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**TALC-SILICON GLASS-CERAMIC WASTE FORMS
FOR IMMOBILIZATION OF HIGH LEVEL
CALCINED WASTE**

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**TALC-SILICON GLASS-CERAMIC WASTE FORMS FOR IMMOBILIZATION
OF HIGH LEVEL CALCINED WASTE***

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ABSTRACT

Talc-silicon glass-ceramic waste forms are being evaluated as candidates for immobilization of the high level calcined waste stored onsite at the Idaho Chemical Processing Plant. These glass-ceramic waste forms were prepared by hot isostatically pressing a mixture of simulated nonradioactive high level calcined waste, talc, silicon and aluminum metal additives. The waste forms were characterized for density, chemical durability, and glass and crystalline phase compositions. The results indicate improved density and chemical durability as the silicon content is increased.

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INTRODUCTION

Since 1963 the high-level liquid waste generated at the Idaho Chemical Processing Plant (ICPP) is routinely solidified into granular calcined high level waste (HLW). Currently experimental glass-ceramic waste forms are being developed at ICPP for immobilization of the HLW that is stored onsite. A glass-ceramic waste form is a promising option because it can potentially reduce HLW volume significantly compared to glass waste forms while maintaining similar leach rates.¹⁻⁵ One of the waste forms that is being developed is a talc-silicon glass-ceramic form consisting of crystalline phases in a glassy matrix that is prepared by hot isostatically pressing (HIPing) a precompacted mixture of calcine (70 wt%), talc (28-23 wt%), silicon 3-5 wt% and aluminum 2 wt%. In this report the experimental waste form characteristics of density, chemical durability, and microstructure are discussed.

EXPERIMENTAL PROCEDURE

This section describes the development of glass-ceramic formulations, the preparation of glass-ceramic forms by hot isostatic pressing (HIPing), and characterization of these waste forms. Characterization techniques include density measurements, Materials Characterization Center (MCC-1) 14-day leach tests⁶ at 90 °C in deionized water, scanning electron microscope (SEM) analysis with the associated energy dispersive spectroscopy (EDS), and X-ray diffraction analysis (XRD).

The calcined waste at ICPP consists of a large variety of chemical components depending on the composition of the High-Level Liquid Waste (HLLW) formed from processing of different fuels. The composition of one of the calcines, which simulates a recently prepared Fluorinel-sodium blend calcine, is presented in Table I. Thus in this report the research work performed to develop one of the waste forms for Fluorinel-sodium calcine is discussed. While the components Al_2O_3 , B_2O_3 , CaO , CdO , CeO_2 , Cr_2O_3 , Cs_2O , Fe_2O_3 , K_2O , Na_2O , and SrO , could possibly be accommodated in the silicate glass phase, the major components CaF_2 and ZrO_2 form crystalline phases. Additives talc (SiO_2 66.4 wt%, MgO 33.4 wt%), Si and Al metal powders are added to the calcine to produce the desired glass and ceramic host phases. The nominal compositions of the glass-ceramic formulations are presented in Table II.

Glass-Ceramic Formulation

Candidate experimental glass-ceramic waste formulations were estimated using a spreadsheet computer program.^{7,8} The program calculates the glass phase composition, the glass phase empirical quality ratios and 28- and, 14-day MCC-1 normalized elemental leach rates for Si, assuming a free energy of hydration model.⁹ Assumptions were made in the spreadsheet about the glass phase compositions that are expected to be present in the resulting glass-ceramic form.

TABLE I
Chemical Composition of Simulated
Fluorinel-Sodium Calcine

Component	Simulated Calcine (wt %)
Al ₂ O ₃	8.3
B ₂ O ₃	4.4
CaF ₂	35.1
CaO	11.5
CdO	3.9
CeO ₂	1.1
Cl ¹⁻	0.2
Cr ₂ O ₃	1.2
Cs ₂ O	0.1
Fe ₂ O ₃	0.3
K ₂ O	1.7
Na ₂ O	5.3
SeO	0.2
SrO	0.6
ZrO ₂	16.9
SO ₄ ³⁻	0.2
Misc.	9.0
Total	100.0

TABLE II
Nominal Composition of Talc-Si Glass-Ceramic Waste Forms (wt%)

Component	Waste Form			
	Talc0Si	Talc3Si	Talc4Si	Talc5Si
Calcine	70.0	70.0	70.0	70.0
Talc	28.0	25.0	24.0	23.0
Silicon	0.0	3.0	4.0	5.0
Aluminum	2.0	2.0	2.0	2.0

