## EXECUTIVE SUMMARY


## BACKGROUND AND RATIONALE

One of the major environmental issues in the mining industry is that of acid rock drainage (ARD), caused by the disposal of sulphide-bearing wastes. The legacy of the ongoing generation of ARD from the disposal of low grade dump rock, of tailings and from the mine site itself may continue for decades following active metal extraction. Acid rock drainage is recognised as a major challenge to South Africa owing to water scarcity, environmental impact of the polluted waters and the substantial cost of treatment. The latter is estimated to exceed R100 million per annum for one site only.
Changes in legislation have put the burden of responsibility for perpetuity on mining companies. This, and understanding of the sheer magnitude of the problem, is driving a change in process thinking in order to reduce potentially harmful emissions from deposits and thus reduce long-term costs of tailings management and ARD remediation. Re-examination of the manner in which waste materials are disposed from the mineral processing and extraction stages of metal recovery is required to relieve the environmental burden created and reduce the time frame of risk. Particularly, the delay in the time of ARD formation is no longer acceptable and the need to remove the risk accepted.
In this study, the approaches to the removal of risk through removal of sulphur species were considered through both a paper-based review of key South African workings and a set of case studies addressing specific mineral wastes. Aspects of disposal of dump rock and tailings from mining operations processing mineral sulphides (especially pyrite) have been addressed, specifically with the focus of reducing capacity to form ARD through removal of the sulphidic component of the waste. The understanding of the factors governing ARD generation from dump rock and tailings (similar to those governing mineral bioleaching) has been used to improve categorisation, separation and planned disposal of its components to mitigate ARD generation. While flotation and accelerated bioleaching have been used in the case studies to demonstrate sulphide removal by separation and reaction, a review of suitable unit operations is provided. Further, use of acid base accounting and net acid generation methods as static chemical methods for evaluating ARD potential was supported by the development of a biokinetic test for assessing ARD potential under an environment more cognisant with the ARD generating environment, as well as providing kinetic data over a shortened time frame to conventional kinetic tests. The biokinetic test also delivers solutions through which to analyse metal deportment through ARD.

## OBJECTIVES AND AIMS

To meet the aims and objectives of the study, the following were addressed:

1. A framework for the discussion of the challenges of ARD in mineral processing.
2. A review of mineral resources and wastes in South Africa to highlight key contributors to ARD and to assess the potential of the material for sulphide removal through separation or accelerated oxidation.
3. A review of unit operations available for the removal of sulphidic materials through separation or accelerated oxidation.
4. Selection of appropriate tests for the quantification of ARD, and subsequent development of further tests,
including biological tests and metal deportment.
5. A case study, centred on a specific mineral tailings, of the potential for ARD prevention through sulphide removal by flotation.
6. A case study of the potential for accelerated bioleaching for the removal of the sulphidic fraction from waste rock.

## METHODOLOGY

Six components are included to meet the project aims and objectives: characterisation of the waste materials, review of appropriate unit operations, review of typical waste materials, study of removal of sulphide rich materials from tailings by physical separation (and its potential for recovery of values from the additional processing) through a case study, study of the removal of sulphide rich species from waste rock through reaction using a case study. Both waste rock and finely divided tailings materials are considered with respect to their potential for ARD formation from waste material. Cross disciplinary expertise in mineral processing, bioprocessing and environmental engineering has been drawn into the study. Specific emphasis has been placed on characterisation procedures of waste rock and tailings, through literature review on ARD formation as well as the in-house expertise.
Through this characterisation, the sulphide-rich components requiring removal from the waste to prevent ARD formation are highlighted and the typical form and accessibility of these fractions considered to inform selection of appropriate unit operations. While some generic approach is useful, much value is lost by avoiding dealing with the complexity of specific ores in terms of their mineralogy, gangue materials, mineral dissemination, etc.

Hence, the detailed characterisation has been undertaken through case studies using specific ore deposits. A case study was undertaken on base metal sulphide tailings in which physical separation of the sulphide species was mediated by flotation. A second case study on waste rock from a base metal sulphide deposit was treated to assess accelerated bioleaching as a means to remove the sulphidic fraction. Success of these approaches was assessed through a combination of ARD potential tests, including acid base accounting (ABA) and net acid generation (NAG) tests as well as a biokinetic test developed through this project. Further to the impact of sulphide, the resultant metal deportment associated with ARD formation has been studied in these systems.

