The Canadian MEND program – the first twenty-five years

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ABSTRACT

Acidic drainage has long been recognized as the largest environmental liability facing the mining industry, and the public through abandoned mines. In 1989, provincial and federal governments, and the Canadian mining industry formed a consortium called Mine Environmental Neutral Drainage (MEND), to develop technologies and strategies to prevent and reduce acidic drainage.

The MEND program focussed the effort to develop technologies to reduce the effect of acidic drainage, and examined four key areas; prediction, prevention and control, treatment and monitoring. A toolbox of technologies was developed to plan for, operate and decommission mines in an environmentally acceptable manner. In 2002, a multi-year research strategy was put in place, based on regional priorities established by an extensive network of Canadian experts. On the world stage, through the Global Alliance, MEND has forged international partnerships among other organizations involved in acidic drainage research.

MEND's continued success lies in its collaborative multistakeholder approach, with members from two levels of government, the mining industry, and non-governmental organizations working on a common problem. Today, the MEND model of co-operation is copied in Canada and internationally to tackle both policy and science-based challenges.

Technology transfer remains central to MEND's activities. MEND has published over 200 technical reports and guidance documents; these are now all available on the MEND website. Workshops are considered the best route for timely and efficient transfer of technologies and case studies, and MEND has sponsored or co-sponsored over 40 workshops, including the hosting of three ICARDs. As a result of the efforts of MEND and other partners, our understanding of acidic drainage has greatly increased, and significant advances have been made in environmental stewardship.

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Keywords: Multistakeholder, consortium, MEND

CANADA'S ROLE IN ACIDIC DRAINAGE AND THE MEND PROGRAM

Canada's research into acidic drainage technologies started in the 1970's and 1980's and focussed on tailings from metal mines. Canadian mining companies and the Government of Canada recognized the serious impacts of acidic drainage from mining activities on the environment, and the projected enormous liabilities for Canada and the mining industry. Extensive research was undertaken to develop methods to establish vegetative growth on tailings in an attempt to alleviate and prevent acidic drainage. These efforts were successful in revegetation of tailings sites, but did not improve water quality. There was a realization that this was not a sustainable solution – and the mining industry was left with few options to deal with acidic drainage, namely perpetual lime treatment. There was need for a better understanding of processes involved, and for new remedial technologies to be developed and demonstrated; a concerted effort was required.

The National Uranium Tailings Program (NUTP) (1983-1988) provided an early model for an acidic drainage program. NUTP's mandate was to develop predictive models to reduce liability for uranium mine tailings, the primary concern being the isolation of low levels of radioactivity. However, the research soon concluded, as it was realized that the real concern was acid generation from the residual sulphides in Ontario uranium tailings. This realization combined with the concerns of base metal and gold mining companies and government agencies led to the establishment of the Reactive Acid Tailings Stabilization (RATS) Task Force in 1986. One of the key lessons learned from NUTP was that more stakeholder involvement was necessary for any future multistakeholder program. The RATS Task Force was created with representatives from the mining industry, and federal and provincial governments. They produced a multi-year research plan and recommended that a coordinated approach be used to carry out the program. In addition to acidic drainage from tailings, it was quickly realized that waste rock was also a major source that had to be dealt with. Consequently, a new name was adopted, the Mine Environment Neutral Drainage (MEND) program. In 1988 the MEND consortium was launched and charged with the following two key objectives; (i) to provide a comprehensive information base to allow the mining industry and government agencies to establish long-term management requirements for reactive tailings and waste rock; and (ii) to establish techniques that permit the operation and closure of acid generating mine waste disposal areas in a predictable, affordable, and environmentally acceptable manner.

