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A critical review of acid rock drainage prediction methods and practices

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ABSTRACT

Failure to accurately predict acid rock drainage (ARD) leads to long-term impacts on ecosystems and human health, in addition to substantial financial consequences and reputational damage to operators. Currently, a range of chemical static and kinetic tests are used to evaluate the acid producing nature of materials, from which risk assessments are prepared and waste classification schemes designed. However, these well-established tests and practices have inherent limitations, for example: (i) best-practice sampling is not pursued; (ii) risk assessments rely on limited static and kinetic test data, thus compromising the accuracy of resulting ARD block models; (iii) static tests are completed off-site and do not reflect actual field measurements; (iv) kinetic test data do not become available until later stages of mine development; (v) waste classification schemes generally categorise materials as only three types (i.e., PAF, NAF and UC) with other drainage forms (e.g., neutral metalliferous or saline) not considered; and (vi) conventional testing fails to consider that reactivity of waste is controlled by parameters other than chemistry (e.g., microbiology, type and occurrence of minerals, texture and hardness). Thus, accurate prediction is challenging because of the multifaceted processes leading to ARD. Hence, risk assessments need to consider mineralogical, textural and geometallurgical rock properties in addition to predictive geochemical test data. Instead, a new architecture of integrative, staged ARD testing should be pursued. Better ARD prediction must start with improving the definition of geoenvironmental models and waste units. Then, a range of low-cost and rapid tests for the screening of samples should be conducted on site prior to the performance of established tests and advanced analyses using state-of-the-art laboratories. Such an approach to ARD prediction would support more accurate and cost-effective waste management during operation, and ultimately less costly mine closure outcomes.

Contents

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1. Introduction

Predicting acid rock drainage (ARD) is usually not an aspect that is strongly embedded into the development of mineral deposits as other aspects such as resource evaluation and testing for beneficiation, mineral processing and recovery attributes of ores and different ore types take priority. However, published evidence for the consequences of failing to predict and manage ARD for individual operations and for the mining industry as a whole is abundant, with estimated costs of US$ 100 billion for total worldwide liability associated with current and future remediation (Tremblay and Hogan, 2001). For large mines in settings favourable to the generation of ARD, unplanned closure costs have frequently been in the range of AS$50–100 million, and sometimes beyond (Dowd, 2005).

Therefore, today's mine regulators will only permit mining if robust waste management plans have been developed. However, this is not just a government requirement, with many financiers and stakeholders adopting guidelines to minimising environmental risk as published by the International Finance Corporation (IFC, 2007) and the Equator Principles III (2013). The typical requirement is for mine wastes to be appropriately characterised as part of an environmental impact assessment, with future characteristics of the materials also predicted (Azapagic, 2004; Price, 2009). Most significantly, the International Network for Acid Prevention (INAP) published the Global Acid Rock Drainage guide (GARD, 2014), a web-based Wikipedia-style handbook that covers pertinent topics relevant to ARD including prediction, rehabilitation and management. Whilst these up-to-date handbooks provide systematic information on how to undertake site-by-site ARD prediction, they do not greatly deviate from Morin and Hutt's (1998) wheel approach to drainage chemistry prediction (Fig. 1). This comprises a variety of tests which are either field or laboratory based, and can be geochemical or mineralogical in nature.

Management and treatment of ARD affected sites can vary, but typically active additive approaches are preferred whereby neutraliser such as limestone ($CaCO_3$) and quick lime (CaO) are used to treat waste rock piles and tailings storage facilities (Kuyucak, 2001; Johnson and Hallburg, 2005; Akcil and Koldas, 2006; Carabello et al., 2009; Zhang, 2009; Simate and Ndlovu, 2014). Alternative strategies include those which focus on physical–chemical methods e.g., electrowinning (Vegliò et al., 2003; Gorgievski et al., 2009) and cation–anion exchange resins (Akcil and Koldas, 2006; Fu and Wang, 2011); and biological–chemical methods e.g., selective sequential precipitation of metals (Tabak et al., 2003; Luptakova et al., 2012) and packed bed bioreactors (Diz, 1997). Considering the magnitude and persistent occurrence of ARD liabilities, the long-term impacts on the environment, and the financial consequences to industry and society (Azapagic, 2004; Johnson and Hallburg, 2005), there is a growing need to provide accurate information of intrinsic rock characteristics likely to result in ARD. Such information is required early in the life-of-mine cycle because it impacts in particular on waste management throughout each phase. Early acid rock drainage (ARD) characterisation and risk assessment at the exploration, pre-feasibility and feasibility stages supports more effective management and valuation of ores and wastes during mineral processing, subsequent storage of waste and ultimately improved mine closure outcomes. Consequently, the existing ARD predictive tools and protocols need to be evaluated whether they provide robust, accurate and cost-effective characterisation in an industrial setting.

The objective of this paper is to critically review the methods and practices currently used for characterising mine and processing wastes for their ARD potential. The review does not present a complete catalogue of predictive tools nor does it document these

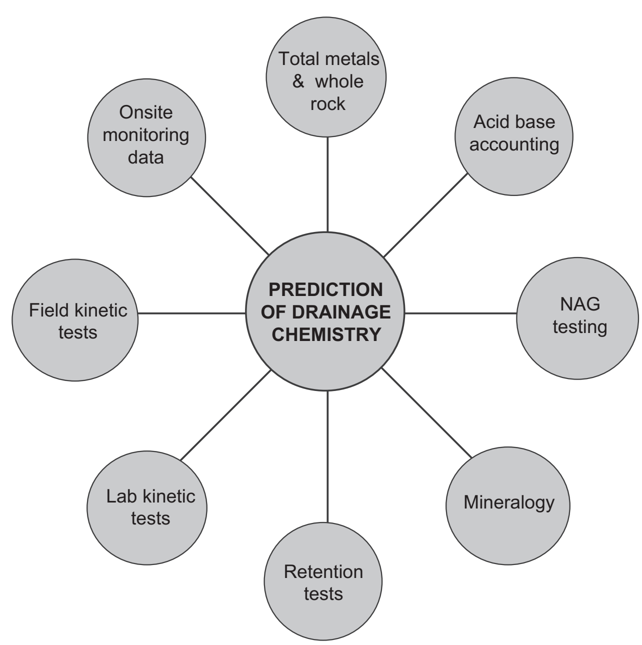

Fig. 1. The wheel approach for predicting acid rock drainage (ARD) risks (Morin and Hutt, 1998).