BC Metal Leaching/ARD Workshop

Vancouver, British Columbia

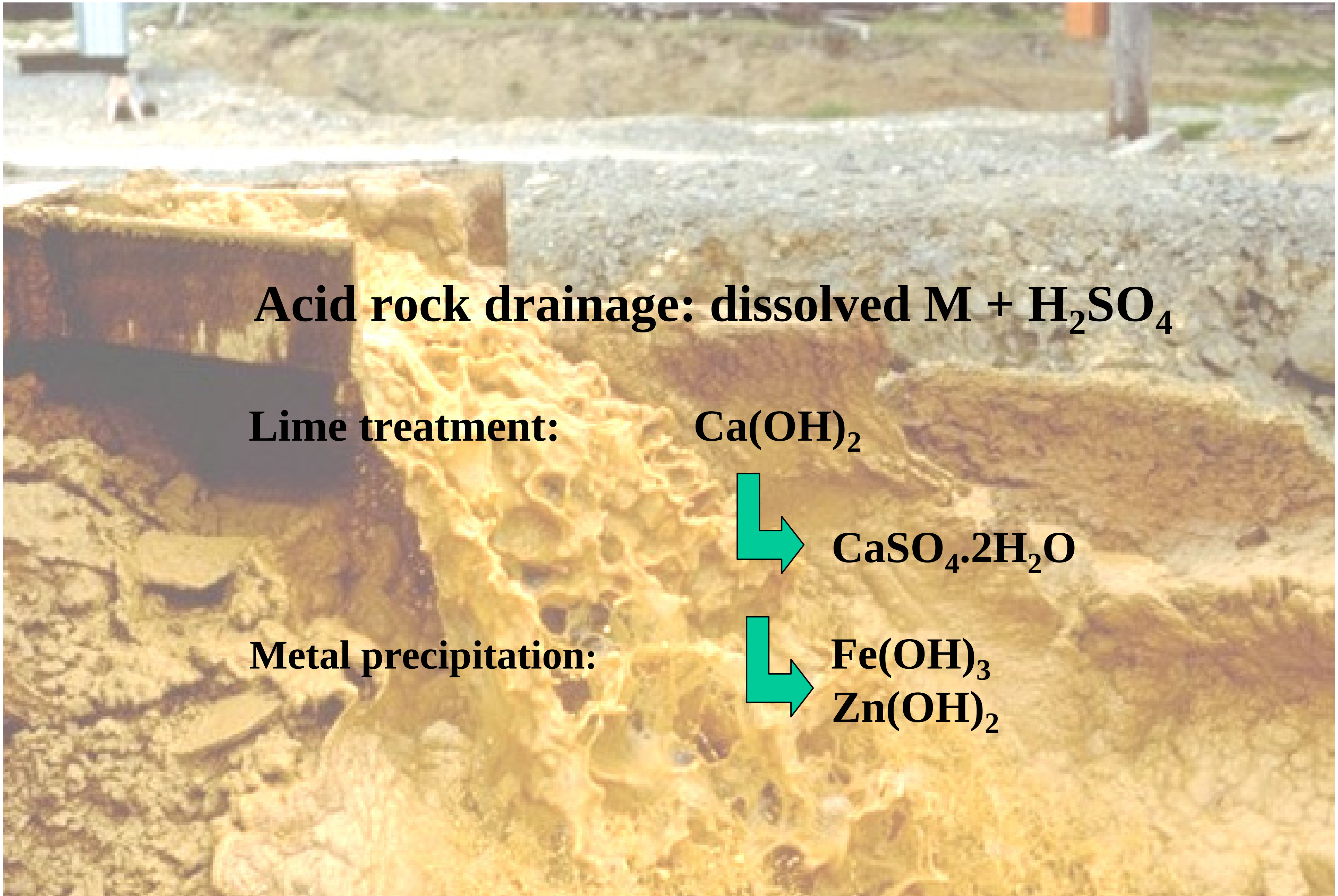
Lime Sludge Management – An Update on Technologies

