The Mining Association of Canada | L'association minière du Canada

Managing Risks of Tailings Disposal

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ABOUT THE MINING ASSOCIATION OF CANADA (MAC)

- Established in 1935, MAC
  - promotes industry nationally and internationally
  - works with governments on policies affecting the sector
  - educates the public on mining
- Members account for most of Canada's production of metals and major industrial minerals
  - includes metals, diamonds, oil sands and metallurgical coal
- Associate members comprise a wide range of services and equipment supplied to the mining industry

TOWARDS SUSTAINABLE MINING® (TSM®)

- *TSM* established in 2004
  - intended to improve performance, starting with tailings management
- Evolved into industry-led, voluntary program to improve environmental and social performance in critical areas beyond regulations:
  - environmental footprint
  - energy efficiency
  - community and people
- Program strengths:
  - performance measured at facility-level, and results externally verified
  - monitored by external Community of Interest (COI) Advisory Panel
  - encourages continual improvement

SCOPE OF TSM

Environmental Stewardship

Tailings Management

Biodiversity Conservation Management

Water Stewardship

Communities & People

Aboriginal & Community Outreach

Safety & Heath Management

Crisis Management

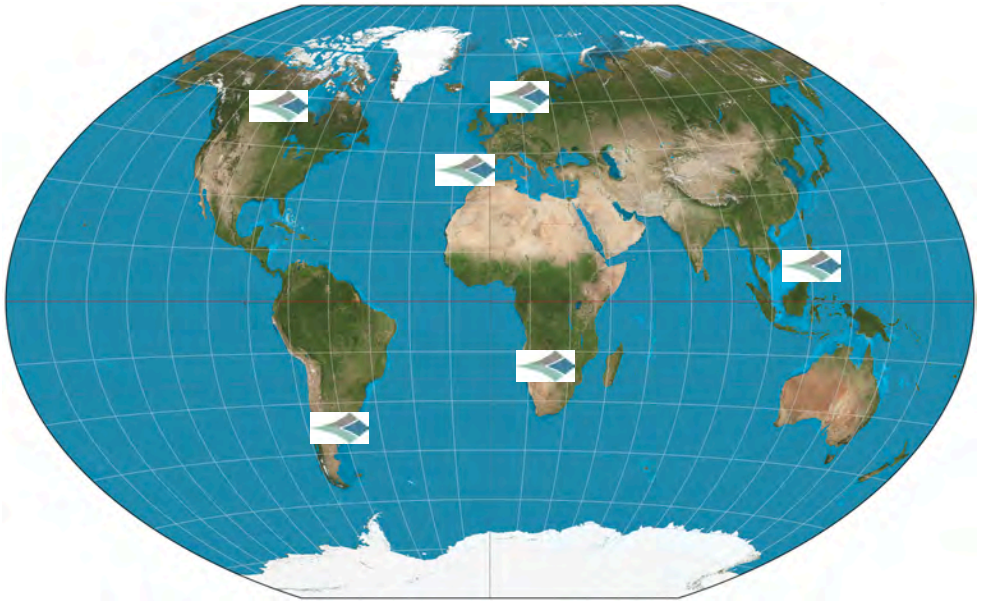
Energy Efficiency

Energy Use & Greenhouse Gas Emissions Management

Community of Interest Advisory Panel

APPLICATION OF TSM

- Participation in *TSM* is mandatory for all MAC members for their operations in Canada
- Some MAC members also applying *TSM* at their operations in other countries: e.g., Finland, Turkey, Surinam, Burkina Faso, Mexico, Portugal
- Growing interest in *TSM* around the world
  - adopted by industry associations in Finland, Argentina, Botswana, the Philippines, and Spain
  - being seriously considered in several other countries



MAC LEADERSHIP ON TAILINGS MANAGEMENT

- The first edition of MAC's *Guide to the Management of Tailings Facilities* (the Tailings Guide), released in 1998, was developed in response to tailings-related incidents in the 1990s
  - describes management systems approach for tailings management
- MAC introduced a companion document in 2003: *Developing an Operation, Maintenance, and Surveillance Manual for Tailings and Water Management Facilities* (the OMS Guide)
  - provides guidance on the preparation of OMS manuals to be used as tools to help implement tailings management systems
- In 2004, MAC established *TSM* with tailings management as a core component
  - *TSM Tailings Management Protocol* describes performance indicators for tailings management

