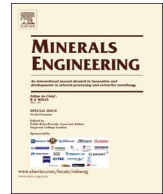




Contents lists available at ScienceDirect

Minerals Engineering

journal homepage: www.elsevier.com/locate/mineng

Improved mine waste characterisation through static blended test work

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ARTICLE INFO

Keywords:

Prediction
Waste management
Acid rock drainage
Static testing
Geoenvironmental
Mine planning

ABSTRACT

Prediction of the geoenvironmental characteristics of mine waste materials typically relies on the static and kinetic testing of individual waste units. In reality, waste rock piles are heterogeneous landforms containing potentially acid forming (PAF) units juxtaposed with non-acid forming (NAF) units. Despite this, predictive geoenvironmental test work programs rarely characterise blends of waste materials. Through undertaking laboratory-based blended static testing and mineralogical assessments, a first insight into the leachate chemistry of a waste landform can be ascertained. This was tested using three waste units (Type A – alkaline, B – neutral and D – PAF; n = 31) obtained from the Savage River mine, Western Tasmania. Seven daughter blend types (1–7; n = 42) were prepared using different ratios of the individual waste types, and characterised by acid base accounting and mineralogical techniques. Blend types were NAF when a maximum of 20% of Type D was used, with daughter blend 4 (90% Type A + 10% Type D) the most inert when screened against ANZECC (2000) aquatic protection trigger values. This study demonstrates that through first-pass static blended testing, opportunities exist to improve waste-rock handling practices and design NAF waste piles once field trials, involving a range of particle sizes, have been conducted.

1. Introduction

The critical importance of accurately forecasting leachate quality produced by mined and processed waste materials (i.e., waste rock, tailings) at the earliest stages of mine development cannot be underestimated in order to cost-effectively plan for economic operation and mine closure. Leachate quality is significantly influenced by the oxidation of sulphide minerals (e.g., pyrite, pyrrhotite) contained within these materials which may generate low pH (< 4.5) fluids in which dissolved metals (typically cationic species) can be readily transported e.g., Cd, Co, Cu, Ni, Pb and Zn (Hageman et al., 2015). However, in higher pH conditions, metals and metalloids which form anionic species e.g., As, Sb, Se, Cr, V and Mo are more soluble. Predicting leachate chemistry accurately can determine if a mining project is truly socio-economically viable as on-going waste management by remediation and rehabilitation after mine closure can be costly (GARD Guide, 2017). This is common knowledge and practice in today's mining industry and indeed, is mandated by regulatory authorities and project financiers. Such early-stage geoenvironmental predictive campaigns focus heavily upon geochemical testing and remain the *status quo* despite their well-documented limitations which were most recently articulated in Hageman et al. (2015), Parbhakar-Fox and Lottermoser (2015) and

Dold (2017). To address this, improved static (short-term chemical laboratory tests to define acid forming and neutralising capacities on milled material), kinetic (20 week minimum test involving periodic irrigation of crushed waste material kept either heated or kept in humid conditions) and mineralogical test work have been proposed e.g., Miller et al. (2010), Opitz et al. (2016), Brough et al. (2017), Fox et al. (2017) and Parbhakar-Fox et al. (2017). Whilst these tests and protocols offer a more detailed understanding of the mineralogy and resulting leachate chemistry of future waste materials, they generally test one individual homogenised waste type. Whilst it is important to have such baseline data, the reality is that waste landforms (i.e., waste rock pile, tailings repository) are heterogeneous, conventionally constructed in layers, or with acid forming materials encapsulated or blended with geoenvironmentally inert, clay, or neutralising materials (GARD Guide, 2017). Therefore, any leachate generated from such a landform is chemically influenced by several materials- not just one individual waste unit. Considering this, to improve the predictive capacity of laboratory testing procedures, modified static (and kinetic) testing procedures which focus on testing blended waste materials should be developed. Further, if volumes of future waste materials are known as well as the reactivity of these materials over a range of particle sizes, then using such blended static predictive tests could be the first step in engineering

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Fig. 1. Location of the Savage River iron Mine, Tasmania, Australia.

the least geoenvironmentally harmful landform. This study presents results from a static blended test work programme developed using three waste rock materials obtained from the Savage River mine, Australia.

