Energy, Mines and Resources Canada | Énergie, Mines et Ressources Canada

CANMET

Canada Centre for Mineral and Energy Technology | Centre canadien de la technologie des minéraux et de l'énergie

AN OVERVIEW OF ACID MINE DRAINAGE RESEARCH IN CANADA

J.E. Udd
Mining Research Laboratories

K. Ferguson
Mining and Metallurgy Program, Environmental Protection,
Conservation and Protection, Environment Canada,
West Vancouver, B.C.

MAY 1988

Presented by K. Ferguson at the International Conference on Control of Environmental Problems from Metal Mines, Røros, Norway, June 20-24, 1988

and

Published in the proceedings.

MINING RESEARCH LABORATORIES
DIVISIONAL REPORT MRL 88-37 (OPJ)

AN OVERVIEW OF ACID MINE DRAINAGE RESEARCH IN CANADA

by

J.E. Udd* and K. Ferguson**

ABSTRACT

Acid mine drainage (AMD) is recognized as one of the most significant environmental problems facing the mining industry in Canada. Not only can it cause severe environmental impacts, but it can strain the financial resources of a company. AMD can continue to be produced for decades, centuries, or perhaps millennia after mining has ceased. The solution to the AMD problem has been divided into four areas: prediction, prevention, treatment and control. Two task forces have recently been formed in Canada to coordinate AMD research. The national Reactive Acidic Tailings Study (RATS) was established to examine the problem associated with acidic tailings. In 1987 the program was expanded to include research related to AMD from open pits and waste rock. The second research group is the B.C. task force established in February, 1987 to focus on some unique aspects of the AMD problem in the Province of British Columbia, including emphasis on waste rock, pre-mine prediction and environmental monitoring. This paper outlines the history of these task forces, examines their structure and objectives, and summarizes ongoing research and possible future research topics.

---

* Director, Mining Research Laboratories, CANMET, Energy, Mines and Resources Canada, Ottawa, Ontario.

** Head, Mining and Metallurgy Program, Environmental Protection, Conservation and Protection, Enviornment Canada, Kapilano 100, Park Royal, West Vancouver, B.C.

Keywords

Acid Mine Drainage, AMD, British Columbia, Canada, mine waste, mill tailings, monitoring, pollution abatement, RAT, reactive tailings, research.

par

J.E. Udd* and K. Ferguson**

RÉSUMÉ

Les eaux acides de mines (EAM) sont reconues comme l'un des plus sérieux problèmes environnementaux auxquels l'industrie minière est confrontée au Canada. Non seulement entrainent-elles un impact environnemental majeur, mais elles peuvent en plus réduire les ressources financières des sociétés. Les EAM peuvent continuer à être généreés des decernnies, des siècles et peut-être des millénaires aprs la cesation de l'activité minière. Le solution au problème des EMA a été divisée en quatre secteurs: prédiction, prévention, traitement et contrôle. Deux groupes dédiés d'internenants ont récemment été constitués au Canada, afin de coordonner la recherche sur les EAM. Le groupe national d'étude des résidus reactifs acides (ERRA) a été formé pour étudier le problème des résidus acides. En 1987, le programme fut élargi pour incorporer la recherche sur les EAM d'exploitations à ciel ouvert et des haldes à stérites. Le second groupe de recherche est le groupe dédié de Colombie-Britannique, constitué en février 1987 et qui concentre ses efforts à solutionner certains aspects du problèmes des EAM particuliers à la probince, identifiant notamment les haldes de stériles, la prédiction avant exploitation et le contrôle environnemental à l'aide de moniteurs. L'article décrib l'historique de ces groupes dédiés d'internenants, analyse leurs structure et objectifs, et résume la recherche en cours et les futurs sujets de recherche possiles.

---

* Directeur, Laboratoires de Recherche minière, CANMET, Energie, Mines et Ressources Canada, Ottawa, Ontario.

** Chef, programme de mines et métallurgie, protection environnementale, Conservation et Protéction, Environnement Canada, Kapilano 100, Park Royal, Vancouver Ouest, B.C.

