval, slowly increase the pressure in 10 psi increments to a maximum of 50 psi. After each incremental increase of 10 psi, if the
pressurizing gas has not moved through the filter, and if no additional liquid has passed through the filter in any 2 minute interval, proceed to the next 10 psi increment. When the pressurizing gas begins to move through the filter, or when the liquid flow has ceased at 50 psi (i.e., filtration does not result in any additional filtrate within a 2 minute period), stop the filtration.

Note: Instantaneous application of high pressure can degrade the glass fiber filter and may cause premature plugging.

7.2.8 The material in the filter holder is defined as the solid phase of the waste, and the filtrate is defined as the liquid phase. Weigh the filtrate. The liquid phase may now be either analyzed (See Section 7.2.12) or stored at 4°C until time of analysis.

Note: Some wastes, such as oily wastes and some paint wastes, will obviously contain some material that appears to be a liquid. Even after applying vacuum or pressure filtration, as outlined in Section 7.2.7, this material may not filter. If this is the case, the material within the filtration device is defined as a solid and is carried through the extraction as a solid. Do not replace the original filter with a fresh filter under any circumstances. Use only one filter.

7.2.9 If the waste contains <0.5% dry solids (see Section 7.1.2), proceed to Section 7.2.13. If the waste contains >0.5% dry solids (see Section 7.1.1 or 7.1.2), and if particle size reduction of the solid was needed in Section 7.1.3, proceed to Section 7.2.10. If the waste as received passes a 9.5 mm sieve, quantitatively transfer the solid material into the extractor bottle along with the filter used to separate the initial liquid from the solid phase, and proceed to Section 7.2.11.

7.2.10 Prepare the solid portion of the waste for extraction by crushing, cutting, or grinding the waste to a surface area or particle size as described in Section 7.1.3. When the surface area or particle size has been appropriately altered, quantitatively transfer the solid material into an extractor bottle. Include the filter used to separate the initial liquid from the solid phase.

Note: Sieving of the waste is not normally required. Surface area requirements are meant for filamentous (e.g., paper, cloth) and similar waste materials. Actual measurement of surface area is not recommended. If sieving is necessary, a Teflon coated sieve should be used to avoid contamination of the sample.

7.2.11 Determine the amount of extraction fluid to add to the extractor vessel as follows:

\[
\text{Weight of extraction fluid} = \frac{20 \times \text{percent solids (Section 7.1.1)} \times \text{weight of waste filtered (Section 7.2.5 or 7.2.7)}}{100}
\]
Slowly add this amount of appropriate extraction fluid (see Section 7.1.4) to the extractor vessel. Close the extractor bottle tightly (it is recommended that Teflon tape be used to ensure a tight seal), secure in rotary agitation device, and rotate at $30 \pm 2$ rpm for $18 \pm 2$ hours. Ambient temperature (i.e., temperature of room in which extraction takes place) shall be maintained at $22 \pm 3^\circ C$ during the extraction period.

Note: As agitation continues, pressure may build up within the extractor bottle for some types of wastes (e.g., limed or calcium carbonate containing waste may evolve gases such as carbon dioxide). To relieve excess pressure, the extractor bottle may be periodically opened (e.g., after 15 minutes, 30 minutes, and 1 hour) and vented into a hood.

7.2.12 Following the $18 \pm 2$ hour extraction, separate the material in the extractor vessel into its component liquid and solid phases by filtering through a new glass fiber filter, as outlined in Section 7.2.7. For final filtration of the TCLP extract, the glass fiber filter may be changed, if necessary, to facilitate filtration. Filter(s) shall be acid-washed (see Section 4.4) if evaluating the mobility of metals.

7.2.13 Prepare the TCLP extract as follows:

7.2.13.1 If the waste contained no initial liquid phase, the filtered liquid material obtained from Section 7.2.12 is defined as the TCLP extract. Proceed to Section 7.2.14.

7.2.13.2 If compatible (e.g., multiple phases will not result on combination), combine the filtered liquid resulting from Section 7.2.12 with the initial liquid phase of the waste obtained in Section 7.2.7. This combined liquid is defined as the TCLP extract. Proceed to Section 7.2.14.

7.2.13.3 If the initial liquid phase of the waste, as obtained from Section 7.2.7, is not or may not be compatible with the filtered liquid resulting from Section 7.2.12, do not combine these liquids. Analyze these liquids, collectively defined as the TCLP extract, and combine the results mathematically, as described in Section 7.2.14.

7.2.14 Following collection of the TCLP extract, the pH of the extract should be recorded. Immediately aliquot and preserve the extract for analysis. Metals aliquots must be acidified with nitric acid to pH <2. If precipitation is observed upon addition of nitric acid to a small aliquot of the extract, then the remaining portion of the extract for metals analyses shall not be acidified and the extract shall be analyzed as soon as possible. All other aliquots must be stored under refrigeration ($4^\circ C$) until analyzed. The TCLP extract shall be prepared and analyzed according to appropriate analytical methods. TCLP extracts to be analyzed for metals shall be acid digested except in those instances where digestion causes loss of metallic analytes. If an analysis of the undigested extract shows that the concentration of any regulated metallic analyte exceeds the regulatory level, then the waste is hazardous and digestion of the extract is not necessary. However, data on undigested
extracts alone cannot be used to demonstrate that the waste is not hazardous. If the individual phases are to be analyzed separately, determine the volume of the individual phases (to ± 0.5%), conduct the appropriate analyses, and combine the results mathematically by using a simple volume-weighted average:

\[
\text{Final Analyte Concentration} = \frac{(V_1) (C_1) + (V_2) (C_2)}{V_1 + V_2}
\]

where:

- \( V_1 \) = The volume of the first phase (L).
- \( C_1 \) = The concentration of the analyte of concern in the first phase (mg/L).
- \( V_2 \) = The volume of the second phase (L).
- \( C_2 \) = The concentration of the analyte of concern in the second phase (mg/L).

