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**GUIDELINES FOR THE PREDICTION OF ACID ROCK DRAINAGE
AND METAL LEACHING FOR MINES IN BRITISH COLUMBIA:
PART II. RECOMMENDED PROCEDURES FOR STATIC AND KINETIC TESTING**

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ABSTRACT

To improve existing practices in the prediction of metal leaching and acid rock drainage, the British Columbia Ministry of Employment and Investment has produced a Prediction Manual entitled "Guidelines and Recommended Methods for the Prediction of Metal Leaching and Acid Rock Drainage at Minesites in British Columbia." This paper provides an overview of the recommendations for static and kinetic testing.

Recommended static test information includes elemental concentration, concentration of soluble constituents, an expanded series of acid-base accounting analyses and refined geological and mineralogical characterization. Screening criteria are provided for some static test data. Recommended kinetic test procedures include laboratory humidity cell testing, on-site field test pads and on-site wall washing stations. Mines should also monitor drainage from specific mine components.

For both static and kinetic testing, additional interpretative considerations, sampling and sample analysis requirements may result from the unique properties of different mine components. For example the prediction work carried out on tailings should consider the affects of milling, depositional segregation and drainage limitations.

Keywords: acid rock drainage (ARD), metal leaching, prediction, static testing, kinetic testing, recommended procedures, acid-base accounting (ABA), ARD screening criteria, British Columbia (BC)

INTRODUCTION

In response to frequent requests for advice and to improve existing practices, the British Columbia (BC) Ministry of Employment and Investment (MEI) has developed a Prediction Manual entitled "Guidelines and Recommended Methods for the Prediction of Metal Leaching and Acid Rock Drainage at Minesites in British Columbia" as a companion to its General Guidelines entitled "General Metal Leaching and Acid Rock Drainage Guidelines." The Prediction Manual includes general guidelines, recommended methods for laboratory analysis and data interpretation, and a discussion of critical prediction questions which commonly need to be addressed.

Informed, site-specific decision-making requires comprehensive testing and is only possible if the necessary information is collected and correctly interpreted. This paper provides an overview and some examples of the recommendations for static and kinetic testing. While the recommended methods provide generally required information, the final decision about which methods to use should be based on the necessary level of understanding and the site-specific conditions.

STATIC TESTS

Static test is a term used in acid rock drainage (ARD) and metal leaching studies to describe analyses that measure the composition of a sample at a single point in time; for example, the total and soluble concentration of a particular metal. There are a great variety of possible static test analyses. The tests described below, measure parameters specific to metal leaching and should be considered for inclusion in any metal leaching/ARD program.

Information derived from recommended static tests, in conjunction with previous experience, can form the basis for preliminary estimates of metal leaching and ARD. For example, by comparison with other samples whose performance is known, static test results may suggest how a sample has been altered in the past, or may weather in the future. Static test screening criteria can be very useful for identifying materials with no ARD potential or elements of little concern. However, given the present ignorance regarding rock and mineral reactivity, and the lack of detailed historic site characterization and monitoring, static test screening criteria are generally coarse and conservative, and kinetic information is required to develop refined and precise, site-specific estimates.

Many of the recommended static tests provide complementary, somewhat redundant information. These seeming redundancies often provide critical cross-checks on predictive information, with discrepancies pointing to unusual conditions warranting further examination and clarification.

STRONG ACID DIGESTION MULTI-ELEMENT TRACE ANALYSIS BY INDUCTIVELY-COUPLED PLASMA

The objective of multi-element trace analysis is to provide a measure of the various metals that may be of environmental concern. Combined with metal leaching rates, the measured

concentrations allow the calculation of metal depletion times and provide a screening tool that can be used to detect which materials and elements are most likely to be a drainage chemistry concern. Determination of which elements occur in high concentrations can be made by comparing results with the normal range of concentrations found in rock and soil. Metal concentrations below the normal range may indicate rapid metal leaching and depletion. All materials impacted by the mine should be screened using multi-element analytical techniques.