The elements Ca, Cd, Cr, Mg, Sr, Al, Zr, F, O, and Si were assumed to be distributed in both glass and crystalline phases. The compositions of the additives talc, Si and Al in each formulation were adjusted to meet the empirical glass-phase quality criteria: wt% of alkali oxides/wt% of B_2O_3 = 1.0-2.5, wt% of SiO_2 /(wt% of alkali oxides + B_2O_3) = 2.0-3.5, wt% of Al_2O_3 + SiO_2 /wt% of amorphous product = 0.5-0.67, and wt% of Al_2O_3 /wt% of alkali oxides < 1.6. The resulting predicted nominal compositions of the formulations are presented in Table III. All the listed formulations were prepared at 70 wt% calcine loading, 2 wt% Al, and varying amounts of talc and Si.

Glass-Ceramic Form Preparation

Prior to mixing of the components shown in Table II, the simulated calcine was heat-treated in air at 600 °C for 30 hours to remove volatile species. The additive talc was heat treated for 4 hours at 1200 °C, then mixed with the heat-treated, ground (< 180 microns) calcine and the reactants Si and Al. The mixture was precompacted at 34.5 MPa (5000 psi) into a 2.54 cm (1 inch) OD, 7.62 cm (3 inches) high 304 stainless steel can, evacuated to < 100 millitorr, and sealed by welding.

TABLE III

Nominal Chemical Composition of Talc-Si Glass-Ceramic
Waste Forms (wt%).

Component	Waste Form			
	Talc0Si	Talc3Si	Talc4Si	Talc5Si
Al ₂ O ₃	8.4	8.1	8.0	8.0
B ₂ O ₃	3.1	3.0	2.9	2.9
CaF ₂	24.4	23.6	23.4	23.1
CaO	8.0	7.7	7.6	7.5
CdO	2.8	2.7	2.6	2.6
CeO ₂	0.7	0.7	0.7	0.7
Cl ¹⁻	0.2	0.1	0.1	0.1
Cr ₂ O ₃	0.8	0.8	0.8	0.8
Cs ₂ O	0.1	0.1	0.1	0.1
Fe ₂ O ₃	0.2	0.2	0.2	0.2
K ₂ O	1.2	1.1	1.1	1.1
MgO	9.9	8.9	8.1	7.7
Na ₂ O	3.7	3.6	3.5	3.5
SeO	0.2	0.2	0.1	0.1
SiO ₂	18.0	21.7	22.9	24.0
SO ₄ ³⁻	0.2	0.2	0.1	0.1
SrO	0.4	0.4	0.4	0.4
ZrO ₂	11.7	11.4	11.2	11.1
Misc.	6.0	5.5	6.2	6.1
Total	100.0	100.0	100.0	100.0

Glass-ceramic forms of 70 wt% calcine loading with 0-5 wt% Si were formed by hot isostatic pressing (HIPing) at 1050 °C, 138 MPa (20,000 psi) for 4 hours. The formulation with 5 wt% Si was also HIPed at the same temperature of 1050 °C and pressure of 138 MPa for HIP soak times of 8, 16 and 24 hours. The heat-up and cool-down rates were 1.5 and 1.3 hours, respectively, with rates of temperature changes of 10.5 °C/minute. After HIPing, the outer stainless steel cladding was removed and samples were prepared for characterization.

Glass-Ceramic Form Characterization

The Talc-Si waste forms were characterized by gas displacement density measurements, 14-day MCC-1 leach tests for total and normalized elemental leach rates, SEM/EDS analysis for microstructure and glass phase composition, and X-ray diffraction analysis for crystalline phases.

Density Measurements

A portion of each glass-ceramic form was sectioned into small (surface area = about 400 mm²) monoliths and polished using 320 grit silicon carbide. The sample density was measured using a AccuPyc 1330 Pycnometer.

