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THE ADAPTABILITY OF VITRIFICATION TECHNOLOGY TO K-65 RESIDUE MATERIAL

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REPORT

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J. L. Buelt

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Pacific Northwest Laboratory
Richland, Washington

INTRODUCTION

This letter report describes the results of a study designed to determine the adaptability of vitrification technology to the stabilization and final disposal of K-65 residue material. K-65 residue materials are currently in storage at the Feeds Material Production Center near Fernald, Ohio. The vitrification technologies considered for this study include In Situ Vitrification and the joule-heated ceramic melter.

ISV is a thermal treatment process that converts contaminated residues, such as soils and sludges, into a durable product composed of glass and crystalline phases that appears similar to obsidian or basalt. Figure 1 illustrates how the process operates. A square array of four molybdenum and graphite electrodes is inserted into the material to be treated. Because the residue is not electrically conductive once the moisture has been driven off, a conductive mixture of graphite flakes and glass frit is placed in 5 by 5 cm trenches among the electrodes to act as a starter path. An electrical potential is applied to the electrodes, which establishes an electrical current in the starter path. The resultant power heats the starter path and surrounding soil up to 2000 C, which is well above the initial melting temperature of typical soils (i.e., 1100 to 1400 C). The graphite starter path is eventually consumed by oxidation, and the current is transferred to the vitrified residue, which becomes electrically conductive in the molten state. As the vitrified zone grows, it incorporates radionuclides and heavy metals and destroys organic components by pyrolysis. The pyrolized components migrate to the surface of the vitrified zone, where they oxidize in the presence of oxygen. A hood placed over the processing area confines and collects off gases which are cleaned in the process' transportable off gas treatment system.

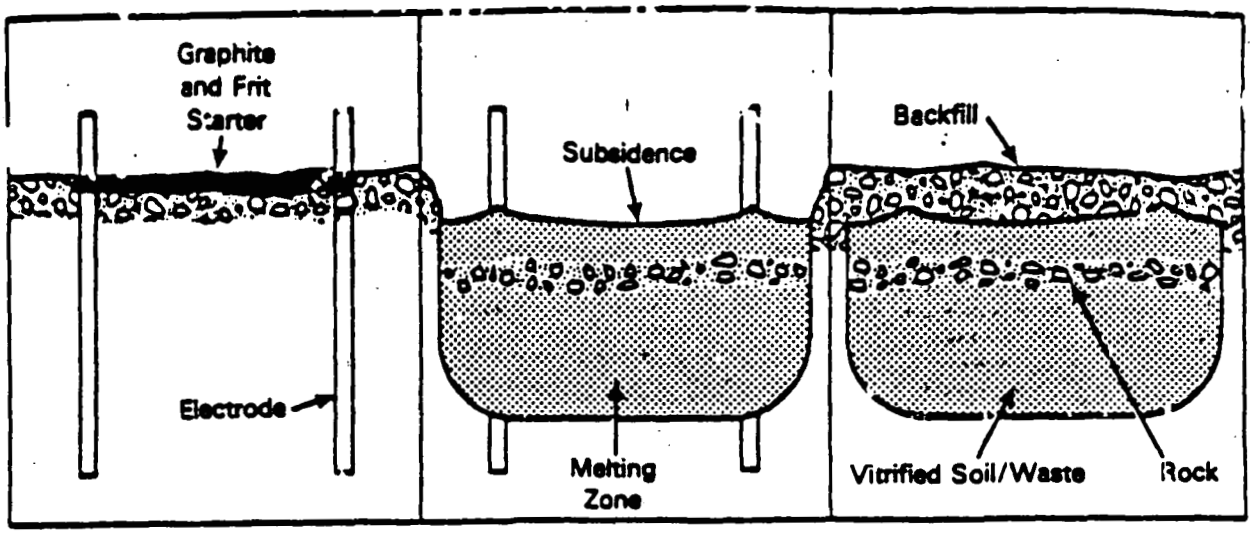

FIGURE 1. Operating Sequence of In Situ Vitrification

The joule-heated ceramic melter is a glass melting chamber lined with refractory ceramics. Residues to be vitrified are fed to the surface of a molten glass pool contained within the ceramic lining. The residues are dried and/or decomposed in the ceramic melter, which incorporates the radionuclides and heavy metals into a glass matrix. The molten glass is poured, continuously or periodically, into receiving containers. The final product can be poured in a variety of shapes and sizes, simplifying transport for final disposal.