MEND (1989 - 1997)

Initially, a budget of $12.5 million Canadian over five years (1989-1994) was allocated for MEND research. MEND was a tripartite consortium that included the Canadian mining industry, 5 provincial governments and the Federal government of Canada. MEND was an unusual consortium, driven primarily by the 130 volunteer representatives of the different participating agencies; including regulators, mining company managers and engineers, and government officials and scientists who freely contributed their time and expertise. The program adopted an organizational structure that included a Board of Directors, a management committee and several technical committees, and a coordinating secretariat. Roles were simple. The Board of Directors provided vision and approval of annual plans and budgets; the management committee provided "hands-on" management of the program; and the technical committees addressed technological issues and solutions. The Secretariat was essentially the "hub" of the organization and ensured

coordination of the elements within, and external to MEND. NRCan, with a long history of mining R&D and mineral economic policy and an extensive network across Canada, was a natural fit for the Secretariat.

The research and development program focussed on four cornerstones: prediction, prevention and control, treatment and monitoring. The objectives for each area were:

Prediction: To develop better techniques to predict acid generation from mine waste material, as well as the rate and effect of acid generation, and to develop mathematical models to simulate acid generation processes.

Prevention and Control: To develop techniques to minimize or prevent acid generation, and to demonstrate these techniques in the field.

Treatment: To develop and demonstrate chemical and passive treatment systems, and to examine lime treatment sludge stabilization methods.

Monitoring: To develop new technologies to improve site monitoring of acid drainage, to develop field sampling methods and analytical reference standards, and to develop closure criteria.

In 1992, MEND revised its research plan to narrow its focus, solicit research on a competitive basis, increase its technology transfer and international liaison roles, and encourage innovation and the testing of new ideas. The plan extended MEND to a 9-year program, with an expanded budget of $18 million C$.

The Liability and the Results

In 1994, Natural Resources Canada surveyed mining companies and provincial databases to determine the amount of acid generating materials; an estimate of 1,900 Mt of tailings and 750 Mt of waste rock was obtained (MEND 5.8e, 1994). Geocon (MEND 5.8.1, 1995) estimated the associated liability at between $1.9 billion and $5.3 billion C$.

An evaluation of the MEND program was undertaken in 1996 by Young and Wiltshire (MEND 5.9. 1996). The survey concluded that liability had been reduced by $340 million C$ for five mine sites, alone. It was also acknowledged that the reduction in liability is significantly higher than this quoted value, with a minimum of $1 billion C$ commonly accepted by the mining industry. This was an impressive return on an investment of $17.5 million C$ over eight years. Other observations underline the value of the MEND program to Canadian science and policy:

- Increased diligence by regulators, public and industry
- Greater common understanding of issues and solutions
- Research has led to reduction in environmental impact
- Recognition of MEND as a model for industry-government co-operation
- The need to continue and strengthen international connections

As a result of MEND and associated research, technologies are in place to open, operate and decommission a mine property in an environmentally acceptable manner, both in the short and long term. This can have a major impact on new mine financing and development. Moreover, mining companies and consultants have acquired a great deal more capacity to deal with water contamination from mine wastes, including acid generation. Canada gained a reputation for expertise in dealing with acidic drainage issues, and that advisory expertise was sought internationally. MEND fostered working relationships with environmental groups, ensuring that they are an integral part of the process.

Over the first ten years, the two levels of government, together with the Canadian mining industry, spent over $17.5 million C$ within the MEND program to find ways to reduce the estimated liabilities. Planned funding for MEND was divided equally among the three major partners: the mining industry, the federal government and five provincial governments. When the first round of funding ended in December 1997, the federal government had contributed 37% of the funding, the provinces 24%, and industry 39%.

By 1997, about 200 MEND projects were completed across Canada. Some of the key technical results and observations are noted below; these are still important areas for MEND research today.

- Prevention is the best strategy. Once sulphide minerals start to react and produce contaminated runoff, the reaction is very difficult to stop.
- Prediction ensures that extraction of minerals occurs with minimal impact on the receiving environment. Chemical prediction methods, procedural manuals, and predictive models were developed and applied to predict the geochemical behaviour of wastes.
- In Canada, the use of water covers and underwater disposal are being confirmed as the preferred prevention technology for unoxidized sulphide-containing wastes. This technology is well suited to Canada geography and climate.
- Dry covers can be applied as effective oxygen and infiltration barriers. Innovative research has shown that a range of materials, including low cost waste materials from other industries (lime stabilized sewage sludge, paper mill sludge) may provide excellent potential for generating oxygen-reducing surface barriers. Non-acid generating tailings and membranes were also evaluated as covers.
- Studies verified that sludges will remain stable, if properly disposed. Concerns had been raised about the long-term chemical stability and the potential liability arising from dissolution of heavy metals contained in the sludge.
- In Canada, experience indicates that passive systems have niche applications for acidic drainage treatment. These range from complete systems for treating small seeps to secondary treatment systems, such as effluent polishing ponds.
- Several other disposal technologies were also investigated, including permafrost, using an elevated water table and in-pit disposal.