MCC-1 Static Leach Test

The glass-ceramic monoliths with a surface to volume ratio of 10 m^{-1} were subjected to the MCC-1 static leach test in deionized water at 90°C for 14 days. After the 14-day leach test, the monoliths were removed, dried at 100°C and then weighed. The sample weights before and after the leach test were used to calculate the total mass loss rates in $\text{g/m}^2\text{-day}$, using the formula:

Total mass loss rate (TMLR)

$$= (m_i - m_f) / (t * A_s),$$

where, m_i and m_f , are the initial and final masses (before and after the leach test), respectively of the monoliths in grams, A_s is the surface area of the monolith in square meters, and t is the leach time in days. The leachates were acidified with concentrated nitric acid to pH 2 and then analyzed for chemical composition by inductively coupled plasma atomic emission spectroscopy (ICP) for Al, B, Ca, Cd, Cr, Sr, Si, Mg, and Zr, and by atomic emission spectroscopy (AES) for Cs, Na and K. The results of the elemental analyses were converted to normalized elemental leach rates using the following formula:

The normalized elemental leach rate L_i for the i th element is given by:

$$L_i = C_i * V_i / (A_s * t * f_i),$$

where, C_i is the concentration of the i th element in the leachate in grams/cc, V_i is the volume of the leachate in cc, A_s is the surface area in square meters, t is the leaching time in days, and f_i is the mass fraction of the i th element in the monolith.

Glass and Crystalline Phase Composition

The glass phase composition was determined from the results of SEM/EDS analysis. Several ASTM standards including CaF_2 , ZrO_2 , Al_2O_3 , CaO , SiO_2 , ZrSiO_4 , cadmium sulfide were used for quantitative analysis. Back scattered electron images at 200-2000 X were taken. Glass phase composition was obtained by measuring the elemental composition.

Crystalline Phase Determination Using the X-ray Diffraction Analysis.

Powder XRD analysis was performed on all of the glass-ceramic forms prepared for this study to identify the crystalline phases present. Samples of each glass-ceramic form were ground to finer than 100 mesh for powder XRD.

The powder samples were analyzed with a Phillips XRG-3000 Diffractometer using the copper K-alpha radiation by scanning from diffraction angles of $8-75^{\circ}$ at 2° per minute. A diffraction pattern of intensity versus diffraction angle for each sample was printed on a strip-chart. Then crystal plane spacings were determined using the Bragg's law. The X-ray spectra were indexed using Joint Committee on Powder Diffraction Standards (JCPDS) cards to identify the phases present. The microcomputer software Powder Diffraction Search/Match System was used to identify the crystalline phases present in the glass-ceramic forms. The program is run in an interactive mode so that the operator can choose between nearly identical matches of phases based on previous knowledge about the glass-ceramic sample. Relative abundance of each crystalline phase was estimated based on the intensity of prominent peaks in the spectrum.

RESULTS AND DISCUSSION

The densities of the talc waste forms Talc0Si-Talc5Si decreased from 3.25 to 3.21 g/cm³ as the Si metal content increased from 0 to 5 wt%. The densities for the Talc5Si waste form reached the equilibrium level of 3.23 g/cc at about 8 hours of the HIP soaking time. These densities are relatively higher compared to 3.0 g/cm³ for alumino-boro-silicate glass-ceramic waste forms that are being developed at ICPP⁵.

The higher densities are due to the addition of talc that contains 33.4 wt% MgO. The increased density is a potential cost incentive for immobilization of the high level calcined waste at ICPP.

Silicon and aluminum metal powders were introduced as reducing additives in the preparation of the talc waste forms Talc0Si, Talc3Si, Talc4Si, and Talc5Si in which the Si concentration was varied from 0 to 5 wt%, respectively. Talc, $\text{Mg}_3\text{Si}_4\text{O}_{10}(\text{OH})_2$ is composed of layered structure¹⁰. The monolith sample from Talc0Si with no Si additive subjected to the 14-day MCC-1 leach test crumbled into a flakey heap, presumably due to its weak Van der Waal bonding between layers. However, when silicon metal was added 3-5 wt% to the formulation, it appears that the strength of the waste form was increased and it remained intact during leach testing. The total mass loss and normalized elemental leach rates for most of the elements (See Table IV) decreased as the Si content increased. The normalized elemental leach rates for B, Ca, Cd, Cr, Si, Sr and Mg are below, and for Al, Cs, K, Na, Se are above 1 g/m²-day for the waste forms Talc4Si and Talc5Si.

