

# ARD GEOCHEMISTRY IN THE DEVELOPING WORLD – DEALING WITH UNCERTAINTY, REGULATIONS AND THE NEED FOR CHARACTERIZATION OF MINE WASTE<sup>1</sup>

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**Abstract.** While many countries and international organizations have specific regulations for mining effluent and receiving water quality, the cause-and-effect link between mine wastes and the surrounding environment are often missed by regulators or mining companies. As a result, it is often the case that only limited data are available to decision makers at a time when it is most critical (e.g. project design and development phases). In an ideal world, the project would be delayed until sufficient data have been gathered to answer all pertinent questions. However, this is not always deemed feasible and therefore, decisions must be made with limited, often incomplete data sets due to aggressive scheduling and budgetary pressures. The decision making process is further complicated by regulations that are suitable for developed countries but may not be suitable for countries where socioeconomics, background chemical concentrations and artisanal mining are already causing significant human health impacts.

This paper will discuss decision-making in the face of uncertain data and will outline data requirements for the exploration stage that can reduce project delays and increase the confidence of particular decisions during project planning that are appropriate for the given, local conditions.

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## Introduction

In mining operations, the natural weathering of soils and rock typically is accelerated as these materials are disturbed and exposed to the atmosphere. This enhanced weathering may result in impacts to water resources. It is therefore necessary to evaluate the quantity and composition of possible runoff and leachate from the disturbed material to assess the potential implications to mine design and the environment. The results may influence mine planning and have ramifications with respect to overall acceptance of the project by the appropriate regulatory agencies and other stakeholders. If a potential problem is identified, mitigation measures can be developed to prevent, reduce or eliminate the impact.

Environmental impacts of most concern at sulfide-ore mines commonly are those associated with the presence of reactive sulfide minerals. When sulfides are exposed to the atmosphere, they have the potential to react with O<sub>2</sub> and water to produce acid rock drainage (ARD). The resulting acidity may then be neutralized by minerals that contain buffering capacity. Carbonate minerals generally are the most effective in counteracting acidic conditions, but other minerals (e.g., silicates) may contribute as well. If insufficient buffering minerals are present, significant quantities of acidity, SO<sub>4</sub><sup>-2</sup> and metals may be released from the mine wastes. However, it should be noted that metal leaching (ML) can also occur in the absence of reactive sulfides under non-acidic conditions due to dissolution of other soluble mineral phases. Significant concentrations of sulfate may be released even if the acid-neutralization capacity of the rock is sufficient to prevent acidification. In addition, release of nutrients (e.g., NH<sub>4</sub>NO<sub>3</sub>) may take place due to the presence of residual explosives or the breakdown of cyanide if it is used in mineral processing.

In order to capture all of these issues, a comprehensive geochemical characterization program is required as the results will affect almost every facet of the mine. The context of this paper is that of mine development. This process is a catalyst for an extensive set of multi-disciplinary studies to characterize the existing environment, any impacts and the technical details of mine operations such as extraction, processing and infrastructure. Development will require baseline investigations, feasibility studies and impact assessments. This process will not only determine whether a mine is viable but will also demonstrate to the government of the host country that not only is it economically beneficial in the first instance but that it will not impact the surrounding environment, potentially leaving the host country with not only severe long-term environmental and health impacts, but also to the economy.

One very important component of this process is the characterization of any generated mine wastes. Experienced mining companies, regulators and practitioners are aware of the steps required for this proper characterization, and the process is well documented and laid out in several publications (e.g., INAC, 1992; MEND, 1991; Price, 1997; U.S EPA 1994). However a complete and proper characterization requires significant effort, time and money. These three may not always be available. Therefore decision to proceed may be made without complete data. Decision making in developing countries is hampered further by circumstances which, while most developed countries have, are often not as extreme. Often the environment and particularly water quality are already impacted by historical and/or artisanal mining, agriculture, poor sanitation and other existing activities. Water quality standards may exist, but may be incomplete or not particularly protective of aquatic or human health. In addition, these developing countries may not have the technical expertise to properly assess the data collected

for ARD characterization. Also, there may be no regulatory requirement to assess mine wastes, despite the fact that they are directly related to water quality.

