# APPLICATION OF ACID-BASE ANALYSIS TO WASTES FROM BASE METAL AND PRECIOUS METAL MINES[1]

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Abstract--Acid-base analysis is used to assess the potential for waste materials to generate acid when exposed to an oxidized leaching environment. Even though the procedure was initially developed for coal mine overburden and reject, it has become widely accepted as tool in the assessment of waste rock and processing wastes from base metal and precious metal operations.

This paper examines the applications of the acid-base analysis to non-coal situations based on the authors' direct experience at more than 30 base metal and precious metal projects in Australia, New Zealand and Papua New Guinea. The fundamental principles of the technique are outlined and the major potential pitfalls in interpretation and use of acid-base data are described. The paper concludes that the acid-base technique is an essential tool for the assessment of waste characteristics as well as being suitable as a monitoring procedure at non-coal mines. However, the interpretation of results is site-specific and requires detailed geochemical investigation to provide the understanding and data base for this interpretation.

## INTRODUCTION

The acid-base analysis has been used extensively for at least 10 years to identify acid forming and potentially acid-forming mining wastes. The procedure reported by Sobek et al. (1978) for coal mining wastes has been applied in many and varied environments, geological materials and in many countries. Even though the procedure was initially developed for coal mine overburden and reject, it has become widely accepted as a tool in the assessment of waste rock and processing wastes from base metal and precious metal operations.

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## THE ACID-BASE ACCOUNT: THEORY AND PRACTICES

The acid-base account, also known as the Net Acid Producing Potential (NAPP), is calculated from the total sulphur content and the inherent acid neutralizing capacity (ANC) of a material. NAPP is defined as follows:

$$NAPP = \%S \times 3.125 - ANC$$

where ANC and NAPP are in % $CaCO_3$ equivalents.



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A negative NAPP indicates that there is excess neutralizing capacity and that the material is non-acid forming whereas a positive NAPP indicates that the material is acid or potentially acid forming. The pH and electrical conductivity of a saturated paste of crushed (-2mm) material is used to support the NAPP classifications.

Geochemically there are a number of fundamental concerns in the theoretical basis on which the acid-base or NAPP technique is based. The major concerns are as follows:

1. Assumes all sulphur occurs as pyritic sulphide and is acid forming;

2. Assumes all ANC is available to neutralize acid; and

3. Does not consider the kinetics of either the acid forming or acid neutralizing processes.

The first two concerns may be considered to balance each other, however, failure to consider the site specific mechanisms and kinetics when assessing the likely field geochemistry of a particular waste can result in significant error.

The NAPP procedure is an essential tool in waste characterization but the interpretation and identification of the implications for waste management requires a more detailed determination of waste geochemistry. Once the broad principles of the site-specific processes have been identified, a monitoring and management program can normally be developed which is based on the NAPP procedure.

The most important step in carrying out a NAPP assessment of waste rock and ore from a base metal sulphide or gold operation is sample selection. There is generally wide variability in the degree of alteration or mineralization associated with a mineral deposit. Spatial variability in the occurrence of sulphides and carbonates is critical and has been responsible for incorrect predictions of the acid-forming potential of material when composite samples are used in the testing program. It is essential that individual depth samples from a number of drill holes are tested to provide an indication of the variability before composite samples are prepared for any detailed geochemical analysis.

## APPLICATION OF ACID-BASE ANALYSIS AT SULPHIDE MINERAL DEPOSITS

### General

The objectives of carrying out an acid-base analysis are:

1. Determine the acid-forming characteristics of waste rock, ore and processing wastes;

2. Classify waste rock types with respect to the potential for acid generation;

3. Determine the impact on the quality of drainage from the mine and waste dumps;

4. Provide design and management criteria for waste disposal, pollution control and rehabilitation.

Our experience at more than 30 base metal and precious metal deposits throughout Australia, New Zealand and Papua New Guinea has aimed to provide the engineers with workable and practical design and operational criteria. This includes the classification of waste types, disposal needs and constraints on the operation. With respect to the acid forming characteristics, 4 geochemical types are defined as follows.

| CLASSIFICATION | TRIGGER LEVEL CRITERIA pH | %S | NAPP (%CaCO3) |
|---|---|---|---|
| Acid | <4 | <0.5 | |
| Acid Forming | <4 | >0.5 | >0 |
| Potentially Acid Forming | >4 | | >0 |
| Non-Acid Forming | >4 | <0.5 | <0 |

In addition to the above 4 types, a 'barren' classification is frequently applicable for material which is essentially devoid of sulphide and acid neutralizing capacity.