The glass phase compositions of the talc waste forms are given in Table V. Talc decomposes into enstatite (MgSiO_3), quartz (SiO_2), forsterite ($2\text{MgO} \cdot \text{SiO}_2$), and periclase (MgO) at temperatures greater than 750 °C¹⁰. The general compositional areas for $\text{MgO-SiO}_2\text{-CaO}$ and $\text{MgO-Al}_2\text{O}_3\text{-SiO}_2$ systems^{11,12,13} are given in the ternary phase diagrams

TABLE IV
14-day MCC-1 Leach Rates (g/m²-day)

Talc-Si Waste Form							
	TalcOSi (4 hr)	Talc3Si (4 hr)	Talc4Si (4 hr)	Talc5Si (4 hr)	Talc5Si (8 hr)	Talc5Si (16 hr)	Talc5Si (24 hr)
<u>Total Mass Loss Rate</u>							
	2.5	1.1	0.5	0.4	0.9	0.9	1.0
<u>Normalized Elemental Leach Rates</u>							
Element							
Al	1.7	1.9	1.5	1.5	1.2	1.3	1.4
B	124.9	1.4	0.0	0.01	0.03	0.03	0.03
Ca	0.2	1.1	0.7	0.6	2.2	2.1	2.2
Cd	0.01	0.01	0.01	0.01	0.02	0.02	0.02
Cr	a	a	a	a	0.07	0.09	0.07
Cs	26.1	8.3	5.4	4.5	20.5	19.1	20.1
K	13.5	2.9	2.1	1.3	1.2	1.0	1.5
Mg	0.07	0.0	0.02	0.03	0.01	0.01	0.01
Na	133.2	28.4	14.6	8.7	11.8	9.9	13.5
Se	2.3	18.6	8.8	4.1	b	b	b
Si	0.7	0.7	0.7	0.7	0.5	0.6	0.6
Sr	a	a	a	a	0.8	0.8	0.8

^aNot detected.

^bNot analyzed.

TABLE V
Glass Phase Composition (wt%)

Component	Talc-Si Waste Form					
	Talc0Si (4 hr)	Talc3Si (4 hr)	Talc4Si (4 hr)	Talc5Si (4 hr)	Talc5Si (8 hr)	Talc5Si (24 hr)
Al ₂ O ₃	28.9	17.1	17.8	16.8	22.0	23.0
B ₂ O ₃ ^a	7.1	7.5	7.4	6.8	8.6	9.1
CaF ₂ ^b	4.5	4.7	4.7	4.3	19.3	20.6
CaO	2.1	0.0	0.0	0.0	0.0	0.0
CdO	0.0	0.0	0.0	0.0	0.3	0.0
CeO ₂	0.0	0.0	0.0	0.0	0.1	0.1
Cr ₂ O ₃	0.2	0.0	0.0	0.0	0.0	0.0
Cs ₂ O	0.0	0.0	0.0	0.0	0.1	0.2
FeO	0.6	0.5	0.0	0.0	0.0	0.0
K ₂ O	3.6	3.6	2.4	6.1	3.0	5.1
MgO	0.0	16.4	17.2	16.5	17.7	16.2
Na ₂ O	6.7	2.0	1.7	1.0	2.8	2.0
SiO ₂	46.1	48.0	48.8	47.5	24.6	22.6
SeO	0.0	0.0	0.0	0.0	0.0	0.0
SrO	0.0	0.0	0.0	0.0	1.3	0.9
ZrO ₂	0.2	0.0	0.0	0.9	0.2	0.2
Total	100.0	100.0	100.0	100.0	100.0	100.0

MgO-SiO₂-Al₂O₃ System for 4-24 hr Waste Forms

	Talc0Si (4 hr)	Talc3Si (4 hr)	Talc4Si (4 hr)	Talc5Si (4 hr)	Talc5Si (8 hr)	Talc5Si (24 hr)
MgO	0.0	20.1	20.6	20.4	27.6	26.2
SiO ₂	61.4	58.8	58.2	58.8	38.2	36.5
Al ₂ O ₃	38.6	21.1	21.2	20.8	34.2	37.3

MgO-SiO₂-CaO System for 4-24 hr Waste Forms

	Talc0Si (4 hr)	Talc3Si (4 hr)	Talc4Si (4 hr)	Talc5Si (4 hr)	Talc5Si (8 hr)	Talc5Si (24 hr)
MgO	0.0	22.4	24.6	25.8	41.9	41.8
SiO ₂	95.7	65.5	69.7	74.2	58.1	58.2
CaO	4.3	0.0	0.0	0.0	0.0	0.0

^a Estimated assuming that the total glass content is about 40 wt%.

