CANMET Mining and Mineral Sciences Laboratories

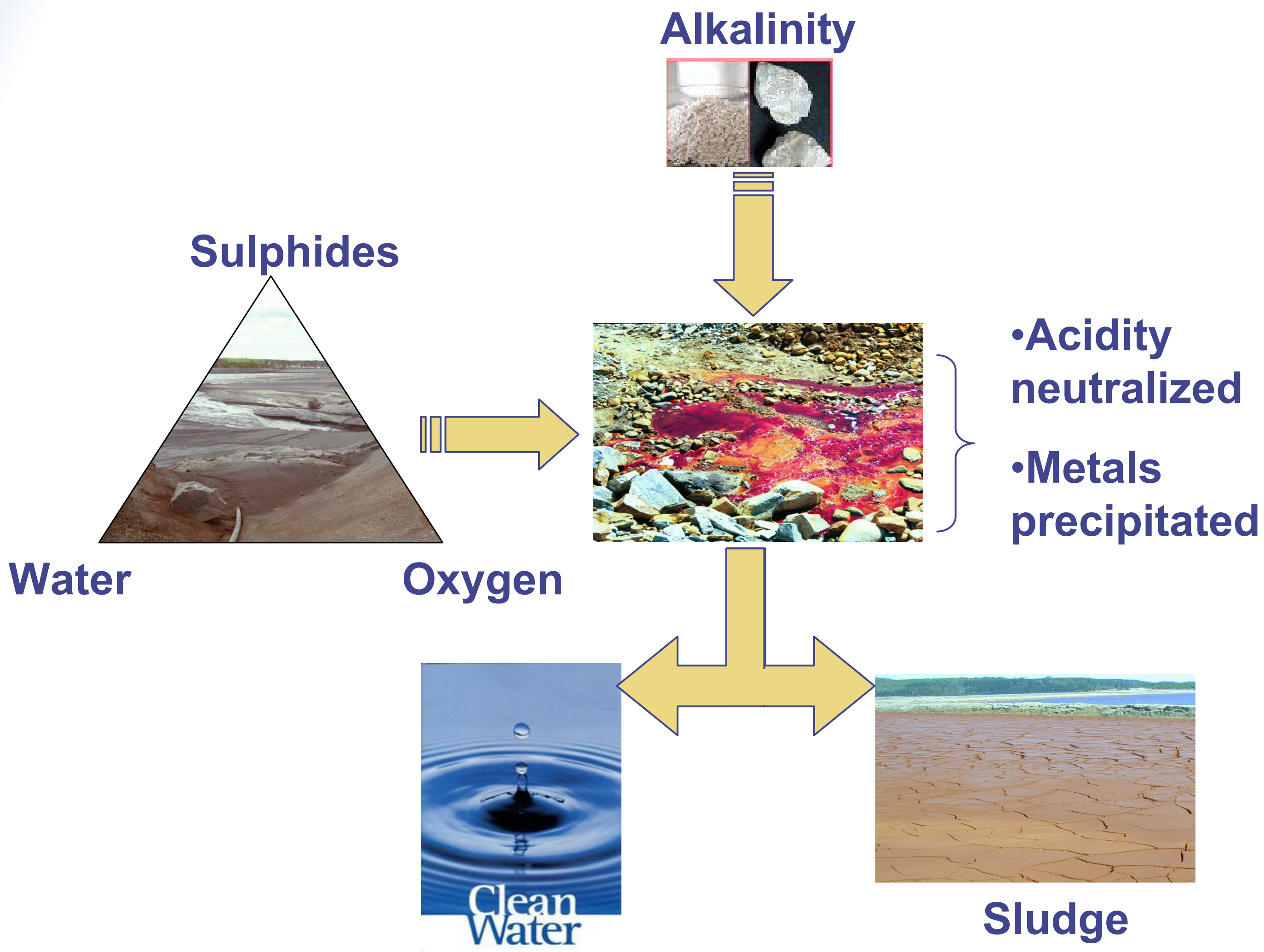
MEND Workshop – Halifax – May 2006

Update on Treatment Sludge Management:
Properties, Stability and Options for Disposal

Janice Zinck

General Outline

- Characterization
  - Sludge properties
- Sludge stability
  - Factors affecting stability
- Sludge management options
  - Disposal
  - Reprocessing
  - Reuse

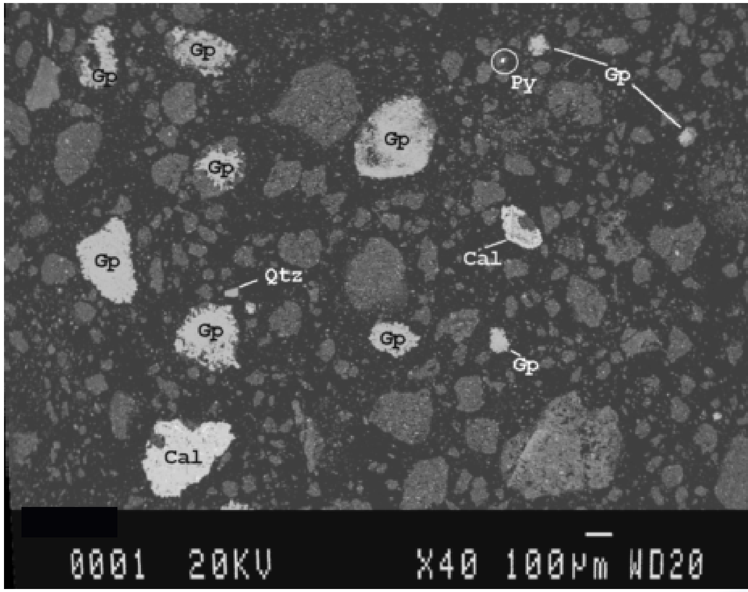

Alkalinity
Sulphides
Water
Oxygen
•Acidity neutralized
•Metals precipitated
Clean Water
Sludge

