AMD PREVENTION AND CONTROL METHODS USED IN CANADA

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For:
The THIRTEENTH ANNUAL WEST VIRGINIA
SURFACE MINE DRAINAGE TASK FORCE SYMPOSIUM

By:

George H. Hope

Manager, Mineral Processing
LAC Minerals Ltd.
P.O. 156, Toronto, Ont, M5J 2J4
Tel. (416) 777-2375 Fax(416) 777-2399

Acid mine drainage produced from metal mining residues has become a major problem in many areas in the world. Those most affected are operations that have mined large quantities of sulphide bearing ores in areas that have more rainfall than evaporation. In drier areas, where evaporation is much higher than rainfall, acidic drainage is much less of an issue. Thus it is easy to identify the areas of the world that are most susceptible to acidic drainage; Canada, the Northern States, the Scandinavian countries, parts of Australia and probably, major parts of what was previously the Soviet Union.

Although the problem has undoubtedly been around for many centuries, it was not until 198a that a sincere effort was started in Canada to identify the problem and start looking for solutions. It may seem difficult to understand why the investigation of this problem did not start earlier, but I believe there were two influences; we thought the solutions were reasonably simple i.e. grow some grass on it, and the general increase in public awareness of environmental concerns. Regardless, we are off and running and searching for solutions to a problem which is proving to be far more difficult and tenacious than originally anticipated.

Firstly to define the problem, "AMD". Within MEND, the term AMD has been abandon in favour of "Acidic Drainage" to reflect the more general nature of the problem. Acidic drainage is produced from the chemical and biological oxidation of inorganic sulphides and expresses itself as low pH waters containing deleterious quantities of various metal species.

Secondly to identify the problem. The original RATS (Reactive Acid Tailings Stabilization) Program in Canada was directed almost totally at sulphide tailings from base metal and gold mining operations as these were identified early on as the major problem. As time has passed and the program has evolved, we now realize that the waste rock piles created by our large open pit operations is a greater problem than that of tailings.. Th volume of material is frequently much larger than that of tailings, the particle size is much larger and less homogeneous, and the material is generally very porous allowing for unrestricted flow of both water and air through the piles.

The solution to the problem is not so easy. To begin with, we don't have any "Made in Canada,, solutions to the problem. We do have a significant effort being made to study the problem but we have probably come up with more new problems than we have solutions. During our recent MEND long term planning exercise, a list of what we knew or thought we knew before we started and what we now know was produced (Figure 1 and 2). Also, during this planning exercise, I have come to the belief that the program has two distinct targets; (1) treatment/closure etc. of existing dumps ' and (2) proper handling of new wastes to avoid the problem in the first place. We believe we are a lot further down the road on proper disposal of new wastes than we are on the handling of existing problems.

The aim of the MEND program has been identified as follows; develop solutions that are PREDICTABLE ' RELIABLE and AFFORDABLE leading to "WALK AWAY MINE CLOSURE". This is undoubtedly optimistic. We think we have now developed some solutions that are reliable, possibly predictable but probably not affordable. I stress 'probably', because solving environmental problems is never truly affordable. The solutions we are currently developing are certainly not cheap and they may well inhibit future developments in the mining industry but can we really afford not to do them. I leave that one to your imagination.

Having thus introduced the subject, I want to focus on some of the work that we have done in Canada with the idea to lead you through our philosophy and train of thought and as we proceed, to identify some areas that we consider of interest, some answers that we still require and some problems that we see no answers to. The areas I intend to foucus on include: (1) underwater disposal of fresh tailings, (2) post operational flooding of existing tailings, and (3) the placement of natural dry covers on both tailings and waste rock.

Underwater Disposal

Since 1988, a fairly significant study of four existing lakes which have had tailings deposited in them has taken place. These lakes include Mandy and Anderson in Northern Manitoba and Benson and Buttle in British Columbia. The studies on each lake included preliminary biophysical and detailed geochemistry. This initial effort was to determine what happens to the minerals when they are deposited underwater and can oxidation be prevented. No detailed biological study has been done for two reasons;(l) no background biological data was available before deposition took place so evaluation of damage to the biota is not possible and (2) we felt it better to find out if placement underwater prevented oxidation prior to more extensive (and expensive) biological studies.

The conclusions at the end of this phase of work are generally:

-The reactivity of the tailings material is low as illustrated by the low levels of dissolved metals (low ppb to ppt range) thus confirming the original hypothesis.