^b Estimated assuming 5 wt% in the glass phase.

(Figures 1, 2). In the CaO-MgO-SiO₂ system, the glass phase compositions for the waste forms Talc3Si, Talc4Si and Talc5Si are MgO 22-26 wt%, SiO₂ 66-74 wt%, and CaO 0 wt%, respectively. Glass-ceramic materials of the type MgO-Al₂O₃-SiO₂ can be prepared from compositions falling within the range of Al₂O₃ 10-30 wt%, SiO₂ 40-65 wt%, and MgO 10-35 wt%.¹⁴ In the MgO-Al₂O₃-SiO₂ system, the glass phases for these three waste forms are in the stability field for cordierite (2MgO.2Al₂O₃.5SiO₂). The glass phase compositions lie in the compatibility triangle for cordierite, enstatite, and silica. The estimated glass phase compositions for cordierite, enstatite, and silica are 68, 28, 4 wt%, and 65, 25, 10 wt%, for 4 hour Talc3Si and 4 hour Talc5Si waste forms, respectively. Although the phase diagram for the MgO-Al₂O₃-SiO₂ system indicate that temperatures greater than 1400 °C are required for cordierite glass phase, the high temperature cordierite glass phase appear to be achieved at the HIPing temperature of 1050 °C at 20,000 psi. However, no stoichiometric cordierite crystals were identified in the 4 and 24 hour waste forms by XRD, indicating that the crystallization is sluggish. For the waste form Talc0Si, no MgO was detected in the glass phase (see Figure 1), and it appears that the compositions of SiO₂, Al₂O₃, or SiO₂, CaO are outside the regions of stability fields discussed above. This consistently indicates that the waste forms Talc3Si, Talc4Si, and Talc5Si are relatively more durable than the waste form Talc0Si. The dehydrated talc composition is shown at the bottom of the phase diagram Fig.2. The MgO-SiO₂-CaO, or MgO-Al₂O₃-SiO₂ glass-ceramics are easily formed from talc because, the talc is fine grained and platy, and consequently plastic and non abrasive.

Figure 1. Glass phase compositions in the ternary system CaO-MgO-SiO₂.

Figure 2. Glass phase compositions in the ternary system $\text{MgO}-\text{Al}_2\text{O}_3-\text{SiO}_2$.

These glass-ceramic forms have high electrical resistivity, high mechanical strength and low thermal expansion coefficient. Any mismatch in thermal expansion coefficient between crystalline phase and residual glass phase is small. Hence, microstresses within the glass-ceramic can be relatively small¹⁴. The glass phase composition for Talc5Si remained essentially constant at 8 and 24 hours of HIP soak time which is consistent with the constant density reached at 8 and 24 hours.

The SEM micrographs at 200 X in Figure 3(a,b,c,d) consist of white, gray and dark regions. The white areas are ZrO_2 crystal grains that are uniformly distributed in Figure 3(a) for Talc-0Si waste form, and for other three waste forms the grains are distributed in patchy regions. The gray areas are essentially CaO , Al_2O_3 , and ZrO_2 rich regions and the dark areas are glassy regions. The micrograph at higher magnification (2000 X) in Figure 4(a) shows crystals in the glass region of Talc0Si waste form. As the Si content increased in the formulation, the glass regions for Talc3Si-Talc5Si waste forms in Figures 4(b)-(4d) appear to be increasingly devoid of crystalline grains. It appears from these micrographs that the viscosity of Talc-0Si glass is relatively low compared to that of Talc3Si-Talc5Si waste forms. Possibly, the impediment in crystal growth has been caused by increase in the viscosity of the glass phase in Talc3Si-Talc5Si waste forms. The microstructure for Talc5Si waste form HIPed for soak times of 8 and 24 hrs showed essentially similar structure.

(a) Glass Ceramic Waste Form Talc0Si

(b) Glass Ceramic Waste Form Talc3Si

Figure 3. Backscattered SEM micrographs at 200 X for the Talc-Si waste forms.

(c) Glass Ceramic Waste Form Talc4Si

(d) Glass Ceramic Waste Form Talc5Si

Figure 3. (Continued) Backscattered SEM micrographs at 200 X for the Talc-Si waste forms.

(a) Glass-Ceramic Waste Form Talc0Si

(b) Glass-Ceramic Waste Form Talc3Si

Figure 4. Backscattered SEM micrographs at 2000 X for the Talc-Si waste forms.

