

# Acid Rock Drainage Management



## Introduction

Acid rock drainage (ARD) is a general term for weathering of sulfide minerals, such as pyrite, and the resulting storm water runoff or leachate that contains elevated acidity and dissolved metals. It is a naturally occurring process that may be increased and/or accelerated by certain mining and mined rock management practices. If not properly managed, the environmental impacts from ARD can result in serious degradation of water quality, wildlife and vegetation. Terminology such as acid mine drainage (AMD), acid drainage (AD), and mine impacted waters (MIW), are generally interchangeable for the term ARD as used in this discussion.

The well-documented occurrence of sulfide bearing rocks (associated with some metallic mineral and coal deposits) has led to improved mining techniques and the ability to mitigate past impacts from older mines. With appropriate planning and operating practices, ARD will either not form at all, or is safely managed on site and will not impact the environment. The following is intended to provide an overview of ARD management practices in mining and mineral processing, and resources for additional information.

## Chemistry and Neutralization

ARD is a water solution containing elevated acidity and elevated dissolved metals. The three essential ingredients necessary in its formation are: 1) sulfide minerals, 2) water or a high humidity, and 3) oxygen or air. The rate at which ARD forms is a function of many parameters including temperature, pH, sulfide mineral surface area, oxygen concentration of air or water, the degree of saturation with water, and the presence of certain bacteria. The resulting sulfuric acid and dissolved metal concentrations are a function of site specific sulfide mineral composition and concentration, the rate of oxidation, and interactions with neutralizing materials. If improperly managed, ARD can degrade drinking water quality, and it can be toxic to plants and animals.

Without any one of the three essential ingredients (sulfides, air, and water), ARD will not form. For example, sulfide minerals will not dissolve in water without first oxidizing in air. Conversely, if sulfide minerals occur in a dry environment, and are oxidized in air but there is no contact with water, then the constituents will not be dissolved or mobilized. Or if sulfides are submerged beneath surface or groundwater that has a low concentration of dissolved oxygen, then little or no oxidation can occur.

Iron sulfides (such as pyrite) and other metallic sulfides (such as of zinc, copper, and lead) are minerals that can form ARD. Iron sulfides occur naturally in many numerous rock types throughout the world (even non ore bearing rock types), including some coal deposits, and some metallic mineral deposits. Sulfide minerals are also found in active geologic settings such as hot springs (e.g. at Yellowstone National Park) and at deep marine springs (e.g. "black smoker" vents). Natural weathering of many mineralized areas yield ARD, even without mining or other human disturbance. In some areas, this has led to the exploration discovery of a mineral deposit.

Contacting certain natural alkaline materials such as limestone, dolomite, some silicate minerals, and alkaline soils will neutralize ARD and attenuate its constituents. Wetlands and other organic rich environments will naturally neutralize ARD and often will precipitate insoluble sulfide minerals. Organic biosolids and certain manufactured chemicals will also neutralize and attenuate ARD constituents. The degree of neutralization and attenuation is a function of the overall acidity and metal concentration of ARD, versus the amount and concentration of neutralizing and attenuating material available.

### **Management Practices**

Significant strides in understanding, preventing, and controlling ARD have occurred worldwide in the past 20 years. Depending on site specific conditions, sulfide minerals may be exposed to air and water in mine workings (such as surface or underground mine walls), concentrated ore stockpiles, rock storage facilities, and tailings storage (residual ground rock from a milling process) facilities. Careful management of these occurrences will prevent or minimize ARD formation.

Pre-mining laboratory testing of drill hole and other samples provides valuable estimations of the ARD potential of rocks to be mined and processed, and of the neutralizing potential of surrounding rocks and soils. Several test methods are used to calculate the net balance of acidic versus neutralizing characteristics. Baseline water quality, vegetation, and wildlife surveys are also invaluable for establishing pre-mining conditions. These results will be useful during monitoring of mining operations and reclamation to ensure that the site is not generating ARD constituents at levels above baseline conditions or allowable water quality standards.

