Guide to Initial Phase Metal Leaching/Acid Rock Drainage Assessment

Jeff Martin
SENES Consultants Limited
121 Granton Drive, Unit 12
Richmond Hill ON L4B 3N4
jmartin@senes.ca 905 764 9389 ext 349

Abstract

Assessment of the potential for metal leaching and acid rock drainage (ML/ARD) from mining activities is an important step in the mining process in order to protect the environment, and is especially relevant to the long-term sustainability of the mining process and to mine site rehabilitation issues. In Ontario, ML/ARD assessment has recently been regulated through the Mine Rehabilitation Code, which is part of Ontario Regulation 240/00. This paper provides a guide to initial phase ML/ARD assessment taking into consideration the requirements of the Mine Rehabilitation Code.

A ML/ARD assessment requires an understanding of the objectives for the program, which will vary depending on the stage of mining at the site, potential rehabilitation options under consideration, and other factors. The initial stage of a ML/ARD assessment should be review and interpretation of any existing data that may be relevant. Existing data is often extensive and may include: site geology; site history; mining plans (past and future); ML/ARD history; surface water and groundwater quality; climate; topography; depositional history of waste deposits; and ML/ARD information from adjacent similar mines. Following interpretation of existing data, any data gaps and requirements can be identified and the appropriate field program can be designed and implemented. In this paper a typical first stage field program is described including: sampling procedures for waste rock and tailings; field assessment procedures (descriptions, paste pH, paste conductivity, fizz test, etc.); and water sampling. Typical first-phase laboratory analyses are presented. These include acid-base accounting (ABA); elemental, major element, and acidity analyses; and simple leach tests. Data presentation and interpretation issues are then discussed. The iterative nature of the ML/ARD assessment process is also addressed.

Ontario Regulation 240/00 and BC Guidelines for ML/ARD Assessment

Ontario Regulation 240/00 regulates mine development and closure under the Mining Act. Within the regulation the Mine Rehabilitation Code specifies how certain activities relevant to closure should be carried out. ML/ARD assessment is addressed under Part 7 of the Code. The stated objective of Part 7 is to "determine the potential for significant metal leaching (ML) or acid rock drainage (ARD) and, if necessary, to ensure the development and implementation of effective prevention, mitigation and monitoring strategies" (Section 56). Sections 57 and 58 require that sampling, testing and interpretation of materials remaining on-site, that have been excavated, exposed or otherwise disturbed by mining activities, be undertaken in accordance with the *Guidelines for Metal Leaching and Acid Rock Drainage at Mine Sites in British Columbia* (BC Ministry of Energy and Mines, 1998) and the *Draft Guidelines and Recommended Methods for the Prediction of Metal Leaching and Acid Rock Drainage at Mine Sites in British Columbia* (BC Ministry of Energy and Mines, 1997).

If the interpretation shows no ML/ARD issues, no further work is required. If, however, the interpretation shows that the materials to remain on-site have the potential to develop ML/ARD, then Part 7, Section 59(1) of the Mine Rehabilitation Code comes into effect, which states that: "Where the interpretation indicates that the materials have the potential for ML or ARD, a management plan shall be developed to ensure that these materials do not adversely affect the quality of the environment".

Some relevant advice from the two BC publications noted above is summarized below, however it is also recommended that these publications be reviewed prior to a ML/ARD assessment. One of the key points made in the BC Guidelines is that the most efficient and preferred way to conduct ML/ARD investigations is through "an iterative process of testwork and review, similar to that used to determine other geologic characteristics such as ore reserves" (BC Ministry of Energy and Mines, 1998). A phased program will allow an investigator to focus on areas of greatest concern, avoid unnecessary work, and make refinements to the program based on intermediate results or unforeseen conditions.

The BC Guideline also stresses the importance of an often overlooked first step, which is the identification and characterization of geologic materials that have been or will be affected by mining, and that much of this information is generally already available at an advanced exploration project or an existing mine site.

Objective of ML/ARD Assessment Program

Ultimately the objective of any ML/ARD assessment program is to provide sufficient information for informed decisions to be made with respect to management of the materials being assessed. The specific requirements of a ML/ARD assessment program will vary depending of the stage of mining at the site, potential rehabilitation options under consideration, the stage of the assessment, and other factors. Some examples are provided below.

