A PRACTICAL APPROACH TO TESTING FOR ACID MINE DRAINAGE IN THE MINE PLANNING AND APPROVAL PROCESS

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ABSTRACT

Acid mine drainage is one of the biggest environmental issues facing mining companies today. Government agencies, the general public and mine owners require that potential for acid generation can be predicted and controlled with a high degree of confidence. Failure to satisfy these concerns about acid mine drainage can slow the approval and permitting process delaying the start of production at the mine and considerably adding to the cost of mine development. These costs can be reduced by selection of predictive testing procedures appropriate to the level of mine development which will answer immediate environmental concerns in the context of the mine plan and indicate whether further testing is required.

We present a procedure for the prediction of acid generation which integrates the stages of deposit exploration and approval for mine development with suitable predictive testwork to determine the potential for acid generation, the rate of acid production and suitable acid control techniques.

1.0 INTRODUCTION

Acid mine drainage is perhaps the biggest environmental problem facing the mining industry today. In response to public pressure, government agencies now require extensive testing to predict and design controls for acid mine drainage prior to the start of production. Inadequate acid mine drainage prediction will slow the approval process for new mines and lead to high costs due to environmental problems during operation and closure. Proper prediction of acid mine drainage would assist mining companies in making decisions at all phases of mine development with respect to development (exploration phases), design of the mine plan (pre-feasibility) and development of concepts for closure.

Due to increasing public and government concerns, as well as real operating and closure costs to industry, an approach to prediction of acid mine drainage during the planning process has been developed. Acid generation testwork should be conducted at each stage of mine development to satisfy the government and mine planner/owner to a high degree of confidence that the potential for acid mine drainage can be predicted and controlled. Thus, our approach to predicting acid mine drainage involves a smooth transition through the testing and permitting process which relies on the careful selection of tests appropriate to each level of development and planning in conjunction with the approval process.

The approach to designing environmental protection against acidic drainage consists of a series of iterative and interdependent tasks with the actual number of tasks depending on the results obtained. These tasks are: mine planning, environmental comparisons with other sites, rock sampling, simple static predictive tests, detailed kinetic predictive tests, modelling and design and testing of control techniques. The acid generation prediction program must be reevaluated following completion of each step, requiring the decision to continue with the prediction program, skip to a later phase or run a second iteration of the current task. Failure to recognize this iterative nature of the tasks may lead to failure of all following tasks and ultimately failure to meet the objectives of the acid generation prediction program.

A potential project flow sequence for the evaluation of acid generation potential and mitigation techniques has been developed (Figure 1). An essential component of the prediction process is the treatment of each stage on a case-by-case basis. Emphasis is placed on understanding geochemical mechanisms at every stage since these will be different for each mine and its components due to differences in climate, physiography, geology and ore beneficiation. In addition, special attention is paid to defining the variability involved in sampling so that factors which are a function of position and time can confidently be extrapolated to the entire mine and its impact on the environment during operation and after closure.

The folbwing discussion is divided into the typical stages of mine development, which include exploration and initial project disclosure (Prospectus Level in British Columbia) pre-feasibility and feasibility stages (Stage I in B.C.) and permitting stage (Stage III in B.C.).