7.2.15 Compare the analyte concentrations in the TCLP extract with the levels identified in the appropriate regulations. Refer to Section 8.0 for quality assurance requirements.

7.3 Procedure When Volatiles are Involved

Use the ZHE device to obtain TCLP extract for analysis of volatile compounds only. Extract resulting from the use of the ZHE shall not be used to evaluate the mobility of nonvolatile analytes (e.g., metals, pesticides, etc.).

The ZHE device has approximately a 500 mL internal capacity. The ZHE can thus accommodate a maximum of 25 grams of solid (defined as that fraction of a sample from which no additional liquid may be forced out by an applied pressure of 50 psi), due to the need to add an amount of extraction fluid equal to 20 times the weight of the solid phase.

Charge the ZHE with sample only once and do not open the device until the final extract (of the solid) has been collected. Repeated filling of the ZHE to obtain 25 grams of solid is not permitted.

Do not allow the waste, the initial liquid phase, or the extract to be exposed to the atmosphere for any more time than is absolutely necessary. Any manipulation of these materials should be done when cold (4°C) to minimize loss of volatiles.

7.3.1 Pre-weigh the (evacuated) filtrate collection container (See Section 4.6) and set aside. If using a TEDLAR® bag, express all liquid from the ZHE device into the bag, whether for the initial or final liquid/solid separation, and take an aliquot from the liquid in the bag for analysis. The containers listed in Section 4.6 are recommended for use under the conditions stated in Sections 4.6.1 - 4.6.3.

7.3.2 Place the ZHE piston within the body of the ZHE (it may be helpful first to moisten the piston O-rings slightly with extraction...
Adjust the piston within the ZHE body to a height that will minimize the distance the piston will have to move once the ZHE is charged with sample (based upon sample size requirements determined from Section 7.3, Section 7.1.1 and/or 7.1.2). Secure the gas inlet/outlet flange (bottom flange) onto the ZHE body in accordance with the manufacturer's instructions. Secure the glass fiber filter between the support screens and set aside. Set liquid inlet/outlet flange (top flange) aside.

7.3.3 If the waste is 100% solid (see Section 7.1.1), weigh out a subsample (25 gram maximum) of the waste, record weight, and proceed to Section 7.3.5.

7.3.4 If the waste contains < 0.5% dry solids (Section 7.1.2), the liquid portion of waste, after filtration, is defined as the TCLP extract. Filter enough of the sample so that the amount of filtered liquid will support all of the volatile analyses required. For wastes containing > 0.5% dry solids (Sections 7.1.1 and/or 7.1.2), use the percent solids information obtained in Section 7.1.1 to determine the optimum sample size to charge into the ZHE. The recommended sample size is as follows:

7.3.4.1 For wastes containing < 0.5% solids (see Section 7.1.1), weigh out a 500 gram subsample of waste and record the weight.

7.3.4.2 For wastes containing ≥ 0.5% solids (see Section 7.1.1), determine the amount of waste to charge into the ZHE as follows:

\[
\text{Weight of waste to charge ZHE} = \frac{25}{\text{percent solids (Section 7.1.1)}} \times 100
\]

Weigh out a subsample of the waste of the appropriate size and record the weight.

7.3.5 If particle size reduction of the solid portion of the waste was required in Section 7.1.3, proceed to Section 7.3.6. If particle size reduction was not required in Section 7.1.3, proceed to Section 7.3.7.

7.3.6 Prepare the waste for extraction by crushing, cutting, or grinding the solid portion of the waste to a surface area or particle size as described in Section 7.1.3. Wastes and appropriate reduction equipment should be refrigerated, if possible, to 4°C prior to particle size reduction. The means used to effect particle size reduction must not generate heat in and of itself. If reduction of the solid phase of the waste is necessary, exposure of the waste to the atmosphere should be avoided to the extent possible.

Note: Sieving of the waste is not recommended due to the possibility that volatiles may be lost. The use of an appropriately graduated ruler is recommended as an acceptable alternative. Surface area requirements are

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meant for filamentous (e.g., paper, cloth) and similar waste materials. Actual measurement of surface area is not recommended.

When the surface area or particle size has been appropriately altered, proceed to Section 7.3.7.

7.3.7 Waste slurries need not be allowed to stand to permit the solid phase to settle. Do not centrifuge wastes prior to filtration.

7.3.8 Quantitatively transfer the entire sample (liquid and solid phases) quickly to the ZHE. Secure the filter and support screens onto the top flange of the device and secure the top flange to the ZHE body in accordance with the manufacturer’s instructions. Tighten all ZHE fittings and place the device in the vertical position (gas inlet/outlet flange on the bottom). Do not attach the extract collection device to the top plate.

Note: If waste material (>1% of original sample weight) has obviously adhered to the container used to transfer the sample to the ZHE, determine the weight of this residue and subtract it from the sample weight determined in Section 7.3.4 to determine the weight of the waste sample that will be filtered.

Attach a gas line to the gas inlet/outlet valve (bottom flange) and, with the liquid inlet/outlet valve (top flange) open, begin applying gentle pressure of 1-10 psi (or more if necessary) to force all headspace slowly out of the ZHE device into a hood. At the first appearance of liquid from the liquid inlet/outlet valve, quickly close the valve and discontinue pressure. If filtration of the waste at 4°C reduces the amount of expressed liquid over what would be expressed at room temperature, then allow the sample to warm up to room temperature in the device before filtering. If the waste is 100% solid (see Section 7.1.1), slowly increase the pressure to a maximum of 50 psi to force most of the headspace out of the device and proceed to Section 7.3.12.