Mots-Clés

Eaux acides de mines, EAM, Colombie-Britannique, Canada, stériles,

TABLE OF CONTENTS

TABLES

AN OVERVIEW OF ACID MINE DRAINAGE RESEARCH IN CANADA

INTRODUCTION

The Canadian mining industry is becoming increasingly concerned with the long-term implications of managing the solid wastes which it produces. It has been estimated that some 500 million tonnes of mill tailings and waste rock are produced annually. Much of these wastes contain sulphide minerals, which, upon weathering, produce sulphuric acid (acid mine draingae - AMD). The acid, in turn, unless confined and treated, can transport heavy metals into the environment.

At present, mining and environmental regulations require that there be treatment systems for the AMD. The long-term objective is to design systems which will function not only during the operational phase of mining operations but also long after decommissioning has taken place. The industry is greatly concerned that there is no technology presently available which will permit mine operators to be able to "walk away" from solid wastes with any degree of confidence.

In the past, before people were aware of the long-term environmental impacts of mining operations, and when regulations for waste management were less demanding, there was much less treatment of the drainage from mine wastes. In the light of current knowledge and environmental goals, there are many sites in Canada which could require rehabilitation. It has been estimated that about 14 000 hectares are affected, of which 9 000 hectares are occupied by mill tailings and the remainder by waste rock. It has also been estimated that the clean-up costs during the next 15 years could exceed 1,5 billion $ Canadian.

THE REACTIVE ACIDIC TAILINGS STUDY (RATS)

History

During the early 1980's, the Canada Centre for Mineral and Energy Technology, CANMET, was responsible for a National Uranium Tailings Program, referred to as the NUTP. Coordinated through a special office of CANMET, the program was designed to address concerns regarding the safe disposal of mineral wastes from Canadian uranium mines and mills. The studies which were part of the NUTP included: mathematical modelling of tailings systems; monitoring of conditions at disposal sites; evaluations of potential disposal technologies; and control techniques - including re-vegetation. Although the program was formally concluded during the 1986-1987 fiscal year, there are aspects of it (such as the monitoring of the Rio Algom Nordic Mines tailings site, at Elliot Lake, Ontario) which have continued.

While the NUTP was in progress, studies were made to determine the extent of the problems of acid mine drainage from tailings and waste rock. The first study, by MONENCO (1984) related to mine tailings and the second, by Nolan, Davis and Associates (1987), addressed the problems of waste rock.

Concurrently, in 1986, in response to a collective need to develop technologies for the prevention and control of acid mine drainage, the Reactive Acid Tailings Stabilization program, RATS, was born. A Steering Committee, to provide overall direction, and a Technical Working Group, to develop, monitor, and manage the projects, were formed comprised of members representing the Canadian mining industry and the federal and provincial governments. The committees are chaired by members from the industry; the Steering Committee by Dr. F. Frantisak, of Noranda, and the Technical Working Group by Mr. C. Ferguson, of INCO. The present membership of the two groups is shown in Tables 1 and 2.

TABLE 1

RATS PROGRAM - STEERING COMMITTEE

Wm. A. Bardswich	Director, Mines	Manitoba
V.E. Dawson	Chief, Inspector, Mines	British Columbia
R. Duquette	Ministry of Environment	Quebec
C. Ferguson	Director, Environment	INCO
F. Frantisak*	Vice-President, Environment	Noranda
W. Fraser	Director, Environment	H.B.M. & S.
Wm. Gibson	Director, M.O.E.	Ontario
G.J. Greer	Director, Mineral Development	New Brunswick
E.G. Joe	CANMET, MSL	Canada
D. Kelly	Director, Environment	Canada
J. LeBois	Energie et Ressources	Quebec
D. McKay	Manager, Research	Cominco
F. Pickard	Vice-President	Falconbridge
L.L. Sirois	Director, MSL, CANMET	Canada
W.D. Tieman	ADM, Mines & Minerals	Ontario
J.E. Udd	Director, MRL, CANMET	Canada

*Committee Chairperson

TABLE 2

RATS PROGRAM - TECHNICAL WORKING GROUP

B. Bell	INCO
M. Campbell	CANMET
D. Cook	Manitoba
N. Davé	CANMET
J. Errington	British Columbia
C. Ferguson*	INCO
K. Ferguson	Environment Canada
W. Fraser	H.B.M. & S.
B. Gardiner	Cominco
J. Hawley	Ontario
E.G. Joe	CANMET
S. McEwan	New Brunswick
R. Michelutti	Falconbridge
R. Patterson	Equity Silver
J.-M. Robert	Quebec
Wm. Scheding	Curragh Resources
J. Scott	Environment Canada
R. Siwik	Noranda
R. Tervo	CANMET
K. Wheeland	Noranda

