

GARD GUIDE

Treatment Overview
Chapter 7

Janice Zinck
CANMET-MMSL, Natural Resources Canada

17th Annual BC/MEND Metal Leaching / Acid Rock Drainage Workshop
Vancouver, Dec 1-2, 2010

INAP

Chapter Outline

- Mine drainage treatment - objectives and approach
- Mine drainage collection
- Selection of appropriate treatment technology
- Treatment technologies
  - Active treatment
  - Passive treatment
  - In situ treatment
- Treatment residues and waste
- Recovery of useful by-products
- Drainage treatment during mine closure and post closure

Treatment Objectives

- Recover and re-use mine water
- Protect human health
- Environmental protection
- Recover valuable by-products
- Meet regulatory requirements
- Return recovered water to beneficial use
- Assure sustainable operation of mine and community engagement

Source: Natural Resources Canada

Generic Mine Water Process

Mine Drainage
- Suspended material
- Dissolved solids
- Metal and anions
- Acidity

→ Treatment
- Chemical
- Biological
- Physical
- Hybrid

→ Compliant Discharge

Residue

Treatment Approach

- Identify Treatment Objectives
  - Water flow, quality, use and cost
- Consider temporal and seasonal changes
- Assess influent properties
  - Acidity, alkalinity, sulphate, salinity, metals, mine-specific compounds, microbiological quality
- Assess commodity-specific impacts
- Consider changes of mining phases
- Utilize mine features to advantage
  - Layout/topography, space, climate, location of source and discharge users
- Consider handling and disposal of treatment waste

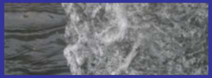
Mine Drainage Collection and Management

- Treatment systems design is based primarily on flow rate
  - Better flow control better treatment performance
- Consider mine drainage properties
  - Corrosivity, scaling, silting, precipitation and fouling
- Variable mine flows (seasonal, other)
- Sizing collection ponds and ditches
- Topographic considerations
- Materials of construction
- Engineering features
- Maintenance requirements