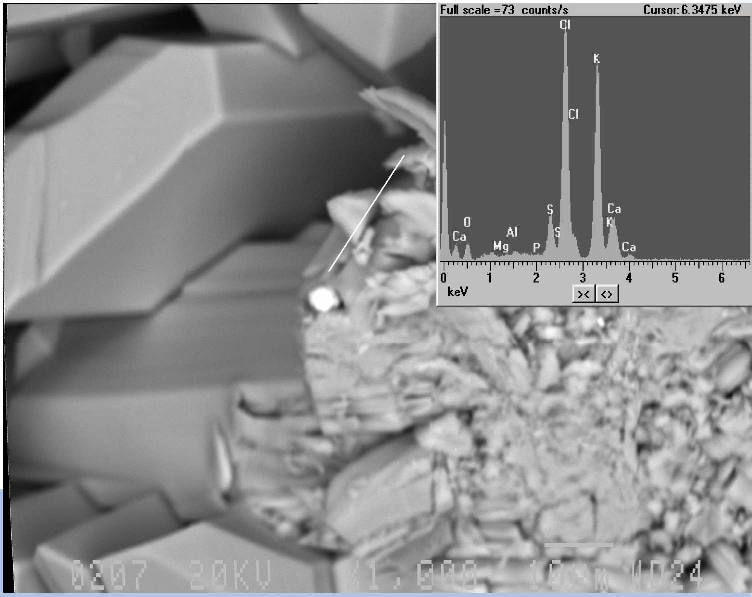
Issues

- Volume
  - ~6.7 million m^3 sludge/yr (1995)
- Low percent solids
- Long-term stability?
  - amorphous
  - metal speciation
  - gypsum/calcite
- Physical stability

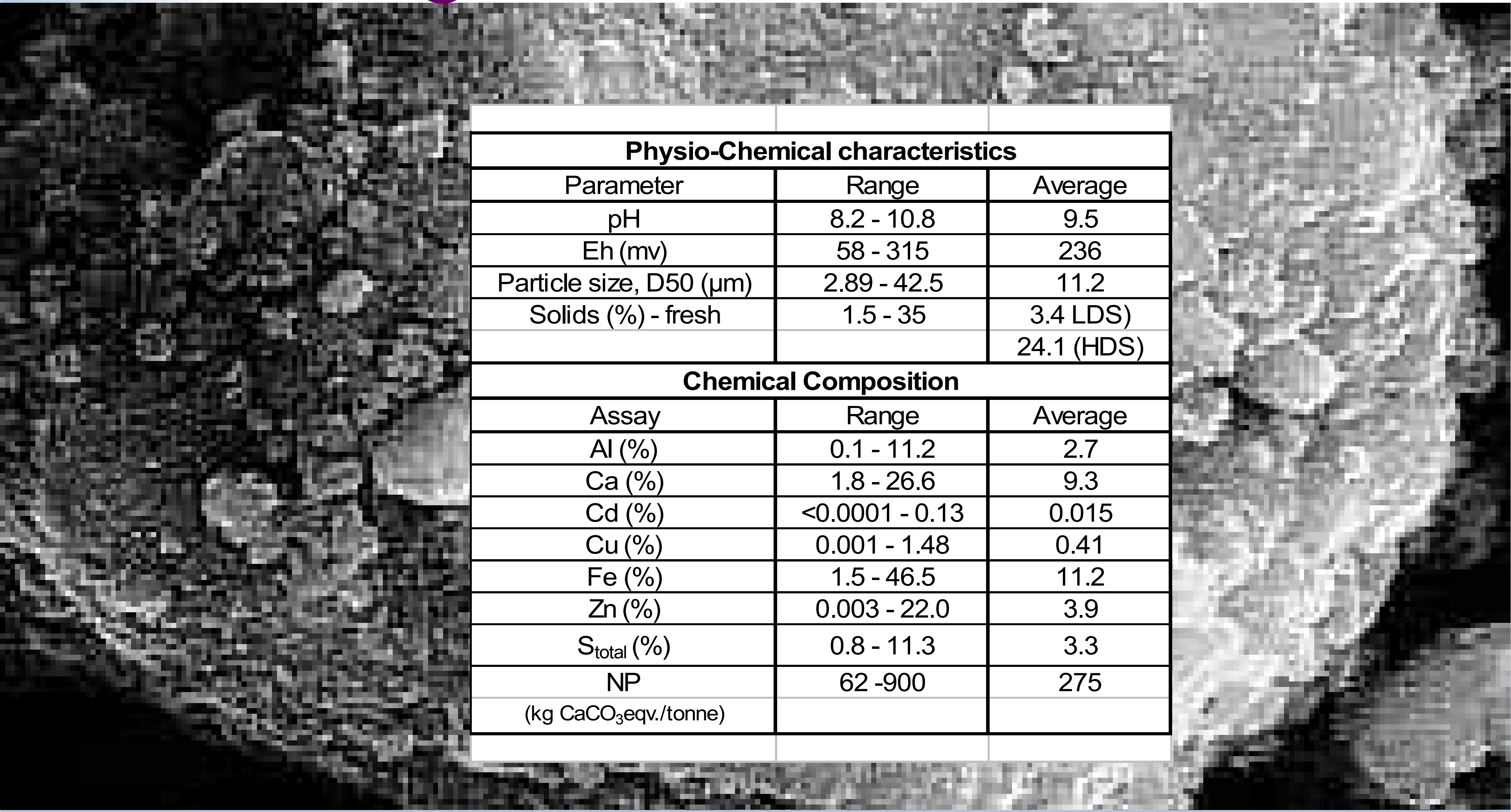
Sludge Properties

- 2-35% solids
- amorphous mass containing most metals (Fe, Zn, Cu, Cd…)
- calcite, gypsum
- 2-40 µm
- pH 8.5 to 11
- neutralization potential
  - 100-900 $CaCO_3$ equiv.