To accomplish the purpose of this study, a sample of the K-65 residue was melted to determine its melting behavior. In addition, extraction procedure (EP) toxicity testing was performed on an untreated sample of the residue, and the chemical and radionuclide composition of the residue was determined. Based on the results of these analyses, the findings and conclusions of the adaptability of vitrification technology to the K-65 residues is presented.

ANALYTICAL RESULTS

The K-65 residue was analyzed for elemental composition by an inductively coupled plasma (ICP) technique. A sample of the residue was fused in KOH in a Ni crucible and another sample was fused in NaOH and Na_2O_2 in a Zr crucible. The solution of dissolved residue was then diluted for analyses, and the results were converted to wt% oxide values. Table 1 presents the analyses for each solution, the average values, and the concentrations normalized to a dry oxide

basis. The normalized values are the ones of importance for determining the adaptability of vitrification technology. In the vitrification process, the moisture is driven off and the solids in the residue are decomposed to their oxides. Therefore, the composition of the final product will be identical to the normalized concentrations.

When examining the results of the normalized oxide values, it is important to observe the relative abundance of glass formers, fluxes, and stabilizers. Glass formers provide the basic elements for a glass matrix and usually consist of silicon, boron, or phosphorous. Typical vitreous products range in silica composition from 45 to 90 wt%. The K-65 residues obviously fall within this range for a typical vitreous product. Fluxes are normally composed of first order family elements such as sodium or potassium. Ceramic melter glasses normally accommodate 5 to 20 wt% fluxes in the oxide form, whereas the ISV product accommodates materials in the 0.5 to 8 wt% range. The combined Na2O and K_2O concentrations of the K-65 residue is 3.0 wt%, ideal for the ISV product. Adapting the composition to the ceramic melter process would probably require the addition of fluxes to reduce the melting temperature to 1200 C, but this approach is commonly applied for most waste processing flowsheets involving the ceramic melter. The concentrations of stabilizers such as alumina and oxides of the second order family elements are much less crucial. They tend to reduce melt temperature while maintaining the leach resistance of the glass product. The combined concentrations of Al2O3, CaO, MgO, and BaO are 14.9 wt%. Except for Pb, all other elemental concentrations are typical of waste glasses.

The impact of the high lead content is evident in the EP toxicity data for the untreated K-65 residue given in Table 2. All other heavy metals on the EP toxicity list (As, Ba, Cd, Cr, Hg, Se, and Ag) are below the concentration limit for possessing toxic characteristics. The concentration of Pb, 630 mg/L, exceeds the toxicity limit of 5 mg/L. Once vitrified, however, past data shows that the glass and/or crystalline product will meet the criteria for EP toxicity. Past results for ISV products show that the EP toxicity limits have never been exceeded.

Table 1. Composition of K-65 Residues, wt%

	K/Ni	Na/Zr	Average	Normalize
Al2O3	3.07	3.14	3.11	3.66
B2O3	0.108	0.074	0.09	0.11
BaO	5.59	5.19	5.39	6.35
CaO	2.82	---	2.82	3.32
CeO2	0.28	0.31	0.30	0.35
Co2O3	0.27	0.26	0.27	0.31
Cr2O3	0.05	0.07	0.06	0.07
CuO	0.105	0.1	0.10	0.12
Fe2O3	3.46	4.03	3.75	4.41
K2O	---	0.86	0.86	1.01
La2O3	0.25	0.26	0.26	0.30
MgO	1.32	1.23	1.28	1.50
MnO2	0.034	0.032	0.03	0.04
MoO3	0.212	0.196	0.20	0.24
Na2O	1.6	---	1.60	1.89
Nd2O3	0.124	0.124	0.12	0.15
NiO	---	0.441	0.44	0.52
P2O5	0.67	0.61	0.64	0.75
PbO	9.15	8.55	8.85	10.43
SiO2	54.8	52.7	53.75	63.37
SrO	0.11	0.108	0.11	0.13
ThO2	0.07	0.05	0.06	0.07
TiO2	0.33	0.29	0.31	0.36
UO2	---	---	0.16	0.19
V2O3	0.13	0.125	0.13	0.15
Y2O3	0.011	0.011	0.01	0.01
ZrO2	0.146	0.146	0.15	0.17
Total			84.8	100