-The basic physical conditions detected in each lake has allowed estimates of the basic chemical mechanisms which may be acting to maintain low reactivity conditions in and around the deposited tailings.

-The biological community in a natural lake will be degraded by the deposition of tailings,

-Biological communities exist in some of the lakes studied indicating therefore that the lakes can recover given sufficient time.

Having drawn these conclusions, and after a thorough peer review, the following comments can be made;

-Underwater disposal is a good procedure to prevent oxidation of potentially acid generating tailings,

-Public acceptance of placing tailings in a biologically active lake, particularly when we can demonstrate short term impairment, is unlikely. Extensive biological studies to evaluate the biological impact may not be worthwhile if natural lake disposal is not acceptable under any circumstances.

-Two alternatives to partially impairing a large, active lake have been suggested;

1. Selection of a small, well contained lake and accepting that the biota will suffer major, if not complete, impairment during the active tailings deposition phase. This effectively means that the appropriate government ministry would have to write the lake off but anticipating that some form of lake type of environment could be returned, this may be negotiable.
2. Creation of a lake through the construction of low permeability dams and the provision of an adequate water supply to assure water cover. Since this latter case does not require the impairment Of an aquatic environment, and may in fact create such an environment on closure, this may be the most politically acceptable method.

Some of the issues that have been raised, and must be answered, in regards to underwater disposal of tailings are:

-Long term stability of man made structures; erosion, earthquake design, permeability etc.

-The ability to maintain water cover on the tailings requiring a good knowledge of the area hydrology (rainfall, evaporation, run off, storm events etc.) the basin hydrogeology (seepage, flowpaths, structural constraints etc.)

-System water balance in the long term relating to such unknowns as global warming, 1000 year flood and drought events etc.

-The in-situ density of tailings deposited underwater - it has been suggested that the tailing density could be as low as go LB/ft^3 rather than 100 to 110 lb/ft^3 for land disposed, fully drained tailings. This could result in an increase in the storage volume of 25 to 30%.

-The fate of such species as thiosulphate when disposed of underwater since natural oxidation will be inhibited.

In the next year, we plan to develop a preliminary underwater disposal manual that will focus on the storage of acid generating tailings in man made lakes. In the preparation of this manual, it is hoped to document the circumstances under which this disposal strategy might be used and outline some of the evaluations that will be required to adequately address the hydrology and hydrogeology issues. The development of this manual will likely be done by a geotechnical consulting firm and will focus on the physical aspects rather than the environmental or political issues involved in this disposal technique. Several under-water disposal sites are currently being operated and several others are proposed in Canada. If a satisfactory site can be found, monitoring and data collection will be started on what could be considered, **a full** scale test.

Flooding of Existing Tailings

From the study of tailings deposited underwater, we can confirm that sulphide oxidation can be severely reduced and possibly eliminated through the use of a water cover. The post flooding of tailings that have already been oxidized raises a new question; What is the fate of the oxidation products that are stored in the tailings? Further oxidation of the sulphides is not expected once the tailings are underwater but we know from experience that there will be substantial quantities of metal hydroxides stored in the interstitial pore water and on the surfaces of the particles. It is known that many of these products will be soluble in low ionic strength water and therefore tile potential exists to mobilize tile metals into either the ground water or surface water flow. Tile mobilization of these metal ions will therefore imply ongoing collection and treatment until such time as they are all washed out. A project we are currently developing will result in laboratory and modelling procedures to evaluate the fate of these products. Concurrent with this laboratory project is a field trial of this concept by Rio Algom at the Quirke Mine in Elliott Lake, Ontario. For this project, a 60 hectare site containing acid generating uranium mine tailings has been prepared for flooding as proof of concept. The project included construction of new dams to minimize seepage losses and to divert water from an adjacent watershed into the tailings area, the levelling of the tailings beaches to minimize exposed beaches and the addition of a crushed limestone into the top 6" of the tailings. From this work it is expected that a minimum water cover of 0.7 metres (approx. 21) can be maintained on the tailings. A program to monitor the surface and ground water flows in this trial area will help answer many of the questions regarding the fate of the soluble metals.

