Mobilisation of salts from mine waste—A pinch or a pound?

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Abstract The salinity of seepage from mine waste is a key requirement of impact assessments in semi-arid climates, such as South Africa, where water resources are limited. Seepage quality from mine waste materials is typically based on leach test results. Leachate concentrations depend on several factors, including the liquid to solid ratio adopted for the test. Various test protocols require different liquid to solid ratios. Seepage quality estimates therefore depend critically on the leach test methodology employed. Experiments were conducted to assess the mobilisation of salts from gold tailings. The results indicate that mobilisation is dependant on the amount of water used in the leach test. However, a "plateau" of mobilisation was obtained at liquid to solid ratios less than about 10. Methods espoused by South African authorities, employ a liquid to solid ratio of 20. The experimental results indicated that seepage loads estimated using these methods can be significantly overestimated and may be too conservative when very large volumes of waste are considered, such as gold mine tailings. Impact assessments require an estimate to be made of contaminant mobilisation so that surface and groundwater quality changes can be estimated. The experimental results suggest that leach tests for gold tailings employ liquid to solid ratios in the range 2 to 10 to avoid overestimating leachable salt loads.

Key Words tailings, leachate, drainage, assessment

Introduction

The central northern portion of South Africa has a semi-arid annual precipitation of 650 mm to 850 mm per year. Most gold mines lie in this climatic zone. Under these conditions seepage from gold tailings is typically saline and commonly acidic. Gold tailings facilities contain tens or hundreds of millions of tonnes of material and cover areas of several hundred hectares. The volume of seepage from infiltration of 1% to 3% of rainfall is considerable and results in a significant impact on surface and groundwater resources. Assessment of tailings drainage quality is therefore a key component of tailings impact and risk assessments.

Various leach test protocols call for different liquid to solid ratios, as summarised in Table 1. This is apparently to achieve a compromise between a standard test that can be easily and widely applied by laboratories, and a liquid to solid ratio that reasonably reflects site conditions.

In South Africa mine drainage assessments on tailings are not governed by a standard test requirement. The South African Department of Water Affairs offers a guideline on waste characterisation which suggests the use of a test based on the USEPA TCLP test for organic wastes and a similar test using an acid rain lixiviant for inorganic wastes (DWAF, 1999). Both procedures indicate that a liquid to solid ratio (L/S) of 20 to 1 should be used. This ratio is far in excess of what may be expected under field conditions. However, these tests are not intended to assess seepage quality, but to indicate potential loads of contaminants that could be mobilised from the material.

In jurisdictions without well-defined regulations, the GARD Guide recommends that test methods should be selected to simulate anticipated site-specific conditions (INAP, 2009). Modifications to standard protocols, such as solution to solid ratio, may be required to improve the predictive ability of testing.

It appears therefore, that the assessment of short-term drainage quality will depend on the leach test employed, and how the results are applied. An understanding of how leach test liquid

***Table 1** Liquid to solid ratios required for a range of standard leach tests*

Test method	Liquid to solid ratio (by mass)
Price (1997)	3:1
Modified ASTM D3987	4:1
Nevada Mining Association (1996)	1:1 (for crushed rock)
USEPA1312	20:1
DWAF (1999)	20:1

to solid ratio could affect the assessment of short-term gold tailings drainage quality was developed through the experiment described in this paper.

Method

A borehole (designated “CB”) was drilled into a South African gold tailings facility using a portable hydraulic auger. Composite samples were collected from each 1m length of the auger string and labeled according to their depth (eg. “CB 5”, for the sample collected from the 5m to 6m interval). Selected samples were submitted for leach test analysis using a deionised water lixiviant and L/S ratios of 20, 10, 5, 2 and 0.35. The samples were agitated for 24 hours before filtering. The extracts from each procedure were analysed in a commercial laboratory for pH, conductivity, K, Na, Ca, Mg, F, Cl, SO_4, Fe and Si.

Results and Discussion

The supernatant concentrations were normalised to obtain a mass of key chemical species mobilised per unit mass of sample. This allowed comparison of results between different L/S ratios.

As expected, the mass of dissolved solids mobilised per unit mass of sample increased with increasing L/S, as indicated in Figure 1. Mobilisation of dissolved solids is approximately constant between L/S 10 and 2. The results suggest that this trend may not hold for deep tailings, as indicated by the results for CB 27.

The same trend holds for cations which show a lack of sensitivity to L/S between 10 and 2, as indicated by the Na results (Figure 2). However, the trend is not as well developed for anions, as shown for Cl (Figure 3).

A feature of all the graphs is a marked change in trend below L/S of 2. At L/S of 0.35, which approximates field capacity for these tailings, mobilisation of dissolved solids is 4 to 5 times less than at L/S of 20. This is attributed to factors such as pH, particle size, complexation with organic or inorganic chemicals, liquid to solid ratio (L/S), leaching time, kinetics, redox conditions, and chemical speciation (Townsend et al, 2003). The impact of acid generation on drainage quality, especially in the longer term, is a key factor in gold tailings drainage quality which has not been considered in this discussion.

