CANMET Mining and Mineral Sciences Laboratories

MEND MANITOBA WORKSHOP

Challenges in Acidic Drainage for Operating, Closed or Abandoned Mines

June 4, 2008

Update on Status of Sludge Management in Canada

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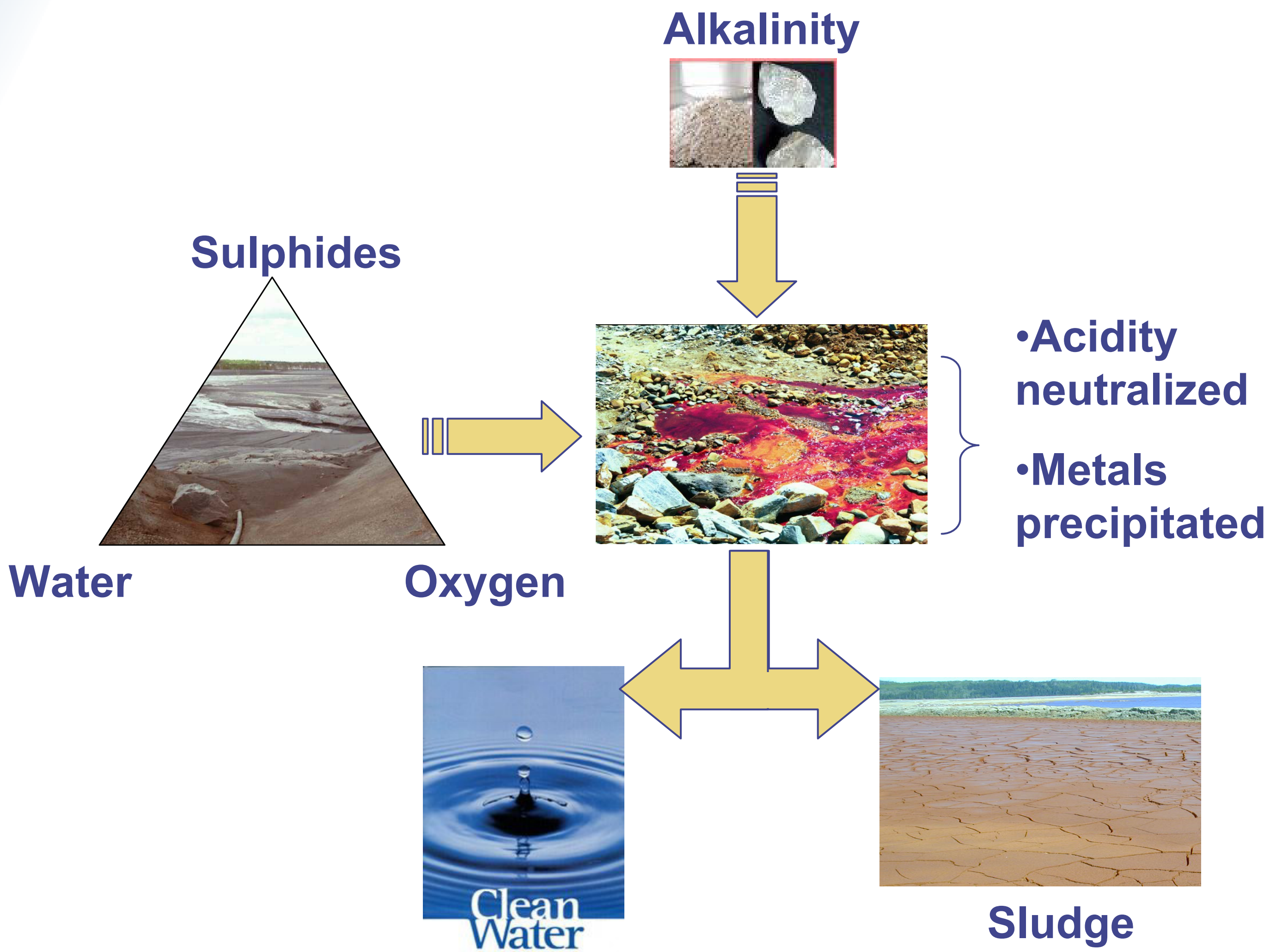
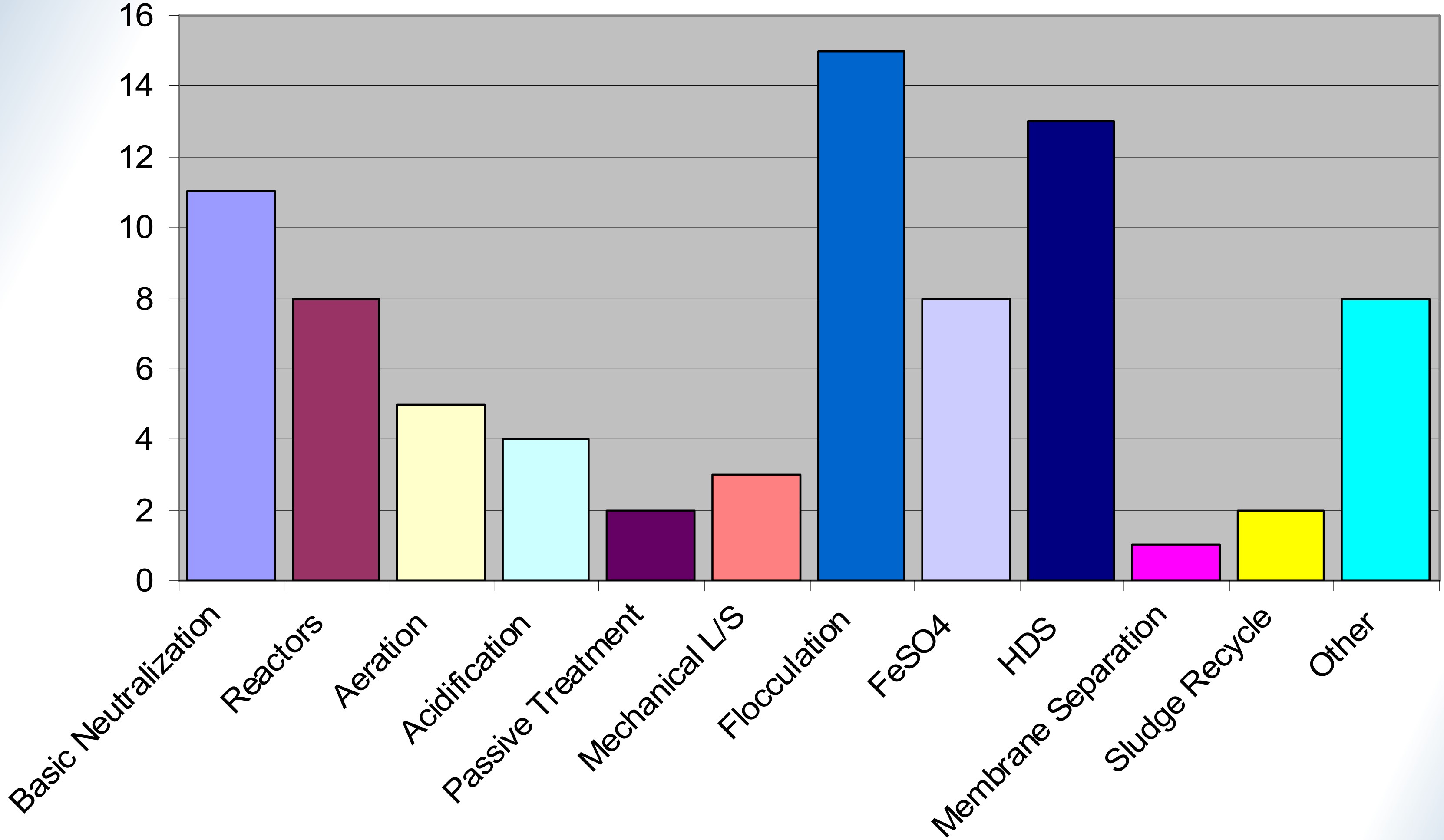
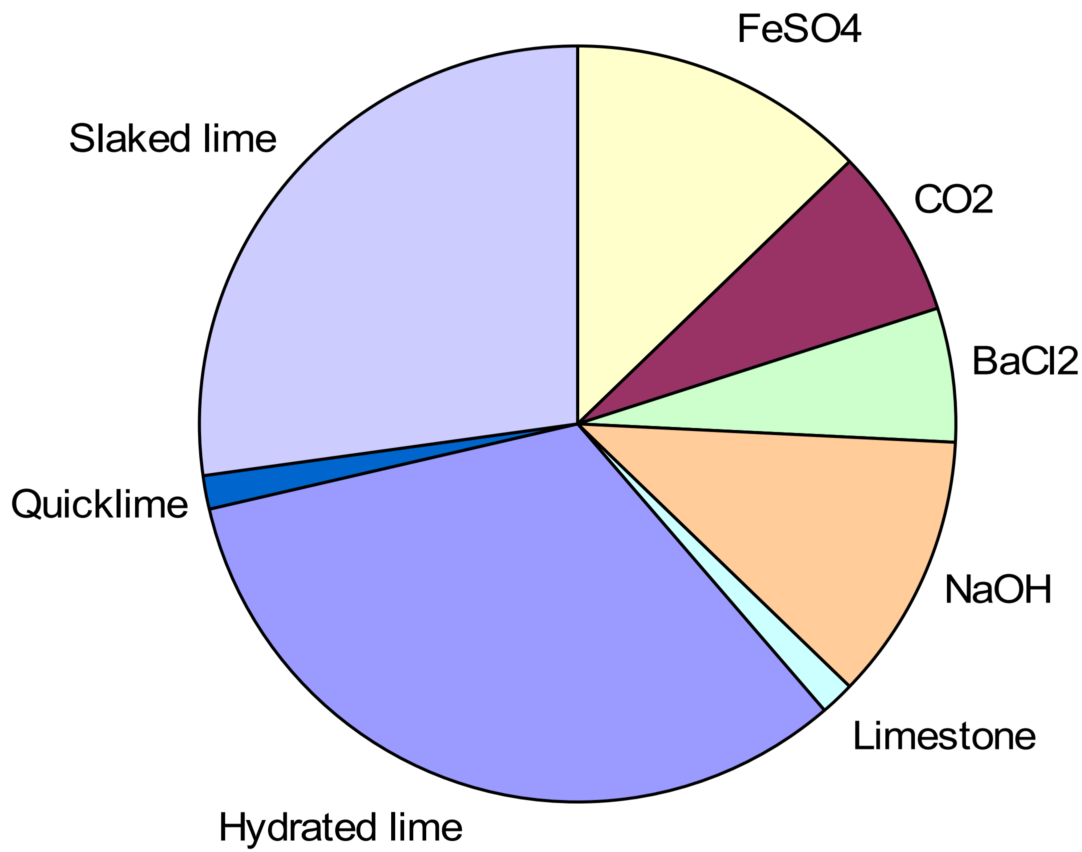