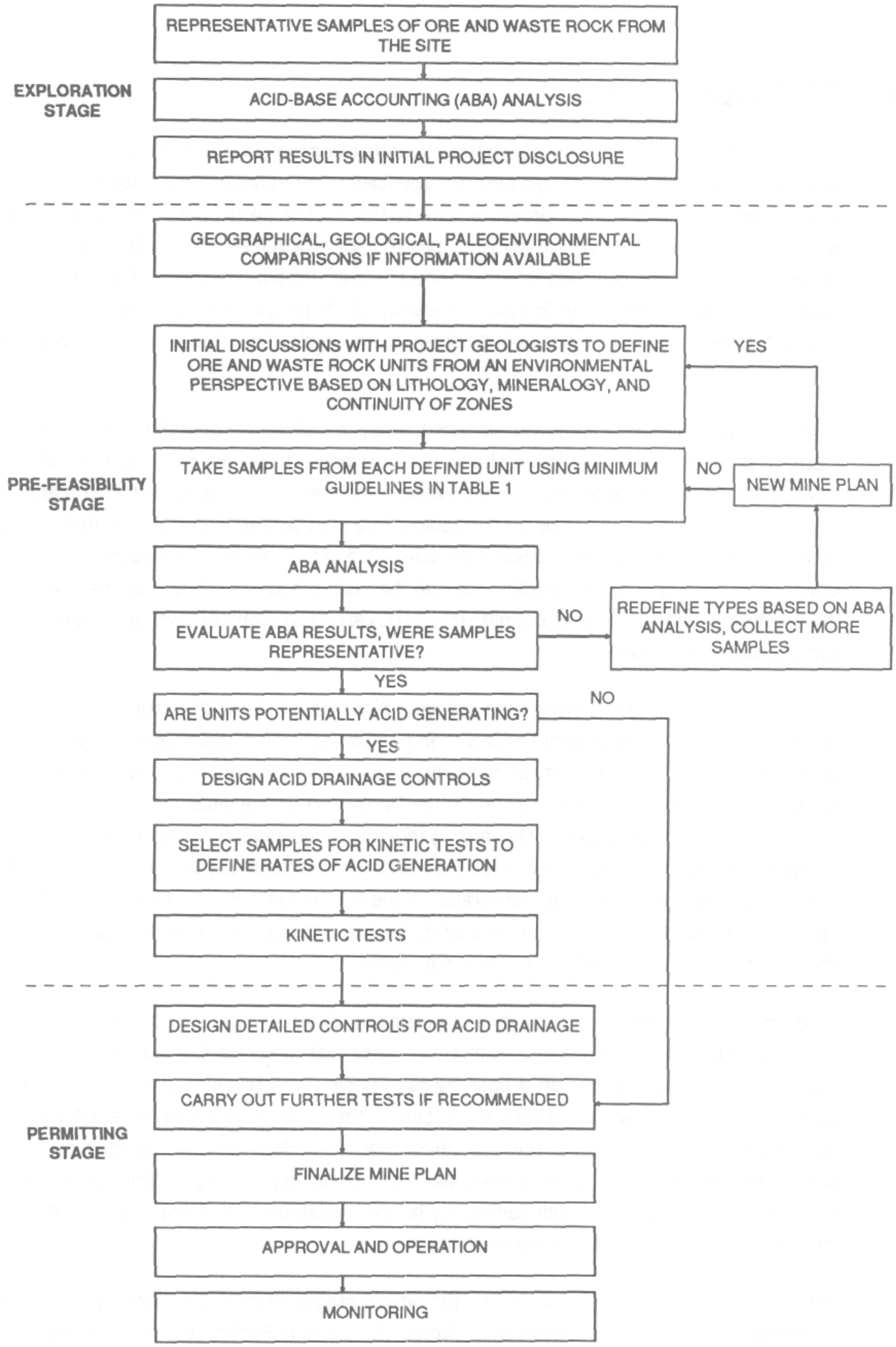

Figure 1. Procedure for Evaluating the Potential for Acid Generation at a Mine Site

2.0 EXPLORATION AND INITIAL PROJECT DISCLOSURE LEVEL

2.1 Initial Assessment

Development of a mineral property begins with exploration which may culminate in an initial report (Prospectus) disclosing the intention to develop a producing mine.

An initial step is that of preliminary mine planning, based on the geology as known at that time, which defines the location, size and management of each mine component. The primary mine components are: the mine itself, waste-rock/spoils/overburden dumps, ore stockpiles, the millsite, and tailings impoundment (Morin, 1988). Each component is evaluated for its potential for acid generation as each component has a different potential impact due to differences in physical conditions, geochemical characteristics, and exposure to climatic conditions.

It is important to identify through static predictive tests whether any of the mine units have a potential to generate acid (Figure 1). Reliable information of this type obtained early in the mine planning process is invaluable in initial conceptual mine planning and identification of potential issues, costs and additional testwork that may be required.