For example, consider a first stage ML/ARD assessment of an existing waste rock dump. where the assessment shows a mixture of currently acidic rock with the strong potential to generate ML/ARD, mixed with sporadic zones of neutral rock with no potential to generate ML/ARD. In this case a typical first stage assessment (described below) may generate enough information to decide on a management plan. In this case it may be decided that the random mixing of rock types plus the currently acidic zones and strong potential to generate further ML/ARD suggests that management of the entire dump is required, perhaps by underwater disposal.

In general, if waste is to be placed below water less characterization is warranted than for the case where it is planned that waste rock be left in surface dumps. In the above case it may be decided that further efforts to characterize the rock types in the dump would not be particularly useful given the practical difficulties in rock separation. Furthermore, dynamic test work would not required, as the dump itself is already in effect a full scale dynamic test.

At the other end of the mining cycle, consider a first stage ML/ARD assessment at an advanced exploration project where preliminary results showed distinct zones of waste rock, with some rock initially characterized as uncertain with respect to ML/ARD potential. In this case considerable additional effort may be warranted to determine what rock can be safely segregated and stored without the need for management to inhibit ML/ARD. Such additional effort may include more detailed sampling and dynamic test work such as humidity cells.

Finally, consider an operational mine where some zones of waste rock coming from the operation have been classified as non-acid generating. Ongoing assessment at this stage may consist mainly of a simple test program with a quick turnaround time that can be used in addition to ABA test work to confirm waste rock characteristics as mining proceeds. An example of such a test would be a cut-off based on total sulphur content. Such an operational test procedure would have to be developed as part of a more detailed ML/ARD program and would be site and material specific.

Typical Initial Phase ML/ARD Assessment

Review and Interpretation of Available Data

An important first step in a ML/ARD assessment is review and interpretation of existing data. The available relevant data is often extensive and may include: site geology; geochemical analyses conducted as part of exploration and development programs, site history; mining plans (past and future);

ML/ARD history; surface water and groundwater quality; climate; topography; depositional history of waste deposits; and ML/ARD information from the site in question and/or adjacent similar sites. In addition to physical data sources, resources in the form of existing and past employees at a mine site should not be overlooked as a valuable resource. These personnel may be able to provide information that does not exist elsewhere with respect to site history, past practices and deposit composition. Review of all such available information will greatly improve the quality of the assessment.

Following review and interpretation of the existing information, data gaps and requirements can be identified and the appropriate first stage field program can be designed and implemented. Such an investigation would typically consist of site investigations and sampling for static test work, as described below. Depending on the need, further stages of the assessment (if required) may focus on collection of additional but similar data in an iterative fashion, or on more detailed analytical programs such as dynamic test work.

Number of Samples

It is generally accepted that the determination of what constitutes a "representative sample" of a waste rock pile is a challenging task. The *Review of Waste Rock Sampling Techniques* (SENES, 1994) for Canada's Mine Environment Neutral Drainage (MEND) program, provides the following guidance on sampling:

- Sampling strategies should be site-specific. The number of samples required to characterize the waste rock at a site will depend on numerous factors including geology, uniformity of the mine rock, size of the geological units. Characterization of waste rock piles is typically more complicated than sampling of in-situ rock, due to the mixing that can occur during placement and physical sampling issues.

- There are mathematical formulations which can be applied to determine the number of samples. One technique presented in the B.C. AMD Draft Manual suggests the number of samples could be based upon the size of the geological unit. As a general comment this technique should be used with caution.

- In virtually all waste rock assessments a staged program is warranted. Analyses of the initial sampling provides guidance as to how many more samples may be required and which geological units/strata should be re-sampled in more detail. The input of a project geologist is important in determining sample locations.

- Compositing of samples should be avoided where possible, as each distinct zone should be assessed separately. If composite samples are used, each composite must be made from a single distinct lithology or alteration zone (in the case of in-situ rock sampling), or from a distinct layer or zone within a waste rock dump. Compositing may be necessary in order to provide a sample of adequate size for testing (i.e. for dynamic testwork).

