The ADTI/SME Prediction Volume: Techniques for Predicting Metal Mining Influenced Water: The Consensus Process and What's New

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ABSTRACT

Techniques for Predicting Metal Mining Influenced Water, which addresses the prediction and management of mine-affected water, is Volume 5 in the series of collaborative publications between the Acid Drainage Technology Initiative (ADTI), and the Society for Mining, Metallurgy and Exploration (SME),. Other volumes in the ADTI/SME series have included: Volume 1, *Basics of Metal Mining Influenced Water*, Volume 2, *Mitigation of Metal Mining Influenced Water*, Volume 3, *Mine Pit Lakes, Characteristics, Predictive Modeling, and Sustainability*, and Volume 4, *Sampling and Monitoring for the Mine Life Cycle.* A final volume addressing methods for modeling future water quality is in preparation.

Acidic and metal-enriched mine-affected water is a worldwide environmental problem resulting from weathering of mine-tailings and waste-rock. Management of mined materials is necessary to control impacts on surface and groundwater. The Prediction Volume summarizes the status of acid drainage and metal leaching prediction methods within the context of current best management practice. The volume repeatedly stresses the importance of a detailed understanding of geology including lithology, mineralogy and alteration history to interpret both static and kinetic acid drainage test results. The volume also proposes flexibility for kinetic test duration through the development of a site-specific objective-based framework that can be developed and modified to address project specific objectives.

INTRODUCTION

ADTI and the partnership with SME (after Hornberger, et al., 2000)

In 2014, the Acid Drainage Technology Initiative (ADTI)/Society of Mining, Metallurgy and Exploration (SME) published their prediction volume*: Techniques for Predicting Metal Mining Influenced Water (Prediction)*, one of several guidance documents being prepared by ADTI. The ADTI was initiated in 1995 by federal agencies, the National Mining Association, and the Interstate Mining Compact Commission to identify, evaluate and develop cost-effective and practical acid drainage management technologies. A founding team of regulatory, academic, and industry scientific experts envisioned that a consensus could be developed on reliable, standard static and kinetic test methods and other aspects of mine drainage prediction in the Appalachian Coal Basin. The name ADTI was also selected to emphasize the organization's central focus on technology development and transfer, rather than regulatory or policy issues. Early meetings of the Working Groups demonstrated the great value of coal-mining and metal-mining representatives working together on common objectives to address acid drainage problems confronting both sectors of the mining industry. Although initial efforts at developing various ADTI guidance went well, significant differences between coal mining and metal mining suggested the need for a Metal Mining Sector of ADTI (ADTI-MMS) to more effectively represent the interests of the metal-mining industry and the agencies involved in regulating and remediating metal mine sites. A more detailed historical review of the foundation of ADTI is provided by Hornberger et al., 2000.

The ADTI mission is to use the consensus process to refine prediction methods and management technology for the prevention, treatment and abatement of AMD/ARD pollution in an effective and economical manner. ADTI members believe that it is more productive to solve differences of opinion through the application of good science and consensus process rather than litigation.

Five technical focus areas were identified: (1) Sampling/Monitoring, (2) Prediction, (3) Mitigation, (4) Pit Lakes, and (5) Modeling. In 2007 the ADTI-MMS entered into an agreement with the Society for Mining, Metallurgy and Exploration (SME) to publish the workbooks noted above. The first of these workbooks was published in 2008: *Basics of Metal Mining Influenced Water*. Subsequent volumes include: *Mitigation of Metal Mining Influenced Water* (2009), *Mine Pit Lakes Characteristics, Predictive Modeling and Sustainability* (2009), and in most recently, in 2014, the volume described here, *Techniques for Predicting Metal Mine Influenced Water* and another, *Sampling and Monitoring for the Mine Life Cycle*. The last of the five volumes, on the subject of modeling, is anticipated in 2015.

Prediction Volume

Work on the ADTI prediction volume, began shortly after SME and ADTI agreed to coordinate on the series of workbooks in 2007. As with all the workbooks, volunteer collaboration within the consensus process has proceeded somewhat slowly. Initial drafts of the volume prepared with input from multiple authors were circulated in 2010. Following extensive reviews and edits, a final version was delivered to SME in the fall of 2013 for more detailed editing by SME. The volume was released in March of 2014.

Much of the volume's topics will look familiar to anyone working with rock characterization and acid drainage prediction:

- Chapter 1: Introduction
- Chapter 2: Acid Rock Drainage, Sulfide Mineral Geochemistry Affecting Drainage
- Chapter 3: Prediction: Background
- Chapter 4: Overview of Predictive Methods (Tools)
- Chapter 5: Evaluation
- Chapter 6: Application and Conclusion
- Appendices of Test Methods

Chapter 2, taken largely from Lapakko et al. (2004), focuses on mineral dissolution reactions that influence mine-waste drainage quality. The reactions presented result in acid generation, acid neutralization, and trace metal release. Within the chapter, soluble and insoluble ferrous and ferric solid phases of interest in mine and process waste characterization are identified.