Janice Zinck

December 2, 2003

Overview

- **Introduction**
  - Sludge characteristics
  - Issues
- **Sludge Disposal Options**
  - Pond disposal
  - Co-disposal
  - Disposal in Mine Workings
  - Sludge in Backfill
  - Reprocessing of Mine Sludge
  - Stabilization with Additives
  - Landfill
  - Sludge re-use options
  - Sludge management in the North
  - Reclamation
- **Information gaps**
- **Conclusions**



Acid rock drainage: dissolved M + H_2SO_4

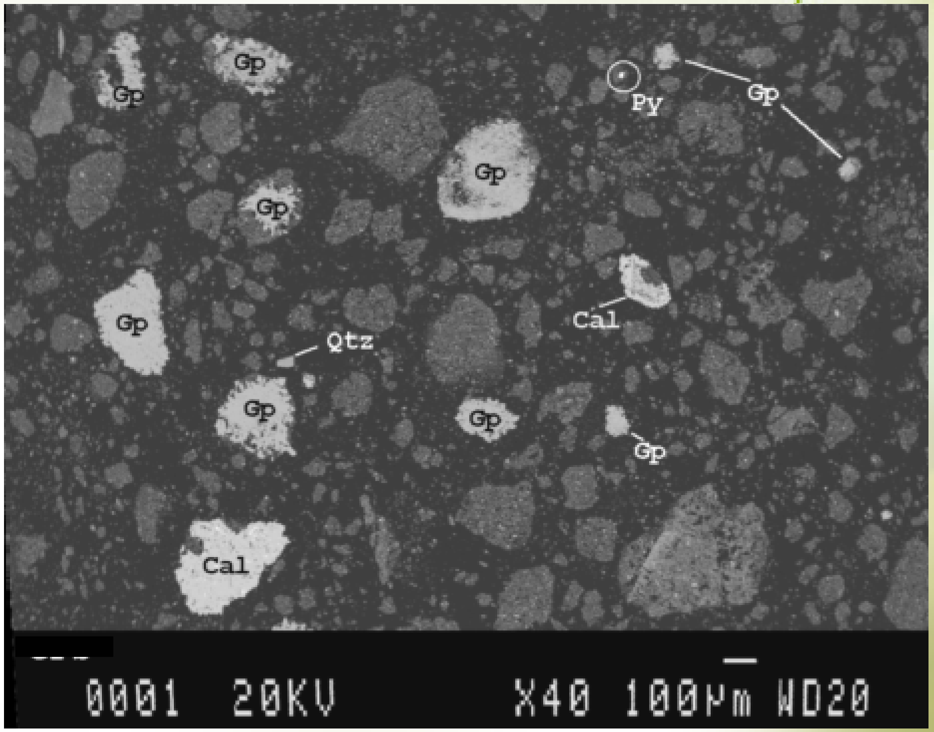
Lime treatment: $Ca(OH)_2$ → $CaSO_4.2H_2O$

Metal precipitation: → $Fe(OH)_3$, $Zn(OH)_2$

- **Volume**
  - ~6.7 million m^3 sludge/yr
- **Low percent solids**
- **Long-term stability?**
  - amorphous
  - metal speciation
  - gypsum/calcite
- **Physical stability**

Sludge Properties

- 2-40% solids
- amorphous mass containing most metals (Fe, Zn, Cu, Cd…)
- calcite, gypsum
- 2-30 microns
- pH 8.5 to 11

