

## EXECUTIVE SUMMARY

### Background

This project was undertaken by the CSIR, Pretoria, and the University of Pretoria, Department of Plant Physiology and Microbiology. The project was sponsored by the WRC and originated from another project on the passive treatment of mine water (WRC K5/700), which was also partially sponsored by the WRC.

By the time the motivation for the present project was submitted to the WRC, the passive mine water treatment project had been running for some 12 months. It was observed that the initial sulphate reduction achieved through the operation of the pilot scale plants, had declined significantly over the past weeks in most of the systems. Some of the questions asked in discussing the problem were related to the suitability of the carbon sources for the biological treatment of acid mine water, whilst others were related to the medium-to-long term suitability of such carbon sources in the treatment of acid mine water. Limited initial test work had been undertaken on the carbon sources included in the pilot plant systems and the need to better understand and test potential carbon sources for the use in passive mine water treatment systems was identified by the project team.

The primary objective of this project was to develop a quick test method for the assessment of potential carbon sources regarding their suitability for use in passive treatment systems. The objective was defined by developing a test procedure. The test procedure would compare the sulphate reduction under controlled experimental conditions in an anaerobic reactor using defined carbon sources such as lactic acid and others with undefined (complex) carbon sources.

### Methodology

It was initially envisaged that up to 20 defined and undefined carbon sources could be tested in triplicate for their suitability to support sulphate reduction in passive treatment systems for mine water. The experiments would most likely require 20 to 30 days to obtain suitable data for the evaluation of the respective carbon sources. The main problem was that a larger number of anaerobic reactors would be required which could be sampled without changing the environmental conditions in the reactor. The envisaged volumes of matter to be incubated was 1,000 mL.

Intravenous feeding apparatus, in short 'drip bags', were identified as a suitable reactor for the experiments as they were quite readily available from hospitals in volumes of 1,000 and 5,000 mL.

These bags were made from durable plastic and were also gastight and flexible enough to expand to accommodate any gas produced during the testing of the carbon sources. Initial testing of the drip bags confirmed that the idea was feasible.

The initial work was followed up with experiments to evaluate defined and undefined carbon sources regarding their suitability to support sulphate reduction in the anaerobic reactors. Seven defined carbon sources were identified from a comprehensive literature review and used in further experimental work to generate baseline data regarding sulphate reduction with defined carbon sources. The removal of 90% of the sulphate over time was used as a benchmark for the evaluation of the experiments. The experiments confirmed that under the selected experimental conditions 90% of the sulphate in artificial acid mine drainage (initial sulphate concentration was approximately 2,500 mg/l) could be removed within seven days. Two carbon sources which achieved more than 90% sulphate reduction were butyric acid and propionic acid.

The other defined carbon sources used were found to be less effective, ranging from 73.6% sulphate removal for pyruvate to 87.7% sulphate removal for methanol. Some variation in the time period was also found for the same carbon source, probably due to a slight variation in the water chemistry between the different batches of mine water used in the experiments.

Experiments with undefined (complex) carbon sources confirmed that some of these carbon sources can remove sulphate from the artificial mine water quite effectively. Sulphate reduction in excess of 90% was achieved for kikuyu grass cuttings, silage, mushroom compost and hay. Fresh cow manure fell short of the benchmark by 9.0 % with 81.1 % sulphate removal. The other carbon sources ranged between 0% sulphate removal with composted cow manure, to 86.7% sulphate removal with fly ash.

## **Literature Review**

The literature review showed that an increasing amount of work has been undertaken on bacterial sulphate reduction in acid mine water and industrial effluents since the mid 1960s. The majority of work cited in the literature is concerned with active systems for the removal of sulphate while the discussion of passive treatment systems for mine water treatment focuses largely on the removal of metals, particularly iron, rather than the removal of sulphate. No information pertaining to the assessment of carbon sources for the purpose of biological sulphate removal could be found in the literature and the work undertaken and documented in this report is therefore considered to be novel.