This paper does not present case-studies but is a collection of issues that the authors have experienced as consultants. It is meant to provide awareness to the readers and audience with the challenges presented in the context of mine feasibility and permitting process in developing a mine in developing countries. Perhaps it is better discussed in a round-table format but the goal is to at least provoke discussion and is certainly not meant as a critique of mining companies, regulators or consultants or as a commentary on the knowledge or capabilities of developing countries. However, many of these problems are also present and relevant in the developed world. The following describes common issues and some solutions that may be used to overcome these difficulties.

### **Environmental Data Requirements**

The Issue: It may not be possible to obtain all of the information that is desired based on the proponent's aggressive schedules and limited budgets

A geochemical characterization requires much data from many sources. Without this data, compromises must be made in order to produce results. Information such as background water quality and hydrology for a full year that includes a dry and wet season, hydrology of surrounding rivers and streams, metallurgical information and correct baseline stations should all be available. Certain types of data can be made available if countries have the proper infrastructure and records available, but this is not always possible. This places the onus on the proponent to obtain this baseline data whereas in developed countries some of this information may already be available. In a permitting and feasibility situation, schedules would be adjusted to allow for the collection of the missing information, but this is not always deemed feasible. Therefore, compromises must be made. Information from similar or neighboring mines sites may be used but usually a range of extreme conditions are used in order to make adequate design decisions.

Most importantly the proper geochemical testing must be performed. A staged approach is best. This starts with proper sample selection that includes a large enough number of samples that are representative of the deposit and mine wastes. Secondly, static tests are performed to determine the magnitude of the problem. Supplementary sample selection may then be required to fill in any data gaps. Long-term kinetic testing is required to gain an understanding of weathering and mineral reaction rates. These tests can take a significant amount of time, weeks to months, to produce meaningful data.

### **Suggested Approach**

The only way to overcome this, as a consultant, is to inform the client of the limitations that proceeding with incomplete data sets and assumptions imposes and to provide conservative estimates that will be protective of the environment. Some possible approaches to this include:

- 1) Working with uncertainties and building ranges of possible results based on the data available and precedent data from mine sites in similar geological settings. Data from several mine sites must be reviewed based on geological conditions, alteration types, site considerations and deposit types to develop a suitable range of possible conditions that are reasonable and conservative.

- 2) The risks associated with proceeding using non-site specific data need to be clearly and effectively articulated. The risks include increased costs for monitoring, increased cost and scope of mitigation and loss of reputation if statements regarding risks need to be significantly amended or updated.

If the range of uncertainties is so great that the use of limited data would result in unacceptable financial burdens to the mining company if mitigation were required, or unacceptable environmental conditions leading to mine closure, then delays to the project schedule are inevitable while more site specific data is collected.

While documents related to pre-feasibility, feasibility, and permitting are being reviewed by the authorities or banking institutions, it is the responsibility of the mining companies to ensure that sufficient site specific data is collected to confirm that the assertions and ranges presented within the documents is acceptable. If the site specific data cannot confirm the assertions of the regulatory submissions and feasibility documents, then addenda and amendments to the documents must be prepared and submitted. This is a part of the risk assumed when a company decides to proceed when complete site specific data is not available, and must be articulated by the professionals working on the project. Having the follow-up data available should questions arise during the document review would also assist in speeding up the review process and minimize possible delays to the project.

### **Water Quality Standards**

**The Issue:** The appropriateness and usefulness of existing water quality standards of the host country.

In developed countries water quality standards are entrenched in mine planning, operation and closure. Generally, they have been around long enough and enforced appropriately so that they are generally now protective of relatively pristine water quality. However, in developing countries, existing water quality and water quality standards are not necessarily comparable.

Often, water quality standards are not sufficient for the protection of aquatic life or human health. Developing countries may not have a complete list of chemical parameters in their guidelines. In addition, the concentration limits may be too high for any real meaningful protection. In other cases, although standards are suitable, the countries may not have the resources to police or enforce existing standards, and in fact, may not have the political will to impose or police environmental restrictions where imposition of these restrictions would affect local economies.

#### **Suggested Approach**

In these cases it is the ethical responsibility of the mining company and professionals working on the job to ensure that internationally recognized and/or western standards are used and adhered to in such a way that project impacts are sufficiently reduced and tolerable. The risks associated with a mining company knowingly allowing harmful discharges to the environment, regardless of regulatory requirements, includes, at the very least, the risk of negative public perception. Negative public perception can negatively influence stock prices and cash flow. In addition, as governments and regulators in developing countries become more knowledgeable, long term liabilities may be incurred as governments may seek to recoup costs for past environmental damage.

