BRITISH COLUMBIA | Ministry of Energy, Mines and Petroleum Resources

Water Treatment: Experiences with Old and New Technologies in BC

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Outline

- Guiding Regulatory Principles in BC
- Mitigation Requirements
- Water Treatment at BC Mines
- General Challenges with Water Treatment
- New and Emerging Technologies
- Key Challenges and Examples
- Conclusions

Guiding Regulatory Principles in BC

Mining and exploration activities in British Columbia will be regulated in a manner which supports the Province's goals of:

- sustainable resource development,
- reclamation,
- environmental protection and
- minimization of economic risks.

ML/ARD Guidelines: https://www2.gov.bc.ca/gov/content/industry/mineral-exploration-mining/permitting/ml-ard

Regulatory Tools and Resources for BC

- **Mines Act and the Health, Safety and Reclamation Code**
  https://www2.gov.bc.ca/gov/content/industry/mineral-exploration-mining/health-safety/health-safety-and-reclamation-code-for-mines-in-british-columbia

- **BC EMPR & ENV joint policy on ML/ARD** https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/mineral-exploration-mining/documents/permitting/ml-ard_policy.pdf

- **ML/ARD Guidelines**
  https://www2.gov.bc.ca/gov/content/industry/mineral-exploration-mining/permitting/ml-ard

- **ML/ARD Prediction Manual**
  http://mend-nedem.org/mend-report/prediction-manual-for-drainage-chemistry-from-sulphidic-geologic-materials/

Mitigation Requirements

- Mitigation strategies to prevent, reduce and control ML/ARD should be based on the ability to meet receiving environment objectives and minimize liability, risk, and long term land alienation:
  - Avoidance
  - Sub-aqueous Storage
  - Blending
  - Covers
  - Segregation
  - **Water Treatment**

Sullivan

Water Treatment (Pros)

Treatment of contaminated drainage can be a highly effective and reliable means of protecting the downstream environment

Dependent on a good understanding of the site, processes leading to loadings, influent chemistry and the downstream receiving environment

Can prevent further ARD migration, reduce downstream metal concentrations and prevent off-site impacts.

Sullivan

Water Treatment (Cons)

Does not reduce sulphide oxidation, leaching of weathering products or the amount of contaminated drainage in collection systems

Numerous drawbacks, including :

- High costs
- On-site contamination
- Secondary waste production
- High maintenance requirements
- Land alienation
- Long-term liabilities

Mitigation Strategy of Last Resort

Nickel Plate

Water Treatment Drivers in BC

- Mineral Deposit Types
  (Porphyry Cu, Metallurgical Coal, etc..)
- Increased waste volumes on surface
- Changing regulatory requirements
  (eg. BC WQG, pending Federal Coal regulations)
- Emerging contaminants of concern
  (Se – what's next?)
- Insufficient dilution available for discharge
- Incorrect predictions and mine planning
  (eg. Equity Silver, Samatosun, etc…)

Brenda

When is Water Treatment Acceptable in BC?

