23. E. J. Bonano, M. S. Y. Chu, S. H. Conrad (SANDIA) and P. T. Dickmann (DOE-NEV), "The Disposal of Orphan Wastes Using the Greater Confinement Disposal Facility", Waste Management '91, Vol. 1, Post & Wacker Eds., pp. 861-868.

24. T. A. Baer, N. E. Olague, L. L. Price, and S. H. Conrad, "Results From The Second Performance Assessment Iteration for the Greater Confinement Disposal Facility", doc. # SAND93-0088C, paper Presented at the 1993, International HLW Radioactive Waste Management Conference, Las Vegas, NV, April 26-30, 1993.]

25. R. W. Benedict et. al., *Radwaste Magazine*, July 1998, pp. 23-28.

26. C. M. Jantzen et. al., "Characterization of the Defense Waste Processing Facility (DWPF) Environmental Assessment (EA) Glass Standard Reference Material", doc. WSRC-TR-92-346, Rev 1, June 1, 1993.

27. Shi-Ben Xing and Ian L. Pegg, "Effects of Container Materials on PCT Leach Test Results for High-Level Nuclear Waste Glasses", *Mat. Res. Soc. Symp. Proc. Vol. 333*, pp. 557-564, 1994 (Scientific Basis for Nuclear Waste Management XVII)

28. "Lea's Chemistry of Cement and Concrete, 4th Edition", Peter Hewitt, Ed., ARNOLD Pub. Co. London, 1998, p.p. 458-459. Se also: J.Davidovits, D. C. Comrie, J. H. Patterson, and D. J. Ritcey, "Geopolymeric Concretes for Environmental Protection", *Concrete International*, 12:30-39, 1990.

29. J.K. Rawlins, "Feasibility Study Report for Calcine Hydroceramic Facility", doc. INEEL/INT-98-00798, Sept. 1998 (an "internal" document produced for an upcoming INEEL HLW Environmental Impact Statement).

30. Fluor-Daniel, Inc., "High Level Liquid Waste Alternative Approach Evaluation", DOE Delivery Order DE-ADO7-97ID60034, November, 1996.

31. "INEL Chemist Advises That High Level Waste be Cement, Not Glass", Idaho State Journal (Pocatello), p. A-3, November 20, 1996.

32. D. D. Siemer, "Hot Isostatically Pressed Concrete as a Radwaste Form", *Advances in Ceramics, Volume 61, Ceramics Transactions*, pp. 657-664, (Proceedings of 1995 American Ceramics Society Symposium on Waste Management, Cincinnati, OH, April 29 - May 4, 1995)

33. D. D. Siemer, B. E. Scheetz, and M. L. D. Gougar, "Hot Isostatic Press (HIP) Vitrification of Radwaste Concretes", *Materials Res. Soc. Symp.* Vol. 412, 1996, pp. 403-410.

34. Federal Register/Vol.57, No. 101, Tuesday, May 26, 1992, pp. 22046-22047. (discusses BDAT status of HIPing ICPP-type HLW)

35. "Alternative High level Waste Treatments at the Idaho National Engineering and Environmental Laboratory", National Academy Press, Washington D. C., 1999.