7.3.9 Attach the evacuated pre-weighed filtrate collection container to the liquid inlet/outlet valve and open the valve. Begin applying gentle pressure of 1-10 psi to force the liquid phase of the sample into the filtrate collection container. If no additional liquid has passed through the filter in any 2 minute interval, slowly increase the pressure in 10 psi increments to a maximum of 50 psi. After each incremental increase of 10 psi, if no additional liquid has passed through the filter in any 2 minute interval, proceed to the next 10 psi increment. When liquid flow has ceased such that continued pressure filtration at 50 psi does not result in any additional filtrate within a 2 minute period, stop the filtration. Close the liquid inlet/outlet valve, discontinue pressure to the piston, and disconnect and weigh the filtrate collection container.

Note: Instantaneous application of high pressure can degrade the glass fiber filter and may cause premature plugging.

7.3.10 The material in the ZHE is defined as the solid phase of the waste and the filtrate is defined as the liquid phase.
Note: Some wastes, such as oily wastes and some paint wastes, will obviously contain some material that appears to be a liquid. Even after applying pressure filtration, this material will not filter. If this is the case, the material within the filtration device is defined as a solid and is carried through the TCLP extraction as a solid.

If the original waste contained <0.5% dry solids (see Section 7.1.2), this filtrate is defined as the TCLP extract and is analyzed directly. Proceed to Section 7.3.15.

7.3.11 The liquid phase may now be either analyzed immediately (See Sections 7.3.13 through 7.3.15) or stored at 4°C under minimal headspace conditions until time of analysis. Determine the weight of extraction fluid #1 to add to the ZHE as follows:

\[
\text{Weight of extraction fluid} = \frac{20 \times \text{percent solids (Section 7.1.1)} \times \text{weight of waste filtered (Section 7.3.4 or 7.3.8)}}{100}
\]

7.3.12 The following Sections detail how to add the appropriate amount of extraction fluid to the solid material within the ZHE and agitation of the ZHE vessel. Extraction fluid #1 is used in all cases (See Section 5.7).

7.3.12.1 With the ZHE in the vertical position, attach a line from the extraction fluid reservoir to the liquid inlet/outlet valve. The line used shall contain fresh extraction fluid and should be preflushed with fluid to eliminate any air pockets in the line. Release gas pressure on the ZHE piston (from the gas inlet/outlet valve), open the liquid inlet/outlet valve, and begin transferring extraction fluid (by pumping or similar means) into the ZHE. Continue pumping extraction fluid into the ZHE until the appropriate amount of fluid has been introduced into the device.

7.3.12.2 After the extraction fluid has been added, immediately close the liquid inlet/outlet valve and disconnect the extraction fluid line. Check the ZHE to ensure that all valves are in their closed positions. Manually rotate the device in an end-over-end fashion 2 or 3 times. Reposition the ZHE in the vertical position with the liquid inlet/outlet valve on top. Pressurize the ZHE to 5-10 psi (if necessary) and slowly open the liquid inlet/outlet valve to bleed out any headspace (into a hood) that may have been introduced due to the addition of extraction fluid. This bleeding shall be done quickly and shall be stopped at the first appearance of liquid from the valve. Re-pressurize the ZHE with 5-10 psi and check all ZHE fittings to ensure that they are closed.

7.3.12.3 Place the ZHE in the rotary agitation apparatus (if it is not already there) and rotate at 30 ± 2 rpm for 18 ± 2 hours. Ambient temperature (i.e., temperature of room in...
which extraction occurs) shall be maintained at 23 ± 2°C during agitation.

7.3.13 Following the 18 ± 2 hour agitation period, check the pressure behind the ZHE piston by quickly opening and closing the gas inlet/outlet valve and noting the escape of gas. If the pressure has not been maintained (i.e., no gas release observed), the device is leaking. Check the ZHE for leaking as specified in Section 4.2.1, and perform the extraction again with a new sample of waste. If the pressure within the device has been maintained, the material in the extractor vessel is once again separated into its component liquid and solid phases. If the waste contained an initial liquid phase, the liquid may be filtered directly into the same filtrate collection container (i.e., TEDLAR® bag) holding the initial liquid phase of the waste. A separate filtrate collection container must be used if combining would create multiple phases, or there is not enough volume left within the filtrate collection container. Filter through the glass fiber filter, using the ZHE device as discussed in Section 7.3.9. All extract shall be filtered and collected if the TEDLAR® bag is used, if the extract is multiphasic, or if the waste contained an initial liquid phase (see Sections 4.6 and 7.3.1).

Note: An in-line glass fiber filter may be used to filter the material within the ZHE if it is suspected that the glass fiber filter has been ruptured.

7.3.14 If the original waste contained no initial liquid phase, the filtered liquid material obtained from Section 7.3.13 is defined as the TCLP extract. If the waste contained an initial liquid phase, the filtered liquid material obtained from Section 7.3.13 and the initial liquid phase (Section 7.3.9) are collectively defined as the TCLP extract.

7.3.15 Following collection of the TCLP extract, immediately prepare the extract for analysis and store with minimal headspace at 4°C until analyzed. Analyze the TCLP extract according to the appropriate analytical methods. If the individual phases are to be analyzed separately (i.e., are not miscible), determine the volume of the individual phases (to 0.01%), conduct the appropriate analyses, and combine the results mathematically by using a simple volume-weighted average:

\[
\text{Final Analyte Concentration} = \frac{(V_1)(C_1) + (V_2)(C_2)}{V_1 + V_2}
\]

where:

- \(V_1\) = The volume of the first phases (L).
- \(C_1\) = The concentration of the analyte of concern in the first phase (mg/L).
- \(V_2\) = The volume of the second phase (L).
- \(C_2\) = The concentration of the analyte of concern in the second phase (mg/L).
7.3.16 Compare the analyte concentrations in the TCLP extract with the levels identified in the appropriate regulations. Refer to Section 8.0 for quality assurance requirements.

8.0 QUALITY CONTROL

8.1 Refer to Chapter One for all required quality control procedures. A minimum of one blank (using the same extraction fluid as used for the samples) for every 20 extractions that have been conducted in an extraction vessel.