Of course, total concentration data provides no information about the form(s) in which elements exist and therefore cannot be taken as a direct measure of their threat to the environment. In many cases, the mineral source may be inert or only sparingly soluble. Where elements are present in high concentrations, further testing and analysis should be done to determine the mineral source(s), the potential rates of release and the environmental significance.

The recommended procedure for trace element analysis is a strong acid dissolution using aqua regia or other concentrated acid mixture, combined with low detection inductively-coupled plasma (ICP) analysis. Since aqua regia does not dissolve the entire sample it may underestimate the concentration of elements that dissolve slower or are part of more inert minerals. Elements whose concentration may be underestimated include Al, Ba, Be, Ca, Cr, Ga, La, Mg, Sc, Na, Sr, Th, Ti and W. In many cases, incomplete dissolution may not be a concern, since minerals that remain inert in the test procedures are expected to be similarly unreactive in the field. Whenever concentration results are reported they should be prefaced by the analytical procedure. For example, if aqua regia is used, results should be referred to as aqua regia metal concentrations, and any unusual problems with incomplete sample dissolution should be reported.

The main disadvantage with the standard 32 element aqua regia digestion and low level ICP analysis is that some potentially important trace elements are not assayed (Se) or detection limits may be too high (As, Hg and Sb). Modifications or additional assays may be required until it is determined that these elements are not a concern.

ANALYSIS FOR SOLUBLE CONSTITUENTS

In addition to primary mineral weathering affects, significant contaminant release may also occur from the dissolution of surface coatings or soluble minerals, such as carbonates and salts. Solubility is generally only a concern where materials are already oxidized as a result of historic supergene processes, previous mining or a delay in the use of prevention measures. Metal release through dissolution tends to occur as a result of changes in the leaching rate or through the removal of solubility constraints. These latter processes can result from submergence, exposure to precipitation or movement of material into a drainage path.

The recommended solubility testing procedure is a modification of the shake flask, leachate extraction procedure outlined in the *Special Waste Regulation* of the *BC Waste Management Act*. The sample should be shaken for 24 hours, using distilled water, at a 3:1 water to solid ratio by weight. A 3:1 solution is used to ensure all soluble products can dissolve without solubility limitations. Gentle agitation for 24 hours is required to ensure continuous exposure of all surfaces and mixing of the rinse solution.

To determine presently leachable components, the recommended procedure is a distilled water leach. Distilled water can be replaced with a weak acid solution to determine solubility under low pH conditions that would result from ARD.

For unconsolidated materials, tests should be conducted on an "as is" (uncrushed) subsample. For consolidated materials such as drill core, crushing is required and only the "crushed" soluble constituents can be measured. For fine-textured materials or pulverized bedrock, analysis should be done on a subsample of the total sample. For materials containing coarse fragments (for example, till and waste rock), analysis should be conducted on a subsample of the entire sample or on a subsample of the "reactive" size fraction of the material.

Since solubility is only a concern in a limited number of situations, soluble-constituent testing should be used selectively. The potential for metal solubility should be determined from the initial characterization of geological materials, the sulphate content and results of petrographic examinations.

The determination of potential impact and a need for mitigation will depend on site-specific conditions. Test results are affected by factors such as solid-to-water ratio and dilution, conditions which may be very different from actual site conditions. This should be considered in data interpretation.

ACID-BASE ACCOUNTING

The combined measurements of sulphur species, neutralization potential (NP) and pH, accompanied by the calculation of acid potential (AP), net neutralization potential (NNP) and neutralization potential ratio (NPR) are known as acid-base accounting (ABA). ABA can provide a rough guide as to whether a sample is potentially ARD generating (PAG), an assessment that can be further refined and calibrated with detailed mineralogical characterization, site-specific observation and kinetic testing. Although universal ABA rules do not exist, ABA characteristics, particularly the NPR, are often used for operationally identifying and separating PAG materials, or as screening criteria in the early phases of a prediction program.

There are several versions of ABA. The simplest procedure is to use sulphide-S to calculate AP and one procedure to determine bulk NP. The analytical suite recommended is an expanded version of the Sobek or EPA-600 method (Sobek et al, 1978) which includes a determination of all sulphur species. Modifications include the additional measurement of carbonate-carbon, a revision in the procedure for measuring pH and possible corrections for barite and iron and manganese carbonates.