In cooperation with the project geologist, homogeneous geological units of ore and waste rock and their relative proportions in the mine are defined and a selection of representative samples are obtained, ideally from fresh drill core stored under dry conditions or as part of the bulk testing procedure at the mine. At this stage, it is usually sufficient to obtain a minimum of three samples from each unit. These samples are submitted for static predictive tests to determine their potential for acid generation and consumption.

2.1.1 Static Predictive Tests

Static tests are laboratory methods which determine the amounts of sulphur and weak acid soluble minerals in rock or tailings samples. The tests define the balance between potentially acid-generating minerals (for example, reactive sulphides) and acid-consuming minerals (for example, carbonates) hence the technique is also called acid-base accounting. Theoretically, a rock unit will only generate net acidity at some point in time if acid-generating minerals are more abundant than acid-consuming minerals. It is extremely important to note that these tests do not give acid generation rates but only give a preliminary indication of the potential to generate net acidity in different materials at the mine.

Defining the acid-generating/acid-consuming balance in a sample begins with a preliminary visual mineralogical determination. Next, chemical analysis follows with the determination of total sulphur (Figure 2), which is converted to a measure of the total amount of acid the rock can produce (maximum potential acidity, MPA) in limestone equivalent units and a gross measure of the ability of the rock to neutralize acid (neutralization potential, NP) in limestone equivalent units. The difference between the two tests yields the common net neutralization potential (CNNP):

CNNP = NP - MPA

The CNNP is a useful index of the risk of producing acidic drainage. A large negative CNNP indicates a strong potential to generate acid mine drainage, whereas a large positive CNNP indicates that there are potentially enough neutralizing minerals in the sample to consume all acid generated from weathering of sulphides. As the relative amounts of acid-consuming and acid-producing minerals becomes more finely balanced, the uncertainty in predicting whether acid mine drainage will occur increases. In which case further testing is required to better define the distribution of environmentally relevant minerals (for example, Norecol, 1988; diPretoro and Rauch, 1988).

Results of the initial assessment for potential acid generation are reported and used to design the subsequent programs. The variability of results will also indicate whether in fact lithological units defined as homogeneous must be subdivided into additional units to better define the distribution of net neutralization potential. If results indicate that there is insignificant potential for acid generation further testing is not required. However, should the conceptual mine plan change to include new ore bodies or a different mining development (for example, underground to open pit) a new program of testing is warranted.

3.0 PRE-FEASIBILITY STAGE (Stage I)

The conceptual mine plan is designed! in the pre-feasibility stage of mine development. The conceptual design will incorporate the results from baseline environmental characterization and potential waste streams to predict the likely impacts of the mine and to design mitigative strategies for operation and closure. The objectives of the acid generation prediction program at this stage are to define the acid generation potential of each lithologie unit using static tests and initiate timed tests for acid generating units to determine how long acid generation will continue and how acid mine drainage can be controlled.

An optional procedure at this level is the comparison of the proposed operation with other similar operations in the vicinity or in similar geographic and geologic environments to determine the potential for problems with acid generation and the possible cost of mitigation (Figure 1) (Errington and Ferguson, 1987; Carrucio et al., 1977). Geographical and geological comparisons are potentially useful but are poorly exploited due to the lack of suitable mine classifications and lack of a database of case histories.

