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Technology Readiness Levels (TRL)

Guidance for the R&D of source control and treatment technologies for mines in British Columbia

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Outline

- Source Control and Treatment
- Challenges
- Emerging Technologies
- Technology Readiness Levels (TRL)
- Technology Readiness Assessment (TRA)
- Technology Readiness Reviews (TRR)
- Future Work





Source Control and Treatment

- Source Control
 - An approach or measure that is intended to prevent or reduce the production and/or release of parameters of potential concern from a mined material or disturbed area into the receiving environment.
- Treatment
 - A process that improves the quality of mine contact water to make it appropriate for discharge to the environment or other specific end-uses. Types of treatment processes include chemical, biological, physical, or a combination of the three. Types of treatment technologies include active and semi-passive.





Source Control and Treatment - Challenges

- Site geology, hydrology, and geography
- New and lowered WQ requirements for contaminants of concern (Se, SO₄, etc...)
- Demonstrating that proposed mitigation will work over the range of expected site conditions over the time required
- Increasing length of time that they are required to be implemented
- Substantial capital and operating costs
- Requirement to post security upfront for operating costs



Emerging Technologies – Source Control

- Source Control
 - Engineered Waste Rock Dumps (oxygen limiting layers)
 - Engineered Cover Systems







Emerging Technologies - Treatment

- Treatment
 - Reverse Osmosis/Nano-filtration
 - Saturated Rock Fill (SRF)
 - Biochemical Reactor (BCR)
 - Permeable Bed Reactor (PBR)

Organic matter

Limestone

• Engineered Wetlands

Water







Emerging Technologies – Information Requirements







Emerging Technologies - Uncertainties

- Lack of research and pilot testing to demonstrate effectiveness under site conditions
- Questions of longevity and reversibility
- Health, safety, and environmental risks
- Operating, monitoring, and maintenance requirements
- Capital and Operating Costs
- Proprietary information and unwillingness by industry to share information





Emerging Technologies – What is the Risk?

- The total liability associated with Major Mines in BC is > \$5B
- Source Control and Treatment Technologies account for > \$1.5B
- A substantial percentage of Source Control and Treatment Technologies are required to be in place and operating effectively in-perpetuity (> 100 yr)
- Example Mine Site Single Water Treatment System
 - \$450M Capital Cost, \$17-25M/yr Operating Cost
 - Required Security \rightarrow \$380M discounted; \$1.45B undiscounted





Emerging Technologies – Who Holds The Risk?

• Major Mines Reclamation Security Policy:

At all times in a mine's life there must be sufficient reclamation security in place to provide assurance that taxpayers <u>will not</u> be required to pay for mine site reclamation and environmental clean-up if companies default on their obligation to do this work.





Emerging Technologies – Who Holds The Risk?





Emerging Technologies – Who Holds The Risk





Emerging Technologies – Supporting Innovation





Technology Readiness Levels (TRL)



TRL - Development

- Developed by a EMLI/ENV, KNC, and Teck Emerging **Technology Working Group**
- Based on Innovation Canada TRL
 - https://ised-isde.canada.ca/site/innovation-٠ canada/en/technology-readiness-levels
- Adapted as Technical Guidance for all Mines in BC by EMLI, ENV, and EAO



Levels

Interim Technical Guidance



TRL - Purpose

- Provide consistent guidance to industry for the research and development of technologies
- Align with the guidance, approach, and expectations that EAO, EMLI and ENV have been communicating to industry over the past decades





TRL - Objectives

- Support the advancement of technologies by the mining industry;
- Guide research and development to ensure the regulatory information required to advance the technology is collected:
- Enable consistent, uniform discussion of a technology's • maturity; and
- Align TRLs with regulatory processes (e.g. EAC, Mines Act, Environmental Management Act)



Levels

Interim Technical Guidance



Technology Readiness Levels







TRL 1 – Basic Principles Observed and Reported

TECHNOLOGY READINESS LEVELS (TRL)	CRITERIA	CONNECTION TO REGULATORY PROCESSES
LEVEL 1: BASIC PRINCIPLES OBSERVED AND REPORTED	 Translation of scientific research into applied research and development. Literature review of technology's basic properties. 	 Research conducted by a proponent. Authorization under MA and/or EMA not required.