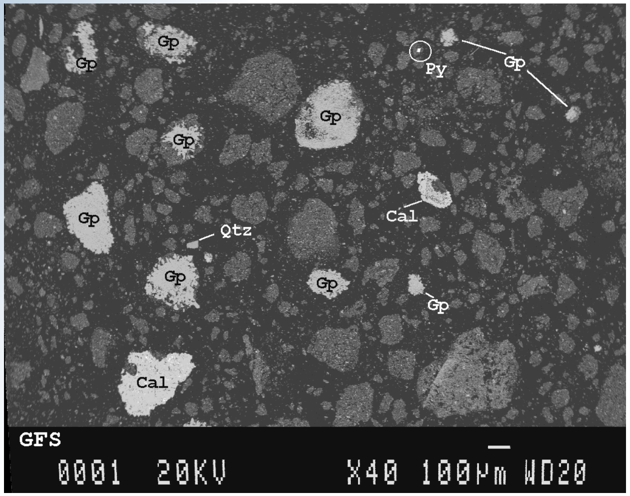


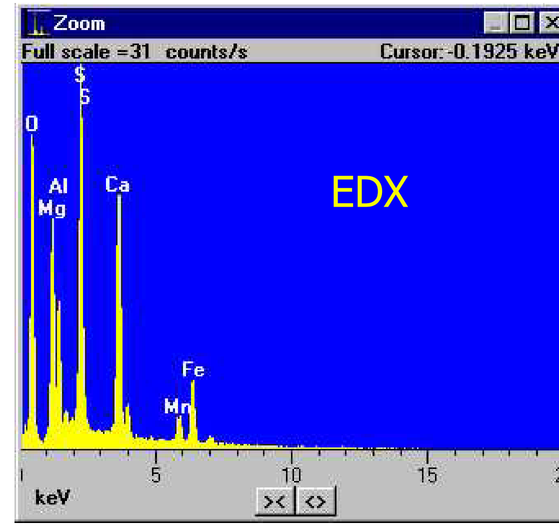
Sludge Characteristics



Physio-Chemical characteristics		
Parameter	Range	Average
pH	8.2 - 10.8	9.5
Eh (mv)	58 - 315	236
Particle size, D50 (µm)	2.89 - 42.5	11.2
Solids (%) - fresh	1.5 - 35	3.4 LDS)
		24.1 (HDS)
Chemical Composition		
Assay	Range	Average
Al (%)	0.1 - 11.2	2.7
Ca (%)	1.8 - 26.6	9.3
Cd (%)	<0.0001 - 0.13	0.015
Cu (%)	0.001 - 1.48	0.41
Fe (%)	1.5 - 46.5	11.2
Zn (%)	0.003 - 22.0	3.9
S_{total} (%)	0.8 - 11.3	3.3
NP	62 -900	275
(kg $CaCO_3$eqv./tonne)		

Sludge Mineralogy





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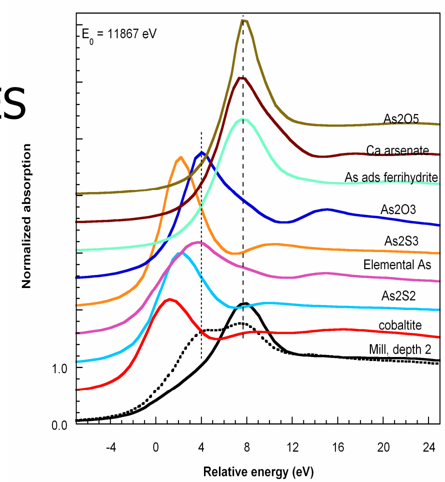
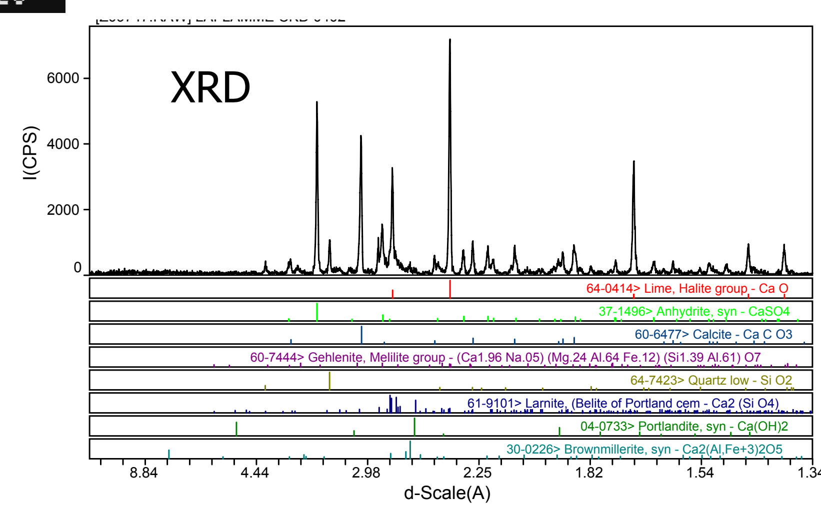
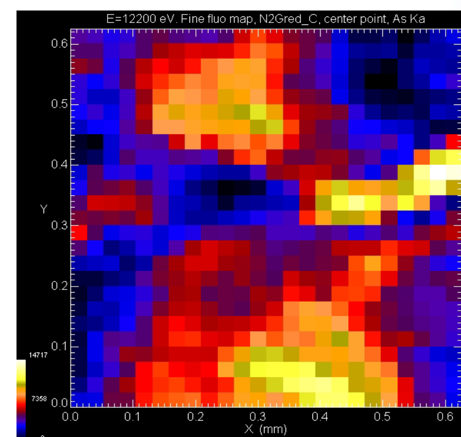






XAS

Sludge Stability

Regulatory Context

- Treatment sludges are waste products which may be subject to waste management regulations
- Leachate extraction tests used to evaluate if the waste should be classified as hazardous
- Leachate regulations vary by jurisdiction and site specific licenses