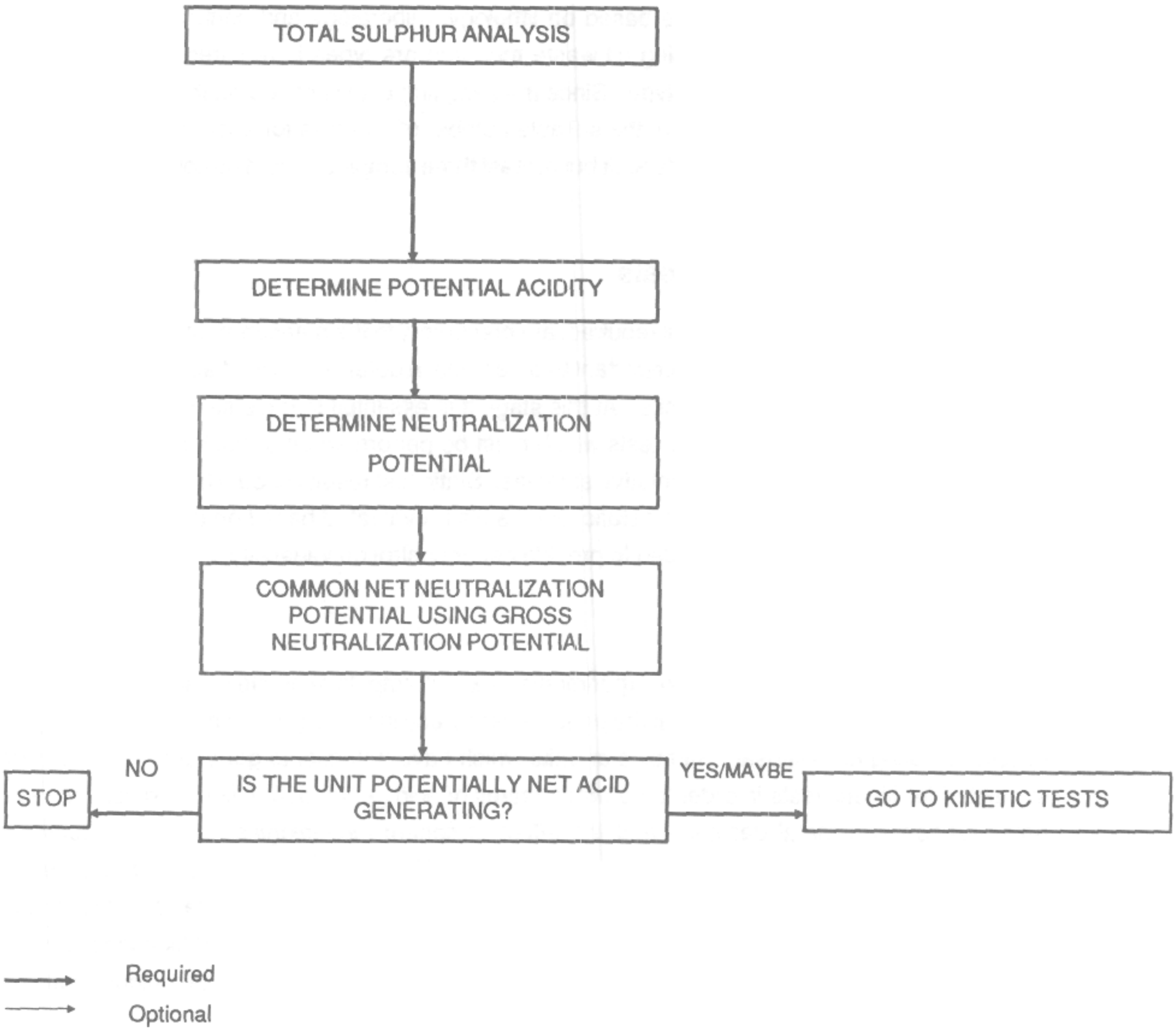

FIGURE 2. STATIC TEST PROCEDURE FOR EACH GEOLOGIC UNIT

3.1 Confirmatory Testing

Updated geological controls and mine plans are used to further define ore and waste rock units from an environmental perspective based on lithotogy, mineralogy and continuity of zones. A comprehensive program of sampling all waste rock and ore types is required with a minimum number of three samples for each *typo.* Since the sampling plan is based on the homogeneity of lithological units at each project site, the suitable number of samples for each unit is determined by its spatial abundance in the ore deposit but at least three samples should be collected from each unit.

3.1.1 Refined Static Predictive Tests

Static tests conducted at this level, if required, are precursory to the measurement of reaction rates using kinetic tests. Therefore, it is important to determine in detail the form of acid-generating and acid-consuming minerals in the rocks. At this stage it is essential to have satisfactory control of geological variability so that kinetic tests which must be performed on a much smaller subset of samples are carried out on representative samples. Static test results should be evaluated and, if necessary the mine plan revised and static test results reevaluated based on the new mine plan. More sampling may be recommended to provide better control on variability.

