



### Benefits of using liquid carbon sources for passive treatment systems

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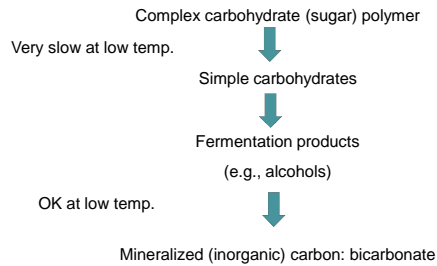
### The Problem



- Treatment systems in Eastern Appalachia use compost/manure mix
- Biodegradation of compost/manure mix is slow <math><4^{\circ}\text{C}</math>
- Compost/manure mix may be susceptible to plugging
  - Depends on metal species, loading
- Bioreactors fed liquid carbon may solve these problems
  - Concept promoted by Tsukamoto & Miller

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### The Problem



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### Bioreactors fed Liquid Carbon



- Tulsequah Chief: full-scale bioreactor operated for five years inside an underground mine
- Smoky River Coal: pilot-scale bioreactor designed for year-round treatment
- Pend Oreille: pilot-scale bioreactor for underground mine

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### Tulsequah Chief



- Remote, polymetallic underground mine (Cu, Pb/Zn)
- Abandoned in late 1980's
- Discharges ARD into Tulsequah River
- New owner required to treat during mine exploration

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### Tulsequah Chief



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Tulsequah Chief



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Tulsequah Chief – Pilot-scale bioreactor



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Tulsequah Chief – Pilot-scale bioreactor



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Tulsequah Chief – Pilot bioreactor



Parameter	ARD	Pilot-scale bioreactor
pH	3.0-3.7	6.0-6.7
Al	10-30	0.1-1.0
Cd	0.22-0.47	<0.050
Cu	16-30	0.1-1.0
Fe	20-120	0.1-2.0
Zn	56-120	30-50

Average temperature: 6.8 °C

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Tulsequah Chief – Pilot-scale bioreactor



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Tulsequah Chief – Full-scale bioreactor



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Tulsequah Chief – Full-scale bioreactor



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Tulsequah Chief – Full-scale bioreactor



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Tulsequah Chief – Full-scale bioreactor



	ARD	Full-scale bioreactor (Limestone only)	Full-scale bioreactor (Limestone + SRB)
pH	3.0-3.7	4.0-6.0	6.1-6.7
Al	10-30	0.9-7.7	0.06-2.5
Cd	0.22-0.47	0.22-0.38	0.07-0.30
Cu	16-30	9-13	2-7
Fe	20-120	0.03-0.7	0.04-4.0
Zn	56-120	56-118	42-77

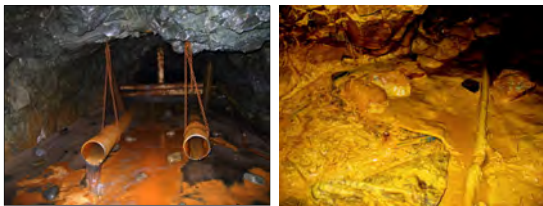
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Tulsequah Chief – Full-scale bioreactor



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Bioreactor problems – plugging



- Bioreactor became plugged gradually
- Sufficient permeability remained during five years of treatment
- Exploration was successful and project became a mine

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Smoky River Coal Bioreactor



- Smoky River is abandoned coal mine in Alberta
- Excessive selenium in mine drainage
- Want to treat year-round with minimum oversight
- Bioreactor seeded with bacteria, fed ethylene glycol

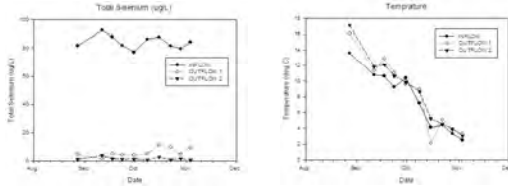


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Smoky River Bioreactor - Results



- Test run continually from August to November 2009
- Average inflow 80-90 µg/L vs average outflow: 3.6 µg/L



Conclusion: Se removal is unaffected by temperature, even at 2 °C. Bioreactor constructed below frost line should operate year-round

Pend Oreille Mine - Bioreactor



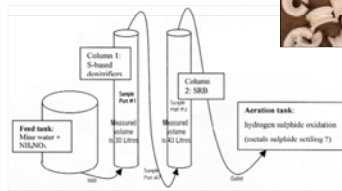
- Underground mine in northeastern Washington State
- Excessive zinc and nitrate (from blasting residue) in mine water
- Could bioreactor treat at bottom of the mine, instead of pumping back to the top into a treatment plant?
- Column study conducted underground



Pend Oreille Mine - Bioreactor



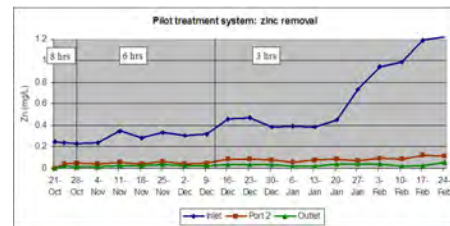
- Bacterial cultures isolated, seeded into columns
- Column study conducted underground
  - Ethanol fed to columns
  - Tested metal removal vs retention time



Pend Oreille Mine - Bioreactor



- RT decreased from 8 → 3 hrs
- Zinc completely removed
- At 3 hrs RT, bioreactor can be built in lowest sump



Conclusions



- Liquid carbon source allows for treatment in the cold
  - Costs are not onerous
  - Unattended operation possible
- Avoiding compost/manure may solve plugging problems
- Consider new possibilities: supplement liquid organic carbon for winter operation of existing bioreactor or wetlands?

QUESTIONS?