*Committee Chairperson

5

During the past two years both groups have met on several occasions. Program planning is now at a very advanced stage - with individual projects determined, and estimates of times, resources, and costs, made. It is visualized that the costs of the program will be shared equally by the mining industry, the provincial governments, and the federal government, and efforts are now underway to secure the funding. The total cost over a five-year period is estimated at 12,5 million $ Canadian. A concerted effort is being made to enlist support from all possible "stakeholders", including the Mining Association of Canada, and the several provincial Mining Associations.

Proposed Studies

The proposed program, which has evolved after two years of planning and discussions, addresses research in the management of both mill tailings and waste rock. The projects may be grouped under five main headings, which are: Prediction; Prevention and Control: Treatment; Monitoring; Technology Transfer. The titles of the individual projects are shown in Tables 3 to 7, inclusive.

The projects under the heading of "Prediction" are directed at improving the techniques for predicting whether or not a particular site will prove to be a problem in the future. Because much more is known of the process of acid generation in mine tailings than is known for open pits and waste rock dumps, the emphasis will be placed upon the latter aspects. Field studies, involving hydrogeochemical techniques are planned at three open pits and two waste rock dumps. An evaluation will also be made of all current predictive techniques, with a view towards determining the most promising tests for tailings. That work is underway.

Baseline and detailed characterization studies are also planned for two major tailings sites. It is expected that the results of the baseline studies, to be conducted at the Waite Amulet and Faro sites, will provide data for the development of predictive models and assessments of engineered covers for control purposes.

Also, it is proposed that mathematical models for the prediction of acid generation should be developed for tailings ponds, open pits and waste rock dumps.

Previously, some models were developed under the NUTP. These will be of great benefit to the RATS program research.

TABLE 3

RATS PROGRAM - PROJECTS PROPOSED - PREDICTION

Literature review of waste rock acid generation	1.11
Compilation of prediction information from waste rock dumps, open pits, tailings sites	1.12
Evaluation of prediction techniques for waste rock sites	1.13
Field evaluation of hydrochemistry of waste dumps	1.14
Field evaluation of acid production from open pits	1.15
Evaluation of prediction techniques for tailings	1.16
Hydrogeochemical investigation of the Waite Amulet tailings site	1.17
Hydrogeochemical characterization of the Faro tailings site and sub-sites	1.18
Development of a model to predict acid generation in tailings and evaluation of control technologies	1.21
Modelling of acid generation in waste rock and open pits	1.22

TABLE 4

RATS PROGRAM - PROJECTS PROPOSED - PREVENTION AND CONTROL

Evaluation of underwater disposal sites	2.11
Evaluation of underwater disposal in open pits	2.12
Evaluation of underwater disposal in flooded tailings sites	2.13
Establishment of vegetative wetlands over tailings	2.14
Engineered dry covers for tailings and waste rock	2.21
Assessment of the use of hardpan as a cover	2.22
Documentation of disposal methods for tailings and waste rock	2.23
A manual for vegetation techniques	2.24
Evaluation of alkaline trenches	2.34
Field evaluation of dry covers on waste rock	2.31
Laboratory & In-situ blending/segregation of waste rock	2.32
Construction of cellular dumps	2.33

TABLE 5

RATS PROGRAM - PROJECTS PROPOSED - TREATMENT

Evaluation of natural wetlands as passive treatment systems	3.11
Evaluation of constructed wetlands as treatment areas	3.12
Upgraded chemical treatment of acid mine drainage	3.21
In-situ treatment using chemicals/bactericides	3.22

TABLE 6

RATS PROGRAM - PROJECTS PROPOSED - MONITORING

A field method manual for tailings	4.1
A manual for analytical methods	4.2
Establishment of standard reference materials	4.3
Closure criteria for tailings and waste rock sites	4.4
A field methods manual for waste rock	4.5
Evaluation of monitoring technology	4.6

TABLE 7

RATS PROGRAM - PROJECTS PROPOSED - TECHNOLOGY TRANSFER

Review of NUTP documentation

Review of RATS reports and allied publications

Information acquisition from other key services

Liaison between project implementors and clientele

Overview report of the program

TABLE 8

RATS PROGRAM - ESTIMATED COSTS

Prediction	$3 765 000
Prevention and Control	$5 705 000
Treatment	$1 285 000
Monitoring	$ 385 000
Technology Transfer	$ 225 000
Contingency	$1 135 000
Total for the program	$12 500 000

The work proposed under the "Prevention and Control" set of projects comprises the major part of the RATS program. It is currently thought that because sulphide minerals can not produce acids without the presence of oxygen, the key to an effective control strategy lies in the development of effective oxygen barriers.

