Contaminated Site Clean-Up Information

Welcome to the CLU-IN Internet Seminar

Mining-Influenced Water: Environmental Issues, Remediation Research, and Tools for Estimating Remediation Cost

Sponsored by: EPA Technology Innovation and Field Services Division (TIFSD)

Delivered: September 19, 2012, 1:00-3:00 PM EDT

Instructors: Dan Bench (EPA Region 8), Michele Mahoney (EPA OSRTI), Brent Means (U.S. Office of Surface Mining), Dr. Courtney Young (Montana Tech)

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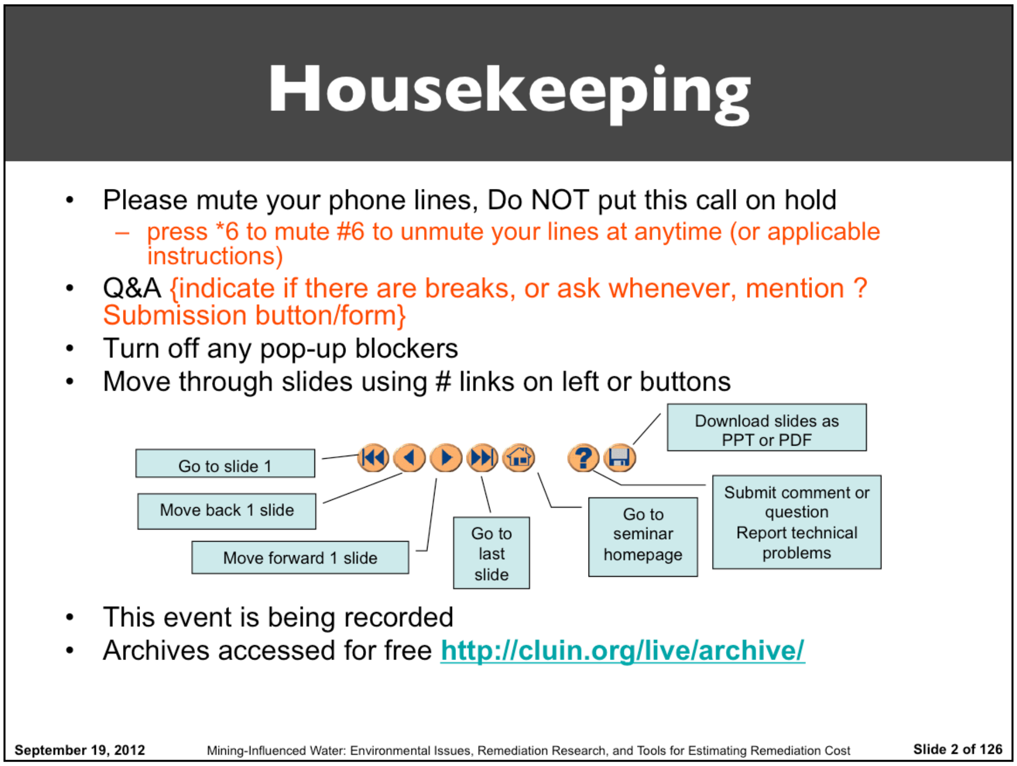
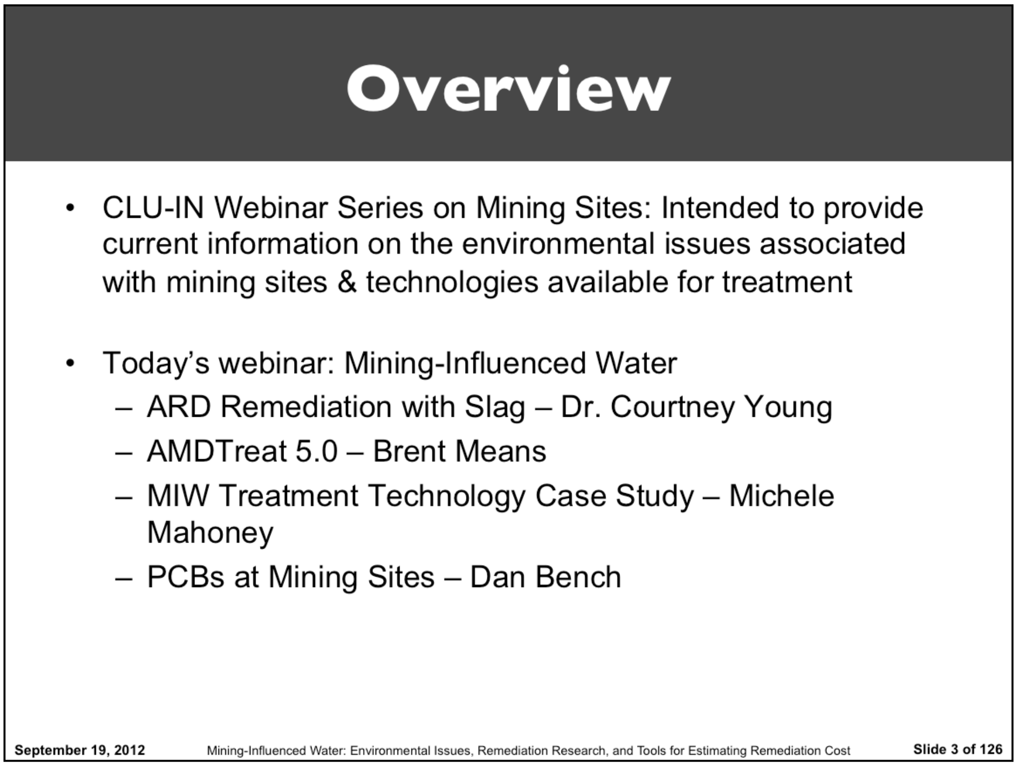


Although I'm sure that some of you have these rules memorized from previous CLU-IN events, let's run through them quickly for our new participants.

Please mute your phone lines during the seminar to minimize disruption and background noise. If you do not have a mute button, press *6 to mute #6 to unmute your lines at anytime. Also, please do NOT put this call on hold as this may bring delightful, but unwanted background music over the lines and interupt the seminar.

You should note that throughout the seminar, we will ask for your feedback. You do not need to wait for Q&A breaks to ask questions or provide comments. To submit comments/questions and report technical problems, please use the ? Icon at the top of your screen. You can move forward/backward in the slides by using the single arrow buttons (left moves back 1 slide, right moves advances 1 slide). The double arrowed buttons will take you to 1st and last slides respectively. You may also advance to any slide using the numbered links that appear on the left side of your screen. The button with a house icon will take you back to main seminar page which displays our agenda, speaker information, links to the slides and additional resources. Lastly, the button with a computer disc can be used to download and save today's presentation materials.

With that, please move to slide 3.



Today's seminar is the second in the webinar series launched by Technology Innovation and Field Services Division in June 2012 as part of its new CLU-IN Mining Sites Focus Area. The webinars are intended to serve as a source of relevant and current information on the environmental issues associated with active, closed, and abandoned mining sites, as well as the technologies available for treatment.

Our webinar today will focus on the treatment of mining-influenced water. We will begin with a presentation by Dr. Courtney Young, who will highlight some of his work on acid rock drainage remediation at the Berkeley Pitlake site in Butte, Montana. Next, we will hear from Brent Means about AMDTreat, a tool developed by the U.S. Office of Surface Mining, the Pennsylvania Department of Environmental Protection, and the West Virginia Department of Environmental Protection to estimate cost of abatement for water pollution caused by acid mine drainage. After that, I (Michele Mahoney) will discuss a mining-influenced water treatment technology case study at EPA, where we are working to identify and evaluate mining-influenced water treatment technologies being employed at both active and abandoned mining sites. Dan Bench will wrap up our webinar today with a presentation on the issue of PCBs at mining sites, discussing PCB environmental hazards, identification, hidden sources to look for, potential liabilities, and what to do when PCBs are found.

With that, let's move to the next slide and begin our webinar.

"ARD REMEDIATION WITH SLAG: AN APPLICATION TO BERKELEY PITLAKE WATER"

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Outline

- Berkeley Pitlake
- Previous Research
- Silicate Slags
- Objectives
- Procedures
- Results & Discussions
- Conclusions
- Acknowledgements

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Interstate-15
tailings pond
road
Continental Pit
terraces
tailings
Treatment Plant
Horseshoe Bend Water
Berkeley Pit
MR Concentrator
Viewing Stand
Butte
Walkerville
Interstate 15/90
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Mining-Influenced Water: Environmental Issues, Remediation Research, and Tools for Estimating Remediation Cost
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Mining-Influenced Water: Environmental Issues, Remediation Research, and Tools for Estimating Remediation Cost
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Brief History of Berkeley Pit

1880 - Butte was an early copper-mining town:
- Referred to as "The Richest Hill on Earth"
- One of the world's largest sulfide ore deposits

1920 - ACC controlled most mines

1955 - ACC began phasing out underground mining

1977 - ARCO purchased all operations

1982 - Operations halted and pumps turned off

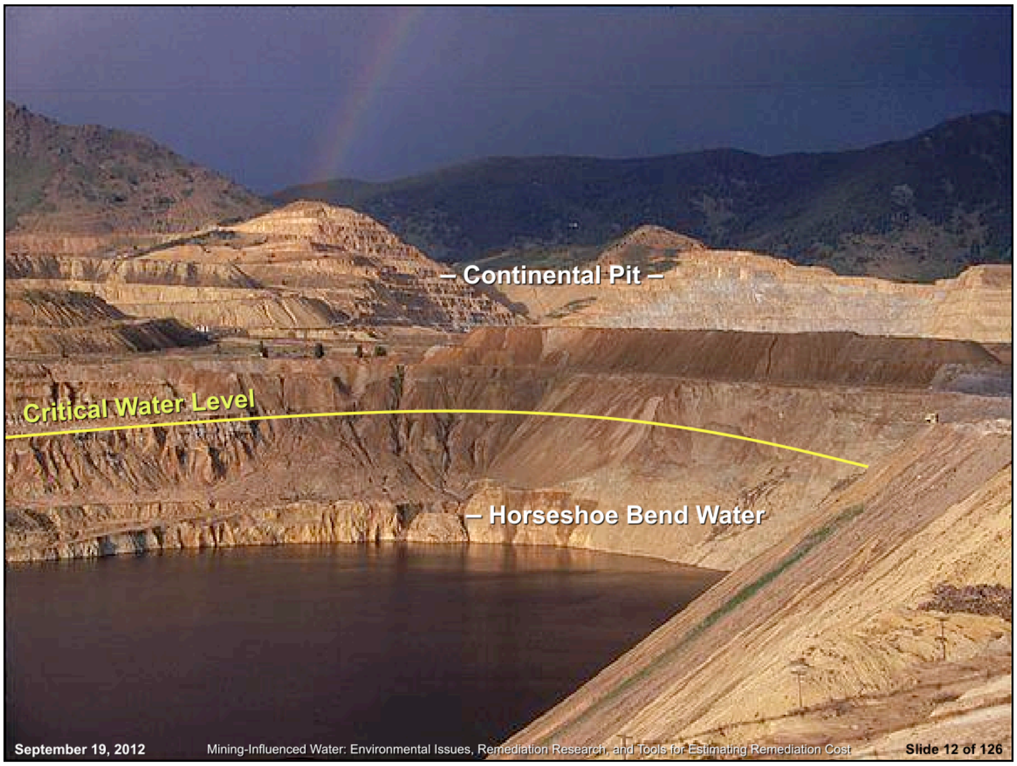
1983 - Water first appeared in the pit
- Listed as a Superfund site
- Part of the largest mining Superfund site

Berkeley Pitlake Water:
- is acidic near pH 2.5
- contains metals at high concentrations (99% Water):

SO_4	(7500 ppm)
Fe	(1000 ppm)
Zn	(650 ppm)
Al	(300 ppm)
Mn	(250 ppm)
Cu	(200 ppm)
Cd	(2.5 ppm)
As	(0.5 ppm)

Concentrations change with position, depth and time

Berkeley Pitlake Water:
- encompasses ~700 acres
- is ~1,000 feet deep
- contains ~40 billion gallons
- fills at 2.6 million gallons per day
- will reach “critical level” in 2023


– Continental Pit –
Critical Water Level
– Horseshoe Bend Water
September 19, 2012
Mining-Influenced Water: Environmental Issues, Remediation Research, and Tools for Estimating Remediation Cost
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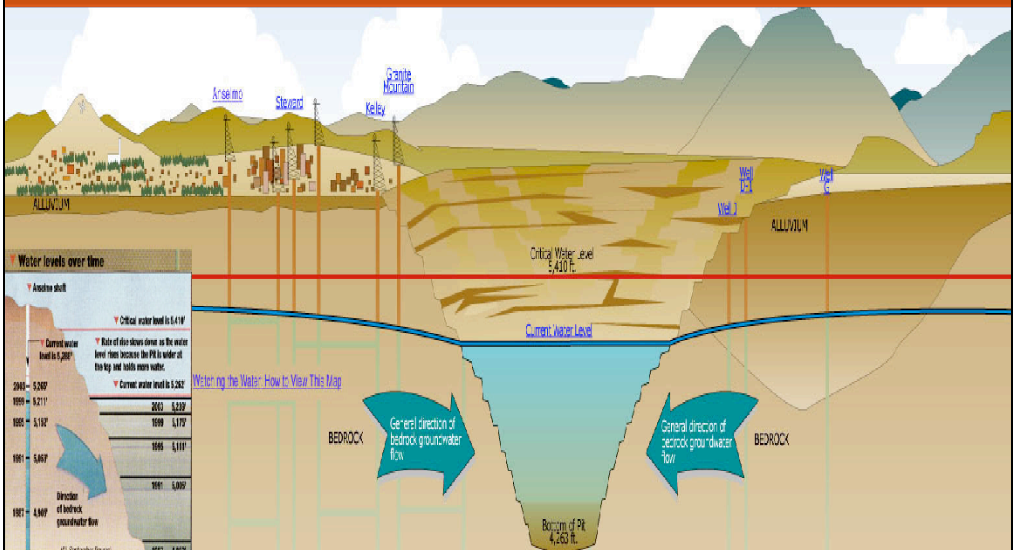
Monitoring the Water Level



Brief History of Berkeley Pit

1995 - HSBW also diverted to pond (3M GPD)
- MR starts operating Continental Pit to the east
- ARCO and MR named responsible parties

2000 - MR halts operations including diversion

2003 - HSBW Treatment Plant is commissioned
- two-stage lime precipitation process
- diversion of treated water begins
- sludges are disposed into the BPL

2004 - MR reopens and begins full operations

2005 - MR pumps BPL water to Cu-cementation


Horseshoe Bend Water Treatment Plant
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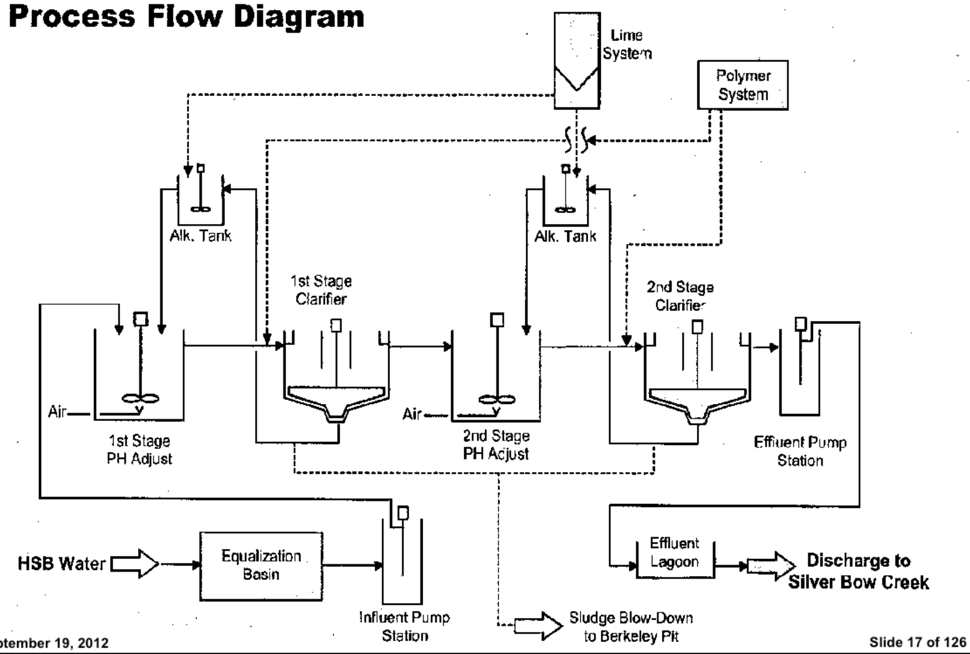
Horseshoe Bend Water Treatment Plant

ARCO / Montana Resources
Horseshoe Bend Water Treatment Facility
Process Flow Diagram



September 19, 2012

Outline

- ✓ Berkeley Pitlake
- **Previous Research**
- Silicate Slags
- Objectives
- Procedures
- Results & Discussions
- Conclusions
- Acknowledgements

Previous Research

- Participate in a "series" of 5 studies to summarize available information
- Generate new information to formulate conceptual environmental models for the Berkeley Pitlake from all of its features
- Provide data for the development of advanced treatment technologies

Series I – Selective Recovery

	Fe	As	Mn	Cu	Cd	Zn	Al
Initial BPL Water	1019.8	5.9	214.2	151.2	2.3	566.3	243.5
Stage 1A - H_2O_2/UV	8.43	< 0.11	198.5	146.3	1.9	529.7	222.7
Stage 1B - $KMnO_4$	0.23	< 0.11	4.5	138.8	1.84	495.6	213.2
Stage 2 - Na_2S	0.27	< 0.11	4.9	0.09	1.7	482.6	203.2
Stage 3 - Na_2S	0.22	< 0.11	4.2	< 0.05	< 0.02	49.4	186.2
Stage 4 - NaOH	< 0.04	< 0.11	3.72	< 0.05	< 0.02	18.2	0.24
Drinking Standard	0.3	0.05	0.05	1.3	0.005	5	0.2

Stage 1A: $H_2O_2 = 2OH^\bullet$; $Fe^{2+} + OH^\bullet = Fe^{3+} + OH^-$; $Fe^{3+} + 3OH^- = Fe(OH)_3$

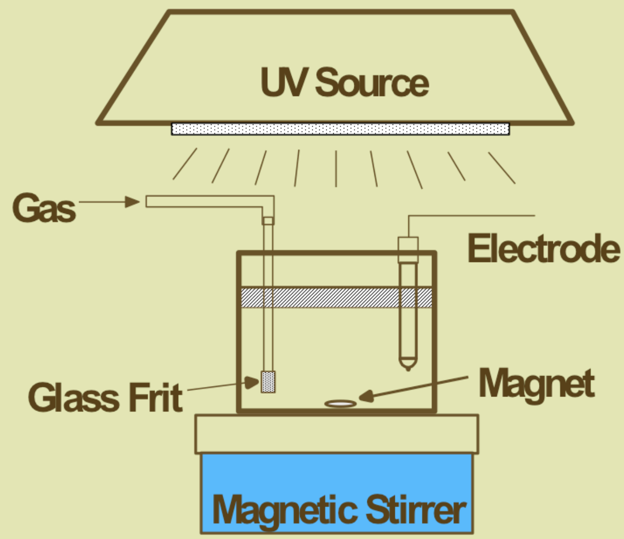
Stage 1B: $3Mn^{2+} + 2MnO_4^- + 2H_2O = 5MnO_2 + 4H^+$

Stage 2: $Cu^{2+} + S^{2-} = CuS$

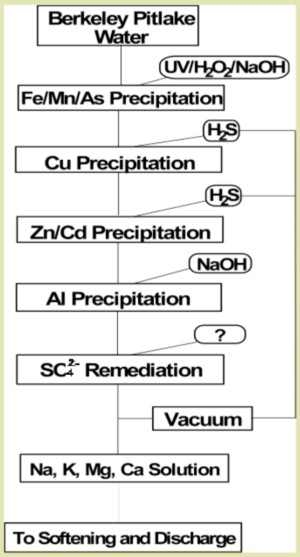
Stage 3: $Cd^{2+} + S^{2-} = CdS$; $Zn^{2+} + S^{2-} = ZnS$

Stage 4: $Al^{3+} + 3OH^- = Al(OH)_3$

Series I – Selective Recovery



Series I – Selective Recovery



- Selective metal recovery is possible
- A 7-stage process has been envisioned and shown to work (in batch mode)
- Fe, As, Cu and Cd met DWS
- Al almost met DWS
- Mn and Zn did not meet DWS
- $KMnO_4$ addition needs to be precise
- Zn may have precipitated amorphously
- SO_4 removal was not done but options are
  - Freeze Crystallization
  - Reverse Osmosis
  - Gypsum Precipitation
  - SRB Bioreduction
  - Chemoreduction
  - Photoreduction
  - Reductive Precipitation
- Softening to remove Na, K, Mg and Ca