In mineral deposits the mineralogy of sulphides and the content of carbonate have a major controlling impact on the lag period for acid generation and the eventual rate of acid generation. Some materials with less the 2% sulphur can generate acid in less than 6 weeks following exposure, whereas other materials with 30% sulphur may require 20 years of oxidized leaching before acid conditions become established.

Leaching tests are used to provide design and management criteria for controlling acid generation. Column and batch leaching tests are commonly used, and where possible, larger scale field trials are also utilized. Our approach is to use coarse (-25mm) size material in columns and leach under simulated rainfall conditions. This provides an indication of leachate quality, weathering behavior, and incorporates the effect of the kinetics of the acid formation and acid neutralization processes. Batch (humidity cell) leaching tests are generally carried out using dilute sulphuric acid to neutralize any inherent acid neutralizing capacity and create conditions under which acid formation can be examined, including inoculation with a mixed bacteria culture.

The objectives of the leaching test are to provide an indication of the reactivity of sulphides, the presence and likely scale of any lag period for acid generation, the ability of the material to generate acid support bacterially catalyzed oxidation, and the nature of short term leachates.

### Case Studies

The variability at any one site can be demonstrated by a plot of sulphur and the acid neutralizing capacity. Figures 1 and 2 show this type of plot for a base metal sulphide deposit in Tasmania, Australia (Figure 1) and a gold deposit in New Zealand (Figure 2).

FIGURE 1: ACID FORMING POTENTIAL - BASE METAL SULPHIDE DEPOSIT

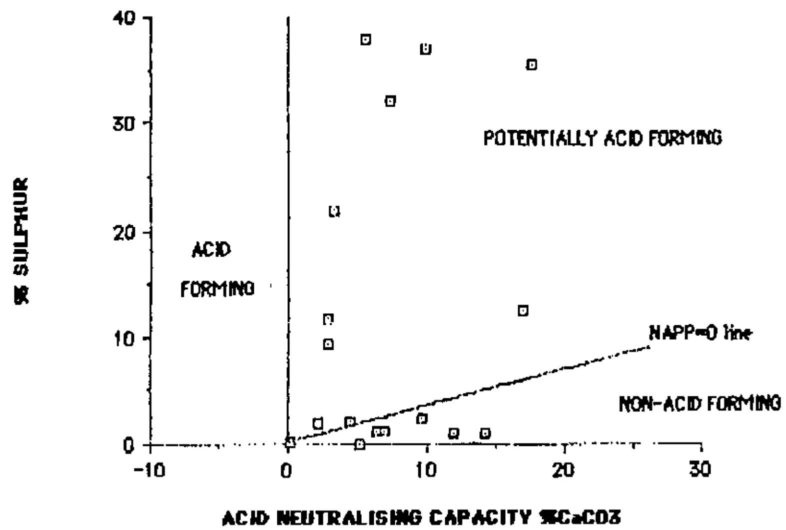
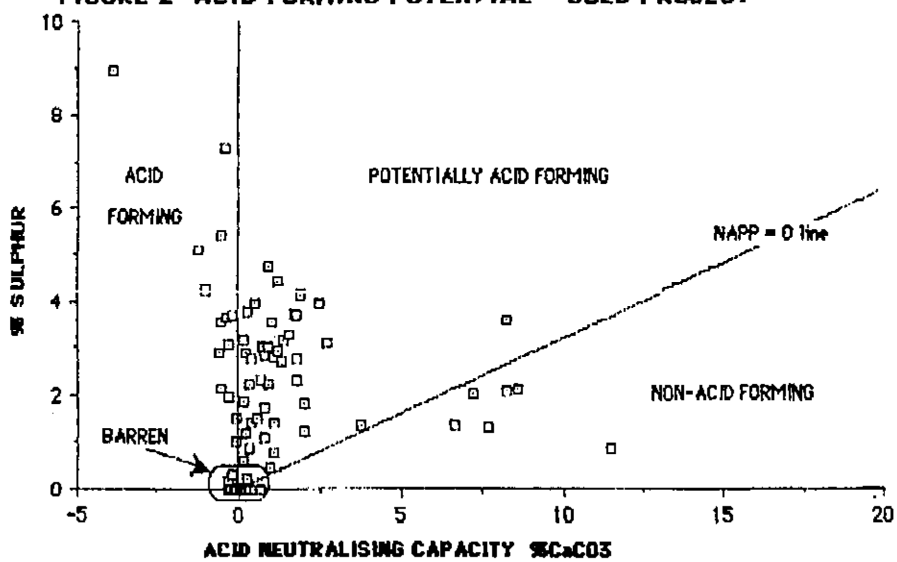



