USING KINETIC GEOCHEMICAL TESTWORK TO ASSIST WITH MINE PLANNING, OPERATIONS AND POST CLOSURE

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ABSTRACT

Kinetic geochemical testwork is routinely used to assist with the acid and metalliferous drainage (AMD) assessment component of environmental and social impact studies during the pre-feasibility and feasibility stages of mine project development. Such studies are generally completed to fulfil regulatory requirements, but kinetic testwork data can also be relevant to mine planning, operations and the development of closure strategies.

The three main types of kinetic geochemical test procedures are column or test pile leach, humidity cell and oxygen consumption. The primary aim of these tests is to quantify acidity generation rates, estimate the likely lag time prior to the onset of acid drainage and to provide an indication of the likely quality of leachate from mine materials. In essence, these tests routinely identify the need for AMD / NMD management and provide focus on problematic materials and potential soluble pollutants. The three common procedures offer different capabilities for assessing the geochemical behaviour of mine materials and the strengths and limitations of each approach is discussed.

Recent advances in kinetic test procedures have extended their capabilities beyond routine assessment of material behaviour under wetting and drying scenarios, to the evaluation of closure scenarios of increasing complexity. Kinetic procedures now permit accurate determination of acidity generation rates from waste rock, wallrock in pits, underground voids, tailings, ore and concentrate as a function of particle size distribution, sulfide type, sulfide concentration, moisture content (analogue for oxygen diffusion), humidity, temperature, oxygen concentration and pore moisture pH. With independent control over these test variables, mine plans, closure strategies, remediation options and water treatment requirements can be more accurately designed and evaluated.

Kinetic test procedures make it possible to quantify the likely performance of management strategies such as: oxygen limiting cover systems; waste rock encapsulation, waste rock blending or waste rock-tailings co-disposal; optimising waste rock compaction and moisture contents to limit acidity generation; limiting moisture contents in waste rock in arid settings; paste tailings, paste rock or tailings-cement mixtures; alkalinity producing covers to decrease the pyrite oxidation rate in mine wastes; variable depth water covers over tailings; and inert atmospheres in mine voids. The procedures can also assist with pit lake water quality modelling and dewatering water quality predictions.

As their predictive capability improves, kinetic geochemical test procedures are becoming increasingly relevant to mine planning, operational activities, closure planning and site rehabilitation.

1.0 INTRODUCTION

Kinetic geochemical testwork is routinely used to assist with the assessment of acid and metalliferous drainage (AMD, also called acid mine drainage or acid rock drainage) as a component of environmental and social impact studies during the pre-feasibility and feasibility stages of mine project development. Such studies are generally completed...
primarily to fulfil regulatory requirements and are rarely subject to further interpretation. However, kinetic geochemical testwork can in fact provide a range of important and highly useful information that can greatly assist mine planning, operations and the development of effective closure strategies. This technical review presents the types of information that can be obtained using the latest kinetic test methods, and the range of potential management strategies that can be both developed and directly evaluated using kinetic testwork.

The main objectives of effective AMD management are to:

- Prevent sulfide oxidation where possible;
- If sulfide oxidation cannot be avoided:
  - minimise sulfide oxidation rates;
  - maximise the potential for the neutralisation of generated acidity;
  - maximise the formation of insoluble acid sulfate salts;
  - lower net acidity release rates to levels that can be handled naturally by the receiving environment or treated by passive measures.
- If acidity release rates cannot be sufficiently minimised, then appropriate water treatment is required.

The purpose of kinetic geochemical testwork is to identify the likely rate of acidity or metals release over time due to the oxidation of sulfide minerals (primarily pyrite), and assess likely leachate chemistry. Kinetic testwork is needed because sulfide oxidation rates vary with the specific type of reactive sulfides, including mineralogy (e.g. pyrite, pyrrhotite, chalcopyrite, etc), thermo-barometric and structural evolution (e.g. metamorphic grade and deformation history / dislocation density), the surface area (e.g. framboidal or coarsely crystalline materials), and crystal chemistry (i.e. element substitutions, impurities) of sulfides. As sulfide oxidation rates can vary by orders of magnitude between different samples and cannot be reliably estimated from static geochemical data or mineralogy alone, kinetic geochemical testwork is needed to determine the sulfide oxidation rate, or pollution generation rate, of any given material.