The full list of recommended ABA analyses is:

- total-sulphur, acid leachable sulphate-sulphur, acid insoluble sulphate-sulphur and sulphide-sulphur,
- bulk neutralization potential,
- carbonate-carbon and
- pH.

Acid Potential

The recommended procedure for determining the maximum potential for future mineral acid generation is to calculate it using the sulphide-S content measured using an expanded sulphur speciation analysis. Complete sulphur speciation may not be required if there are no organic-S or sulphate-S components present, however, these assumptions should be verified. As many base metal deposits contain significant sulphate-S; the use of total-S as a sulphide-S measure may result in a large over-estimation of AP. A different approach may be required under acidic conditions where significant potential acidity may also reside in acid sulphate minerals and in certain forms of iron and aluminum.

Neutralization Potential

ARD will only result if there is insufficient production of neutralizing alkalinity and most common rock forming minerals are capable of producing alkalinity. However, there is an important distinction between effective field-NP and other forms of alkalinity generation (Morin and Hutt, 1994; Morin and Hutt, 1997). Effective field-NP is the ability of a potential NP source to maintain a neutral drainage chemistry. To be effective NP, alkalinity must be available to neutralize acidity. Alkalinity generated after the onset of ARD is not effective NP. Effective NP and the determination of whether a mine component will produce ARD, therefore depends, in part, on the rate of acid generation..

The rates of acid generation may not be significant if the NP comes from calcium and magnesium carbonate minerals whose solubility is stimulated by a decrease in pH. However, the relative rates of acid generation and neutralization rates are very important if NP is derived from slowly dissolving aluminosilicate minerals which will only contribute effective field-NP if the in-field rate of acid generation is relatively small. If the in-field rate of acid generation is relatively large, aluminosilicate minerals containing alkalinity may not react fast enough to neutralize acidity.

Two different measures of neutralization potential are recommended; NP measured directly from the Sobek hot acid leach and the NP calculated from the carbonate content. Carbonate NP (Carb-NP) is required both as a check and to provide greater understanding of the mineralogical basis for this critical but poorly understood parameter. The Sobek procedure is recommended for the bulk NP because of its use by most mines and in most ARD research allows a comparison between sites. A determination of whether lab-NP methods makes the assessment of effective field-NP easier or more accurate is dependent on the NP mineralogy and its field performance under site-specific conditions.

The best practice for determining effective field-NP is to interpret lab-NP measurements in combination with:

- resulting manifestation of effective field-NP,
- mineralogy involved and its distribution on exposed surfaces, and
- rates of acid and alkalinity generation for the entire sample and for specific minerals under site-specific environmental conditions.

The possible contribution of non-neutralizing iron and manganese carbonate minerals, must be checked when Carb-NP or Sobek-NP measurements are used (Lapakko, 1994). Great care is also required when working with rocks containing low sulphur and low carbonate levels, where minor variations in concentrations can significantly change weighted parameters.

It is especially important to define the form of NP (field or laboratory) and the type of measurements being referred to. An important objective of the Prediction Manual is to encourage practitioners to be more precise in their terminology.

Neutralization Potential Ratio

Two statistics are commonly calculated to show the balance between a sample's AP and NP. NNP is calculated from NP minus AP. The NPR is the NP:AP ratio. NPR can be used over the large range in AP values and is therefore the statistic used by MEI.

Refined Geological and Mineralogical Characterization

Static test parameters such as trace multi-elements and ABA parameters such as Carb-NP do not identify contributing minerals. This can be a significant limitation for prediction work since the mineralogical form(s) in which elements occur play a major role in determining their contribution to drainage chemistry. Identification of participating mineralogy is also necessary for interpreting kinetic test results. Suggested information requirements include:

- identification of potential acidity and metal sources, with particular emphasis on sulphide mineralogy;
- determination of potential contribution of barite to the sulphate-S measurement;
- identification of the potential neutralization sources, with particular emphasis on carbonate mineralogy and any potentially significant slow-release alkaline aluminosilicate sources;
- identification of clay or carbonate (for example, siderite and ankerite) minerals which contribute to the lab-NP, but may not provide similar contributions in the field;
- evaluation of the most reactive acid generation and neutralization sources (carbonates and sulphides) and their potential to preferentially occur along fracture planes and in the fine size fraction, where they are available to contribute to geochemical reactions;
- identification of readily soluble constituents; and,
- identification of any mineralogical or rock fabric characteristic that will influence weathering.