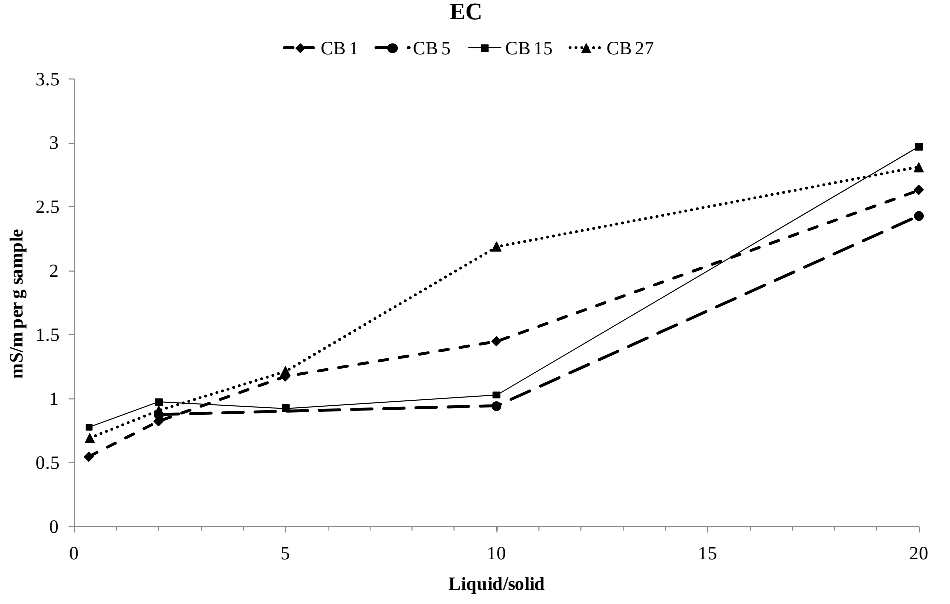

Figure 1 *Dissolved solids, as indicated by electrical conductivity (EC), mobilised from gold tailings at five liquid to solid ratios*

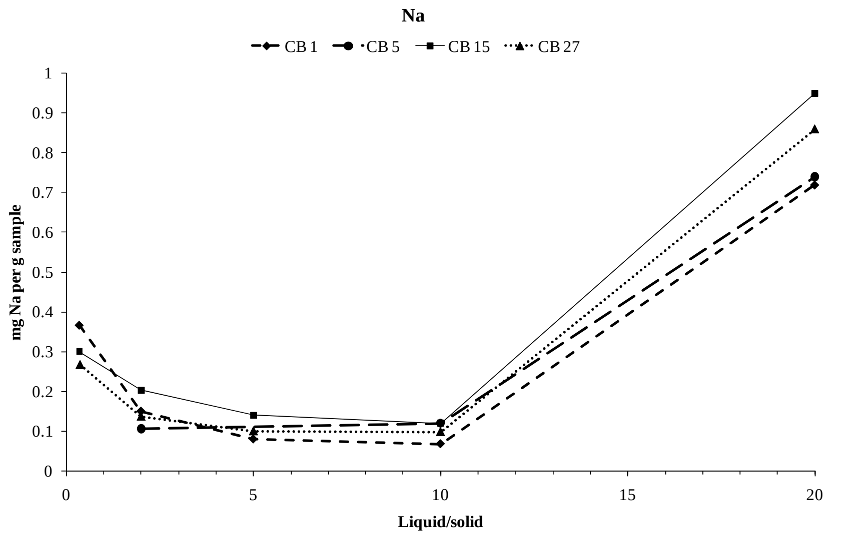

Figure 2 *Normalised mass of Na mobilised from gold tailings at five liquid to solid ratios*

Conclusion

Prediction of drainage quality is required for impact and risk assessments. Leach testing is a tool for assessing the leachable salt load. However, the results of standard tests do not necessarily represent field conditions. For tailings material, drainage will occur at or above field capacity. The results of leach testing on gold tailings show that an estimate of salinity from standard tests recommended by South African authorities will overestimate salt loads by a factor of three or more, depending on the chemical species considered. While upper bound estimates of drainage quality are prudent in impact prediction, the mass of a typical tailings dam and the volume of seepage are large. Overestimates of leachable solids can therefore result in very significant overestimates in impact. It appears from these results that leach tests, for gold tailings at least, should be conducted at L/S between 2 and 10.

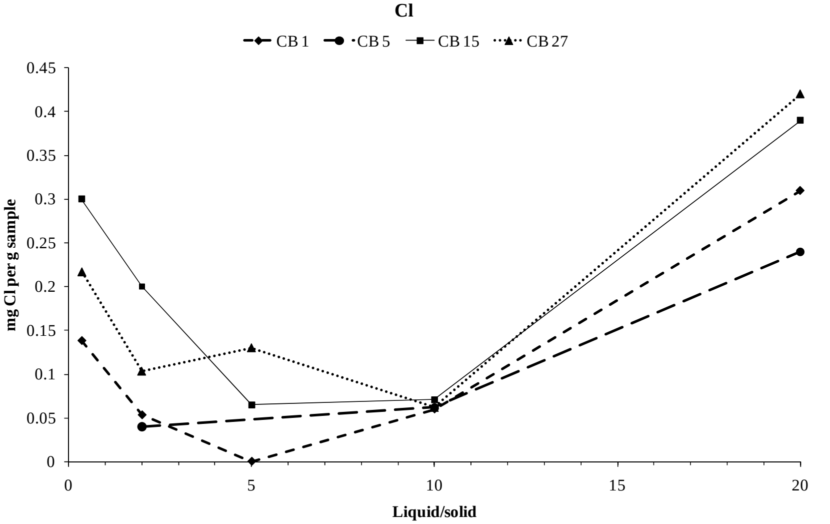

Figure 3 *Normalised mass of Cl mobilised from gold tailings at five liquid to solid ratios*

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For reasons of space, tabulated results are not presented. Results are available from the author.