2.0 KINETIC GEOCHEMICAL TEST METHODS

Three different kinetic geochemical test procedures are currently in widespread use, each with differing capabilities, advantages and disadvantages: column leach tests (or test piles), humidity cell tests and oxygen consumption tests. The primary aim of these tests is to quantify acidity generation rates, estimate the likely lag time prior to the onset of acid drainage, and to provide an indication of the likely quality of leachate from mine materials. In essence, these tests are routinely used to identify the need for management of AMD, neutral metalliferous drainage (NMD) and salinity, and provide focus on problematic materials and potential soluble pollutants.

2.1 Column Leach and Humidity Cell Tests

Column leach tests, most commonly conducted as a free-draining leach test, involve measurement of the sulfate flux from a periodically wetted column of test material (such as waste rock or tailings) normally over a period of 12-24 months. The rate of sulfide oxidation is then estimated from the measured sulfate flux. Humidity cell tests are conducted on a similar principle but aim to accelerate sulfide oxidation by applying elevated temperature and humidity.

These tests are used worldwide, but are subject to a number of important limitations and potential inaccuracies with respect to determining the rate of sulfide oxidation and hence acidity generation. Most significantly, the measured sulfate flux often does not accurately reflect actual sulfide oxidation rates for the following reasons:
In the majority of natural materials, sulfur released by the oxidation of sulfides will at least in part be re-mineralised as secondary sulfate salts, such as jarosite, in the presence of aluminosilicates and hence may not be present in leachate.

- The dissolution of existing jarosite (which is sparingly soluble) in test materials, particularly from significantly oxidised materials, during periodic flushing will contribute to the measured sulfate flux, even if no sulfide is present.
- The dissolution of gypsum (which has relatively high solubility) during wetting and flushing will contribute to measured sulfate flux, even if no sulfide is present. Gypsum can be present as a primary mineral in some cases, but is often present in oxidised sulfidic materials containing reactive acid neutralising capacity (ANC).
- The conditions of the test (temperature, moisture, flushing frequency) can differ considerably from actual conditions in the field.
- Repeated wetting and drying is generally inconsistent with climatic conditions at most mines and can result in unrepresentatively short acid residence times that interrupt slower acid neutralisation processes such as aluminosilicate dissolution.

Column leach tests do, however, provide good approximations of likely sulfate release and metal leach rates, and are therefore valuable for leachate characterisation tests. Sulfide oxidation rates estimated from column leach tests, however, are generally considered to be unrepresentative for the reasons above, sometimes significantly so (by an order of magnitude or more, both under- and overestimated).

### 2.2 Oxygen Consumption Tests

Oxygen consumption cell tests involve direct measurement of oxygen consumption due to sulfide oxidation in a hermetically sealed cell, providing a direct and robust measurement of the sulfide oxidation rate for a given test material, independent of gypsum/jarosite formation and dissolution. Oxygen consumption-based tests for the determination of sulfide oxidation rates have been used in the field (ANSTO 1997; Cook et al. 2004; Kempton, 2009; Ward et al. 2004a, 2004b; Scarek et al. 2006), and laboratory (Anderson et al. 1999; Bennett et al. 2005; Eidsa et al. 1997; Hollings et al. 2001; Bourgeot et al. 2011 and Schmieder et al. 2012) for over a decade, but the utility of the method for AMD management, not just measurement, has yet to be widely recognised. In some oxygen consumption apparatus, the test also permits measurement of carbon dioxide generation rates derived from carbonate dissolution (i.e. carbonate neutralisation rates). Such measurements also permit assessment of the impact of carbon dioxide on dilution of oxygen measurements to be accounted for in the test method.

The key advantages of oxygen consumption tests compared with leach tests are discussed in Bourgeot et al. 2011 and Schmieder et al. 2012. These include:

- Better accuracy through direct measurement of sulfide oxidation rates via oxygen consumption (no sulfate interferences).
- Rapid determination of sulfide oxidation rates – in most cases accurate oxidation rates can be obtained within 1-4 weeks, compared with 12-24 months for a column leach test.
- Tests can be performed at considerably lower cost due to shorter test durations and fewer analyses.
- Test configurations permit assessment of sulfide oxidation rate as a function of moisture content.
- Tests can be configured to investigate any number of specific parameters or material management strategies, such as water covers, low permeability covers, low oxygen atmospheres, neutralisation agent blending etc.
- Due to the relatively low cost and short duration, multiple tests can be performed to investigate a particular pyrite oxidation control variable of interest, the effectiveness
of material management strategies or to refine material management strategy parameters.

- Carbon dioxide generation can be measured independently to improve measurement accuracy and in some cases to quantify neutralisation rates.