Source: Natural Resources Canada

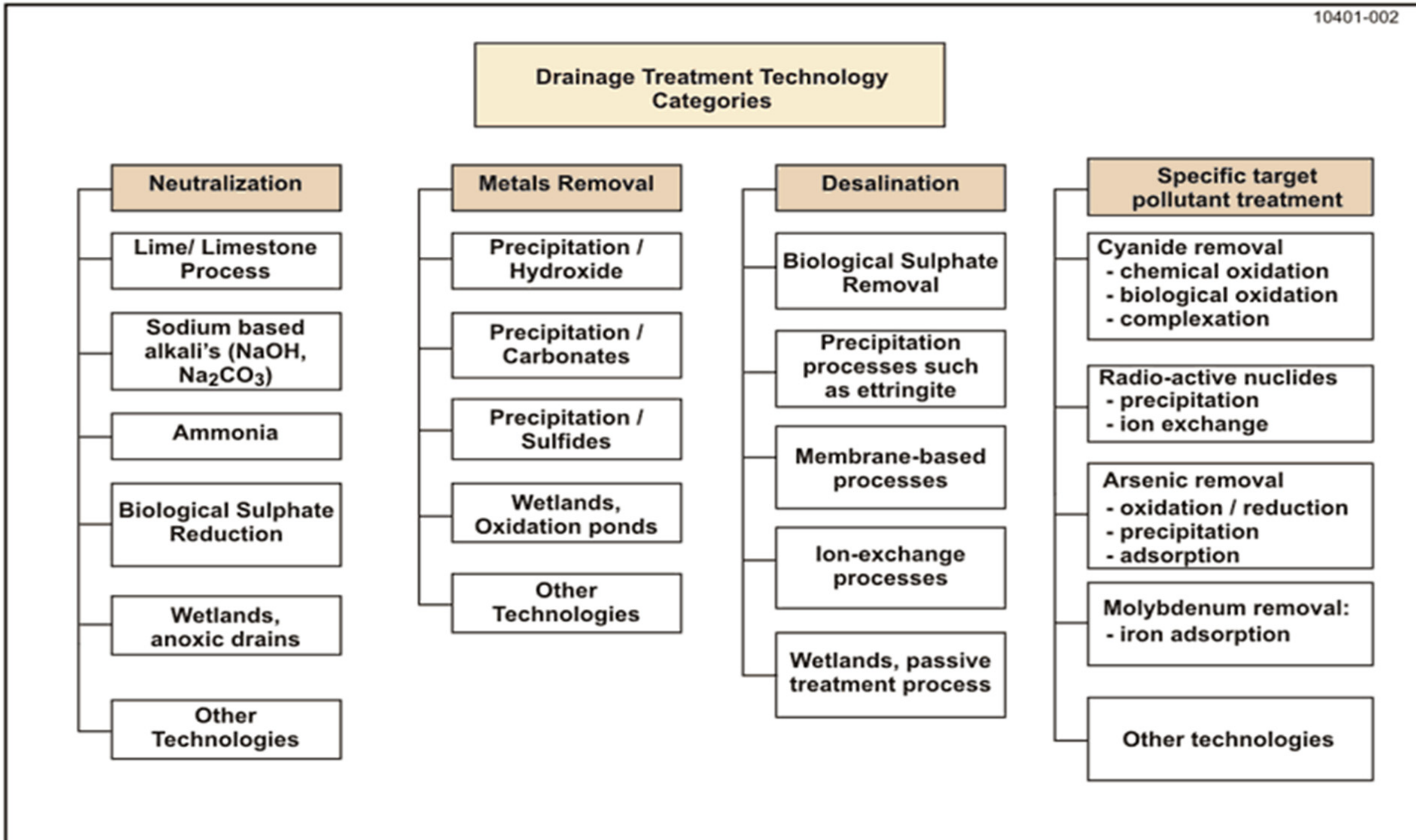
Selection of Treatment Technologies





- Technical Factors
  - Scale, location, raw water composition, mine phase, discharge requirements, performance reliability, implementation risks
- Operational Factors
  - Labour, process control, utilities, consumables, maintenance, logistics and communications
- Environmental Factors
  - Impacts of treated water, climatic conditions, waste disposal, land-use requirements, regulatory approvals
- Financial Factors
  - Capital, replacement costs, O&M costs
- Management Factors
  - Negotiations, decision, funding, company's credibility
- Social Factors
  - Community acceptance and involvement

Treatment Technologies



Comparison of Treatment Types

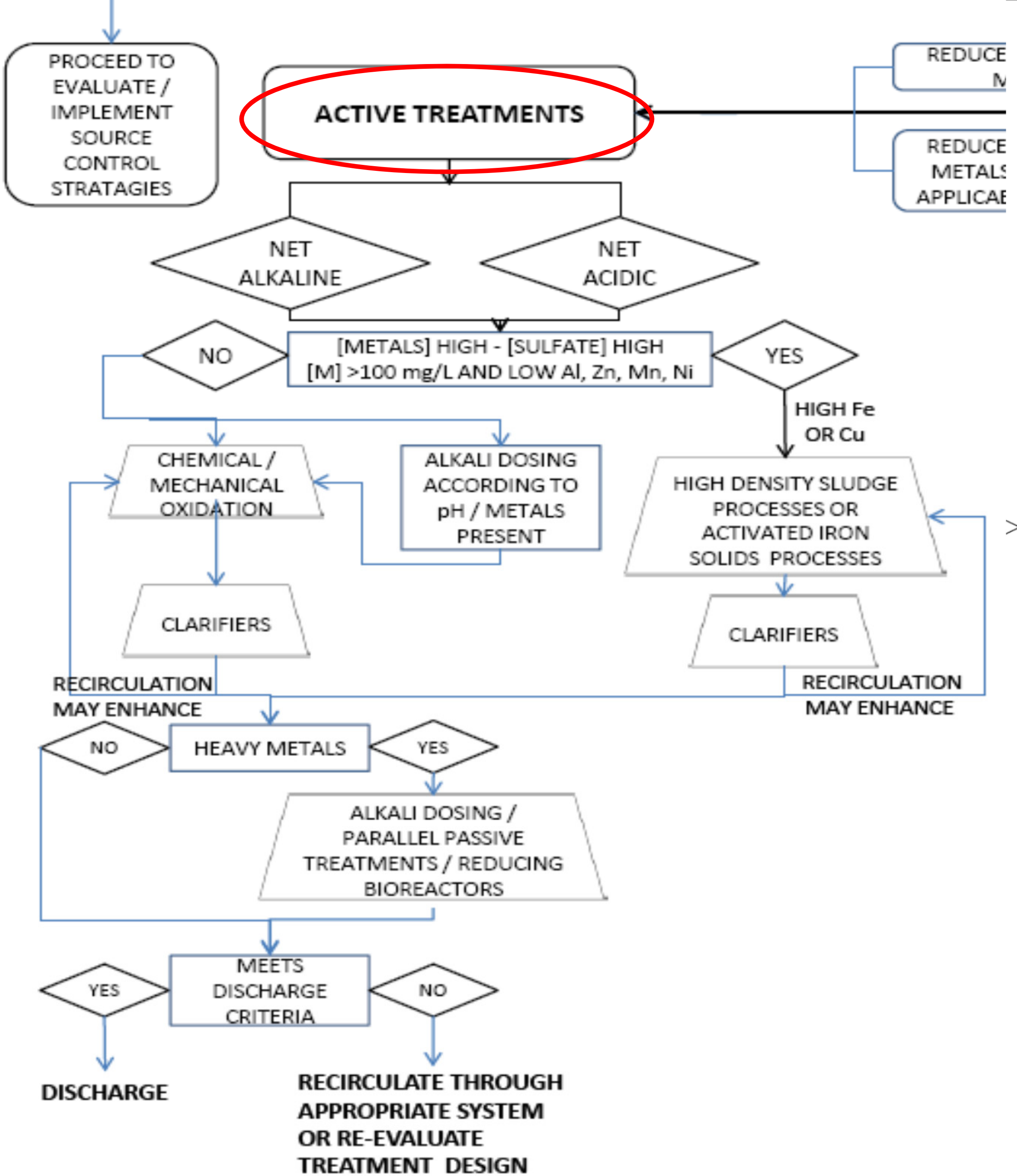
Treatment Types

- Active
  - technologies requiring ongoing human operations; maintenance, and monitoring based on external sources of energy and engineered systems
- Passive
  - processes that do not require regular human intervention, operations, or maintenance
- In Situ

Compared Features

- Mining phase
- Man power
- Operational inputs
- Power
- Management
- Flexibility
- Water Quality
- Waste & Brine
- Capital Costs
- Operating Costs

Acidic Drainage Treatment Decision Tree



08

INAP

Active Treatment Technologies

- Aeration
- Neutralization
- Metal precipitation
- Metals removal
- Chemical precipitation
- Membrane processes
- Ion exchange
- Biological sulphur/sulphate reduction