Numerous methods for managing sulfide materials are available to prevent ARD formation, and many treatment methods are available if prevention is not achievable. Prevention methods include sulfide material selective handling, lining, capping, underwater submergence, alkaline addition, and storm water controls. Isolating sulfide materials from air or water will prevent ARD from forming and/or leaving a facility. Capping is one way to isolate the sulfide material and therefore reduce oxidation and contact with storm water. Submergence beneath surface or ground water has been successful in reducing ARD at some sites by limiting the amount of available oxygen (analogous to a steel ship that is submerged in a low oxygen lake or ocean and may not rust for decades or more). Blending limestone or other neutralizing materials into sulfide materials will neutralize ARD as it is formed and minimize the possibility of its mobilization.

Surface and groundwater monitoring during and after mining operations is used to determine if ARD is present. For sites where the prevention methods are unsuccessful, monitoring will alert the operator and agencies to the occurrence. A properly designed monitoring program will provide an "early warning" of ARD or conditions that could allow its formation. Contingency plans must be in place and implemented so as to contain the ARD on site, and trigger its treatment.

Treatment of ARD, while achievable, is often more costly and resource intensive than preventing its formation. Methods for treatment include collection and neutralization of impacted water and attenuating the dissolved constituents using one or more methods. These often require capture systems, pumping, and conveyance piping, treatment tanks or vessels, and/or constructed wetlands. Neutralization and attenuation are accomplished by contacting the ARD water with materials such as crushed limestone, hydrated lime, soda ash, caustic soda, hydrated ammonia, or organic biosolids. Treatment can also be accomplished at some sites by routing the ARD waters through a constructed wetland. Some ARD treatment systems require multiple steps to meet allowable water quality standards.

Appropriate application of these management methods and technologies often will in effective prevention and treatment of ARD at mine sites that contain sulfide minerals.

#### **For More Information**

To learn more about ARD and how it is managed at mine sites, we recommend the following sources:

#### **International Network for Acid Prevention (INAP)**

<http://www.inap.com.au/inap/homepage.nsf>

This website and industry organization globally coordinates information sharing and research on acid drainage knowledge and promotes significant improvements in the management of sulfide mine materials.

#### **Acid Drainage Technology Initiative – Metal Mining Section (ADTI-MMS)**

<http://www.unr.edu/mines/adi/index.html>

This website is the location for this U.S. initiative led by representatives of state and federal government, academia, the mining industry, consulting firms, and other interested parties. The initiative is designed to identify, evaluate, develop, and disseminate information about cost effective, environmentally sound methods and technologies to manage mine waters and related metallurgical materials at mine sites.

#### **Australian Center for Mining Environmental Research (ACMER), and the 1994 Handbook “Management of Sulfide Mine Wastes and Acid Drainage”**

<http://www.acmer.com.au/>

<http://www.acmer.com.au/publications/attachments/Management%20of%20Sulfidic%20Mine%20Wastes.pdf>

The ACMER website and organization is led by Australian mining industry, government, and other stakeholder representatives. It is designed to provide the scientific and technological support to enable the minerals industry to enhance

its environmental performance from exploration to active mine management and closure.

Their 1994 Handbook "Management of Sulfide Wastes and Acid Drainage" is a comprehensive description of ARD including preventive measures, monitoring, and mitigation. An electronic copy of the document is posted at the above website address.

**Mine Environment Neutral Drainage (MEND) - Natural Resources Canada**

[http://www.nrcan.gc.ca/mms/canmet-mtb/mmsl-lmsm/mend/default\\_e.htm](http://www.nrcan.gc.ca/mms/canmet-mtb/mmsl-lmsm/mend/default_e.htm)

This Canadian government website provides information about the MEND program that was implemented to develop and apply new technologies to prevent and control acidic drainage at mine sites. The program is jointly funded by the Natural Resources Canada and the Mining Association of Canada.

**Acid Mine Drainage Index (AMD I) – U.S. Dept. of the Interior, Office of Surface Mining**

<http://www.osmre.gov/amdint.htm>

This U.S. government website is maintained by the Office of Surface Mining, which is charged with managing surface coal mining activities. The site is a source of ARD prevention and mitigation technologies as it applies to coal mining sites.

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