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ACID ROCK DRAINANGE

What is Acid Rock Drainage?

Acid Rock Drainage (ARD) forms when sulphide-bearing mine wastes (principally pyrite [FeS_2]) are exposed to oxidising conditions. Potential sulphide-bearing materials include waste rock from overburden, interburden or partings and processed ore (tailings). In some situations, low-grade ore stockpiles, open pits and exposed rock in underground mines may generate acidic conditions.

ARD can cause major long-term environmental problems at mine sites if appropriate prevention and/or management strategies are not adopted.

Not all mining operations that expose sulphide-bearing rocks result in ARD. In some situations the sulphide minerals may be non-reactive or there may be sufficient inherent buffering capacity to neutralise any acid released from sulphide oxidation.

In order to effectively manage ARD and minimise the risk of long-term liability, it is necessary to gain a thorough understanding of the materials to be disturbed by mining activities. There are considerable advantages in mining companies taking a proactive approach to the management of ARD. Remediation of advanced ARD is considerably more difficult and expensive than early prevention. The effective use of geological modelling, appropriate waste characterisation testwork and attention to the degree of environmental risk are integral to developing a strategy for the safe handling and subsequent rehabilitation of mine wastes.

Why does Acid Rock Drainage Occur?

The principle cause of ARD is the oxidation of pyrite. The pyrite oxidation process is complex and involves several chemical, biological and electrochemical reactions. The rate of reaction is dependent on several factors including the surface morphology of the pyrite, the oxygen concentration, the pH, the presence of bacteria and the presence of acid-consuming materials. The reaction process can be exposed by the three reaction stages for the oxidation of pyrite:

Stage 1 $FeS_2 + 7/2\ O_2 + H_2O \rightarrow Fe^{2+} + 2SO_4^{2-} + 2H^+$

Stage 2 $Fe^{2+} + ¼\ O_2 + H^+ \rightarrow Fe^{3+} + ½\ H_2O$

$Fe^{3+} + 3\ H_2O \rightarrow Fe\ (OH)_3 + 3H^+$

Stage 3 $FeS_2 + 14\ Fe^{3+} + 8H_2O \rightarrow 15Fe^{2+} + 2SO_4^{2-} + 16H^+$

The impacts associated with ARD are primarily caused by the generation of acidity and the subsequent release of dissolved metals, either directly from sulphide minerals or by acid attack on associated minerals within the rock.

How is the Acid Generation of Mine Wastes Predicted?

The first step in managing mine wastes should be to identify the wastes that are potentially acid generating. The identification of potentially acid generating wastes typically involves a step-by-step process of preparing geological models, examining comparative information, sampling, laboratory analysis and classification. As this process unfolds a predictive model of waste behaviour (eg. relative acid generating capacity and acid neutralising capacity) should be developed along with appropriate waste handling and management protocols.

⇒ ***Geological Modelling***

Geological, chemical and geotechnical information should be used to provisionally identify distinct waste units within the proposed mine plan.

⇒ ***Comparative Information***

Regional geological and geochemical information should be included in the geological model. This comparative approach is particularly applicable to coal mines where a higher degree of stratigraphic continuity can be expected.

⇒ ***Sampling***

Effective sampling is critical to any waste characterisation programme. Representative samples should be taken of all provisional waste units. The number of samples required to adequately assess an area is site specific and should reflect the nature of the potential ARD problem being assessed.

⇒ ***Laboratory Analysis***

Chemical analyses undertaken in the laboratory can include initial screening tests, geochemical static tests, solubility tests and kinetic tests.

What Laboratory Analytical Tests are Available to Characterise Mine Wastes?

Good, reliable and reproducible analytical data is essential if a true assessment of potential ARD problems and liabilities is to be made.

ALS has an in-depth understanding of ARD and provides a full range of relevant analytical services to help the ARD investigator assess and monitor this potential problem.

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Because of ALS's experience and professional capabilities, the ARD investigator can be confident that testing is being carried out in a controlled environment using correct reagents, proper equipment, suitable instrumentation, established procedures and experienced staff.

Analytical methods applicable to the evaluation of ARD potential and the processes involved include the following:-

APP - Acid Production Potential

APP is a measure of the total acid producing potential of a material, irrespective of whether that material may also have the potential to produce alkali. APP is determined from the analysis of total sulfur in the sample and is calculated assuming a total conversion of sulfur to sulfuric acid. APP is reported as kg H_2SO_4 per tonne.