The specific properties of interest will depend on the questions raised by other test work and the specific conditions of each site, material and disposal option. Existing drill log data, exploration reports, metallurgical test work and other information sources should be analyzed prior to any mineralogical testing. In most cases, it will be necessary to augment this information with prediction-specific petrographic, submicroscopic and/or geochemical analyses.

Mineralogical work should generally include a petrographic examination of a representative subset of samples; ideally samples for which ABA and elemental data already exist. However, the information obtained from petrographic examinations are limited to coarse and

medium-grained mineralogy and similar sized physical features. More sophisticated investigative procedures are needed to describe finer-scale features and for mineral-specific elemental analysis. X-ray diffraction may be required to identify specific clay-sized phyllosilicate minerals. Scanning electron microscopy (SEM) may be needed to determine the mineralogy of grains < 100 µm. A major limitation of both petrographic and SEM analyses is that the small size of the specimen may not truly represent a coarse-grained grab sample or waste rock pile. Although x-ray diffraction can be conducted on a representative sample created through pulverization and proper splitting, it is limited in its diagnostic capability and its ability to detect trace element constituents (< 5 %).

Significant variations in major and minor mineral concentrations can sometimes be detected in geochemical data if a single mineral is the only source of a particular element. For example, the concentration of lead may be used to estimate the amount of galena in a sample. This procedure should be used with caution since trace elements occur as minor constituents in many common minerals. Submicroscopic techniques should be used to check assumptions regarding the composition of solid solution minerals and/or the mineral hosts of a particular element.

A cost-effective strategy for acquiring the necessary mineralogical data to support predictive test work is:

1. Perform a comprehensive program of geochemical analysis to detect pronounced mineralogical differences and determine a subset of samples for petrographic and/or SEM analysis.
2. Conduct additional SEM analyses to fill in petrographic blind spots and as a confirmation for assumptions of geochemical composition.
3. Perform quantitative measurements of solid solutions and trace mineral compositions if accurate mineral weathering rates constitute an essential component of the proposed ARD prevention/mitigation program.
4. Incorporate mineralogical and geochemical data into the metal leaching/ARD program as it becomes available during the various stages of mineral exploration and metallurgical test work.

Acid-Base Accounting Screening Criteria

The following ABA parameters are recommended for the identification and screening of PAG materials:

1. No testing is required of unconsolidated materials such as glaciofluvial and fluvial deposits derived from wide areas since they have little opportunity for either sulphide or trace element concentration or deposition.
2. Materials with a sulphide-S content less than 0.3 % and a pH greater than 5.5 require no further ARD testing and are considered safe to excavate if there are no other metal leaching concerns. A cutoff of 0.3% sulphide-S is appropriate for most geological conditions. Exceptions are, if a rock matrix consists entirely of base poor minerals (for example, quartz and sericite in pervasive phyllic alteration) or if sulphide minerals contain heavy metals, such as As and Zn, which are soluble in weakly acidic leachate. If the sulphide content is 0.3% or more, an ABA assessment is required. Due to the greater solubility of metals at low pH, if the pH is less than 5.5, a 24 hour shake flask

extraction is required to determine the soluble metal content (See Prediction Manual section on Analysis of Soluble Constituents). This abbreviated ABA screening criteria is intended for situations, like road construction in non-mineralized terrain, where there is no reason to expect low NP or significant trace element release. Where materials are likely to be mineralized or hydrothermally altered, a proponent is advised to carry out the full ABA/metal leaching analyses, and use the NPR screening criteria listed in Table 1.

- Where materials are mineralized, the full suite of ABA testing should be conducted. Screening criteria based on ABA test results are presented in Table 1.