3.1.2 Kinetic Tests

Kinetic tests are laboratory and field experiments which attempt to simulate weathering under the conditions likely to be encountered at the project site thereby indicating which materials will require special handling for disposal. Samples of units which have potential to generate net acidity are submitted for kinetic tests in order to determine rates of acid generation, sulphide oxidation, acid neutralization and metal depletion and the effect of control technologies such as underwater disposal, blending of waste and addition of limestone. This information is critical because, for example, the rate of acid generation may be severe for only a short period of time so that long term control or treatment techniques may not be necessary. Based on the results of kinetic tests, long term rates of acid generation can be predicted and treatment and control techniques can be optimized to minimize overall costs of acid generation abatement.

Since kinetic tests are costly and potentially of long duration, the program objectives must be clearly defined before proceeding (Figure 3). The program objectives should be based on the mine plan and the proposed handling of the acid generating rock. One or more of the following objectives should be included: (1) selection or confirmation of disposal options; (2) determination of overall water quality impacts; (3) determination of the effect of the flushing rates through a sample on water quality and (4) determination of the influence of bacteria on the acid generation process in a sample.

The initial step in conducting kinetic tests is the definition of important material characteristics in addition to the characteristics defined by the static tests (Figure 3). These include sample mineralogy, surface area and acid teachable metal concentrations.