Alkalinity
Sulphides
Water
Oxygen
•Acidity neutralized
•Metals precipitated
Clean Water
Sludge

Treatment Process Details



Reagent Usage

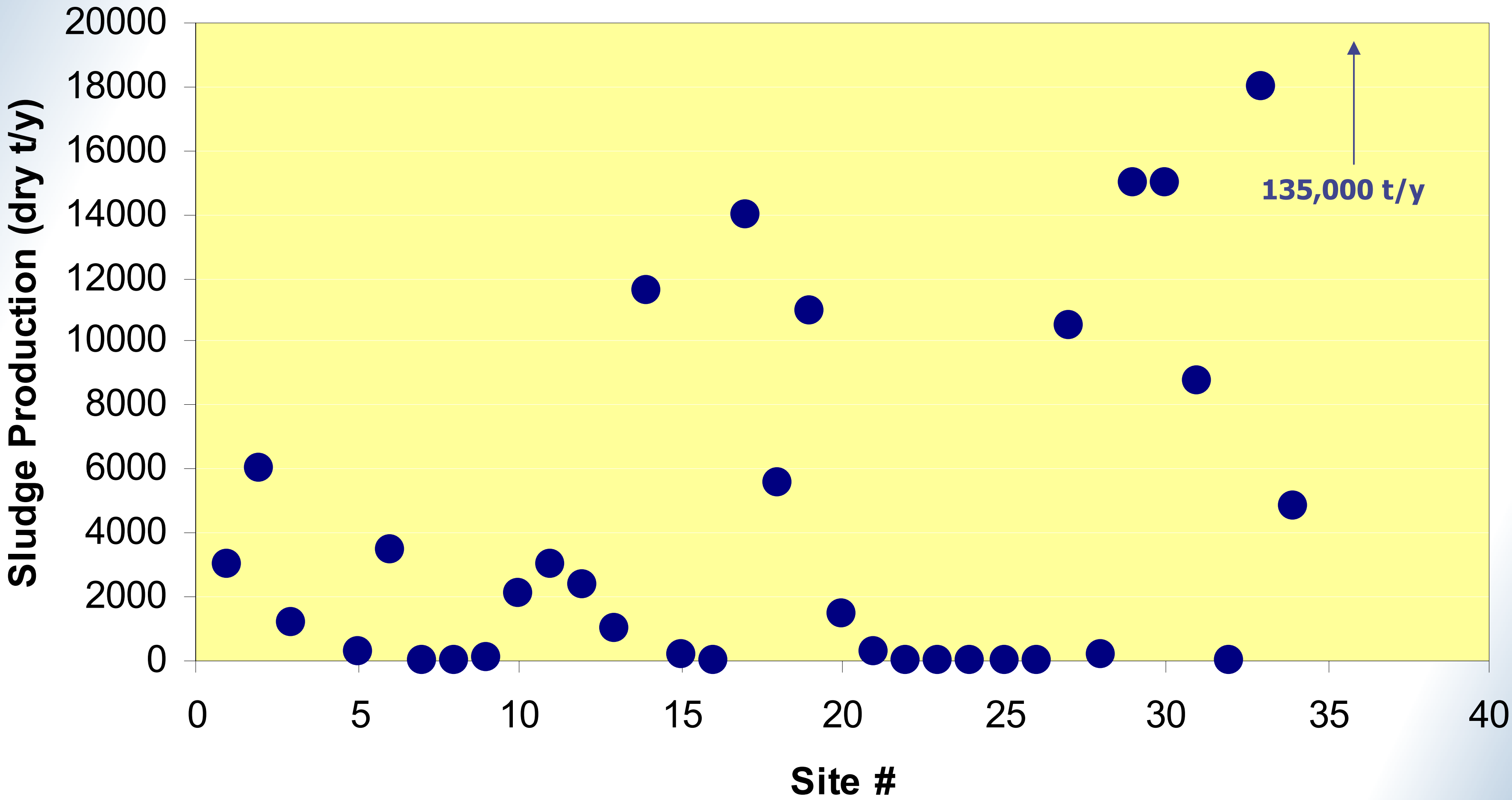


Sludge Management Issues

- Volume
- Low percent solids
- Physical properties
- Long-term stability
  - Amorphous
  - Metal speciation
  - Gypsum/calcite
- Generated in perpetuity?

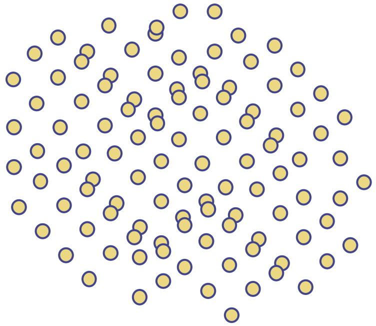
Physio-Chemical characteristics		
Parameter	Range	Average
pH	8.2 - 10.8	9.5
Eh (mv)	58 - 315	236
Particle size, D50 (µm)	2.89 - 42.5	11.2
Solids (%) - fresh	1.5 - 35	3.4 LDS)
		24.1 (HDS)
Chemical Composition		
Assay	Range	Average
Al (%)	0.1 - 11.2	2.7
Ca (%)	1.8 - 26.6	9.3
Cd (%)	<0.0001 - 0.13	0.015
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)		

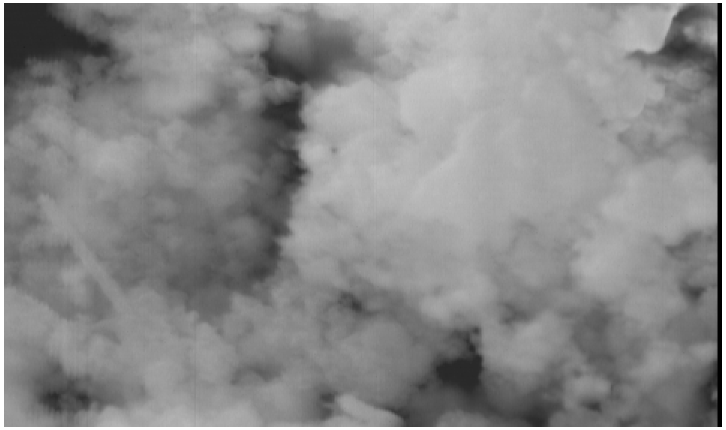
Annual Sludge Production (dry)



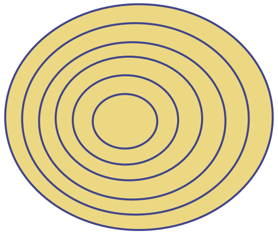
Sludge Densification

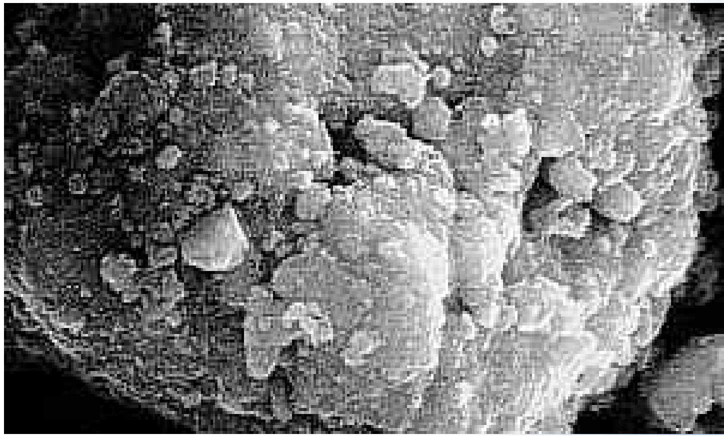
Particle Nucleation





Particle Growth



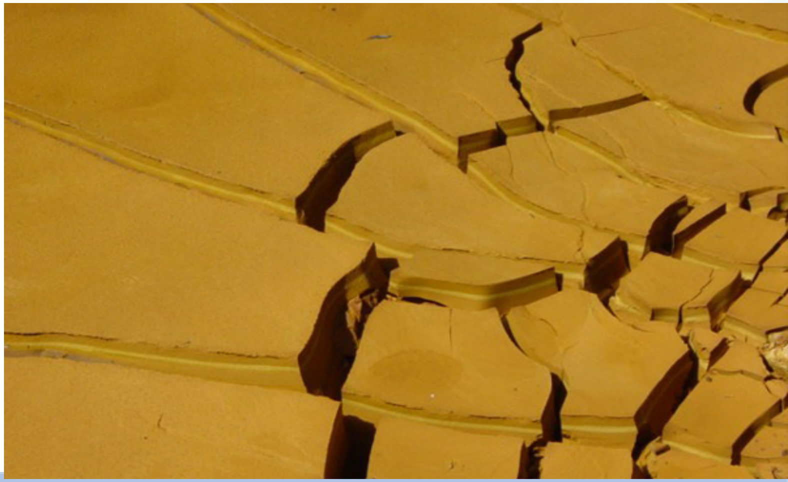


Sludge Density

- Densification affected by:
  - Raw water composition
    - Fe↑, SO_4↓,
    - Al, Zn, Mn, Ni do not densify easily
    - Low TDS (< 100 mg/L) →LDS
  - Neutralization/treatment process
    - Rapid, uncontrolled neutralization →LDS
    - Seeding
      - Enhances particle growth

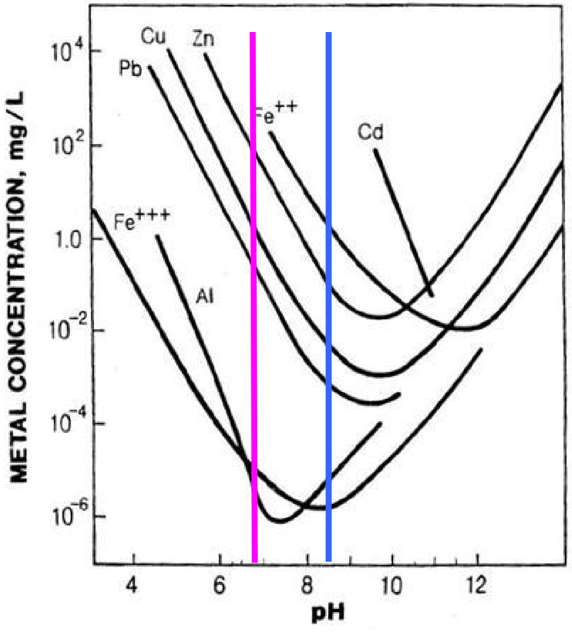
Factors Affecting Sludge Stability

- Leachant pH
- Precipitate crystallinity and composition
- Raw water composition
- Excess alkalinity
- Treatment process
- Sludge aging