RECENT UPDATES

- After the Mount Polley tailings dam failure in Canada in 2014, independent and internal reviews were conducted
- 2017: (English and French):
  - Third edition of the Tailings Guide
  - Revised *Tailings Management Protocol*
- March 2019 (English and French):
  - Second edition of the OMS Guide
  - Version 3.1 of the Tailings Guide
  - Revised *Tailings Management Protocol*
- Spanish versions will follow in mid-2019
- All documents available for download free of charge
- Tailings Guide and OMS Guide are written to be stand-alone documents that can be applied to tailings management at any mine, anywhere in the world

OVERALL OBJECTIVE

Objective is to continually work towards *minimizing harm*

Minimizing harm encompasses both physical and chemical performance and risks associated with tailings facilities, including:

- zero catastrophic failures of tailings facilities; and
- no significant adverse effects on the environment or human health

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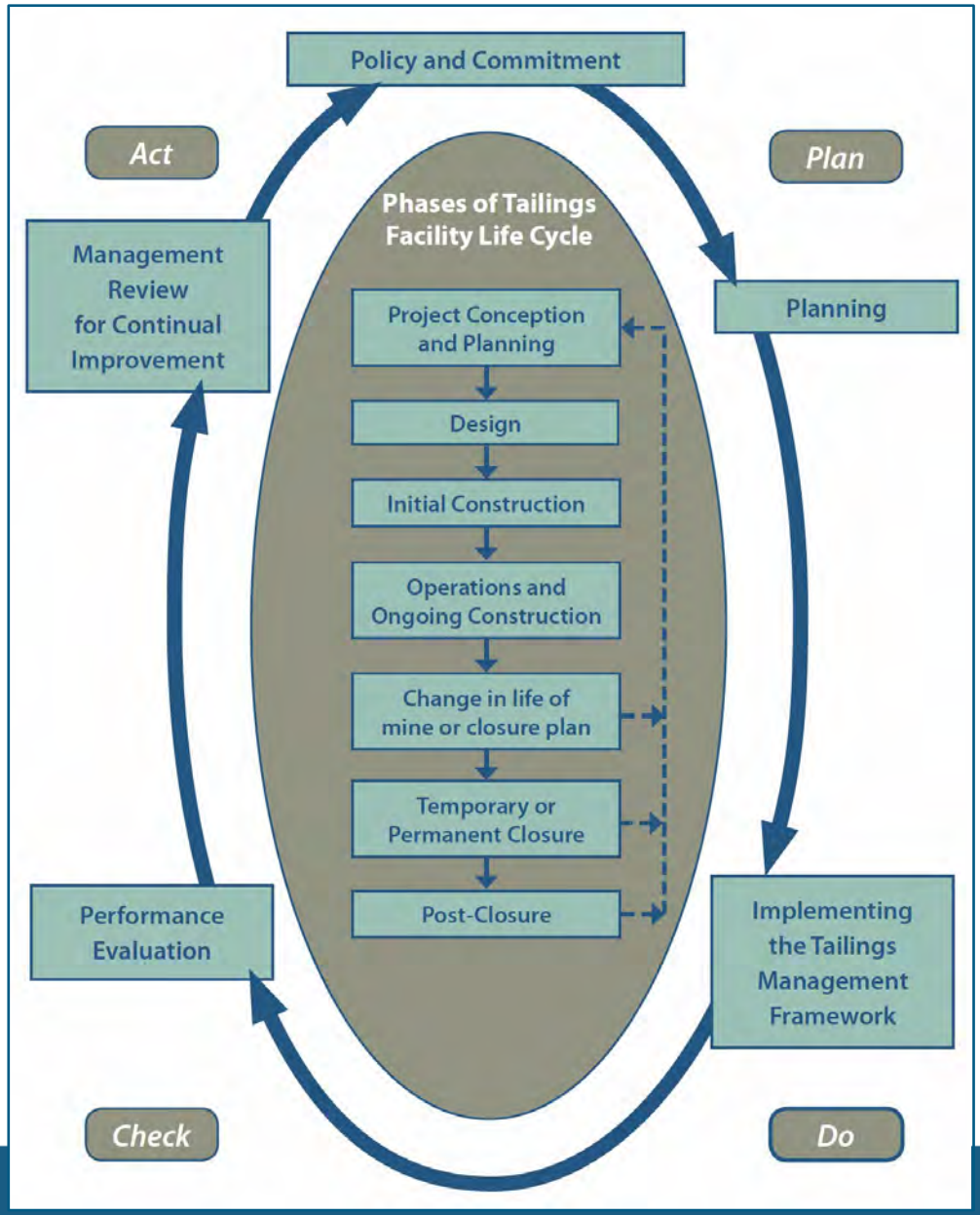
OVERVIEW OF THE TAILINGS GUIDE