Neutralization/Hydrolysis

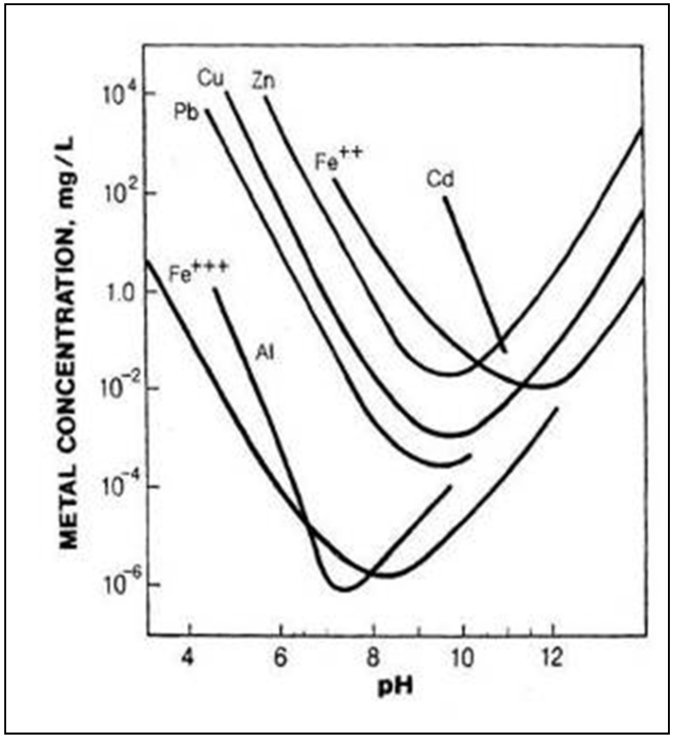
Acidic drainage: dissolved M + H_2SO_4

Lime treatment: $Ca(OH)_2$

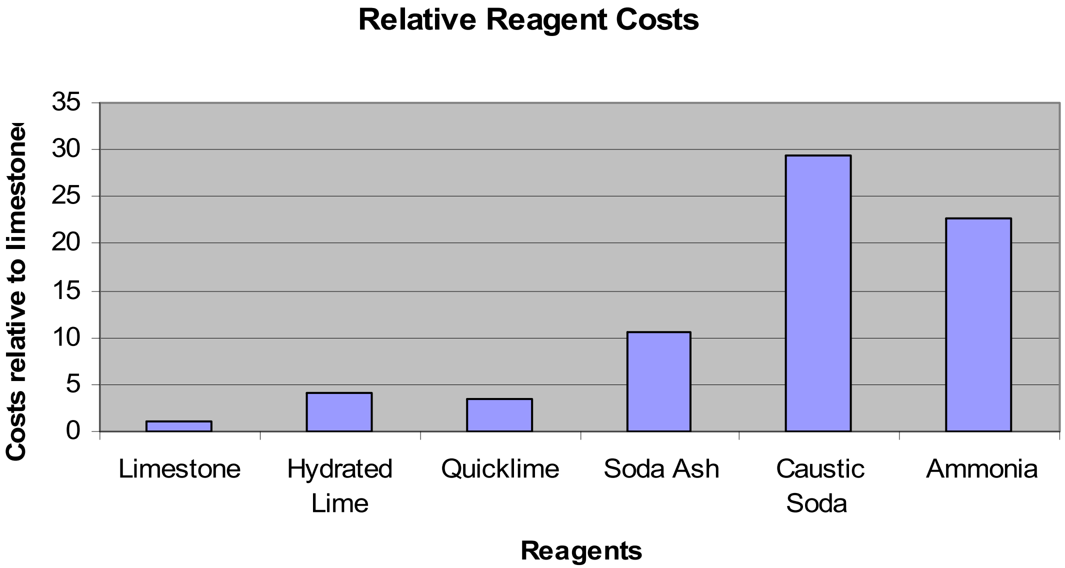
→ **$CaSO_4.2H_2O$**

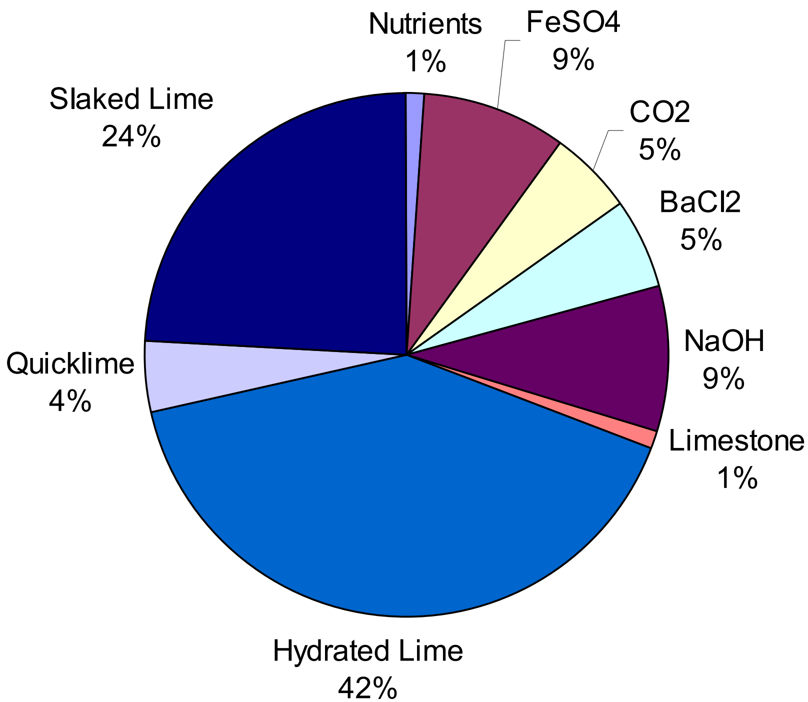
Metal precipitation:

→ **$Fe(OH)_3$**
$Zn(OH)_2$



Chemical Treatment - Reagent Use





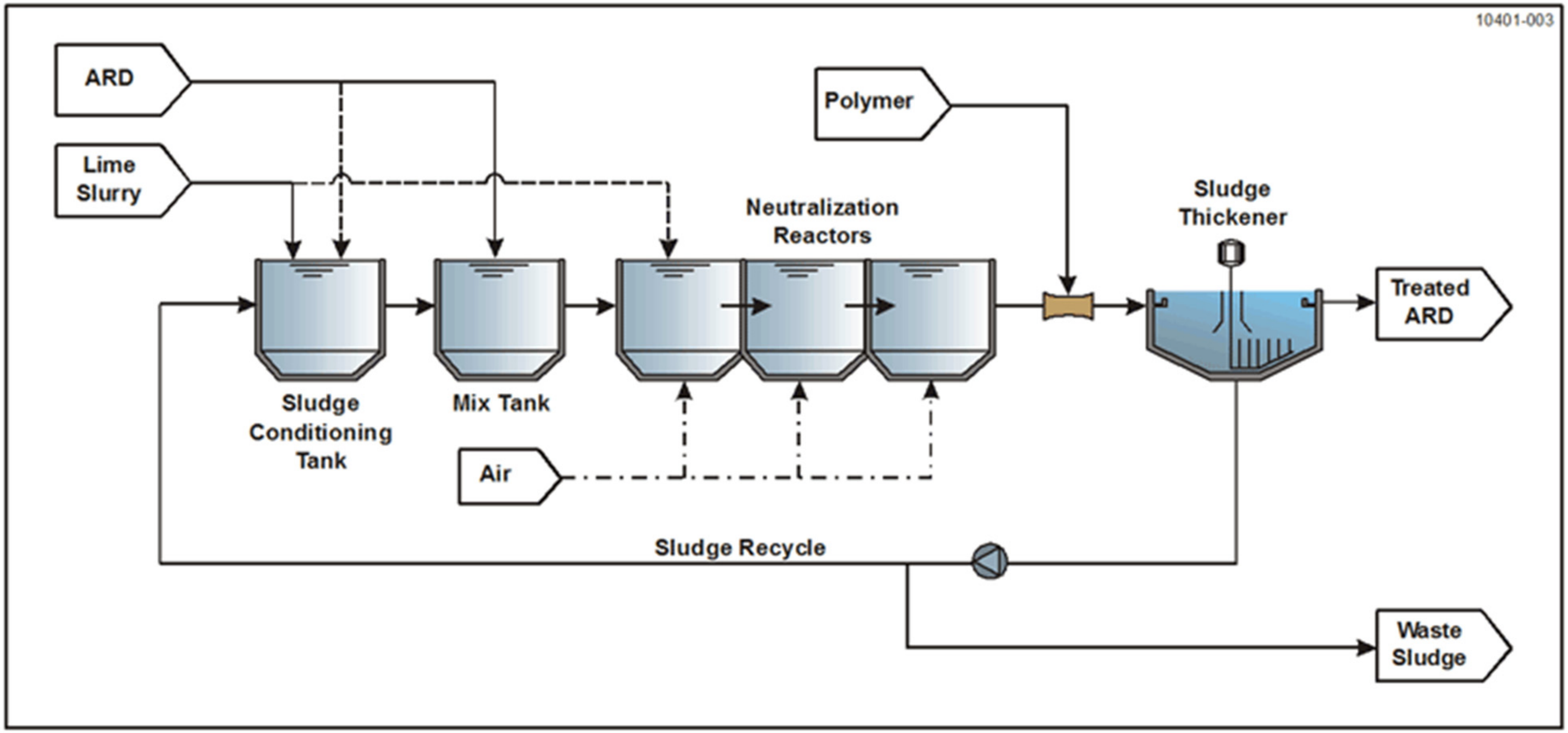
- Lime is the most common reagent used for chemical treatment
- Effective for metal removal and neutralization

Source: Zinck and Griffith 2009

Lime neutralization (HDS)

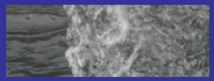
- High density sludge (HDS) process configuration is the industry standard treating high flow drainage
  - Relative low cost of lime
  - Efficient use of lime
  - High density of sludge requiring a smaller site for disposal
  - Scale control on treatment plant structures, pipelines, equipment, and instrumentation
  - Good solid/liquid separation
  - Robust process, able to treat variable flows, acidity and metal loadings

High Density Sludge Process



Comparison of HDS processes





- Benefits:
  - Relative low cost of lime
  - Efficient use of lime
  - High density of waste sludge requiring a smaller site for disposal
  - Scale control on treatment plant structures
  - Good solids/water separation
  - Robust process, able to treat variable flows and acidity/metals loadings

	Conventional HDS	Cominco Process	Geco Process	Tetra (Doyon) Process	Staged-neutralization
Efficient lime utilization	X	XX	XX	XX	XXX
Waste sludge density	X	XX	XX	XX	XXX
Sludge viscosity	XXX	XX	XX	XX	X
Sludge stability	XXX	XX	XX	XX	X
Treated water quality	XX	XX	XX	XX	XX