Chapter 3 focuses on geology, lithology, and alteration, and includes a discussion of geoenvironmental models which can provide an initial assessment of potential water quality impacts based on characteristics of a mineral deposit. The chapter also includes a discussion of analytical techniques used to identify sample mineralogy, a critical need for interpreting both static and kinetic tests as noted below.

Chapter 4 includes a more detailed discussion than the GARD Guide (INAP, 2011) of the various static tests, short term and field leach tests, and kinetic tests, including field test methods that are, or have been used to, characterize materials. The strengths and limitations of the tests are discussed here and some examples of their use are also in Chapter 5, Evaluation.

Prediction of the acid-generating material at mine sites is now recognized as a crucial element of mine feasibility, permitting, and environmental review. Predictive technology has advanced considerably in recent years but still requires a detailed understanding of the entire range of complexities in the various units at a mine site needing evaluation. The ADTI/SME Prediction volume attempts to present a thorough discussion of the variety of predictive tests that might be considered for evaluating material that has the potential to be acid-generating:

- Will the material to be mined produce acid?
- Will the properties of the material change as mining proceeds?
- Are there units to be mined that can be used to neutralize or isolate acidic units?
- Will any acid produced impact ground- or surface water(s)?
- What series of test protocols accurately characterizes the material?
- Of these tests, which can be used to operationally segregate material that might need special handling or storage?
- Can any of the tests be interpreted to supplement geochemical modeling?
- Can any of the tests be used to develop field-scale tests that may help to confirm the laboratory tests?
- Can field-scale tests be interpreted to confirm geochemical predictions and modeling?

Together this iterative process should lead to a waste characterization system that enables a mine to accurately characterize and manage material at operational scales and timeframes. This system must incorporate all the information from all the testing and it must be both continuous and flexible enough to allow for the recognition and management of changed conditions.

The volume highlights the importance of a detailed understanding of sample mineralogy. The mineralogy of rock mined from ore deposits may host many generations of minerals, with many associated elements. Mineral composition and surface area, habit, encapsulation, and solubility direct influence reactivity, and therefore control sulfide oxidation and metal/metalloid release potential. A detailed evaluation of the minerals and their composition thus may be required, not only for the purpose of ARD potential and waste characterization but also for efficient recovery of the desired economic products. The choice of methods used for mineral and/or element analysis will depend on the questions that need to be answered. For example, is it more important to know the bulk concentration of an element of interest, or the mineralogical residence of that element? A number of analytical methods used for these purposes, such as XRD and SEM-EDX, are reviewed and discussed in the volume. Regardless of the technology or evaluation method selected, it is critical to remember that an understanding of the mineralogy is essential to understanding and interpreting any of the various predictive tests, not the other way around.

Evaluation

Where the ADTI/SME prediction volume differs from the GARD guide (INAP, 2011) and other guidance documents describing ARD testing methods is the discussion of evaluation provided in Chapter 5. Because these materials require: (1) subjective judgement in deciding when HC tests should be terminated, (2) may be used to answer multiple questions, and (3) are complex to interpret, the ADTI-MMS Steering Committee requested that the editors of the prediction volume examine this issue and include a discussion of humidity cell duration and provide a recommended framework that might aid in clarifying HC test objectives and termination criteria.

Although many have attempted to standardize the methods used to evaluate and predict the geochemistry of mined materials, the application of the individual analytical methods within testing programs continues to vary between jurisdictions and mine localities. One reflection of this is the varied duration of humidity cell (HC) tests during mine permitting baseline studies, which was raised as an issue during the preparation of this volume. Early work on HC method development indicated the potential need for extended run times (Lapakko, 1988, 1990; White and Jeffers, 1994), yet the initial ASTM standard developed in 1996 mentioned a minimum run time of 20 weeks (ASTM, 1996). Though other sections of the ASTM clarified that this was meant to be a minimum, this 20-week duration nevertheless became the "standard" run time. This led, inevitably, to arguments over humidity cell tests not being run long enough to accurately represent the potential for material to produce problematic drainage in a real world setting. It also, of course, led to the over-testing of some types of materials. Examples include samples with obvious potential to produce acidity in the short term being run longer than necessary to make an accurate determination of the material's need for special handling. Another, and particularly interesting example of this are inert materials, which have both low sulphide and low neutralization potential, which may appear to have uncertain potential for acid generation when they have little if any potential to produce acidity at all.