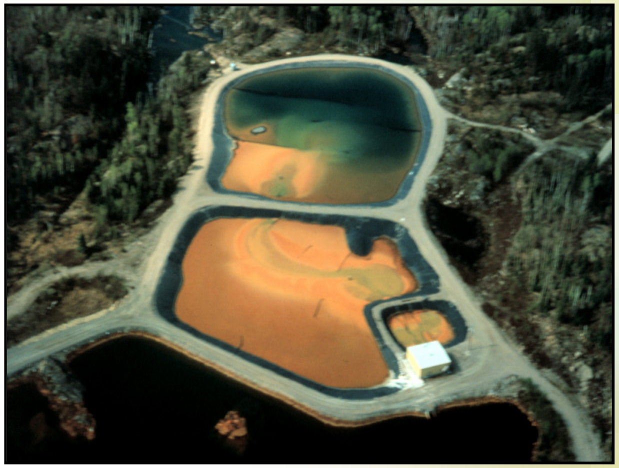


Sludge disposal considerations

- Dewatering ability
- Slurry density – moisture content
- Volume – rate of production
- Metal stability – available alkalinity
- Sludge composition
- Economics

Pond Disposal

- Dewatering and storage areas
- Issues
  - Wind – resuspension, dusting
  - Land costs
  - Pond failure – thixotropic sludge properties
- Types
  - Excavation, earthen dam, concrete, lined, beached
  - Polishing a/o long term storage
- Costs
  - Depend on sludge production rate, stability
  - Mechanical sludge removal may be required (\$10-20/m^3)



Pond Disposal

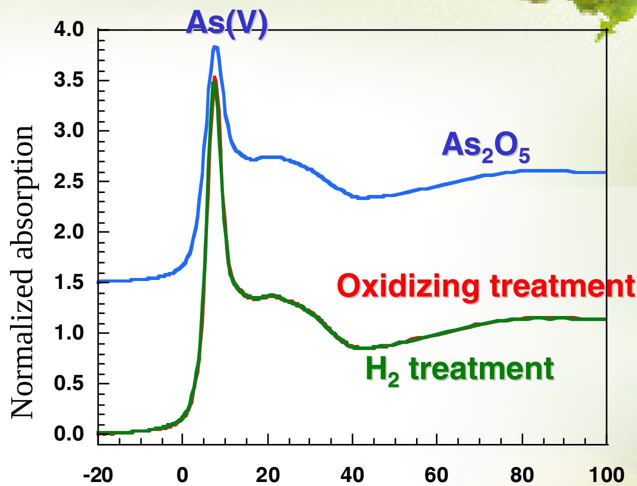
- **Disposal above water table**
  - Erosion (wind, water) and surface infiltration increase
- **Disposal below water table**
  - Sludge remains wet, cracking limited
  - Isolate sludge from surface erosion and hydraulic gradients

Pond Disposal Study

- Metal mobility was not a concern for the given leaching period (>3 years)
- Addition of a water cover over sludge significantly decreased metal mobility
  - sludge cracking avoided
  - better distribution of buffering capacity to the system

Stability of sludge under reducing conditions – Laboratory Study

- Monitoring of pore water chemistry at intervals
- Automated, continuous *in situ* monitoring of multiple redox measurements in the sludge columns
- XAS As characterization in the sludge at the end of reduction and reoxidation.
- For the studied sludge, 9 mo of imposed reducing treatments did not reduce As(V) to As(III) nor mobilize As

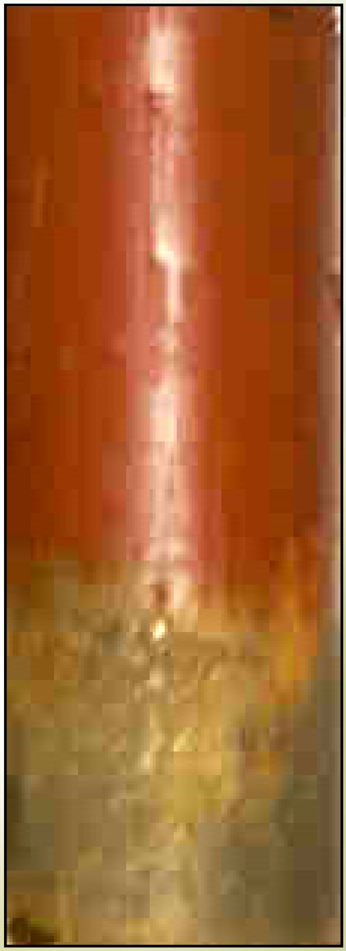


Co-disposal with other wastes

- **Eliminates additional waste management facility**
- **Sludge-tailings co-disposal environment**
  - Beneficial both in terms of sludge stability and the abatement of acid generation at least in the short term.
    - source of excess alkalinity
    - fill interparticular voids and reducing oxygen and water penetration
  - Sludge could become unstable if in contact with higher levels of acidity
    - tailings oxidation
  - Lime sludge should never be deposited with partially oxidized tailings as metal leaching is inevitable