- Applies across the life cycle, from conceptual planning to closure and post-closure
- Describes a management framework for tailings based on the ISO 14000 *Environmental Management Standard* but tailored to tailings management



OVERVIEW OF THE TAILINGS GUIDE

- Provides guidance on:
  - establishing a corporate policy for tailing management
  - accountability and governance for tailings management
  - risk assessment, risk management and critical controls management
  - establishing performance objectives
  - managing change
  - emergency preparedness (added in Version 3.1)
  - performance evaluation
  - management reviews
  - assurance mechanisms, including independent review

OVERVIEW OF THE OMS GUIDE

- Provides guidance on:
  - integration of OMS activities with tailings management system, risk management plan and critical controls management
  - integration of OMS into effective decision-making
  - preparing effective, site-specific OMS manuals
  - reviewing and updating OMS manuals
  - document control
  - OMS governance
  - designing and implementing OMS activities
  - linkages with emergency preparedness

OVERVIEW OF THE TAILINGS MANAGEMENT PROTOCOL

- Describes five performance indicators:
  1. Having a corporate tailings management policy or commitment
  2. Developing and implementing a site-specific tailings management system, and emergency preparedness
  3. Assigning accountability and responsibility for tailings management
  4. Conducting an annual tailings management review
  5. Developing and implementing a site-specific OMS manual

SIXTH VICTOR DE MELLO LECTURE – PROF. NORBERT MORGENSTERN

- Sixth Victor de Mello Lecture was given in Salvador, Brazil in August 2018 by Prof. Norbert Morgenstern (Emeritus) of the University of Alberta
  - distinguished expert in the field of geotechnical engineering
  - involved in investigations of failures of many dams and tailings facilities worldwide including Mount Polley and Samarco
- Stated that there is "no set of simple prescriptions will resolve the crisis" with tailings dams
  - e.g, ban upstream dams, required minimum factor of safety
- "One of the most important learnings can be seen in failure of other structures in the world. This is that a highly integrated team effort and success of an individual structure relies on the operational discipline of planning, technology, operations, geotechnical engineering and regulatory bodies." McRoberts *et al*. (2017), cited by Morgenstern

SIXTH VICTOR DE MELLO LECTURE – PROF. NORBERT MORGENSTERN

- Morgenstern concluded that the "dominant cause of these failures arises from deficiencies in engineering practice associated with the spectrum of activities embraced by design, construction, quality control, quality assurance and related matters"
- ICMM Tailings Governance Framework (2016) not adequate
- Recommended Performance-Based, Risk-Informed Safe Design, Construction, Operation, and Closure (PBRISD) of tailings facilities
- Underlying principle is accountability, achieved by multiple layers of review, recurrent risk assessment and performance-based validation from construction through closure
- Recommended that "ICMM support the tailings management system based on PBRISD, as outlined here, and fund the development and publication of a guidance document that would facilitate its adoption in mining practice"

Performance-Based, Risk-Informed Safe Design, Construction, Operation, and Closure (PBRISD)