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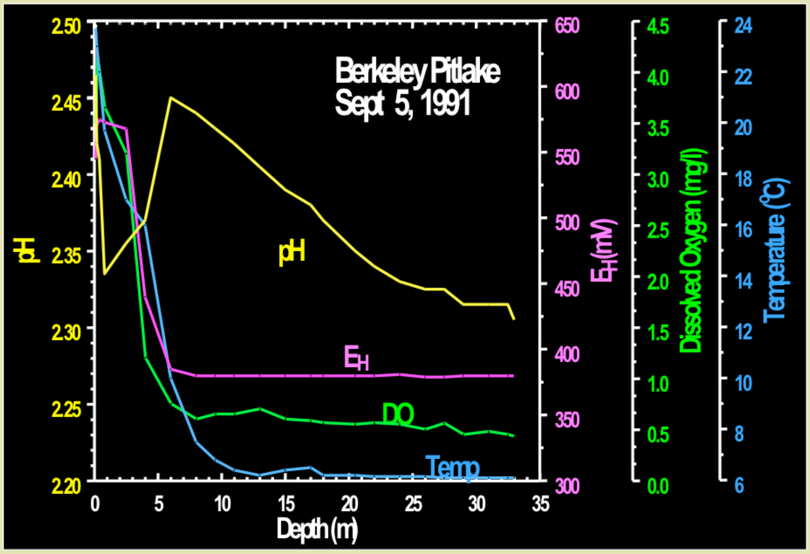
Series II – Surface Waters



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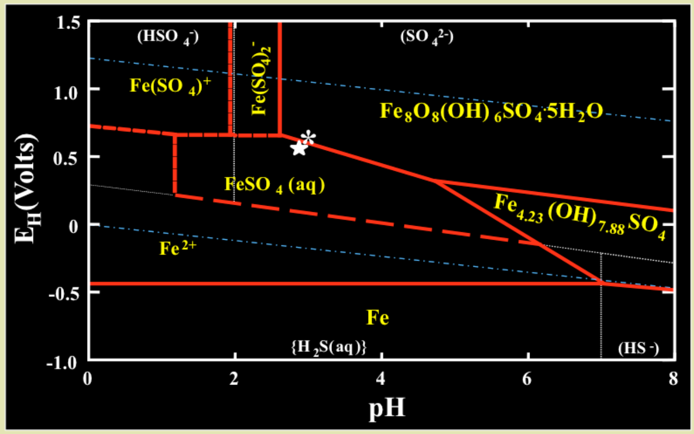
Series II – Surface Waters



Series II – Surface Waters

- Profiles indicated chemoclines/thermoclines existed and were successfully reproduced in lab
- They have been explained by, but can not be totally attributed to
  - HSBW being less dense than BPLW so, when it enters the pitlake, it floats on top rather than mixes in, and
  - Biological activity which should increase DO as well as pH
- Experiments showed that the interaction of sunlight (UV radiation) and air with BPL water plays a significant role

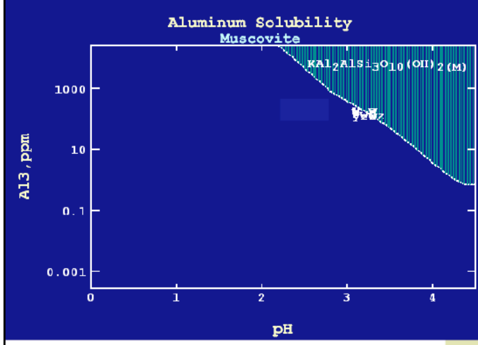
Series III – At Depth

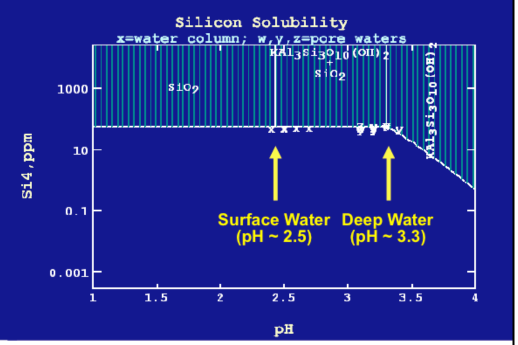
(Deep Water, Pore Water and Sediment)

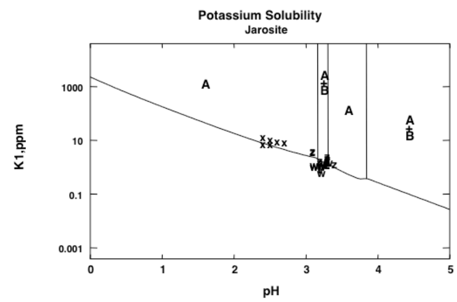
Siphon/Filter Off
Deep/Pore Water

Analyze the Water
& Solid Contents

Concentrations are controlled by the solubility of identified minerals and precipitates!







Series III – At Depth

(Deep Water, Pore Water and Sediment)

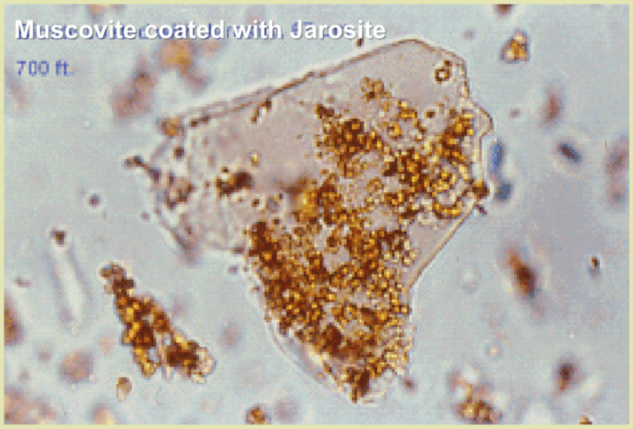
- Muscovite [$KAl_3Si_3O_{10}(OH)_2$] controls Al^{3+} concentration
- Quartz (SiO_2) controls Si^{4+} concentration
- Schwertmannite [$Fe_8O_8(OH)_6SO_4$] precipitate controls the Fe^{3+} concentration
- Jarosite [$KFe_3(SO_4)_2(OH)_6$] precipitate controls K^+ concentration
- Cu^{2+}, Fe^{2+}, Zn^{2+} and Cd^{2+} concentrations could not be associated with a mineral or precipitate are therefore considered to be unsaturated
- However, Cu^{2+}, Fe^{2+}, Zn^{2+} and Cd^{2+} concentrations were found to increase with depth giving the appearance that supergene deposition is occurring

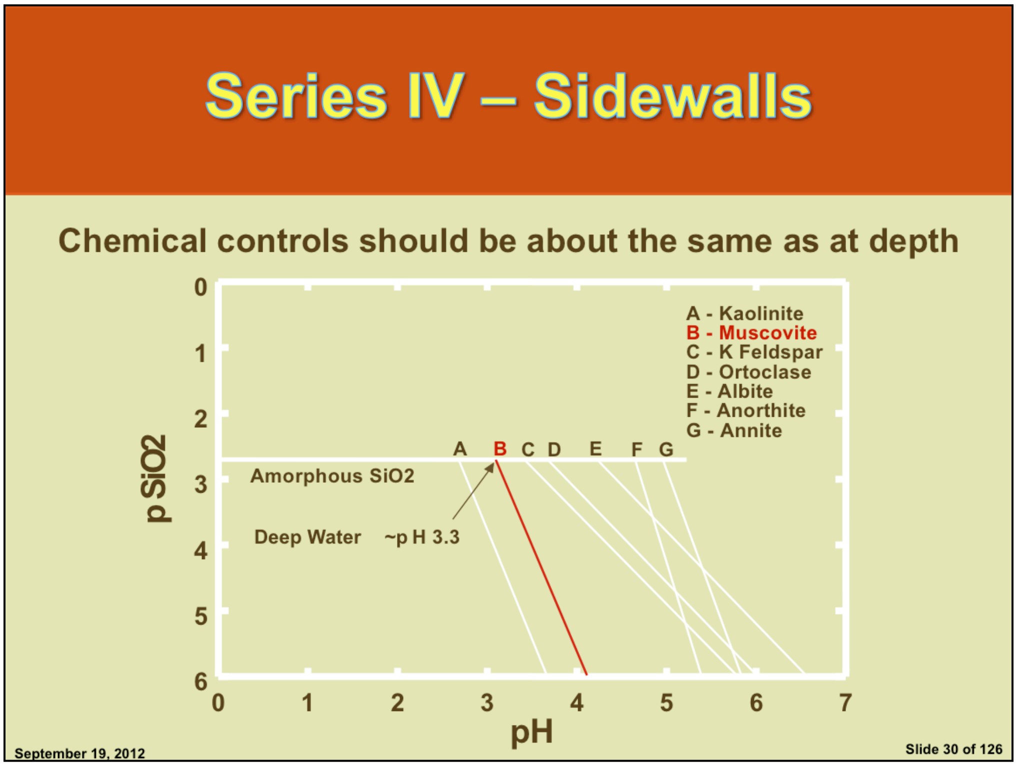
Series IV – Sidewalls

Mineralogy is essentially the same except fine native rock (granite) and gypsum precipitate are more abundant:

Native:
- Granite (38%)
- Quartz (33%)
- Muscovite (4%)

Precipitate:
- K-jarosite (22%)
- Gypsum (3%)





Series IV – Sidewalls
Chemical controls should be about the same as at depth
A - Kaolinite
B - Muscovite
C - K Feldspar
D - Ortoclase
E - Albite
F - Anorthite
G - Annite
A B C D E F G
Amorphous SiO2
Deep Water ~p H 3.3
p SiO2
0
1
2
3
4
5
6
0 1 2 3 4 5 6 7
pH
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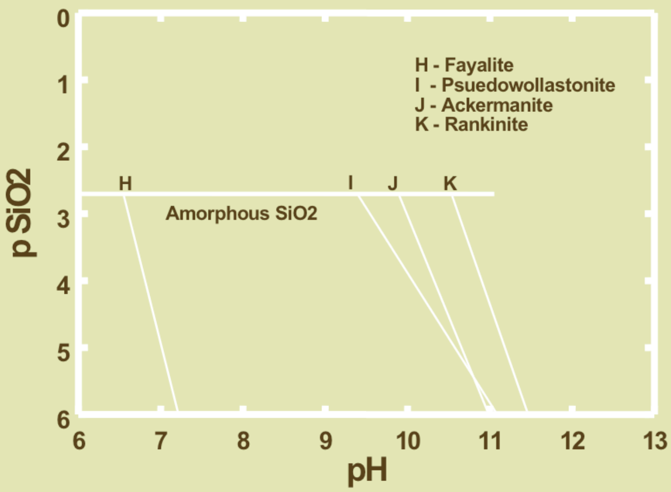
Series V – Silicate Slags

Silicate (and oxide) slags should do the same thing!



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Silicate Slags

Source of Silicate (and lime)

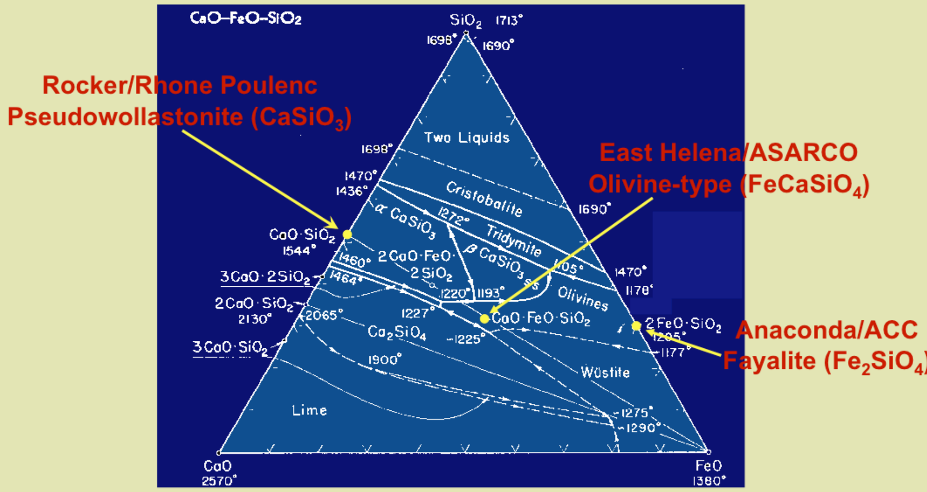
Act as pH-Buffers (replace lime)

Available in Montana (inactive)

- Anaconda (ARCO) - Fayalite, Fe_2SiO_4
- East Helena (ASARCO) - Olivine-type, $CaFeSiO_4$
- Rocker (Rhone) - Pseudowallastonite, $CaSiO_3$

Slag	Ca (%)	Fe (%)	Si (%)
Rhone	30.3	0.4	19.0
ASARCO	14.0	27.6	12.7
Anaconda	2.6	30.9	15.8

Silicate Slags



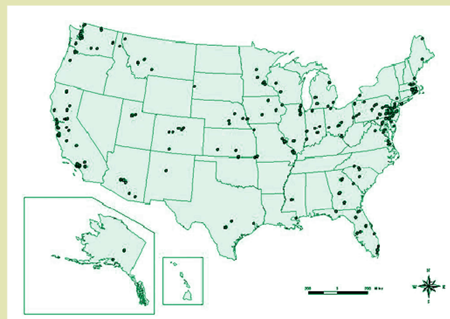
Silicate Slags

Other Global Sources
- Columbus (Stillwater)
- Salt Lake City (Kennecott)
- Trail, BC (Teck Cominco)

Dual Ecosystem Enhancement
- Remove Slag Piles
- Remediate Berkeley Pitlake
- *In-Situ* or *Ex-Situ*

Provide Entertainment
- Golf Courses
- Parks & Walkways
- Sports Complexes

Attract Businesses



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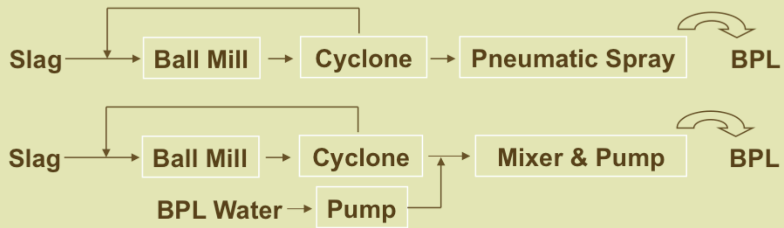
Objectives

Conceptual Flowsheet Designs

Dry Grinding



Wet Grinding

Outline

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Procedures

- Characterize Montana Slags
  - Bond Work Index
  - SEM/EDX/MLA Analysis
  - Remediation Potential
- Model Effects
  - Parameters
    - Slag Type (Fe/Si Ratio)
    - Particle Size (100-400 Mesh)
    - Slag Amount (200-800 g/L)
  - Experimental Design (StatEase)

Outline

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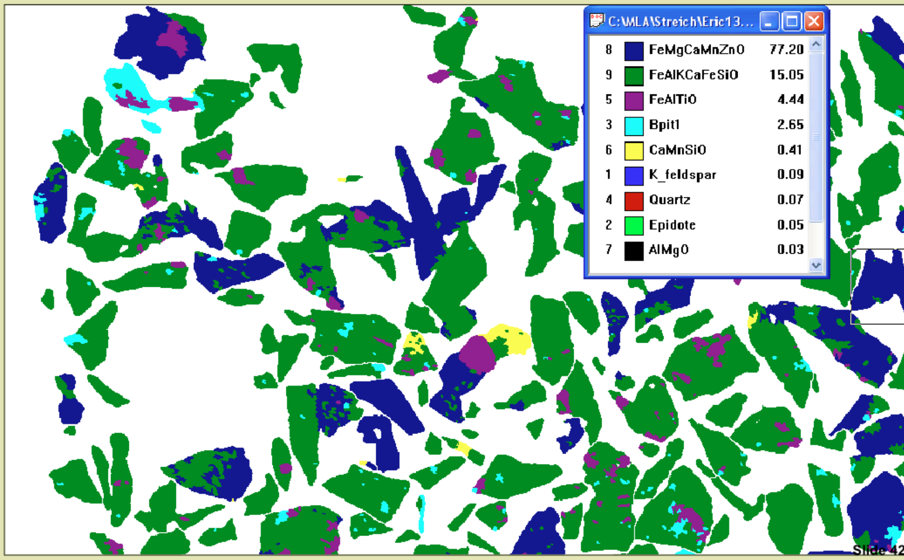
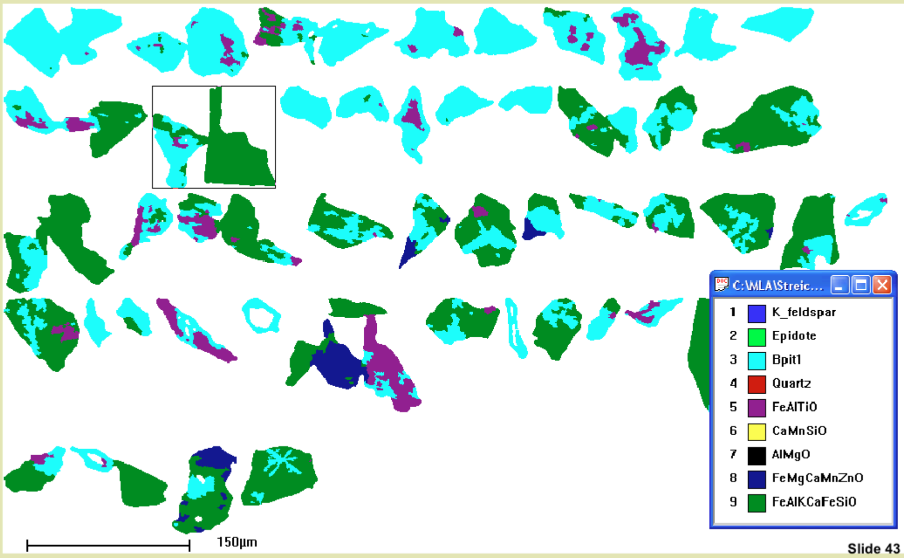
Bond Work Index

Date	Slag	Target Size Mesh (mm)	F80 (mm)	P80 (mm)	Avg Gbp	Bond Work Index
1/29/05	ACC	48 (0.295)	2.825	0.205	0.95	20.52
2/17/05	ACC	100 (0.147)	2.603	0.117	0.94	20.44
2/20/05	ACC	200 (0.074)	2.603	0.058	0.53	24.86
1/29/05	ASARCO	48 (0.295)	2.652	0.230	1.76	16.26
2/12/05	ASARCO	100 (0.147)	2.555	0.113	1.24	15.93
1/30/05	ASARCO	200 (0.074)	2.603	0.053	0.50	24.68
2/26/05	RP	48 (0.295)	1.414	0.251	2.79	14.18
3/4/05	RP	100 (0.147)	1.414	0.121	1.53	15.48
3/4/05	RP	200 (0.074)	1.414	0.063	0.76	20.66

SEM/EDX/MLA Analysis
(150 um Asarco Slag Before)



SEM/EDX/MLA Analysis
(150 um Asarco Slag After)



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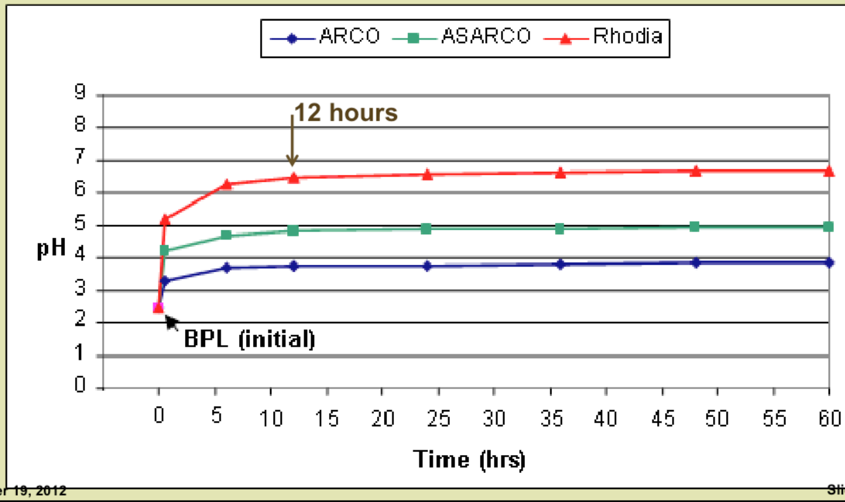
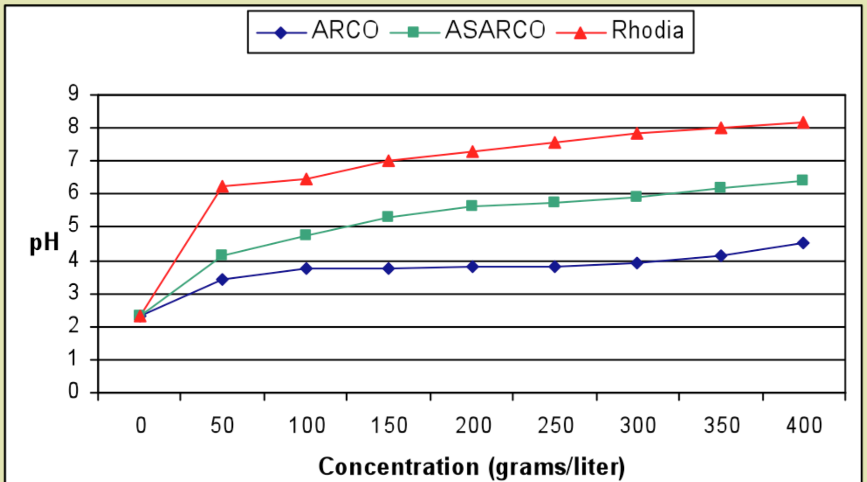
Remediation Potential
(Bottle Roll Tests)