The MEND program cemented Canada's leadership in research into acidic drainage technologies applied to metal mines. Technology transfer activities were an important element of the 1987 – 1997 MEND program and were significantly expanded in its last few years. The dissemination of information on developed technologies to partners and the public is a major function of MEND and must continue.

MEND 2000 (1998 - 2000)

The MEND program concluded in 1997 and had achieved tremendous progress in reduction of liability. Partners agreed that additional work was needed to broadcast the research information, and to verify MEND-developed technologies in the field. A stream-lined program was established, funded by the Mining Association of Canada and Natural Resources Canada. The focus was on promoting technology transfer, monitoring and completing MEND-initiated projects, and providing an essential link among industry, governments and environmental organizations.

One of the key deliverables for MEND 2000 was the six-volume MEND Manual. This manual consists of a detailed summary volume, and five technical volumes addressing acidic drainage issues: sampling and analyses; prediction; prevention and control; treatment; and monitoring. The information from the more than 200 technical reports and workshop notes produced under MEND is compiled in this manual. The manual provides practitioners in the Canadian industry and government with a single reference on acidic drainage for the diverse and complex research undertaken during the MEND program. Given that acidic drainage is a highly technical area, where site-specific influences likely necessitate site-specific investigations and evaluations, the manual is not a "how to" document.

The transfer of information on developed technologies to partners and the public has always been an important part of MEND. A bilingual website http://mend-nedem.org was created in the 1990's and underwent several major updates as technologies advanced. For example, paper copies of MEND reports were originally ordered on-line; they are now all available electronically, for free, on the website. The website contains over 200 MEND reports and related publications, and features an advanced search function to enhance site accessibility.

Over its 25 years, MEND hosted over 40 workshops and conferences on key areas of technology at locations across Canada. These events were a successful and popular way to transfer current information. Each year the annual BC-MEND ARD/ML Workshop invites case studies and technical presentations from leading practitioners. In recent years, the workshop consistently attracted over 200 delegates. This workshop is regarded as one of best values for money events. Links were also established with international organizations involved in acidic drainage research, such as INAP (International Network on Acid Prevention), ADTI-USA (Acid Drainage Technology Initiative), and CETEM (Brazil).

MEND (2001 - 2015)

Sustainable development is a strong driving force for industry in dealing with environmental and societal issues such as water contamination from mine wastes. The MEND program focussed on developing technologies to reduce the effects of acidic drainage, and developed a toolbox of technologies to plan for, operate and decommission mine properties in an environmentally acceptable manner. Although the original MEND Program and its successor, MEND 2000, made major contributions to prevention and management of acidic drainage, it remained a significant environmental issue.

In 2001, funding was provided for a renewed MEND initiative focussing on regional and national needs. A Gap Analysis report (MEND 8.1, 2002) was completed to identify opportunities to advance acidic drainage research, along with a list of regional research needs. Subsequently, a multistakeholder expert Strategy Session was held in 2002, and a number of activities were proposed for a multi-year program (MEND 8.2, 2002). A questionnaire was distributed to the Canadian MEND network to help define research activities. The top-ranked priorities were closure management, verification of technologies, metal (neutral) leaching, passive treatment, early prediction, sludge management, cold temperature effects and paste backfill. Guidance documents and manuals, workshops and other technology transfer activities were identified as important issues that cut across all priorities.

Based on the widespread support from all stakeholders, a recommendation was made to move ahead with a renewed MEND with a research program that focused on these top priorities.

Funding was provided by the Mining Association of Canada, with support from other government departments and in-kind support from the project contractors.

