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Humidity cell tests for the prediction of acid rock drainage

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ABSTRACT

This paper presents a study of various geochemical humidity-style weathering tests that were carried out on waste mine rock from Avoca, County Wicklow, Ireland. The aim of this paper is to present data that demonstrate some of the geochemical controls on weathering rates together with release rates from laboratory testwork. These data are used to determine the applicability of various interpretations of humidity cell data for prediction of acid rock drainage. Furthermore, within this context the paper offers opinion on common questions related to the use of such tests: should humidity cells be aerated? How long should the test be run for? Is pre-treatment of the samples required? Is inoculation of the samples with iron and sulfur oxidising microbes required? And should these tests really be considered to be accelerated weathering tests?

1. Introduction

This paper concerns the use of humidity cell and similar leaching tests for the prediction of acid rock drainage (ARD). ARD (also known as acid mine drainage, AMD) is contaminated effluent resulting from the oxidation of iron-sulfide minerals when exposed to oxygen and water due to mining and other earth works. If the rate of acid generation due to sulfide oxidation is in excess of acid consumption by neutralising minerals then low pH mine water results. In addition to the acidity produced, the consequent solubilisation and mobilisation of metals at low pH can lead to severe impact to the receiving environment. ARD from mining operations is one of the most problematic environmental issues facing the mining and minerals industry. Once ARD begins, the process is extremely difficult to halt and long-term treatment of mine waters is often required to protect the environment. By predicting mine-waste drainage quality prior to the inception of mining, plans for mineral-resource development and mine-waste management can be made that minimize adverse environmental impacts throughout the lifetime of the working mine, and after mine closure.

The task of prediction is often hindered by the complex rock types encountered and the proliferation of proposed test techniques to predict whether or not a specific rock type will produce acid. Nevertheless, a number of test techniques are commonly used to aid in the prediction of ARD. Humidity cell test work is one such technique and is the focus of this paper. Humidity cell test work involves periodic leaching of a rock sample (typically 1 kg) over time; the generated leachates are analysed, typically for pH and dissolved constituents (Lapakko and White, 2000; White and Lapakko, 2000). The data generated from these tests are used in the prediction of ARD. The objective of this paper is to present data from a study of humidity cell and humidity cell-style tests, and using these data to examine controls on weathering rates and release rates and the consequent applicability of various common methods of data interpretation. In addition, opinions are advanced on some common and often debated questions together with recommendations for the use of humidity cell tests and the data that they generate.

The general process of prediction involves two steps: (1) identify and describe geological materials and (2) predict their ARD potential (Price, 1997). The most widely used tests to quantify ARD potential are 'static' tests and 'kinetic' tests. The ultimate goal is to use static and kinetic tests in conjunction with other relevant data to assist in developing strategies for the environmentally sound management of mine wastes (Lapakko, 2003).

Kinetic tests are weathering tests conducted to aid prediction of drainage quality from mine wastes. The most common kinetic tests are laboratory-based columns, humidity cells and field-based test pads (Price, 1997; Lawrence, 1990; Lapakko and White, 2000). According to Price (1997), kinetic tests can provide prediction information including: (1) the relative rates of acid generation and neutralisation (important in determining if a sample will "go acid"), (2) the time to ARD onset and (3) drainage chemistry and the resulting downstream loading for each of the probable geochemical conditions. This paper concentrates on 'humidity cell' tests. Humidity cells are widely used to estimate the rates of weathering in order to predict the rates of acid generation and neutralization potential (NP) depletion, and the lag time to ARD

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generation (Frostad et al., 2002; Miller et al., 1997; Price, 1997; Bowell et al., 2000; EGi, 2002). However, the limitations of these tests with regard to the validity of interpretations and extrapolation of data has not been widely discussed in the literature.

1.1. Factors influencing the reactivity of mine waste in the field and the laboratory

Ultimately the purpose of all mine drainage prediction is to predict whether the receiving environment (e.g., groundwater, surface water) will suffer any deleterious impacts from mine wastes (e.g., Fig. 1a (3)). To predict the environmental impact at the receptor it is necessary to understand the source of the contamination (e.g. the pile of mine waste in Fig. 1a) and the mechanisms that transport the contaminants from the source to the receiving environment (Fig. 1a (2)). Unfortunately, from the perspective of prediction of ARD, both the dissolution of contaminants from mine wastes and their transport are complex processes involving coupled physical, chemical and biological phenomena (Bowell et al., 1999a; Bowell, 2002; Lefebvre et al., 2001; Nordstrom and Alpers, 1999). Further complication arises because comparisons between mineral weathering rates determined in the laboratory and field commonly reveal large discrepancies, with order(s)-of-magnitude lower rates commonly observed in the field (Malmstrom et al., 2000) although there are also cases where mineral weathering rates in the field are higher than those recorded under laboratory conditions.

