Alternatives for Low-Temperature Waste Immobilization

Cementitious Materials Technical Exchange

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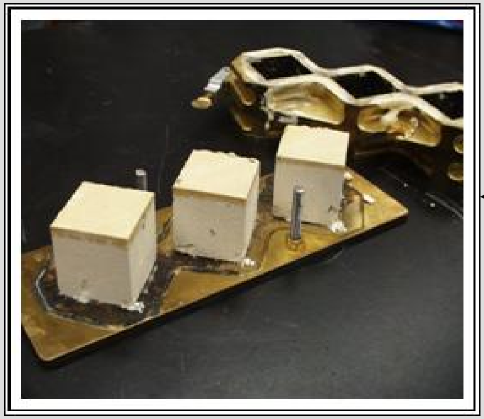
Project Scope

- Seek solutions from private sector to demonstrate low-temperature immobilization technologies for mixed radioactive and hazardous waste
  - Low-temperature waste forms to contain volatile radionuclides including Tc and I
  - Mature technologies with feasibility of deployment within 1 to 2 years
- Conduct screening tests using low-temperature (<150°C) immobilization technologies on Hanford WTP caustic scrubber and Idaho Sodium Bearing Waste (SBW) simulants

Waste Forms Selected for Evaluation



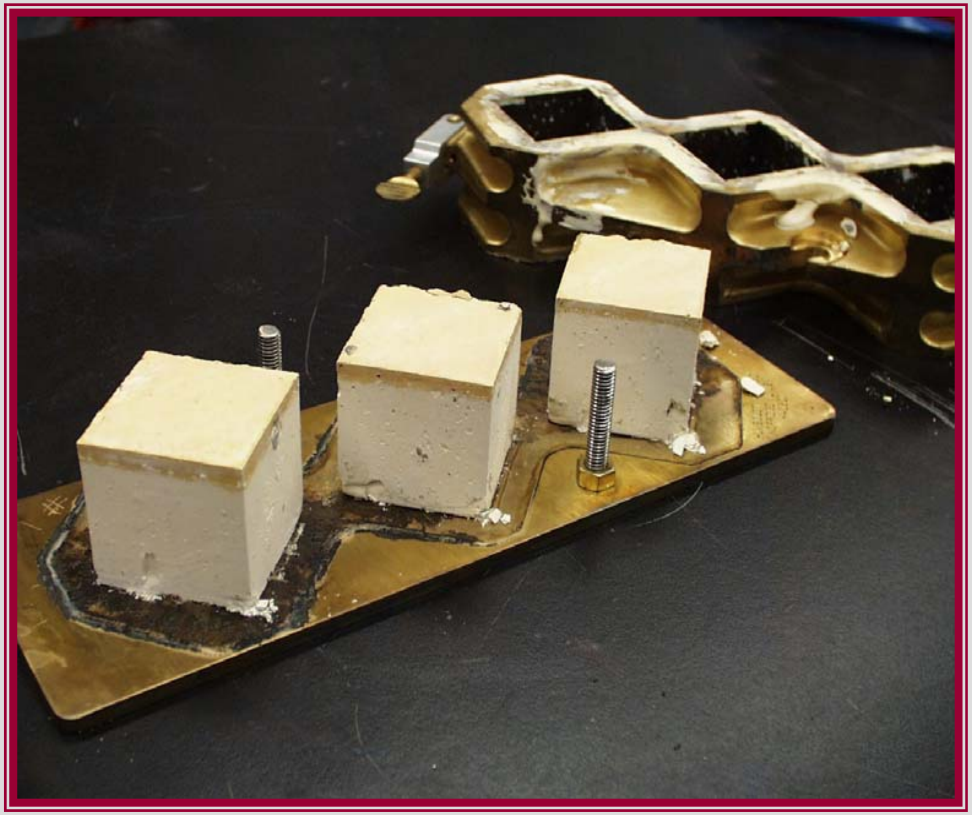
- **Alkali Aluminosilicate Hydroceramic Cement**: Diagnostic Instrumentation and Analysis Laboratory (DIAL) at Mississippi State University