TRL 2 – Technology Concept and/or Application Formulated

TECHNOLOGY READINESS LEVELS (TRL)	CRITERIA	CONNECTION TO REGULATORY PROCESSES
LEVEL 2: TECHNOLOGY CONCEPT AND/OR APPLICATION FORMULATED	 Activities are limited to analytical studies. Observation of basic principles. 	 Research conducted by a proponent. Authorization under MA and/or EMA not required.







TRL 3 – Analytical and Experimental Critical Function / Proof of Concept

TECHNOLOGY READINESS LEVELS (TRL)	CRITERIA	CONNECTION TO REGULATORY PROCESSES
LEVEL 3: ANALYTICAL AND EXPERIMENTAL CRITICAL FUNCTION AND/OR PROOF OF CONCEPT (Laboratory experiments to demonstrate basic function)	 Active research and development initiated. Analytical studies or laboratory studies. Testing of components that are not yet integrated or representative. Collection of empirical data. 	 Research and development conducted by a proponent. Authorization under MA and/or EMA not required.







TRL 4 – Component Validation In A Laboratory Environment

TECHNOLOGY READINESS LEVELS (TRL)	CRITERIA	CONNECTION TO REGULATORY PROCESSES
LEVEL 4: COMPONENT VALIDATION IN A LABORATORY ENVIRONMENT (Prototype system or system component operating in a laboratory)	 Basic technological components are integrated to establish that they work together in the laboratory. Collection of empirical data. 	 Research and development conducted by a proponent. Authorization under MA and/or EMA not required.







TRL 5 – Component Validation in a Simulated Environment

TECHNOLOGY READINESS LEVELS (TRL)	CRITERIA	CONNECTION TO REGULATORY PROCESSES
LEVEL 5: COMPONENT VALIDATION IN A SIMULATED ENVIRONMENT (Prototype system or system component operating under relevant site-specific conditions)	 Basic technological components are integrated in the laboratory. Testing in a laboratory or simulated environment. Collection of empirical data. 	 Research and development conducted by a proponent. Activity may be conducted on-site and may require authorization under MA and/or EMA. Reclamation security is required for the removal of the prototype and reclamation of the disturbed area.







TRL 6 – Prototype Demonstration in a Simulated Environment

TECHNOLOGY READINESS LEVELS (TRL)	CRITERIA	CONNECTION TO REGULATORY PROCESSES
LEVEL 6: PROTOTYPE DEMONSTRATION IN A SIMULATED ENVIRONMENT (Demonstration system operating under relevant site-specific conditions)	 Development of a prototype that represents or nearly represents the final configuration. Testing in a laboratory or simulated environment. Collection of empirical data. 	 Research and development conducted by a proponent. Activity may be conducted on-site and may require authorization under MA and/or EMA. Reclamation security is required for the removal of the prototype and reclamation of the disturbed area.







- EAO/EMLI/ENV do not make decisions on TRL 1 to 6
- MA and/or EMA authorization may be required for on-site trials
- Level of review/authorization is dependent on the potential risk of the trial
- Security only required for the reclamation of the ground disturbance







TRL 7 – Prototype Demonstration in Site-Specific Environment

TECHNOLOGY READINESS LEVELS (TRL)	CRITERIA	CONNECTION TO REGULATORY PROCESSES
LEVEL 7: PROTOTYPE DEMONSTRATION IN SITE- SPECIFIC ENVIRONMENT (Demonstration system operating at near full-scale under relevant site-specific conditions)	 Development of a prototype representative of the final configuration. Testing in the actual field setting. Empirical data supports the implementation of the technology to meet receiving environment requirements under a range of conditions representative of the expected life and application of the technology. A risk management approach and risk register have been developed. Identified risks have proposed mitigations through operational and management actions. MA and EMA Joint Application Information Requirements for the technology, excluding capital and operating costs, that are technology-specific can be met (JAIR Section 5.6.4). An independent peer review may be used <i>in lieu</i> of literature and analogue data. 	 Research and development conducted by a proponent. Activity may be conducted on-site and may require authorization under MA and/or EMA. The technology may be proposed for use in MA and/or EMA planning processes. The technology may be included in EAC applications. Reclamation security is required for the removal of the prototype and reclamation of the disturbed area. Reclamation security may be required for the provision of an alternative, proven, technology.