FIGURE 2 ACID FORMING POTENTIAL - GOLD PROJECT




In the base metal sulphide deposit two geochemical waste rock types were identified vis. potentially acid forming and non-acid forming. All samples contain significant levels of carbonate and even the samples with greater than 30% S contain between 5 and 20% $CaCO_3$ equivalent. Leaching studies have been carried out on these rock types which confirms the non-acid nature of the non-acid forming rock but also confirm the very long lag period required for acid generation in the potentially acid forming material. It is predicted that at least 10 years of oxidized leaching will be required before acid is generated in these potentially acid forming rocks. Three years of operational experience supports this prediction. Rock excavated from the underground operation is visually assessed as being acid forming or non-acid forming with occasional check analysis when new areas are opened up. The non-acid material is used for engineering works and the acid-forming material placed in a controlled stockpile area for later use as underground fill in worked out stopes. Mine drainage is currently non-acid with a flow rate of approximately 30 L/sec. This water is being monitored, but it is not expected that acid drainage will occur during the life of the mine. Final decommissioning will involve sealing and flooding of the underground workings.

Figure 2 shows the acid-base relationship for waste rock and tailings from a major gold prospect in New Zealand. Four basic waste types are identified by this plot as acid forming, potentially acid forming, non-acid forming and barren.

The non-acid material has a negative NAPP and can be used as general fill or cover for engineering works. The barren waste rock is essentially devoid of sulphides and also has a low ANC. This material plots at the intersection of NAPP=0 line and the ANC=0 line. The barren waste can be used for any construction purposes providing its engineering properties are suitable.

An important consideration in material classified as non-acid is that selective dissolution and leaching of carbonates may eventually lower the ANC resulting in long term acid generation. However, this is only likely to occur where the sulphur level is greater than 2 or 3 percent.

Integrated geological and geochemical investigations show that approximately two-thirds of the waste rock and all the tailings fall into the acid forming and potentially acid zones. The natural pH of the potentially acid forming material is greater than 5 but since it has a positive NAPP there is a potential for acid generation and establishment of low pH conditions (ie. pH less than 4) after a period of oxidized leaching. The period of oxidized leaching required to generate acid conditions increases as the ANC increases (ie. as the lag period increases). Also, the potential scale of acid generation increases with increasing sulphur content.

Detailed mineralogical and leaching tests carried out on the potentially acid forming waste material has shown that acid conditions will not occur unless the material is exposed to oxidized leaching for at least 2 years. At this operation, waste materials have been classified according to geotechnical and geochemical characteristics. The waste disposal strategy has been designed to place acid forming and potentially acid forming material in cells which are constructed as 'sealed' units using non-acid, barren and soft argilic acid forming material as cell walls and cover. The soft argilic material can be used as intermediate cover since it can be compacted to high density and very low permeability. In addition, the mineralogical studies show that the clay matrix effectively isolates the sulphides thus minimizing exposure to oxidized leaching.

The tailings generated by processing operations in the two gas studies presented are classified as potentially acid forming. The base metal sulphide tailings contain approximately 30% sulphur whereas the gold tailings contain approximately 2% S. For control of acid formation it is essential that oxidized leaching of the tailings is prevented. Both tailings require a long period of exposure before acid formation is likely to occur and since both sites are in wet environments the long term rehabilitation strategy is to saturate the tailings and store under permanent water cover. The tailings dam walls are designed as water-retaining structures and the disposal strategies are aimed at providing maximum stability to the dam wall. It is considered that storage under water is the most effective way of preventing long-term acid formation in these waste materials.

## CONCLUSIONS

The approach presented in this paper for determining the acid-forming characteristics of waste rock, tailings and mine rock has been applied to a wide range of base metal sulphide and gold mining operations. Acid-base analysis is an essential tool in the investigation strategy but the interpretation of the results and, most importantly, the engineering implications for waste management, pollution control and rehabilitation, must be carefully considered. Sampling and laboratory testing programs must be planned on a site-by-site basis and the acid-base analysis must be applied on individual samples rather than composite samples.

Once the geochemical waste types have been identified at a particular mine operation it is essential that a simple monitoring procedure be developed for the operation phase. In some situations a simple pH determination or visual inspection is all that is required. In others it may be necessary to determine pH and ANC while the complete NAPP and pH determinations may be necessary at difficult sites. In any mining situation it is generally best to attempt to limit the number of waste types to 3 or 4, otherwise scheduling difficulties could result in problems for reclamation, pollution control and decommissioning.

It is essential to communicate with the design and operation personnel since the success of acid mine drainage control and prevention of acid soil problems for reclamation will depend on the incorporation of geochemical factors into the scheduling and management of the waste materials. Numerous alternatives to the acid-base procedure and have been devised and are presented in the literature. However, from a practical point of view, in relation to the control of acid problems through implementation of selective material placement and dump design, we believe the acid-base procedure along with experienced interpretation is an effective and applied approach.

## LITERATURE CITED

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