Process Testing Results and Scaling for the Hanford Waste Treatment and Immobilization Plant (WTP) Pretreatment Engineering Platform

Pacific Northwest NATIONAL LABORATORY

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PEP Testing Objectives

- Qualitatively demonstrate leaching and ultrafiltration processes, equipment design and process control strategies
- Obtain data to improve process model projections for leaching and ultrafiltration
  - Develop scaling factors to form link between laboratory-scale and engineering-scale test results

Unit Operations

- Filtration to concentrate solids and separate washing solutions
- Caustic leaching to dissolve aluminum solids (gibbsite and boehmite)
- Solids washing to remove soluble components
- Oxidative leaching with sodium permanganate to oxidize and dissolve chromium compounds

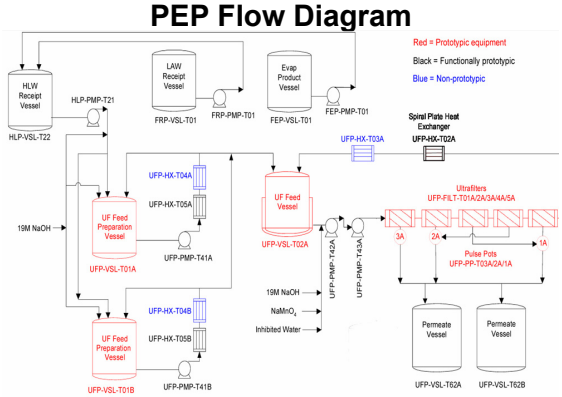
Process Flowsheets

- Baseline: caustic leaching in UF feed preparation vessels
  - Caustic added directly to as-received feed (3-8 wt% solids)
- Alternative: caustic leaching in UF feed vessel
  - Caustic added after initial solids concentration to 20 wt%
- All other process steps conducted in the UF feed vessels.

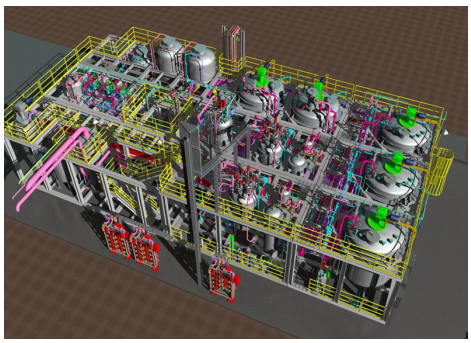
Process Description

Baseline	Alternative
Caustic leach in UF feed preparation vessel	Solids concentration
Solids concentration	Caustic leach in UF feed vessel
Solids wash	Solids concentration
Solids concentration	Solids wash/concentration
Oxidative leach	Oxidative leach
Solids wash	Solids wash
Solids concentration	Solids concentration

PEP Flow Diagram



PEP Computer Rendering



Scaling Considerations

- 1/4.5-scale facility: linear dimensions
- PJM mixing
  - Newtonian slurry: power/volume
  - Non-newtonian: plant velocity
- Air sparge mixing
  - Match power/volume at intermediate vessel level
  - Flow rate reduced at T > 90 °C
- Mixing from recirculation pump return nozzle fixed at plant velocity

Scaling Considerations (con't)

- PEP not capable of simultaneously matching all aspects of full-scale WTP processes
  - Operating parameters selected so that the most important scaling aspects of PEP were preserved
- Scale-time (1/4.5) operations
  - Solids washing
  - Reagent additions
- Plant-time operations
  - Caustic and oxidative leaching
- Filtration
  - Plant-time when depth fouling of filter was most important

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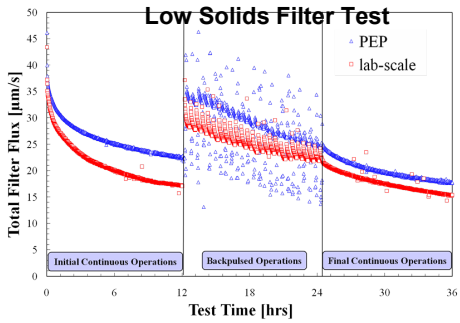
Testing Strategy

- Functional Testing
- Integrated Test A
  - Caustic leaching in UF feed preparation vessel @ 98°C
- Integrated Test B
  - Caustic leaching in UF feed vessel @ 98°C
- Integrated Test D
  - Caustic leaching in UF feed vessel @ 85°C

Filtration

- Low solids tests
  - Approximately 5 wt% undissolved solids
  - Filtration process limited by filter resistance and depth fouling
  - Scaling factor defined as the ratio of corrected filter fluxes (PEP:laboratory-scale)
- High solids tests
  - 15-25 wt% undissolved solids
  - Filtration process limited by filter cake resistance
- Laboratory samples taken directly from PEP prior to the start of the PEP test