## RESULTS AND DISCUSSION

The review of ARD-generating mineral wastes in South Africa has led to the highlighting of the following important sources of ARD: gold-bearing sulphidic ores, coal, PGM tailings (although low in sulphide, these are voluminous), base metal sulphide ores and antimony ores. The review of unit operations for sulphide removal has targeted specifically flotation, gravity concentrators and reaction through leaching as having potential for sulphide removal. Using these, a conceptual approach to the removal of sulphide has been prepared for the tailings mineral waste. This proposes the generation of an additional values stream (where appropriate), a sulphide rich tailings (of small volume) and a sulphide lean tailings accounting for the bulk of the tailings sample and benign with respect to ARD generation potential. While a suite of chemical tests for ARD-generation potential have been selected for the study, their limitations are understood. These have been partly overcome by the development of a biokinetic test, providing relevant data more rapidly than the standard abiotic kinetic tests. Further refinement of this test to decouple the kinetics of acid neutralisation and acid generation is proposed. A case study using flotation for the physical separation of sulphide from tailings allowed the demonstration of the concept of risk removal. Through this approach, a chalcopyrite rich values stream and two tailings streams were prepared. The small volume tailings stream, accounting for approximately 10% of the tailings, was characterised by an increased sulphide concentration of 3.9% while the bulk tailings stream (90% of the tailings by mass) contained 0.21% sulphide and was non-acid forming. In the second case study using reaction to remove the sulphide fraction, the relative impacts of removal of acid neutralising and acid forming capacity were apparent, with the rate of the former exceeding that of the latter and being largely complete within 50 days. Further, the addition of a low amount of finely divided pyrite was demonstrated to augment biological sulphide oxidation and the concomitant sulphide removal. While the preliminary case study on coal desulphurisation by flotation was unable to demonstrate significant separation of total sulphur from coal ultra-fines, both visual observation and net acid generation prediction tests demonstrated a significant separation of sulphidic sulphur, with the majority of the acid-generating sulphidic sulphur reporting to the concentrate fraction, resulting in an acid-forming concentrate while the residual tailings showed an increased NAG pH and reduced acid forming ability over the feed material.

## CONCLUSIONS

In summary, the following project objectives have been met:

_ Review, classification and characterisation of ARD generating mineral wastes in South Africa have been
conducted, allowing identification of important materials for study.

_ Unit operations available for sulphide removal have been reviewed.

_ Characterisation methods to quantify ARD generation potential from waste rock have been reviewed and
a sub-set selected for application. Further an additional biokinetic assay has been developed.

_ Factors affecting the oxidation rate of metal sulphides have been reviewed. Further the potential for reduction of ARD generating capacity through accelerated bioleaching has been presented.

_ Physical separation of sulphidic materials from tailings has been demonstrated to provide the major tailings fraction as non-acid forming while the reactive gangue may be contained in a small fraction of the tailings for additional recovery of values, utilisation of the sulphide or contained disposal.

## RECOMMENDATIONS FOR FUTURE RESEARCH

Following the review of ARD-generating wastes in South Africa, it is recommended that the range of mineral wastes studied be expanded to include some of coal wastes, waste materials from gold-bearing ores and PGM ores while expanding work on base metal-bearing ores (nickel, copper and complex ores). In coal studies, it is recognised that sulphur is present in varied forms which need to be taken into account. In the determination of ARD-generating potential, it is proposed that the biokinetic test be further refined to enable kinetic data to be collected in which acid neutralising capacity and acid generating capacity are decoupled and through which metal deportment can be studied. The costing of the methods investigated for sulphide removal is required, both with respect to physical separation and reaction. Further, the extent of removal requires consideration. The processing of the waste removed, as a sulphide concentrate on physical separation or as a sulphate rich aqueous stream on reaction, requires further consideration in terms of the final fate of the sulphur species removed.