### **Availability of carbon sources**

The review of the potential carbon sources available showed that a number of "renewable" carbon sources existed, such as grass and wood, whilst a number of waste products were also identified as potentially suitable carbon sources. The distribution of carbon sources needs to be considered in the context of the geographical distribution of the mines as transport of carbon sources beyond a radius of 100 km may not be cost-effective. It was confirmed that for a number of the carbon sources, that exist in the respective mining areas, alternative uses are established. Such uses may render the carbon sources a commercial commodity rather than a freely available waste product. Potentially, therefore, this could add to the capital cost of the passive treatment system as the cost of carbon could become one of the major cost items in the construction operation costs of the system.

### **Conceptual model**

To document and better understand the complexity of the biocenosis in a passive treatment system for mine water, a conceptual model was developed of the main bacterial physiological groups potentially present in the sulphate reducing reactor of the mine water treatment system. The model described the fate of the complex carbon via the various pathways of the respective bacterial groups and provided an indication of preferable pathways, that would maximise the conversion of the complex carbon into suitable products for bacterial sulphate reduction. In addition, the model also indicated the competitive reactions that scavenge (remove) carbon which is potentially available for sulphate reduction. Such competing reactions lead to a net loss of the total carbon available for sulphate reduction in the treatment process, thereby reducing the overall efficiency of the treatment system. The environmental conditions in the sulphate reduction reactor therefore have to be controlled in such a manner as to minimise competing reactions and maximise the amount of carbon available for sulphate reduction.

### **Conclusions**

The work undertaken during the project gave valuable insights into the suitability of certain defined and undefined carbon sources for the use of sulphate reduction in small-scale anaerobic reactors. The methodology developed was found to be reproducible and low in cost, and can easily be implemented in other laboratories to screen potentially suitable carbon sources for sulphate reduction. Not all the objectives of the project have been met satisfactorily and recommendations for further research work are given at the end of the report.

### **Recommendations for further work**

The main issue requiring further work is the release of carbon from complex carbon sources over time. In particular, it is important to develop test procedures to simulate the 'ageing' of carbon in passive treatment reactors so that carbon release can be examined over medium-to-long term periods of 2 to 10 years, as well as a need for further work to more fully understand the sustainability of carbon release from potential carbon sources.

The specific outputs emanating from this project are as follows

Dill, S., T.E. Cloete, L. Coetser, & L. Zdyb. *Determination Of The Suitability Of Alternative Carbon Sources For Sulphate Reduction In The Passive Treatment Of Mine Water.* (This report). WRC TT

### **MSc thesis**

Coetser, S.E. (1997). *Microbial sulphate reduction using defined carbon sources and artificial acid mine drainage.* University of Pretoria, Department of Microbiology and Plant Pathology.

### **MSc thesis (agric): Microbiology**

Zbyd, L. (1999). "Microbial sulphate reduction as a method of passive treatment of acid mine drainage using undefined carbon sources". University of Pretoria, Department of Microbiology and Plant Pathology.

### **Poster and Oral Paper**

Coetser, S.E., S. Dill & T.E. Cloete (2000). *Biological Sulphate Reduction in Artificial Acid Mine Drainage using Defined Carbon Sources*, BioY2K Conference in Grahamstown, South Africa.

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The Steering Committee responsible for the project consisted of the following persons:

Mr HM du Plessis	Water Research Commission
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Mr W Pulles	Pulles, Howard and de Lange
Dr JP Maree	CSIR, Division of Water, Environment and Forestry Technology
Dr ME Aken	AMCOAL (Chamber of Mines)
Ms MC Eksteen	Department of Water Affairs and Forestry

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**K5/700: PILOT SCALE DEVELOPMENT OF INTEGRATED PASSIVE WATER TREATMENT SYSTEMS FOR MINE EFFLUENT STREAMS.**

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