

An investigation into the mechanism underlying enhanced hydrolysis of complex carbon in a biosulphidogenic recycling sludge bed reactor (RSBR)

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Abstract

The potential for using readily available and cost-effective complex carbon sources such as primary sewage sludge for a range of biological processes, including the bioremediation of acid mine drainage, has been constrained by the slow rate of solubilisation and low yield of soluble products, which drive the above mentioned processes. Previous research into the hydrolysis of complex organic matter, such as primary sludge, under biosulphidogenic conditions within a novel Recycling Sludge Bed Reactor (RSBR) demonstrated solubilisation in excess of 50%. However, further investigation was required into the mechanism of this enhanced hydrolysis. The current study was aimed at confirming that hydrolysis is enhanced under biosulphidogenic conditions, and to obtain an estimate of the relative rates of hydrolysis using toluene as a specific metabolic inhibitor.

The solubilisation of primary sewage sludge under sulphate reducing conditions was conducted in controlled flask studies and previously reported findings of enhanced hydrolysis were confirmed. The maximum percentage solubilisation obtained in this study over a 10-day period was 31% and 64% for the methanogenic and sulphidogenic systems respectively. By using toluene as an inhibitor of bacterial uptake of soluble carbohydrates, it was possible to determine the rate of production of various key products of the hydrolytic step. From the results of the current experiment, the rate of production of soluble carbohydrate, and therefore the rate of hydrolysis of complex carbohydrates, in terms of COD equivalents was estimated at 543 mgCOD·ℓ⁻¹·d⁻¹ and 156 mgCOD·ℓ⁻¹·d⁻¹ under sulphidogenic and methanogenic conditions, respectively.

Introduction

Acid mine drainage (AMD) is a worldwide environmental hazard associated with current and past mining activities, and poses a serious threat to the quality of valuable surface water. Between 1988 and 1991, the mean volume of water being pumped from the East Rand mining basin was 65.4 Mℓ·d⁻¹ (Scott, 1996). By 1997, Grootvlei was pumping 110 Mℓ·d⁻¹ (Grootvlei, 1997). Currently, heavy metals are removed by a High Density Sludge (HDS) process and the mean iron concentration in the water being discharged into the Blesbok Spruit is less than 1mg·ℓ⁻¹. However, at times, the concentration exceeds 44 mg·ℓ⁻¹. The high salt content of the water is still problematic, with sulphate being the dominant contaminant of concern in the effluents from South African mining operations (Pulles et al., 1995).

Attempts to reduce the pollution caused by AMD are aimed at increasing the pH of the water and reducing the concentrations of metals and salts to acceptable levels. Ideally, the methods used should be relatively inexpensive, easy to carry out and produce as little solid waste as possible (Gazea et al., 1996), and must be suitable for the remediation of large volumes of water. Popular non-biological treatment methods include lime treatment (Thompson, 1980; Barnes and Romberg, 1986) and the Bethlehem process (Henzen and Pieterse, 1978). Although chemical neutralisation is effective, the major drawbacks are the costs associated

with the purchase of reagents (lime), the transport and disposal of metal-laden sludge and plant construction (Gazea et al., 1996).

Biological treatment systems have a number of advantages over traditional chemical treatment methods, predominantly financial ones. Costs associated with chemical reagents, labour and sludge removal are negligible. Instead, costs are usually measured in terms of land (Gazea et al., 1996), making biological treatment particularly attractive in developing countries such as South Africa. Biological treatment includes treatment by wetlands and by bacterial consortiums, both in situ and in specially designed reactors.

Sulphate reducing bacteria (SRB) are found in a wide range of anaerobic environments, particularly in the anoxic sediments of freshwater (Elsgaard et al., 1994) and marine (Marty, 1981; Hines and Buck, 1982) systems. The potential involvement of these microbes for the bioremediation of AMD and other sulphate- and metal-rich industrial effluents has also been realised (Tuttle et al., 1969; Maree and Strydom, 1985; Maree et al., 1986; Maree et al., 1987; Maree and Hill, 1989; Widdel and Hansen, 1992).

As is the case with the construction of artificial wetlands, one of the most important obstacles to the implementation of biological treatment systems on a large-scale is the availability and cost of a suitable carbon source and electron donor. Under anaerobic conditions, SRB are able to oxidise a range of organic acids such as lactate, acetate and propionate as well as hydrogen. Sulphate is then used as an electron acceptor, and is reduced to sulphide (Widdel, 1988). Simple electron donors, including methanol and ethanol, are relatively expensive and are therefore not suitable for use in developing countries. A wide variety of relatively inexpensive agricultural and domestic wastes have been investigated as possible alternative sources of soluble carbon. These have included cattle waste (Ueki et al., 1988), molasses (Maree and Hill, 1989),

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