- Stage 1: (Conceptual)
  - Qualified Operator
  - Establish Independent Review Board
  - Uncertainty Assessment
  - Potential Problems Analysis (PPA)
  - Multiple Account Analysis (MAA)
- Stage 2: (Feasibility)
  - Engineer-of-Record (EoR)
  - Designer
  - Design Basis Memorandum (DBM)
  - Risk Assessment
  - Quality Management
  - Documentation
- Stage 3: (Construction and Operations)
  - Operations
- Stage 4: (Closure Implementation)

PRINCIPLES OF RESPONSIBLE TAILINGS MANAGEMENT

- Paper by me and Michael Davies (Teck Resources) for ICOLD 2019 proposes a suite of holistic, interlinked principles for tailings management:
  - accountability and responsibility
  - effective planning and design
  - performance-based, risk-informed approach
  - management systems approach
  - operation, maintenance, and surveillance
  - emergency preparedness
  - assurance, including independent review
- Builds upon:
  - PBRISD
  - MAC Tailings Guide and OMS Guide
  - ICMM Tailings Governance Framework

PRINCIPLES OF RESPONSIBLE TAILINGS MANAGEMENT

- To improve tailings management, reduce risks, and minimize harm a systematic, holistic approach that effectively addresses all aspects encompassed by these principles must be implemented at the site-level
- Systematic approach to tailings management, following these principles, helps to mitigate what can perhaps be the greatest risk of all: *the human element*
  - Humans, however professional and qualified, make judgments and decisions based on their own experiences and biases
  - Sometimes, humans make mistakes
  - A systematic approach, with checks-and-balances, helps reduce the risk that human errors, experiences, or biases can ultimately lead to ineffective tailings management, or worse, a failure of a tailings facility

ACCOUNTABILITY AND RESPONSIBILITY

- Accountability must rest with the owner and at the highest level of the company
  - stakes are too high for accountability to rest at the site level
  - accountability must not be delegated or offloaded, either internally or to a consultant
- Accountability needs to be backed-up by the owner's commitment to manage tailings in a manner consistent with these principles
  - includes providing resources needed to support objectives for responsible tailings management

EFFECTIVE PLANNING AND DESIGN

- Decisions made at the planning and design phases affect entire life cycle and have implications for long-term risks and liability
- Considerations:
  - Designing for closure
  - Integrated mine-planning: a holistic approach to planning all aspects of a mine to optimize design, minimize short and long-term risks and achieve closure objectives
  - Risk analysis
  - Alternatives assessment: selection of tailings management technology and facility location using a rigorous, transparent decision-making tool
  - Independent review
  - Consideration of engineering standards (e.g., ICOLD, Canadian Dam Association)
  - Community engagement

PERFORMANCE-BASED, RISK-INFORMED APPROACH

- **Performance-based approach** includes settings performance objectives, operating in accordance with those objectives, and assessing whether objectives are being met
- **Risk-informed approach** involves managing tailings in a manner commensurate with the risks they pose and making decisions based on those risks, including:
  - risk assessment to understand all potential risks
  - development and implementation of a risk management plan
  - regular reviews and updates as needed
- **Rigorous decision-making approach** to ensure that decisions are:
  - carefully considered
  - based on relevant information, including surveillance results
  - taken by persons with appropriate authority and competencies
  - properly documented and communicated

MANAGEMENT SYSTEMS APPROACH

- "help organizations improve their performance by specifying repeatable steps that organizations consciously implement to achieve their goals and objectives, and to create an organizational culture that reflexively engages in a continuous cycle of self-evaluation, correction and improvement of operations and processes through heightened employee awareness and management leadership and commitment" (ISO)
- Management systems approach to tailings management:
  - encompasses governance and decision-making
  - provides a mechanism to systematically and rigorously implement the other principles described

OPERATION, MAINTENANCE, AND SURVEILLANCE

- Tailings management system, performance objectives, and risk management plan provide a framework, but OMS is needed to operationalize them on a day-to-day basis
- Owners that do not effectively implement OMS activities cannot adequately understand their risks, proactively manage tailings, make informed decisions, or have any assurance that tailings and associated risks are being effectively managed
- OMS activities must be aligned with performance objectives, tailings management system, risk management plan and critical controls
- Outcomes of OMS, particularly surveillance results, provide feedback for decision-making, including identifying:
  - deficiencies or opportunities for improvement
  - upset or emergency conditions requiring immediate response