In one group of projects, evaluations will be made of underwater disposal sites at lakes, flooded open pits, and flooded tailings areas. The intent is to study alternative approaches and to establish disposal criteria. The feasibility of establishing wetlands over tailings areas, will also be studied. All of these projects may be characterized as involving "wet barriers".

In a second group of projects, the use of dry covers and hardpans as barriers will be evaluated. The former include covers such as clays, soils, tills, synthetic membranes, and cementitious materials. Existing methods for the disposal of tailings and waste rock will also be reviewed with a view towards the production of a reference manual. A second manual, referring to techniques for the establishment of vegetation on acid-generating tailings and waste rock, is also visualized.

In a third group of projects, the effectiveness of various control strategies, including cellular dumps, blending and segregation of waste materials, dry covers, and alkaline trenches, will be evaluated.

The overall objective of the projects proposed under the heading of "Treatment" is to develop passive treatment systems. It is assumed that, with better prevention and control strategies, less treatment

will be required in the future. Nonetheless, methods for long-term and continuing treatment must be found. Because of the high cost of treatment chemicals and their use, consideration will be given to both natural and constructed wetlands as alternatives. Improved methods of chemical and bactericide treatment schemes will also be evaluated.

There is also a need to develop improved techniques for the sampling and "Monitoring" of mine waste areas. The projects which are proposed in this aspect of the RATS program address both of these needs. Manuals are to be prepared to provide guidance on all facets of mine waste management (Table 6).

Finally, it is critical that the technology to be developed be transferred effectively. The work which is proposed under "Technology Transfer" all relates to this goal. The preparation of overview reports, project reports, information bulletins, and manuals, are all important. In planning, provision has been made to provide a level of funding which is considered to be adequate to ensure that this is done in a timely and effective manner.

The Technical Working Group has estimated that about five years will be required for the completion of the projects that have been listed. The assumption is that the program will be delivered by a wide range of participants, including both industrial and governmental organizations. As mentioned, efforts are now being made to explore the possibilities offered through various funding mechanisms. It is hoped that the program will be implemented at the earliest possible opportunity.

The costs that have been estimated are shown in Table 8. Since all estimates can only be regarded as "best guesses", a sum which is equivalent to about 10% of the total project cost, has been included to cover the costs of contingencies.

B.C. ACID MINE DRAINAGE TASK FORCE

The second group in Canada coordinating research into the problem of acid mine drainage is the British Columbia (B.C.) Acid Mine Drainage Task Force, established in March, 1987 by the B.C. Mining Association, mining companies, and Provincial and Federal Governments. The purpose of the task force is to focus on, and solve special concerns of AMD to B.C. These include the prediction and prevention of AMD from all mining wastes and the control of AMD from waste rock.

The comprehensive review and approval system (Mine Development Review Process - MDRP) for new mine projects in B.C. focuses attention on the prediction and prevention of AMD. All proposed mines are expected to conduct thorough studies to demonstrate that acid mine drainage can be addressed by technically sound and economically affordable means prior to mine construction. Laboratory techniques to predict AMD were developed in B.C. in the early 1970's and have been used extensively and further refined since that time. Considerable uncertainty remains, however, about the accuracy of prediction techniques and the effectiveness of proposed prevention plans.

The province contains about 72,000,000 tonnes of acid generating tailings, or about 4% of the total in Canada. However, there are about 250,000,000 tonnes of acid generating waste rock or 80% of the Canadian total, which is increasing by about 25,000,000 tonnes per year. As such, B.C. contains a disproportionate amount of acid generating waste rock and, therefore, the mining industry and regulatory agencies have a great interest in abating AMD from that waste type.