Since 2003, the MEND Steering Committee developed an annual work plan to address many of the key research priorities. Many of these new projects re-examined issues and re-visited sites that were the subject of earlier MEND studies. Advances in technologies and knowledge made it timely to re-examine some of these issues. As well, several projects verified the full-scale application of MEND supported technologies, and investigated their long-term performance. There have been some shifts in priorities since 2003, with a greater interest in best management practices, cold temperature issues, guidance documents and more recently, regulatory concerns.

Several MEND reports, activities or project areas in the past five years are outlined below.

Accurate and timely prediction of acidic drainage and metal leaching is central to prevention of potential environmental impacts, and to minimize the high costs of mitigation. Prediction of drainage chemistry is a technically challenging subject, involving numerous methods, properties and processes. The *Prediction Manual for Drainage Chemistry from Sulphidic Geologic Materials* (MEND 1.20.1, 2009) provides a comprehensive document for use by technical experts or practitioners to conduct a prediction program and/or review the results. It is also a reference document for the public, educators or students studying or reviewing drainage chemistry.

With the large number of mines opening in Northern Canada, the effect of cold temperature on various technologies is of increasing importance. Research was conducted across a number of areas including dry covers. In 2004, MEND produced the *Dry Covers: Design, Construction and Monitoring of Covers Systems for Waste Rock and Tailings* (MEND 2.21.4), which integrated the best available technology for the design and construction of cover systems over mine wastes. One of the key gaps identified was the application of covers in the cold regions. Three projects were completed. The first, *Mine Waste Covers in Cold Regions* (MEND 1.61.1a, 2009), reviewed soil covers on mine waste in cold regions. Several dozen cold region processes were identified that could affect soil covers. In the second project, *Cold Regions Cover Research* (MEND 1.61.5b, 2010), cold region phenomena that could impact soil cover performance, including ground freezing, snow-distribution, and limits to revegetation were reviewed. The third report, *Cold Regions Cover System Design Technical Guidance Document* outlined the current state-of-knowledge of soil cover system design in cold regions, best practises on how a cover system design should be conducted, and a summary of information that should be provided during the design process (MEND 1.61.5c, 2012).

Climate change poses several risks to mining operations. MEND completed a high-level risk analysis on climate change, *Climate Change and Acid Rock Drainage – Risks for the Canadian Mining Sector* (MEND 1.61.7, 2011). It focuses on risks associated with acid rock drainage and metal leaching produced from mining activities. At mine sites, the prevention and management of acidic drainage includes the management of water, tailings and waste rock. Therefore, climate change risks related to acidic drainage arise from the impacts of a changing climate on water-management structures and activities, on waste-impoundment structures, and on the hydrologic/ hydrogeologic/ geochemical conditions affecting the flow of water and contaminants at mine sites. Previous studies on climate change impacts in Canada identified a range of potential impacts for the mining sector, including those on acidic drainage. This assessment builds on previous work by looking more closely at the impacts for specific infrastructure elements and determining which are most probable and significant for mining operations and for society.

Acidic drainage treatment and sludge management are important aspects of mine site environmental control practices. Sludge production is of increasing concern to industry, as the

inventory of sludge continues to grow from "perpetual pump and treat" operations. Several MEND projects were completed in sludge treatment and disposal, stability and re-use. The most recent is a survey of mine drainage treatment and sludge management practices titled *Acidic Drainage Treatment Operations in Canada – An Interactive Database* (MEND 3.43.1, 2013). Data on treatment practices and sludge management were collected on more than 100 Canadian and international sites. A comprehensive database, containing an extensive number of parameters, was developed to store the information. This report offers many potential uses and information for treatment processes with respect to planning and guidance.