Evaluating Sludge Stability

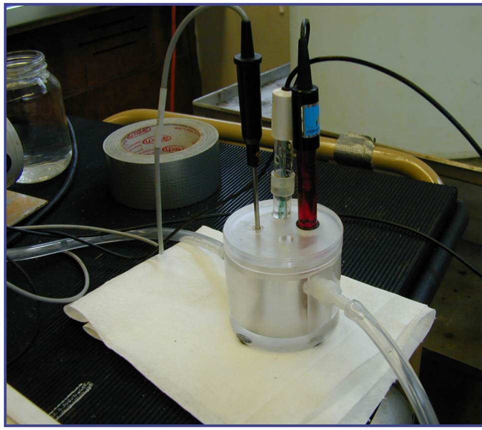
- Presently no regulatory leach protocols designed for sludges or solid mine waste
- Current leach tests (TCLP) use acetic acid
  - organic acid does not mimic disposal scenario
  - false mobilization of some metals (e.g. Pb)
- Synthetic acid rain leachant is more appropriate (SPLP)
- Aggressive agitation
  - simulate long-term leaching

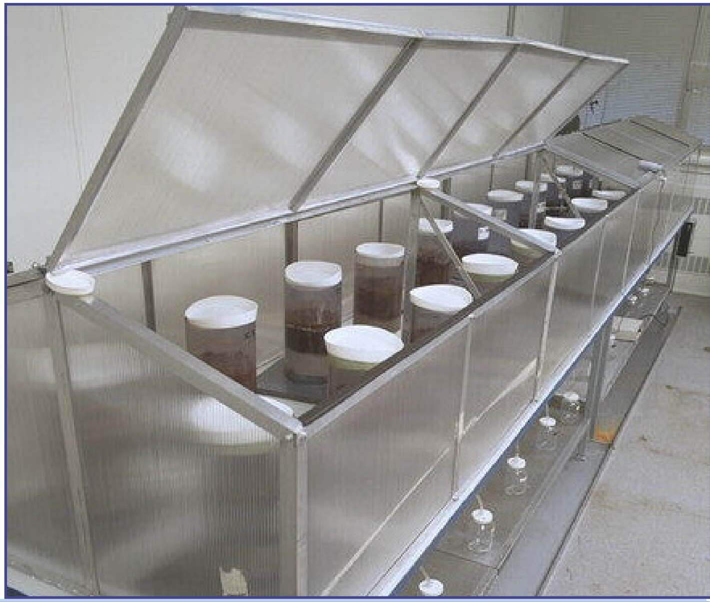
Sludge Stability – Batch Tests

- Leachate concentrations are generally 5x lower than regulated limits
- In general, sludge consistently pass the leaching tests with synthetic rain
- Sludge occasionally ‘fail’ acetic acid type tests
  - Zn, Cd, and Ni most mobile
- Sludges with more carbonate fare better
- Sludge with greater crystallinity more stable
- Aged sludges crystallize and stabilize

Column Leaching Tests

- Conceptually more realistic since they better simulate natural leaching processes
- Observations derived from column tests may be used to estimate the potential environmental impact of various sludge disposal scenarios
- Require a longer (years) leaching period to assess long term sludge stability





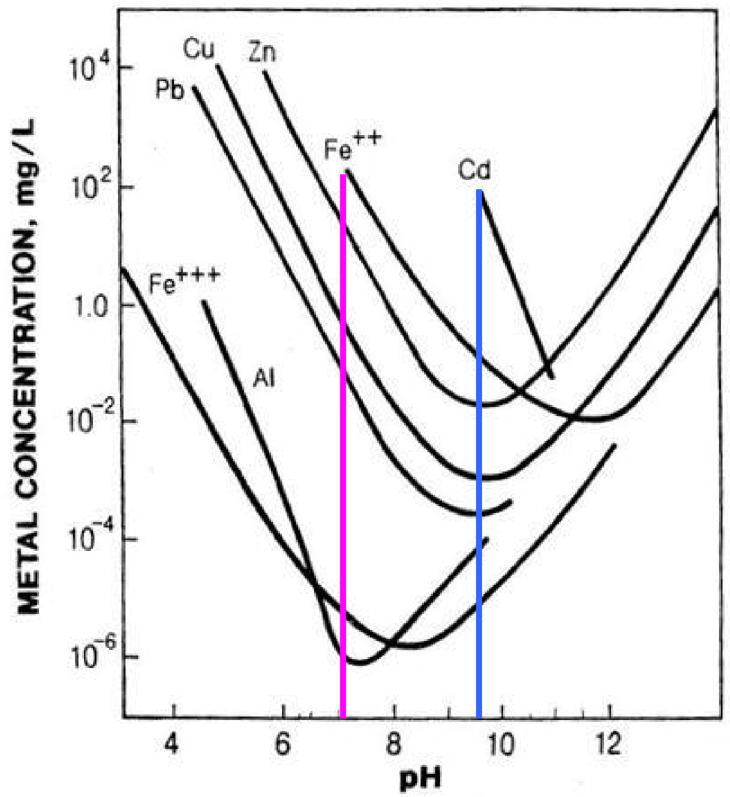
Leachate Regulatory Limits

Parameter	Federal Regulatory Limit (mg/L)	
	(US)	(Canada)
Arsenic	5	2.5
Barium	100	100
Boron	-	500
Cadmium	1	0.5
Chromium	5	5
Lead	5	5
Mercury	0.2	0.1
Selenium	1	1
Silver	5	-
Uranium	-	10

Factors Affecting Sludge Stability

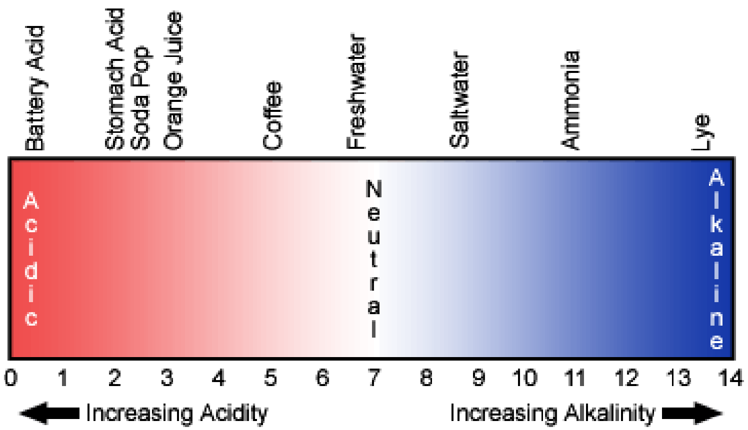
Leachant pH

- Sludge leachability
  - strongly dependent on the leachant pH
- 1000 years of marginally acidic rainfall percolating through the sludge required to give a modest pH depression
- Sludge samples tested (batch) yielded final leachant pH ranging from 5.0 to 10.6
  - will become unstable with the addition of enough acid