8.2 A matrix spike shall be performed for each waste type (e.g., wastewater treatment sludge, contaminated soil, etc.) unless the result exceeds the regulatory level and the data are being used solely to demonstrate that the waste property exceeds the regulatory level. As a minimum, follow the matrix spike addition guidance provided in each analytical method.

8.2.1 Matrix spikes are to be added after filtration of the TCLP extract and before preservation. Matrix spikes should not be added prior to TCLP extraction of the sample.

8.2.2 In most cases, matrix spikes should be added at a concentration equivalent to the corresponding regulatory level. If the analyte concentration is less than one half the regulatory level, the spike concentration may be as low as one half of the analyte concentration, but may not be not less than five times the method detection limit. In order to avoid differences in matrix effects, the matrix spikes must be added to the same nominal volume of TCLP extract as that which was analyzed for the unspiked sample.

8.2.3 The purpose of the matrix spike is to monitor the performance of the analytical methods used, and to determine whether matrix interferences exist. Use of other internal calibration methods, modification of the analytical methods, or use of alternate analytical methods may be needed to accurately measure the analyte concentration in the TCLP extract when the recovery of the matrix spike is below the expected analytical method performance.

8.3 All quality control measures described in the appropriate analytical methods shall be followed.

8.4 Samples must undergo TCLP extraction within the following time periods:
9.0 METHOD PERFORMANCE

9.1 Ruggedness. Two ruggedness studies have been performed to determine the effect of various perturbations on specific elements of the TCLP protocol. Ruggedness testing determines the sensitivity of small procedural variations which might be expected to occur during routine laboratory application.

9.1.1 Metals - The following conditions were used when leaching a waste for metals analysis:

<table>
<thead>
<tr>
<th>Varying Conditions</th>
<th>19:1 vs. 21:1</th>
<th>16 hours vs. 18 hours</th>
<th>20% vs. 60%</th>
<th>190 mg vs. 210 mg</th>
<th>yes vs. no</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquid/Solid ratio</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extraction time</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Headspace</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Buffer #2 acidity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acid-washed filters</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

If sample holding times are exceeded, the values obtained will be considered minimal concentrations. Exceeding the holding time is not acceptable in establishing that a waste does not exceed the regulatory level. Exceeding the holding time will not invalidate characterization if the waste exceeds the regulatory level.
Of the seven method variations examined, acidity of the extraction fluid had the greatest impact on the results. Four of 13 metals from an API separator sludge/electroplating waste (API/EW) mixture and two of three metals from an ammonia lime still bottom waste were extracted at higher levels by the more acidic buffer. Because of the sensitivity to pH changes, the method requires that the extraction fluids be prepared so that the final pH is within ±0.05 units as specified.

9.1.2 Volatile Organic Compounds - The following conditions were used when leaching a waste for VOC analysis:

<table>
<thead>
<tr>
<th>Varying Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquid/Solid ratio</td>
</tr>
<tr>
<td>Headspace</td>
</tr>
<tr>
<td>Buffer #1 acidity</td>
</tr>
<tr>
<td>Method of storing extract</td>
</tr>
<tr>
<td>Aliquoting</td>
</tr>
<tr>
<td>Pressure behind piston</td>
</tr>
</tbody>
</table>

None of the parameters had a significant effect on the results of the ruggedness test.

9.2 Precision. Many TCLP precision (reproducibility) studies have been performed, and have shown that, in general, the precision of the TCLP is comparable to or exceeds that of the EP toxicity test and that method precision is adequate. One of the more significant contributions to poor precision appears to be related to sample homogeneity and inter-laboratory variation (due to the nature of waste materials).

9.2.1 Metals - The results of a multi-laboratory study are shown in Table 6, and indicate that a single analysis of a waste may not be adequate for waste characterization and identification requirements.

9.2.2 Semi-Volatile Organic Compounds - The results of two studies are shown in Tables 7 and 8. Single laboratory precision was excellent with greater than 90 percent of the results exhibiting an RSD less than 25 percent. Over 85 percent of all individual compounds in the multi-laboratory study fell in the RSD range of 20 - 120 percent. Both studies concluded that the TCLP provides adequate precision. It was also determined that the high acetate content of the extraction fluid did not
present problems (i.e., column degradation of the gas chromatograph) for the analytical conditions used.

9.2.3 Volatile Organic Compounds - Eleven laboratories participated in a collaborative study of the use of the ZHE with two waste types which were fortified with a mixture of VOCs. The results of the collaborative study are shown in Table 9. Precision results for VOCs tend to occur over a considerable range. However, the range and mean RSD compared very closely to the same collaborative study metals results in Table 6. Blackburn and Show concluded that at the 95% level of significance: 1) recoveries among laboratories were statistically similar, 2) recoveries did not vary significantly between the two sample types, and 3) each laboratory showed the same pattern of recovery for each of the two samples.