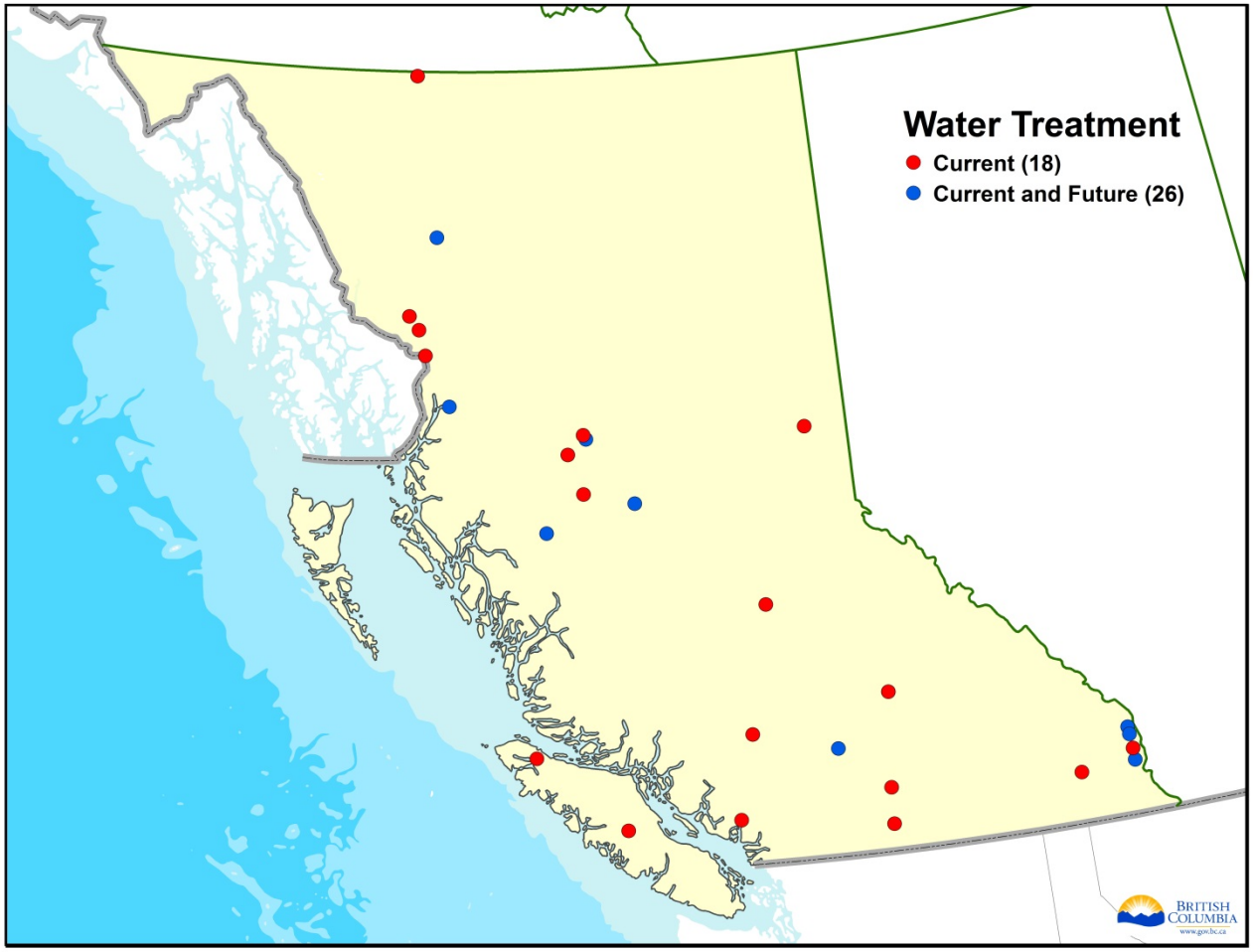
Other mitigation strategies have been demonstrated to be unfeasible or create more risk

As a contingency where there is uncertainty in ML/ARD predictions or performance of primary mitigation(s)

With satisfactory fulfillment of information and design requirements.

Trend-Roman

Current Status of Water Treatment Facilities in BC



Permitted Active Water Treatment Systems in BC

Treatment Technology	Parameters
Low Density Sludge	metals, acidity
High Density Sludge	metals, acidity
Lime Addition in mill	Metals, acidity
Ferric Sulphate	Mo, Sb, As
Biological	CN, neutral metals
Pike Lake Bioreactor	Metals, acidity
Fluidized Bed Reactor	Se, NO_3
Advanced Biological Metals Removal (ABMet)	Se, NO_3
Modular, multistage systems	TSS, metals
Flocculant	TSS
Anti-scalant	Calcite