- **Phosphate Bonded Ceramic** (Ceramicrete - magnesium potassium ($Mg\text{-}K\text{-}PO_4$) system): CH2MHILL

- **Alkali Aluminosilicate Geopolymer** ("DuraLith"): The Catholic University of America Vitreous State Laboratory (VSL)

Alkali Aluminosilicate Hydroceramic Cement

- MSU-DIAL
- Ingredients:
  - Sodium Hydroxide
  - Metakaolin
  - Vermiculite
  - Silica
  - Sodium Sulfide
  - Waste
- Developed as higher temperature process yielding insoluble sodalites and zeolites



Phosphate Bonded Ceramic

- CH2MHILL
- Ingredients:
  - Magnesium oxide
  - Potassium acid phosphate
  - Calcium silicate
  - Waste
- MWFA-developed technology

Ceramicrete
Idaho Sodium Bearing Waste

Alkali Aluminosilicate Geopolymer

- CUA-VSL
- Ingredients
  - Silica and alumina source (proprietary)
  - Alkaline solution
- Forms amorphous or partially microcrystalline geopolymer

Hanford Secondary Waste Simulant

Element	Target (moles/L)	Target (g/L)
Na	2	46
Al	0.011	0.299
Cr	2.80E-04	0.0145
Ag	2.20E-04	0.0237
Cd	1.40E-05	0.00157
Re (Tc)	6.00E-07	1.12E-04
I	2.90E-06	3.68E-04
Hg	2.40E-06	4.81E-04
Pb	1.50E-04	0.031
CO_3^-	0.96	57.6
NO_3^-	0.018	1.116
OH^-	0.094	1.598
TOC	0.18	13.86

Sodium Bearing Waste Simulant

Element	Target (moles/L)	Target (g/L)
Na	1.88	43.24
Al	0.575	15.5
K	0.175	6.825
Cr	0.0033	0.172
Cd	0.0007	0.0786
Hg	0.002	0.401
Pb	0.0013	0.269
Re (Tc)	3.13E-06	5.83E-04
I	5.66E-05	7.18E-03
SO_4^-	0.0491	4.71
NO_3^-	4.91	304.4