10.0 REFERENCES


<table>
<thead>
<tr>
<th>Compound</th>
<th>CAS No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetone</td>
<td>67-64-1</td>
</tr>
<tr>
<td>Benzene</td>
<td>71-43-2</td>
</tr>
<tr>
<td>n-Butyl alcohol</td>
<td>71-36-3</td>
</tr>
<tr>
<td>Carbon disulfide</td>
<td>75-15-0</td>
</tr>
<tr>
<td>Carbon tetrachloride</td>
<td>59-23-5</td>
</tr>
<tr>
<td>Chlorobenzene</td>
<td>108-90-7</td>
</tr>
<tr>
<td>Chloroform</td>
<td>67-66-3</td>
</tr>
<tr>
<td>1,2-Dichloroethane</td>
<td>107-06-2</td>
</tr>
<tr>
<td>1,1-Dichloroethylene</td>
<td>75-35-4</td>
</tr>
<tr>
<td>Ethyl acetate</td>
<td>141-78-6</td>
</tr>
<tr>
<td>Ethyl benzene</td>
<td>100-41-4</td>
</tr>
<tr>
<td>Ethyl ether</td>
<td>60-29-7</td>
</tr>
<tr>
<td>Isobutanol</td>
<td>78-83-1</td>
</tr>
<tr>
<td>Methanol</td>
<td>67-56-1</td>
</tr>
<tr>
<td>Methylene chloride</td>
<td>75-09-2</td>
</tr>
<tr>
<td>Methyl ethyl ketone</td>
<td>79-93-3</td>
</tr>
<tr>
<td>Methyl isobutyl ketone</td>
<td>108-10-1</td>
</tr>
<tr>
<td>Tetrachloroethylene</td>
<td>127-18-4</td>
</tr>
<tr>
<td>Toluene</td>
<td>108-88-3</td>
</tr>
<tr>
<td>1,1,1,-Trichloroethane</td>
<td>71-55-6</td>
</tr>
<tr>
<td>Trichloroethylene</td>
<td>79-01-6</td>
</tr>
<tr>
<td>Trichlorofluoromethane</td>
<td>75-69-4</td>
</tr>
<tr>
<td>1,1,2-Trichloro-1,2,2-trifluoroethane</td>
<td>76-13-1</td>
</tr>
<tr>
<td>Vinyl chloride</td>
<td>75-01-4</td>
</tr>
<tr>
<td>Xylene</td>
<td>1330-20-7</td>
</tr>
</tbody>
</table>

1 When testing for any or all of these analytes, the zero-headspace extractor vessel shall be used instead of the bottle extractor.

2 Benzene, carbon tetrachloride, chlorobenzene, chloroform, 1,2-dichloroethane, 1,1-dichloroethylene, methyl ethyl ketone, tetrachloroethylene, and vinyl chloride are toxicity characteristic constituents.
<table>
<thead>
<tr>
<th>Company</th>
<th>Location</th>
<th>Model No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analytical Testing and Consulting Services, Inc.</td>
<td>Warrington, PA</td>
<td>4-vessel extractor (DC205); 8-vessel extractor (DC20); 12-vessel extractor (DC208)</td>
</tr>
<tr>
<td>Associated Design and Manufacturing Company</td>
<td>Alexandria, VA</td>
<td>2-vessel (3740-2); 4-vessel (3740-4); 6-vessel (3740-6); 8-vessel (3740-8); 12-vessel (3740-12); 24-vessel (3740-24)</td>
</tr>
<tr>
<td>Environmental Machine and Design, Inc.</td>
<td>Lynchburg, VA</td>
<td>8-vessel (08-00-00); 4-vessel (04-00-00)</td>
</tr>
<tr>
<td>IRA Machine Shop and Laboratory</td>
<td>Santurce, PR</td>
<td>8-vessel (011001)</td>
</tr>
<tr>
<td>Lars Lande Manufacturing</td>
<td>Whitmore Lake, MI</td>
<td>10-vessel (IOVRE); 5-vessel (5VRE)</td>
</tr>
<tr>
<td>Millipore Corp.</td>
<td>Bedford, MA</td>
<td>4-ZHE or 4-liter bottle extractor (YT300mHW); 4-vessel (SD1M362CO)</td>
</tr>
</tbody>
</table>

1 Any device that rotates the extraction vessel in an end-over-end fashion at 30 ± 2 rpm is acceptable.
Table 3. Suitable Zero-Headspace Extractor Vessels

<table>
<thead>
<tr>
<th>Company</th>
<th>Location</th>
<th>Model No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analytical Testing &amp;</td>
<td>Warrington, PA</td>
<td>C102, Mechanical Pressure Device</td>
</tr>
<tr>
<td>Consulting Services, Inc.</td>
<td>(215) 343-4490</td>
<td></td>
</tr>
<tr>
<td>Associated Design and</td>
<td>Alexandria, VA</td>
<td>3745-ZHE, Gas Pressure Device</td>
</tr>
<tr>
<td>Manufacturing Company</td>
<td>(703) 549-5999</td>
<td></td>
</tr>
<tr>
<td>Lars Lande Manufacturing²</td>
<td>Whitmore Lake, MI</td>
<td>ZHE-11, Gas Pressure Device</td>
</tr>
<tr>
<td></td>
<td>(313) 449-4115</td>
<td></td>
</tr>
<tr>
<td>Millipore Corporation</td>
<td>Bedford, MA</td>
<td>YT3009OHW, Gas Pressure Device</td>
</tr>
<tr>
<td></td>
<td>(800) 225-3384</td>
<td></td>
</tr>
<tr>
<td>Environmental Machine</td>
<td>Lynchburg, VA</td>
<td>VOLA-TOXI, Gas Pressure Device</td>
</tr>
<tr>
<td>and Design, Inc.</td>
<td>(804) 845-5424</td>
<td></td>
</tr>
<tr>
<td>Gelman Science</td>
<td>Ann Arbor, MI</td>
<td>15400 Gas Pressure Device</td>
</tr>
<tr>
<td></td>
<td>(800) 521-1520</td>
<td></td>
</tr>
</tbody>
</table>

¹ Any device that meets the specifications listed in Section 4.2.1 of the method is suitable.

² This device uses a 110 mm filter.
Table 4.
Suitable Filter Holders

<table>
<thead>
<tr>
<th>Company</th>
<th>Location</th>
<th>Model/Catalogue #</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nucleopore Corporation</td>
<td>Pleasanton, CA</td>
<td>425910</td>
<td>142 mm</td>
</tr>
<tr>
<td></td>
<td>(800) 882-7711</td>
<td>410400</td>
<td>47 mm</td>
</tr>
<tr>
<td>Micro Filtration Systems</td>
<td>Dublin, CA</td>
<td>302400</td>
<td>142 mm</td>
</tr>
<tr>
<td></td>
<td>(800) 334-7132</td>
<td>311400</td>
<td>47 mm</td>
</tr>
<tr>
<td></td>
<td>(415) 828-6010</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Millipore Corporation</td>
<td>Bedford, MA</td>
<td>YT30142HW</td>
<td>142 mm</td>
</tr>
<tr>
<td></td>
<td>(800) 225-1384</td>
<td>XX1004700</td>
<td>47 mm</td>
</tr>
</tbody>
</table>