Sludge-Tailings Co-Disposal

- **Sludge as cover over Tailings**
  - Sludge permeability
    - low permeability maybe an effective barrier to water
    - wet/dry cycles cause cracking allowing water and oxygen to reach the tailings
  - Sludge layer disposal not effective to stop or to significantly slow down oxidation
    - short term solution only

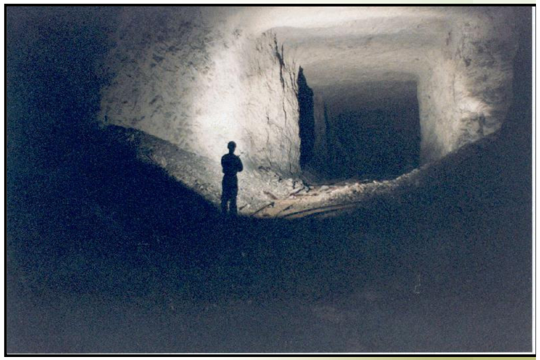


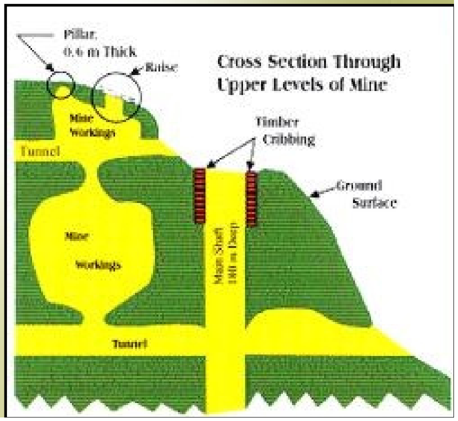
Sludge-Tailings Co-Disposal

- **Sludge mixed with tailings prior to disposal**
  - ~<5% sludge in tailings
  - Fill void spaces in tailings
  - Only reduce the metal mobility in the short term
  - Longer term
    - higher degree of oxidation
    - dissolution/depletion of sludge will occur
- **Sludge disposed with waste rock**
  - Fill void spaces in waste rock, not effective as a seal or cap
  - Short term amendment
  - Low cost, no adverse environmental issues
  - Does not prevent acid generation
  - Potential for sludge dissolution

Disposal in Mine Workings

- Sludge pumped/trucked to boreholes drilled into u/g inactive deep mines
- Sludge alkalinity provides some neutralization of acidic mine water
- Ferric hydroxide does not dissolve rather accumulates in workings
- Surface reclamation not required
- Considerations
  - Site availability and access
  - Mine capacity, void space, configuration
  - Sludge properties – viscosity
- Advantages
  - Filling of mine voids may reduce subsidence
  - Sludge may assist neutralization of mine water
  - Low surface land consumption/reclamation