X	Good
XX	Better
XXX	Best

Equity Silver, BC, Canada

- Replaced LDS plant
- Complete site water management
- $10 M project
- 600 m^3/h water treatment plant – startup Dec 2004
- Pumping and placement of sludge in abandoned pit
- Designed for full automation and remote control

Source: Higgs

Equity Design Feed and Effluent

Parameters	Design Feed	Permit Limits
	(mg/L)	
pH	2.4	6.5 to 9.5
Acidity	13,500	
Al	650	0.5
Cu	280	0.05
Fe	2000	0.3
Zn	350	0.2
SO4	12,500	
Cd	1.2	0.01
As	2.5	0.05

Source: Higgs

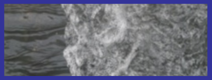
Performance Data

ARD Treatment Statistics	2008	2007
Lime (tonnes)	4,014	7,290
ARD treated (m3)	793,459	1,629,420
Average ARD Acidity (mg/L)	9,004	8,404
Treatment sludge produced (m3)	99,240	125,930
Water discharged (m3)	1,476,793	3,836,848

Source: Goldcorp

Active Biological Processes





- Pacques process (SULFATEQ™)– sulphide generated by bacterial reduction of sulphate in AMD to produce H_2S
- Bioteq process (BioSulphide®)– uses elemental sulphur to produce sulphide
- The main advantages of using the biological H_2S generation include:
    - Low cost of sulphide compared to the cost of Na_2S, NaHS, or H_2S
    - Minimal hazards and increased safety mainly due to the low system pressure and low inventory of H_2S
    - Easy to scale-up and down over a wide range of H_2S production capacities

Bisbee copper recovery project

- BioteQ and Phelps Dodge have a Joint Venture to use the process to recover copper at Bisbee, Arizona
- Fully commissioned BioSulphide® plant recovering Cu from dump drainage. Concentrate (50% Cu) to Miami smelter for profitable water treatment. Design capacity 3.6 tonnes Cu/day
- The plant is in operation and ramping up production. Currently recovering more than 4000 lb Cu per day

