MEND IN THE 21ST CENTURY[1]

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Abstract. Sustainable development has become a driving force in how the mining industry approaches all existing and future activities. Progress has been made to advance environmental performance and stewardship and provide benefits to civil society. Technologies are now in place to plan for, open, operate and decommission a mine property in an environmentally acceptable manner, both in the short and long term. Moreover, mining companies, governments and consultants have acquired a great deal more capability to deal with environmental and societal issues such as water contamination from mine wastes, including acid generation.

The Mine Environment Neutral Drainage (MEND) program was the first international multistakeholder initiative to develop scientifically-based technologies to reduce the effect of acidic drainage. The original program (1989-1997) and its successor, MEND 2000 (1998-2000) contributed enormously to the understanding of acidic drainage and how to prevent it. MEND focused the acidic drainage effort and developed a toolbox of technologies that is available to all stakeholders. Despite this progress, acidic drainage remains one of the most significant environmental issues facing the mining industry. In 2001-2002 MEND laid the groundwork for a renewed research program by identifying Canadian national and/or regional priorities through a strategy session and subsequent survey. Since then, many of these priorities are being addressed through projects, workshops, reviews on emerging technologies and guidance documents.

MEND is a partner in the Global Alliance, an international alliance between regional groups involved in acidic drainage research. This group will continue its collaboration to enhance technology transfer towards improving the understanding of acidic drainage.

The successes of MEND and other partnership programs have come through the cooperative efforts of the partners, the sharing of experiences, the thorough evaluation of technologies and practices. Through these efforts a significant advancement in environmental management is achieved and thus has contributed to the long-term sustainability of the mining industry and the environment.

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Introduction

Mining with environmental stewardship involves not only optimizing the technical performance of mining and extraction processes so as to maximize the profitability of an operation, but also entails leaving a positive environmental and social legacy. Up until the 1970s, the focus was primarily on generating profits. Since that time, there has been a growing awareness of the need to minimize the negative imprint that mining has left on the natural environment. In the 1980s a collective approach to problem solving emerged in Canada. Multi-stakeholder initiatives that address technical issues of national importance have been models for cooperation among industry, various levels of government, NGOs (non-governmental organizations) and First Nations (i.e. aboriginal Canadians).

Programs are frequently launched to focus research efforts into areas of concern, and also to obtain information for formulating sound policy. It is especially important in the environmental area to ensure that government policy is underpinned by sound science. The benefit of the collaborative programs has come through the sharing of experiences, the thorough evaluation of technologies and their incremental improvement.

The Mine Environment Neutral Drainage (MEND) initiative was the first international multistakeholder program to develop scientifically based technologies to reduce the effect of acidic drainage. The MEND model of collaboration is now being used by both Canadian and international programs to address issues of national importance. The National Orphaned and Abandoned Mines Initiative (NOAMI), the subject of a separate paper in these proceedings, adopted the MEND framework to develop a policy-based program for remediation of orphaned and abandoned mine sites in Canada.

Background

Acidic drainage has long been recognized as the largest environmental liability facing the Canadian mining industry, and to a lesser extent, the public, through abandoned mines. Since 1987 the Canadian mining industry and governments have been cooperating to develop technologies to prevent and control acidic drainage.

The original 9-year MEND Program (1989-1997) and its subsequent initiative MEND2000 (1998-2000) contributed greatly to the understanding of acidic drainage. Tremendous technical progress was made in the areas of prediction and modelling, prevention and control, disposal technologies, lime treatment, passive treatment and monitoring. Despite this progress, acidic drainage remains the most significant environmental issue facing the mining industry, governments and the public. Therefore in 2001, funding was provided to launch a renewed initiative, to identify Canadian national and/or regional information needs.

The first major activity was a "gap analysis" report (MEND 8.1) that identified opportunities to advance acidic drainage knowledge, along with a prioritized list of research needs. In April 2002, the recommendations of this study were reviewed during a multistakeholder Strategy Session held in Ottawa (MEND 8.2). This session developed and recommended a number of research activities for a multi-year program. A questionnaire was also distributed to the MEND Canadian Network to help define research priorities. The conclusion was that closure management, verification of technologies, metal leaching, passive treatment, early prediction and sludge management were viewed as the top priorities. Strong support was also given for more information on cold temperature effects and paste backfill. The need for guidance documents, technology transfer activities (e.g. workshops), and updates on emerging technologies was identified as a crosscutting theme within each of the priorities.