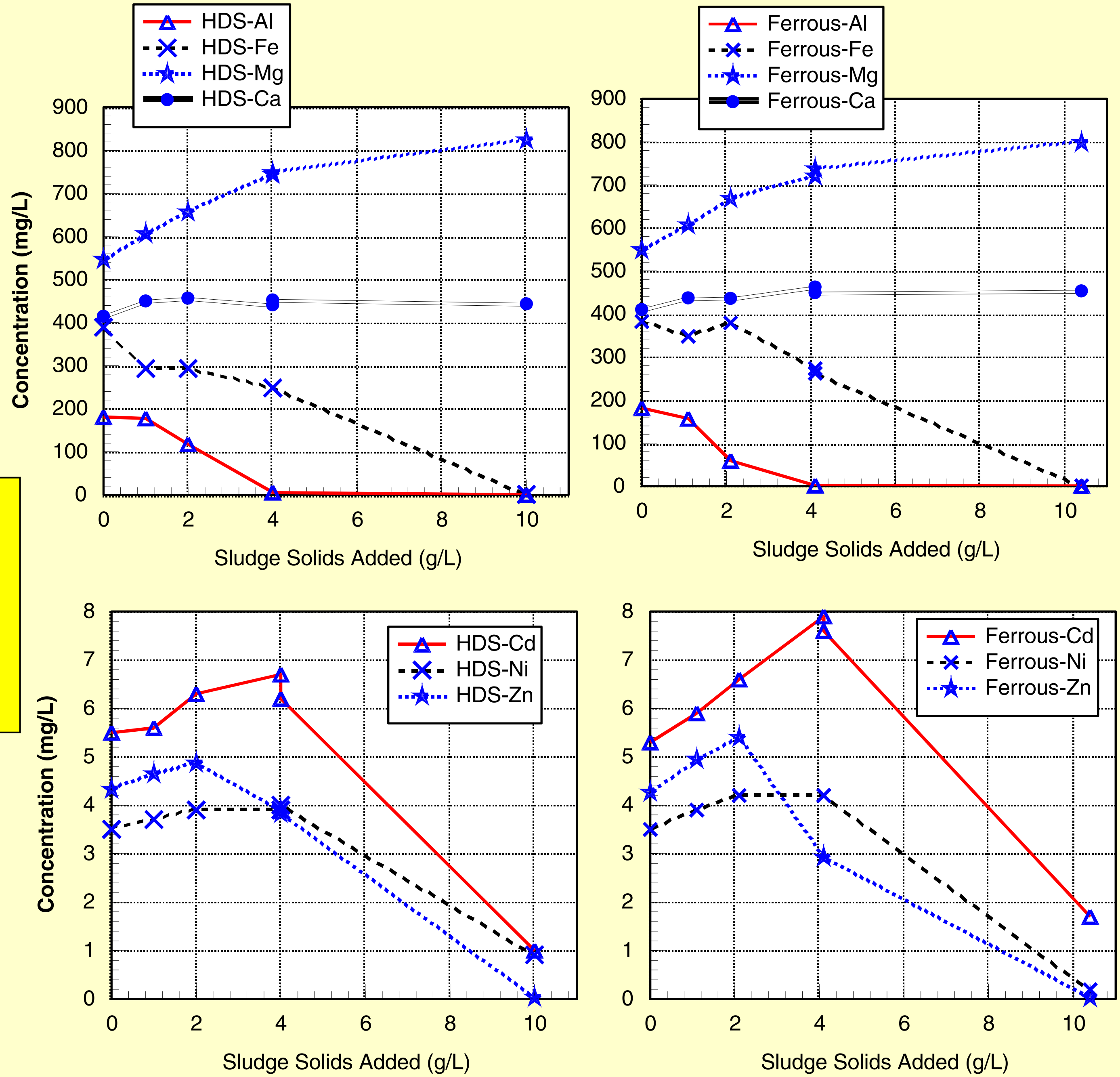




Laboratory study

> ferrous sludge

> HDS



Sludge in Backfill

- Paste backfill is a common practice in the mining industry integration of sludges and slag as a backfill material to reduce the amount of waste to dispose at the mine surface
- Cementitious stabilization of slag, tailings and sludge
- Chemical and physical stability
- Pogo mine (Alaska) proposed disposal (2003)
  - Sludge from water treatment facilities backfilled underground during operation.