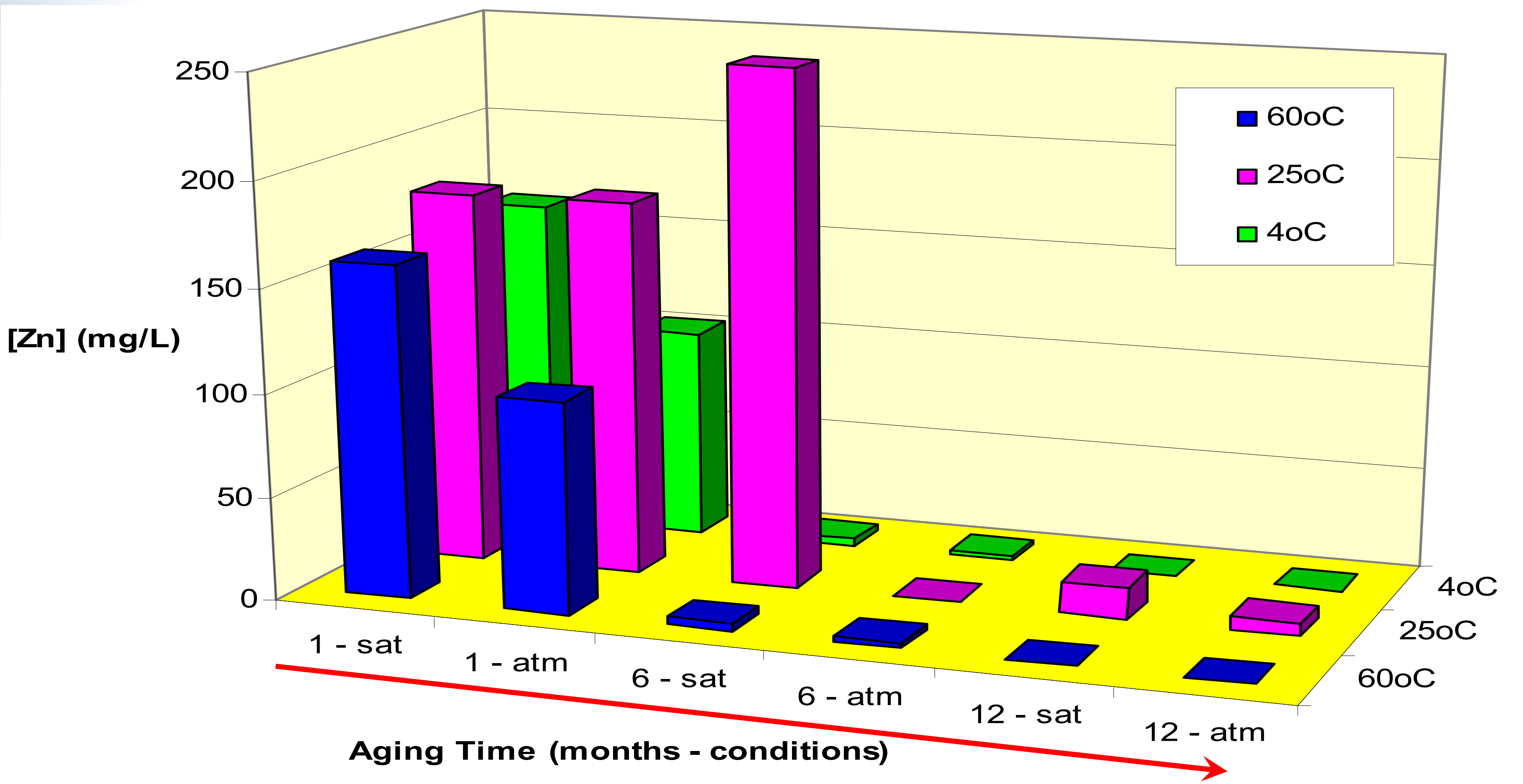


Example - Leachant pH/Excess Alkalinity

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



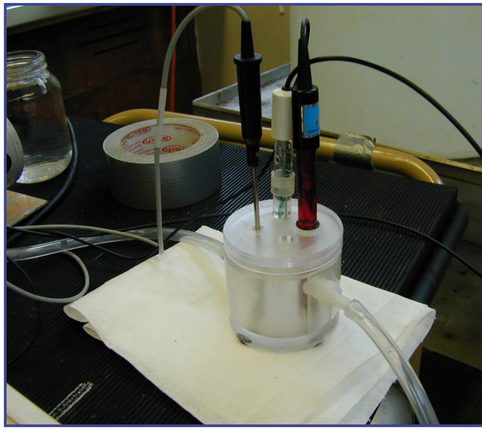
Example - Sludge Aging



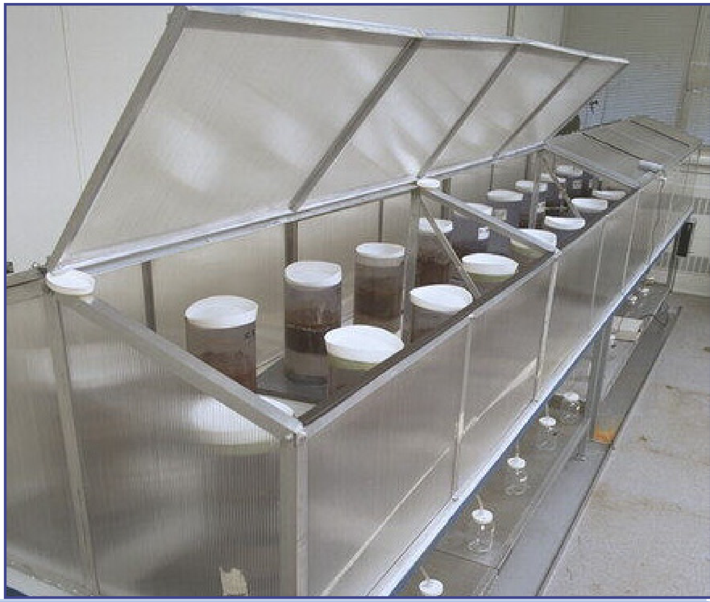
Sludge Stability – Batch Tests

- TCLP or similar acetic acid based leach tests
- Leachate concentrations are generally 5x lower than regulated limits
- Sludge consistently pass the leaching tests with synthetic acid rain
- Zn, Cd, and Ni most mobile

Column Leaching Tests



- More realistic
  - Better simulate natural leaching processes
- 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
- Challenges with column testing