Low Solids Filter Test



Caustic Leaching

- Concentration data from single PEP batches and duplicate laboratory-scale tests
- Rate equation based on a shrinking core model for boehmite dissolution
  - Gibbsite typically dissolved quickly
- Scale factor defined as the ratio of experimental rate constants for Boehmite dissolution (PEP:laboratory-scale)
- Kinetic model parameters fit to the dissolved aluminum concentrations
- Uncertainties determined using a Monte Carlo approach

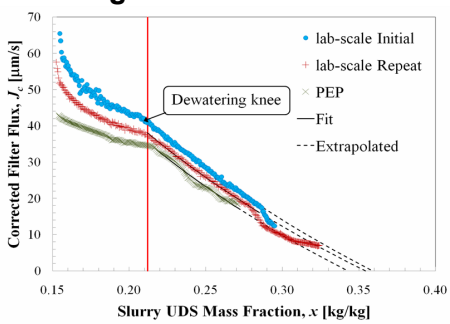
Simulant

- Targeted:
  - Mass loss >80% of projected WTP batches
  - Treatment time >80% of projected WTP batches
- Solids phase (~5wt%)
  - Gibbsite, Boehmite, CrOOH, sodium oxalate, iron rich
- Supernate (5 M sodium salts)
  - AlO_2^-, NO_3^-, NO_2^-, CO_3^{-2}, PO_4^{-3}, SO_4^{-2}, OH^-

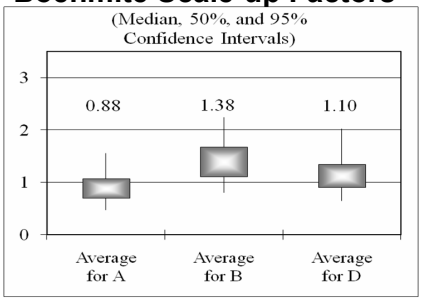
Filtration Scaling Factors

Scaling parameter	Scaling factor
Low solids filter flux test 1	1.1-1.4
Low solids filter flux test 2	1.1-1.2
Limiting gel concentration	0.97 ± 0.03
Mass transfer	0.96 ± 0.05
Recommended scaling factor	1.0

High Solids Filter Test



Boehmite Scale-up Factors



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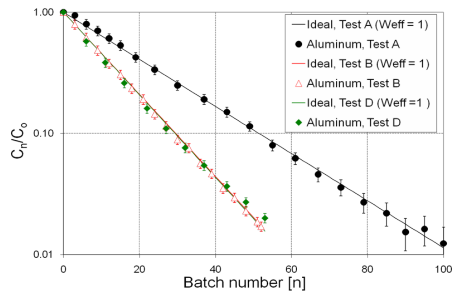
Washing Efficiencies

- Solids washing performed in the same manner as planned for WTP
- Measured concentrations of analytes as a function of washing batch
  - Analytes selected were fully soluble and above analytical reporting limits
- Scaling factors: ratio of actual washing efficiency to that expected in an ideal system
  - Washing efficiency = 1 for an ideal system

Typical Solids Washing Results



Oxidative Leaching

- Obtained oxidative leaching data from single PEP batches and laboratory-scale tests (duplicates for Integrated Test D).
- Scale factors defined as the ratio of the leach factors obtained in the PEP to those obtained in the laboratory-scale tests
- Leach factors based on Cr concentration change in solids (method 1) and liquids (method 2)

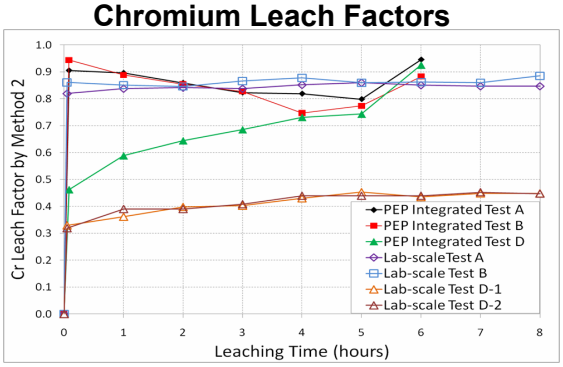
Washing Efficiencies

- Average post Caustic Leach Wash = 1.00 ± 0.01
  - Based on aluminate, sulfate, nitrate, nitrite, hydroxide
- Average post Oxidative Leach Wash = 0.98 ± 0.01
  - Based on chromium and oxalate

Oxidative Leaching Results

- Cumulative Cr leach factors were all ~ 0.9 and did not vary significantly between the PEP and laboratory-scale tests
- Recommended scaling factor for oxidative leaching is 1.

Chromium Leach Factors



Summary and Conclusions

- Recommended scaling factor for filtration, solids washing and oxidative leaching operations is 1.
- Caustic leaching scale factors
  - 0.88 for leaching in UF feed preparation vessel (baseline)
  - 1.1 and 1.38 for leaching in UF feed vessel (alternative)
- PEP Integrated Tests Demonstrated the Baseline and Alternative WTP Pretreatment Flowsheets