EMERGENCY PREPAREDNESS

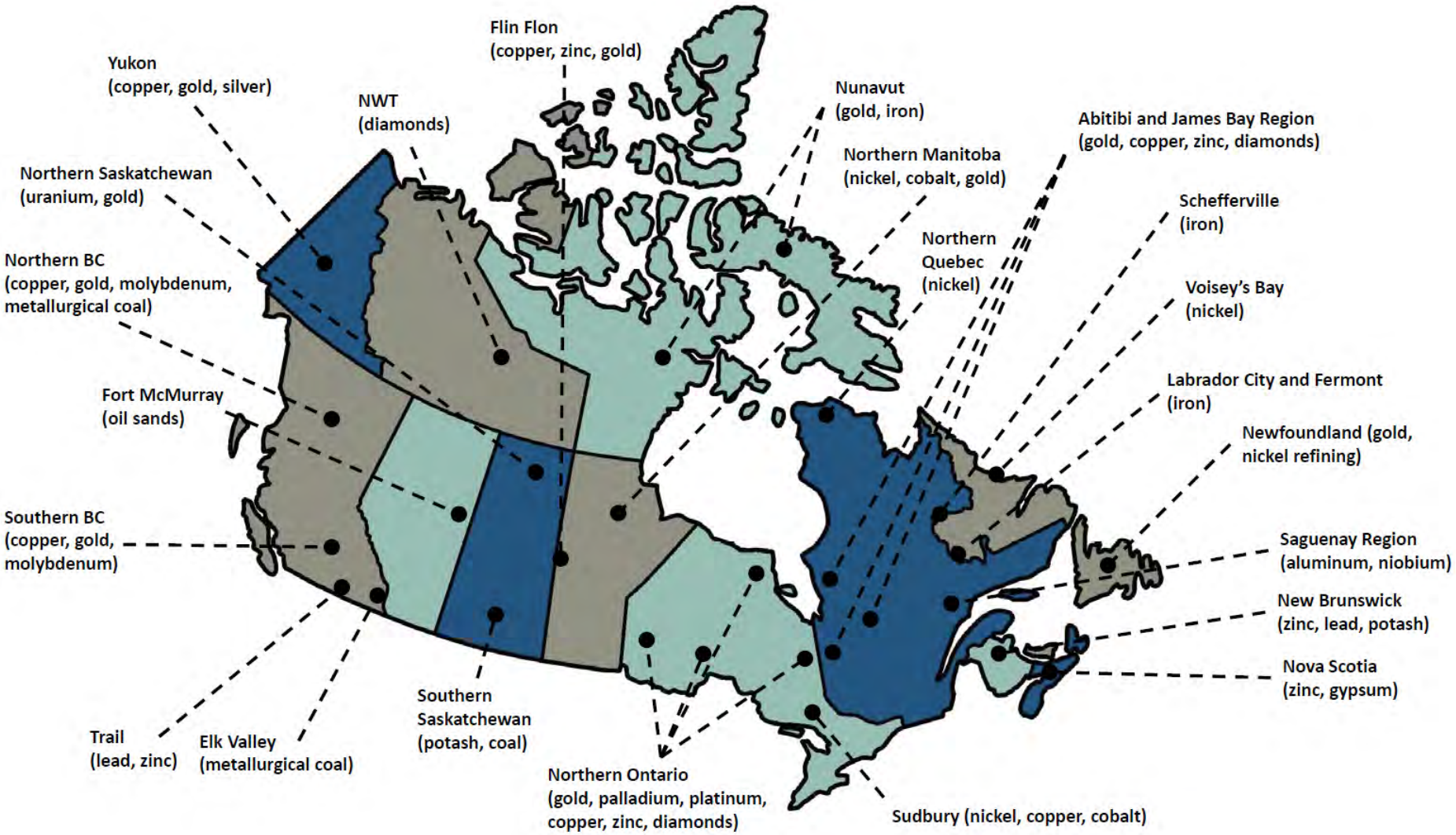
- Emergency planning needed for all tailings facilities, taking into consideration the risk profile and risk management plan
- Level of detail and aspects addressed commensurate with potential consequences if an emergency occurs
- Owners need to:
  - plan for potential tailings-related emergencies
  - assist local communities and others in the development of their own plans for an emergency
- For tailings facilities that could lead to an inundation risk in the event of a failure, emergency planning needs to include inundation mapping
- Regular review and testing needed to ensure that:
  - plans are adequate and up-to-date
  - all relevant personnel are familiar with the plans and their roles and responsibilities if an emergency occurs