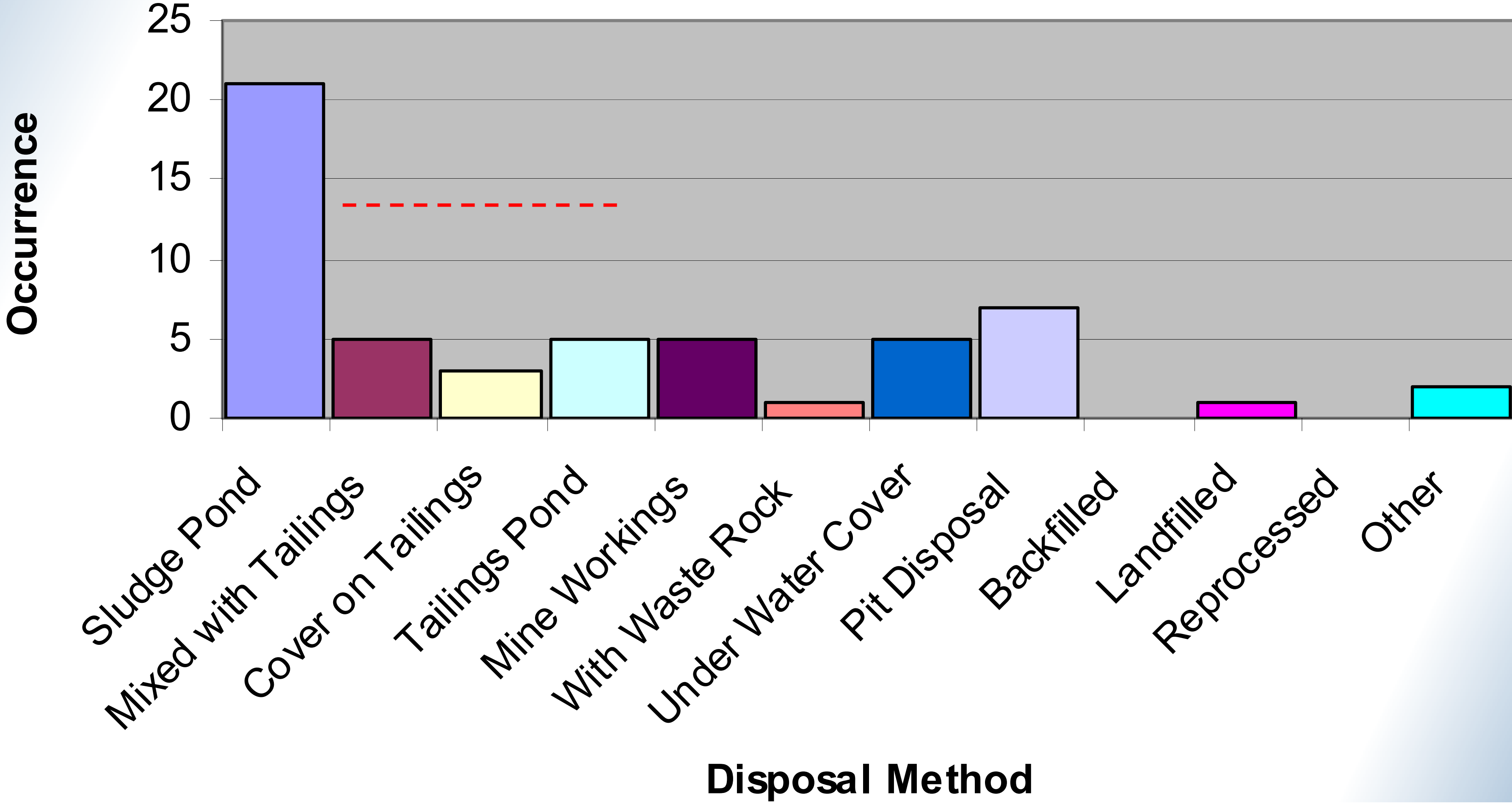
Leachate Regulatory Limits

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

Sludge Disposal Considerations

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

Sludge Disposal

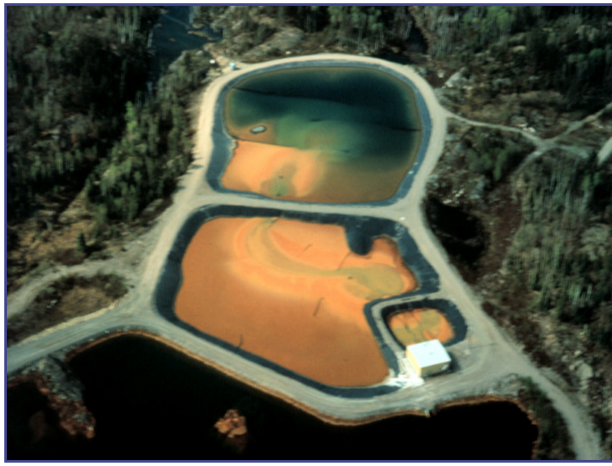


Dewatering and Relocation

- Various dewatering methods
  - Clarifiers, filter press, centrifugation, ponds, etc.
- Once dewatered sludge frequently relocated
- Trucked to waste disposal site
- Filter press, then trucked off site
- Excavate dewatered sludge and haul to sludge storage
- Pumping
  - Floating pump
  - Sludge difficult to pump
- Dredging

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
  - Decreased metal mobility

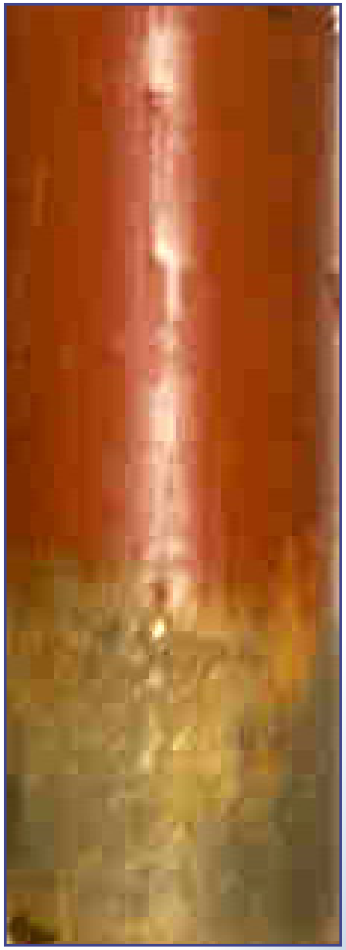


Co-disposal with Other Wastes

- Eliminates additional waste management facility
- Source of excess alkalinity
  - Fill interparticular voids and reduce oxygen and water penetration
  - Only reduce the metal mobility in the short term
  - Dissolution/depletion of sludge will occur in long term
- Sludge could become unstable if in contact with higher levels of acidity

Sludge Cover Over Tailings

- Sludge permeability
  - Low permeability maybe an effective barrier
  - Wet/dry cycles cause cracking allowing water and oxygen to reach the tailings
- Lab studies found sludge layer disposal not effective to stop or to significantly slow oxidation
- Field studies needed
  - Fresh tailings + water cover