As with the underwater disposal of fresh tailings, the subjects of stability, hydrology and hydrogeology must be fully addressed to assure adequate water cover can be maintained at all times. Since most current tailings areas are not designed for flooding, difficulty in attaining full water cover will undoubtedly be encountered. We will therefore address and study the effect of exposed beaches and look for other solutions i.e. organic covers, wetland covers etc., that can be used in conjunction with flooding. From the laboratory work and confirmatory field testing we would hope to model the release and mobilization of the metals and predict tile time and cost of treating the effluents until a self sustaining system can be created. As with other systems we have and will evaluate, we hope to develop a methodology to evaluate the economic impact for a given set of conditions. The goal being to be able to evaluate and model various solutions from a list of options and come up with the most economic solution for a particular site.

Dry Covers

A dry cover refers to a cover that prevents water from flowing through into the tailings as opposed to one that is made out of dry materials. Dry covers range from various natural and modified clay and soil materials to synthetic covers such as plastic membranes and cementitious layers. While some work and evaluation has gone into some of the synthetic covers, the main item I will describe is the development and testing of composite natural covers. This type of cover is now on field test on tailings (Waite Amulet near Rouyn, in Northwestern Quebec) and on waste rock (Heath Steele near Newcastle in Northern New Brunswick. These composite natural covers were designed by Noranda at their technology centre.

These covers are designed to curtail the flow of oxygen and water to the tailings and each involves multiple layers of various materials. In order to obtain maximum reductions in the oxygen fluxes, the design is aimed at maintaining a water saturated layer of soil material. The diffusion of oxygen in a saturated soil layer is several orders of magnitude lower than through unsaturated soil. A single soil layer placed at high moisture content is not satisfactory because it will eventually desaturate by drainage and evaporation. The single cover layer will be subject to desiccation cracking, root penetration and freeze/thaw cracking. The design of the composite soil cover calls for a layer of compacted, fine grained material underlain and overlain by coarse-grained drainage layers. The bottom layer serves as a capillary suction break to prevent the drainage of the saturate layer while the overlying layer prevents dewatering by evaporation. The total thickness of the cover will be 1 to 1.2 metres thick (3 to 4 ft) depending on the application and the materials available.

Waite Amulet Dry Cover on Tailings

Waite Amulet is an abandon sulphide tailings site in near Rouyn, Quebec. The site continues to generate acid mine drainage which is treated by conventional lime neutralization and metals precipitation. The hydrogeochemistry, the hydrology and the state o f the sulphide oxidation have been studied extensively several years. The site was selected as a test plot site because of the extensive background information already available and because of the availability of suitable local borrow materials.

The composite layers at Waite Amulet consist of a 30 cm layer of gravelly sand as the lower capillary break, a 60 cm layer of compacted varved clay as the saturated layer and a 30 cm layer of fine to medium grained sand on the top. Four 20 m x 20 m test plots were designed as follows:- (1) control plot with no cover, (2) composite cover with the clay layer compacted at 91% modified Proctor and a water content of 25%, (3) composite cover with the clay layer compacted to 92% modified Proctor and a water content of 26%, and (4) a composite plot consisting of an 80 mil HDPE geomembrane between the tipper and lower sand layers. Each plot has been fully instrumented and Is being monitored as follows:

- Moisture and oxygen fluxes through the cover by Time Domain Reflectometry (TDR).

- Thermal conductivity sensors to measure the matric suction in the soil.

- Pore gas samplers and piezometers to sample the unsaturated and saturated zones below the covers.

- Lysimeter and access manholes to collect water samples from immediately below the covers.

- Thermocouples both in and below the cover to monitor temperatures.

The initial results from this cover appear to be very positive. The oxygen flux has been reduced and no water has yet collected in the lysimeters under any of the covers. It Is too early in the monitoring program to draw many conclusions at this time.

Having thus designed a cover and assuming it does curtail the production of acid mine drainage, the next questions become the practicality and cost of installing such a cover. A similar cover has now been placed on a 2 acre site at Millenbach and it is believed that reasonable quality control could be maintained. There was doubt expressed as to whether this quality could be extended over 10's to 100's of acres. The maintenance of consistent slopes to avoid pending and the maintenance of consistent layer thickness will require very good control. The question of cost will greatly depend on the local availability or appropriate materials as any substantial haul distances will increase the cost dramatically.

Other concerns that I have with any dry cover include:

- The long term stability of the impermeable layer: rigid covers may be affected by cracking, saturated covers by freezing and thawing and membrane covers by degradation. We will not be able to adequately evaluate this stability in most cases because of the long time frames (10's of years) that we hope they will last.