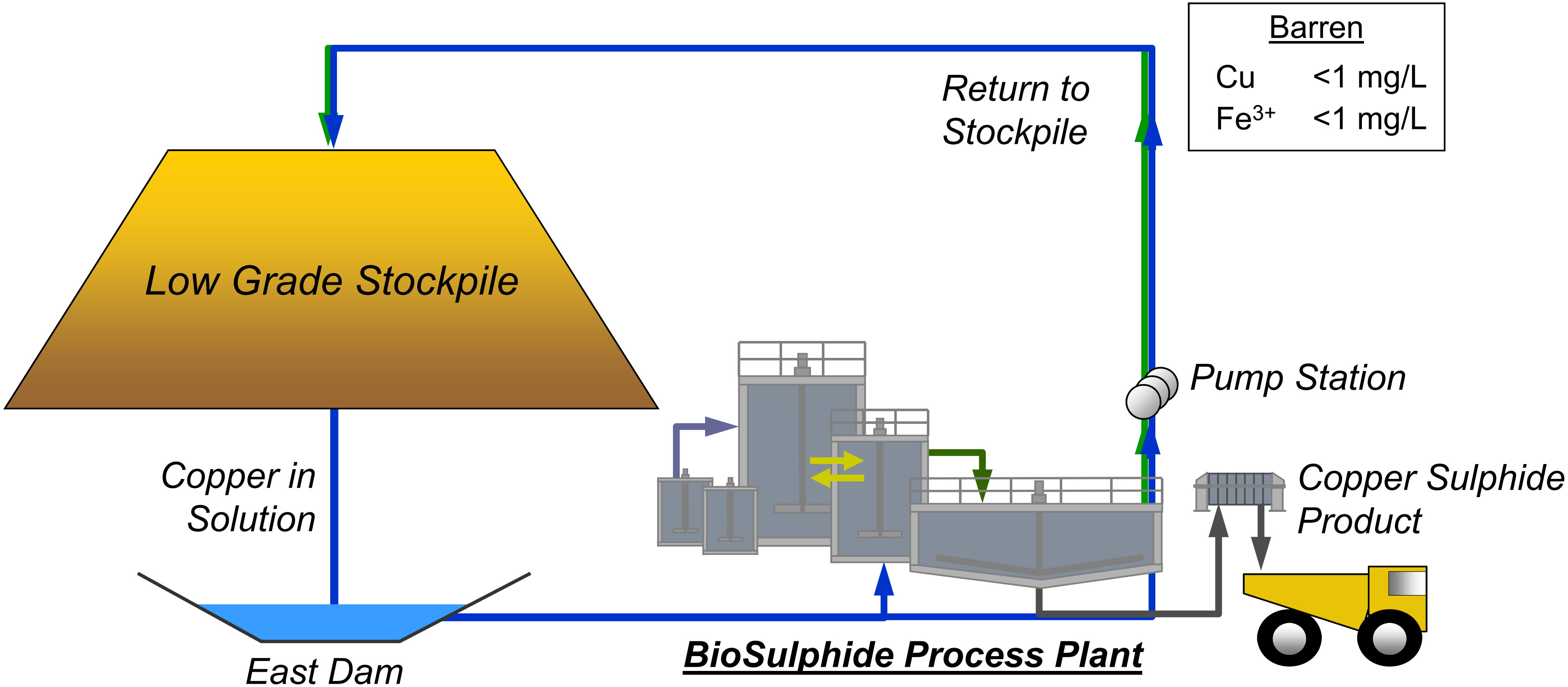
Source: BioteQ

Bisbee - No. 7 stockpile

Source: BioteQ

INAP

Copreco - Bisbee Project



PLS	
10,900 m^3/day	
Cu	350 mg/L
Fe^{3+}	550 mg/L

Source: BioteQ

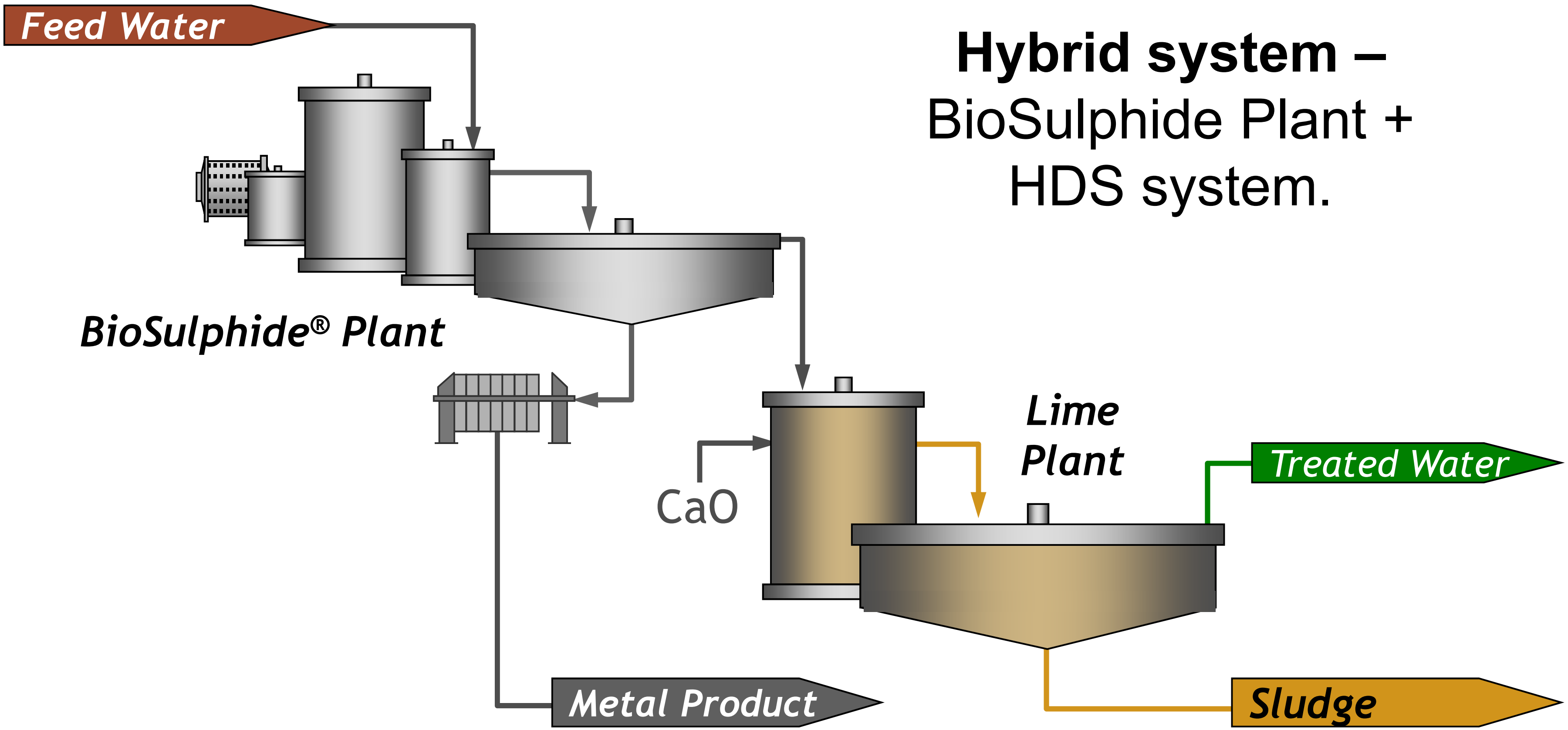
INAP

BioteQ Plant at Bisbee, AZ

Source: BioteQ

Hybrid system

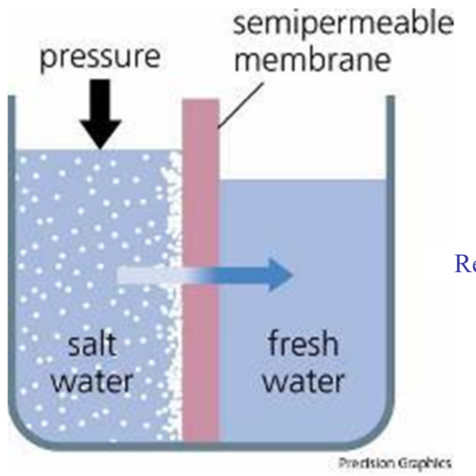
Hybrid system –
BioSulphide Plant +
HDS system.