ANC - Acid Neutralising Capacity

ANC measures the capacity of a sample to neutralise any acid that is produced. In the ANC analysis a finely ground sample is reacted with a known amount of hydrochloric acid. The resultant solution is back titrated to pH 7.0 with sodium hydroxide to determine the amount of acid neutralised by the carbonates and other acid consuming minerals present in the original sample. ANC may be reported as either kg $CaCO_3$ or kg H_2SO_4 equivalent per tonne.

NAPP - Net Acid Production Potential

Based on the British Columbia test as outlined in Coastech Inc (1990) Acid Mine Drainage Prediction Manual, NAPP gives a theoretical prediction of whether the Acid Production Potential (APP) of a material is greater than its Acid Consumption (AC) capacity. AC, which uses a titration end point of pH 3.5, has been replaced in recent times by ANC (titrated to pH 7.0).

When NAPP is requested, Acid Production Potential (APP), Acid Neutralising Capacity (ANC) and whether the NAPP is positive or negative are all reported.

NAPP is a worse case scenario test and is therefore useful for screening samples into potential acid producers and non-acid producers. NAPP suffers from the tendency to over predict the acid production potential because it does not differentiate between acid producing and non-acid producing forms of sulfur.

NAG - Net Acid Generation

NAG, or NAP (Net Acid Production) as it is sometimes called, is based on methodology from Stuart Miller of Environmental Geochemisty International (1998). This static method uses hydrogen peroxide to oxidise any sulfides present in the sample. The acid produced from the oxidation reaction may subsequently be partially or totally consumed by acid neutralising components of the sample. Any remaining acidity is determined by back titration to both pH 4.5 and 7.0, and reported as NAG, expressed in kg H_2SO_4 equivalent per tonne.

Forms of Sulfur

Sulfide

The Acid Production Potential (see APP above) uses a measure of total sulfur by high temperature LECO furnace as an estimate of "sulfide sulfur". The LECO determination does not take into account any oxidised or partly oxidised sulfur (eg. Sulfates & Sulfites) nor the presence of organic sulfur (eg. in coal mine tailings) but rather reports a "total sulfur" figure.

Better estimations of sulfide can be made from one of the following:

i) Reporting sulfides as the difference between total sulfur and sulfate. Sulfate is determined by ICPAES on a dilute hydrochloric acid or sodium carbonate leach. The leach procedures are simple techniques but do not necessarily dissolve all the nonsulfide sulfur bearing compounds. The hydrochloric acid leach does not take up insoluble sulfates such as barium sulfate (Barite) and strontium sulfate (Celestine) nor acid insoluble organic sulfur compounds. The method may, therefore, lead to an overestimation of the sulfide problem, as it underestimates the sulfates. The sodium carbonate leach will determine all sulfates; however, as sulfide is reported by difference, elemental and organic sulfur will still report as sulfide.

ii) Sulfide can be measured directly using a low temperature (850-900^{o}C) LECO determination. Elemental sulfur and organic sulfur will still report as sulfide, however all sulfate compounds are excluded.

Sulfate

Soluble sulfate can be measured on a 1:5 solid:water leach. Along with changes in pH, soluble sulfate is useful in monitoring the production of sulfuric acid through the oxidation processes.

Forms of Carbon

Organic Carbon

Organic carbon may be present in tailings or in topsoil. It is routinely measured by high temperature LECO furnace with a CO_2 infrared detector, after prior treatment of the sample with acid to drive off the inorganic carbon.

Inorganic Carbon

Inorganic carbon (carbonate) is important as a source of acid consuming capacity. Inorganic carbon is determined as the difference between total carbon (by LECO) and organic carbon as measured above.

pH (1:5)

The pH value indicates whether the material is acid or alkaline. A pH below 5.5 suggests that prior acid generation may have occurred. pH is routinely analysed on a 1:5 sample / water extract, however, paste pH is available as an alternative.

EC - Electrical Conductivity

The electrical conductivity indicates the level of soluble salts (salinity) readily leached from the material and is analysed on a 1:5 sample / water extract. Electrical conductivity is reported in μS/cm. Total Soluble Salts (in mg/kg) can be calculated from the electrical conductivity.