Where the results of column leach tests provide limited accuracy and utility in mine planning, the data that can be obtained through oxygen consumption tests present some valuable opportunities for testing and refinement of proposed geochemical engineering management strategies.

3.0 KEY KINETIC GEOCHEMICAL PROCESSES RELEVANT TO MINE PLANNING

Using oxygen consumption tests, it has been possible to reveal and explore a number of important geochemical processes and relationships relevant to the generation of AMD and NMD, as outlined below. Each of these processes has the potential to be applied to AMD management.

3.1 Pyrite Oxidation Rate and Pyrite Decomposition Over Time

The results of kinetic geochemical tests are typically reported in units of kilograms of sulfur oxidised per tonne of material per year (kg S/t/yr), or kilograms of oxygen consumed per tonne of material per second (kg O₂/t/s). Both of these units effectively describe only the intrinsic rate of acidity generation for the sample under test (i.e. for a specific sulfide content). That is, these values cannot be readily applied to materials with different sulfide contents, or even the same sample after a period of oxidation. Hence the values provide little information on acidity generation rate 2, 10 or 100 years in the future.

Another way to represent sulfide oxidation rates is by normalising the observed oxidation rate against the sulfide content of the sample. This is typically performed using the pyrite equivalent content, which assumes all sulfide is present as pyrite (the most common sulfide), and can be expressed as a pyrite oxidation rate (POR) in units of weight percent of remaining pyrite (equivalent) that oxidises to form sulfuric acid (equivalent) acidity per year (wt% Py/yr).

In-house oxygen consumption cell tests and those conducted by ANSTO and others have shown that the oxygen consumption rate is proportional to sulfide sulfur content for materials having the same type of pyrite (i.e. rocks with the same geological / thermo-barometric history). An example of such data is obtained through in-house oxygen consumption cell testwork is shown in Figure 1(a).

When expressed in units of wt% Py/yr, the POR remains effectively constant over a wide range of sulfide concentrations for comparable pyritic 'lithologies', as shown conceptually in Figure 1(b). An example of data obtained using oxygen consumption tests for different samples of the same lithology (but differing sulfide content) is shown in Figure 1(c). In this example, the POR determined by oxygen consumption cell tests varies between ~3 and 4 wt% Py/yr, whereas column leach tests on the same materials gave widely varying POR values of 2.5-44 wt% Py/yr, in this case reflecting the dissolution of gypsum and release of non-pyrite-related sulfate.
3.2 Net Acidity Generation Rate

Using normalised POR values, it is possible to predict the long-term evolution of the acidity generation rate consistent with the progressive decomposition of sulfide, as shown in Figure 2. This prediction provides an estimation of the longevity of sulfide oxidation (and hence acidity generation), as well as a prediction of the maximum potential acidity generation at any time point in the future.

As the POR can be considered constant for materials with comparable geological histories, the acidity generation rate and its evolution over time can be recalculated for any sulfide content, such as a lithological average for example, permitting estimation of field-scale acidity generation rates for waste rock piles or reactive portions of tailings accumulations.

The acidity generation rate over time can also be used to evaluate acidity loads on mine closure and beyond, providing key information for assessing potential short- and long-term AMD management requirements.
By drawing on ANC data (a static geochemical parameter), it is possible using the POR to estimate the lag time to onset of acid conditions for any given material. However, the standard ANC test effectively treats all potentially neutralising mineral content as 100% available and efficient for acid neutralisation. This is rarely achieved under real-world conditions and results in a significant overestimation of ANC in most cases\(^1\). Hence, a better estimate of lag time can be established by using a combination of a sample’s POR and the acidity consumed to pH 4.5 on its acid buffering characteristic curve (ABCC) test. An example of this is shown in Figure 3. The ABCC test is a quasi-kinetic geochemical test that involves incremental addition of acid to a test material. As with kinetic testwork, the ABCC test is under-utilised in the interpretation of geochemical characteristics, but essentially can be considered analogous in many ways to the progressive oxidation of sulfide and associated acid generation.

That is, the amount of acid required to lower the rock material-water mixture pH to 4.5 can be considered a good approximation of the ANC that is effective in maintaining non-acid conditions over time. In Figure 3, two rock samples with the same measured ANC yield significantly different ANC\(_{4.5}\) values, due to the different reactivity and/or availability of the acid neutralising minerals within the sample. ANC\(_{4.5}\) values can be a factor of 10 or more less than measured ANC for a given sample.