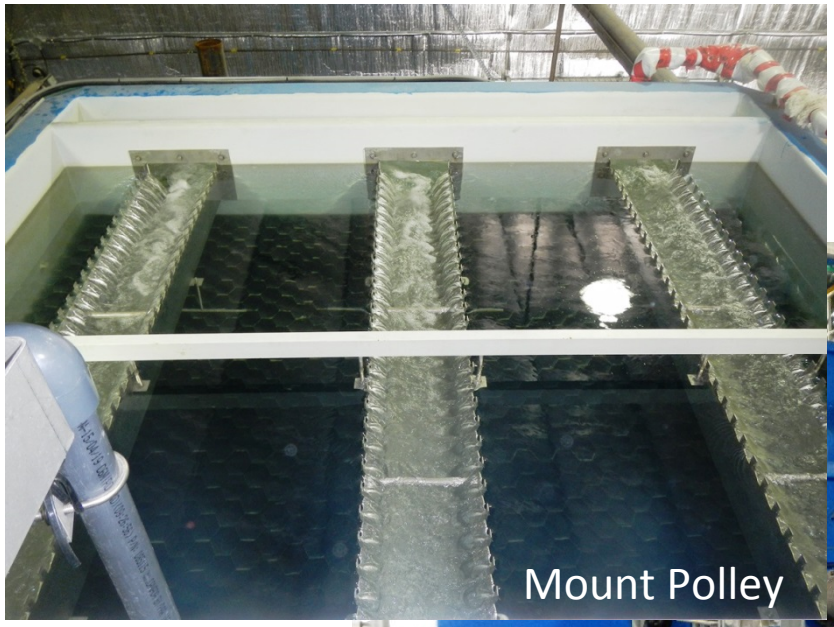
Proposed Active Water Treatment Systems in BC

- Ion Exchange (IX)
- Nanofiltration (NF)
- Electro-coagulation
- Reverse Osmosis (RO)/Evaporation
- Neutralization and Hydroxide Precipitation
- Biological Oxidation/Reduction
- Electrochemical Oxidation/Reduction

Semi-Passive Water Treatment Systems in BC

Treatment Technology	Parameter
Bioreactor	Metals, CN
Saturated Rock Fill (form of bioreactor)	Se, NO_3
Permeable Reactive Barrier	Metals, acidity
Limestone Drains	Metals, acidity
Natural and Engineered Wetlands	Metals

General Challenges with Water Treatment


Mount Polley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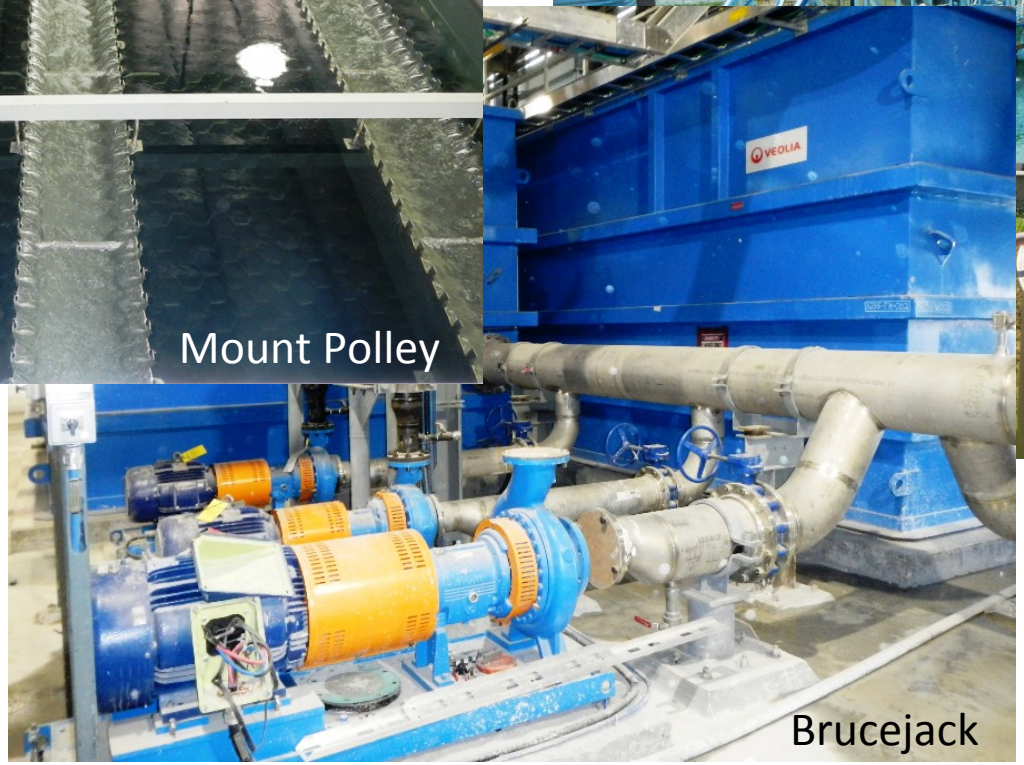