1 Any device capable of separating the liquid from the solid phase of the waste is suitable, providing that it is chemically compatible with the waste and the constituents to be analyzed. Plastic devices (not listed above) may be used when only inorganic analytes are of concern. The 142 mm size filter holder is recommended.
Table 5.
Suitable Filter Media

<table>
<thead>
<tr>
<th>Company</th>
<th>Location</th>
<th>Model</th>
<th>Pore Size (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Millipore Corporation</td>
<td>Bedford, MA</td>
<td>AP40</td>
<td>0.7</td>
</tr>
<tr>
<td>Nucleopore Corporation</td>
<td>Pleasanton, CA</td>
<td>211625</td>
<td>0.7</td>
</tr>
<tr>
<td>Whatman Laboratory Products, Inc.</td>
<td>Clifton, NJ</td>
<td>GFF</td>
<td>0.7</td>
</tr>
<tr>
<td>Micro Filtration Systems</td>
<td>Dublin, CA</td>
<td>GF75</td>
<td>0.7</td>
</tr>
<tr>
<td>Gelman Science</td>
<td>Ann Arbor, MI</td>
<td>66256 (90mm)</td>
<td>0.7</td>
</tr>
<tr>
<td></td>
<td>(800) 521-1520</td>
<td>66257 (142mm)</td>
<td></td>
</tr>
</tbody>
</table>

1 Any filter that meets the specifications in Section 4.4 of the Method is suitable.
<table>
<thead>
<tr>
<th>Waste</th>
<th>Extraction Fluid</th>
<th>Metal</th>
<th>$\bar{x}$</th>
<th>S</th>
<th>%RSD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia</td>
<td>#1</td>
<td>Cadmium</td>
<td>0.053</td>
<td>0.031</td>
<td>60</td>
</tr>
<tr>
<td>Lime Still</td>
<td>#2</td>
<td>Cadmium</td>
<td>0.023</td>
<td>0.017</td>
<td>76</td>
</tr>
<tr>
<td>Bottoms</td>
<td>#1, #2</td>
<td>Chromium</td>
<td>0.015</td>
<td>0.0014</td>
<td>93</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lead</td>
<td>0.0032</td>
<td>0.0037</td>
<td>118</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lead</td>
<td>0.0030</td>
<td>0.0027</td>
<td>90</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lead</td>
<td>0.0032</td>
<td>0.0028</td>
<td>87</td>
</tr>
<tr>
<td>API/EW Mixture</td>
<td>#1, #2</td>
<td>Cadmium</td>
<td>0.0046</td>
<td>0.0028</td>
<td>61</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Chromium</td>
<td>0.0005</td>
<td>0.0004</td>
<td>77</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Chromium</td>
<td>0.0561</td>
<td>0.0227</td>
<td>40</td>
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<tr>
<td></td>
<td></td>
<td>Lead</td>
<td>0.0031</td>
<td>0.0031</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lead</td>
<td>0.0124</td>
<td>0.0136</td>
<td>110</td>
</tr>
<tr>
<td>Fossil Fuel Fly Ash</td>
<td>#1, #2</td>
<td>Cadmium</td>
<td>0.080</td>
<td>0.069</td>
<td>86</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Chromium</td>
<td>0.093</td>
<td>0.067</td>
<td>72</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Chromium</td>
<td>0.017</td>
<td>0.014</td>
<td>85</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lead</td>
<td>0.0087</td>
<td>0.0074</td>
<td>85</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lead</td>
<td>0.0457</td>
<td>0.0083</td>
<td>18</td>
</tr>
</tbody>
</table>

%RSD Range = 17 - 118
Mean %RSD = 74

Note: $\bar{x}$ = Mean results from 6 - 12 different laboratories
Units = mg/L
Extraction Fluid #1 = pH 4.9
#2 = pH 2.9
### Table 7. Single-Laboratory Semi-Volatiles, Precision