TRL 8 – Actual Technology Completed and Qualified

TECHNOLOGY READINESS LEVELS (TRL)	CRITERIA	CONNECTION TO REGULATORY PROCESSES
LEVEL 8: ACTUAL TECHNOLOGY COMPLETED AND QUALIFIED THROUGH TEST AND DEMONSTRATIONS (First-of-a-kind system complete and proven at full-scale)	 A risk management approach and risk register have been developed/updated. Identified risks have proposed mitigations through operational and management actions. The technology is transferable and can conceptually be implemented at any site, subject to site-specific conditions. The operational and replacement costs of the technology can be calculated for bonding requirements. MA and EMA Joint Application Information Requirements for the technology are fully met (JAIR Section 5.6.4) using an appropriate combination of literature, analogue data, and empirical data for the technology. 	 The technology may be proposed for use in MA and/or EMA planning processes. The technology may be included in EAC applications. The technology may be included in MA and/or EMA permit applications as a proven technology. MA/EMA Joint Application Information Requirements can be met with empirical data. Reclamation security is required for the technology's capital and operating costs and reclamation of the disturbed area.





TRL 9 – Actual Technology Proven Through Successful Deployment

TECHNOLOGY READINESS LEVELS (TRL)	CRITERIA	CONNECTION TO REGULATORY PROCESSES
LEVEL 9: ACTUAL TECHNOLOGY PROVEN THROUGH SUCCESSFUL DEPLOYMENT IN OPERATIONAL SETTINGS (System complete and proven at full-scale in multiple settings)	□ MA and EMA Joint Application Information Requirements for the technology are met (JAIR Section 5.6.4) using an appropriate combination of literature and analogue data for the technology. Empirical data may not be required.	 The technology may be proposed for use in MA and/or EMA planning processes. The technology may be included in EAC applications. The technology may be included in MA and/or EMA permit applications as a proven technology. MA/EMA Joint Application Information Requirements can be met without empirical data. Reclamation security is required for the technology's capital and operating costs and removal and reclamation of the disturbed area.





Regulatory Requirements – TRL 7, TRL 8, TRL 9

- Existing authorization processes serve as *de facto* decisions on TRL 7 and 8
 - EA Certificate \rightarrow TRL 7
 - *Mines Act/Environmental Management* Permit → TRL 8
- TRL 9 are technologies where removal mechanisms and ability to work under a range of site conditions are well understood and transferable between sites
- A list of technologies that are considered TRL 7, 8, or 9 does not currently exist





Technology Readiness Assessment (TRA)

- A systematic, evidence-based, process that evaluates the readiness of emerging technologies
- May be used by proponents to identify risks and highlight critical technology information gaps
- Does not necessarily eliminate risk or preclude taking risks; rather, it may alert a proponent to gaps in the understanding of a proposed technology that could potentially be raised during a MA, EMA, and/or EAC review process







Technology Readiness Assessment (TRA)

- A TRA is not an EMLI, ENV, or EAO information requirement for applications
- Proponents may choose some or all of it to use it to internally track their R&D progression
- Does not require the involvement of Government or Indigenous Nations
- Can be used to support an EAC or permit application process, in addition to the existing information requirements





Technology Readiness Review (TRR)

- An optional technical review process conducted by EMLI and ENV in order to determine the TRL of a proposed technology
- Meant to provide an alternative pathway for proponents to seek EMLI and ENV review of a technology outside of a formal EAC or permit application process
- Focus on the source control or treatment mechanism(s) and how they work
- Non-binding and does not result in a statutory decision



Technology Readiness Review (TRR)

- Review process still under development
- Only for TRL 7 or TRL 8 determinations
- Can be requested by a proponent, but must be accepted by EMLI and ENV
- The TRA will be a key component of the process





Technology Readiness Level – Future Work

- Incorporation of TRA reporting guidance into MA/EMA permitting processes
- Development of specific MA/EMA information requirements:
 - Source Control trials
 - Treatment trials
 - Source Control full scale
- Development of a list of TRL 8 and TRL 9 technologies



QUESTIONS?

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