Legacy of Innovative Remediation

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Presentation Overview

- Legacy of innovative projects
- Suggestions going forward
Legacy of Innovative Approaches
Keep Clean Water Clean
Leviathan
Bat Gate and Polymer Seal to Close Adits
US Forest Service
Pit Lake and Very Acid Rock
Barite Hill --Remediation of Hot Waste Rock via Grading and Capping
Deep Quench( at 400 feet) of Hottest Material
Barite Hill Pit Lake
After Remediation and Establishing a viable SRB culture
Waste Rock/Tailings  USFS New Mexico Site
One Third leached Pb... treated with TSP
Rest only Contact/Ingestion Hazard... cover
Tailings/Rock..... Chemical Immobilization

- Many Metals... Add Alkali...acid base accounting
- Pb...Add Phosphates
- As...Add iron or iron compounds
- Hg...Polysulfides, ZVI
RCTS Technology
Lime Rotating Cylinders
Treated 9 million gallons in 2011
Tim Tsukamoto, Ionic Water Technologies, Leviathan
ZVI PRB for Arsenic—East Helena, MT
Rick Wilken - EPA
Bioreactors

More Appropriately Called

Bio-Chemical Reactors
Big 5 Portal – Const Wetland/Bioreactor
1987-1990……CDM, CSM, EPA
Burleigh Tunnel Compost Bioreactors
Anaerobic Compost-Constructed Wetlands System (CWS) Technology (EPA/540/R-02/506) 2002
BLM and Karl Ford have constructed several bioreactors--this one near Silverton in operation over 7 years when photo taken in 2007
Luttrell Bioreactor Ten Mile Range, MT
Jim Gusek and David Reisman, built 2002
Luttrell Bioreactor Proved

- Bioreactor can be built for very cold climate
- May become a frozen poop-sickle in winter
- Will thaw and still work well
So Where Are We Going To Build This Bioreactor? Golinski Mine, CA
No flat area? Pipe the water to a flat area.

photos Jim Gusek, Golinski Mine
Leviathan Bioreactor System
Slope Stability Analysis Preceded Const.
Leviathan Uses Cobbles Not Organic Substrate
Microbes Fed Ethanol
Gravity Flow or Recycle
Designed in 2001-2002 by Tim Tsukamoto, Glenn Miller, Ed Bates
Innovative Use of Standpipes, In Place of Valves, to Control Flows
In Recycle Mode, Metals are Precipitated Outside the Bioreactor in a Settling Lagoon (black plume)
Leviathan Rock Substrate Bioreactor

- In continuous successful operation since 2004
- Has survived several upset conditions
- Has been successfully flushed following an upset
- Treated 7 million gallons in 2011
- Unplanned down time 0.4% in 2011
- Remote monitoring/operation

Compost-Free Bioreactor Treatment of Acid Rock Drainage
Leviathan Mine, California EPA/540/R-06/009 2006

www.epa.gov/region9/leviathanmine
Nacimiento Mine Bioreactor
Design by Tim Tsukamoto, Ed Bates

- Forest Service New Mexico
- Treating groundwater plume (pumped)
- Rock substrate, recycle, bioreactor
- Constructed Fall 2008, start-up Spring 2009
- Treated 18 million gallons thru 2011
- Turned off for 1 year, restart with success
Nacimiento Bioreactor Under Construction
Suggestions Future Directions

- Better define eng. properties of rock reactors
- Expanded use of both organic and rock reactors
- Better partnering between regulators & mining
- View impacts/remediation on watershed basis
Better Define Eng Properties of Rock Reactors

- Optimum size of rock
- Treatment capacity per unit of volume
- Define microbe culture
- Investigate use of wastes as food
- Reduce/increase food with loading
- Reduce hydrogen sulfide emissions
Expand Use of Both Organic and Rock Reactors

- Improved designs available
- Both gravity and recycle modes
- Remote monitoring feasible
- In mine use of bioreactors
Better Partnering Between Regulators & Mining

- Increased R&D cooperation
- View re-mining as a solution to pollution
- Ease discharge requirements for re-mining existing sources
- Consider alternative legacy cleanup to full compliance on some point discharges
View Impact/Remediation on Watershed Basis

- Allocate $ to achieve a clean stream, not just on basis of total load removed
- Relax discharge requirements for innovative cleanup of legacy sites
- Encourage good Samaritan cleanups
- Think broadly--remediating 90% of 5 sources may be better than 99% of 1 source
Some Final Advice
Think Outside the Box
What food can you feed to Rock Substrate bioreactors ???
Can you feed ethanol to organic substrate bioreactors??

Yes !!!

“Beats the heck out of eating crap and sawdust”, actual quote from a microbe
Don’t Let Your Thinking Get Locked Up In A Knot
Get the Best Help You Can Find Regardless of Species
If Desperate: Hire Consultants
END
Comparison Gravity-Recirculation

Designed Flow Schematics

Flow Schematics with Recirculation

FIGURE 2-6
COMPARISON OF ASPEN SEEP BIOREACTOR OPERATION WITH AND WITHOUT RECIRCULATION LEVIATHAN MINE SUPERFUND SITE ALPINE COUNTY, CALIFORNIA

Modified from Tsukamoto 2004

Tetra Tech EM Inc.
To Rock or Not to Rock ???
## Bioreactors: Rock vs. Organic Substrate

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Rock</th>
<th>Organic</th>
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</thead>
<tbody>
<tr>
<td>Food Source Built in</td>
<td>No</td>
<td>Yes</td>
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<tr>
<td>External Food Supply</td>
<td>Yes</td>
<td>Optional</td>
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<tr>
<td>Flushable</td>
<td>Optional</td>
<td>No</td>
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<tr>
<td>Gravity Mode</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Recycle Mode</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Substrate Needs Replacement</td>
<td>No</td>
<td>Yes</td>
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</tbody>
</table>
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<th>Parameter</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Bed Depth Limited</td>
<td>No</td>
<td>Yes</td>
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<tr>
<td>Prone To Short Circuits</td>
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<td>Yes</td>
</tr>
<tr>
<td>Requires Rebuilding</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Complex Microbial Culture</td>
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<td>Yes</td>
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<tr>
<td>Easy Start Up</td>
<td>?</td>
<td>Yes</td>
</tr>
<tr>
<td>Quick Response to Controls</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Requires constant food addition</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>
Black Cloud of Sulfide Precipitation
Leviathan Aspen Seep Mine Tails
This Mine has a Hydraulic Seal
Hydraulic Mine Seals

- Like a dam
- Where does the water come from ?
- Where will the water go ??
- How will the water be treated ?
- Will the rock hold water or leak ?
- Blowout risk ?
- Will there be a release valve ?