Size = 53 um; Amount = 100 g/L



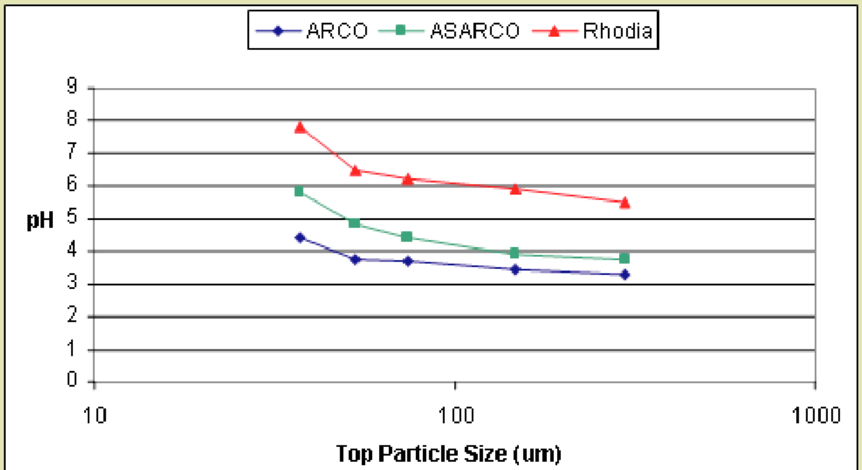
Remediation Potential
(Bottle Roll Tests)

Size = 53 um; Time = 12 hrs



Remediation Potential
(Bottle Roll Tests)

Amount = 100 g/L; Time = 12 hrs



StatEase Design of Experiments
(Box-Behnken Matrix)

Run	Slag Type (Fe/Si Ratio)	Particle Size (µm)	Slag Amount (g/L)
1	0 = Rhodia	-37 = 400 mesh	500
2	2 = ARCO	-37	500
3	0	-147 = 100 mesh	500
4	2	-147	500
5	0	-74 = 200 mesh	200
6	2	-74	200
7	0	-74	800
8	2	-74	800
9	1 = ASARCO	-37	200
10	1	-147	200
11	1	-37	800
12	1	-147	800
13	1	-74	500
14	1	-74	500
15	1	-74	500

	pH	Al	As	Cd	Cu	Fe	Mn	SO_4^{2-}	Zn
Test Run	BPL Concentrations (mg/L)								
	2.5	289	0.15	2.1	168	793	276	2723	621
	Final Responses (mg/L)								
1	9.08	0.043	0.0025	0.002	0.19	0.29	4.42	829	0.24
2	5	6.32	0.09	2.1	2.26	95	276	1980	621
3	7.77	0.20	0.001	0.034	0.063	0.069	57.8	1075	2.02
4	5.19	11.6	0.09	1.69	34.2	772	276	2210	621
5	7.68	0.20	0.0008	0.055	0.136	0.096	83.7	619	3.84
6	4.55	37.8	0.15	2.1	168	793	268	2450	621
7	8.42	0.041	0.001	0.002	0.179	0.014	5.13	879	0.11
8	5.52	0.37	0.039	1.13	0.566	271	276	1720	531
9	5.62	1.39	0.0049	1.03	0.39	6.99	266	1680	601
10	4.74	26.1	0.021	1.57	18.05	595	265	2045	621
11	6.89	0.20	0.0014	0.059	0.095	0.069	181	1270	24.1
12	6.16	0.444	0.0023	0.38	0.141	2.37	248	1395	212
13	6.02	0.62	0.0023	0.44	0.174	4.77	250	1410	278
14	6.08	0.53	0.0023	0.42	0.139	3.76	248	1410	254
15	6.08	0.51	0.0022	0.45	0.277	3.67	252	1450	257
	Drinking Water Standards (mg/L)								
	6.5 - 8.5	0.05	0.01	0.005	1.3	0.3	0.05	250	5

StatEase Model Equations

A = Fe/Si Ratio (0-2); B = Size (um); C = Amount (g/L)

$pH = 8.31 - 3.49A - 0.0012B + 0.0018C + 0.006AB + 0.7A^2$

$Log\ [H] = -8.31 + 3.49A + 0.0012B - 0.0018C - 0.006AB - 0.7A^2$

$Log\ [Al] = 2.05 + 1.44A + 0.0063B - 0.0011C - 0.0011AC$

$[As]^{0.5} = 0.39 + 0.48A + 0.0015C - 0.006AC + 3.35A^2$

$[Cd]^{0.5} = 16.77 + 20.36A - 0.027*C$

$Log\ [Cu] = 2.29 + 0.17A + 0.0074B - 0.0019C + 0.0083AB - 0.0023AC - 0.00002BC + 0.59A^2 + 0.0000038C^2$

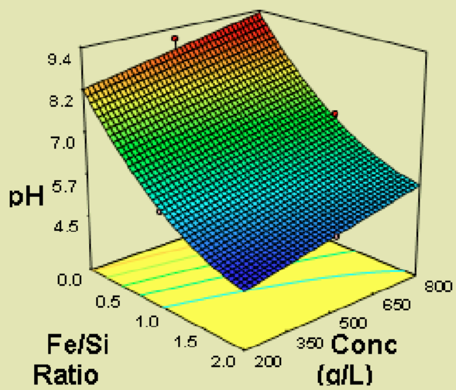
$Log\ [Fe] = 2.1 + 1.95A + 0.0099B - 0.0025C$

$[Mn] = 738886 + 26555A + 252B - 127C + 63.5AC - 86310A^2$

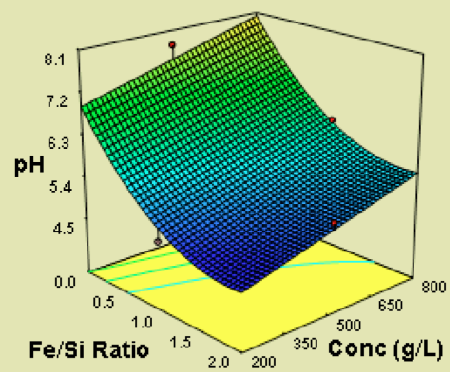
$[Zn]^{0.5} = 315.4 + 420A - 0.49C$

StatEase Model Plots

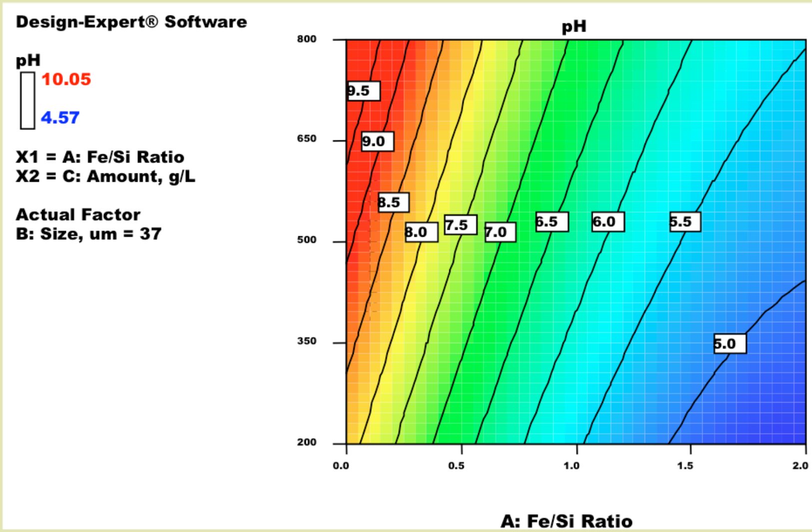
Size = 37 µm



Size = 147 µm

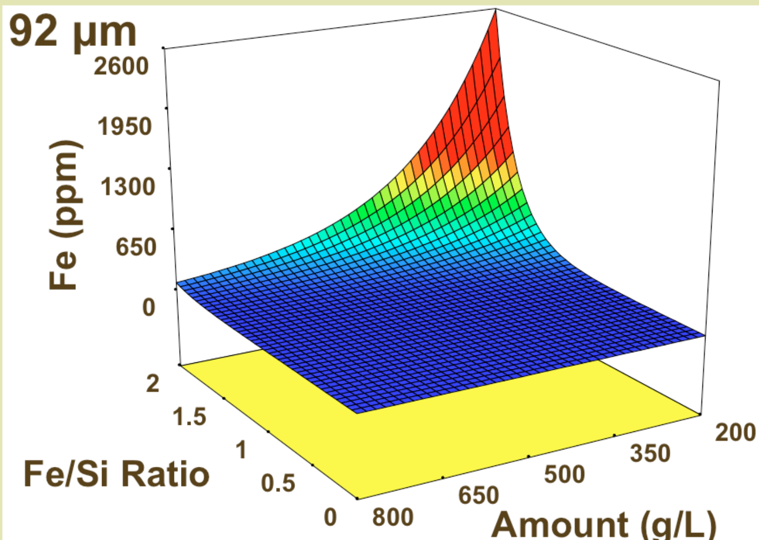


StatEase Model Plots

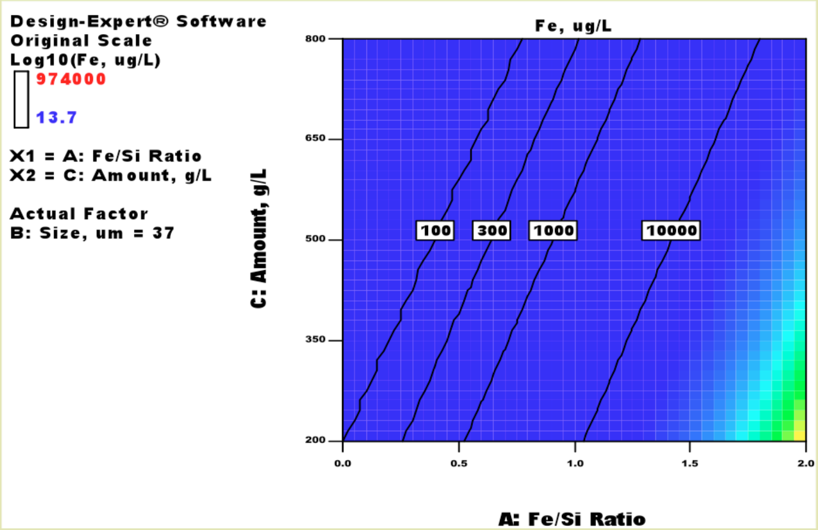


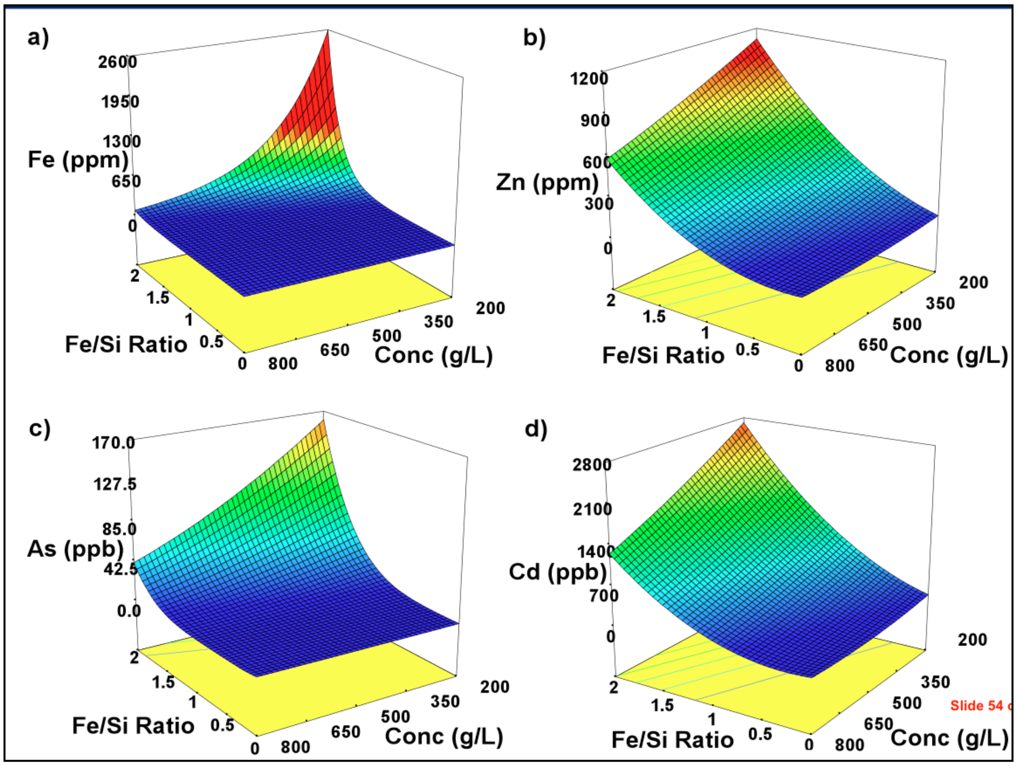
StatEase Model Plots

Size = 92 µm



StatEase Model Plots




a)
2600
1950
1300
650
0
Fe (ppm)
2
1.5
1
0.5
0
Fe/Si Ratio
800
650
500
350
200
Conc (g/L)
b)
1200
900
600
300
0
Zn (ppm)
2
1.5
1
0.5
0
Fe/Si Ratio
800
650
500
350
200
Conc (g/L)
c)
170.0
127.5
85.0
42.5
0.0
As (ppb)
2
1.5
1
0.5
0
Fe/Si Ratio
800
650
500
350
200
Conc (g/L)
d)
2800
2100
1400
700
0
Cd (ppb)
2
1.5
1
0.5
0
Fe/Si Ratio
800
650
500
350
200
Conc (g/L)

Outline

- ✓ Berkeley Pitlake
- ✓ Previous Research
- ✓ Silicate Slags
- ✓ Objectives
- ✓ Procedures
- ✓ Results & Discussions
- **Conclusions**
- Acknowledgements

Conclusions

- ✓ Slags can be an effective for remediating ARD
- ✓ Their use could or will:
  - replace lime (pseudowollastonite slag)
  - diminish lime consumption (fayalite/olivine)
  - lead to remediation of two ecosystems
- ✓ Depending on the slag type and particle size:
  - effluent pH from 5-9 can result
  - effluent concentrations can meet DWS
- ✓ Al and Cu concentration profiles are similar to Fe
- ✓ Likewise, Al and Cu redissolution at high pH is minimal similar to Fe

Outline

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Acknowledgements

This research was previously funded by the MWTP via an Interagency Agreement (IAG) between the U.S. EPA and the U.S. DoE, IAG No. DW89935117-01-0.

Thanks are also extended to the Department of Metallurgical & Materials Engineering at Montana Tech for bearing the costs for some analyses and the MBMG for helping collect samples: James Madison and Ted Duaime.

Sincere appreciation is given to the workforce who have worked on these projects over the years. MS students included Ray Ziolkowski, Tom McMillan, Yu Chuan Tai, Eric Streich and Krag Filius. BS students include Sonny Adams, Jennifer Gambill and Brian Ross.

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We are always on the lookout for funding Series VI to ∞!

Outline

- ✓ Berkeley Pitlake
- ✓ Previous Research
- ✓ Silicate Slags
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- ✓ Results & Discussions
- ✓ Conclusions
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Thanks For Your Attention!

Mining-Influenced Water: Environmental Issues, Remediation Research, and Tools for Estimating Remediation Cost


?
September 19, 2012
Mining-Influenced Water: Environmental Issues, Remediation Research, and Tools for Estimating Remediation Cost
Slide 61 of 126

Overview of AMDTreat 5.0: Mine Drainage Treatment Cost-Estimating Software

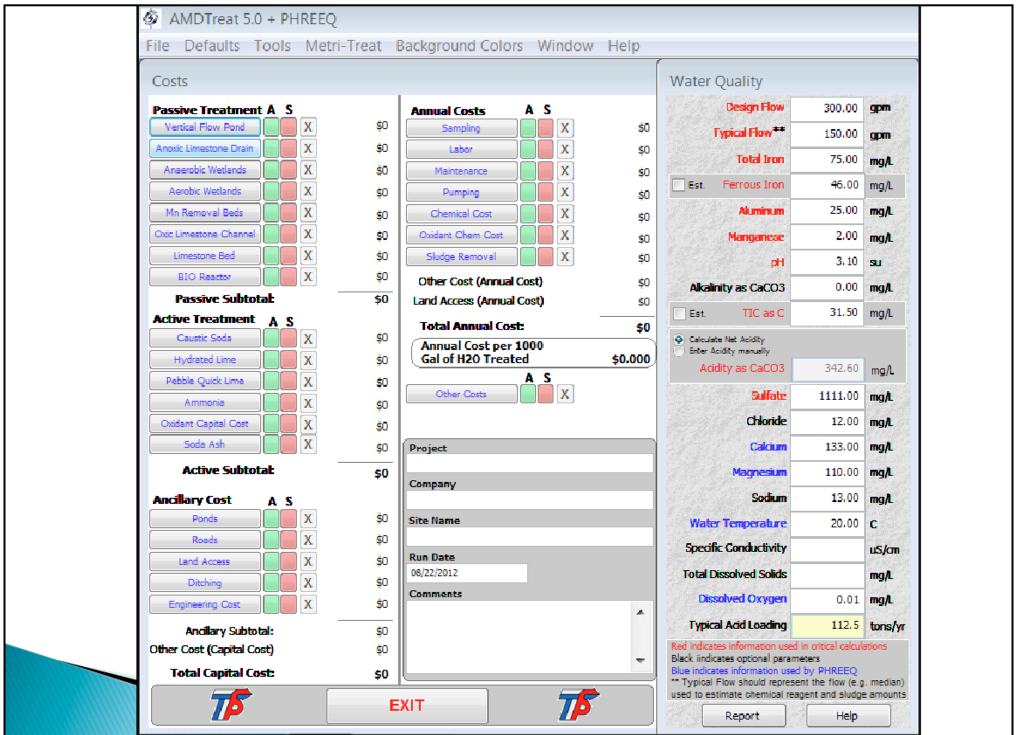
Brent Means
U.S. Office of Surface Mining

AMDTreat 5.0

- www.amdtreat.osmre.gov

Why Estimate Treatment Costs?

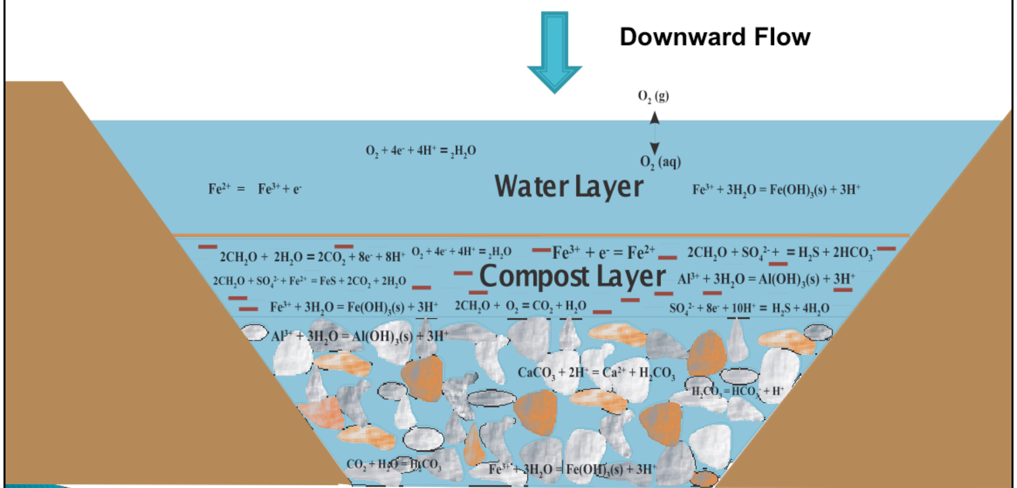
- Treatment costs are needed to calculate bond amount in case of bankruptcy for active mines and to estimate the cost of treating abandoned mine drainage.
- AMDTreat estimates annual treatment costs for both passive and active treatment