Reprocessing of Sludges

- **Sludges can contain significant concentrations of metals**
  - Zn, Cu, Ni
  - Metal recovery to offset costs
- **Hydrometallurgical approaches**
  - Solvent extraction
  - Fluidized Bed Ion Exchange
  - Acid Leaching
- **Smelting**
  - Requires sludge drying (rotary dryer less than 20% moisture)
  - Impurities impacts
  - No additional disposal costs, recycling, no additional liabilities

Smelting Sludges - Examples

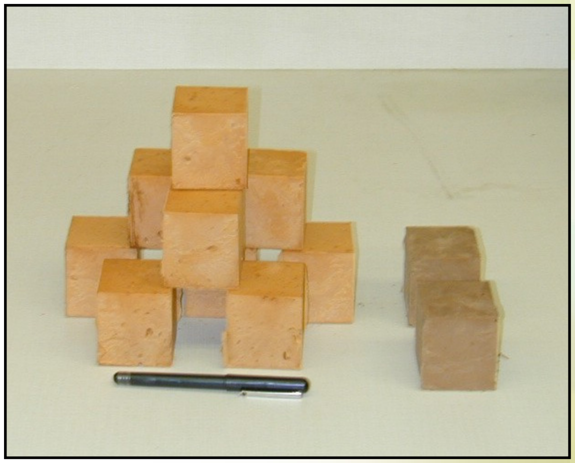
- **Asarco's California Gulch**
  - Pb reports to the bullion, Cu to the matte, Cd to the bag-house dust, and Zn, Fe, Al, and other trace metals to the slag.
  - Primary benefit of sludge addition is the lime content and incidental Pb and Cu units recovered well.
- **Pasminco Port Pirie Smelter (PPPS) South Australia**
  - Lime neutralization, sodium sulphide and ferric chloride
  - Slurry is thickened and filtered with the solids being returned to the smelter for re-processing.

Stabilization with Additives

- Chemical and/or Physical Stabilization
- Physical entrapment, chemical fixation, binding
- Compatibility of binder with sludge is crucial
- Six major stabilization methods
  - Sorption, lime-based, cement-based, thermoplastic techniques, polymeric and encapsulation
- Typically cost prohibitive but may be applicable to certain high risk sludges
  - $50 to $300 per tonne

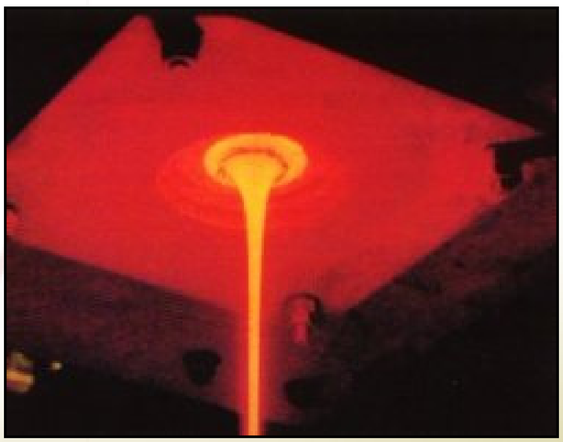
Sludge Stabilization

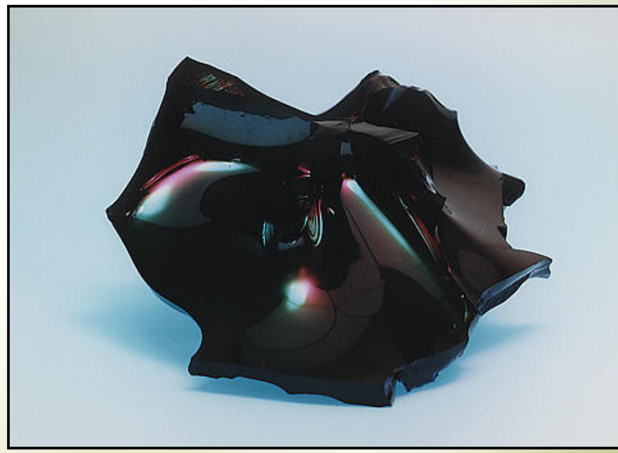
- Objectives
  - Stabilize leachable metals
    - As, Ba, Zn, Cd, Cr, Cu, Ni, Pb, Zn and Se
  - Obtain an inert and insoluble material
  - Improve physical properties of the sludge
- Benefits
  - Use sludge as a dry barrier over tailings
  - Sludge stabilization (chemical and physical)
  - Use if other wastes to stabilize (red mud, fly ash, etc.)
  - Sludge as landfill/backfill material
  - ~$5/tonne for PC and fly ash only