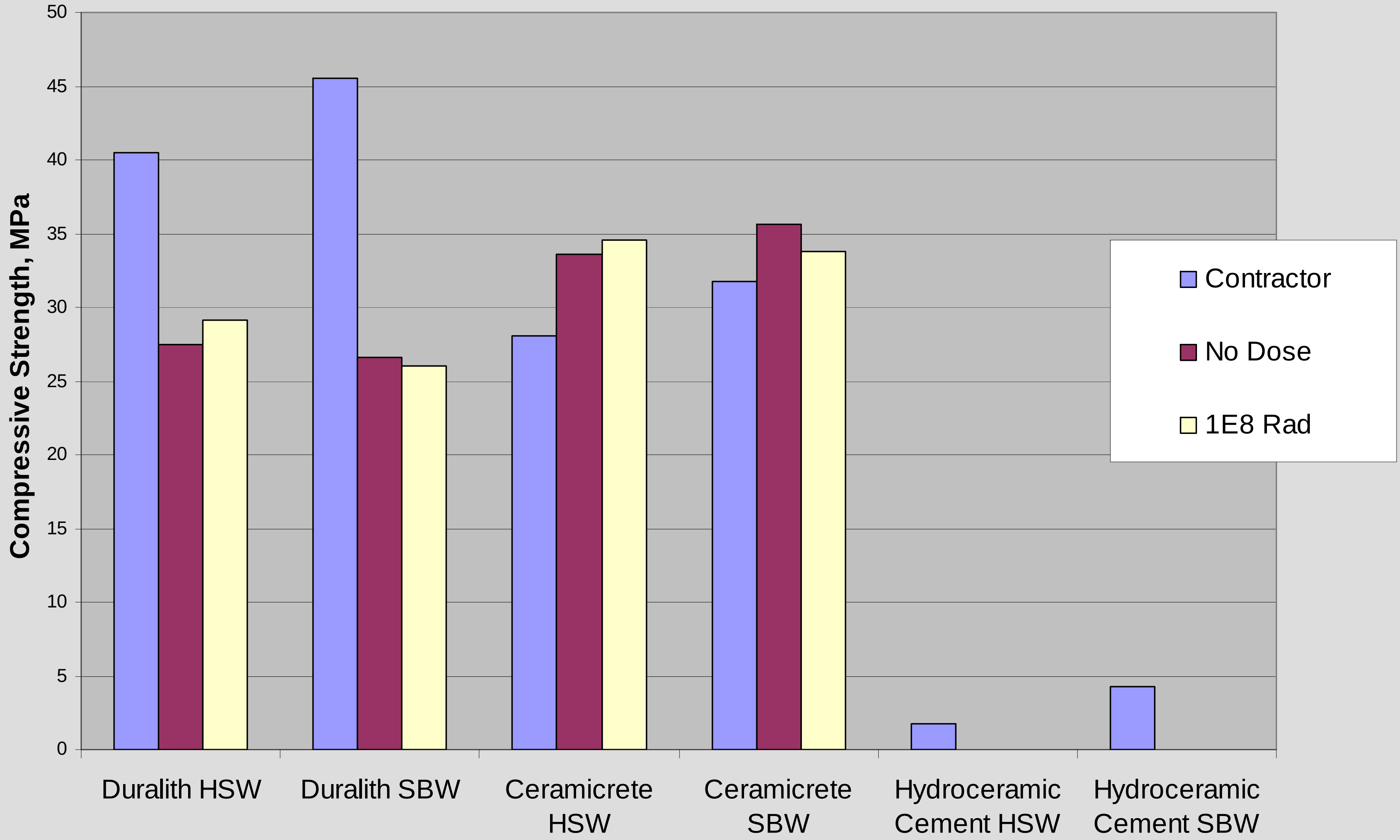
Waste Form Characterization

- Contractors prepared and characterized waste forms using PNNL provided simulant
  - Chemical composition
  - Waste loading
  - Toxicity Characteristic Leaching Procedure
  - Compressive strength
- PNNL conducted additional testing on Contractor-provided specimens
  - Product Consistency Test
  - ANSI/ANS 16.1 Leachability
  - Compressive strength after exposure to radiation

TCLP Results, mg/L

	Duralith		Ceramicrete		Hydroceramic Cement	
	HSW	SBW	HSW	SBW	SBW	UTS
Ag	<0.07	<0.07	0.008	0.003		0.14
Cd	<0.03	<0.03	<0.0003	<0.0003	0.6	0.11
Cr	0.015	0.04	0.05	<0.002	0.003	0.6
Hg	<0.01	<0.01	<0.008	<0.008	0.1	0.025
Pb	<0.1	<0.1	0.01	0.001		0.75

Compressive Strength



PCT Results

- Using standard PCT sample preparation, observed evidence of sample dissolving or breaking up
- Tried washing with acetone and using larger particles
- Results presented in final report (PNNL-16052 1)
- Significant work needed to understand non-glass waste form performance in PCT and to interpret in terms of disposal facility