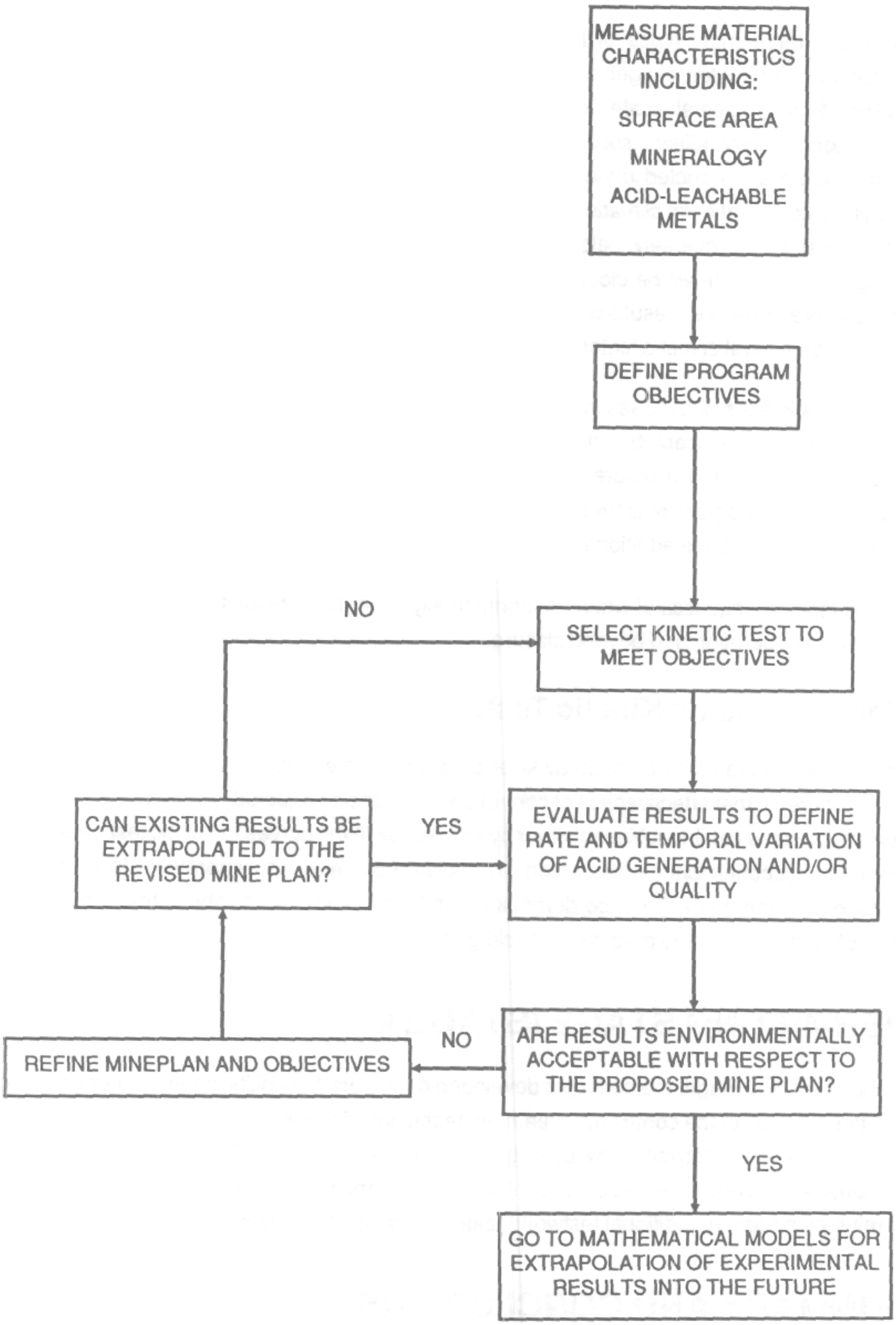

FIGURE 3. KINETIC TEST PROCEDURE

There are three main types of kinetic tests: (1) laboratory tests which directly measure the interaction of sulphides, oxygen and water (for example, shake flasks) but do not attempt to model field conditions; (2) small-scale laboratory weathering tests (for example, humidity cells, columns) which model field conditions such as leaching by precipitation or the effect of moist air and (3) field tests which are conducted under on-site conditions. Laboratory tests have the advantage of permitting control of each climatic variable so that specific mechanisms can be isolated and control options tested. Conversely, field tests are conducted under fluctuating natural conditions using configurations which will be closer to those eventually used to dispose of waste or tailings and stockpile ore. However, results of the field tests may be difficult to interpret given the simultaneous variation of several climatic factors.

As with static tests, kinetic testing must be iterative (Figure 3). If the results from the tests are environmentally unacceptable in the context of the mine plan then the mine materials plan may need to be reevaluated to ensure that appropriate acid generation control and treatment techniques are used. The program objectives may have to be redefined to incorporate changes in the mine plan which may require additional kinetic tests (Figure 3).

Kinetic tests are successful when environmentally acceptable results can be extrapolated to the mine during operation and beyond closure.

3.2 Modelling using Kinetic Tests

Acid generation rates determined by kinetic tests can be extrapolated to the life of the mine and after closure so that effectiveness of control options can be projected. Prediction of long term acid generation rates can be achieved either by empirically fitting curves to kinetic test data or by using theoretical geochemical models which extrapolate each reaction separately. In either case, the limitations of the model must be determined and built in as uncertainty factors which define the level of confidence in the prediction of acid generation rates.

4.0 PERMITTING STAGE (STAGE III)

At the permitting stage, the concepts developed during pre-feasibility stage are turned into design realities. Details of the control and treatment techniques for acid drainage are developed. Further static and kinetic testwork may be required to develop the details at this stage or to further demonstrate the effectiveness of the control treatment options chosen. Any changes to the geology or mine plan require additional testwork before the mine plan is finalized.

5.0 SUMMARY AND CONCLUSIONS

In order for a mine to come into production, the government, general public and mine owner must be satisfied that acid generation during mining and after closure can be predicted and appropriate control methods can be implemented to prevent any impact on the environment. Therefore, it is necessary to identify any acid generation problem early in mine development so that the mine can be designed based on economic and environmental considerations. Recognition of an acid generation problem late in mine development will lead to added costs due to changes in the mine plan and delays in the start or continuation of production. A schedule of predictive testwork (Figure 1) which parallels mine development and the approval process has been developed so that mine plan concepts can incorporate acid generation control.

The target of the exploration stage is to show that the deposit is potentially viable economically and environmentally. The potential of any rock units at the mine to produce acid should be determined using currently accepted, tow cost tests which chemically measure the balance between acid-producing and acid-consuming minerals.

At the pre-feasibility stage the target is to produce a conceptual mine plan which optimizes mine economics while minimizing the environmental impact to acceptable levels. Environmentally, this is achieved through detailed sampling to determine the spatial distribution of net neutralization potential and kinetic testing to determine the rate of acid generation and the effectiveness of control options in the long term.

Finally, at the permitting stage the conceptual mine plan is finalized, incorporating details of control and treatment of acid generation.

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