(c) Glass Ceramic Waste Form Tale4Si

(d) Glass Ceramic Waste Form Tale5Si

Figure 4. (Continued) Backscattered SEM micrographs at 2000 X
for the Tale-Si waste forms.

It appears that the glass in Talc3Si-Talc5Si waste forms is a high temperature glass phase which is consistent with the high temperature glass phases discussed earlier. However, the glass phase consists of B_2O_3 at about 9 wt% and which may have reduced the glass melting temperature below or equal to the HIPing temperature of 1050 °C. No significant microstructural differences were noticed between the Talc5Si waste forms that were HIPed for 8 and 24 hours.

The X-ray diffraction results in Table VI show the presence of aluminum, calcium, sodium and magnesium silicates including, $Ca_4Si_2O_7F_2$, $Ca_3ZrSi_2O_9$, $CaMg(SiO_3)_2$, $NaAlSiO_4$ (nepheline), and $MgSiO_3$ (enstatite) in varying proportions with Si addition. The X-ray results also indicate increases in the abundance of CaF_2 with increase in Si content. A decrease in ZrO_2 content in Talc4Si and Talc5Si appear to complement the increased $Ca_3ZrSi_2O_9$ trend as a function of Si additions. The crystalline phases appear to be durable except $NaAlSiO_4$. The abundance of crystalline $NaAlSiO_4$ must have caused the high normalized Na release rates in these Talc waste forms.

The SEM/EDS analysis indicates that the calcine is partitioned such that the components ZrO_2 , CaF_2 , CdO and Cr_2O_3 are preferably excluded from the glass phase in favor of the accommodation of the calcine components in the $MgO-Al_2O_3-SiO_2$ and/or $MgO-CaO-SiO_2$ network, irrespective of the additive Si. However, for Talc5Si waste form HIPed for 8 and 24 hours showed increased amounts of CaF_2 in the glass phase.

TABLE VI

XRD Crystalline phase composition (Relative abundance in wt%)

Component	Talc-Si Waste Form			
	TalcOSi (4 hr)	Talc3Si (4 hr)	Talc4Si (4 hr)	Talc5Si (4 hr)
CaF ₂	20.9	23.9	24.5	42.1
ZrO ₂	31.5	37.9	28.7	14.3
MgSiO ₃	13.8	11.2	a	a
CaMg(SiO ₃) ₂	a	a	a	11.8
NaAlSiO ₄	8.1	8.3	13.1	8.4
Ca ₄ Si ₂ O ₇ F ₂	12.1	18.7	18.7	12.4
Ca ₃ ZrSi ₂ O ₉	10.3	a	15.0	10.9
Mg _{3.5} Al ₉ Si _{1.5} O ₂₀	3.3	a	a	a

*Not identified

The variations in minor elements, however, appear to depend on composition and the extent of equilibration between the phases of glass and crystals. The normalized elemental leach rates for Cr and Sr are below the detection limit as Si content increased, and none of these components are detected in the glass phase indicating that the crystalline phases of Cr and Sr are highly durable. A similar trend is inferred for Cd.

PRINCIPAL OBSERVATIONS AND CONCLUSIONS

It appears that talc forms a more durable waste form with the calcine when Si and Al reactants are added. Although the phase diagram for the $\text{MgO-Al}_2\text{O}_3\text{-SiO}_2$ system indicate that temperatures greater than 1400 °C are required for cordierite glass phase, the high temperature cordierite glass phase appear to be achieved at the HIPing temperature of 1050 °C at 20,000 psi. The densities of the talc glass-ceramic waste forms are significantly higher than the alumino-silicate glass-ceramics which is a cost incentive for immobilization of the calcine waste. The TMLR and normalized elemental leach rates for B, Ca, Cd, Cr, Si, Sr and Mg are all less than 1 g/m²-day for the glass-ceramics Talc4Si and Talc5Si. However, the leach rates for Al, K, Se and Na are high. The total and normalized elemental leach rates and density for the waste form Talc5Si reached equilibrium level at about 8 hours of the HIPing time. It appears that the Talc5Si waste form is a potential experimental candidate for immobilization of the fluorinel-sodium calcine waste stored onsite at ICPP, if the normalized leach rates for Al, K, Se and Na can be reduced, possibly by optimizing the HIPing parameters of temperature and pressure and/or introducing appropriate reactants to vary the formulation.

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