2. Materials and methods

2.1. Site description

The Savage River iron ore mine (operated by [Grange Resources](#)) is located on the Savage River 420 km from Hobart on the northwest coast of Tasmania (Fig. 1). The operations consist of open cut workings which exploit a group of magnetite-rich lenses irregularly distributed within a series of highly metamorphosed rocks of marble, schist and metabasic rocks ([Jackson and Parbhakar-Fox, 2016](#)). Three open pits (North, Central and South) are currently mined covering a 4 km strike length and are on average 100–150 m deep ([www.grangeresources.com.au](#)). Cut-back and extension of these pits are proposed, and will deepen them by a further 250 m, generating additional waste rock. Mining methods include the use of conventional off-highway rear-dump trucks and hydraulic excavators, with drilling and blasting used to prepare the ground prior to mining ([www.grangeresources.com.au](#)). Subsequently, grade control sampling is conducted on all blast holes within the ore-body, as well as on selected holes around the periphery. Processing is undertaken onsite with ore from the northern and southern section tipped into two gyratory primary crushers (Allis Chalmers 54/74 and 54/62 respectively), reduced to 200 mm and transported to a 100,000 tonne capacity crushed ore stockpile via truck or overland conveyors ([www.grangeresources.com.au](#)). Ore is reclaimed via a tunnel system and fed into the concentrator after being ground by two autogenous mills (previously Hardinge 9.75 m × 3.66 m and now Metso 10.06 m × 3.66 m) and second by two ball mills (Nordberg 8.84 m × 3.96 m). Finally, magnetic separators recover the magnetite and the gangue is pumped to the tailings dam. The magnetite concentrate slurry is then pumped from the concentrator to Port Latta (c.83 km) where it is pelletised (using bentonite as a binder) using heat induced processing methods. The finished pellets are screened to remove excess fine and coarse material; transferred by conveyor onto a stockpile and once cooled they are shipped nationally and internationally ([www.grangeresources.com.au](#)).

2.2. Sample description and preparation

Solid waste materials (i.e., waste rock) at the Savage River mine are designated into one of four types (A to D) based on their geochemical and mineralogical characteristics (Table 1). In addition, these waste rock materials are considered to have four classes of properties (I to IV),

also described in Table 1. This classification is exclusively for waste rock materials handled prior to mineral processing and therefore is not applied to processed wastes (i.e., tailings). In summary, Type A has significant alkalinity, Type B is variable material (generally NAPP negative or neutral), Type C is non-acid forming and Type D is the most acid forming material and is typically in greater abundances in proximity to ore horizons. In this study, materials from waste types A, B and D were only studied as Type C is considered to be geochemically inert in ARD terms (and is instead used as a waste capping material across the operations). This classification is applied to all waste rock across the entire Savage River operations (i.e., North Pit, Centre Pit and South Deposit Pit). Current five-year waste forecasting shows that Type A dominates across the operations with 50% of waste rock given this classification in year 1. However, the quantity of Type B is predicted to increase from 13% (year 1) to 30% (year 2) with Type A decreasing to 38% (year 2) but still dominating, before increasing again to 41% (year 5). Quantities of Type D is also forecast to fluctuate as different parts of the operations are targeted, with an increase from 30% (year 1) to 57% (year 3) followed by a decrease to 35% (year 5). Type C remains consistently below 8% across this period. Considering the fluctuating volumes of waste rock types forecasted over the next five-year period, an understanding of how blending these wastes (i.e., using different ratios and types) has potential to influence waste placement allowing efficient use of materials with neutralising capacity.

In this study, 31 waste rock samples representing Types A (n = 7), B (n = 11) and D (n = 13) were collected by Grange Resources personnel from the North Pit operations. Each sample (~2 kg) was crushed to -4 mm and a 150 g riffle split was pulverised to < 75 µm in a ring/puck mill prior to static testing at SGS Renison, Tasmania. Additional riffle splits of each waste type were sent to the University of Tasmania (UTas) laboratories and represented the 'parent' materials from which 'daughter blends' were created. In this study, two blended tests were pursued: (i) dual blends comprising Type A + D; and (ii) tri-blend comprising Type A + B + D. Seven daughter blend types (BT1 to BT7) were prepared from the parent materials with six blends produced per type resulting in the production of 42 individual samples (Table 2). These daughter blends were prepared by placing calculated quantities of individual parent materials into clear 70 ml labelled plastic vessels and sealed. Each vessel was manually agitated for 5 min, stirred with a plastic rod for an additional 2 min before finally being agitated again for a further 2 min to homogenise the materials.

2.3. Mineralogical characterisation

To determine the mineralogy of both the parent waste rock and each daughter blend materials, all samples were subjected to XRD analysis using a Bruker D2 Phaser X-ray diffractometer instrument with a Co X-

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