Lawrence, 2008

Membrane Separation

- Pressure driven membrane separation process types:
  - Reverse Osmosis (RO)
  - Nanofiltration (NF)
  - Ultrafiltration (UF)
  - Microfiltration (MF)
- Other:
  - Electrodialysis
- Retentate (concentrate) – concentrated retained liquid
- Permeate (treated water)- the liquid passing through the filters



Reverse Osmosis

Case History - Membrane

- Kennecott Utah Copper's Bingham Canyon Mine to treat acidic drainage and contaminated groundwater
- The leach water and the acidic groundwater were pre-filtered, anti-scalant agent added and directly pumped to the NF membrane step
- Water from the sulphate plume was directly treated with an RO system and the permeate discharged with the NF wash water and permeate
- Main issue was scale deposition in the lines and membrane modules
  - Resolved with addition of anti-scaling agent

Source: H. Bayer

Case History - Membrane

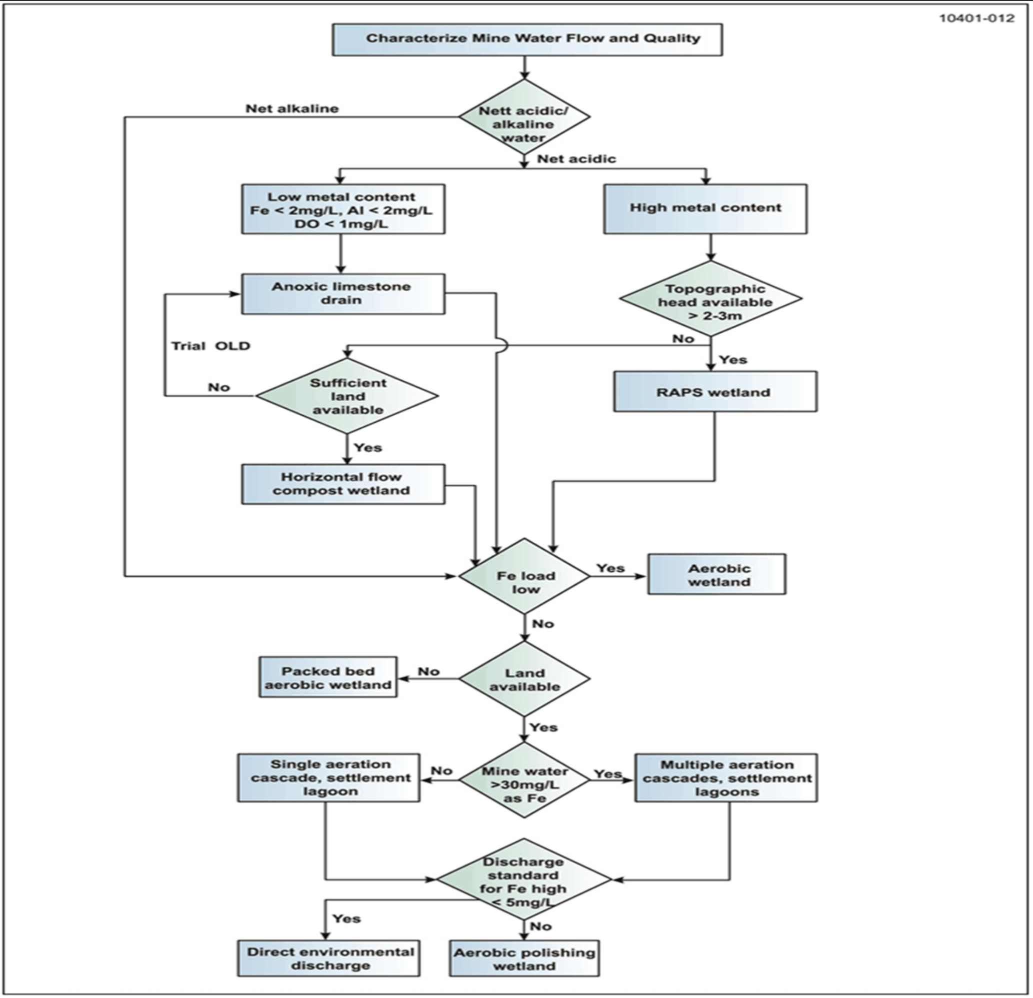
Parameter	Feed (ppm)	Permeate (ppm)	Concentrate (ppm)	R (%) Solute Retention
Al	5,959	119	8,780	98.0
Ca	488	12	726	97.5
Cu	153	2	250	98.7
Fe	420	11	640	97.4
Mg	9,910	229	14,750	97.7
Mn	472	12	720	97.5
Zn	228	6	350	97.4
SO_4	73,796	1,690	109,940	97.7
TDS	92,000	2,095	137,500	97.7
pH	2.9	2.5	3.0	-

Source: H. Bayer, S. Mortazavi

Passive Treatment Technologies

Passive Treatment Technology	Application Niche in Mine Drainage
Aerobic wetlands	Net alkaline drainage
Anoxic limestone drains (ALD)	Net acidic, low Al, low Fe, low DO drainage
Anaerobic wetlands	Net acidic water with high metal content
Reducing & alkalinity producing systems (RAPS)	Net acidic water with high metal content
Open limestone drains (OLD)	Net acidic water with high metal content, low to moderate sulphate

Passive Treatment Selection



- Passive treatment systems mechanisms include:
  - Oxidation
  - Precipitation as hydroxides and carbonates under aerobic conditions
  - Precipitation as sulphides and hydroxy-sulphate (aluminum special case) under anaerobic conditions
  - Complexation and adsorption onto organic matter
  - Ion exchange with organic matter
  - Uptake by plants (phyto-remediation)

Case History – Passive Treatment

- Cape Breton Development Corp.
  - Neville Street, Sydney, Nova Scotia
- Passive treatment system installed to treat coal mine drainage
  - 315 L/s passive treatment system consisting of aeration cascades
  - 1.2 hectare settling pond (23,000 m^3 capacity)
  - 1.1 hectare reed bed wetland
- Designed for 50 hour retention time for the mine water based on an average flow of 126 L/s.
  - configuration of five floating pond curtains was installed to increase retention time by guiding the mine water leaving the cascades in a slow
- Treatment efficiency – Fe (in) – 8.39 mg/L, Fe (out) 0.67 mg/L