![Figure 3: Example acid buffering characteristic curves (ABCCs) for two different rock samples with similar measured ANC.](image)

Using the ANC\(_{4.5}\) value and the POR, the evolution of the net acid generation rate (i.e. net acid generation after the effect of acid neutralisation) over time can be predicted, as shown in Figure 4.

![Figure 4: Conceptual evolution of net acidity generation rate (NAGR) over time based on POR (in units of wt% pyrite per year), ANC\(_{4.5}\) and total ANC.](image)

The NAGR curve shows the minimum lag time for a material (based on ANC\(_{4.5}\)), providing a quantitative measure of the maximum handling time for potentially acid forming materials including ore and concentrate. The utility of the NAGR curve in mine planning is clear and is

\(^1\) pH values achieved in the standard ANC test are routinely below pH 2, which may result in overestimation of the measured ANC with respect to real-world conditions, due to the enhanced dissolution of some alumina-silicate minerals in the sample.
both readily understandable and directly applicable to materials scheduling and management.

3.3 Temperature

Temperature has a pronounced effect on sulfide oxidation rates even over the range of typical natural conditions. The trend observed from oxygen consumption cell tests is shown in Figure 5. Oxygen consumption cell data for multiple samples of comparable material (as reported in Anderson et al. 1999) suggests that from 20°C to 30°C, the POR for the same sample increases by 6-8 times.

![Fig. 5: Conceptual relationship between ambient temperature and POR.](image)

Understanding temperature effects and accounting for them in laboratory kinetic geochemical testwork is crucial, as laboratory results can differ markedly from those under field conditions for both cold (Elberling et al. 2005) and hot regions.

Managing temperature effects can be crucial for AMD mitigation. In some sulfidic materials, pyrite oxidation (an exothermic reaction) can locally increase temperatures to a point where pyrite oxidation becomes instantaneous (i.e. spontaneous combustion occurs). Detailed dump construction methods specifically designed to control waste rock heating rates have been developed for highly reactive waste materials. Strategic placement of limited tonnages of reactive waste between layers of non-sulfidic materials with sufficient thermal mass to dissipate heat, lower oxidation rates and ultimately to prevent spontaneous combustion, is an example waste management to limit pyrite oxidation rates.

3.4 Particle Size

In-house oxygen consumption cell testwork indicates that the POR is proportional to the particle size of the sample. The conceptual relationship is shown in Figure 6(a). The shape of the curve closely follows the theoretical surface area per volume curve, suggesting that pyrite surface area provides a fundamental control on pyrite oxidation rate. The exact position and shape of the particle size - oxidation rate curve varies between samples with different geological histories. Figure 6(b) shows an example of typical data obtained in the course of in-house oxygen consumption cell testwork aimed at testing the influence of particle size on POR.
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Fig. 6: (a) Conceptual relationship between particle size and POR. (b) Examples of data obtained in oxygen consumption cell tests for the same sample at different particle sizes.

The importance of understanding the reactivity of mine wastes as a function of particle size is important for mine operations as careful use of explosives can influence the particle size distribution of waste materials.

3.5 Moisture Content

The typical relationship between POR and gravimetric moisture content (GMC) of geologic materials as obtained through oxygen consumption cell testwork is shown in Figure 7(a). The POR typically peaks at a GMC equivalent to approximately 33-66% of saturation, but notably does not decrease to zero at either 0% GMC or complete saturation. A ten-fold variation in POR across the full moisture range is common, and at least a two-fold variation across the range of intermediate GMC conditions (20-80% of saturation) can be expected. Figure 7(b) shows an example of the variation in POR for the same sample at different GMCs. These data are taken from oxygen consumption cell testwork aimed at characterising the effect of moisture content on POR.

Fig. 7: (a) Conceptual relationship between moisture content and POR. (b) Example of data obtained in oxygen consumption cell tests for the same sample at different gravimetric moisture contents (GMCs).

This GMC vs POR relationship is one of the most important relationships that can be demonstrated and explored using oxygen consumption cell tests. Such data cannot be obtained by column leach methods. The typical relationship shows that pyrite oxidation can be significantly lowered at the moisture extremes (dry and saturated), but apparently cannot be easily halted.

At the very low moisture end, it is considered likely that even trace water levels, or atmospheric moisture concentrations only, are sufficient to allow pyrite oxidation to continue,
albeit at a diminished rate that reflects the role of water in the oxidation process (Jerz and Rimstidt 2004). At the initial point of saturation, sulfide oxidation can continue at a lower rate via the diffusion of oxygen through pore water.