Stabilization

- **Vitrification**
  - Metals stabilized in solid inert glass
  - Material very durable and stable over long term
  - Volume reduction up to 97%
  - For extremely hazardous sludges
  - Cost very high





Landfill

- Solid or hazardous waste
- Solid-liquid separation issues
- Requires dewatering and drying before transport
- Stabilization may be required
- Public concern over sludge transport to off site landfill
- Costs

Sludge Reuse Options

- **Sludge as brick material**
  - Sludge proportion and firing temperature key to compressive strength
  - Metal leaching low
- **Agricultural land applications**
  - To raise soil pH
  - Limited
- **Metal adsorbent in industrial wastewater treatment**
  - Able to remove a wide variety of contaminants, including Cu, Zn, Ni, Cr, Pb, As, and natural organic matter (NOM).
  - Surface charge easily altered by adjusting the solution pH.
  - Can be regenerated in-*situ* by reversing the solution of pH
- **Replacement in cement manufacturing**
  - Calcite/gypsum/free lime content
  - Drying required (<2% moisture)

Sludge disposal in the North

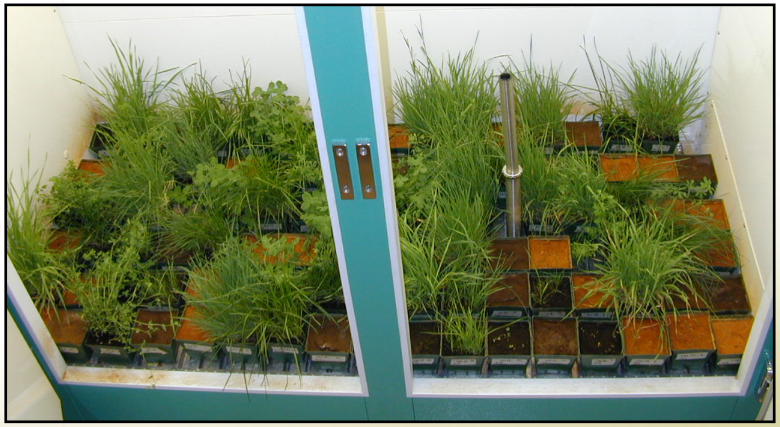
- **Field freeze-thaw**
  - Percent solids in dewatered sludge after one winter

	UKH	Faro
Initial	23 %	28 %
Final	60 %	58 %

- **No metal mobility differences observed**

Reclamation

- Revegetation of mine sludge
- Provide ground cover to limit wind and water erosion
- Overcome nutrient deficiencies
- Degree and impact of metal uptake
- Alkaline tolerate plant species



Information Gaps

- **Better understanding of metal speciation in amorphous phase**
- **Cost effective metal recovery technologies**
- **Improved treatment methods to eliminate or reduce sludge production**
- **In-situ densification technologies**
- **Required studies**
  - smelting of hydroxide sludge
  - disposal of sludges in mine workings
  - sludge in paste backfill
- **Policy to make sludge reuse feasible**
  - further studies to support

Conclusions

- Sludge disposal is an ever increasing issue
- Current practices do not address long term storage, and in some cases, long term stability issues
- Appropriate sludge disposal options are site specific
- Further research is required into disposal options that can either recover metal, densify existing sludge or safely dispose of the material in a way that it can either be easily reclaimed or disposed in mine workings
- Promising options must be both technologically feasible and also cost effective
  - Short and long term
  - Meet increasing environmental standards and pressures

Acknowledgments

- This study was supported by contributions from:
  - MEND, MAC and CANMET-MMSL

Mining Association of Canada
L'Association minière du Canada

CANMET Mining and Mineral Sciences Laboratories
Laboratoires des mines et des sciences minérales de CANMET

Thank You

Questions?