The Issue: Baseline conditions exceeding guidelines prior to mining.

In many mining districts in developing countries historical mining may have already impacted areas where proponents are planning new developments. Usually, these historical operations were unregulated, are possibly abandoned and have had significant environmental impact. In areas of mineralization, artisanal mining, while small in size, may have already significantly degraded local water quality. Lack of proper sanitation and agricultural impacts may also lead to a degradation of water quality. In some cases past practices have degraded water quality to an extent that the existing background conditions do not meet applicable water quality standards for drinking water, aquatic health, or agricultural use. In many instances there is no particular accountability with respect to historical degradation of water quality.

If a mine has proposed development in such areas, meeting ambient water quality standards may not be practical as it is already at an unacceptable level and the generally accepted treatment may not result in better ambient water quality anyway. This is not to say that mining companies should not be released from their obligations for effluent control, but it is not practical to enforce regulations that are unattainable even before mining begins.

#### Suggested Approach

This issue highlights the need for proper baseline data collection to distinguish existing impacts. Furthermore, companies proposing development can expect to be held liable for past degradation of water quality unless ample, high quality baseline data, is collected and presented publicly, prior to mine construction.

Responsible mining companies treat their effluent to industry standards and will often produce a better quality of water than the existing streams. In these areas of mineralization, mining companies acquire property with historical mines and artisanal mining. As part of their responsibility to control effluent, mines may clean up these historical sites and control the artisanal mining populations. Development in the area and in the surrounding communities may also lead to proper sanitation and a chance to improve water quality in that regard.

Once it can be demonstrated that the project is improving human and environmental health and is improving the quality of life for the people that may be affected by the project, then it is necessary to negotiate with applicable government agencies regarding exemptions to standards already exceeded by background conditions, and to commit to site specific, protective water quality and environmental targets.

### **Regulator Knowledge**

The Issue: ARD characterization is not always required explicitly by regulators. The mine development process results in highly a technical, multi-disciplined product that is not always intuitively understood.

Many countries and international regulatory agencies have ambient and discharge water quality regulations that are designed to be protective of aquatic or human health. However, the link between the effect of mine wastes and these water quality limits are not often realized. The effluent concentrations are regulated but often there is no regulatory requirement to characterize these wastes which are the single-most important component to discharge water qualities.

As already mentioned, the need for a complete characterization is not always recognized in some countries as it is not a specific requirement of the permitting process. If the

characterization of ARD is not required by regulation, then often there is no recognition of the importance of testing for ARD and the relationship between ARD and water chemistry. Given the importance of this characterization to all aspects of the project, the proponent should be aware that regardless of the regulatory environment, ARD testing is necessary in order to answer key questions in the mine design and waste disposal options. Unfortunately, the roll of educating key individuals often falls upon the professionals, and if the professionals are not successful in convincing the proponent of the importance of baseline geochemistry characterization, or do not strongly insist on a proper characterization program being completed, then project delays and liability issues on the part of the proponent may result.

When done, a proper characterization results in a highly technical document with information that is not always intuitive to many regulators. Many assessments result in prediction of water qualities using large complicated models that are difficult to understand at the best of times. This leaves room for others (both pro-mining factions, and anti-mining factions) to take advantage by blinding the regulators with too much science, or by attempting to distort the results of the assessment. Often times, there is no sufficient technical expertise on the part of the regulator to properly assess and understand the data or interpretation.

#### Suggested Approach

Despite the lack of any specific requirements by regulators, ARD to characterization should be an integral component of mine development. While it may not be a requirement of the host country, international financing will require this characterization to be consistent with Equator Principles (June, 2003), International Finance Corporation (IFC) Safeguard Policies (IFC, 1998) and World Bank Pollution Prevention and Abatement Handbook (PPAH) (World Bank, 1998)

Ideally this would be used as a learning experience between the proponent and the regulator. This is an advantageous scenario as it may lead for a smoother permitting process in the future and would serve to increase the technical knowledge base of those developing countries. It would allow for a more informed and streamlined assessment of future projects and identification of the real issues. However this type of exchange is relatively infrequent as there is no requirement for this in the permitting process. Alternatively, the proponent may be required to pay the host to retain independent reviews to provide any paucity of specific technical expertise.