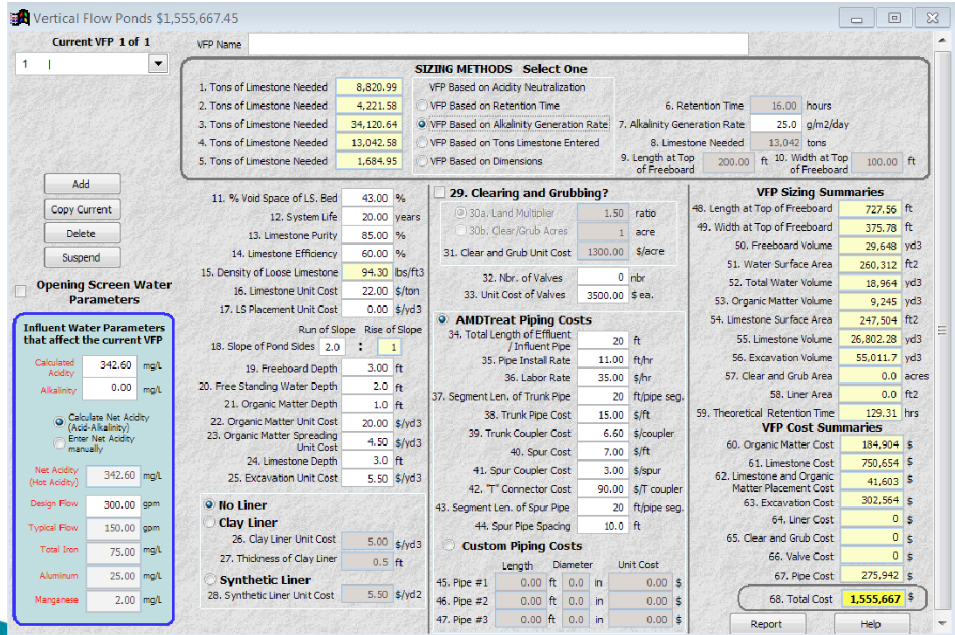

AMDTreat 5.0 + PHREEQ
File Defaults Tools Metri-Treat Background Colors Window Help
Costs
Passive Treatment A S
Vertical Flow Pond
Anoxic Limestone Drain
Anaerobic Wetlands
Aerobic Wetlands
Mn Removal Beds
Oxic Limestone Channel
Limestone Bed
BIO Reactor
Passive Subtotal:
Active Treatment A S
Caustic Soda
Hydrated Lime
Pebble Quick Lime
Ammonia
Oxidant Capital Cost
Soda Ash
Active Subtotal:
Ancillary Cost A S
Ponds
Roads
Land Access
Ditching
Engineering Cost
Ancillary Subtotal:
Other Cost (Capital Cost)
Total Capital Cost:
$0
Annual Costs A S
Sampling
Labor
Maintenance
Pumping
Chemical Cost
Oxidant Chem Cost
Sludge Removal
Other Cost (Annual Cost)
Land Access (Annual Cost)
Total Annual Cost:
$0
Annual Cost per 1000 Gal of H20 Treated
$0.000
Other Costs
Project
Company
Site Name
Run Date
08/22/2012
Comments
EXIT
Water Quality
Design Flow 300.00 gpm
Typical Flow** 150.00 gpm
Total Iron 75.00 mg/L
Est. Ferrous Iron 46.00 mg/L
Aluminum 25.00 mg/L
Manganese 2.00 mg/L
pH 3.10 su
Alkalinity as CaCO3 0.00 mg/L
Est. TIC as C 31.50 mg/L
Calculate Net Acidity
Enter Acidity manually
Acidity as CaCO3 342.60 mg/L
Sulfate 1111.00 mg/L
Chloride 12.00 mg/L
Calcium 133.00 mg/L
Magnesium 110.00 mg/L
Sodium 13.00 mg/L
Water Temperature 20.00 C
Specific Conductivity uS/cm
Total Dissolved Solids mg/L
Dissolved Oxygen 0.01 mg/L
Typical Acid Loading 112.5 tons/yr
Red indicates information used in critical calculations
Black indicates optional parameters
Blue indicates information used by PHREEQ
** Typical Flow should represent the flow (e.g. median) used to estimate chemical reagent and sludge amounts
Report
Help

Passive Treatment Capital Cost Example:

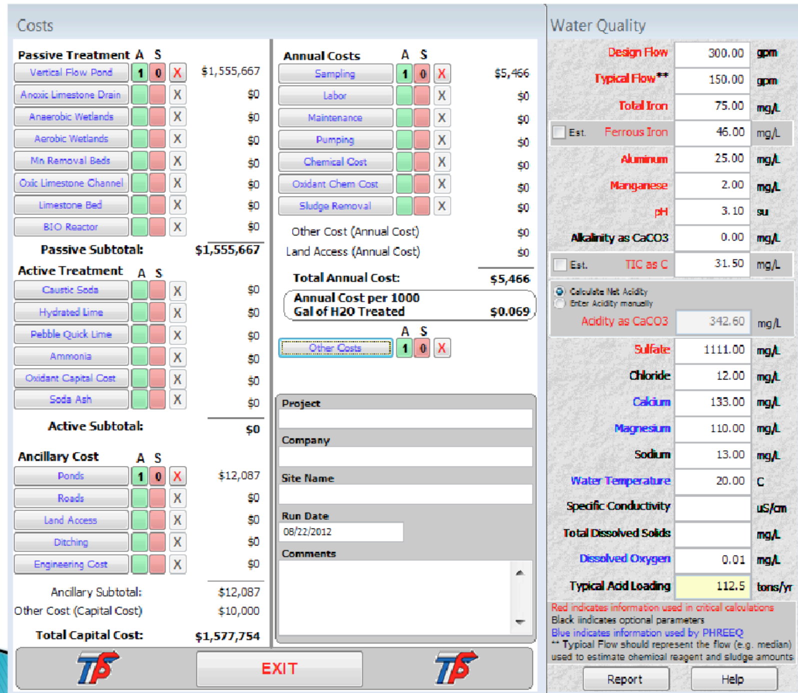
- Vertical Flow Pond (aka: SAPS, VFP, RAPS, etc)

Passive Treatment Capital Cost Example: Vertical Flow Pond

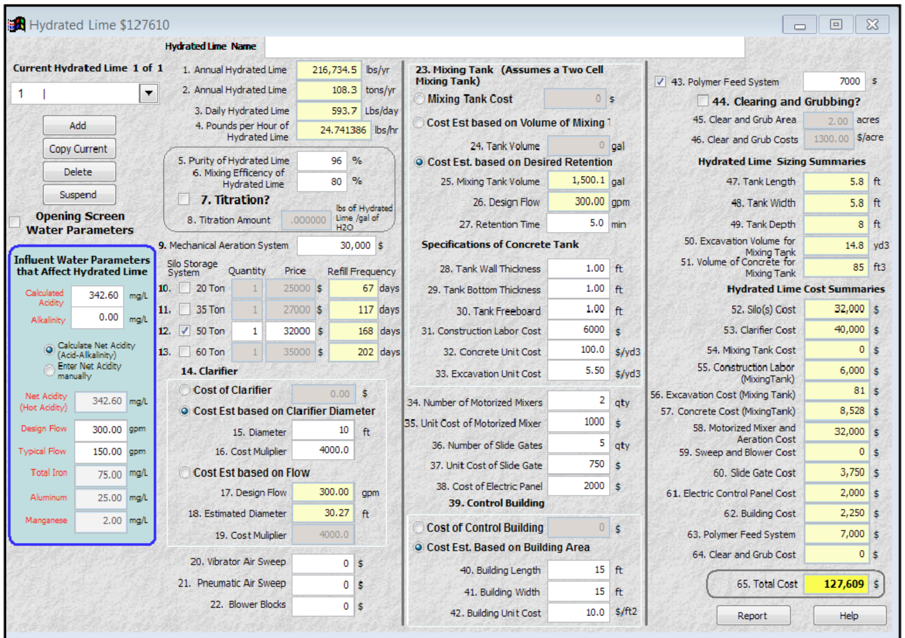




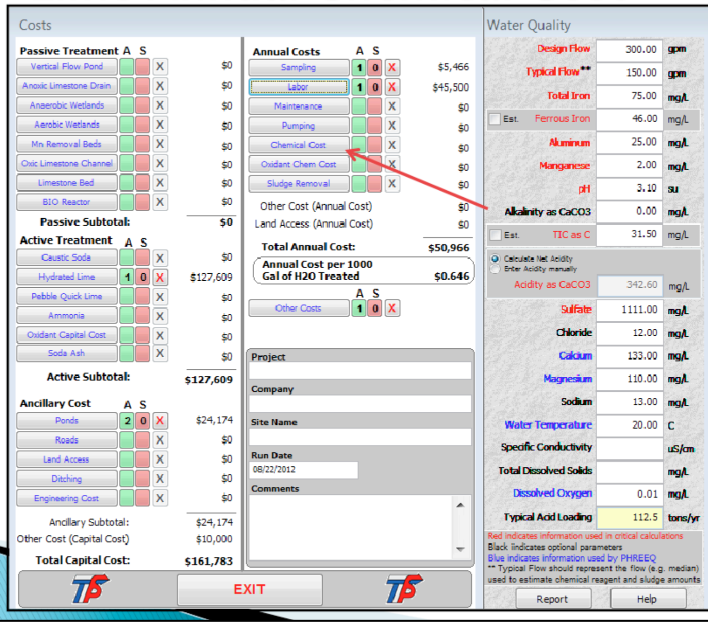
Vertical Flow Ponds $1,555,667.45
Current VFP 1 of 1
VFP Name
SIZING METHODS Select One
1. Tons of Limestone Needed 8,820.99
2. Tons of Limestone Needed 4,221.58
3. Tons of Limestone Needed 34,120.64
4. Tons of Limestone Needed 13,042.58
5. Tons of Limestone Needed 1,684.95
VFP Based on Acidity Neutralization
VFP Based on Retention Time
VFP Based on Alkalinity Generation Rate
VFP Based on Tons Limestone Entered
VFP Based on Dimensions
6. Retention Time 16.00 hours
7. Alkalinity Generation Rate 25.0 g/m2/day
8. Limestone Needed 13,042 tons
9. Length at Top of Freeboard 200.00 ft
10. Width at Top of Freeboard 100.00 ft
Add
Copy Current
Delete
Suspend
Opening Screen Water Parameters
Influent Water Parameters that affect the current VFP
Calculated Acidity 342.60 mg/L
Alkalinity 0.00 mg/L
Calculate Net Acidity (Acid-Alkalinity)
Enter Net Acidity manually
Net Acidity (Hot Acidity) 342.60 mg/L
Design Flow 300.00 gpm
Typical Flow 150.00 gpm
Total Iron 75.00 mg/L
Aluminum 25.00 mg/L
Manganese 2.00 mg/L
11. % Void Space of LS. Bed 43.00 %
12. System Life 20.00 years
13. Limestone Purity 85.00 %
14. Limestone Efficiency 60.00 %
15. Density of Loose Limestone 94.30 lbs/ft3
16. Limestone Unit Cost 22.00 $/ton
17. LS Placement Unit Cost 0.00 $/yd3
Run of Slope Rise of Slope
18. Slope of Pond Sides 2.0 : 1
19. Freeboard Depth 3.00 ft
20. Free Standing Water Depth 2.0 ft
21. Organic Matter Depth 1.0 ft
22. Organic Matter Unit Cost 20.00 $/yd3
23. Organic Matter Spreading Unit Cost 4.50 $/yd3
24. Limestone Depth 3.0 ft
25. Excavation Unit Cost 5.50 $/yd3
No Liner
Clay Liner
26. Clay Liner Unit Cost 5.00 $/yd3
27. Thickness of Clay Liner 0.5 ft
Synthetic Liner
28. Synthetic Liner Unit Cost 5.50 $/yd2
29. Clearing and Grubbing?
30a. Land Multiplier 1.50 ratio
30b. Clear/Grub Acres 1 acre
31. Clear and Grub Unit Cost 1300.00 $/acre
32. Nbr. of Valves 0 nbr
33. Unit Cost of Valves 3500.00 $ ea.
AMDTreat Piping Costs
34. Total Length of Effluent / Influent Pipe 20 ft
35. Pipe Install Rate 11.00 ft/hr
36. Labor Rate 35.00 $/hr
37. Segment Len. of Trunk Pipe 20 ft/pipe seg.
38. Trunk Pipe Cost 15.00 $/ft
39. Trunk Coupler Cost 6.60 $/coupler
40. Spur Cost 7.00 $/ft
41. Spur Coupler Cost 3.00 $/spur
42. "T" Connector Cost 90.00 $/T coupler
43. Segment Len. of Spur Pipe 20 ft/pipe seg.
44. Spur Pipe Spacing 10.0 ft
Custom Piping Costs
Length Diameter Unit Cost
45. Pipe #1 0.00 ft 0.0 in 0.00 $
46. Pipe #2 0.00 ft 0.0 in 0.00 $
47. Pipe #3 0.00 ft 0.0 in 0.00 $
VFP Sizing Summaries
48. Length at Top of Freeboard 727.56 ft
49. Width at Top of Freeboard 375.78 ft
50. Freeboard Volume 29,648 yd3
51. Water Surface Area 260,312 ft2
52. Total Water Volume 18,964 yd3
53. Organic Matter Volume 9,245 yd3
54. Limestone Surface Area 247,504 ft2
55. Limestone Volume 26,802.28 yd3
56. Excavation Volume 55,011.7 yd3
57. Clear and Grub Area 0.0 acres
58. Liner Area 0.0 ft2
59. Theoretical Retention Time 129.31 hrs
VFP Cost Summaries
60. Organic Matter Cost 184,904 $
61. Limestone Cost 750,654 $
62. Limestone and Organic Matter Placement Cost 41,603 $
63. Excavation Cost 302,564 $
64. Liner Cost 0 $
65. Clear and Grub Cost 0 $
66. Valve Cost 0 $
67. Pipe Cost 275,942 $
68. Total Cost 1,555,667 $
Report
Help


Costs
Passive Treatment A S
Vertical Flow Pond 1 0 X $1,555,667
Anoxic Limestone Drain X $0
Anaerobic Wetlands X $0
Aerobic Wetlands X $0
Mn Removal Beds X $0
Oxic Limestone Channel X $0
Limestone Bed X $0
BIO Reactor X $0
Passive Subtotal: $1,555,667
Active Treatment A S
Caustic Soda X $0
Hydrated Lime X $0
Pebble Quick Lime X $0
Ammonia X $0
Oxidant Capital Cost X $0
Soda Ash X $0
Active Subtotal: $0
Ancillary Cost A S
Ponds 1 0 X $12,087
Roads X $0
Land Access X $0
Ditching X $0
Engineering Cost X $0
Ancillary Subtotal: $12,087
Other Cost (Capital Cost) $10,000
Total Capital Cost: $1,577,754
Annual Costs A S
Sampling 1 0 X $5,466
Labor X $0
Maintenance X $0
Pumping X $0
Chemical Cost X $0
Oxidant Chem Cost X $0
Sludge Removal X $0
Other Cost (Annual Cost) $0
Land Access (Annual Cost) $0
Total Annual Cost: $5,466
Annual Cost per 1000 Gal of H2O Treated $0.069
Other Costs 1 0 X
Project
Company
Site Name
Run Date
08/22/2012
Comments
EXIT
Water Quality
Design Flow 300.00 gpm
Typical Flow** 150.00 gpm
Total Iron 75.00 mg/L
Est. Ferrous Iron 46.00 mg/L
Aluminum 25.00 mg/L
Manganese 2.00 mg/L
pH 3.10 su
Alkalinity as CaCO3 0.00 mg/L
Est. TIC as C 31.50 mg/L
Calculate Net Acidity
Enter Acidity manually
Acidity as CaCO3 342.60 mg/L
Sulfate 1111.00 mg/L
Chloride 12.00 mg/L
Calcium 133.00 mg/L
Magnesium 110.00 mg/L
Sodium 13.00 mg/L
Water Temperature 20.00 C
Specific Conductivity uS/cm
Total Dissolved Solids mg/L
Dissolved Oxygen 0.01 mg/L
Typical Acid Loading 112.5 tons/yr
Red indicates information used in critical calculations
Black indicates optional parameters
Blue indicates information used by PHREEQ
** Typical Flow should represent the flow (e.g. median) used to estimate chemical reagent and sludge amounts
Report
Help

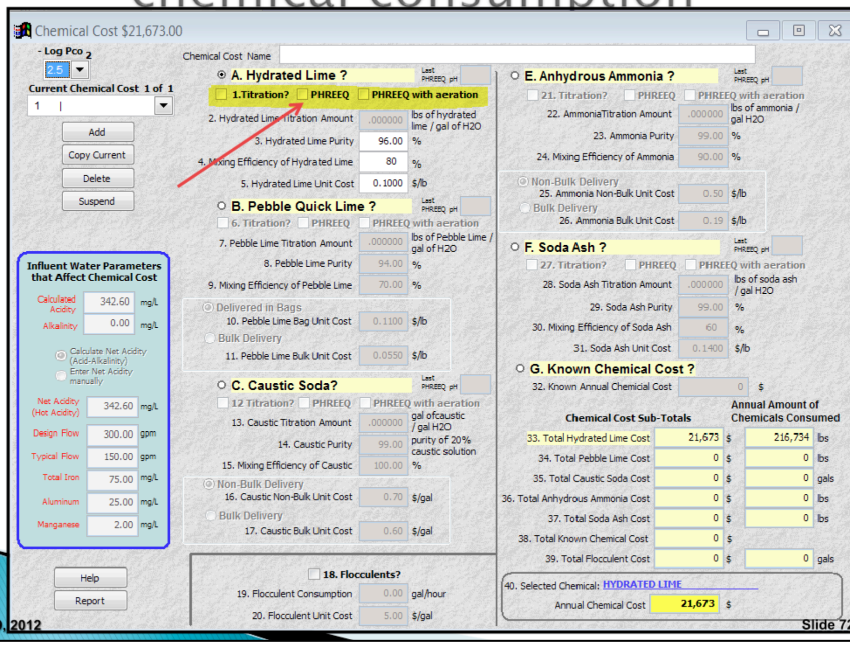
Active Treatment Example: Hydrated Lime


Hydrated Lime $127610
Hydrated Lime Name
Current Hydrated Lime 1 of 1
Add
Copy Current
Delete
Suspend
Opening Screen Water Parameters
Influent Water Parameters that Affect Hydrated Lime
Calculated Acidity 342.60 mg/L
Alkalinity 0.00 mg/L
Calculate Net Acidity (Acid-Alkalinity)
Enter Net Acidity manually
Net Acidity (Hot Acidity) 342.60 mg/L
Design Flow 300.00 gpm
Typical Flow 150.00 gpm
Total Iron 75.00 mg/L
Aluminum 25.00 mg/L
Manganese 2.00 mg/L
1. Annual Hydrated Lime 216,734.5 lbs/yr
2. Annual Hydrated Lime 108.3 tons/yr
3. Daily Hydrated Lime 593.7 Lbs/day
4. Pounds per Hour of Hydrated Lime 24.741386 lbs/hr
5. Purity of Hydrated Lime 96 %
6. Mixing Efficiency of Hydrated Lime 80 %
7. Titration?
8. Titration Amount .000000 lbs of Hydrated Lime /gal of H2O
9. Mechanical Aeration System 30,000 $
Silo Storage System Quantity Price Refill Frequency
10. 20 Ton 1 25000 $ 67 days
11. 35 Ton 1 27000 $ 117 days
12. 50 Ton 1 32000 $ 168 days
13. 60 Ton 1 35000 $ 202 days
14. Clarifier
Cost of Clarifier 0.00 $
Cost Est based on Clarifier Diameter
15. Diameter 10 ft
16. Cost Mulplier 4000.0
Cost Est based on Flow
17. Design Flow 300.00 gpm
18. Estimated Diameter 30.27 ft
19. Cost Mulplier 4000.0
20. Vibrator Air Sweep 0 $
21. Pneumatic Air Sweep 0 $
22. Blower Blocks 0 $
23. Mixing Tank (Assumes a Two Cell Mixing Tank)
Mixing Tank Cost 0 $
Cost Est based on Volume of Mixing
24. Tank Volume 0 gal
Cost Est. based on Desired Retention
25. Mixing Tank Volume 1,500.1 gal
26. Design Flow 300.00 gpm
27. Retention Time 5.0 min
Specifications of Concrete Tank
28. Tank Wall Thickness 1.00 ft
29. Tank Bottom Thickness 1.00 ft
30. Tank Freeboard 1.00 ft
31. Construction Labor Cost 6000 $
32. Concrete Unit Cost 100.0 $/yd3
33. Excavation Unit Cost 5.50 $/yd3
34. Number of Motorized Mixers 2 qty
35. Unit Cost of Motorized Mixer 1000 $
36. Number of Slide Gates 5 qty
37. Unit Cost of Slide Gate 750 $
38. Cost of Electric Panel 2000 $
39. Control Building
Cost of Control Building 0 $
Cost Est. Based on Building Area
40. Building Length 15 ft
41. Building Width 15 ft
42. Building Unit Cost 10.0 $/ft2
43. Polymer Feed System 7000 $
44. Clearing and Grubbing?
45. Clear and Grub Area 2.00 acres
46. Clear and Grub Costs 1300.00 $/acre
Hydrated Lime Sizing Summaries
47. Tank Length 5.8 ft
48. Tank Width 5.8 ft
49. Tank Depth 8 ft
50. Excavation Volume for Mixing Tank 14.8 yd3
51. Volume of Concrete for Mixing Tank 85 ft3
Hydrated Lime Cost Summaries
52. Silo(s) Cost 32,000 $
53. Clarifier Cost 40,000 $
54. Mixing Tank Cost 0 $
55. Construction Labor (MixingTank) 6,000 $
56. Excavation Cost (Mixing Tank) 81 $
57. Concrete Cost (MixingTank) 8,528 $
58. Motorized Mixer and Aeration Cost 32,000 $
59. Sweep and Blower Cost 0 $
60. Slide Gate Cost 3,750 $
61. Electric Control Panel Cost 2,000 $
62. Building Cost 2,250 $
63. Polymer Feed System 7,000 $
64. Clear and Grub Cost 0 $
65. Total Cost 127,609 $
Report
Help

Active Treatment Example: Hydrated Lime Annual Chemical Cost



Three Methods to estimate chemical consumption



Integration of USGS PHREEQ module

- PHREEQ is a geochemical modeling software developed and supported by the USGS;
- Dr. Chuck Cravotta and Dave Parkhurst of the USGS developed a PHREEQ module to simulate mine drainage treatment;
- OSM and USGS developed a team to integrate the PHREEQ module into AMDTreat 5.0.
- The PHREEQ module estimates chemical consumption, effluent quality, and sludge volume. It also calculates mineral saturation indices and can be used to evaluate the effect of CO2 neutralization on treatment costs.