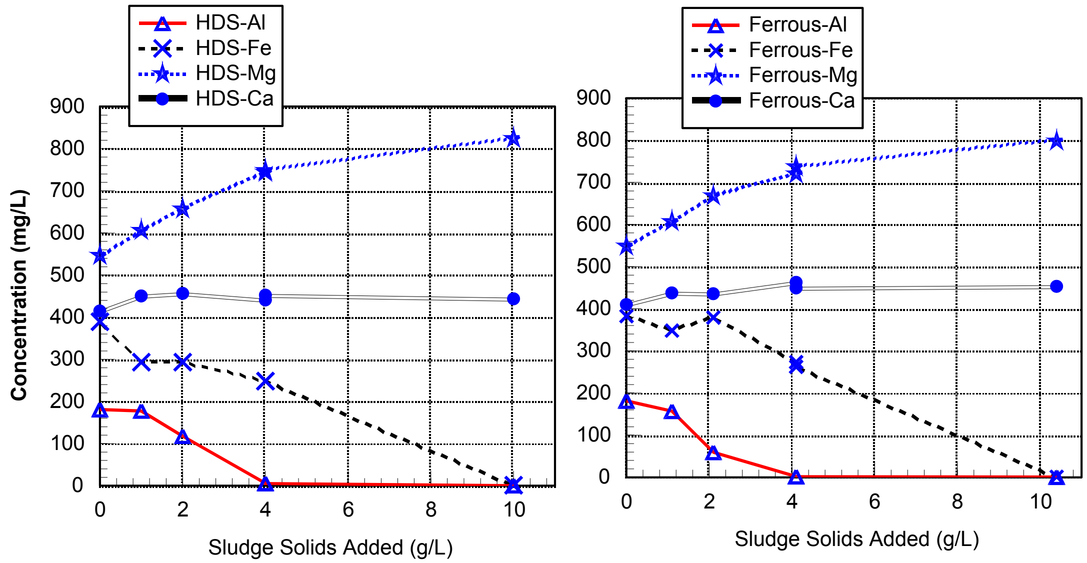


Sludge-Waste Rock Co-disposal

- Fill void spaces in waste rock (NB Coal)
  - Not effective as a seal or cap
- Low cost
- Does not prevent acid generation
- Impacts
  - Raw water pH ↑,
  - Metal concentrations↓
  - Lime consumption ↓
    - 75% reduction
  - No additional costs associated with building new ponds

Disposal in Mine Workings

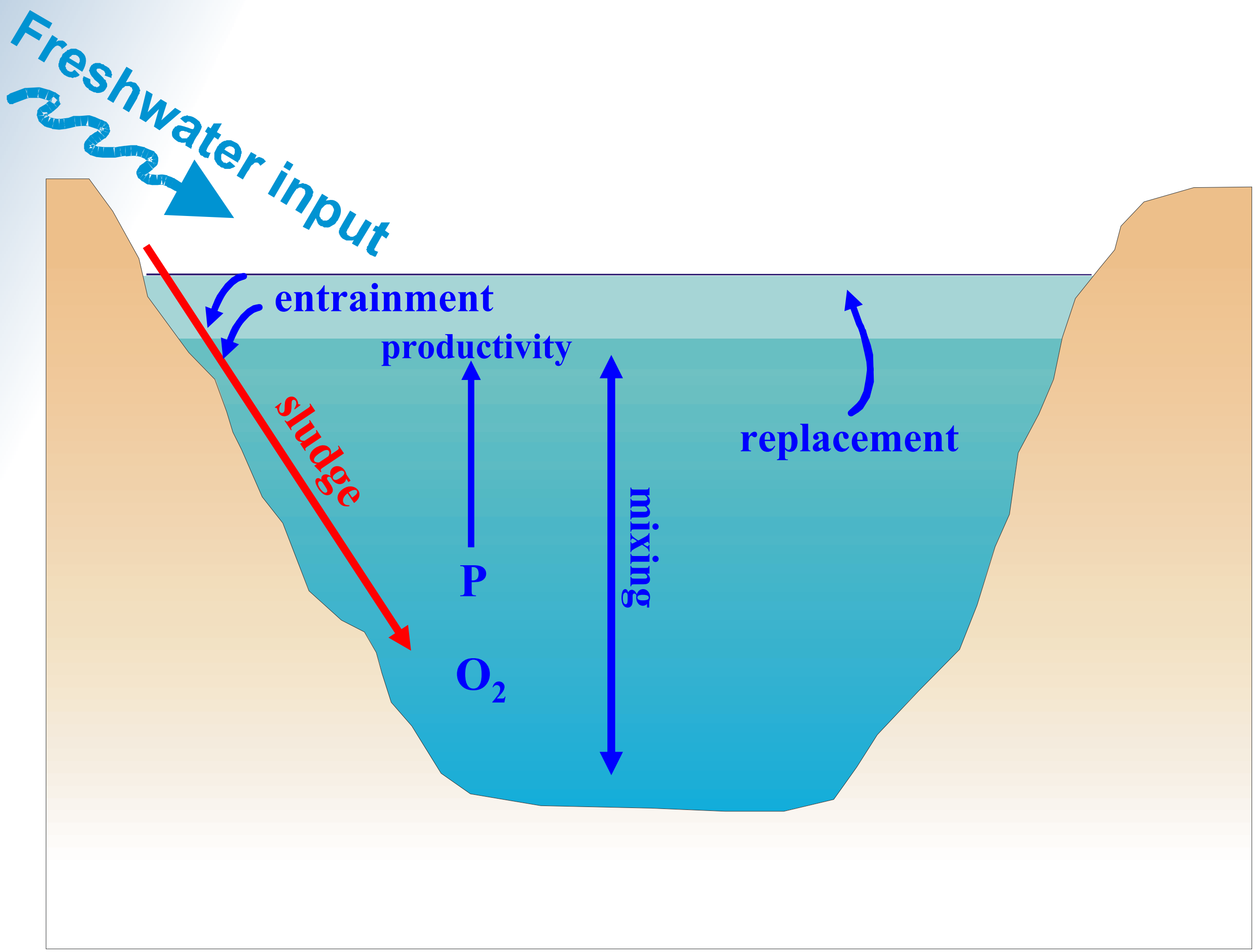
- Sludge pumped/trucked to boreholes drilled into U/G inactive mines
- Sludge alkalinity provides some neutralization of acidic mine water
- Ferric hydroxide does not dissolve, accumulates in workings



Disposal in Mine Workings

- Considerations
  - Site availability and access
  - Mine capacity, void space, configuration
  - Sludge properties – viscosity
- Advantages
  - Sludge may assist neutralization of mine water
  - Low surface land consumption/reclamation
- Risks
  - Flow patterns change
    - Blockages
  - Increased mine water flow