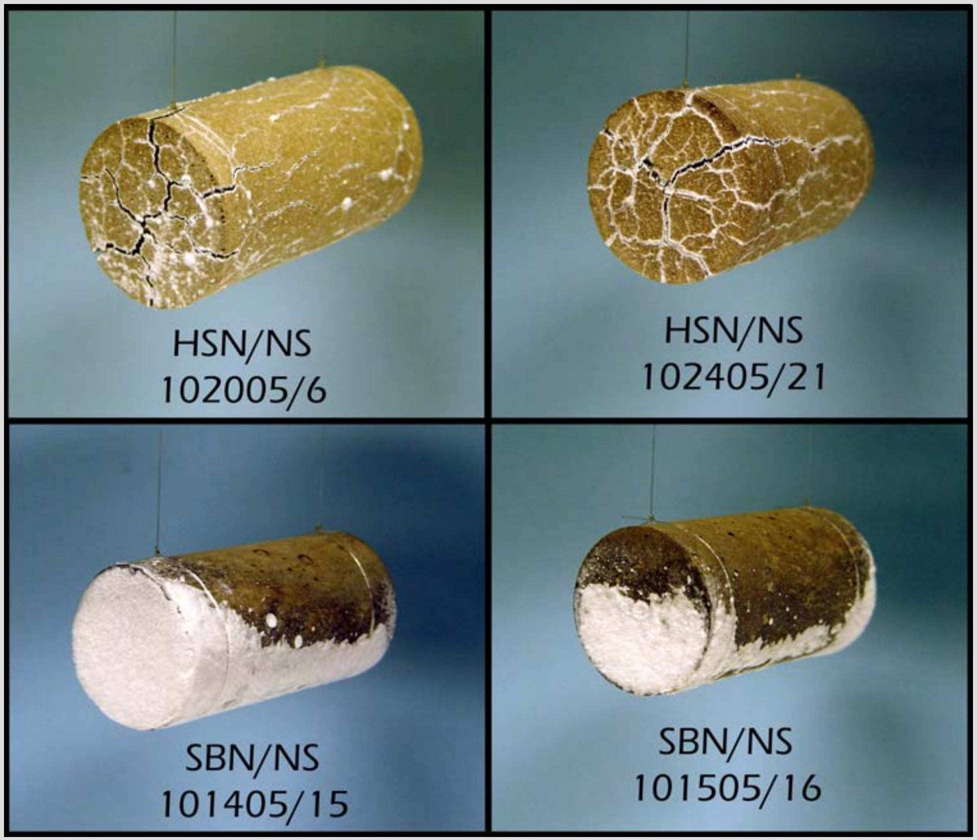
ANS-16.1 Leachability Index Results

Sample Material	Waste Type	Leachability Index Na > 6
Ceramicrete	HSW	8.1
		8.2
	SBW	7.6
		7.6
DuraLith	HSW	8.6
		8.6
	SBW	8.3
		7.7

ANS-16.1 Leachability Index Results (Re and I)

- Duralith
  - Bettered LI target (Tc LI > 9) for both simulants
  - Did not meet LI target (I LI >11) for either simulant
- Ceramicrete
  - Did not meet target for Tc
  - No I detected in leachate so could only report less than values below target
  - CH2M Hill report 7-day LI >11 for both I and Re in highly spiked simulants
- Testing with improved analytical sensitivity required to have confidence in Re and I results

Waste Forms After 90 Days in ANS-16.1



Ceramicrete

Duralith

Summary

- Three low-temperature waste forms selected for scoping studies for Hanford secondary waste and Idaho sodium-bearing waste
- “Ceramicrete” phosphate bonded ceramic and “Duralith” alkali aluminosilicate geopolymer show potential based on TCLP, compressive strength and Na leachability index requirements
- ANS-16.1 immersion test revealed formulation issues that will need to be addressed
- Re (Tc) and I immobilization not easily demonstrated using leach tests at expected low waste concentrations---analytical detection limit problem

Next Steps

- Address the formulation issues identified through the ANSI/ANS 16.1 testing and perhaps also in the PCT testing.
- Using waste simulants spiked with higher concentrations of I and Re, determine whether the waste forms can achieve sufficient reduction in the release of I and Tc.
- Based on observations from ANSI/ANS 16.1 testing and contractor thermal cycling tests on Ceramicrete, expand compressive strength testing to include impacts of thermal cycling and immersion in water.
- Optimize the quantities of binder materials to improve waste loading. If acceptable, this may include the removal of water to concentrate the wastes to be immobilized
- Examine other binder materials that may be less costly.
- Demonstrate the long-term effectiveness of sequestering agents added to reduce the mobility of iodine and technetium in the wastes.
- Demonstrate the preparation of the waste forms on a production scale.
- Determine long-term waste-form-performance characteristics to support disposal-system performance assessments.

Project and Technical Risks/Issues/Opportunities

- Technologies at different stages of maturity
  - Waste form development / optimization
  - Process development / demonstration
  - Waste form characteristics to support disposal system performance assessments
- Out-year activities will be defined based upon ORP and ID decisions whether or not to pursue alternative low-temperature immobilization technology---are any of these LT waste forms really adequate?