This framework/guidance is complicated by the fact that HC tests are often asked to answer two separate questions, neither of which the test is specifically designed to do:

1) How will the material perform in a real world setting and
2) What short term tests can be linked to the HC test results and then be used to accurately characterize the material so it can be managed and handled in a real time setting at a minesite?

Results generated during HC tests are not known in advance, so it is not possible to establish a specific test duration prior to test initiation. This makes it all the more important to develop rational objectives and criteria for test duration.

An understanding of the detailed objectives and rational criteria for test duration is necessary and should include a discussion of which samples are being collected and why samples are tested and evaluated: Why do we run these tests and what is it we're trying to accomplish? A mining company may use HC tests for internal environmental management programs or tests may be run as part of a larger, public permitting program. Tests may be run to identify material for selective handling, and terminated as soon as their character relative to that selective handling strategy (e.g., impoundment or encapsulation) has been identified (i.e., acid material in an HC test terminated at 10 weeks). Tests may also be run to predict the long term water quality of a material and therefore merit longer testing duration to evaluate metal release potential. The intended use, applicable regulatory guidelines, and relevant management scenarios identify the key stakeholders who define the objectives and criteria.

The objectives and rationale developed envision the involvement of knowledgeable stakeholders to develop site specific criteria for the following different possible objectives:

• Confirmation of Static Testing Results

a) For strongly acidic or basic samples
b) For neutral/inert or slightly basic samples

• Evaluation of Reactivity and Leachate Quality for Segregating Mine Waste

a) For neutral/inert samples
b) For inert/non-reacive

Each of the above possible objectives can involve criteria, which includes pH trends, sulfate release rates, Ca/Mg:S ratios, or ANP/AGP ratios among other possibilities. These criteria must be developed on a site/project-specific basis based on the site-specific lithology, mineralogy, trace-metal characteristics, and potential environmental risks.

• Evaluation of Quantity of Neutralization Potential (NP) Available to React with Produced Acid

In the event detailed information on the actual availability and timing of neutralization is critical to developing a comprehensive waste management plan, the following factors must be considered

a) Duration will be based on when NP of carbonate or other neutralizing minerals has been consumed. Tests based on this objective can be expected to have extended durations, potentially years rather than weeks.
b) Mine-waste constituents that are mobilized during weathering need to be identified and characterized.

• Prediction of leachate quality (metals/metalloids)

Given the potential duration of HC tests, the importance of early test initiation cannot be overstated. Other considerations include: (1) ongoing field pilot study tests, which can be used to supplement HC results and support detailed geochemical modeling; (2) geoenvironmental comparisons with closely related deposits; and (3) the possible need for duplicate cells for lithologies with complex mineralogy or conflicted static test results as an alternative to restarting humidity cells with disputed termination decisions.

Once the objectives and criteria for HC tests have been satisfied, this information can then, hopefully be used to develop a sequence of testing that can be used at an operational scale to effectively segregate and manage material at the mine site to meet environmental requirements.

CONCLUSION

The volume describes an iterative process characterizing and classifying mined material. One of five guidance documents developed through a unique consensus process within the ADTI, this volume addresses some key elements of management practice which include the perspective of regulators, corporations, and other stakeholders. While any waste characterization program should be based on clear set of sampling and testing objectives, criteria for terminating kinetic tests which are appropriate to the goals of the overall program (e.g., selective handling vs. use of material for construction, for example). In developing criteria for test duration, a thorough understanding of the following is needed:

- The petrology, mineralogy, alteration, and sequential mineralization history of material.
- The actual procedures used in the static and kinetic tests of the material

This detailed understanding will allow correct evaluation of results from both the static and kinetic tests performed on samples. Characterization of large tonnages of mining and processing waste requires complex and geostatistically sound sampling and characterization programs throughout the mine life to assure that relevant environmental standards can be met both throughout the mine life and beyond as the mine is closed and reclaimed.

The ADTI/SME Prediction volume also presents some ideas on a possible framework that might be used by stakeholders to develop rational objectives and criteria for the duration of HC tests that will contribute to reducing uncertainty and level of risk associated with mineral development.

Collectively this information will help assure that mines identify and manage materials that might adversely affect the environment if not handled appropriately.

ADTI-MMS continues to work towards its goals through coordination with the International Network for Acid Prevention (INAP) and its partners in the Global Alliance; South Africa's WRC (Water Research Commission), MEND (Mine Environment Neutral Drainage) in Canada, PADRE (Partnership for Acid Drainage Remediation in Europe) in the European Union, SANAP (South American Network for Acid Prevention) in South America, SMIKT (Sustainable Minerals Institute, Knowledge Transfer) in Australia, INAD (The Indonesian Network for Acid Drainage), and the CNAMD, The Chinese Network for Acid Mine Drainage in China.

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