<table>
<thead>
<tr>
<th>Waste</th>
<th>Compound</th>
<th>Extraction Fluid</th>
<th>X</th>
<th>S</th>
<th>%RSD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia Lime Still</td>
<td>Phenol</td>
<td>#1</td>
<td>19000</td>
<td>2230</td>
<td>11.6</td>
</tr>
<tr>
<td></td>
<td>2-Methylphenol</td>
<td>#1</td>
<td>2000</td>
<td>297</td>
<td>14.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>#2</td>
<td>1860</td>
<td>32.9</td>
<td>2.8</td>
</tr>
<tr>
<td></td>
<td>4-Methylphenol</td>
<td>#1</td>
<td>7940</td>
<td>1380</td>
<td>17.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>#2</td>
<td>7490</td>
<td>200</td>
<td>2.7</td>
</tr>
<tr>
<td></td>
<td>2,4-Dimethylphenol</td>
<td>#1</td>
<td>321</td>
<td>46.8</td>
<td>14.6</td>
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<tr>
<td></td>
<td></td>
<td>#2</td>
<td>307</td>
<td>45.8</td>
<td>14.9</td>
</tr>
<tr>
<td></td>
<td>Naphthalene</td>
<td>#1</td>
<td>3920</td>
<td>413</td>
<td>10.5</td>
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<tr>
<td></td>
<td></td>
<td>#2</td>
<td>3827</td>
<td>176</td>
<td>4.6</td>
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<tr>
<td></td>
<td>2-Methyl-naphthalene</td>
<td>#1</td>
<td>290</td>
<td>44.8</td>
<td>15.5</td>
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<td></td>
<td></td>
<td>#2</td>
<td>273</td>
<td>19.3</td>
<td>7.1</td>
</tr>
<tr>
<td></td>
<td>Dibenzo-furan</td>
<td>#1</td>
<td>187</td>
<td>22.7</td>
<td>12.1</td>
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<tr>
<td></td>
<td></td>
<td>#2</td>
<td>187</td>
<td>7.2</td>
<td>3.9</td>
</tr>
<tr>
<td></td>
<td>Acenaphthylene</td>
<td>#1</td>
<td>703</td>
<td>89.2</td>
<td>12.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>#2</td>
<td>663</td>
<td>20.1</td>
<td>3.0</td>
</tr>
<tr>
<td></td>
<td>Fluorene</td>
<td>#1</td>
<td>151</td>
<td>17.6</td>
<td>11.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>#2</td>
<td>156</td>
<td>2.1</td>
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<td>Phenanthrene</td>
<td>#1</td>
<td>241</td>
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<td></td>
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<td>243</td>
<td>7.9</td>
<td>3.3</td>
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<td>Anthracene</td>
<td>#1</td>
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<td>18.6</td>
</tr>
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<td></td>
<td>#2</td>
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<td>25.3</td>
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<td></td>
<td>#2</td>
<td>25.6</td>
<td>1.8</td>
<td>7.1</td>
</tr>
<tr>
<td>API/EW Mixture</td>
<td>Phenol</td>
<td>#1</td>
<td>40.7</td>
<td>13.5</td>
<td>33.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>#2</td>
<td>19.0</td>
<td>1.76</td>
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</tr>
<tr>
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<td>2,4-Dimethylphenol</td>
<td>#1</td>
<td>33.0</td>
<td>9.35</td>
<td>28.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>#2</td>
<td>43.3</td>
<td>8.61</td>
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<td>185</td>
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<td>#2</td>
<td>165</td>
<td>24.8</td>
<td>15.0</td>
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<td></td>
<td>2-Methyl-naphthalene</td>
<td>#1</td>
<td>265</td>
<td>61.2</td>
<td>23.3</td>
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<td></td>
<td>#2</td>
<td>200</td>
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<td>9.5</td>
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</tbody>
</table>

%RSD Range = 1 - 33  
Mean %RSD = 12

Note: Units = µg/L  
Extraction were performed in triplicate  
All results were at least 2x the detection limit  
Extraction Fluid #1 = pH 4.9  
#2 = pH 2.9

Revision 0  
November 1990
Table 8. Multi-Laboratory Semi-Volatiles, Precision

<table>
<thead>
<tr>
<th>Waste</th>
<th>Compound</th>
<th>Extraction Fluid</th>
<th>$\bar{X}$</th>
<th>$S$</th>
<th>%RSD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia Lime</td>
<td>BNAs</td>
<td>#1</td>
<td>10043</td>
<td>7680</td>
<td>76.5</td>
</tr>
<tr>
<td>Still Bottoms (A)</td>
<td>BNAs</td>
<td>#2</td>
<td>10376</td>
<td>6632</td>
<td>63.1</td>
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<tr>
<td>API/EW</td>
<td>BNAs</td>
<td>#1</td>
<td>1624</td>
<td>675</td>
<td>41.6</td>
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<tr>
<td>Mixture (B)</td>
<td>BNAs</td>
<td>#2</td>
<td>2074</td>
<td>1463</td>
<td>70.5</td>
</tr>
<tr>
<td>Fossil Fuel</td>
<td>BNAs</td>
<td>#1</td>
<td>750</td>
<td>175</td>
<td>23.4</td>
</tr>
<tr>
<td>Fly Ash (C)</td>
<td>BNAs</td>
<td>#2</td>
<td>739</td>
<td>342</td>
<td>46.3</td>
</tr>
</tbody>
</table>

Mean %RSD = 54

Note: Units = µg/L
$X$ = Mean results from 3 - 10 labs
Extraction Fluid #1 = pH 4.9
#2 = pH 2.9

%RSD Range For Individual Compounds:
- A, #1: 0 - 113
- A, #2: 28 - 108
- B, #1: 20 - 155
- B, #2: 49 - 128
- C, #1: 36 - 143
- C, #2: 61 - 164
<table>
<thead>
<tr>
<th>Waste</th>
<th>Compound</th>
<th>$\bar{X}$</th>
<th>$S$</th>
<th>%RSD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mine Tailings</td>
<td>Vinyl chloride</td>
<td>6.36</td>
<td>6.36</td>
<td>100</td>
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<tr>
<td></td>
<td>Methylene chloride</td>
<td>12.1</td>
<td>11.8</td>
<td>98</td>
</tr>
<tr>
<td></td>
<td>Carbon disulfide</td>
<td>5.57</td>
<td>2.83</td>
<td>51</td>
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<td>1,1-Dichloroethene</td>
<td>21.9</td>
<td>27.7</td>
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<tr>
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<td>1,1-Dichloroethane</td>
<td>31.4</td>
<td>25.4</td>
<td>81</td>
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<tr>
<td></td>
<td>Chloroform</td>
<td>46.6</td>
<td>29.2</td>
<td>63</td>
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<tr>
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<td>1,2-Dichloroethane</td>
<td>47.8</td>
<td>33.6</td>
<td>70</td>
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<tr>
<td></td>
<td>2-Butanone</td>
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<td>36.9</td>
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<tr>
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<td>1,1,1-Trichloroethane</td>
<td>20.9</td>
<td>20.9</td>
<td>100</td>
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<tr>
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<td>Carbon tetrachloride</td>
<td>12.0</td>
<td>8.2</td>
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<td>Trichloroethene</td>
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<td>21.2</td>
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<td>1,1,2-Trichloroethene</td>
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<td>Benzene</td>
<td>37.9</td>
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<td>76</td>
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<td>1,1,2,2-Tetrachloroethane</td>
<td>34.9</td>
<td>25.6</td>
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<td>Toluene</td>
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<td>11.2</td>
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<td>Ammonia</td>
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<td>Lime Still</td>
<td>Carbon disulfide</td>
<td>3.37</td>
<td>2.07</td>
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<td>Bottoms</td>
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<td>31.5</td>
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</tr>
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<td>1,1,1-Trichloroethane</td>
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<td>76</td>
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<td></td>
<td>Benzene</td>
<td>61.3</td>
<td>26.8</td>
<td>44</td>
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<tr>
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<td>1,1,2,2-Tetrachloroethane</td>
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<td>Chlorobenzene</td>
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<td>17</td>
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<td>Ethylbenzene</td>
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<td>58</td>
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<td>Trichlorofluoromethane</td>
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<tr>
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<td>Acrylonitrile</td>
<td>29.4</td>
<td>34.8</td>
<td>118</td>
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</tbody>
</table>