Disposal in Pit Lakes

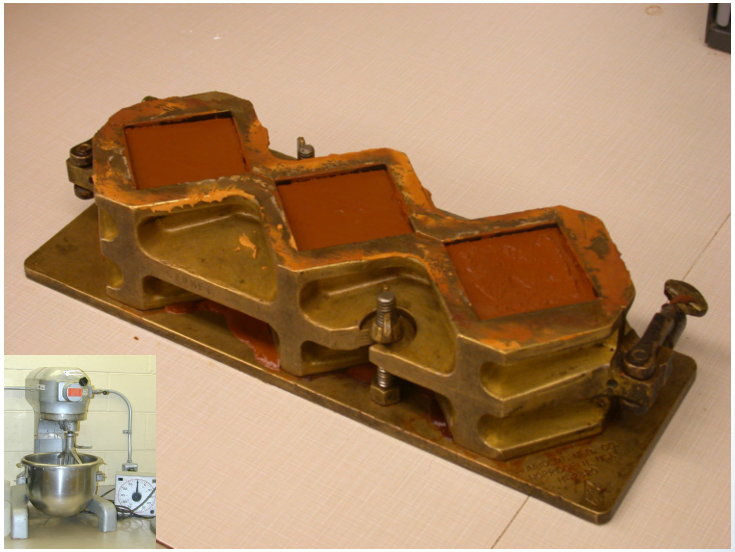


1. Suspended Solids
2. Productivity
3. Dissolved Oxygen
4. Entrainment
5. Whole-lake mixing

J. McNee, 2004

Sludge in Backfill

- Integration of sludges and slag as a backfill material
  - Reduce the amount of waste to dispose on surface
- Cementitious stabilization of slag, tailings and sludge
- Chemical and physical stability are key
- Less than 5% sludge in mix
- Primarily for active sites



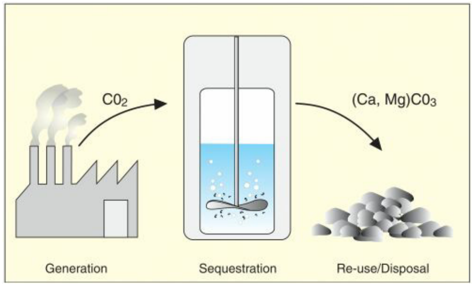
Landfill

- Solid or hazardous waste
- Solid-liquid separation issues
- Requires dewatering a/o drying before transport
- Stabilization may be required
- Public concern over sludge transport to off site landfill
- Estimated costs (2000)
  - $50-90 US/t
  - $120 US/t (with stabilization)
  - $160 US/t (hazardous waste landfill)

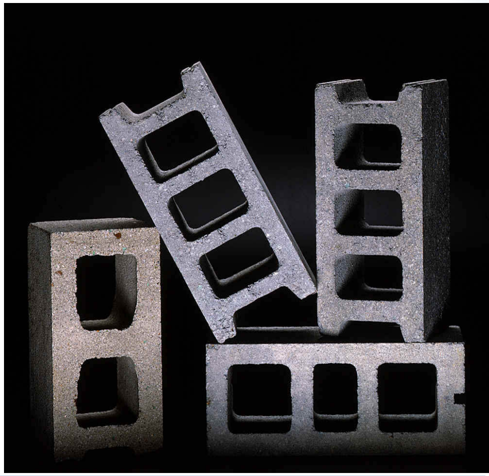
Reprocessing of Sludges

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

Sludge Reuse Options



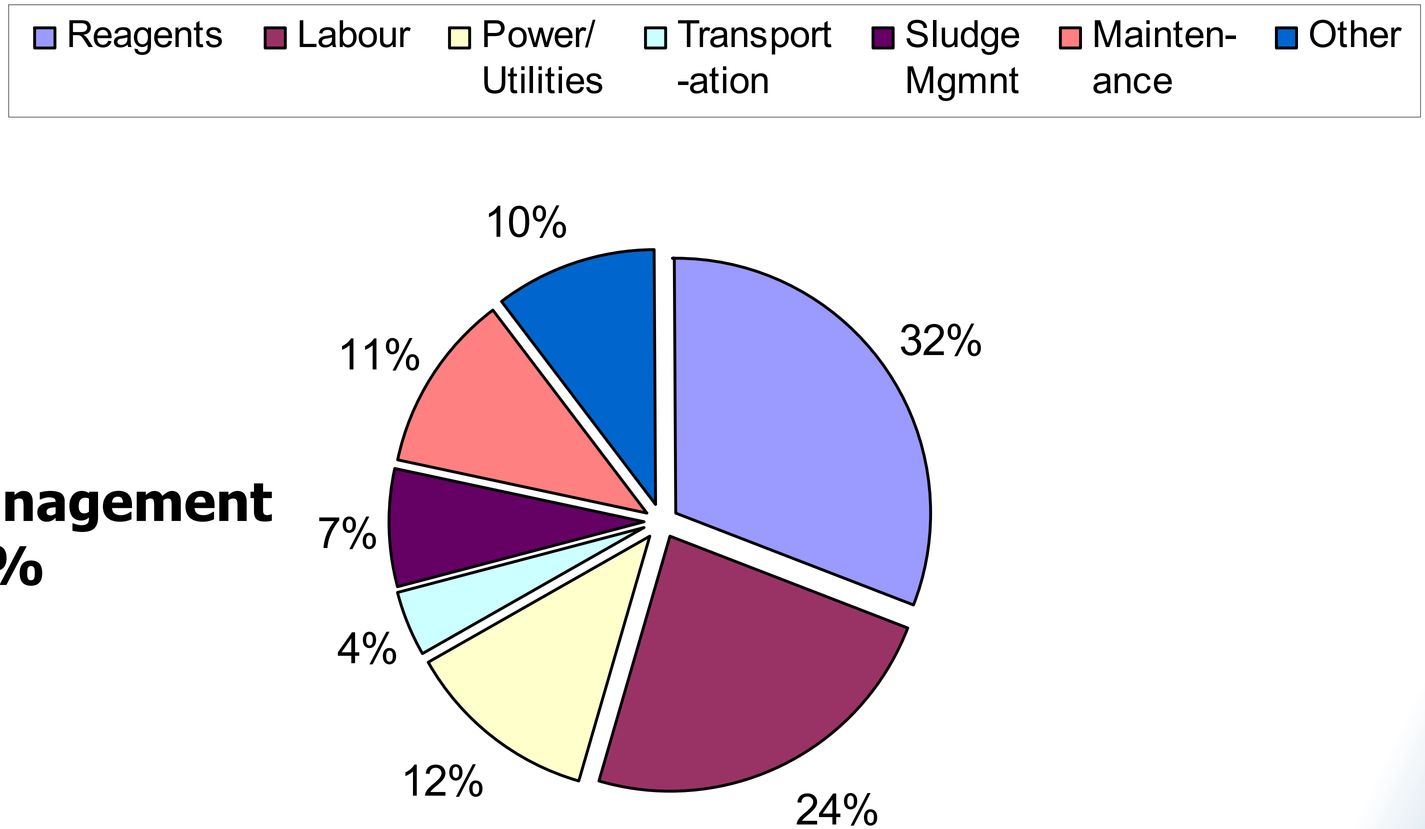
- Sludge as brick material
  - Sludge proportion and firing temperature key to compressive strength
- Replacement in cement manufacturing
  - Calcite/gypsum/free lime content
- Gravel from sludge
  - Road construction
- Metal adsorbent
  - Industrial wastewater treatment
- Pigment (ferrihydrite)