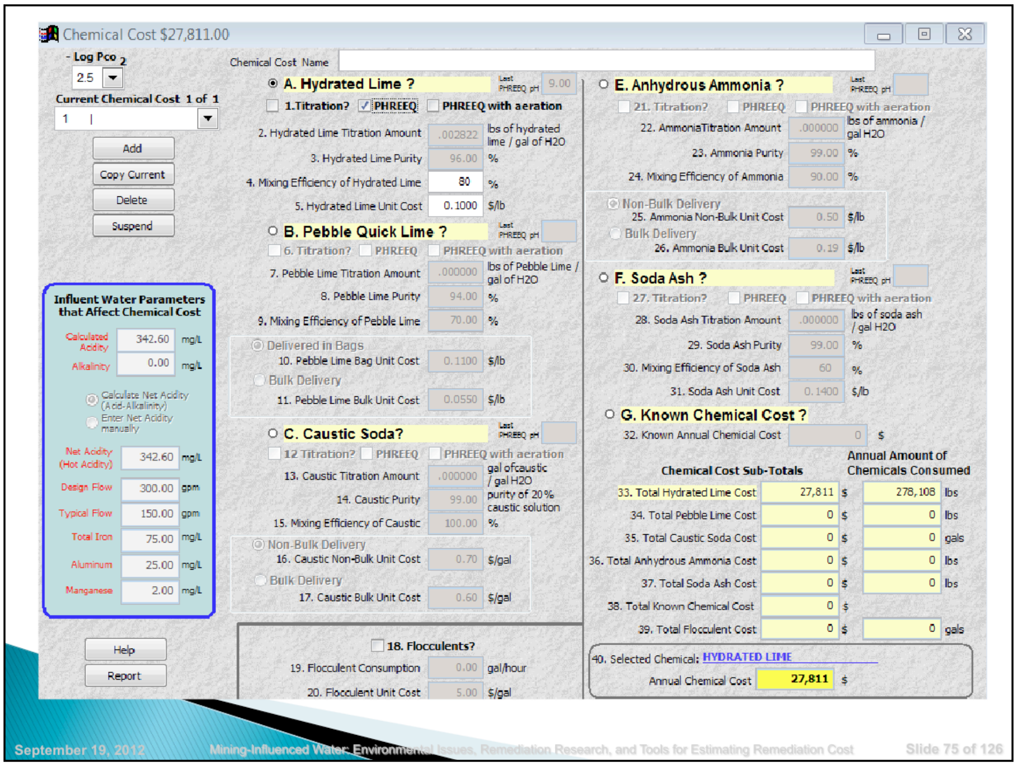
PHREEQ

	pH	pH	CausticTitr	CausticMol	Total Fe	Fe2	Al	Mn	Na	Ca	Mg	SO4	Alkalinity
Select-->	3.100	3.100	0.000000	0.000000	75.114	46.000	25.041	2.003	13.020	133.202	110.135	1112.665	-107.561
Select-->	4.000	4.000	0.000656	0.001062	59.726	45.999	25.041	2.003	13.020	175.748	110.133	1112.644	-15.173
Select-->	4.500	4.500	0.001351	0.002187	48.705	45.999	6.020	2.003	13.020	220.859	110.133	1095.714	-0.595
Select-->	5.000	5.000	0.001564	0.002531	46.745	45.999	0.361	2.003	13.020	234.642	110.133	1090.677	5.824
Select-->	5.500	5.500	0.001798	0.002911	46.229	45.998	0.022	2.003	13.019	249.865	110.131	1112.622	18.609
Select-->	6.000	6.000	0.001966	0.003182	46.074	45.998	0.002	2.003	13.019	260.736	110.131	1112.622	45.482
Select-->	6.500	6.500	0.002195	0.003553	46.026	45.998	0.001	2.003	13.019	275.598	110.131	1112.622	82.514
Select-->	7.000	7.000	0.002372	0.003841	46.011	45.998	0.002	2.003	13.019	287.119	110.131	1112.622	111.250
Select-->	7.500	7.500	0.002465	0.003990	46.006	45.998	0.006	2.003	13.019	293.094	110.131	1112.621	126.174
Select-->	8.000	8.000	0.002522	0.004082	46.005	45.998	0.018	2.003	13.019	296.815	110.130	1112.619	135.527
Select-->	8.500	8.500	0.002638	0.004271	37.127	37.119	0.056	2.003	13.019	304.364	110.130	1112.613	138.678
Select-->	9.000	9.000	0.002822	0.004568	19.551	19.540	0.176	2.003	13.019	316.253	110.129	1112.602	137.545
Select-->	9.500	9.500	0.003344	0.005414	6.179	6.156	0.558	2.003	13.019	350.173	110.128	1112.597	200.344
Select-->	10.000	10.000	0.003681	0.005958	1.023	0.963	1.765	2.003	13.019	371.976	108.897	1112.585	247.134
Select-->	10.500	10.500	0.007234	0.011711	0.347	0.172	1.127	2.003	13.022	493.342	10.869	995.225	263.935
Select-->	11.000	11.000	0.007769	0.012577	0.622	0.082	0.082	0.221	13.022	513.064	1.149	990.094	269.607

Accept | Report | Export to Excel | Cancel

All units expressed in mg/L; Alkalinity expressed as mg/L as CaCO3; PPT represents the concentration of precipitate in g/L

	pH	TDS	PPT	Siderite	FeOH2a	FeOH3a	Schwert175	Boehmite	Basaluminite	AlOH3a	Rhodochrosite	MnOH2a	Pyrochroit
Select-->	3.100	1418.661	0.000	-5.767	-11.480	-1.724	0.417	-3.965	-11.416	-6.160	-6.867	-14.244	-13.844
Select-->	4.000	1501.228	0.029	-3.975	-9.687	0.000	11.080	-1.283	-2.474	-3.478	-5.076	-12.451	-12.051
Select-->	4.500	1508.114	0.136	-2.984	-8.691	0.000	9.342	-0.416	0.000	-2.611	-4.084	-11.455	-11.055
Select-->	5.000	1513.092	0.165	-2.001	-7.693	0.000	7.594	-0.166	0.000	-2.361	-3.102	-10.457	-10.057
Select-->	5.500	1557.074	0.128	-1.053	-6.700	0.000	5.851	0.000	-0.332	-2.195	-2.153	-9.464	-9.063
Select-->	6.000	1583.894	0.128	-0.179	-5.708	0.000	4.094	0.000	-1.335	-2.195	-1.279	-8.472	-8.071
Select-->	6.500	1620.926	0.128	0.565	-4.721	0.000	2.335	0.000	-2.341	-2.195	-0.534	-7.484	-7.083
Select-->	7.000	1649.674	0.128	1.180	-3.731	0.000	0.578	0.000	-3.345	-2.195	0.077	-6.498	-6.098
Select-->	7.500	1664.602	0.128	1.714	-2.742	0.000	-1.175	0.000	-4.346	-2.195	0.598	-5.523	-5.122
Select-->	8.000	1673.944	0.128	2.196	-1.764	0.000	-2.925	0.000	-5.347	-2.195	1.042	-4.582	-4.181
Select-->	8.500	1674.536	0.145	2.500	-0.907	0.000	-4.673	0.000	-6.346	-2.195	1.367	-3.704	-3.304
Select-->	9.000	1668.278	0.179	2.500	-0.283	0.000	-6.420	0.000	-7.343	-2.195	1.559	-2.888	-2.488
Select-->	9.500	1726.881	0.203	2.219	0.000	0.000	-8.173	0.000	-8.345	-2.195	1.683	-2.200	-1.799
Select-->	10.000	1771.565	0.212	1.428	0.000	0.000	-9.921	0.000	-9.344	-2.195	1.715	-1.377	-0.976
Select-->	10.500	1686.316	0.661	0.487	0.000	0.000	-11.722	-0.692	-13.143	-2.888	1.717	-0.434	-0.033
Select-->	11.000	1692.038	0.699	-0.531	0.000	0.000	-13.478	-2.331	-20.700	-4.526	0.732	-0.401	0.000


Chemical Cost $27,811.00
Log Pco2
2.5
Current Chemical Cost 1 of 1
Add
Copy Current
Delete
Suspend
Chemical Cost Name
A. Hydrated Lime ?
1.Titration?
PHREEQ
PHREEQ with aeration
2. Hydrated Lime Titration Amount .002822 lbs of hydrated lime / gal of H2O
3. Hydrated Lime Purity 96.00 %
4. Mixing Efficiency of Hydrated Lime 80 %
5. Hydrated Lime Unit Cost 0.1000 $/lb
B. Pebble Quick Lime ?
6. Titration?
7. Pebble Lime Titration Amount .000000 lbs of Pebble Lime / gal of H2O
8. Pebble Lime Purity 94.00 %
9. Mixing Efficiency of Pebble Lime 70.00 %
Delivered in Bags
10. Pebble Lime Bag Unit Cost 0.1100 $/lb
Bulk Delivery
11. Pebble Lime Bulk Unit Cost 0.0550 $/lb
C. Caustic Soda?
12 Titration?
13. Caustic Titration Amount .000000 gal of caustic / gal H2O
14. Caustic Purity 99.00 purity of 20% caustic solution
15. Mixing Efficiency of Caustic 100.00 %
Non-Bulk Delivery
16. Caustic Non-Bulk Unit Cost 0.70 $/gal
Bulk Delivery
17. Caustic Bulk Unit Cost 0.60 $/gal
18. Flocculents?
19. Flocculent Consumption 0.00 gal/hour
20. Flocculent Unit Cost 5.00 $/gal
E. Anhydrous Ammonia ?
21. Titration?
22. AmmoniaTitration Amount .000000 lbs of ammonia / gal H2O
23. Ammonia Purity 99.00 %
24. Mixing Efficiency of Ammonia 90.00 %
Non-Bulk Delivery
25. Ammonia Non-Bulk Unit Cost 0.50 $/lb
Bulk Delivery
26. Ammonia Bulk Unit Cost 0.19 $/lb
F. Soda Ash ?
27. Titration?
28. Soda Ash Titration Amount .000000 lbs of soda ash / gal H2O
29. Soda Ash Purity 99.00 %
30. Mixing Efficiency of Soda Ash 60 %
31. Soda Ash Unit Cost 0.1400 $/lb
G. Known Chemical Cost ?
32. Known Annual Chemical Cost 0 $
Chemical Cost Sub-Totals
Annual Amount of Chemicals Consumed
33. Total Hydrated Lime Cost 27,811 $ 278,108 lbs
34. Total Pebble Lime Cost 0 $ 0 lbs
35. Total Caustic Soda Cost 0 $ 0 gals
36. Total Anhydrous Ammonia Cost 0 $ 0 lbs
37. Total Soda Ash Cost 0 $ 0 lbs
38. Total Known Chemical Cost 0 $
39. Total Flocculent Cost 0 $ 0 gals
40. Selected Chemical: HYDRATED LIME
Annual Chemical Cost 27,811 $
Influent Water Parameters that Affect Chemical Cost
Calculated Acidity 342.60 mg/L
Alkalinity 0.00 mg/L
Calculate Net Acidity (Acid-Alkalinity)
Enter Net Acidity manually
Net Acidity (Hot Acidity) 342.60 mg/L
Design Flow 300.00 gpm
Typical Flow 150.00 gpm
Total Iron 75.00 mg/L
Aluminum 25.00 mg/L
Manganese 2.00 mg/L
Help
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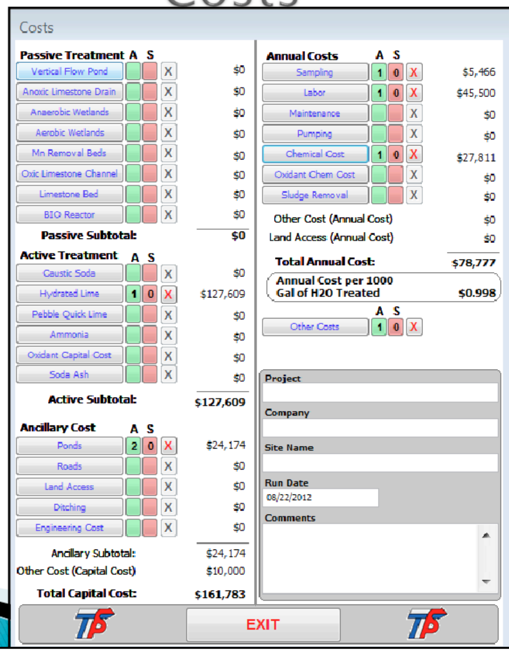
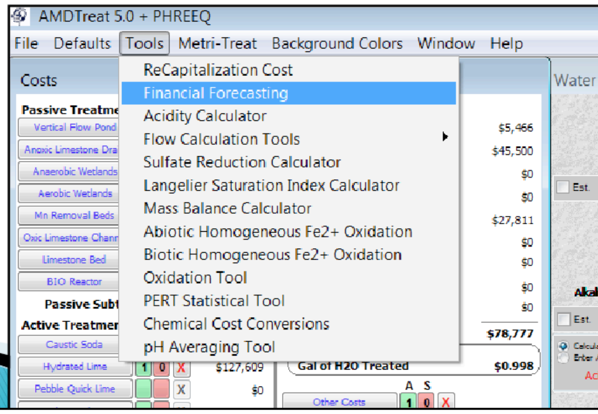
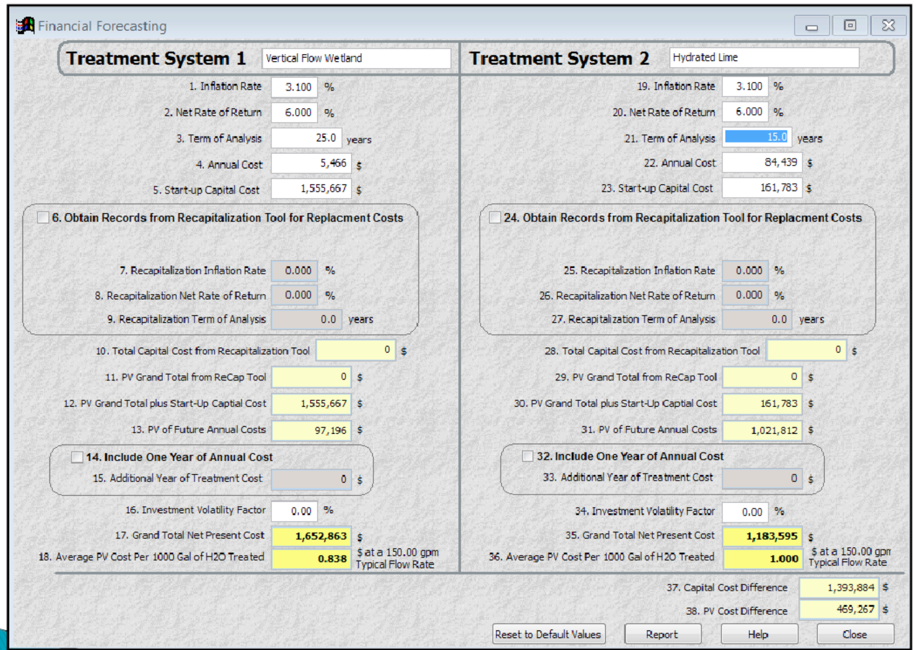
Capital and Annual Hydrated Lime Costs



Which Treatment System is cheaper to operate over a 15 year period?

- Passive Vertical Flow Pond
  - Capital Costs: $1,555,667
  - Annual Costs: $5,466
- Hydrated Lime Plant
  - Capital Costs: $161,783
  - Annual Costs: $84,439





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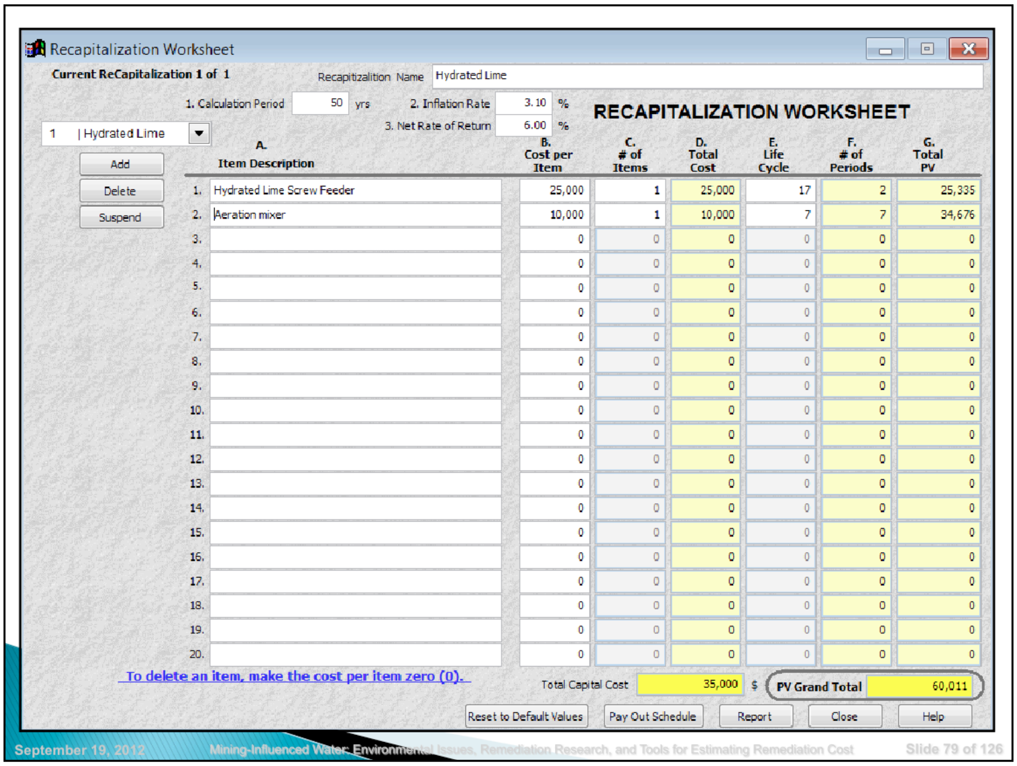


Recapitalization Worksheet

Current ReCapitalization 1 of 1

Recapitalization Name: Hydrated Lime

1. Calculation Period: 50 yrs

2. Inflation Rate: 3.10 %

3. Net Rate of Return: 6.00 %

1 | Hydrated Lime

Add

Delete

Suspend

RECAPITALIZATION WORKSHEET

	A. Item Description	B. Cost per Item	C. # of Items	D. Total Cost	E. Life Cycle	F. # of Periods	G. Total PV
1.	Hydrated Lime Screw Feeder	25,000	1	25,000	17	2	25,335
2.	Aeration mixer	10,000	1	10,000	7	7	34,676
3.		0	0	0	0	0	0
4.		0	0	0	0	0	0
5.		0	0	0	0	0	0
6.		0	0	0	0	0	0
7.		0	0	0	0	0	0
8.		0	0	0	0	0	0
9.		0	0	0	0	0	0
10.		0	0	0	0	0	0
11.		0	0	0	0	0	0
12.		0	0	0	0	0	0
13.		0	0	0	0	0	0
14.		0	0	0	0	0	0
15.		0	0	0	0	0	0
16.		0	0	0	0	0	0
17.		0	0	0	0	0	0
18.		0	0	0	0	0	0
19.		0	0	0	0	0	0
20.		0	0	0	0	0	0

To delete an item, make the cost per item zero (0).