POTENTIAL FOR ARD	INITIAL NPR SCREENING CRITERIA	COMMENTS
Likely	< 1:1	Likely ARD generating.
Possibly	1:1 - 2:1	Possibly ARD generating if NP is insufficiently reactive or is depleted at a faster rate than sulphides.
Low	2:1 - 4:1	Not potentially ARD generating unless significant preferential exposure of sulphides along fracture planes, or extremely reactive sulphides in combination with insufficiently reactive NP.
None	> 4:1	No further ARD testing required unless materials are to be used as a source of alkalinity.

TABLE 1. Acid-Base Accounting Screening Criteria

Samples with an NPR greater than 4:1 are judged to be of no ARD concern and no further ARD test work is required unless the materials are to be used as a source of alkalinity. The ratio of 4:1 is a conservative screening criteria selected to ensure detection of all sites where there is an unfavorable balance between acid generation and neutralization reactions or where the composition of the reactive fine fraction varies significantly from the whole rock analysis. Without additional information, samples with an NPR less than 4:1 will be considered to have an uncertain ARD potential. Where the acid rock drainage potential of a waste material or geological unit is uncertain, it will be considered acid drainage generating until the prediction can be refined through further testing. The type and amount of additional test work required will depend on the ARD potential to a certain degree. For example, the designation of low ARD potential (NPR 2:1 - 4:1) will be changed to non-ARD generating when it is shown that either the sulphides will not be preferentially exposed or the NP is sufficiently reactive.

It is cautioned that acid-base accounting on its own, provides only a rough assessment of the potential for acid drainage. More accurate site and material-specific interpretation or testing should be used to develop less conservative, more refined materials handling criteria. Typically,

the more refined NPR distinction between potentially and non-ARD generating materials is between 1:1 and 2:1. However, with very slowly reacting sulphides and/or significant slow release alkalinity, ARD may not occur in materials with an NPR less than 1:1.

To date, the only materials with NPRs greater than 2:1 that have produced ARD or possess NP/AP depletion rates that could generate ARD are field test pads (Ziemkiewicz and Meek, 1994) and other forms of testing (Morin and Hutt, 1993). In other cases, where ARD was initially ascribed to a $\text{NPR} > 2:1$ it was later discovered that the source was incorrectly characterized or that a discrete portion of the mine component possessed $\text{NPRs} < 2:1$ (for example, low grade ore in a generally benign waste rock dump). The lack of documentation of materials with $\text{NPR} 2:1 - 4:1$ that produce ARD is qualified by the fact that there is a lack of well-characterized minesites with NPR in the range of 1:1 - 4:1. The shortage of evidence and the hypothetical possibilities of chemically unreactive NP and selective NP occlusion in coarse fragments detracts from a blanket statement that ARD is impossible above a NPR of 2:1 or 3:1. Therefore, MEI requires additional evidence to justify the use of less conservative NPR numbers.

The ABA screening criteria listed above apply to individual samples. The development of criteria for rock dumps containing a mixture of PAG and non-PAG waste is more difficult. Data for predicting acid drainage for mixed waste rock dumps are limited, especially for hard rock mines.

KINETIC TESTS FOR AERIALY-EXPOSED MATERIALS

Kinetic tests provide a measure of the dynamic performance or "reactivity" of a sample over time. Prediction information that kinetic testing can provide includes:

1. relative rates of acid generation and neutralization, which determines geochemical conditions, including whether a sample will "go acid";
2. time to ARD onset, which determines how long a delay is permissible before prevention measures are required; and
3. drainage chemistry and the resulting downstream loadings for the predicted geochemical conditions.

Kinetic testing includes a variety of procedures which each measure distinct parameters. Tests are not interchangeable and one should be aware of the differences when selecting a test and interpreting results. Test selection should be based on information requirements, site, exposure environment and specific materials being tested. A critical aspect and a common source of error is the distinction between tests designed to measure primary weathering reactions and those designed to measure drainage chemistry resulting from secondary mineral solubility.