MEND's latest report *Study to Identify BATEA for the Management and Control of Effluent Quality from Mines* identified the best available technologies economically achievable (BATEA) to manage and control effluent from metal, diamond, and coal mines in Canada (MEND 3.50.1, 2014). The study provided reference information for potential forthcoming changes to the Canadian mining effluent regulations. The study described the effluent management and treatment technologies and techniques currently employed at metal (base metal, precious metal, uranium, iron ore), diamond and coal mine operations in Canada. The study identified effluent treatment technologies that could be considered best available technologies (BAT) for the Canadian mining sector. The technologies were screened against a set of criteria, and those that satisfied them were carried forward for consideration as BATEA. Cost estimates were prepared based on capital and operating cost data from vendors and operations, in-house information and literature. Ultimately, BATEA for any given mining operation is site-specific. There are a multitude of geographic and operational factors to be considered that influence effluent quality, impact the technical feasibility of treatment technologies, and dictate financial constraints on capital and operating expenditures that can be borne by operations while still maintaining economic viability.

Another key and highly successful activity of the MEND program was hosting the 9th International Conference on Acid Rock Drainage (ICARD), in Ottawa in May 2012. The event attracted 526 delegates from 19 countries, and featured a conference program that was creative, thought-provoking and entertaining. The technical event covered eight pre-conference short courses (~ 250 participants), an exciting plenary session with experts representing industry, government and civil society, three-days of oral and poster paper presentations by world- leading practitioners (127 presentations and 43 posters), a trade show with 25 exhibitors and a two-day field trip to Northwest Quebec where four mine sites were toured. A social highlight was the banquet at the Museum of Civilization, with entertainment provided by the Painchaud Family assisted by several members of the audience. The proceedings and PowerPoint presentations are available on the MEND web site at http://mend-nedem.org/9th-icard/

CONSORTIUM APPROACH

In the 1980's, a collective approach for governments and industry to cooperate in technology development for advancing environmental management in the mining industry emerged in Canada. The MEND program was the first multistakeholder program to develop scientifically based technologies to reduce the effect of acidic drainage for metal mines. This approach allows policy decisions to be made based on sound science. Since then, this model of collaboration was used by both Canadian and international programs to address issues of national importance. For example, the National Orphaned and Abandoned Mines Initiative (NOAMI) adopted the MEND model to develop a policy-based program for remediation of orphaned and abandoned mine sites

in Canada (http://www.abandoned-mines.org). The success of these programs can be attributed to several factors.

- The partnerships developed among the two levels of government, the mining industry, and environmental groups working together to develop solutions to a major environmental problem.
- An extensive peer-review process, both formal and informal, resulted in enhanced credibility of the information base.
- A small dedicated secretariat that coordinated activities, managed the accounting, reporting and technology transfer, and served as the "glue" that held the program together.

GLOBAL ALLIANCE AND THE GARD GUIDE

Through the years, linkages with other international organizations were maintained by sharing information via conferences, workshops, reports and other publications. In 2002, INAP formally proposed an international model of interaction among organizations involved in acidic drainage research. In 2003, the Global Alliance (GA) partnership was launched. The GA brings numerous benefits to the partners, including minimizing research duplication, maximizing research dollars, worldwide links, and enhanced technology transfer capability.

One important example is the Global Acid Rock Drainage (GARD) Guide, which was published by INAP with support from the GA. The MEND Manual MEND 5.4.2 (2001), described earlier, was one of the key references used to develop the GARD Guide. The Guide described proven technologies to address ARD and ML, and considered climate, geographic and environmental factors and coverage for all stages of mine life. Another project is the Diavik Waste Rock Scale-up Study undertaken by three Canadian universities with support from the Canadian government, INAP and MEND. This project provides great value for Canada; many graduate students have completed their degree work at this site and many publications have been produced.

CONCLUSION

MEND is a good example of a successful, multistakeholder initiative addressing a technical issue of national importance, and is a model for cooperation among industry, various levels of government and environmental groups. The MEND program provided a focus to develop solutions for environmental problems that face the mining industry across Canada and internationally. Through the 25 years of the MEND program, a significant reduction in environmental liability was achieved. MEND is now recognized world-wide for its contribution to the long-term sustainability of the industry and the environment. Although much progress has been made, new challenges are emerging that will require concerted efforts by MEND and other research organizations.

ACKNOWLEDGEMENTS

Thank you to the many dedicated volunteers who over the 25 years of the MEND program so generously contributed their time and expertise.

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