Given the above, it is not easy to determine what is an adequate number of samples to collect to characterize a waste rock deposit, and the advantages of a phased assessment program, with the opportunity to review and interpret data at each stage, becomes apparent.

Sample Collection and Description

It is recommended that all samples be assessed, described and logged in the field to the extent possible using the following categories as a guide:

- location (record GPS co-ordinates and plot location on field map);
- rock or material type;
- colour(s);
- mineralogy including sulphide content and types, and carbonate content (calcite);
- fizz test (to assess for calcite);
- estimate of mineral grain size and distribution;

- visual estimate of waste rock particle size;
- estimate of moisture content (wet, damp, or dry);
- signs of weathering (slaking, cracking, etc.); and
- signs of oxidation (stains, precipitates, secondary minerals, etc.).

These descriptions will aid in the interpretation of the laboratory results. Typically a field form is used to assist in consistently recording the above information. It is also recommended that digital photographs be taken to illustrate each sample and the associated test pit or sampling location. These photographs will be of significant assistance in review of the data when the sampling program is no longer fresh in the sampler's mind.

It is also recommended that “field” paste pH and conductivity be measured on a split of each sample before the samples are sent to the lab, preferably during the field program. These measurements are made on un-pulverized samples. They are essential in determining in-situ conditions and whether acidic conditions occur in the waste rock before all of the neutralizing minerals are consumed. Relying on laboratory paste pH measurements alone is not desirable, as laboratory measurements are conducted on crushed samples. This can liberate additional neutralizing potential (NP) and may indicate neutral conditions when in fact acid conditions have already occurred in the field.

Typically one to two kilogram waste rock samples should be collected, however larger samples may be warranted if additional tests are to be conducted, such as grain size, dynamic testwork, etc.

Sampling procedures vary depending on the situation. For existing waste rock deposits and a first stage assessment it is recommended that test pits be excavated by backhoe. Samples should be collected at various depths and where visually distinct material is encountered. Safety around heavy equipment and test pits should given a priority and samples should be collected from bucket loads carefully collected at a specific depth and then dumped at surface. Test pits should not be entered by sampling personnel. A test pit depth of 2-3 metres is typically adequate for a first-phase program, however this should be reviewed on a site-specific basis and efforts should be made to sample more than just the uppermost lift of a waste rock dump. It should be recognized that sampling of existing waste rock dumps through test pits in many cases is just scratching the surface of the dump. Collection of samples from within a dump is problematic, however, as borehole investigations are physically difficult and may not return sufficient or representative samples, and deep test pits face physical limitations based on safety and cost. In these cases the site history and other data become invaluable in the interpretation.

In the case of a project under exploration or development, typically drill core is the sampling medium. Samples are typically selected by or with the assistance of a site geologist and excellent information is typically available with respect to sample location, rock type, mineralization, etc.

Water Sampling

In addition to waste rock samples, water quality should be measured where water may have been affected by waste rock. Surface water, groundwater and especially seepage from the waste rock pile should be sampled using standard methods. It is especially important to try and sample seepage from existing waste rock dumps. Especially in the case of low flow, care should be taken to not to disturb bottom sediments during sampling. Flow estimates should be made. Seepage sampling may require timing of sampling trips to occur during or shortly after precipitation events and should ideally be taken during the different seasons.

Static Laboratory Analyses

For a first stage laboratory program, it is typically recommended that waste rock samples be analyzed for:

- modified ABA accounting (all samples);

- ICP metals with strong acid digestion (all samples);
- whole rock (or major element) chemistry (selected samples);
- existing acidity levels (selected samples); and
- de-ionized water leach test with ICP analysis (selected samples).

While ABA results are key and are discussed below, metals analyses are also important in order to determine what metals are elevated and could be of concern if ML/ARD occurs. Whole rock analyses are of value in characterizing samples by rock type and site geology. Existing acidity levels are of value in determining the extent of oxidation and the amount of neutralizing material that would be have to be added (if neutralization of existing acidity was determined to be part of the rehabilitation strategy). The de-ionized water leach can provide information on approximate seepage characteristics and potential metals of concern.