Brucejack

Challenge #1 – Inadequate Prediction

Equity Silver

Britannia

Challenge #2 – Water Collection and Management

- Systems must be capable of collecting and storing all significant sources of contaminated drainage
- Must perform over the range of hydrologic and climatic conditions

Line Creek

Challenge #3 - Treatment Effectiveness

- Hydrologic/Climatic Conditions
  - Seasonal water quality
  - Variable flows
  - Temperatures ranges
  - Hydrograph driven discharge criteria
- Variable Influent Chemistry
  (seasonal, LOM changes)
- Multiple COPCs


Johnny Mountain


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Challenge #4 - Residual Waste Management

- Sludge management
- Volume can rival original waste
- Physical containment challenges
- Long-term chemical stability uncertainties
- Brine management


Line Creek Operations

Samatosum

Challenge #5 - Perpetual Water Treatment

Brenda Mine

Nickel Plate

Challenge #6 - High Costs of Water Treatment

- Capital Costs
  - Detailed design and costing required at permitting
- Operating Costs
  - Includes reagents, labour, power requirements, testing, etc…
  - Short and long-term maintenance
- Financial Security
  - Existing and estimated future expenditures for all aspects of the water treatment system
  - Water treatment plant securities range up to approx. $90 million
  - Proposed sites with water treatment securities potentially in the hundreds of millions

New & Emerging Water Treatment Technologies

Large dump requiring active water treatment

- Water treatment now proposed on most projects
- Reflects industry's requirements to meet stringent water quality and also to reduce costs
- Pushing the envelope on technologies
- Presents challenges for industry, regulators, First Nations and communities
- Challenges include those of conventional water treatment

Other Water Treatments (proposed/piloting/research)

- Ion Exchange (IX)
- Nanofiltration (NF)
- Reverse Osmosis (RO)/evaporation
- Electrocoagulation
- Neutralization and Hydroxide Precipitation
- Biological Oxidation/Reduction
- Electrochemical Oxidation/ Reduction
- Pit Lake Treatment
- Saturated Rock Fills
- Bioreactor
- Passive Reactive Barriers
- In situ remediation (waste rock dumps)
- Limestone drains
- Engineered Wetlands
- Natural Wetlands

New Technologies – Key Challenges

- Large uncertainties with performance – no operating history in BC, or elsewhere in a mining context
- Questions of reliability, longevity, and reversibility
- Lack of research, pilot testing and analogue information to demonstrate effectiveness
- Significant time, money and resources needed to prove up
- Substantial health, safety and environmental risks
- Uncertainty of operating, monitoring and maintenance requirements and associated costs
- Proprietary information and unwillingness by industry to share information

Semi-Passive Drainage Treatment – Key Challenges

- Poor performance history for sites in BC
- Difficulty with handling high metal loads or high flow rates and reliably meeting low discharge concentrations.
- Removal mechanisms can be difficult to quantify and engineer
- Best suited as a drainage polishing measure or for treating small seeps.

Demonstration Bioreator

General Mines Act Permitting Requirements for Water Treatment

- Description of the project with location map and diagrams
- Detailed designs of effective drainage collection, conveyance and storage systems that can handle peak climatic and hydrologic events (supported by site hydrology and geotechnical information)
- Detailed engineering designs for the treatment plant including electrical drawings and mechanical information
- Information on treatment methods, process flow sheets, treatment capacity, retention times, materials and reagents used, reagent sourcing and transport etc.
- Demonstration of treatment effectiveness (pilot testing, industry examples etc.)
- Operating requirements such as power, pumping, number of people to operate, volumes of materials and reagents etc.
- Estimate of influent water quality and flows from all sources and anticipated effluent water quality and flows (average and range)
- Volumes and characteristics of by-product waste produced
- Assessment of potential environmental effects and risks, and mitigation/management plans
- Assessment of potential health and safety risks and management plans/safe work procedures
- Assessment of collection and treatment system performance under variable conditions including flow, temperature, and hydraulic retention times, etc.
- Assessment of performance risks for collection and treatment (i.e. extreme weather [icing, snow loading, flows etc.], power outage, wearing of parts, scaling, reagent supply interruption, plugging, by-passing/short circuiting, etc.)
- Maintenance and replacement plans for collection and treatment systems
- Emergency procedures for malfunctions/upsets for collection and treatment
- Contingency plans (for example, contingency storage for water requiring treatment)
- Proposed monitoring programs for collection and treatment (water quality, flow, other aspects of system performance etc.)
- Reporting plans
- Long-term disposal plans for secondary waste/spent substrate that addresses long-term geochemical and physical stability, as well as reclamation and closure
- Time schedule for construction and commissioning etc.
- Capital and anticipated O+M costs