Total Capital Cost: 35,000 $

PV Grand Total: 60,011

Reset to Default Values | Pay Out Schedule | Report | Close | Help

Company Name
Project
Site Name

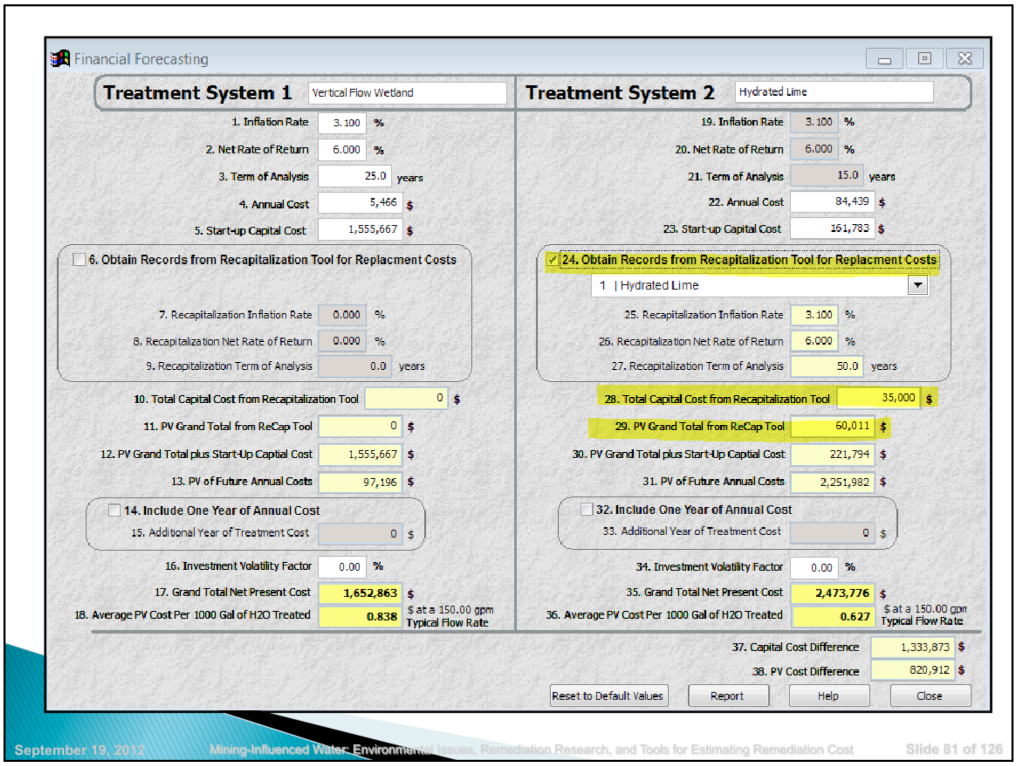
Printed on **09/11/2012**

Life of Trust Fund 50 yrs
Inflation Rate 3.10 %
Return Rate 6.00 %

AMD TREAT
RECAPITIZALITION COST

AMDTREAT

Year	Trust Fund Growth Fund Before Payout	Trust Fund Growth Fund After Payout	Payout Schedule	Year	Trust Fund Growth Fund Before Payout	Trust Fund Growth Fund After Payout	Payout Schedule
	60,011	60,011	Initial Fund Amount				
1	63,611	63,611	0	51	0	0	0
2	67,428	67,428	0	52	0	0	0
3	71,474	71,474	0	53	0	0	0
4	75,762	75,762	0	54	0	0	0
5	80,300	80,300	0	55	0	0	0
6	85,127	85,127	0	56	0	0	0
7	90,234	77,852	12,382	57	0	0	0
8	82,523	82,523	0	58	0	0	0
9	87,474	87,474	0	59	0	0	0
10	92,723	92,723	0	60	0	0	0
11	98,286	98,286	0	61	0	0	0
12	104,183	104,183	0	62	0	0	0
13	110,434	110,434	0	63	0	0	0
14	117,060	101,728	15,332	64	0	0	0
15	107,831	107,831	0	65	0	0	0
16	114,301	114,301	0	66	0	0	0
17	121,159	79,151	42,008	67	0	0	0
18	83,900	83,900	0	68	0	0	0
19	88,934	88,934	0	69	0	0	0
20	94,270	94,270	0	70	0	0	0
21	99,926	80,940	18,985	71	0	0	0
22	85,797	85,797	0	72	0	0	0
23	90,945	90,945	0	73	0	0	0
24	96,401	96,401	0	74	0	0	0
25	102,185	102,185	0	75	0	0	0
26	108,316	108,316	0	76	0	0	0
27	114,816	114,816	0	77	0	0	0
28	121,704	98,195	23,509	78	0	0	0
29	104,087	104,087	0	79	0	0	0
30	110,332	110,332	0	80	0	0	0
31	116,952	116,952	0	81	0	0	0
32	123,969	123,969	0	82	0	0	0
33	131,407	131,407	0	83	0	0	0


Financial Forecasting
Treatment System 1
Vertical Flow Wetland
1. Inflation Rate 3.100 %
2. Net Rate of Return 6.000 %
3. Term of Analysis 25.0 years
4. Annual Cost 5,466 $
5. Start-up Capital Cost 1,555,667 $
6. Obtain Records from Recapitalization Tool for Replacment Costs
7. Recapitalization Inflation Rate 0.000 %
8. Recapitalization Net Rate of Return 0.000 %
9. Recapitalization Term of Analysis 0.0 years
10. Total Capital Cost from Recapitalization Tool 0 $
11. PV Grand Total from ReCap Tool 0 $
12. PV Grand Total plus Start-Up Captial Cost 1,555,667 $
13. PV of Future Annual Costs 97,196 $
14. Include One Year of Annual Cost
15. Additional Year of Treatment Cost 0 $
16. Investment Volatility Factor 0.00 %
17. Grand Total Net Present Cost 1,652,863 $
18. Average PV Cost Per 1000 Gal of H2O Treated 0.838 $ at a 150.00 gpm Typical Flow Rate
Treatment System 2
Hydrated Lime
19. Inflation Rate 3.100 %
20. Net Rate of Return 6.000 %
21. Term of Analysis 15.0 years
22. Annual Cost 84,439 $
23. Start-up Capital Cost 161,783 $
24. Obtain Records from Recapitalization Tool for Replacment Costs
1 | Hydrated Lime
25. Recapitalization Inflation Rate 3.100 %
26. Recapitalization Net Rate of Return 6.000 %
27. Recapitalization Term of Analysis 50.0 years
28. Total Capital Cost from Recapitalization Tool 35,000 $
29. PV Grand Total from ReCap Tool 60,011 $
30. PV Grand Total plus Start-Up Captial Cost 221,794 $
31. PV of Future Annual Costs 2,251,982 $
32. Include One Year of Annual Cost
33. Additional Year of Treatment Cost 0 $
34. Investment Volatility Factor 0.00 %
35. Grand Total Net Present Cost 2,473,776 $
36. Average PV Cost Per 1000 Gal of H2O Treated 0.627 $ at a 150.00 gpm Typical Flow Rate
37. Capital Cost Difference 1,333,873 $
38. PV Cost Difference 820,912 $
Reset to Default Values
Report
Help
Close
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Mining-Influenced Water: Environmental Issues, Remediation Research, and Tools for Estimating Remediation Cost
Slide 81 of 126

Thank You

- Brent Means
  bmeans@osmre.gov
  717-782-4036

- OSM offers AMDTreat training every year in PGH and at various conferences

Mine Influenced Water Treatment Technology Study

Michele Mahoney
EPA Office of Superfund Remediation & Technology Innovation
mahoney.michele@epa.gov

Goals

- Identify and evaluate MIW treatment technologies
- Develop written materials to support selection of appropriate and cost-effective treatment technologies
- Further inform decision makers about the diverse technologies available for MIW

Key Information

- Types of technologies
- Contaminants treated
- System operations
- Engineering constraints
- Initial and long-term costs
- Treatment effectiveness
- Example sites
- Additional research needs

Snapshot of Summary Table

Technology	Technology Description	Treated Constituents	Scale	Example Sites	Operations	Long-term Maintenance	Engineering Constraints	Costs	Effectiveness
Anoxic Limestone Drains (ALD)[5,33,21]	A limestone drain is a simple treatment method which involves the burial of limestone in air-tight trenches that intercept acidic discharge water. Keeping carbon dioxide within the drain can enhance limestone dissolution and alkalinity production. Furthermore, keeping oxygen out of contact with the discharge water minimizes the potential for oxidation of dissolved iron and the consequent precipitation of solid iron hydroxide [Fe(OH)3], which could armor the limestone and clog the drains.	Al, Fe, acidity	Full-scale	Fabius Coal Preparation Plant, AL Copper Basin Mining Site, TN Hartshorne/Whitlock-Jones: Hartshorne, OK Ohio Abandoned Bituminous Coal, SE OH Tecumseh - AML Site 262, IN Tennessee Valley Authority, AL Valzinco Mine, VA	The construction of an ALD consists of a trench containing limestone (typically 90% calcium carbonate equivalent minimum) encapsulated in a plastic liner and covered with clay or compacted soil to maintain anoxic conditions, as well as to prevent water infiltration and to keep CO2 from escaping. The width and length of the trench are based on the levels of dissolved metals present in the mine drainage, the retention time needed to raise the pH, as well as the amount of area that is available for construction. The ALD may be capped with topsoil and vegetation to control erosion. The dimensions of the drain depend upon individual on-site conditions, including topography, geology, and available area and, equipment. However, the two factors that must be considered when sizing an anoxic limestone drain are the accommodation of the maximum probable flow and the desired longevity of the drain.	Routine maintenance is typically limited to inspection of the surface for evidence of leakage in the anoxic cover material, and periodic cleaning of the discharge point to remove accumulated iron oxides. The systems are generally designed for limestone replenishment every 15–25 years, depending on the characteristic of the drainage flow. Maintenance costs for ALD's are not expected to be significant. Apart from monitoring costs which might be required to ensure the effectiveness of downstream systems, costs should be limited to periodic inspection of the site and maintenance of the vegetation cover.	ALDs are suitable to treat MIW that has low concentrations of ferric iron, dissolved oxygen and aluminum. When any of these three parameters are elevated, armoring of limestone can occur and slow the dissolution rate of limestone. When the dissolution rate slows, there is a higher buildup of ferric iron and aluminum on the limestone, which eventually clogs the open pore spaces, resulting in abnormal flow paths that can reduce both the retention time of MIW within the ALD and the reactive surface area of the limestone. With only a few exceptions, passive systems cannot handle Acidity Loads in excess of 100-150 kg of CaCO3 per day. Metal removal must occur elsewhere to prevent clogging of the bed and system failure. ALD's must be kept anoxic to prevent the oxidization of soluble ferrous iron to the insoluble ferric species. Field tests show that relatively high rates of limestone dissolution occur within the initial 15 hours of contact with mine water. After that period, the rate of dissolution is much slower. For this season, ALD's are sized to have a 15-hr retention time at the end of its design life (25-30yrs). Although ALDs are documented to have success in raising pH, the differing chemical characteristics of the influent mine water can cause variations in alkalinity generation and retention of metals. Most ALD systems exhibit reduced effectiveness over time and eventually require maintenance or replacement. To meet effluent compliance limits, (Tennessee Valley Authority) TVA advocates the use of ALDs only as a staged portion of aerobic acid drainage wetlands systems, and does not recommend their use as stand-alone systems, or as a stage of an anaerobic wetlands system.	Passive treatment systems can provide low cost solutions unless they are used for inappropriate applications, which have resulted in many being far more costly (per ton of acid neutralized) than conventional active treatment plants The cost of installing ALDs can vary from site to site, depending largely on location and chemical makeup of the MIW. Operators of the Tennessee Valley Authority abandoned mine site in Alabama reported that their capital cost was approximately $0.25/1000 gal of water and their operation and maintenance costs were approximately $0.10/1000 gal of treated water. Passive treatment systems provide low cost solutions with low to medium capital costs (AU$5,000 -200,000) and generally very low operating costs (<AU$1,000 / year). A 'typical' ALD constructed at most locations in Canada is expected to cost in the range of $4,000 to $25,000 depending on chosen dimensions and design flow. This estimation would not apply to more remote sites, or sites where establishment of an ALD would require extensive excavation or blasting.	Alkalinity concentrations in the effluent ranged 80–320 mg/L as CaCO3 with near maximum levels being reached after approximately 15 hours of detention in the ALD. Where influent mine water contained less than 1 mg/L of both ferric iron and aluminum, the ALDs produced consistent concentrations of alkalinity for over 10 years. An ALD receiving influent mine water containing 21 mg/L of aluminum experienced rapid failure due to permeability reduction within 8 months. Although long term data is not available, the research conducted to date suggests that ALD's can be expected to be effective for 20 to 80 years (Brodie et al. 1992) and perhaps even longer (>100 years), if influent quality is within the required criteria and the system is properly designed and constructed.

Anticipated Outcomes

- Supplement and complement existing materials
- Identify promising technologies and best practices
- Share information
- Implement pilot projects

PCBs Mining and Water Pollution

PCBs abandoned in mines can cause water pollution problems for which there may be no reasonable solution.

This can be prevented!

Mining-Influenced Water
CLU-IN Webinar
September 2012
U.S. Environmental Protection Agency

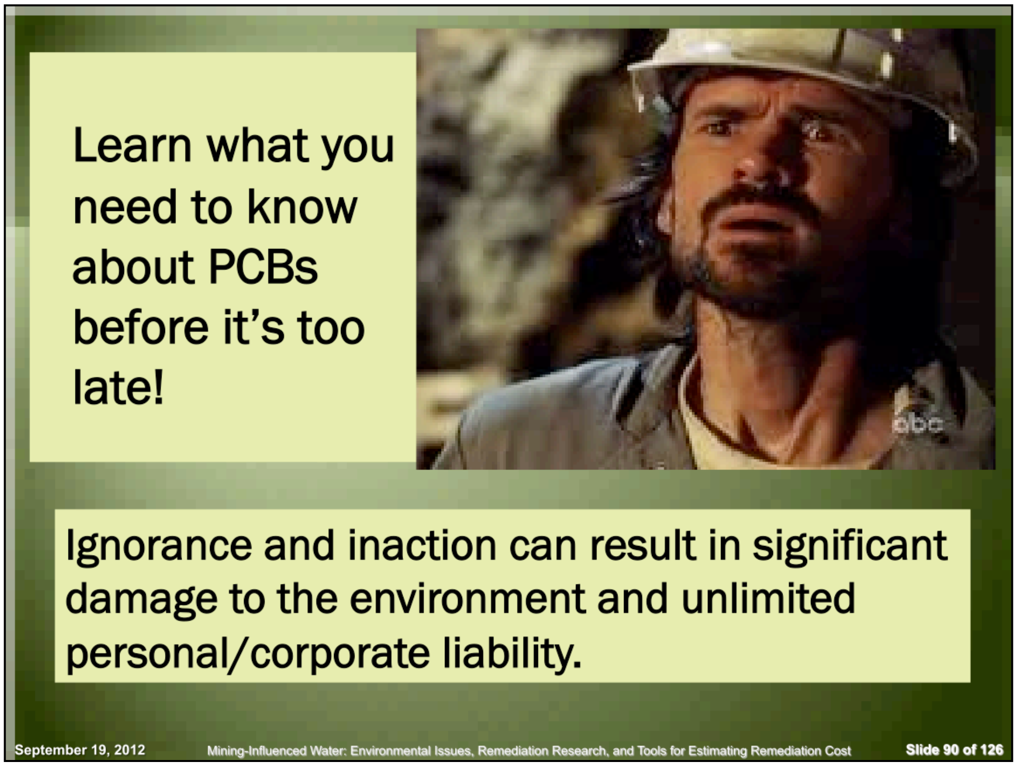
Dan W. Bench, Min. Eng.

USEPA Region 8 PCB Coordinator

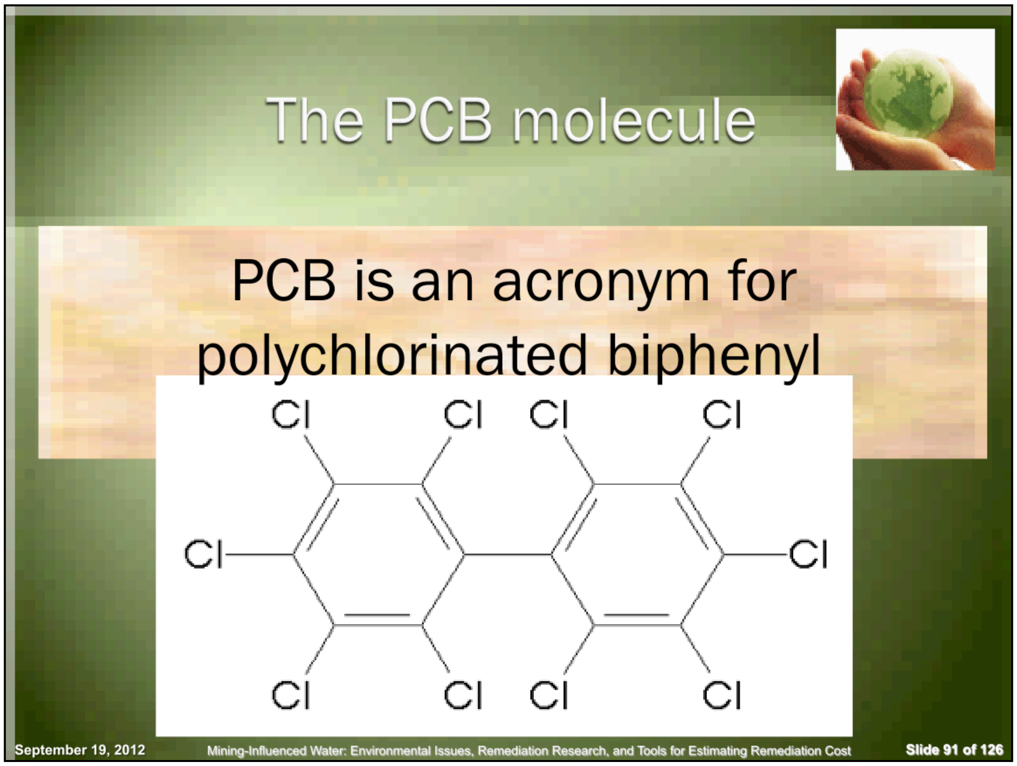
1595 Wynkoop Street

Denver, CO 80202

303 312-6027



Don't let this be you upon discovery of PCBs in your mine.



PCBs are man made chemicals

PCBs due to their stability, insulating properties, and fire resistance, found many industrial uses.

The PCB molecule can occur as one of 209 different congeners.

Different congeners contain different combinations of chlorine atoms on the PCB molecule.

Monsanto Corporation marketed mixtures of PCB congeners as Aroclors until 1977.

Aroclors mixed about 50/50 with trichlorobenze were marketed as trade name dielectrics for transformers.

Examples:	Pyranol	made by General Electric
	Inerteen	made by Westinghouse
	Clorextol	made by Allis-Chalmers

Manufacture was voluntarily discontinued by Monsanto in 1977.

PCB-containing equipment is still in service. A common **misunderstanding of the regulations** is that PCBs are no longer in electrical equipment because manufacture was prohibited in 1978. However, the regulations authorized continued use as dielectrics in electrical equipment for the useful life of the equipment.

Examples: Dielectrics in transformers

capacitors

fluorescent light ballasts

Mineral oil transformers can be contaminated with PCBs. Leaking transformers on the middle left. Very large transformers like those on the right have been observed in iron ore mills near Lander, Wyoming.

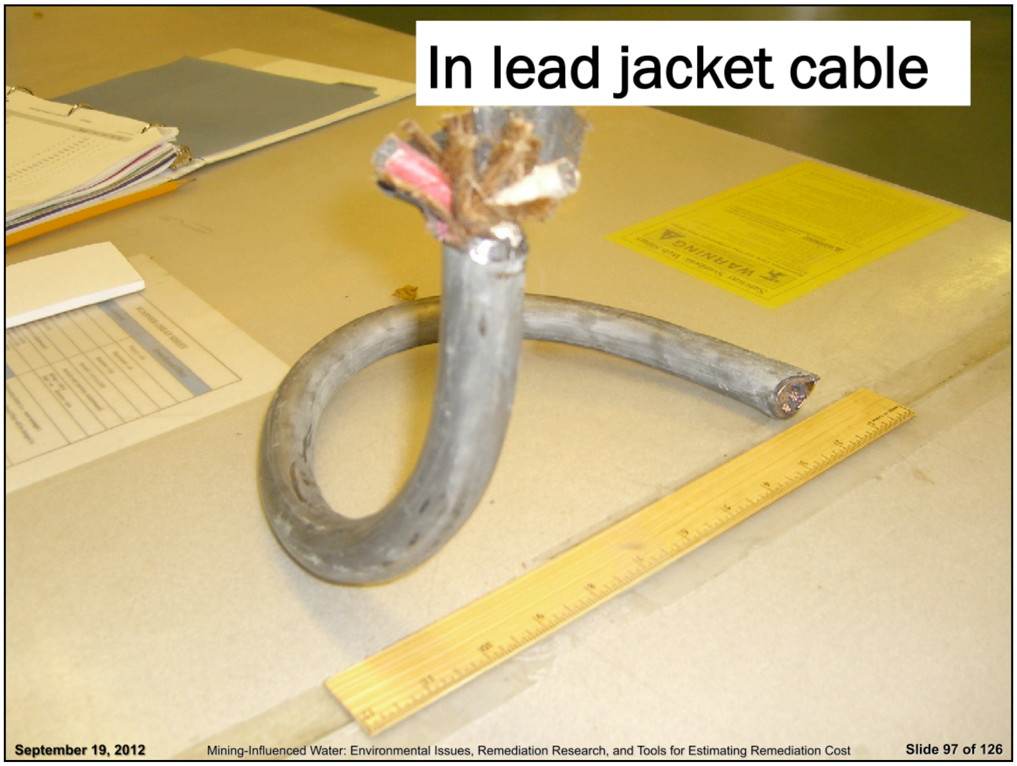
PCB capacitors contain pure Aroclor. Note the PCB mark on the capacitor left from a surface facility at a coal mine in Utah

Mine power center with large PCB capacitors awaiting disposal at a Utah coal mine

Fluorescent light ballasts manufactured prior to 1978 contain PCBs

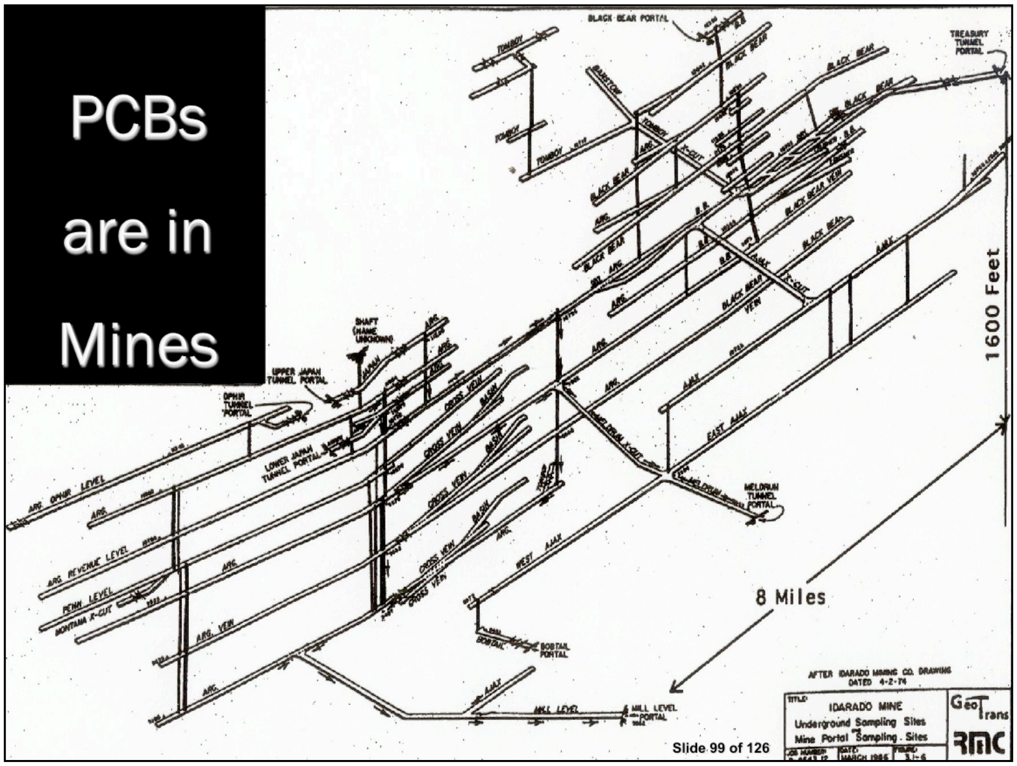
A thimble sized capacitor embedded in the potting compound contains pure Aroclor

A large percentage of ballasts have regulated levels of PCB in the potting compound



Any cable with liquid or damp insulation inside is likely to contain PCBs.