ASSURANCE

- Oversight process to provide outside perspective on whether tailings are being managed effectively and responsibly
- Outcomes can be used to help demonstrate the current state of tailings management to the owner, regulators, communities, and others
- Several assurance mechanisms and all need to be used as they serve different purposes
  - Independent Review: independent evaluation of all aspects of tailings management by competent, objective, third-party reviewers on behalf of the Owner
  - Audits: formal, systematic and documented examinations of the conformance of tailings management with prescribed criteria (e.g., legal requirements, tailings management system)
  - Evaluation of Effectiveness: considers extent to which planned activities have been realized, and extent to which performance objectives have been achieved

Tailings Related Research and Development Activities in Canada

CHALLENGES FOR TAILINGS MANAGEMENT IN CANADA



CHALLENGES FOR TAILINGS MANAGEMENT IN CANADA

Geographic diversity - mines are operating across Canada:

- Alpine regions with very high precipitation (rain forest) or with very low precipitation (arid)
- Arctic conditions, with permafrost and very low precipitation but very low evapotranspiration
- Boreal forest, with wide climate ranges from winter to summer (e.g., +35 to -50°C) and a very high density of water bodies
- Some operating close to populated areas, others in remote areas accessible only by air and winter ice roads or by sea

Wide range of mine types:

- Metal mines range from small underground mines to large open pits
  - volumes and characteristics of tailings produced highly variable
- Other types of mines that also product tailings, including oils sands mines and metallurgical coal mines
- Some mines have been operating for many decades, others are new

CHALLENGES FOR TAILINGS MANAGEMENT IN CANADA

However:

- All tailings facilities are subject to the same natural forces, despite the global variety of facility types and local environments
  - potential effects of gravity, earthquakes, rainfall, wind, geochemical reactions are similar
- Many Canadian companies operate around the world