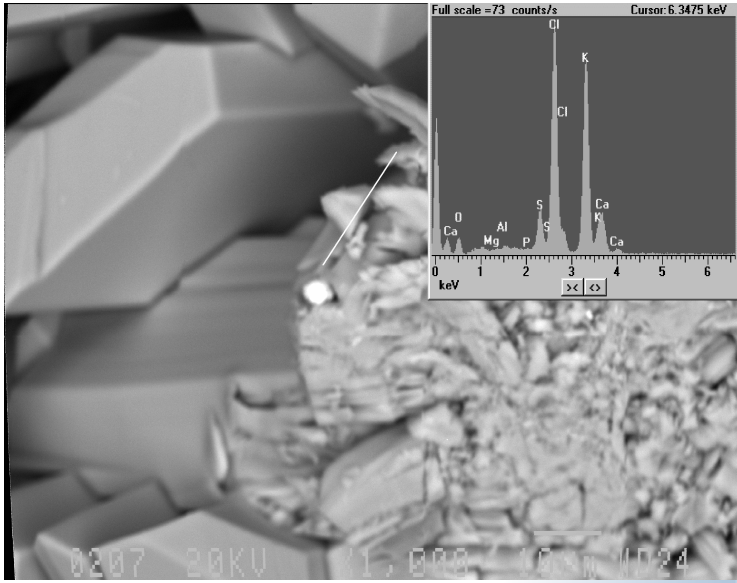
Leachant pH

- Example
  - Site A: 14.2% Zn, NP=142, pH_f=6.8
    - Zn mobility = 27 mg/L
  - Site B: 14.4% Zn, NP=523, pH_f = 8.5
    - Zn mobility = 0.48 mg/L
  - ~ two orders of magnitude difference



Precipitate Crystallinity

- Metal release from crystalline precipitates is generally lower than from amorphous or poorly crystallized material
- Sludge stability depends on the stability of the amorphous mass
- Sludge (Fe) recrystallization may increase mobility of adsorbed metals



Raw Water Composition

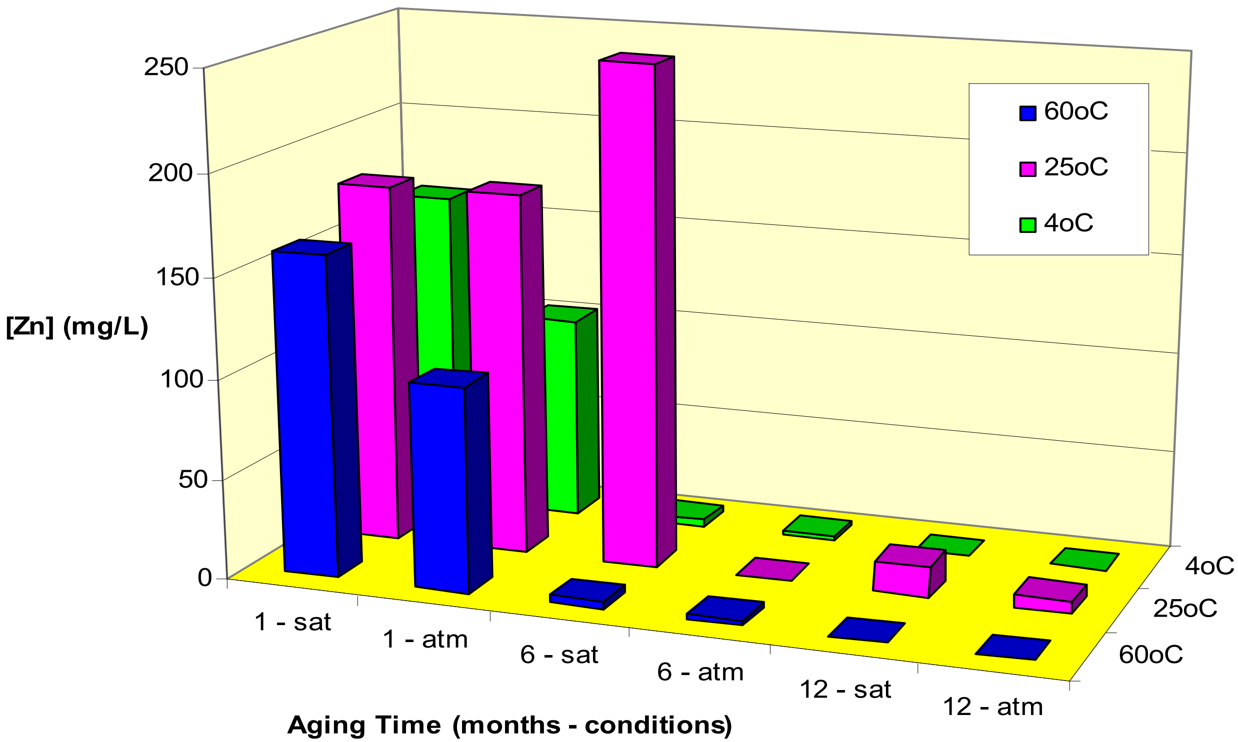
- Raw water has the greatest influence on the sludge characteristics
- Fe(II):Fe(III)
  - zinc leachability
  - solutions with Fe(II) and Fe(III) yield more crystalline, stable precipitates
- Higher sulphate levels
  - yield higher sludge densities
  - detrimental to settleability and particle growth
  - higher levels of metal leachability

Excess Alkalinity/ Treatment Process

- Excess alkalinity serves to reduce metal leachability
  - increase short-term sludge stability
  - buffer the pH in the alkaline or neutral region, limiting the degree of metal leaching
- Basic treatment system
  - poor lime efficiency
  - lower metal leaching (short term)
- High density sludge treatment
  - efficient lime utilization
  - low NP

