Estimating Leaching Behavior of Arsenic-Bearing Solid Residuals

Rio Rico Workshop
February 2006
Wendell Ela
University of Arizona, SBRP
Background

• 2001 revised arsenic in D.W. standard
  • 10 ppb MCL (from 50 ppb)

• Estimated impacts
  • 4000 new utilities impacted ( >95% small)
  • ~ 400 Arizona utilities impacted
  • 6 - 24M lb solid residuals annually
  • ~ 30,000 # As /yr
  • arsenic-bearing solid residuals (ABSR) pass TCLP
  • ABSR suitable for non-hazardous landfill disposal
    (California exception: WET & TTLC)
Spent Solid Sorbents

Alumina-based Media (Alcan AA)
Iron-based Media (GFH, Sorb 33, greensand)
Zeolites (Z33)
Other Sorbents (SAMMS, Mn Oxides, TiO₂)

Precipitated Sludges

• Direct
  Precipitation/Softening
  Conventional coagulation / flocculation
  Coagulation assisted microfiltration

• Indirect
  Anion exchange (incl. enhanced media & recovery*)
  Regenerable sorbents (ArsenXⁿᵖ, AA)
  Reverse osmosis
Leaching Estimation Tools

- Batch “Equilibrium” Tests
  Standard (TCLP, WET), Alternative (LL, SL, tiered)
- Bench/Pilot Column Tests
- Full-scale Tests
- Empirical and Mechanistic Models
  Kinetic, equilibrium, hybrid
Spent Sorbent Leaching

Leach Test

- Init Ldg
- TCLP
- TCLP-48
- CA-WET
- Lndfl Lcht

Leachate Arsenic (ppb)

- GFH
- AA

0 200 400 600 800 1000 1200

1200

1000

800

600

400

200

0

University of Arizona
Precipitated Sludge Leaching

Leachate Arsenic (ppb)

Init Ldg  TCLP  TCLP-48  CA-WET  Lndfl Lcht

31  88  158  765  1015
22  78  118  472  1018
1015 2495 2200 73500 13340

Leach Test

GFH
AA
AFH

TC

University of Arizona
Precipitated Sludge Leaching Test
Leachate Arsenic (ppb)

Init Ldg  TCLP  TCLP-48  CA-WET  Lndfl Lcht

31  88  158  765  1015
22  78  118  472  1018
1015 2495 2200 73500 13340

Leach Test

GFH
AA
AFH

TC
Landfill Simulation Columns

University of Arizona

SYRINGE PUMP (FLOW RATE 0.31mL/min)

DEAERATED, DEIONIZED WATER

INFLUENT

SAMPLING PORTS

GAS COLLECTION

MARIOTTE FLASK
10% NaOH SOLUTION WITH pH INDICATOR

GRAVEL

UNSATURATED ZONE

WATER LEVEL

COLLECTION FLASK

GRAVEL

SATURATED ZONE

EFFLUENT

• 23% SHREDDED PAPER
• 46% YARD WASTE
• 31% SOLID RESIDUAL
• 4L ANAEROBIC DIGESTOR SLUDGE
GFH Column Effluent Totals

- Iron (ppm)
- As (ppm)

Fe (total) and As (total)

Fe 43%  As 12%
GFH Column Effluent Arsenic

As (ppb)

- As(III)
- As(V)
- As(dissolved)
- As(digested)

University of Arizona

As (ppb) vs. time (days)
Sorb-33 Column Leachate

As (ppb)

As (III)  As (V)  As (dissolved)  As (total)

As (total) concentration over time (days):
AFH Column Effluent Arsenic

Graph showing the change in arsenic concentration over time. The x-axis represents time in days (0-400) and the y-axis represents arsenic concentration in ppm (0-250). The graph compares dissolved As (blue diamonds) and digested As (red circles).

Key:
- Dissolved As
- Digested As

Time (days):
- 0
- 50
- 100
- 150
- 200
- 250
- 300
- 350
- 400

Arsenic (ppm):
- 0
- 50
- 100
- 150
- 200
- 250

University of Arizona

AFH Column Effluent Arsenic
Cumulative As Leaching

Fractional As Leached

Time (days)

AA
GFH
E33
AFH

0 100 200 300 400 500 600 700 800 900 1000

0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8
# Critical Influences

**Guiding Premise:** test induces leaching as or more aggressively than conditions of non-hazardous waste disposal

<table>
<thead>
<tr>
<th></th>
<th>TCLP</th>
<th>WET</th>
<th>Mature Landfill</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>4.95</td>
<td>5.05</td>
<td>7-9</td>
</tr>
<tr>
<td>Bioactivity</td>
<td>abiotic</td>
<td>abiotic</td>
<td>biotic</td>
</tr>
<tr>
<td>Duration</td>
<td>18 hr</td>
<td>48 hr</td>
<td>weeks/months</td>
</tr>
<tr>
<td>Particles &amp; Colloids</td>
<td>filtered</td>
<td>filtered</td>
<td>downflow, heterogeneous</td>
</tr>
<tr>
<td>Redox Condition</td>
<td>oxidizing</td>
<td>neutral</td>
<td>reducing</td>
</tr>
</tbody>
</table>
Simple Blackbox Mass Balance

- Steady State \((\text{ABSR}_A \text{ In} = \text{Leachate}_A \text{ Out})\) after residuals dumping in landfill for ??? years.