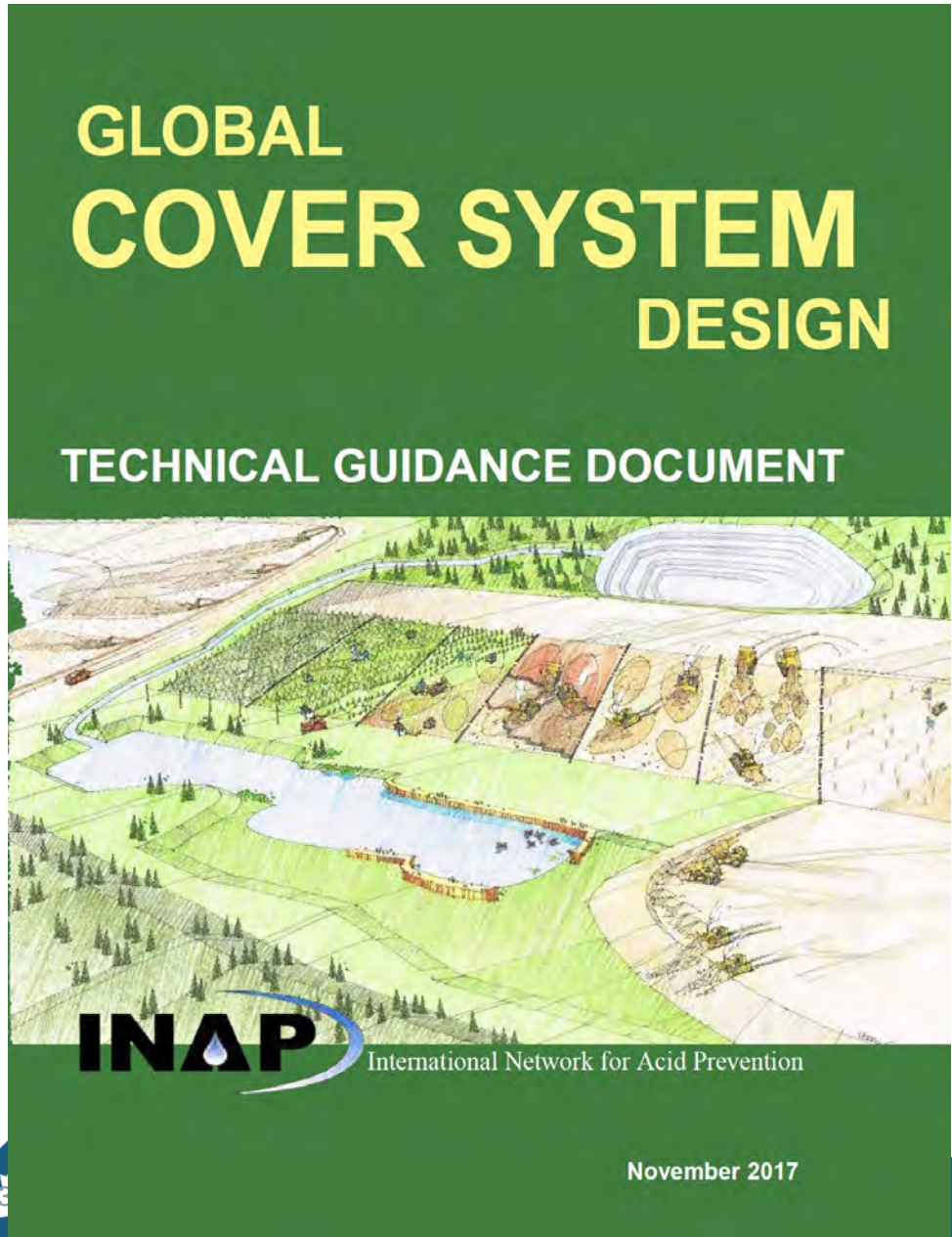
Thus, Canadian conditions may inform some research done Canada (e.g., effects of permafrost on production of acidic drainage), but much of the research is applicable globally

R&D IN CANADA: MINE ENVIRONMENT NEUTRAL DRAINAGE (MEND) PROGRAM

- Industry funded multi-stakeholder program started in 1989
- Focused on developing technologies related to acidic drainage and metal leaching:
  - prediction and modelling
  - prevention and control
  - treatment
  - monitoring and verification of technologies
- Current projects focused on biogeochemistry of subaqueous disposal of potentially acid generating tailings, and in-situ treatment options at closed sites
- Canadian partner in the Global Alliance (GA), an international partnership involved in acidic drainage research that is led by the International Network for Acid Prevention
- www.mend-nedem.org

R&D IN CANADA: LEADERSHIP IN COVER TECHNOLOGY

- MEND R&D in prevention and control of acidic drainage focused on two key areas:
  - subaqueous disposal using elevated water tables or water covers
  - engineered covers
- Has led to the development of significant Canadian expertise in these areas



R&D IN CANADA: TERRE-NET

- Five-year initiative with the overall goal of environmentally responsible, socially acceptable handling of wastes generated during extraction of mineral and energy resources using cutting-edge approaches and technologies
- Large scale program involving seven Canadian universities that already had extensive experience in mining-related research
- Also an extensive network of Canadian and international collaborators and partners representing the mining industry, industry organizations, and provincial, territorial, and federal government agencies
- Will train more than 80 graduate students, post-doctoral fellows, and undergraduate co-op students

R&D IN CANADA: TERRE-NET

- Includes 28 projects structured within seven integrated research themes:
  - Abandoned mine site remediation
  - Predictive tools for mine waste management
  - Cross-cutting methods and technologies
  - Exploring Indigenous Knowledge for Understanding Risks and Costs/Benefits of Mine Reclamation
  - Exploring Indigenous Knowledge for Understanding Risks and Costs/Benefits of Mine Reclamation
  - Remediation Strategies for Mine Wastes
  - Mine waste design