Most humidity cell tests are designed to reveal something about the source of contamination, although specific interpretations differ. Full chemical digests will reveal whether contaminants are present and their concentration, whereas humidity cells are weathering experiments designed to reveal some information about the acid producing potential of a sample, the rate of weathering of minerals within the sample and concomitant contaminant release rates.

1.2. Weathering rates and release rates

'Weathering rate' and 'release rate' are two often poorly defined terms that are commonly used interchangeably in the literature describing humidity cell data and other kinetic test data. For the purposes of this paper and as a recommendation for future work these terms are ascribed more exact meanings to aid in dispelling confusion in the literature surrounding humidity cells and other leaching tests.

Weathering rate – The rate (mass per unit time) at which a primary mineral is transformed into a secondary product (soluble species or insoluble mineral, congruently or incongruently). Many of the reactions of importance are dissolution reactions and therefore depend on the amount of mineral surface area contacting solution. In geochemical studies kinetic data is often normalised to mass per unit time per unit area. However, as it is difficult to accurately measure the reactive surface area of minerals within a mine waste sample, other ways of expressing the rates of weathering are commonly employed that relate the rate to unit sample mass rather than surface area. Typically it is the sulfide (often pyrite) oxidation rate that is the critical weathering rate of importance in mine waste studies.

Release rate – The mass efflux (per unit mass of bulk rock) of an element or species away from a unit mass of rock, per unit time. For example, protocols for humidity cells tests often specify that cell contents are flushed weekly, in this case the release rate units are mg/kg/week. Where all of the reaction products are flushed from the interstitial water, then the release rate is the same as the weathering rate (under the conditions of the test) expressed in unit of mass per unit bulk mass per unit time, e.g., mg/kg/week. In the case of sulfide oxidation, if all the reaction products are flushed from the humidity cell interstices in the weekly rinse then the sulfate release rate (mg/kg/week) is also the same as the sulfate production rate within the cell, which is stoichiometrically proportional to the rate of sulfide oxidation (assuming no other sources of

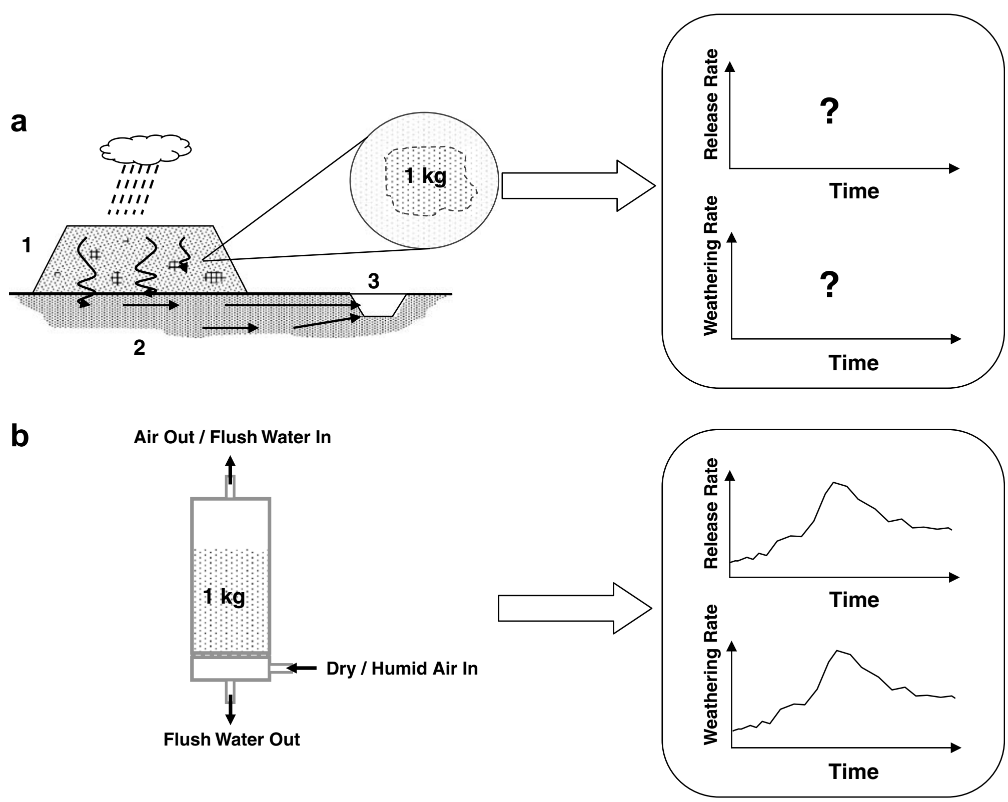

Fig. 1. Comparison of weathering environments in the field (a) and laboratory (b).