A place you feel safe from PCBs and wouldn't expect to find them just above Telluride, Colorado. But around the corner a few hundred yards to the left…



is the Idarado Mine. Inspection revealed 23 85-gallon PCB transformers underground.

This is a typical mine.

8 miles by 3,000 feet.

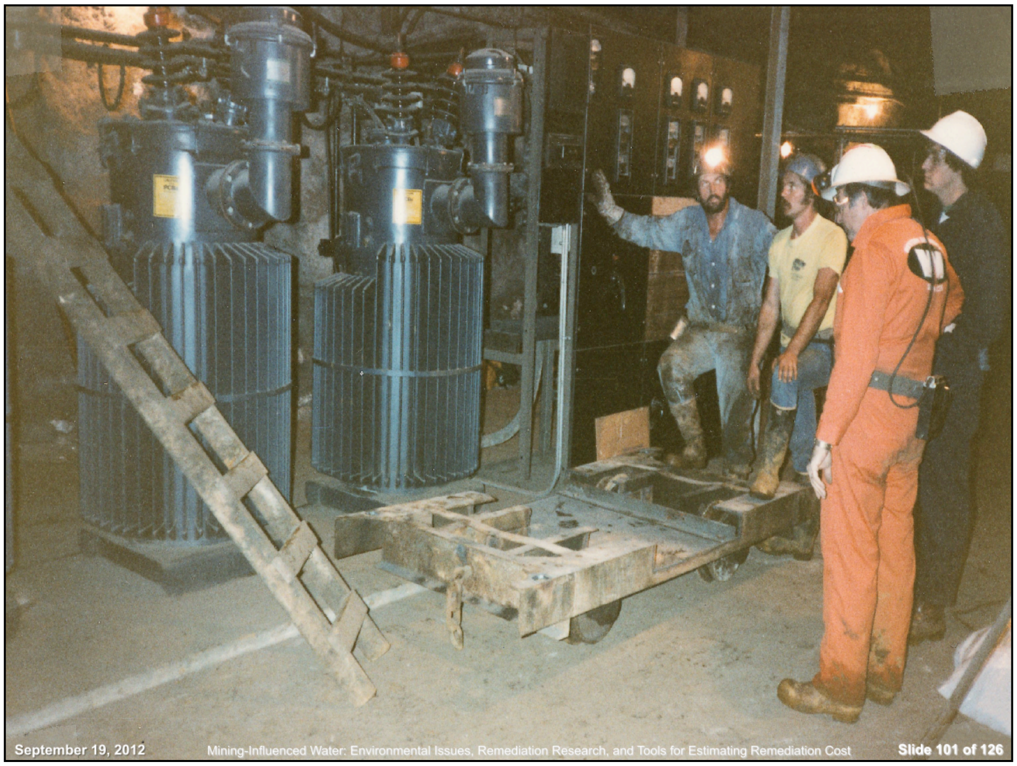
An operation this size has lots of power requirements and is likely to have PCB equipment

The Eagle Mine, a major Zn producer during WWII up until about 1968, contained abandoned PCB transformers and large PCB capacitors underground and on the surface.

This was a CERCLA removal.

Underground:

- three 76 gallon Pyranol transformers at the 2010 substation.
- three 65 gallon Pyranol transformers at the 1623 substation.
- 17 large PCB capacitors (each containing > 3 pounds of pure Aroclor)

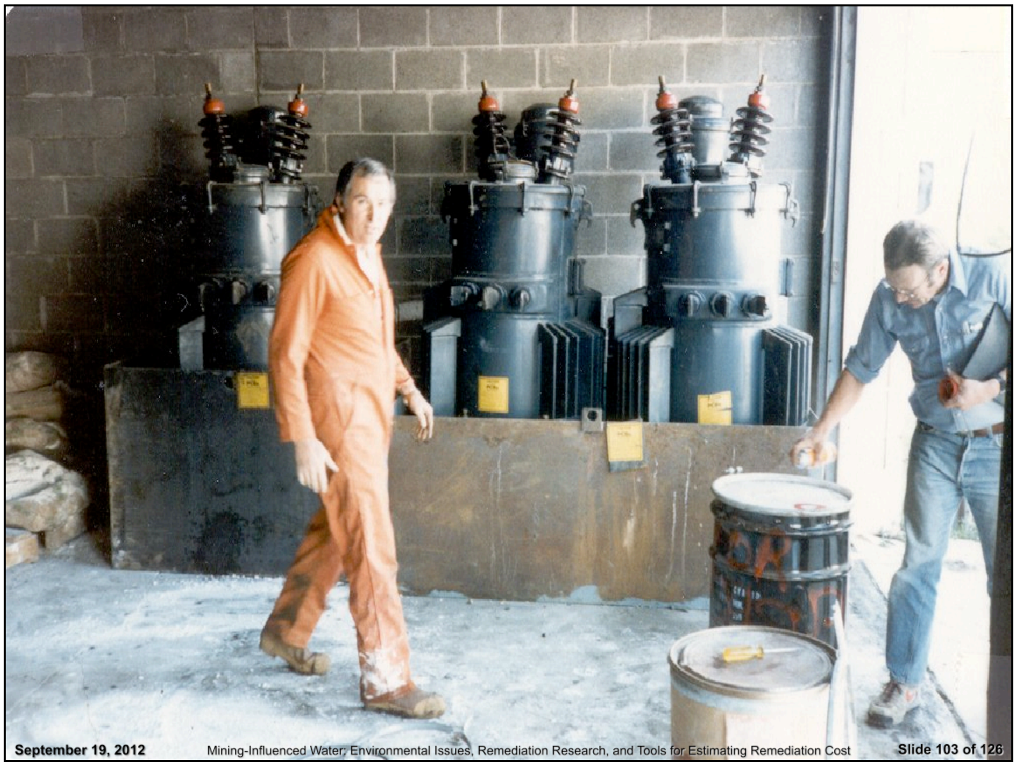


Two of three 76 gallon Pyranol transformers underground at the 2010 substation. There were three drained 65 gallon Pyranol transformers at the 1623 substation behind the fire seals that could not be removed. The mine was on fire at the time of the removal. About six gallons of Pyranol remained in each of these 65 gallon transformers.

Eight hundred feet below the 20 level the mine is flooded down to the 28 level.

What electrical equipment may have been abandoned there is unknown.

This transformer has been removed from the 2010 substation and is on the way to the 2010 incline. The mine is flooded now up the the level of the truck.



76 gallon Pyranol transformers removed from the 2010 substation now in storage in the surface warehouse.

Why are PCBs a problem?

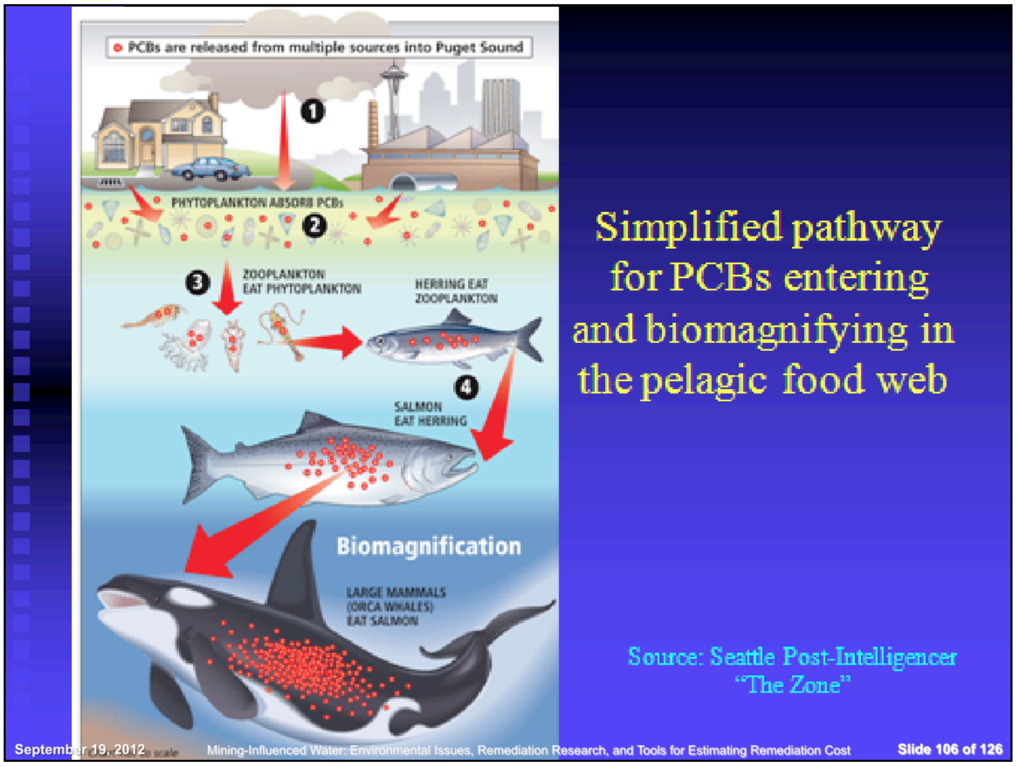
- PCBs are one of the most stable organic chemicals known: PCBs are resistant to biodegradation
- PCBs are soluble both in fat and water
- PCBs are estrogenic compounds
- PCBs harm people, animals, birds, and fish

PCBs circulate globally and continue to accumulate in the environment

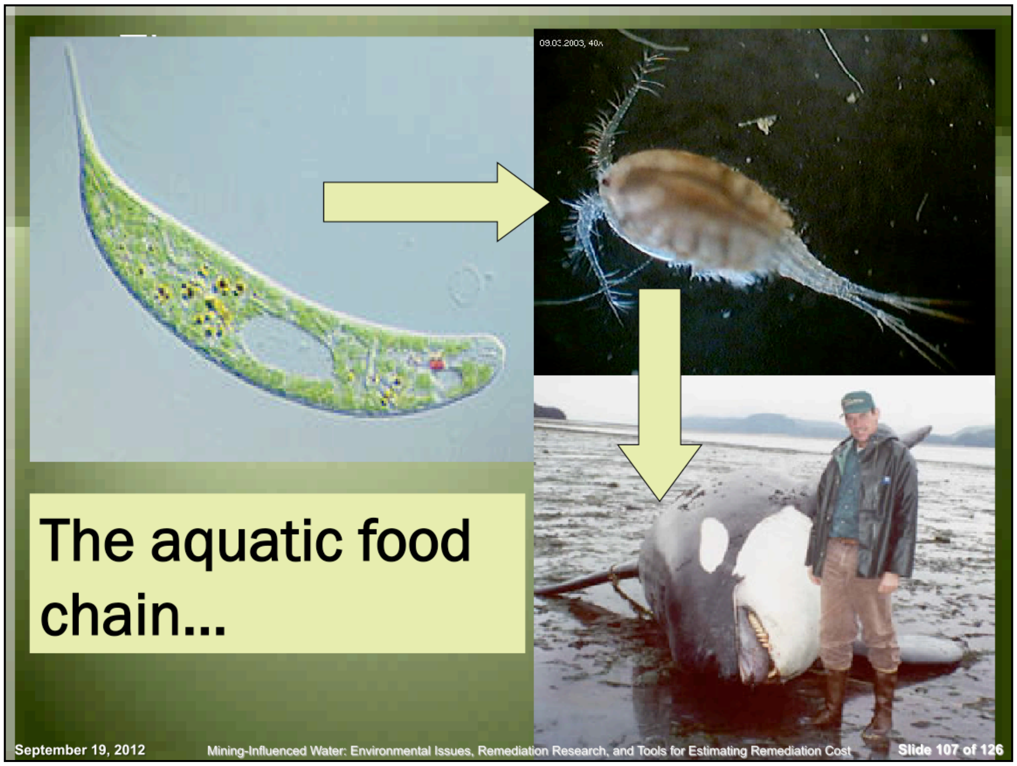
Consider one consequence of a release of PCBs into water

Phytoplankton

- Absorb PCBs from water by a factor of 10,000 to 1,000,000
- Supply 50% of the world oxygen
- Basis of the ocean food chain



Referred from NOAA



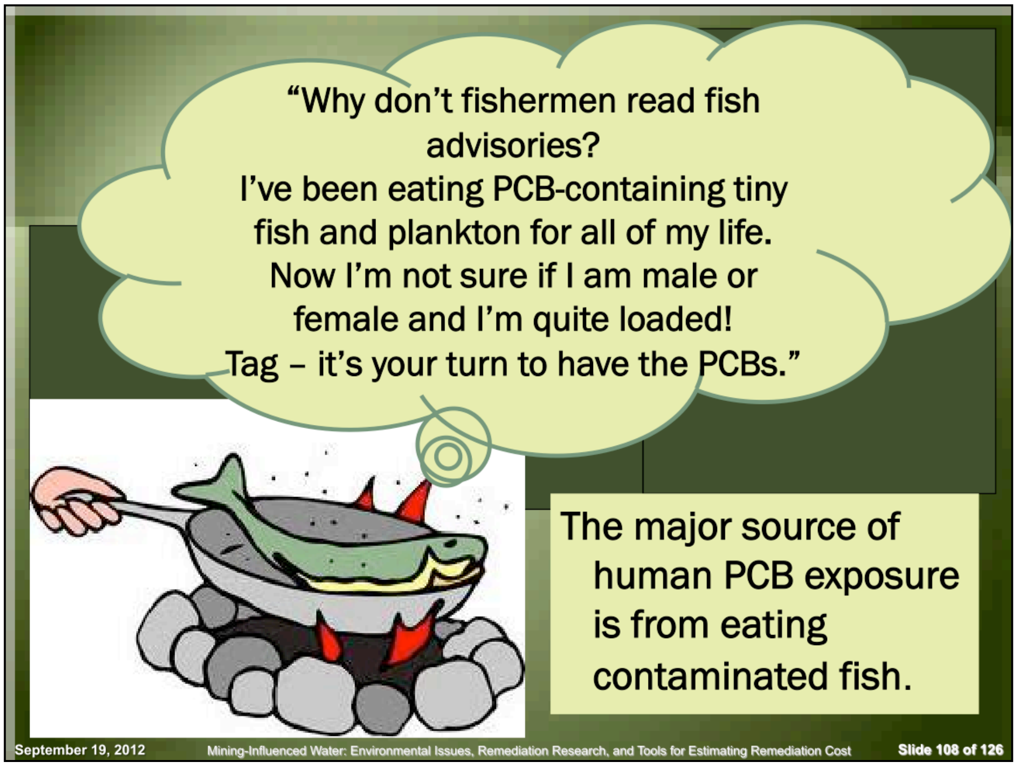
PCBs are absorbed from ocean water into phytoplankton

copepods feed on phytoplankton

Small fish feed on copepods

The food chain leads to killer whales

Killer whales carry the most PCB contamination of any mammal



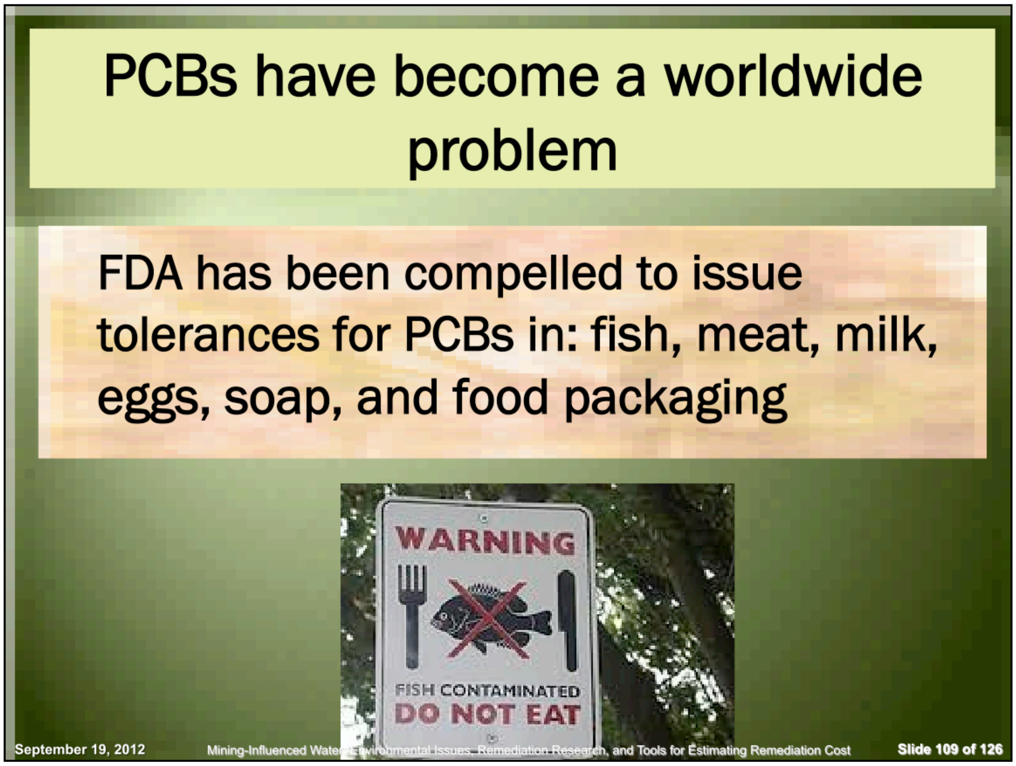
The Killer Whale and man have something in common: they are both predators at the top of the food chain.

The fish isn't sure if it is male or female because PCBs are estrogenic compounds (hormone mimics).

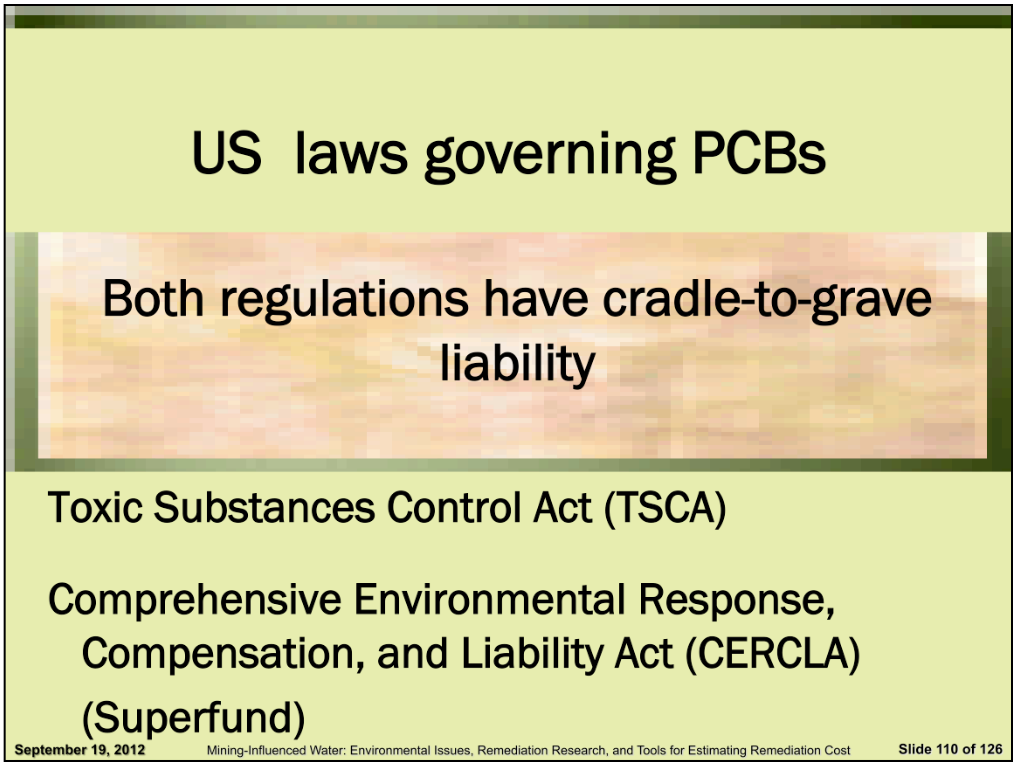
Estrogenic compounds cause

- sexual changes in fish.
- Persistent memory and learning problems and children and adults
- genital defects in children, polar bears, alligators
- deformed sperm in men
- reduced sperm counts in men

•**Affected Organ Systems:** Dermal (Skin), Developmental (effects during periods when organs are developing) , Endocrine (Glands and Hormones), Hepatic (Liver), Immunological (Immune System), Neurological (Nervous System)



FDA tolerances for:	milk	1.5 ppm PCB
	dairy	1.5 ppm PCB
	fish	3.0 ppm PCB
	poultry	3.0 ppm PCB
	eggs	0.3 ppm PCB
	paper food packaging	10.0 ppm PCB
	soap	3.0 ppm PCB



TSCA and CERCLA (Superfund) are the two big drivers

Both are strict liability statutes.