Table 2. EP Toxicity Data, mg/L

Element	Lower Limit	EP Tox Value
Ag	5	<.1
As	5	<1
Ba	100	0.76
Ca	--	820
Cd	1	0.1
Co	--	6
Cr	5	<.2
Cu	--	1
Hg	0.2	<.03
K	--	12
Mg	--	25
Mn	--	1.4
Na	--	307
Ni	--	8
Pb	5	630
Se	1	<.1
Si	--	55
Sr	--	7.3

Isotopic analyses of radium shows that, as expected, the predominant radium isotope is Ra-226. Whereas the concentration of Ra-226 was 0.262 uCi/g, Ra-224 and Ra-228 were nondetectable at $<3.0 \times 10^{-4}$ and $<1.3 \times 10^{-3}$ uCi/g respectively.

MELTING BEHAVIOR

A 70-g sample of the K-65 residue was melted in a furnace in a crucible to determine its melting characteristics. The compositional analyses showed that the composition was fairly typical for soils normally processed by ISV, which generally operates at 1400 to 1800 C. However, the flux concentration was lower than that generally needed for the 1200 C ceramic melter. Consequently a melting temperature of 1400 to 1800 C was expected from the compositional analyses. Results showed that the residue melted uniformly at 1525 C at a viscosity of about 1000 P. Normally, vitrification processes operate at approximately 100 P. Therefore, based on the crucible melt studies results and the relationship of viscosity with temperature for similar compositions, the operating temperature of the residue would be expected to be 1800 C. Of course if the ceramic melter is utilized, it is a simple matter to add a small amount of fluxes and stabilizers to reduce the operating temperature to 1200 C without significantly sacrificing product quality.

CONCLUSIONS REGARDING THE APPLICABILITY OF VITRIFICATION TO K-65 RESIDUE

The results of the preliminary treatability studies of K-65 residue indicates that vitrification technology is highly adaptable to the final treatment and disposal of this material. The residue contains the appropriate constituents necessary for forming a glass and/or crystalline product. The radionuclides that exist with the residue are common constituents for waste glasses. Radium, thorium, and uranium would be retained within the glass product. Past studies have shown that between 99.9 and 99.999 wt% of these radionuclides are retained in the ISV glass product. The remainder is scrubbed out by the off gas system. Past studies have also shown that after vitrification, radon emanation can be expected to be reduced by more than a factor of 1000. The off gas system would be designed to adsorb the radon that is released from residue during vitrification. The retention of lead is

expected to be in excess of 99 wt%, particularly with recycle of the off-gas scrub material.

The decision regarding the choice of ISV or the ceramic melter should be based on the overall costs for treatment and the conformance of the final waste form to transportation and disposal criteria. The costs for vitrification by ISV or the ceramic melter would favor ISV unless in situ disposal is not acceptable. For offsite disposal, the ceramic melter would be more favored. Thus, the process selection depends on transportation and disposal criteria.

ISV is normally applied for in-place treatment and disposal. Since the K-65 residues are contained in silos, they would be either treated within the silos or removed and staged in another location for treatment. In-place treatment would result in the vitrification of the silo walls and floor. Because of the high activity levels of the residues, preparations beyond those normally required for ISV will be necessary. Use of a soil layer to reduce surface dose or remote methods of electrode insertion, starter path placement, and off gas hood placement would likely be required. While these activities are readily achievable, the glass and crystalline product left below grade may need to be retrieved for disposal. Due to the large size of the solidified waste, dust control and other activities are greatly simplified. Excavation activities for disposal and packaging could be initiated about a year after treatment to allow the vitrified material to cool.

If the residues can be economically removed from the silos for treatment, and the off-site waste disposal is needed, the ceramic melter affords a more versatile physical shape of vitrified material. The residues may be vitrified continuously as they are removed. They can be formed to any reasonably desired shape for shipment and disposal. The ISV product could be excavated and packaged for disposal, but would require remote handling methods of large monolithic waste forms. Consequently, if off-site disposal is required, the ceramic melter affords greater versatility. A more detailed comparison of costs and logistics is recommended prior to implementing either option.