Sludge Aging

- Sludges densify and further crystallize with time
- Aged sludges have a lower propensity metal leaching than fresh sludges



Disposal Environment

- Method of disposal ultimately affects the long term sludge stability
- Sludge could become unstable if in contact with moderate levels of acidity

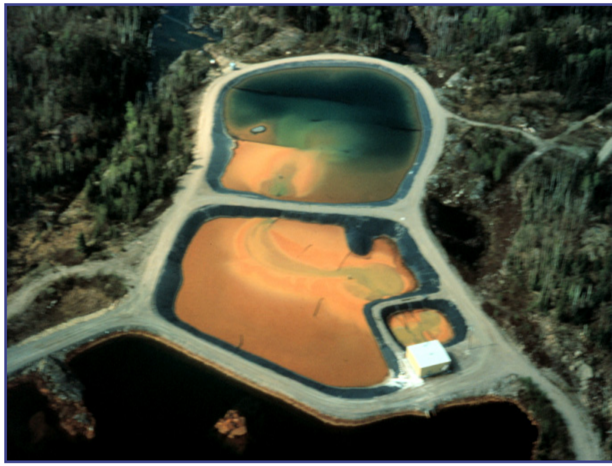
Sludge Disposal, Reuse and Reprocessing Technologies

Sludge Disposal Considerations

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

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 Studies

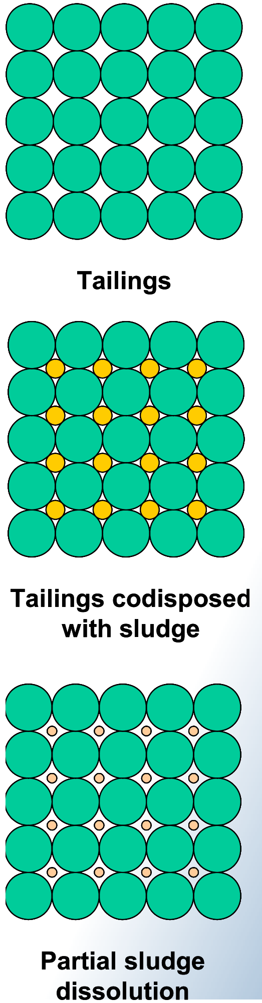
- Metal mobility was not a concern for the given leaching period (>3 years)
- Addition of a water cover over sludge significantly decreased metal mobility
  - sludge cracking avoided
  - better distribution of buffering capacity to the system
- Sludge in reducing environments did not appear to increase metal mobilization (As)

Co-disposal with Other Wastes

- Eliminates additional waste management facility
- Can be 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 reduce oxygen and water penetration
- Sludge could become unstable if in contact with higher levels of acidity

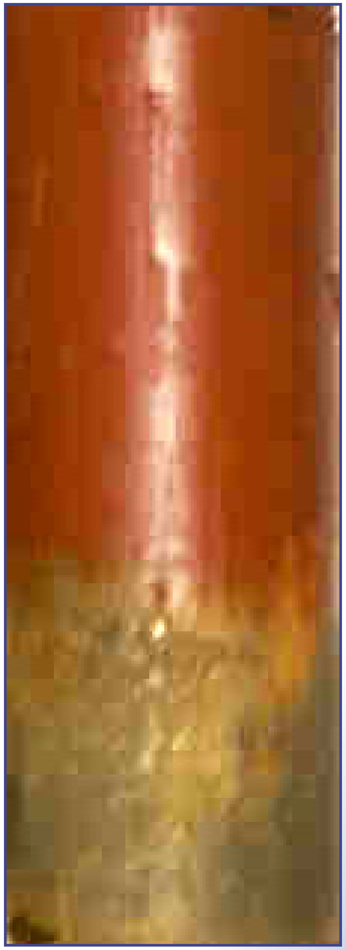
Sludge-Tailings Co-disposal

- 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
    - dissolution/depletion of sludge will occur
    - higher degree of oxidation



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

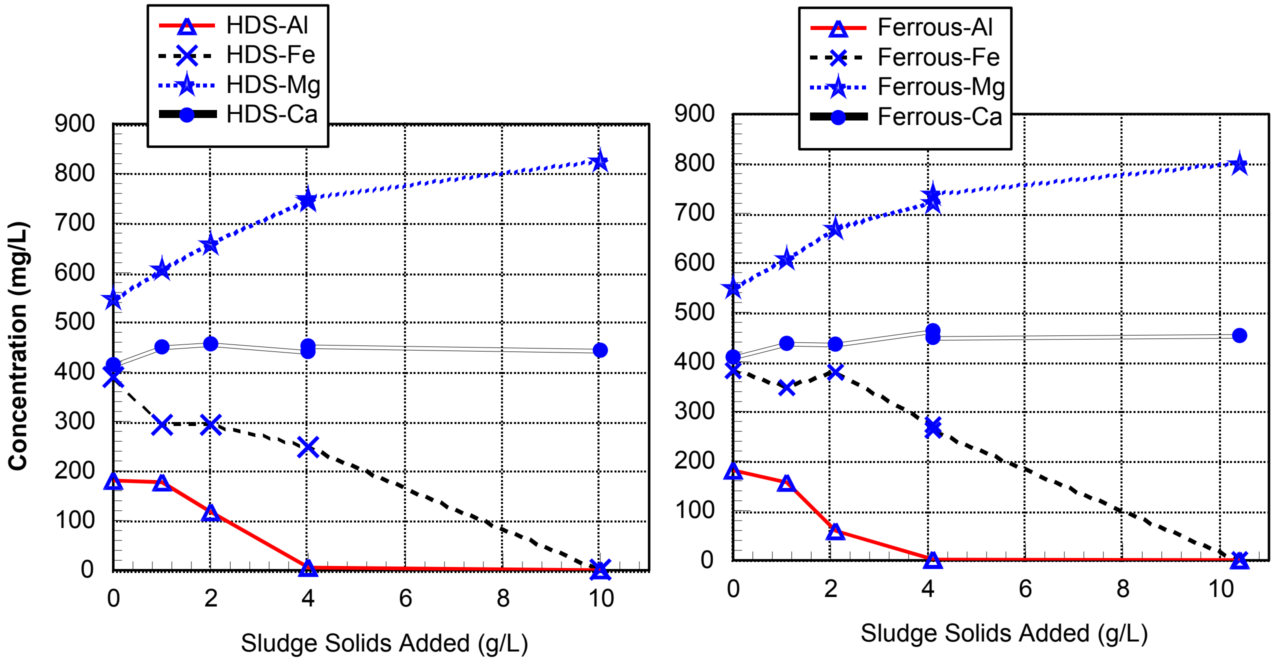


Sludge-Waste Rock Co-disposal

- Fill void spaces in waste rock, not effective as a seal or cap
  - NB Coal
- Short term amendment
- Low cost
- Does not prevent acid generation
- Potential for sludge dissolution
- No adverse environmental issues