MEND Projects 2003/2004

Based on the widespread support received from all stakeholders, a recommendation was made to move ahead with a renewed MEND research program. Since 2003/2004 a number of

research projects have been supported by The Mining Association of Canada, MEND and other partners (Environment Canada, INAP). Brief summaries of the completed projects follow:

- **MEND 2.21.4. Dry Cover Manual - Design, Construction and Performance Monitoring of Cover Systems for Waste Rock and Tailings.** The manual incorporates and integrates the best available technologies for the design and construction of cover systems over mine wastes. Information is garnered from a wide variety of sources, but the document is not intended as a comprehensive design manual. It is meant for use by mining personnel and others interested in cover systems. The control concepts behind the design and construction of cover systems are explained and illustrated, and the types of activities that are required in the design process are described. The manual includes a Summary volume and the following four supporting technical documents: Theory and Background; Site Characterization and Numerical Analyses of Cover Performance; Field Performance Monitoring and Sustainable Performance of Cover Systems; and Case Studies. MEND 2.21.4 is available on both CD-ROM and in paper copy.

- **MEND 1.61.4. Covers for Reactive Tailings Located in Permafrost Regions.** The report provides a brief introduction to permafrost issues and then focuses on applications of covers constructed over reactive tailings in Canadian permafrost regions. Case histories for Nanisivik, Raglan, Lupin and Rankin Inlet are examined, which represent sites with different tailings operations, cover design approaches and physical and climate conditions. Parameters that govern the design of the cover are addressed, including: cover materials, factors affecting the depth of active thaw zone, temperature changes and variations, water saturations, and pore water quality.

- **MEND 3.42.3. Disposal, Reprocessing and Reuse Options for Acidic Drainage Treatment Sludge**. The report provides a review of technologies related to the management of acidic drainage treatment sludges. The technology areas assessed include conventional disposal technologies such as pond disposal and co-disposal with tailings and alternative disposal options such as underground sludge disposal. Options for metal recovery through hydrometallurgical and pyrometallurgical reprocessing as well as novel sludge reuse

technologies are reviewed. In addition, sludge stabilization and reclamation applications are documented. The report identifies and discusses knowledge gaps for sludge management and highlights areas for further work.

- **MEND 10.1. Review of Water Quality Issues in Neutral pH Drainage: Examples and Emerging Priorities for the Mining Industry in Canada.** A review of selected Canadian mining operations was completed to determine priority chemical elements of interest (EOIs) associated with leaching under non-acidic conditions. These EOIs can result in unacceptably elevated concentrations in drainage if loadings to the environment exceed assimilative capacity. They can be a concern for reasons related to; specific environmental or regulatory drivers (or potential environmental impacts), absence of sufficient solubility controls at neutral pH, and element-specific challenges for cost-effective removal from effluent and wastewaters. Key challenges around water quality, mine waste management and potential terrestrial effects and the associated cost implications were summarized, with a focus on arsenic, molybdenum and selenium.

- **MEND 5.10 Checklist of Potential Information Requirements in Metal Leaching/Acid Rock Drainage (ML/ARD) Assessments and Mitigation Work.** The document lists potential information requirements and factors to consider in ML/ARD work and serves as a general guide for practitioners employed by the mining industry, regulators and the public reviewing their work, as well as educators and students. The report is available in both official languages and can be downloaded from the MEND web site.

The following projects are near completion and should be available shortly.

- **Underground Paste Backfill.** The project is a compilation and review of available information pertaining to current practices in the geochemical characterization of paste backfill (using sulphide tailings) and methods used to predict environmental impacts to surface and ground water quality with the application of paste backfill in underground applications. In summary, the use of paste backfill in underground environments has been

generally considered beneficial to reduce overall environmental impacts associated with mining. The general theories associated with paste backfill characteristics and geochemical reactivity appear sound, but there does not appear to be much field validation of the actual influences of key parameters.

- **MEND 9.1 Case Studies of ML/ARD Mines in British Columbia**. Case studies were selected to show the practical benefits and limitations of different site-specific ML/ARD mitigation and assessment practices, and to provide guidance to operators, regulators and the public. These case studies will be a valuable educational tool for students to evaluate ARD and metal leaching potential. **MEND 9.1a -** Johnny Mountain Gold Mine and **MEND 9.1b -** Snip Gold Mine are completed. Sulphurets Mine Site (**MEND 9.1c**) review is almost complete.

- **Case Study Assessments at Canadian Mine Sites.** A study to assess and verify the effectiveness of acidic drainage pollution prevention and control techniques. In Phase I, case study assessments were done on five sites in Canada (Heath Steele, Dona Lake, Mandy Lake, Lorraine and East Sullivan). Phase II involved a field assessment of the water covers on the tailings impoundment at the Heath Steele property in New Brunswick. This included surface water sampling of natural streams and collection ditches reporting to the tailings cells, at various locations within the cells and at the final discharge. In situ equilibrated peepers were also installed to monitor porewater to determine dissolved metal concentration gradients and thus calculate element fluxes in the dissolved phase at the sediment-water interface.