Figure 1

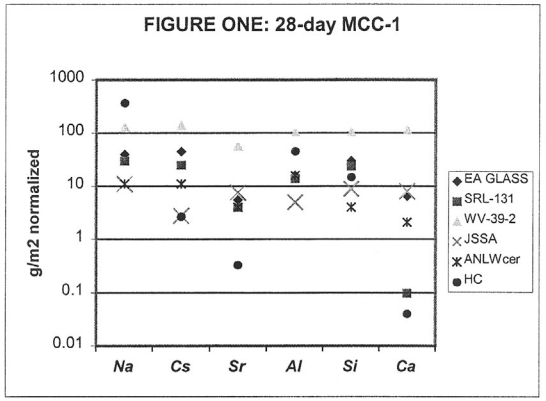

Table I: ANS/ANSI 16.1 Leach Performance*

Interval	Sodium		Cesium		Zirconium		Strontium		Chromium		NO_3^-	
(hrs)	ppm	-logD	ppb	-logD	ppb	-logD	ppb	-logD	ppm	-logD	ppm	-logD
2.83	32	9.55	<2	>13.8	33	15.3	3	14.1	0.28	10.6	23	8.3
5.7	20	9.7	<2	>13.5	68	14.4	2	14.1	0.21	10.6	5	9.3
15.3	28	9.8	<2	>13.9	140	14.1	7	13.5	0.076	11.8	2.3	10.4
19.5	13	10.3	<2	>13.7	<10	>16.3	1	15.0	0.05	11.1	0.9	11.1
22	22	9.8	<2	>13.9	100	14.2	6	13.4	0.03	12.4	1	10.9
35.8	21	10.1	<2	>13.5	<10	>16.4	1	15.2	0.02	13.0	1	11.1
25.5	15	9.9	<2	>13.7	<10	>16.0	3	14.2	0.02	12.6	0.4	11.5
36	14	10.2	<2	>13.7	<10	>16.2	1	14.9	0.01	13.4	0.9	11.0
LI	9.9		13.7		>15.4		14.3		12.0		10.4	
Total % Leached	8.26		<0.0099		<0.0025		0.015		1.2		10.5	

the <> figures in this table are based upon detection capabilities of the analytical instrumentation: ICPAES for all metals except Cs, graphite furnace AAS for Cs, and ion chromatography for nitrate

Table II: Comparison of HCs and glasses on the PCT test

MATERIAL	% Na_2O	mg/l Na in leachate	% Na dissolved
EA GLASS	16.9	1720	13.7
PUREX GLASS	12.1	941	10.4
SRL-131	12.9	931	9.7
HC#1 $NaAlO_2$/NaOH/TROY clay	16.7	718	5.8
HC#2 NaOH, $NaNO_3$ (25% of Na)/TROY clay	12.6	513	5.5 (2.6% of the NO_3 had also leached)
HC#3 38% alumina calcine/NaOH/DEA/TROY clay	13.1	554	5.7
HC#4 46% zirconia calcine/NaOH/TROY clay	12.4	558	6.1
HC#5 30% sugar-calcined SBW/TROY clay*	12.6	925	9.9
HC#6 NaOH/ Englehard Metakaolinite, 9-hr cure @ 200 °C	16.3	229	1.9 (ANSI 16.1 LI_{Na} = 11.6)

*This particular HC violated the "sodalite composition" rule of thumb - too much carbonate

TABLE III: TCLP Results: Sugar-calcined "sodium bearing waste" specimen

Analyte	Found(ug/g)	Limit (ug/g)	Calcine (ug/g)
As	<0.002	5	10.8
Ba	0.35	100	48
Cd	0.13	1	1372
Cr	0.023	5	950
Hg	<0.01	0.2	<0.01*
Pb	<0.1	5	1500
Se	<0.002	1	6.9
Ag	<0.1	5	1510

* Mercury was not added to the liquid simulant because it would have been lost during subsequent calcination. In a properly-implemented real radwaste calcination system, mercury would be recovered from the offgas.

TABLE IV: PCT* leachability of geopolymeric vs hydroceramic concretes

	Hydroceramic	Geopolymer	Geopolymer	Geopolymer
Cure Conditions	200°C, 2 hours	200°C, 2 hours	90°C, 4 days	~20°C, 4 days
pH of leachate	10.7	11.3	11.7	12.3
% Na leached	7.1	9.6	21	52
% Cs leached	0.086	0.060	0.18	2.0
% nitrite leached	26	36	51	71
% nitrate leached	14	46	57	71

*samples crushed to pass 100 mesh (150 micron- no lower size limit) screen, leached with 10x as much 90°C distilled water,