Disposal in Mine Workings

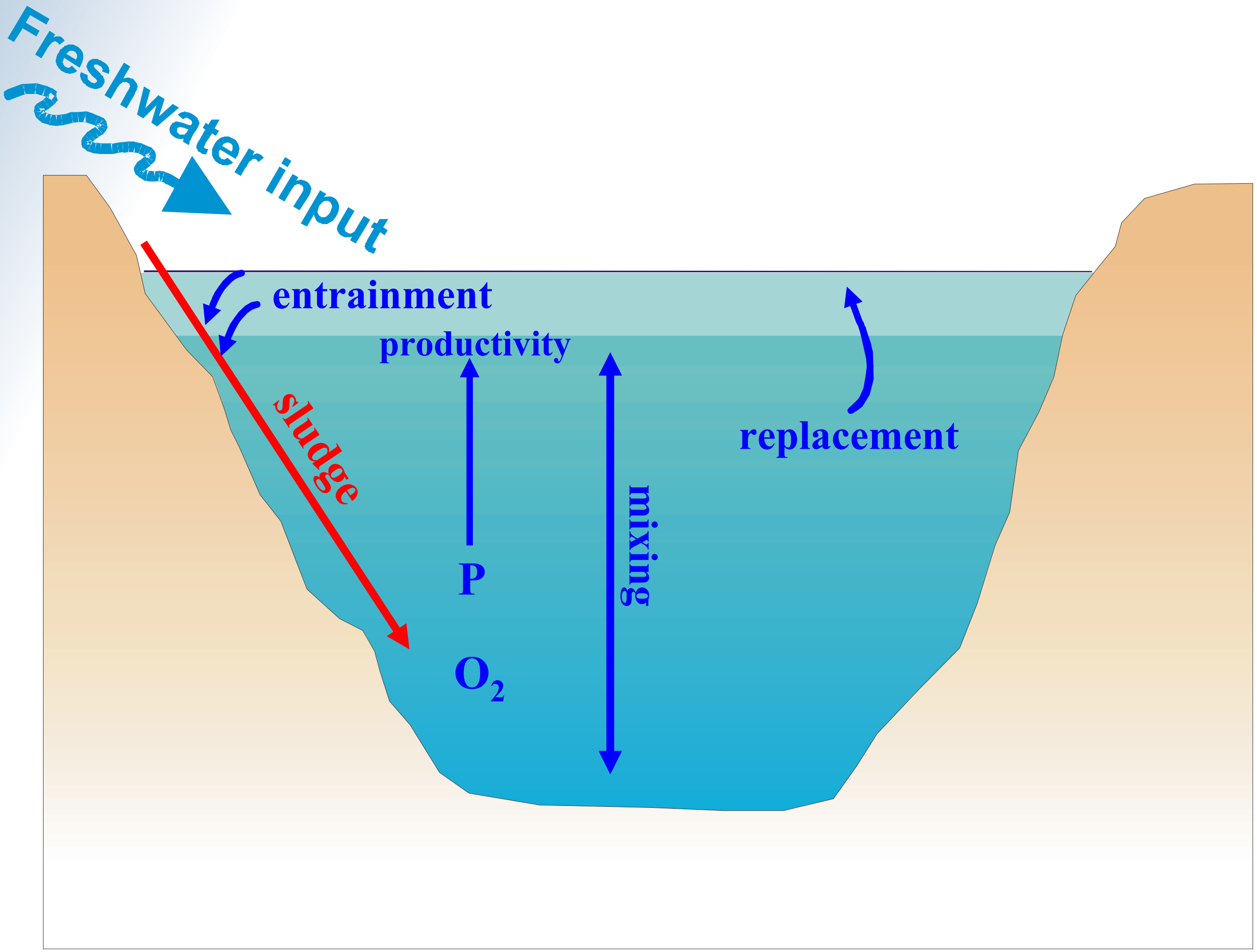
- Sludge pumped/trucked to boreholes drilled into u/g inactive deep mines
- Sludge alkalinity provides some neutralization of acidic mine water
- Ferric hydroxide does not dissolve, accumulates in workings



Disposal in Mine Workings

- **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

Disposal in Pit Lakes

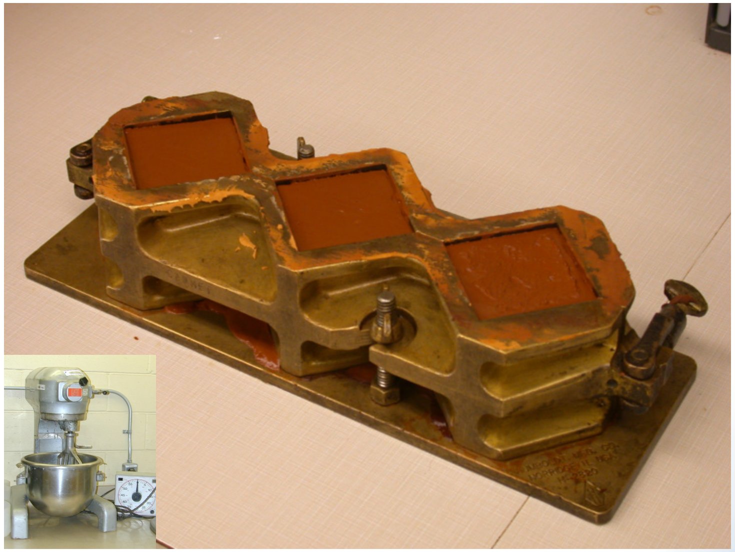


1. Suspended Solids
2. Productivity
3. Dissolved Oxygen
4. Entrainment
5. Whole-lake mixing

J. McNee, 2004

Sludge in Backfill

- Integration of sludges and slag as a backfill material
  - reduce the amount of waste to dispose at the mine surface
- Cementitious stabilization of slag, tailings and sludge
- Chemical and physical stability are key
- Less than 5% sludge in mix