MEND also participated in the organization of three workshops during this period:

- 10th Annual BC-MEND ML/ARD Workshop on "Performance of ARD Generation Wastes, Material Characterization and MEND Projects", Vancouver, December 2003
- Ontario-MEND Workshop on "Sludge Management and Treatment of Weak Acid or Neutral pH Drainage", Sudbury, May 2004 (**MEND W.017**), and the

- 11th Annual BC-MEND ML/ARD Workshop on "Performance of Dry Covers", Vancouver, December 2004.

  Proceedings of these workshops are available on CD-ROM.

MEND Projects 2005/2006

Many of the projects completed in 2003/2004 were state-of-the-art reviews, the results of which are used to better define future research needs. A number of new studies and guidance documents/manuals are now in progress and brief summaries are provided.

- **Molybdenum (Mo) and Selenium (Se) Issues related to Mine Effluent and Drainage.** As identified in **MEND 10.1**, it was recognized that both Mo and Se are coming under increasing scrutiny as part of environmental assessments (EAs). In the absence of hard toxicity field data, toxicity benchmarks may be developed that are completely inappropriate. A scientific review of Mo and Se issues related to terrestrial animal toxicity is underway to better understand their implications for mining projects.

There has been an increased attention on mining issues in the North, driven mainly by Canada's new diamond industry, which has generated interest in extreme temperature effects. Three MEND projects are underway that are studying different aspects of cold region manifestations.

- **Cold Temperature Effects on Geochemical Weathering.** Effects of cold temperatures on mine wastes are examined, along with opportunities to mitigate mine drainage issues. Relevant case histories are being reviewed and evaluated to better understand geochemical mechanisms. Information gaps will be discussed, and recommendations made for future work.

- **Northern Soil Covers.** A study on cold regions phenomena that could impact on the performance of soil covers will be completed. Arctic hydrology, snow re-distribution, infiltration in frozen soils, frost action, periglacial phenomena in general, and several specific topics like thermal convection are some of the phenomenas that are under review to determine their affect on cover performance. From the literature review and case histories, priorities will be identified for research to further develop soil cover design and construction methods suitable for cold regions.

- **Diavik Waste Rock Pile Scale-up.** Little is known about the implications of storing waste rock stockpiles in environmentally fragile regions where there is continuous permafrost and the average annual temperature is below the freezing point of water, such as in northern Canada. A five-year research project aimed at evaluating and preventing the possible leaching of metals and acidic drainage from waste rock piles at the Diavik operation and other similar facilities in the Arctic is underway. The project involves multiple facets including laboratory tests, field instrumentation and measurements, numerical modelling, and various types of analysis.

  The project involves the construction of four well-instrumented, large-scale test piles containing different rock types (on the basis of sulphur content) and two different remedial covers (clean rock/clean rock with till). The project will focus on the understanding of the waste rock leachate geochemistry and fluid movement within the four test piles constructed in 2004 and 2005. This collaborative project involves Diavik and various Canadian universities, with ANSTO, NSERC, INAP and MEND.

The need for guidance documents and manuals has surfaced a number of times, from several of the jurisdictions as well as consultants, regulators and non-government organizations. The Dry Covers Manual (MEND 2.21.4) was developed to incorporate the best available technologies on cover systems and was intended for mine operators and individuals or others interested in the use of cover systems in mining. MEND 2.21.4 primarily addressed micro scale design,

construction, and performance monitoring issues. Further refinements to the dry covers manual will be done under a new project:

- **MEND 2.21.5 Manual on Macroscale Cover Performance Monitoring and the Application of the Observational Method for Evaluating Long-Term Engineered Landscape Performance/Cover System Design.** The design and performance monitoring of earthen covers for waste rock and tailings to a macro- or landscape scale will be addressed, along with the uncertainty associated with long-term cover system performance.

  The manual will address issues such as macroscopic and microscopic topographic effects, the impact of long slopes, slope aspect, etc., and their impact(s) on overall performance. The methodology explained in the manual would be such that one would start with a specific design and monitor it to verify performance and identify key mechanisms. The methodology would then include establishing monitoring systems to track the key elements of performance as the cover system "weathers" or evolves, and then integrate that performance into landscape scale issues such as hydrology and loading to the environment.

Prediction was identified as a top priority for MEND, and has been addressed in this year's program through a project (the Prediction Manual) and as the key theme for a workshop (the 12th Annual BC ARD/ML workshop).