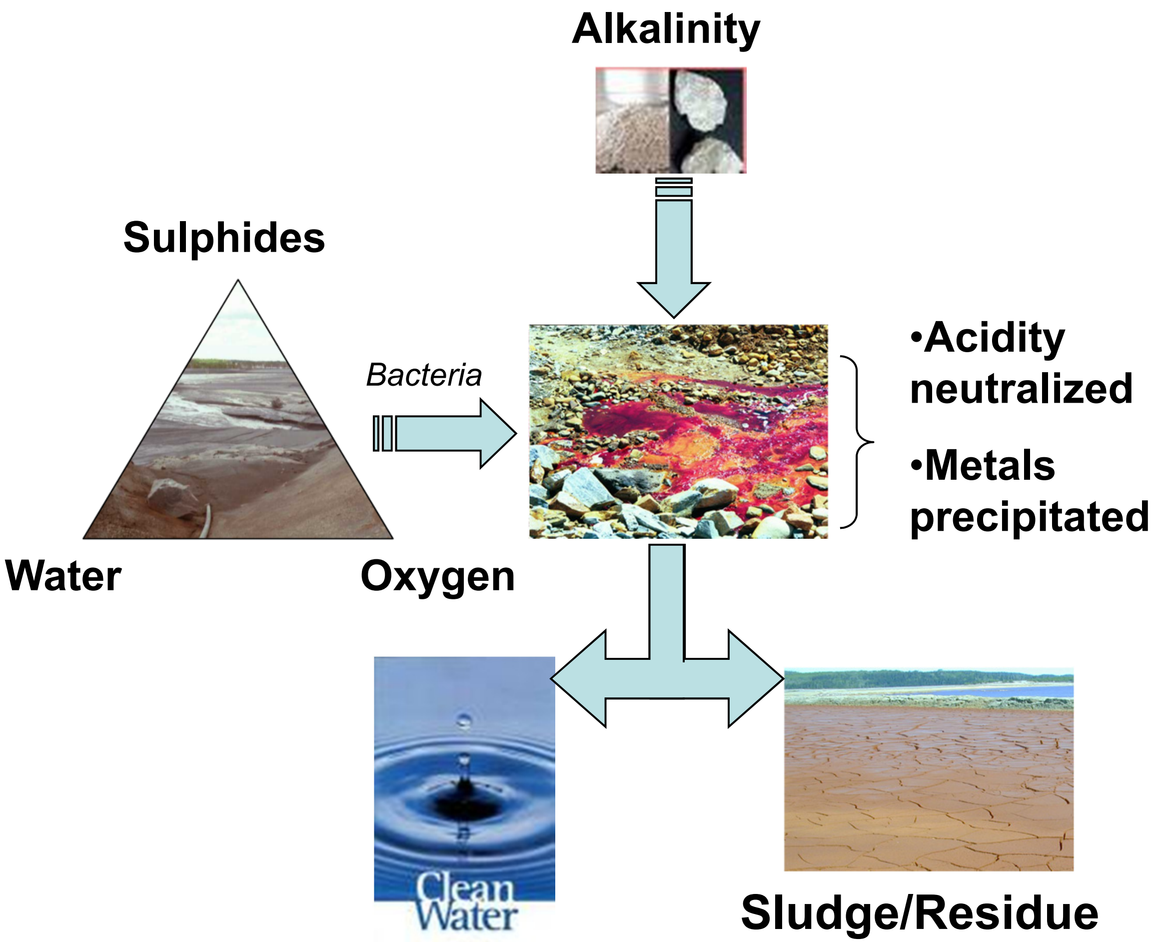
Source: J. Shea, 2010

In Situ Treatment Technologies

- Spreading of alkaline material across mining impacted land and mine waste
- In pit water (pit lake) treatment
- Organic covers of mine land and mining waste
- Permeable reactive barriers (i.e., organic-rich material, zero-valent iron)

Source: C. Pust, 2010

Residue and Sludge Management



Source: J. Zinck

Treatment of Residues & Sludges

- Consider volume and mass
- Characterize chemical composition and physical properties
- Characterize slurry density or moisture content
- Assess potential value and recovery of by-products
- Determine hazardous classification
- Assess potential environmental impacts
- Determine disposal options
- Assess economic options

Source: Zinck

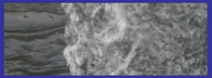
Recovery of Useful Products

- Metal recovery
- Land rehabilitation supplements
- Alkali recovery - $CaCO_3$
- Building materials
- Beneficial use of brine
- Recovery of salable products
- Agricultural products
- Water treatment chemicals
- Pigments - ferrihydrite

Source: Environoxide

Treatment During Closure and Post Closure



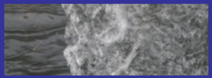


- Treatment is impacted by the following:
  - Changes in mine drainage flow and quality
  - Climate change over the long term
  - Long-term operations and maintenance
  - Reduction of resources and manpower
  - Capital replacement cost
  - Non-mining water user requirements
  - Involvement from non-mining stakeholders

Successful Drainage Treatment

- Often a successful drainage treatment program is less a factor of technical issues and solutions than it is of:
  - Environmental factors
  - Financial factors
  - Management factors
  - Social factors

Comments



MEND Secretariat

Gilles Tremblay

Gilles.Tremblay@nrcan.gc.ca

Charlene Hogan

Charlene.Hogan@nrcan.gc.ca