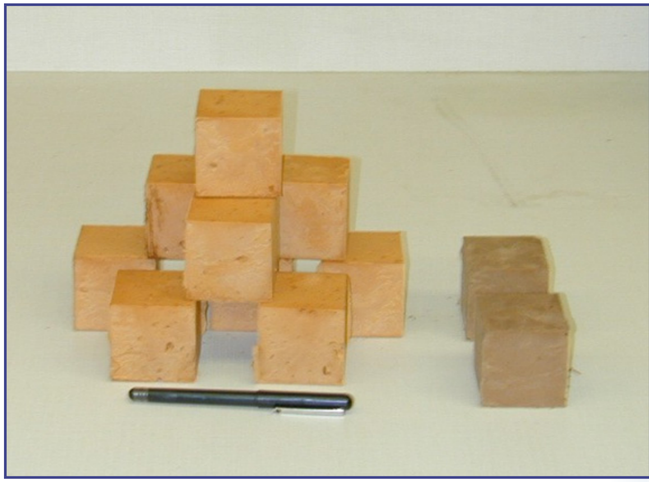


Reprocessing of Sludges

- Sludges can contain significant concentrations of metals
  - Zn, Cu, Ni
- Metal recovery to offset remediation costs
- No additional disposal costs, recycling, no additional liabilities
- Hydrometallurgical approaches
  - Solvent extraction
  - Fluidized bed ion exchange
  - Acid/alkaline leaching
- Smelting
  - Requires sludge drying
  - Impurities impacts ?

Stabilization with Additives

- Chemical and/or physical stabilization
- Physical entrapment, chemical fixation, binding
- Compatibility of binder with sludge is crucial
- Typically cost prohibitive but may be applicable to certain high risk sludges
  - $50 to $300 per tonne

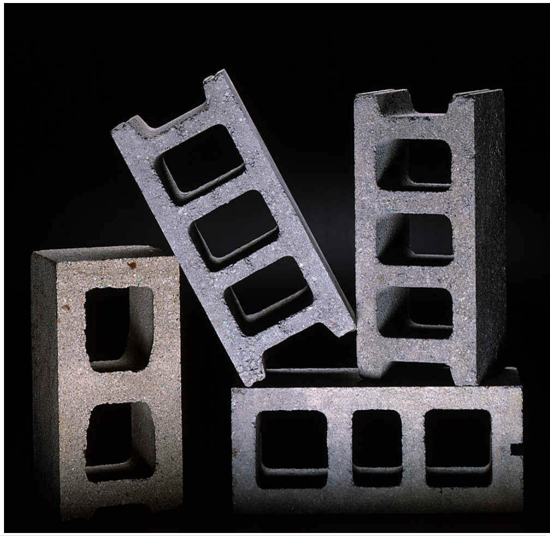


Landfill

- 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
- Estimated costs
  - $50-90 US/t
  - $120 US/t (with stabilization)
  - $160 US/t (hazardous waste landfill)

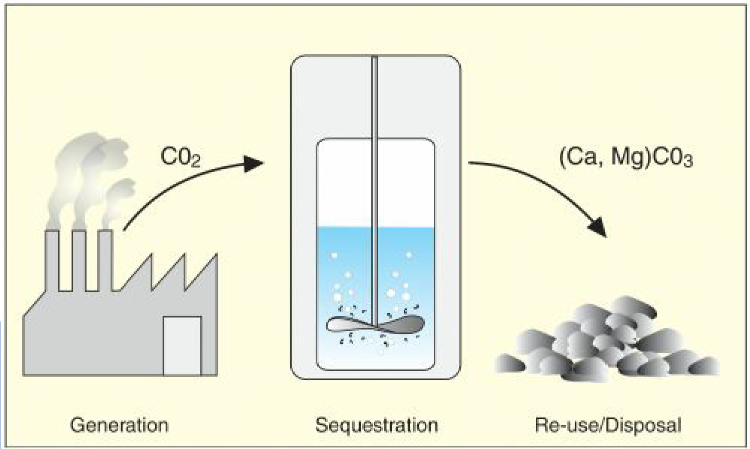
Sludge Reuse Options

- Sludge as brick material
  - Sludge proportion and firing temperature key to compressive strength
  - Metal leaching low
- Agricultural land applications
  - To raise soil pH
  - Limited
- Replacement in cement manufacturing
  - Calcite/gypsum/free lime content
  - Drying required (<2% moisture)



Sludge Reuse Options

- Gravel from sludge
  - road construction
- Metal adsorbent in industrial wastewater treatment
  - able to remove a wide variety of contaminants, including Cu, Zn, Ni, Cr, Pb, As, carcinogenic dyes/colours and natural organic matter (NOM).
  - surface charge easily altered and sludge regenerated by adjusting the solution pH
- Pigment (ferrihydrite)
- Sink for CO_2



Reclamation of Sludge Disposal Areas

- Revegetation of mine sludge
- Provide ground cover to limit wind and water erosion
- Overcome nutrient deficiencies, fertilizer consumption
- Degree and impact of metal uptake
- Alkaline tolerate plant species
  - may make tailings and sludge ponds more amenable to the establishment of vegetation

Summary of Key Points

- Sludge disposal is an ever increasing issue
- Sludge characterization is challenging – amorphous material
  - requires a range of techniques
- Sludge stability is dependant on various factors which can be controlled by appropriate disposal
  - site specific
- Current disposal practices often do not address long term storage (long term stability issues)
  - range of options are available
- Opportunity for metal recovery and sludge reuse

Thank You