Sludge Revegetation

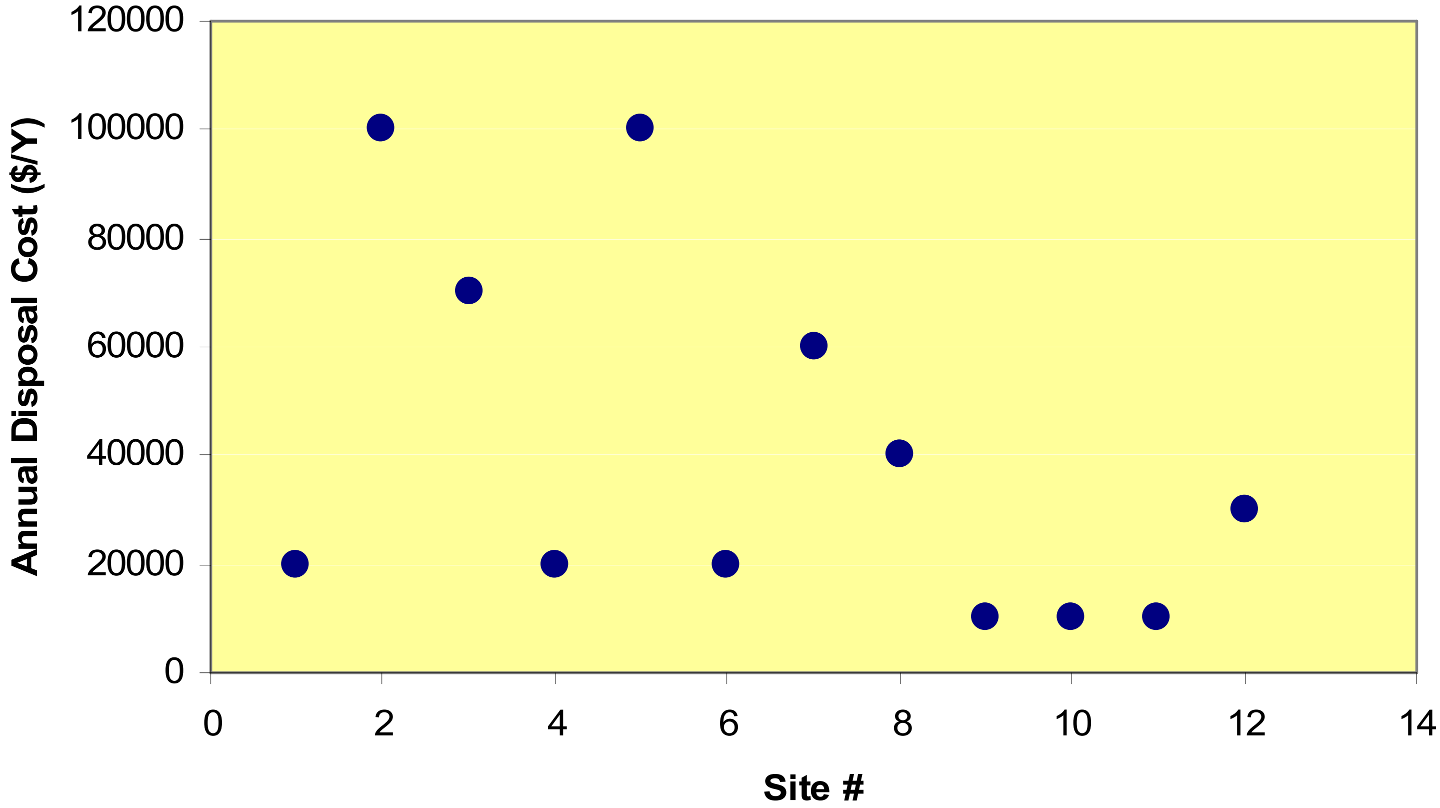
- Provide ground cover to limit wind and water erosion, dusting
- Overcome nutrient deficiencies, fertilizer consumption
- Degree and impact of metal uptake
- Alkaline tolerate plant species

Treatment Costs by Category



Sludge management 7%

Sludge Disposal Costs



Sludge Management Concerns

- Sludge desiccation and dusting
  - Inability to drive machinery on the sludge for dust control
- Sites running out of room to dispose the sludge
  - Disposal off site in the future is inevitable
- Difficulty in dredging sludge ponds/lagoons
- High disposal costs
- Maintenance of status of “non” special waste
- “Find a use for the sludge so that the metals do not have to go into a landfill”

Novel Practices

- Annual sludge removal increases the pH to 10-12
  - High pH water used to treat fresh run-off
- Covering old sludge ponds
  - With or without liner
  - Till and topsoil added
  - Re-vegetated
- Sludge bags
  - Simple dewatering option

Photos courtesy of EnvirAubé

Summary of Key Points

- Sludge management is a significant part any treatment practice
- Sludge will continue to be generated as long as water is treated – in some cases 'in perpetuity'
- Sludge characterization is key to an effective disposal strategy
- Many conventional options available – site specific
- Alternative approaches to sludge management should be considered
  - Sludge reuse and reprocessing

Green Mines – Green Energy
Biosolids to Bioenergy

- CANMET led consortium to examine use of “waste” organic materials to rehabilitate mine sites and establish energy crops (canola, corn, soy etc.) for the production of biofuels

Biosolids + Mine Tailings + Energy Crops = Green Fuel

GMGE Benefits

- Reclamation of mine tailings to a productive land use that represents a major contribution towards sustainable development and GHG reductions
- Beneficial management and reuse of bio-based wastes from municipal and industrial sectors
- Brownfield utilization for green energy production
- Potential for on-going cash flow to subsidize monitoring/ treatment costs
- Use of one industry's waste to remediate another and produce bio-energy

Current Participants

Mining: Vale Inco , Xstrata Nickel, Goldcorp (PGM), BHP-Billiton, Highland Valley Copper, Barrick Gold, Cape Breton Development Corp.

Forestry: Domtar, St. Marys Paper, Abitibi Consolidated, Paprican

Government: Natural Resources Canada, Agriculture Canada, Ont. Ministry of Food & Rural Affairs, Ont. Ministry of Environment (observers)

Academia/Other: Laurentian University/MIRARCO, Alberta Research Council, GSI Environment, City of Greater Sudbury (associate)

Metals in Soils Initiative

- Metal contamination of soil can be a problem in and around many mining sites
- Extent and type of contamination not well understood
- Regulatory initiatives are moving ahead in spite inadequate scientific knowledge ,
- Risk regarding regulatory outcomes overly conservative



Metals in Soils Initiative

- A coordinated and focussed research initiative
  - Targeted research
  - Respond to regulatory gaps
    - reduce and/or eliminate uncertainties
  - International in scale
  - Integrated with existing research projects/programs to maximize value


Thank You
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