- Tile amount of time that contaminated flow will continue to exit the pile. There will be a significant store of contaminated pore water in the tailings. When no further recharge enters the pile, this pore water will continue to drain. flow long this drainage will continue and what affect this has on the short term treatment costs, must be evaluated.

Heath Steele Dry Cover on Waste Rock

Heath Steele is in operating base metal mine in Northern New Brunswick. The project was started in the late 1950's before the implications of acid mine drainage were appreciated. highly pyritic waste rock was excavated from several open pit and underground mines and placed on many small waste dumps adjacent to the point of excavation and used for various construction purposes. The rock piles and much of the disturbed surface, is now generating acidic drainage containing significant levels of Pb, Zn, Cu and Fe. The water Is currently collected and treated but a long term closure strategy is being sought.

A project to evaluate the closure of waste rock dumps using natural composite covers has consisted of four phases:

-Selection of 4 piles for field tests.

-Data collection and characterisation of the 4 piles.

-Column tests to evaluate the performance of potential covers.

-Cover placement and monitoring of full scale test.

The piles have now been monitored for almost two years and a good data base of temperature, pore gas quality and water levels and quality compiled. A composite cover consisting of locally available sands and gravel and clay soils has been developed and tested in the columns. Phase 4 of this project Is in progress at the present time. Tile composite soil cover consisting of 30 cm of sandy gravel overlain by 60 cm of clayey till and topped with 30 cm **of sand and 10 cm of -75** mm rock was placed last fall and monitoring will commence this spring. The till layer was compacted to 951 modified Proctor and at a moisture content of 17%. Similar instrumentation as installed at Waite Amulet will be used to monitor the cover performance and the existing temperature and air and water sampling stations will be used to evaluate the impact on the pile.

The problems of a dry cover on waste rock are somewhat similar to tailings with a couple of significant additions;

- Tile typical waste rock dump is very permeable and unless the air is cut off from the sides as well as the top, then the oxygen will continue to enter the pile.

- The waste rock is generally not compacted on placement and large waste dumps can stiffer from subsidence of several feet to metres. This will cause considerable stress on almost any cover system.

- We have seen dumps with internal temperatures as high as 65'C and there is some concern about build up of gas under the liner before the reaction could be shut down.

Despite all these problems, however, it may be the only technique available for dumps that are already constructed. As we know, old dumps were seldom situated under ideal circumstances **and closing** them out may prove to be a formidable task.

Conclusions

In this paper I have tried to summarize the three techniques that have been advanced the furthest through Canada's MEND program. Many other methods and combinations of methods are being considered, but are not sufficiently advanced to report. We are now better equipped to prevent the onset of acidic drainage from new waste sources but still along way from solutions on existing waste piles. The questions of long term reliability and affordability will continue to face us if the currently known technologies are the only tools we have available. We desperately need to search out innovative new methods of eliminating acidic drainage. Any brilliant ideas?

Figure #1

UNDERSTANDING OF AMD BEFORE MEND

* THERE ARE EASY WAYS TO STOP ACIDIC DRAINAGE.
* EXPERTS SOMEWHERE HAVE ALL THE ANSWERS.
* ACID GENERATION WILL STOP ON ITS OWN.
* IF THERE'S NO ACID GENERATION NOW, THERE NEVER WILL BE.
* IT IS UNREASONABLE TO PROVIDE FOR PERPETUAL TREATMENT AND CARE.
* REVEGETATION WILL PREVENT ACID GENERATION.

Figure #2

MAJOR ACHIEVEMENTS OF MEND

* CHEMICAL PREDICTION TECHNIQUES HAVE BEEN IMPROVED.
* PREDICTIVE MODEL FOR TAILINGS NOW AVAILABLE.
* UNDERWATER DISPOSAL AND WATER COVERS IDENTIFIED AS OPTIONS TO PREVENT ACID PRODUCTION.
* REFERENCE STANDARDS AND SAMPLING PROCEDURES ESTABLISHED FOR TAILINGS.
* GOVERNMENTS WORKING WITH INDUSTRY TO SOLVE THE PROBLEM.
* DRAMATIC INCREASE IN THE UNDERSTANDING OF ACIDIC DRAINAGE.
* PREVENTION MORE COST EFFECTIVE THAN TREATMENT AND CONTROL.