*Review*

# Long-term sustainability in the management of acid mine drainage wastewaters – development of the Rhodes BioSURE Process

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**Abstract**

The decanting of flooded gold mines threatens water supply on the Witwatersrand, South Africa, one of the most intensively mined areas in the world. Large volumes of acid mine drainage wastewaters will require treatment here for decades and possibly centuries. Appropriate treatment technology needs to meet technical, financial, environmental and social sustainable development criteria, with the costs of long-term treatment providing the initial decision gateway. This review details a bioprocess development in which the use of sewage sludge as the electron donor/carbon source for microbial sulphate reduction, and the wastewater treatment public utility as the operator, was investigated in meeting these requirements. A programme is reviewed that led from fundamental studies in microbial ecology, enzymology and mathematical process modelling, through pilot plant studies, to the construction and operation of a full-scale plant treating 10 Mℓ mine water/day. It was shown, in what became known as the Rhodes BioSURE Process, that with careful regulation of the mine water and the sewage sludge dosing flow rates, sulphate levels could be reliably reduced to below 100 mg/ℓ, at hydraulic retention times as low as 12 h. Ancillary metal and sulphide removal unit operations are described, as well as investigations into socially sustainable use of treated mine waters.

**Keywords**: acid mine drainage, mine wastewater treatment, sewage sludge, sulphate removal, metal removal

## INTRODUCTION

The environmental impacts of acid mine drainage (AMD) wastewaters have been the subject of intensive investigation over many years (Lottermoser, 2010), and the processes giving rise to its formation are now well-described (Blowes et al., 2003; Johnson, 2003). A considerable research effort in process development has focused on the treatment and mitigation of the AMD problem and both physico-chemical and biological processes have been applied in active and passive treatment operations (Johnson and Hallberg, 2005; Inter-Ministerial Committee, 2010).

While the hydrogeological modelling of AMD formation and discharge, following mine closure, has had considerable predictive success (Scott, 1995; Hodgson et al., 2001; Lin and Hanson, 2010), quantifying the time period over which flows of contaminated water may be anticipated has been less secure and may range from decades to many centuries (Younger, 1997). Roman mines in Britain and Bronze Age workings in Spain still actively generate AMD (Leblanc et al., 2000; Van Geen et al., 1997), and contamination of rivers by coal mines has been commonly reported 50–100 years after closure (Bell et al., 2001).

South Africa represents a paradigm case where the AMD threat to the public water system has reached acute levels in recent years (Naiker, 2003; Ewart, 2011; McCarthy, 2011; Tandlich, 2012). The water-scarce Witwatersrand region, which accounted for more than 10% of the economic activity of the entire African continent, is one of the largest human settlements in the Southern Hemisphere not located on a river (Turton, 2004). It has also been one of the most intensively mined areas in the world, with 37 million kg fine gold extracted (and 6 billion tons of ore milled) since the 1880s. This represents over 3% of estimated total global gold recovery since prehistoric times (Hartnady, 2009). Since gold production peaked at 1 million tons fine gold/year in the early 1970s, the industry here has been in decline, with the problems of mine closure leaving an increasing legacy of social, financial and particularly environmental consequences requiring urgent management. Given abandoned and orphan mines (Field, 2003), these problems have increasingly passed to the responsibility of the state and thus to the wider community (Inter-Ministerial Committee, 2010; Ewart, 2011).

With the termination of mine dewatering and pump-and-treat operations, as functions of the active mining enterprise, groundwater levels have been rising in the East, Central and West Rand Basins along the Witwatersrand (McCarthy, 2011). Hydrogeological modelling of this situation since the mid-1990s has predicted the time to reach decant status, the quantity and quality of waters that would decant once the filling of the mines was completed, and total volumes of AMD requiring treatment in this region, which may exceed several hundred Mℓ/day (Scott, 1995; Tutu et al., 2008; McCarthy, 2010). The potentially long-term nature of the problem has focused interest on the technical and financial sustainability of treatment operations able to deal with the AMD problem over extended periods of time, and this has in turn led to investigation of the advantages of biological compared to physico-chemical treatment technologies (Van der Merwe and Lea, 2003; Inter-Ministerial Committee, 2010).

Neba (2006) investigated the use of formal decision-support tools required to achieve an integration of environmental, economic and social factors in sustainable technology choice in the

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