Trash + ABSR

\[ \text{Leachate to collection or percolation} \]
Blackbox Assumptions

- Final drinking water arsenic concentration of 8.0 ppb
- Range of leachate production rates
  \[0.15 \text{ -- } 1.60 \text{ L}_{\text{leachate}}/\text{kg}_{\text{waste}}\]
- ABSR are only source of arsenic to landfill
- Source water concentration and population impacted follows EPA final rule estimates
- Landfill only services population impacted by new MCL
Simple Blackbox Estimate

- $2.24 \text{ g}_{\text{As}}/\text{cap} \cdot \text{yr}$
- $560 \text{ kg}_{\text{waste}}/\text{cap} \cdot \text{yr}$
- $0.15 - 11 \text{ L}_{\text{leachate}}/\text{kg}_{\text{waste}}$

$26.7 - 0.36 \text{ ppm}$
Questions and Comments
<table>
<thead>
<tr>
<th>test</th>
<th>pH</th>
<th>ORP (mV)</th>
<th>alkalinity (mg/L as CaCO₃)</th>
<th>TOC (mg/L)</th>
<th>TDS (mg/L)</th>
<th>ionic strength (M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TCLP</td>
<td>4.95</td>
<td>103.5</td>
<td>766</td>
<td>38.6</td>
<td>1480</td>
<td>0.08</td>
</tr>
<tr>
<td>WET</td>
<td>5.05</td>
<td>74</td>
<td>7940</td>
<td>55.8</td>
<td>5160</td>
<td>0.10</td>
</tr>
<tr>
<td>SL1</td>
<td>7.03</td>
<td>121.4</td>
<td>1500</td>
<td>1050</td>
<td>5200</td>
<td>0.03</td>
</tr>
<tr>
<td>SL2</td>
<td>7.55</td>
<td>-37</td>
<td>12 500</td>
<td>1310</td>
<td>8600</td>
<td>0.49</td>
</tr>
<tr>
<td>LL¹</td>
<td>6.82</td>
<td>36.1</td>
<td>1100</td>
<td>160</td>
<td>3600</td>
<td>0.33</td>
</tr>
<tr>
<td>LL²</td>
<td>4.5–9.0</td>
<td>N/R*</td>
<td>300–11 500</td>
<td>30–29000</td>
<td>2000–60000</td>
<td>N/R</td>
</tr>
<tr>
<td>LL³</td>
<td>6.5–8.2</td>
<td>N/R</td>
<td>1250–8050</td>
<td>N/R</td>
<td>1960–16800</td>
<td>N/R</td>
</tr>
<tr>
<td>LL⁴</td>
<td>6.2–7.1</td>
<td>N/R</td>
<td>N/R</td>
<td>236–3160</td>
<td>N/R</td>
<td>N/R</td>
</tr>
</tbody>
</table>

N/R*: Values Not Reported. LL¹: Leachate collected from Tangerine Road Landfill, Tucson, AZ. LL²: Leachate composition reported in Christensen et al., (21). LL³: Leachate composition reported in Jang et al. (22). LL⁴: Leachate composition reported in Hooper et al. (5).
Next Steps for As Residuals

S1. Simulate landfills/repositories to determine appropriate performance bar

S2. Develop tractable protocols based on engineering critical leaching mechanisms to clear bar

S3. Evaluate (technically & economically) treatment options, including potential for stabilization

S4. Develop and evaluate hybrid (conventional & innovative) disposal options
Polymeric Encapsulation

Polymeric Waste Form Synthesis

Aqueous processing route

- PSB latex
- Epoxy resin
- Surfactant (Span 80)

Mixing

Cross-linking agent (DETA)

Solid Waste

Mixing

Drying and curing at 80°C

Final Waste Form

Polymer precursors in aqueous phase

Phase inversion: polymers go from being the discontinuous phase to being the continuous phase, encapsulating solid waste

Encapsulated solid waste

Continuous polymeric matrix

Solid waste
Crystallization
Crystallization Leaching

Weak HCl Leachate

As(t)/As(T)

AGING TIME (Hrs)

pH7
pH8
pH9
pH10
pH11
pH12
Residuals Recommendations

- Push for appropriate leaching test
- Avoid mass loading based standards
- Investigate organic free, contained landfills
- Develop stabilization technologies
- Involve wastewater/solid waste utilities
- Avoid drying bed type options w/out resuspension and final fate controls
- Consign as hazardous waste or hold on-site