Water (surface water, groundwater and seepage) should be analyzed for the parameters suggested by Ontario's Mine Rehabilitation Code (pH, conductivity, cyanide, total suspended solids, alkalinity, acidity, hardness, cyanide, ammonia, sulphate, aluminum, arsenic, cadmium, calcium, copper, iron, lead, mercury, molybdenum, nickel, and zinc) unless there is a valid reason to exclude any of these parameters. For example it may not be necessary to analyzed for cyanide if it has not been used at the site. On the other hand, cobalt would be a parameter that should be added to the analyses if, for example, the assessment focussed on waste rock from Sudbury area nickel-copper deposit, as cobalt is associated and of environmental significance.

Data Presentation

All available data relevant to ML/ARD at the site should be compiled and presented according to standard ABA guidelines. Typically the following information would be presented:

- summary statistics for all parameters;
- evaluation of ABA data with respect to the commonly used acid base screening criteria based on both net neutralizing potential (NNP) and the ratio of neutralizing potential (NP) to acid potential (AP);
- scatterplots of ABA parameters including the following:
    - field paste pH versus lab paste pH;
    - carbonate NP versus lab NP;
    - total sulphur versus sulphide sulphur;
    - NNP versus NP/AP;
    - NNP versus paste pH;
    - NP/AP ratio versus paste pH;
- relevant surface water, groundwater and seepage water quality results; and
- plans and/or sections showing site geology, sample locations, topography, etc.

Interpretation

The draft BC Guidelines (1998) suggest the ABA screening criteria presented in Table 1.

Table 1
NP/AP[1] Acid-Base Screening Criteria Recommended in Draft BC Guidelines

Screening Criteria	Pot. for ARD	Comments
NP/AP < 1	likely	likely ARD generating unless sulphide minerals are non-reactive
1 <= NP/AP < 2	possible	possibly ARD generating if NP is sufficiently unreactive or is depleted at a faster rate than sulphides
2 <= NP/AP <4	low	not potentially ARD generating unless significant preferential exposure of sulphides along fracture planes, or extremely reactive sulphides in combination with insufficiently reactive NP
NP/AP <= 4	none	

1: NP = neutralizing potential, AP = acid potential

Another commonly used set of ABA screening criteria is presented in Table 2 (SENES, 1994).

Table 2
Commonly Used NNP[1]
Acid-Base Screening Criteria

Screening Criteria	Potential for ARD
NNP >= 20 kg $CaC0_3$/tonne	non acid generating
NNP <= -20 kg $CaC0_3$/tonne	potentially acid generating
NNP between 20 and –20 kg $CaC0_3$/tonne	uncertain

1: NNP = net neutralizing potential

For presentation it is useful to colour-code the results by category.

It should be noted that the above criteria are only a starting point for the interpretation. Both sets of screening criteria should be considered. Depending on the composition of the waste materials, either the NNP criteria or the NP/AP criteria will be more conservative. At high NP and AP levels the NP/AP criteria are more conservative while at low NP and AP levels the NNP criteria are more conservative. site-specific and possibly less conservative criteria could be developed as the assessment progresses. While interpretation is relatively easy and definitive if the material is clearly in one category or another, the material that is borderline in terms of the categories presented in Tables 1 and 2 presents difficulties in interpretation and may require additional investigations such as humidity cell test work.

The interpretation should make use of all available information, not just the ABA data. Geology, water quality, site history, climate, should all be considered. Comparison to other similar sites is often useful for interpretation. Experience gained from previous assessments and other sites is especially relevant. It may be worthwhile to have the available data reviewed and interpreted by an independent party.

The scatterplots discussed previously should be reviewed along with geological descriptions to help identify distinct zones or rock types with similar ML/ARD characteristics. Statistical results could also be used to confirm distinct zones exist and to quantify differences.

Scatterplots of field paste pH versus NP, NNP, and lab paste pH may be useful for determining if there is residual NP that is unavailable for neutralization before acidic conditions occur.

Subsequent Stages

As mentioned previously, an iterative approach to ML/ARD assessment is preferred. After the initial phase assessment is complete, an informed decisions can be made regarding any future assessment. This could range from additional sampling of selected "borderline" zones, to kinetic testwork, to geochemical modelling.

References

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