Oxygen consumption cell tests can be used to quantify the effect of moisture on sulfide oxidation rates either to identify target moisture contents for AMD management, or to estimate the likely variation in sulfide oxidation rate across a profile of variable moisture content. For example, the variation in sulfide oxidation rates in de-saturated wall rock above a groundwater cone of depression can be quantified across the moisture profile in order to estimate acidity release rates. The effectiveness or otherwise of irrigating ore stockpiles to suppress sulfide oxidation can also be quantified using oxygen consumption cell techniques.

### 3.6 Water Cover Depth

As mentioned above, achieving initial saturation alone is insufficient to halt all sulfide oxidation. A water cover of some depth is required to halt the process. Oxygen consumption cell tests provide a direct and accurate means of investigating the effect of water cover depth on sulfide oxidation rates. The typical relationship obtained in such tests is shown in Figure 8(a).

![Por vs. Water Cover Depth](image)

**Fig. 8:** (a) Conceptual relationship between water cover depth and POR. (b) Example of data obtained in oxygen consumption cell tests for the same sample at different water cover depths.

Over a range of shallow water depths, the rate of sulfide oxidation decreases approximately linearly with increasing water depth, under the static conditions of an oxygen consumption cell test. This reflects the fact that the rate of oxidation through a water cover is limited to the rate of oxygen diffusion through the water column.

Data obtained using oxygen consumption cells tests examining the effect of different water cover depths for the same material is shown in Figure 8(b).

In addition, the effectiveness of water cover enhancement strategies such as sand covers to prevent sulfide re-suspension and aggregate addition to reduce water surface area (and lower oxygen diffusion rates) can also be tested and refined using oxygen consumption cell tests.

### 3.7 Oxygen Concentration

In most circumstances, the rate of sulfide oxidation is proportional to atmospheric oxygen concentrations. The conceptual relationship based on in-house oxygen consumption cell tests is illustrated in Figure 9(a). The relationship is sublinear in the natural region (0-20.9% O₂). An example of a data series obtained in an oxygen consumption cell test for sulfidic mine waste is shown in Figure 9(b).
Fig. 9: (a) Conceptual relationship between atmospheric oxygen concentration and POR. (b) Example of data series obtained in an oxygen consumption cell test.

This relationship demonstrates that in order to achieve significant suppression of sulfide oxidation, atmospheric oxygen concentrations need to be lowered to approximately 3 vol.% or lower. These findings are of particular relevance to mine closure planning for waste storage facilities relying on limiting oxygen ingress to sulfidic materials.

4.0 USE OF KINETIC GEOCHEMICAL TESTWORK FOR GEOCHEMICAL ENGINEERING

The key kinetic parameters outlined above provide the basis for a wide range of potential geochemical engineering strategies that can be investigated using kinetic geochemical testwork and in particular, oxygen consumption cell testwork. This approach makes it possible to validate and refine closure scenarios of increasing complexity and sophistication.

4.1 Waste Rock Encapsulation / Oxygen-Limiting Cover Systems

The encapsulation of potentially acid forming waste rock within a layer of low-permeability material such as clay can lower sulfide oxidation rates by limiting oxygen supply to sulfides to diffusion related processes. The merits of various encapsulation strategies can be quantified at both laboratory and pilot scales using oxygen consumption cell techniques at the design stage.

4.2 Waste Rock Blending and Waste Rock/Tailings Co-Disposal

Using the sulfide oxidation rate obtained using kinetic geochemical testwork and the net acid generation rate (NAGR) (e.g. see Fig. 4), it is possible to simulate the effect of blending and co-disposal strategies for the management of mine waste. An example of blending potentially acid forming (PAF) waste rock with non-acid forming (NAF) material containing reactive ANC (e.g. enhancing the significant ANC$_{4.5}$ of the blended material) at a 1:1 mass ratio is shown in Figure 10. The resultant material has half the AGR at any time point (due to sulfide ‘dilution’), and the lag time is extended by the addition of reactive ANC, resulting in a considerably more manageable NAGR profile. The aim of such geochemical engineering is to develop a blending strategy that produces a material that is not expected to release acidity over the entire period of sulfide oxidation.
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4.3 Optimisation of Waste Rock Compaction and Enhancing Moisture Content

Limiting oxygen ingress and maximising acid neutralisation potential are key AMD management strategies for waste rock materials. Encapsulation and cover systems are important aspects of this strategy, but the PAF waste rock pile itself can also be optimised through base-up waste rock dump construction to form thin lifts that are compacted at optimal moisture content. The effectiveness of this strategy for lowering sulfide oxidation rates at a site can be quantified directly using oxygen consumption cell tests at laboratory and pilot scales, during the design phase. Carbon dioxide generation can also be monitored at laboratory and pilot scales to quantify acid neutralisation rates using carbonates, a factor that may be relevant to the geotechnical stability of the waste rock dump, should significant quantities of mass loss (via \( \text{CO}_2 \) emissions) be expected.