- Generic Mines Act Permitting Information Requirements
- Similar for various types of treatment
- Also additional requirements for other agencies (ENV, EAO)
- Engage with regulators early and often
- Don’t under estimate the amount of information required

Pit Lake – Semi-Passive Bioreactor

Demonstration Scale - Saturated Rockfill

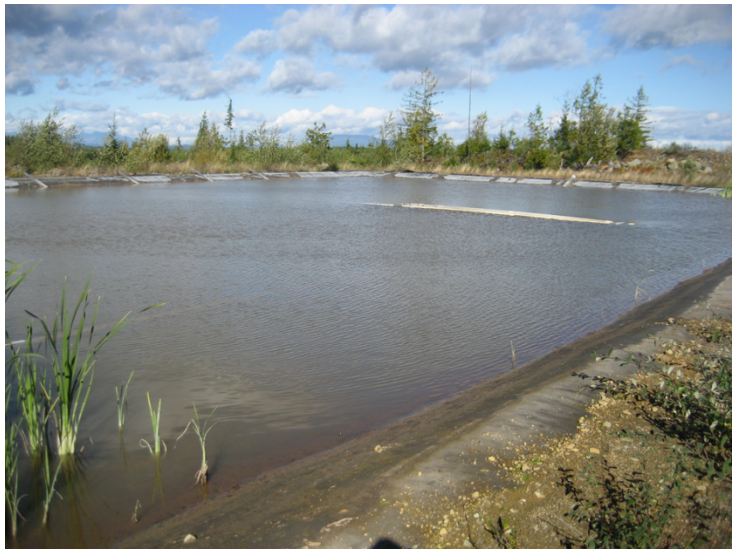
Active Biological Treatment Systems

- Selenium and nitrate reduction
- FBR System at West Line Ck.
- Demonstration ABMet at Trend/Roman
- Commissioning challenges and unexpected issues

Antiscalant Addition – Calcite Treatment

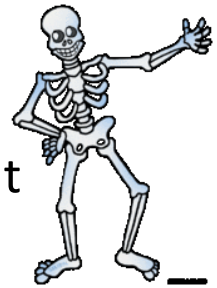
Demonstration Bioreactor

- Coal mine on Vancouver Island
- Demonstration bioreactor and sulphide polishing pond (Fe fillings and organic matter)
- Sulphate
- Insufficient sulphate removal, even with carbon amendment



Wetlands Reclamation

Adventures in Regulating – Errors and Problems



- Poor quality prediction work and lack of understanding of treatment requirements
- Designing and redesigning treatment during review processes
- Inadequate supporting information on mitigation
- “The Trust-us” approach
- False security in BATEA studies and Performance Guarantees
- Beware “Black box” treatment
- Postponement of information to support treatment
- Unrealistic understanding of costs of treatment or of bonding requirements
- Building and operating a different treatment plant than what was permitted
- Not constructing treatment modules required by permit

Conclusions – How to address the Challenges with Old and New Water Treatment Technologies

- Robust geochemical assessment, baseline work and water quality predictions to inform proper mitigation planning.
- Proactive mitigation planning with water treatment as last resort.
- Recognize that water treatment is no silver bullet, onerous operating, monitoring and management.
- Address information requirements, and don't under estimate the amount of research, time and money needed to develop new technologies.
- New water treatment technologies are very difficult to permit as a primary mitigation without significant research, piloting and a proven track record.

- Research on new technologies is better suited for application at sites with existing water quality problems versus greenfield sites.
- Gaps in understanding represent significant risks and uncertainties; formal risk assessment helpful for defining research programs and developing tools to manage potential risks.
- Don't underestimate the costs associated with water treatment, including bonding costs (large public risk – environmentally and financially).
- Systems need to be adaptable over time to respond to changing conditions
- Engage with regulators, FN and stakeholders early and often to understand information requirements, perspectives and values.
- Large opportunity for research collaboration and information sharing in the mining sector!


Thank-you!