#### **Role of the Professional**

The Issue: It is the professional who performs the baseline studies and geochemical characterizations, often under tight budgets and aggressive schedules.

Quite often, professionals from developed countries perform the geochemical characterizations. They usually belong to professional organizations that regulate acceptable levels of technical knowledge and ethical standards. These professionals are typically hired by mining companies either directly or through consulting agencies to perform this task in order to obtain the appropriate permits for operation. This involves a balance between their commitment to their employer or client, regulatory requirements and ethical responsibilities.

Professionals cannot be reasonably expected to work beyond the scope, tasks, and budgets assigned to them, however, within the limitations of their contracts and schedules, it is up to these professionals to ensure that these studies are completed to appropriate industry standards, Equator Principles, IFC and World Bank guidelines using available information. They then must

clearly present the results of these studies to the mining companies, or decision makers within the company.

#### Suggested Approach

When there are scope, schedule or budget limitations that could affect the quality of the data collected, or if there are limitations with respect to the data available, then it is the role of the professional to clearly articulate the risks to the mining company, with respect to permitting, liability, costs, and schedule to the mining company such that appropriate decisions on the project can be made. If necessary, these risks must be accounted for through the use of appropriately conservative values for impact assessments.

### **Mining Companies**

The Issue: Informed proponents with sufficient budgets, flexible schedules and information available to complete the assessment.

It is the mining company for whom the consulting professionals or for whom individual professionals work. The mining company ultimately holds the responsibility for making project decisions and the liabilities that result from those decisions. It is strongly recommended that personnel in decision making roles take an active role in ensuring that they understand the key drivers in the human and environmental health and ensuring that sufficient resources are available to properly evaluate potential mine sites.

Often the limiting factor in characterization is time and aggressive scheduling is common in order to quickly move the mine into production. In addition, there is no doubt that a proper geochemical characterization is a large expense, and budgetary restraints may limit the scope of the geochemical characterization. Also, during feasibility and permitting, project descriptions, mine planning other details required to assess the impacts of the waste are works in progress and are not always available or final. These all result in data gaps and require assumptions to be made.

#### Suggested Approach:

Companies need to recognize in the early stages that strong baseline data is a valuable asset, both in terms of limiting liability for past site activities, and in ensuring proper design decisions can be made. When proper baseline geochemistry and water quality data is collected and proper evaluations are completed during the project planning phase, mitigation measures can often be implemented in the design phase that can have minimal impacts on overall project costs, but will have significant environmental advantages over a poorly planned design.

### **Conclusions**

Mine wastes directly affect the surrounding environment and are often the single-most important component in determining water quality impacts for mining projects. In order to predict water quality, assess impacts and plan for mitigations strategies, a comprehensive geochemical characterization program is required. While the details of this program are well documented and generally accepted, there are certain issues that can prevent proper characterization.

Firstly, there is the set of data requirements. All baseline data (water quality and quantity) and a sufficient number of representative samples of expected mine wastes should be available

and the proper testing should be performed. However, budgetary and scheduling constraints along with a lack of data sometimes require that conservative assumptions be made. In this case the risks of proceeding with conservative assumptions and a lack of data must be clearly articulated to involved parties.

Water quality standards used are often suitable for developed countries but do not consider the societal pressures, background water quality and historical mining activities that may occur in developing countries. Development of the mine can sometimes actually improve water quality, force the closure of historical mines and control artisanal mining. Before blindly applying water quality standard in developing countries a proper social, environmental and economic assessment should be completed to determine whether the standards are appropriate for the conditions encountered and whether more stringent, (or less stringent) water quality targets are required. If changes to the standards are required, then a consultative approach with the regulating agencies is required. In several instances this may mean working with regulators to ensure they understand the technical documents in order that they can make sound decisions.

Through all of this, it is the responsibility of the mining company and their consultants to adhere to established ethical standards, either forged by international organizations (e.g., IFC and World Bank) or by proponents and professional communities and societies. Proper baseline data is a valuable asset for mining companies that can limit potential liabilities and assist in proper design and decision making. Resources should be made available in the exploration phase of a project to ensure that appropriate data is available.

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