Like RATS, the B.C. AMD Task Force is divided into steering and technical committees. The latter committee is further divided into three subcommittees: prediction and prevention, treatment and control, and environmental monitoring. The goals of these subcommittees are:

Subcommittee	Goal
Prediction and Prevention	To review and evaluate prediction and prevention techniques
Treatment and Control	To find cost-effective methods to treat and control AMD
Environmental Monitoring	To establish protocol for environmental monitoring for AMD

The first activity of the task force was to define the state-of-the-art of AMD in B.C. A two-part, 24-page questionnaire (5 pages for Part I and 19 pages for Part II) was prepared. The questionnaire requested quantitative information on the type and amount of wastes produced, climate, geology, AMD potential testing, and physical characteristics of the mine wastes (water content, porosity, and particle site). General information and data availability questions were posed on mine operations, drainage quality, history of AMD, prevention of AMD, treatment and control techniques, and environmental monitoring. Part I of the questionnaire was sent in September 1987 to 94 mining companies in B.C. and Part II to only the 14 companies known to have an AMD problem. In February 1988, the responses were collated and forwarded to a consultant (Steffen, Robertson and Kirsten Ltd. - SRK) for analysis (SRK, 1988).

4. The Task Force should aim for answers within 3 years.

5. Research done elsewhere in the world should be integrated into the B.C. program.

6. The B.C. program should be reviewed by, and integrated into, the national RATS program.

7. Research programs should "piggy-back" existing studies conducted by companies and government agencies whenever possible to conserve resources.

These recommendations have generally been accepted by the technical committee of the Task Force although it is likely the research program will run 5, rather than 3 years (recommendation 4).

SRK also recommended some general and specific research projects. These projects were revised by the Technical Committee in April 1988 and a complete research program was developed (Table 9). This 3 million $Canadian program was submitted to the provincial government for approval and consideration for funding. Like RATS, the intent is to share the cost of AMD research (possibly 50-50) between government and the mining industry. A decision to proceed to implementation of this research program is expected in the near future.

TABLE 9

B.C. AMD TASK FORCE - PROPOSED PROJECTS

General	
Coordination of program and maintenance of database	BC 1.0
Draft technology guide for abatement of AMD	BC 1.1
Prediction and Prevention	
Characterization of AMD potential in tailings	BC 2.1
Evaluation of prediction techniques and modelling	BC 2.2
Effect of underwater disposal in preventing AMD	BC 2.3
Evaluation of subaerial tailings disposal system	BC 2.4
Prediction for open pits	BC 2.5
Treatment and Control	
Evaluation of waste dump hydrogeochemistry	BC 3.1
Effect of bioleaching at Gibraltar waste dump	BC 3.2
Evaluation of cover for Mt. Washington waste dump	BC 3.3
Alternatives for disposal of AMD treatment sludge	BC 3.4
Evaluation of wetland treatment	BC 3.5
Monitoring	
Optimization of sampling frequency	BC 4.1
Value of biological monitoring techniques	BC 4.2
Examination of sediment toxicity and remobilization	BC 4.3

SUMMARY

Acid mine drainage is now recognized as one of the most significant environmental problems facing the mining industry in Canada. The solution to the AMD problem has been divided into five areas: prediction, prevention, treatment, control, and monitoring. Much research is required to find and demonstrate economic solutions to the AMD problem in these five areas.

Two task forces have been established in Canada to coordinate the AMD research effort. The national Reactive Acidic Tailings Stabilization program (RATS), and the provincial British Columbia Acid Mine Drainage Task Force, have identified multi-million dollar, 5-year, research programs. Although these programs are still in the early stages of implementation, there is optimism that cost-effective solutions to the AMD problem will be found in the next few years. These solutions are necessary if Canadians are to continue to benefit from an economically and environmentally sound mining industry.

REFERENCES

MONENCO Ltd. (1984): "Sulphide Tailings Management Study", CANMET, Energy, Mines and Resources Contract Report, Ottawa, Ontario.

Nolan, Davis and Associates Ltd. (1987): "Study of Acid Waste Rock Management at Canadian Base Metal Mines", CANMET, Energy, Mines and Resources Contract Report, Ottawa, Ontario.

Steffen, Robertson and Kirsten (B.C.) Inc. (1988): "Acid Mine Drainage in British Columbia - Analysis of Results of Questionnaire from Acid Mine Drainage Task Force", Report for: B.C. Acid Mine Drainage Task Force, Vancouver, British Columbia.