Liability is determined by present day site conditions.

Owners and operators can be liable regardless of how and when the conditions came about.

Both regulations have cradle-to-grave liability.

TSCA

Controls use authorizations, marking, storage, disposal, recordkeeping, cleanup and prohibits dilution to evade disposal regulations.

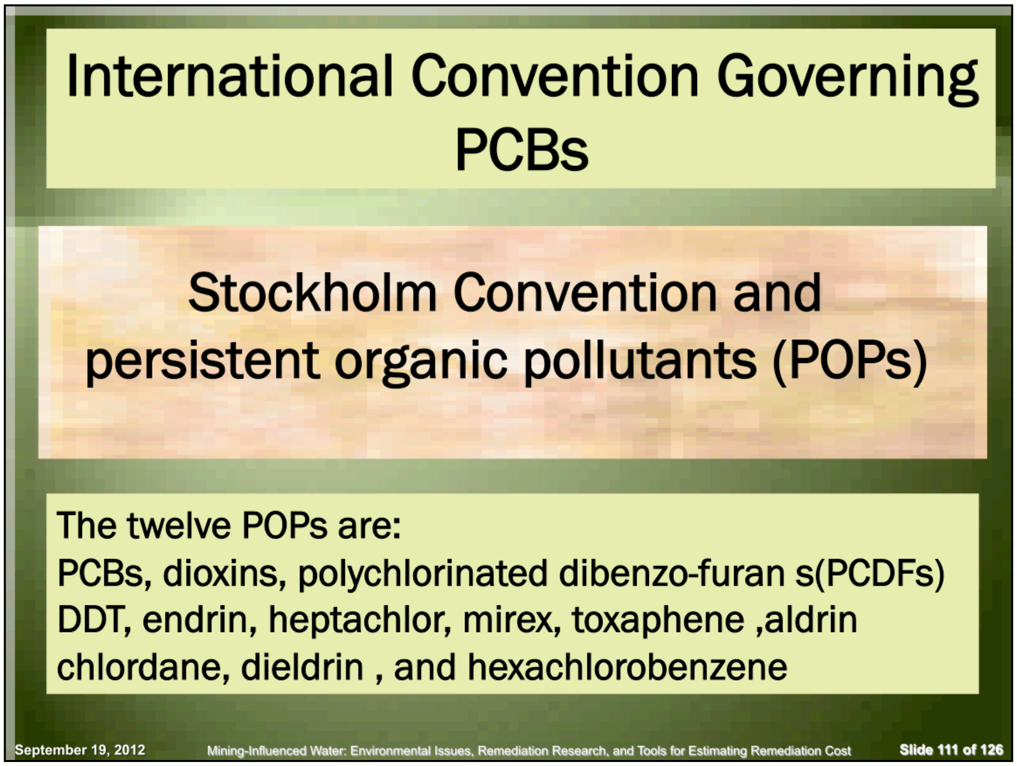
CERCLA

Goals are to assure cleanup and to attach the cost of cleanup to parties other than the taxpayer

Liabilities as defined by CERCLA:

- Present owners and operators may be liable for actions that occurred prior to the legislation.
- Corporations and **individual employees** may be liable.
- PCBs at any concentration may result in liability, if they cause problems.
- The potential liability has no bounds.

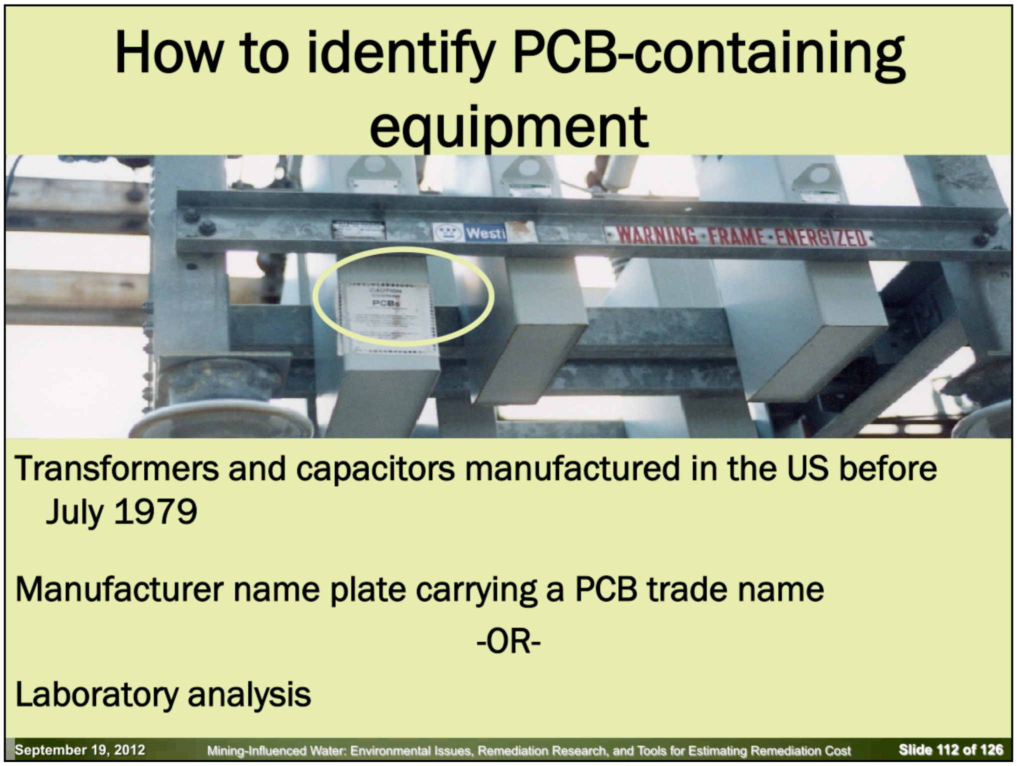
Laws similar to TSCA and CERCLA may be enacted in other countries in the future.



178 nations are parties to this convention.

PCBs, dioxins, and PCDFs concern the mining industry.

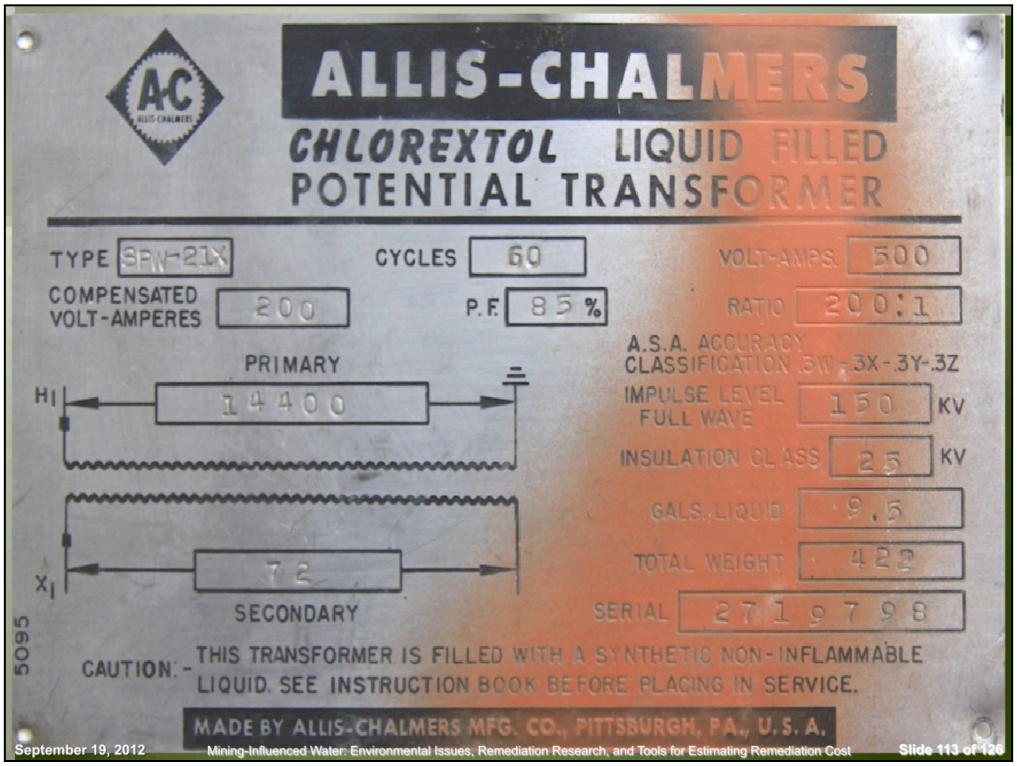
The list of POPs continues to increase.



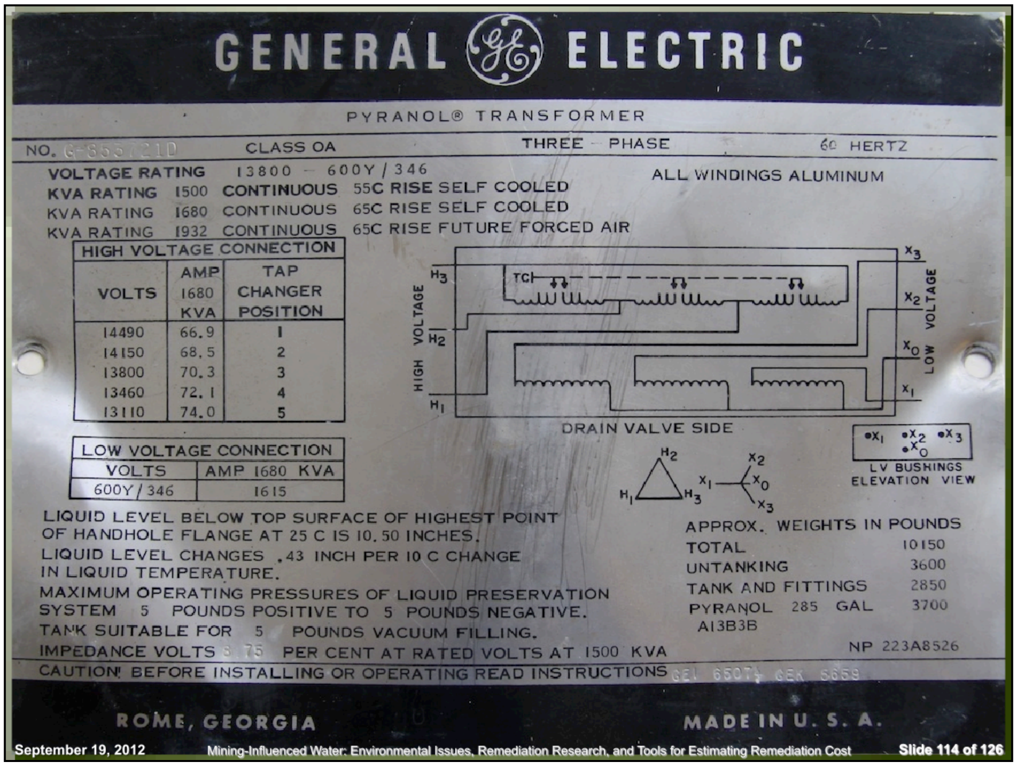
Equipment containing mineral oil may have been contaminated with PCBs and will need laboratory analysis to identify PCBs.

The PCB regulations require transformers and capacitors manufactured before 1979 to be presumed to contain high concentration PCBs

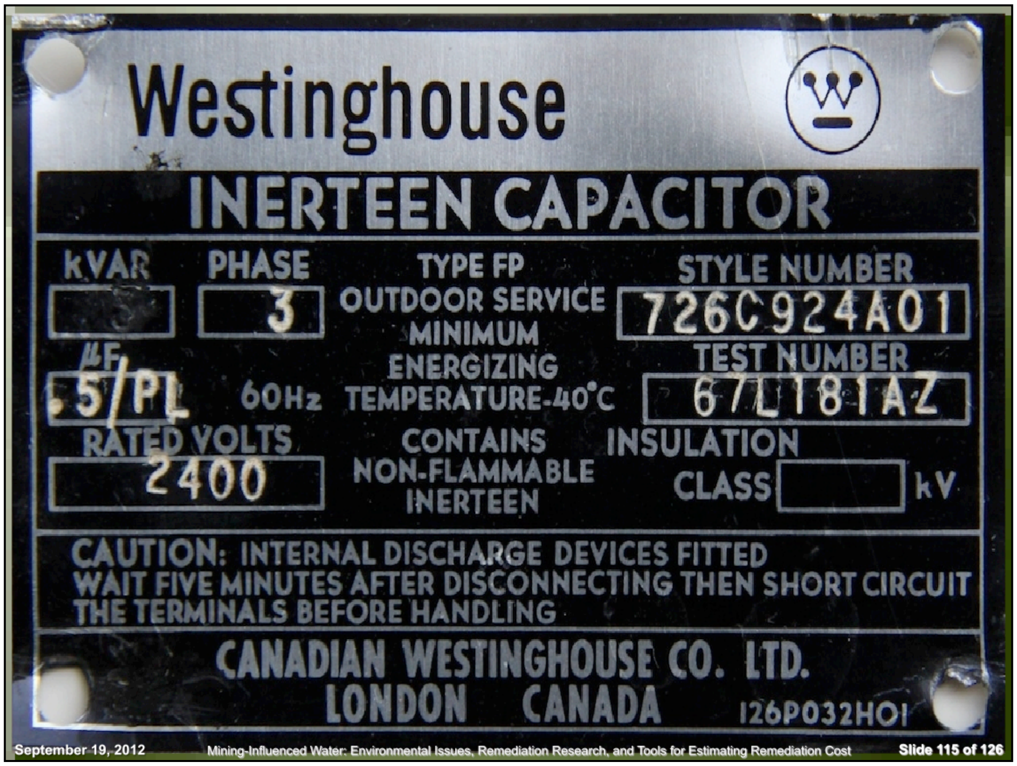
Examples of nameplates with PCB trade names follow:



Example name plate. Chlorextol is a PCB trade name



Example name plate. Pyranol is a PCB trade name



Example name plate. Inerteen is a PCB trade name

This nameplate **does not** mean **No PCBs**.

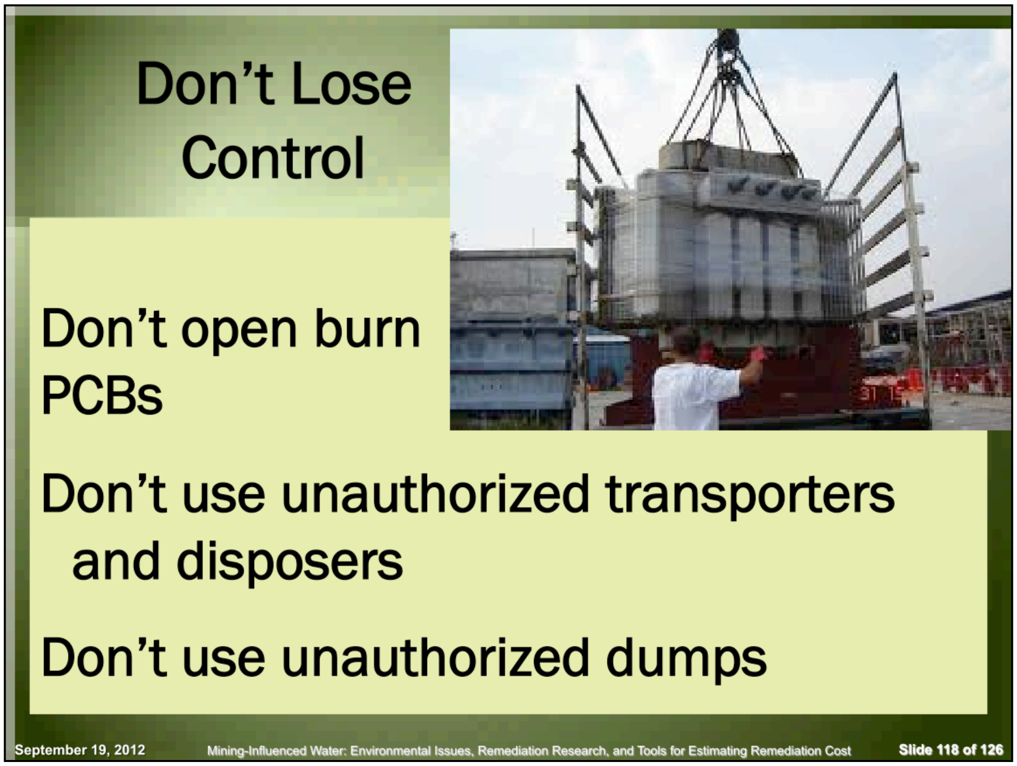
By definition, a non-PCB transformer can contain up to 50 ppm PCBs.

Even though a company is in compliance with TSCA this does not protect against CERCLA liability

Disposal of PCBs

- Approved incineration requires 99.9999% PCB destruction
- Landfilled PCBs remain indefinitely as potential liability
- Equipment decontamination is required for scrap

Incineration is believed by EPA to be the most effective method of PCB destruction.



Products of open burning can be even more hazardous than the original PCBs.

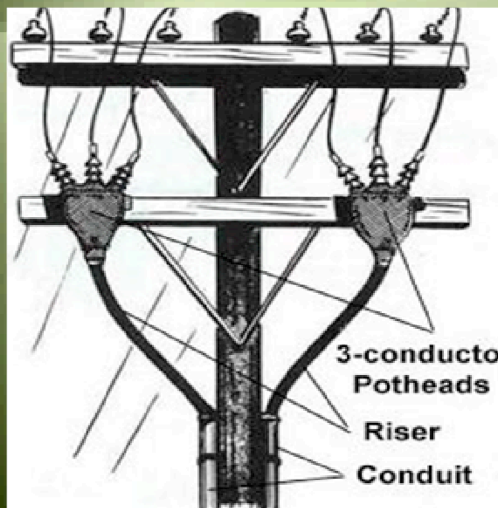
Open burning can

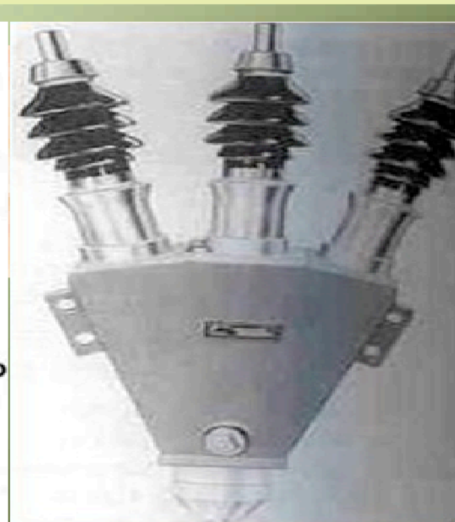
- change PCBs into dioxins and dibenzofurans
- vaporize PCBs along with dioxins and dibenzofurans

Hidden Sources of PCBs

- ✓Transformer bushings
- ✓Voltage regulators
- ✓Any asphalt-like material used as an insulator or dielectric
- ✓Small motor starting capacitors
- ✓Paints, lubricants, and caulks
- ✓Pot heads *(example, next slide)*

Hidden Sources of PCBs - Potheads





The Bottom Line

- Electrical equipment containing PCBs is used on the surface and underground
- Release of PCBs into the environment can be prevented
- Save money, protect the environment and avoid $$ liability

Thank You for Your Attention

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Please see epa.gov/pcb and epa.gov/region8/toxics/pcb for further information

Next Webinar

- Next webinar is scheduled for January 9, 2013, 1:00-3:00 PM EST
- Theme: Mining-Influenced Water, continued with case studies and presentations on specific remediation technologies

We want your feedback!

Are these topics interesting to you?
Do you want to hear about them on the next webinar? Any other suggestions?
Leave us your comments on this webinar's feedback form.

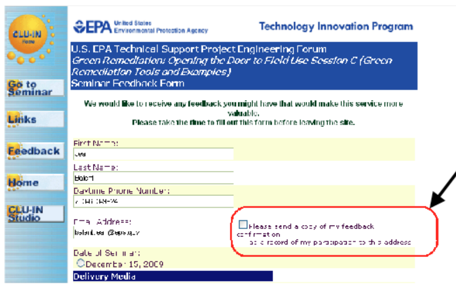
New Workshop Series

- Stay tuned! EPA is launching a new Water Quality and Mining Workshop Series
  - Late 2012 to early 2013
  - Will focus on issues at mine sites related to:
    - Geochemistry
    - Hydrology
    - Water quality modeling and effluent mixing zones

Later this year, EPA is launching a new workshop series that focuses on water quality and mining. The series, which will begin in late 2012 and will run through early 2013, focus on issues at mine sites related to geochemistry, hydrology, and modeling for water quality modeling at mixing zones. More information will be available through the CLU-IN Mining Sites Focus Area later this fall.

Resources & Feedback

- To view a complete list of resources for this seminar, please visit the **Additional Resources**
- Please complete the **Feedback Form** to help ensure events like this are offered in the future



Need confirmation of your participation today?

Fill out the feedback form and check box for confirmation email.

Thank you again for your attention and comments. I want to remind each of you that we are looking for your specific responses to many of the issues discussed today in our feedback form following this session.

Also, there are several resources and related documents included in the links to more resources on this page.

If you have any additional questions or comments, please feel free to contact myself or fill out a comment form on CLUIN.

Thank you and have a great afternoon.

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