R&D IN CANADA: TERRE-NET

- One area of focus is paste rock, a blended mixture of waste rock and tailings with all voids filled with tailings
- Objective is to improve:
  - physical stability by integrating a high shear strength material (waste rock) with the tailings
  - chemical stability by maintaining a high degree of saturation
- Studying blends of different ratios of waste rock and tailings as potential cover material for waste rock at a large open pit
- Hydrogeological and geotechnical properties of blends characterized in the laboratory, and field-scale cells constructed:
  - control cells of uncovered waste rock and reactive tailings
  - experimental cells with paste-rock covers placed on: i) reactive tailings; ii) horizontal waste rock; and iii) waste rock with an inclined surface (2.5:1)
- Goals: improve waste management strategies; and provide modelling tools for designing waste management strategies that incorporate paste rock as a cover material

R&D IN CANADA: MINING WASTE WATER SOLUTIONS PROJECT

- Project led by University of Toronto in partnership with Université de Montréal, UC Berkeley and CSIRO in Australia
- Federal and provincial funding and several industry partners
- Goal is to better understand the role of bacteria in the biogeochemical cycling of sulphur compounds (e.g., acid generation, thiosalts)
  - Depending on type of bacteria and environmental conditions, they can either amplify or reduce contamination
  - Understanding how bacteria operate at various temperatures with different rock types is essential understanding them and potentially harnessing them to reduce risk of contamination
- Using genomics methods to characterize the bacterial species and communities involved in different types of reactions
- Field work being conducted at four different Canadian base metal mines, under both summer and winter conditions

CASE STUDY: ÉLÉONORE MINE

- Underground gold mine in Quebec owned and operated by Goldcorp
- Entered production in 2015, processing about 5000 tonnes of ore per day
- In-plant destruction of cyanide
- Separate flotation circuit in the mill to remove sulphides from tailings
- High sulphur tailings used as paste backfill underground
- Desulphurized tailings dewatered to about 85% solids and transported to tailings facility by truck
- Tailings facility is fully lined
- Tailings will be deposited sequentially in five adjacent cells, allowing progressive reclamation through mine life
- Run-off water collected in lined pond and re-used in the mill or treated and released

CASE STUDY: ÉLÉONORE MINE

CASE STUDY: LOUVICOURT MINE

- Louvicourt Mine was an underground mine in Quebec that operated from 1994 to 2005
- Tailings were potentially acid generating (PAG)
- About 55% of tailings were used underground as backfill
- Remaining tailings were deposited in an engineered tailings facility designed to maintain a permanent water cover over the tailings
- Containment provided by natural topography and constructed dams
  - Dams have been reinforced with buttresses to reduce the risk of failure
- Polishing pond was constructed adjacent to the tailings facility to improve effluent quality
- Five years after closure:
  - water in the tailings pond met provincial requirements for discharge to the environment
  - water in the polishing pond met water quality criteria
- Tailings facility has proven to be effective at preventing acid generation

CASE STUDY: GOLDEX MINE

- Underground gold mine in Quebec owned and operated by Agnico Eagle Mines
- Entered production in 2009, processing about 7000 tonnes of ore per day
- Mine produces very clean tailings, with no sulphides, in-plant destruction of cyanide, and high neutralizing potential
- Mine is in a region with a long history of mining, with many legacy sites in the area
- About 25 km from Goldex is a legacy site, the Manitou Mine, with acid generating tailings
- Province of Quebec is responsible for Manitou
- Manitou tailings have been a source of water pollution for many years, and presented a significant reclamation challenge

CASE STUDY: GOLDEX MINE

- Quebec and Agnico Eagle have an agreement in place
  - Goldex tailings are being placed on top of the acid generating Manitou tailings to provide a cover layer
  - Agnico Eagle contributing financially to cost of rehabilitation at Manitou, province paying the balance
- As cover thickness increases, the water table will rise, saturating the acid generating tailings
- High neutralizing potential of Goldex tailings will help to neutralize the acidic Manitou tailings
- Water treatment in place, and Quebec will retain legal liability for the site

CASE STUDY: GOLDEX MINE

CASE STUDY: EQUITY SILVER

https://vrify.com/embed/projects/7/sites/28

THANK YOU!

For more information:

http://mining.ca/our-focus/tailings-management

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