4.4 Limiting Moisture Content in Arid Settings

The general relationship between moisture content and sulfide oxidation rate (e.g. see Fig. 7) indicates that sulfide oxidation can be suppressed by limiting pore water content and atmospheric moisture. However, this strategy is only likely to be effective in and environments with low moisture and low humidity, and for materials with good drying properties (e.g. coarse waste rock rather than clays). The degree of sulfide oxidation suppression provided by this strategy can be readily quantified at both laboratory and field scales using oxygen consumption techniques.

4.5 Waste Rock and Tailings Co-Disposal

The benefits of waste rock and tailings co-disposal on lowering sulfide oxidation rates can be readily measured at laboratory or field scale using oxygen consumption techniques. Quantifying the optimum mix ratios, moisture content and compaction for retarding sulfide oxidation can be measured directly. The drying rates and associated increases in sulfide oxidation rates can also be measured.

4.6 Alkalinity-Producing Covers

The introduction of alkalinity into mine waste covers can assist with the passivation of reactive sulfide minerals (e.g. precipitated calcium carbonate, caustic magnesia, kiln dust or fly ash; Taylor et al. 2009). The soluble alkalinity raises pore water pH in the underlying waste pile. This can lower sulfide oxidation rates by passivating sulphide minerals through
the precipitation of secondary minerals on sulfide surfaces. Oxygen consumption testwork can be used to quantify the effect of sulfide passivation and neutral pore water pH values on sulfide oxidation rates in comparison to unmodified systems. Such data can permit the refinement of AMD management strategies, including the type and mass of alkalinity addition, the optimal pore water pH and cover design aspects.

4.7 Inert Atmospheres in Mine Voids

Some underground mines offer the possibility of using an atmospheric oxygen-limitation strategy to suppress sulfide oxidation to manageable or environmentally acceptable rates. The void can be filled with inert gas (e.g. CO₂ and/or N₂) under slight positive pressure to significantly lower the rate of sulfide oxidation and hence acidity generation (eg. Taylor and Waring 2001). Oxygen consumption cell techniques offer an easy way to identify target oxygen levels and test the effect of atmospheric gas compositions on effective sulfide oxidation rates. The oxidation rates determined by oxygen consumption cell tests can also be used, for example, to estimate the time required to deplete atmospheric oxygen as a result of sulfide oxidation in an air-sealed (but not water sealed) underground mine.

4.8 Variable Depth Water Covers

In situations where the water cover is expected to fluctuate, it is possible using oxygen consumption cell tests to quantify the change in sulfide oxidation rate with water cover depth (see Fig 8(b) for an example of such an investigation). Specific scenarios can be tested at large and pilot scales using oxygen consumption techniques using HDPE tanks, bags and large columns.

5.0 CONCLUSIONS AND FUTURE DIRECTIONS

Kinetic geochemical testwork methods have advanced significantly in the last decade and the latest techniques are highly flexible and capable of quantitatively exploring the effects of a wide range of parameters on sulfide oxidation rates with unprecedented accuracy, precision and speed, and at low cost. This has significantly raised the utility of kinetic geochemical data for geochemical engineering and AMD management. Oxygen consumption cell tests now permit the fast, accurate and inexpensive determination of acidity generation rates from waste rock, wallrock in pits, underground voids, tailings, ore and concentrate as a function of particle size distribution, sulfide type, sulfide concentration, moisture content, humidity, temperature, atmospheric oxygen concentration and pore water pH. With independent control over these test variables, mine plans, closure strategies, remediation options and water treatment requirements can be more accurately evaluated. Such information can also assist with void dewatering water quality predictions and pit lake water quality modelling.

Kinetic geochemical testwork can be used to design, confirm and refine geochemical engineering strategies at the design stage, providing a wider range of AMD management tools and confidence than previously available. Kinetic geochemical testwork is no longer just a regulatory requirement. Oxygen consumption cell tests represent a valuable tool that can be used to quantify the benefits and water quality outcomes of AMD management strategies during operations and post closure.
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