Kinetic test information presented for review should generally include:

- Detailed static test information showing that the test material has the same composition as the material it is purported to represent. Documentation should include the original ABA, and elemental and mineralogical data used to select test materials. For waste rock, properties that affect mineral exposure, such as composition relative to planes of weakness and occlusion in coarse fragments, should also be evaluated.
- Identification of minerals contributing to the measured drainage chemistry, and evidence that the parameters measured are true indicators of the properties under

investigation. This should include data to support assumptions regarding the mineralogical origins of constituents like sulphate and base cations which are commonly used to estimate rates of acid generation and neutralization.

- Drainage concentration and flow data. The environmental impact of drainage chemistry will depend on downstream loadings and their effects on receiving water quality. Any drainage monitoring should include a measure of the flow rate. This applies to laboratory tests as well as to field monitoring.
- Consideration of the possible differences between tests and actual deposition, exposure and leaching conditions, including effects on mineral availability, reactivity, metal solubility and metal concentrations.

Large disparities often exist between laboratory tests and the actual site conditions due to differences in material creation, climate conditions, scale and in the case of waste rock, particle size. To distinguish the artificial nature of laboratory climate conditions, changes induced in the laboratory should be referred to as simulated weathering.

The onset of ARD is controlled by geochemical processes, such as the leaching of calcite, which may take many years to complete. Consequently, both at minesites and in test work the absence of acidic conditions does not in itself prove that there will be no future ARD.

Depending on materials and site, it may be necessary to consider the affect of additions from biotic and climatic sources.

Three on-site procedures are generally recommended for measuring drainage chemistry:

- pilot scale field test pads for waste rock and tailings,
- wall washing stations for mine walls, and
- operational monitoring of dumps, pits, impoundments and underground workings.

Long-term drainage monitoring and weathering studies are a major source of prediction data consulted in the review of mine closure plans. To determine the source of drainage, verify laboratory predictions and inform future management, BC mines are strongly encouraged to construct field test pads and wall washing stations for each different geological material/waste combination for which there is a significant metal leaching potential.

Humidity Cell Procedure

The humidity cell is the recommended kinetic test for predicting primary reaction rates under aerobic weathering conditions. The resulting data provides a measure of the rates of metal release, acid generation and acid neutralization under the geochemical conditions encountered in the test. Measured rates can be used to estimate the time to mineral exhaustion. The balance between the rates of acid generation and acid neutralization can be used to predict future geochemical conditions like pH, one of the critical information needs for setting site-specific waste disposal criteria.

Humidity cell results can also be used to crudely predict drainage chemistry. There are two possible approaches:

1. When sufficient parameters are measured to permit geochemical modeling, primary humidity cell weathering data can be used to predict resultant secondary precipitation products and their solubilities. This approach can be used prior to the availability of

on-site tests and monitoring. It requires that cell production rates be scaled to the hydrology of the site and the size and volume of the mine component.

2. Site monitoring data, detailing metal concentrations for various pH conditions, combined with geochemical conditions determined by humidity cell tests, and calculated flow rates can be used to predict the loadings from different mine components (for example, Cu concentrations at different pH values, as discussed in Morin et al, 1995a and 1995b; Morin and Hutt, 1997).

The main advantages of humidity cell tests are:

- well-characterized test materials can be utilized,
- consistent reproducible conditions permit comparison with results from other sites and,
- weekly flushing allows measurement of primary reaction rates.

Weekly flushing will only remove weathering products that are water soluble. The assumption that base cations and sulphate are water soluble should be verified as part of the test.

Possible differences in the characteristics and conditions of simulated-weathering in a humidity cell versus weathering in the field include:

- size of particles limited to fines, typically less than 10 mm in diameter;
- constant room temperature, a regular cycle of dry and humid air, and regular rinsing with distilled water;
- no heterogeneity in leaching;
- humidity cell procedures do not simulate the precipitation and dissolution of secondary weathering products.
- no conservation of heat generated by oxidation; and,
- minimal accumulation of soluble secondary weathering products.