%RSD Range = 17 - 144
Mean %RSD = 75

Note: Units = $\mu$g/L
Figure 1. Rotary Agitation Apparatus
Figure 2. Zero-Headspace Extractor (ZHE)
METHOD 1311
TOXICITY CHARACTERISTIC LEACHATE PROCEDURE

START

Use a
careful
even
sample

WHAT IS
the
% solids
in
the
waste?

< 0.5% 

Solid

¿

> 0.5% 

Extract

appropriate
fluid

1. Bottle extractor
for non-volatiles
2. LEC device for volatiles

Reduce
particle size
to < 0.5 mm

Examined

Hurt
the
solid
be
ealed?

Yes

No

Separate
leachate
from
solids
with
0.6
- 0.8 mm
fiberglass
filter

A

A

Reject
solids

Discard
solids
Procedure for Determination of Volume Reduction

1. Determine the bulk density of the initial sample.

2. Determine the apparent density of the final glass.

3. \( \text{volume reduction} = 100\% \times (1 - \frac{\text{initial density}}{\text{final density}}) \)
Procedure for Determination of Gamma Dose Rates of Vitrified Wastes

1. Record the approximate dimensions of the vitrified waste block.

2. Measure and record the gamma dose rate at contact, 25, and 50 cm from the melt crucible along the centerline.

3. Repeat step 2, except measure radially outward at the half height of the vitrified mass.
NUCLEAR WASTE GLASS PRODUCT CONSISTENCY TEST - VERSION 3.0 (U)

A durability test, designated for Product Consistency Test (PCT), has been developed for glasses produced in the Defense Waste Processing Facility (DWPF). The test is designed to meet the requirements of the Waste Acceptance Preliminary Specifications (WAPS) 1.3 and 1.4. Specification 1.3 requires the DWPF to demonstrate control of the radionuclide release properties of the final waste form. Changes in phase composition due to devitrification do not greatly alter the rate of release of material from the glass of the type that will be produced in DWPF. The WAPS Specification 1.4 however requires that the release properties of devitrified glass be similar to those determined in Specification 1.3. The DWPF is responsible for relating the results of the PCT to a repository site-specific release test, or alternatively, for performing the repository site-specific release tests.

The PCT has been developed, in part, to satisfy the WAPS requirements by providing a test which is (1) sensitive to glass composition and homogeneity, and (2) has the potential to be related to repository site-specific release tests. The test was designed to provide confirmation of the consistency of DWPF glass under the following considerations:

- Sensitivity of the test to glass composition and homogeneity
- Time necessary to demonstrate product quality
- Ease of sample preparation for radioactive glass
- Ease of test procedure for remote operation
- Precision of the test results
- Acceptance of waste form developers and repository projects

During PCT development, sample size was limited to 100-200 mesh (149-74 m) crushed glass because leaching of finer mesh sizes can cause overestimation of saturation concentrations, e.g., if finer powders are used, mass balance calculations need to be used to determine the maximum saturation concentration expected from a given particle size. Fine particles also contribute larger errors to the estimation of the sample surface area than coarser sized samples. Moreover, use of a coarser mesh crushed glass simplifies sample preparation for radioactive service.

One test temperature, 90°C, was chosen for the PCT. This temperature is representative of the anticipated temperature in a repository because of the heat of decay of the radionuclides in DWPF waste glass. A single leachant, American Society for Testing and Materials (ASTM) Type I water, was specified so that the test would be dominated by elemental species leached from the glass.

The $v_{solv}/m_{solid}$ ratio for the PCT was chosen as 10 mL/g and test durations of 1, 3, 7, 14, and 28 days were evaluated. Seven days was chosen as the minimum test duration that optimized test precision but did not sacrifice discrimination.
Leachate filtration to <0.45μm was determined to improve the precision of the PCT. Filtering is advantageous because it removes colloidal species that would otherwise dissolve during the leachate acidification step and erroneously be measured as soluble elemental species. Filtering the leachate also removes the potential for fine glass particulates to become entrained in the leachate acidification. Such a dissolved particulate of glass would give an erroneously high soluble leachate concentration or contribute excessive radioactivity to the leachate.

PCT sample preparation specifies that the sieved glass should be washed in ASTM Type I water and absolute ethyl alcohol to remove electrostatically adhering fine particles. Comparisons of B.E.T. specific surface area measurements of alcohol washed and unwashed crushed basalt demonstrated that there was less than a 5 percent difference in the total surface area. Other studies have demonstrated that the <1μm fine particles only affect the initial non-linear kinetics of dissolution, e.g. the first 24-hour period. Thereafter, the fines are consumed with no further effect on the bulk dissolution. The amount of fines adhering to a glass sample however, is an uncontrollable quantity and, hence, sample washing was included in the PCT. Later experimental studies verified that sample washing improved the precision and the accuracy of the PCT.

An Savannah River Laboratory (SRL) internal round robin and a seven-laboratory external round robin were completed to determine the precision and accuracy of the PCT. Confirmatory testing on radioactive samples was also performed. These studies indicated that the PCT was very reproducible, yielded reliable results rapidly, and could be easily performed in shielded cell facilities with radioactive samples.

This draft was submitted to ASTM subcommittee C25.13 on Repository Waste Package Materials Testing in January 1990.
REFERENCES