- **Manual of Methods for the Prediction of Drainage Chemistry for Sulphidic Rock.** MEND, with the support of The Mining Association of Canada, Natural Resources Canada, INAP, the Yukon, NWT, British Columbia and Ontario, has sponsored a project to update the Draft *Guidelines and Recommended Methods for the Prediction of Metal Leaching and Acid Rock Drainage at Minesites in British Columbia* (Price, 1997) making it applicable on a national scale. This draft document is in widespread use and is part of regulatory requirements for BC and Ontario and used internally by several multi-national mining companies. The objective of the updated Prediction Manual will be to create a prediction

"tool-kit" that provides clear, comprehensive guidance, without limiting options and approaches. The manual will be a critical review of the available methods, pointing out limitations, common errors and omissions.

- **Canadian Environmental Network (CEN) Project: Technology Transfer Opportunities.** In 2005 the CEN proposed that MEND provide technology transfer to local community groups regarding issues that fall within MEND's expertise. The North American Indigenous Mining Summit brought together Indigenous Peoples from throughout North America to share their stories, strategies, and solutions about how the mining industry has impacted their communities. The Mining Summit also sought solutions to mining projects that adversely affect the land, air and water, as well as the Indigenous peoples who rely upon these things. Impacts of mining projects from the proposal stage through to closed and abandoned mines were discussed. The Summit was held in Edmonton from July 27 to 30, and was by "invitation only". Ninety participants attended from the communities-of-interest, with MEND invited as a special guest. MEND representatives were invited as technical experts to present two workshops on best practices for managing acidic drainage and prediction. The Summit was organized and hosted by the Western Mining Action Network and the Indigenous Environmental Network. This was an excellent technology transfer opportunity for MEND.

MEND was/is involved in the organization of the following workshops and conferences for 2005/2006:

- "2nd Symposium 2005 on Mines and the Environment", which was held in Rouyn-Noranda on May 15 to 18, 2005. A total of 195 delegates from eight different countries attended the conference and trade exhibit. Presentations at the workshop were divided into seven main technical research areas: mill tailings, underground backfill, waste rock, contaminated water, toxicity, regulations and sites and abandoned mines rehabilitation.

- 12th Annual BC/MEND ML/ARD Workshop. The 2005 workshop is planned for Vancouver on November 30 and December 1, 2005. The main topic will be Challenges in the Prediction of Drainage Chemistry from Rock Weathering. Presentations included case studies of:
    - operational material characterization;
    - prediction prior to mining or mine closure;
    - lessons learnt about different prediction procedures; and
    - temporal changes in weathering and drainage chemistry.
- 7th International Conference on Acid Rock Drainage (ICARD) in St. Louis, Missouri in March 2006.

Technology Transfer

An integral part of MEND is technology transfer - the dissemination of information on developed technologies to the partners and the public. Information is transferred through a number of routes, including the MEND Monitor newsletter, conference presentations, MEND report release announcements, workshops and conference notifications. The MEND Secretariat is located at the federal Department of Natural Resources Canada, and has strong ties to both policy and science. A MEND web site (**http://mend.nrcan.gc.ca**) is regularly updated with information and contains links to other relevant initiatives. The MEND network consists of about 2000 stakeholders who regularly receive relevant information on MEND and other multistakeholder initiatives such as NOAMI (National Orphaned and Abandoned Mines Inititive) and the Global Alliance.

Global Alliance

The International Network for Acid Prevention (INAP) was formed in 1998 by a number of international mining companies dedicated to reducing the liabilities associated with sulphide-bearing mine materials. In 2003, INAP established an international partnership among regional organizations involved in acidic drainage (INAP, MEND, Acid Drainage Technology Initiative (ADTI – Coal, ADTI – Metal (USA)), the Australian Centre for Minerals Extension and Research (ACMER), and the Partnership for Acidic Drainage Remediation in Europe (PADRE)). The Global Alliance partnership between INAP and the regional organizations

brings numerous benefits to the partners, including additional resources, minimization of research duplication, worldwide links and enhanced technology transfer capabilities.

An immediate benefit to the alliance is a greater understanding of the activities of each organization and the joint support of projects that are of mutual interest, as noted above for the Diavik waste rock study.

Conclusions

Canada is well known for establishing multi-stakeholder initiatives that address issues of national importance. These initiatives, applied both nationally and internationally, have been models for cooperation among industry, various levels of government, NGOs and First Nations. MEND is only one of many successful multistakeholder initiatives in Canada.

Sustainable development has become a driving force in how the mining industry approaches all existing and future activities. Progress has been made to advance environmental performance and stewardship and provide benefits to civil society. Mining companies, governments and consultants have acquired a great deal more capability to deal with environmental and societal issues such as water contamination from mine wastes, including acid generation. It is especially important in the environmental area to ensure that government policy is underpinned by sound science. The benefit of the collaborative programs has come through the sharing of experiences, the thorough evaluation of technologies and their incremental improvement.

Through these multistakeholder initiatives, a significant advancement in environmental performance and the understanding of sustainable development as it relates to mining and society is achieved.

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