Laboratory conditions in tests such as the humidity cell may enhance or depress rates of sulphide oxidation, leaching rates and carbonate dissolution relative to field conditions. Some processes which may cause discrepancies between laboratory and field rates include:

- Differences will likely occur in the accumulation of secondary minerals.
- Pretreatment grinding and crushing may damage mineral grains, exposing soluble base cations and hydroxides, making minerals more susceptible to weathering and creating more neutralization potential than is operationally available. This is primarily a concern for waste rock and wall rock, where only a limited portion of the mass ends up in the fines. Damaged, highly-reactive grains normally dissolve within the first few weeks of testing. This may account for the peak concentrations often observed in the early weeks of leaching.
- For a similar mass of material, the portion able to contribute to drainage chemistry will be much larger in a crushed humidity cell sample than in the actual waste rock and pit walls. Consequently, the available amount of sulphide-S and NP will be proportionally much higher in the test sample.
- Pretreatment comminution does not discriminate between high and low strength portions of the rock. Consequently, the fines in the test sample may include material that would normally occur as coarse fragments or relatively unfractured mine walls. This may pose a prediction problem if the "usually inert" material has a higher AP or NP content than the "real operational" fines.

Required items often omitted in humidity cell testing include:

- Tests should be run until a long-term steady state is reached or until the desired geochemical conditions are achieved. In some cases, a pretreatment may be required to remove a component, like gypsum, that masks one of the critical processes.
- Comprehensive static testing to determine the composition of critical parameters in the pre-test material and post-test residue.

CONSIDERATIONS FOR SAMPLING, ANALYSIS AND DATA INTERPRETATION

In addition to the demands of each test procedure, a number of critical interpretative considerations and information requirements result from the unique properties of different mine components. The example provided here are considerations for tailings.

Tailings

The following factors should be considered when predicting the future drainage chemistry of tailings:

- The composition of tailings may change considerably from that of the original ore. Milling procedures used by metal mines can remove sulphides and add alkalinity both of which reduce the metal leaching/ARD potential. Other milling practices can increase the potential for metal leaching/ARD through the addition of metal-bearing reagents like copper sulphate. The precise affect on the metal leaching potential will depend on the milling process, pertinent mineralogy and particle size/grain size relationships.
- Tailings are fine-textured and thus most of its mineralogy is exposed and readily available to contribute to weathering processes.
- Fine tailings have a reduced pore size and thus a lower permeability for both air and water. Restriction of water may result in a raised water table and/or drainage loss into surrounding, more porous strata. Restricted air movement may limit the rate of oxygen replenishment, reducing acid generation and metal leaching and perhaps changing the balance between acid generation and neutralization.
- Significant mineralogical and particle size segregation may occur when tailings are deposited. Selective deposition of heavy minerals may create zones of higher metal leaching potential close to the deposition point. The potential separation of sulphides or carbonates on tailing beaches may result in localized ARD.

Specific prediction needs for tailings are as follows:

- Pre-mining prediction should include a milling/metallurgical study of the removal of sulphides, additions of alkalinity, and additions or removal of metals, to determine their affect on the metal leaching/ARD potential. The study should identify the milling processes, pertinent mineralogy and particle size/grain size relationships and should cover the range in ore composition.

- Regular operational sampling and analysis of tailings, to verify pre-mining material characterization, should include monitoring to determine whether mineralogical and particle size segregation create zones of higher metal leaching potential close to the deposition point. Predictions should be modified according to observed differences.

CONCLUSIONS

The Prediction Manual attempts to provide clear, comprehensive guidance to metal leaching/ARD prediction without limiting options and approaches. Users of the Prediction Manual should consider the site-specific conditions and materials when deciding which rules and procedures should apply and how they should be implemented. Prediction questions should be clearly understood prior to sample selection and analysis and terminology should be succinct. Samples must be representative and materials and methods justifiable. Metal leaching/ARD predictions should be determined using comprehensive methods and analyses, proper data interpretation and all available knowledge of the site.

The Prediction Manual was produced to demonstrate how prediction test work and metal leaching/ARD aspects of individual projects are reviewed by MEI. The manual is a working document; additions and revisions will be made to reflect changes in technology and experiences of practitioners.

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