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# Pilot scale assessment of the continuous biological sulphate removal from coal acid mine effluent using grass cutting as carbon and energy sources

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ABSTRACT

This paper considers the evaluation of the performance of the biological sulphate reduction in continuous mode using grass cutting. Initially the reactor was operated in batch mode for 26 days, followed by a change to a continuous feeding mode at a Hydraulic Retention Time (HRT) varying from 8 to 2 days. At the start of the experimental period the bioreactor was filled with 89 kg of ceramic rings as support medium for Sulphate Reducing Bacteria (SRB) and 50 L SRB (COD = 852 mg/L and $SO_4^2$ = 600 mg/L) obtained from an existing biological sulphate reducing bioreactor. Rumen fluid was collected from a slaughterhouse and added to the bioreactor. Grass cuttings (10 kg) were added to the bioreactor as a carbon and energy source. The results showed that from day 59–106 the bioreactor was operated in continuous mode and the percentage $SO_4^{2-}$ reduction efficiencies were 73%, 85% and 71%, corresponding to the HRT of 8, 6 and 4 days respectively.

## 1. Introduction

Mineral mining generates acidic, saline, metal-rich mine waters, often referred to as acid mine drainage (AMD). Treatment of AMD and the subsequent recovery of saleable products is a necessity since water is, especially in South Africa, a scarce commodity. In recent years the focus for AMD treatment has shifted from chemical to biological treatment systems with the advantage that a denser and more stable sludge is produced during the latter case. The advantage of biological remediation strategies is that they rely on natural biological processes to promote remediation of AMD. Biological processes are mostly reductive and include denitrification, methanogenesis, sulphate reduction and iron and manganese reduction [10]. Sulphate reducing bacteria (SRB) is generally used for this process, which require organic carbon and energy sources. The availability of sulphate and organic carbon determines the extent of microbial activity and, therefore, the bio-treatment efficiency [6]. Selection of the source of organic carbon is usually made on the basis of availability and costs of the added electron donor per unit of reduced sulphate [17]. Biological sulphate removal technologies have an advantage compared to the chemical sulphate removal processes as in most cases the sulphate concentration is reduced to <500 mg/L or even as low as 200 mg/L, and the metals are removed due to metal sulphide precipitation. When the mine water is neutralised chemically with either lime or limestone or a combination of the two, the sulphate concentration can generally only be reduced to about1500 mg/L, which is the solubility of gypsum ($CaSO_4 \cdot 2H_2O$) [15]. In recent developments the use of various low-cost substrates together with new bioprocess designs are increasing the applications of biological bioreactors for AMD treatment and selective metal recovery [11].

Although active biological sulphate removal is a viable treatment option, not many active full-scale technologies are in operation worldwide. Active biological sulphate removal technologies have not reached maturity yet as research are still on-going in order to:

i Find the optimal reactor configuration (upflow anaerobic sludge blanket reactors, fluidised bed reactors or continuously stirred reactors) to maintain the biomass.
ii Identify cost effective carbon and energy sources.

In this regards a new technology for the biological treatment of AMD has been recently developed and is able to reduce the sulphate concentration to less than 500 mg/L and oxidize the sulphide

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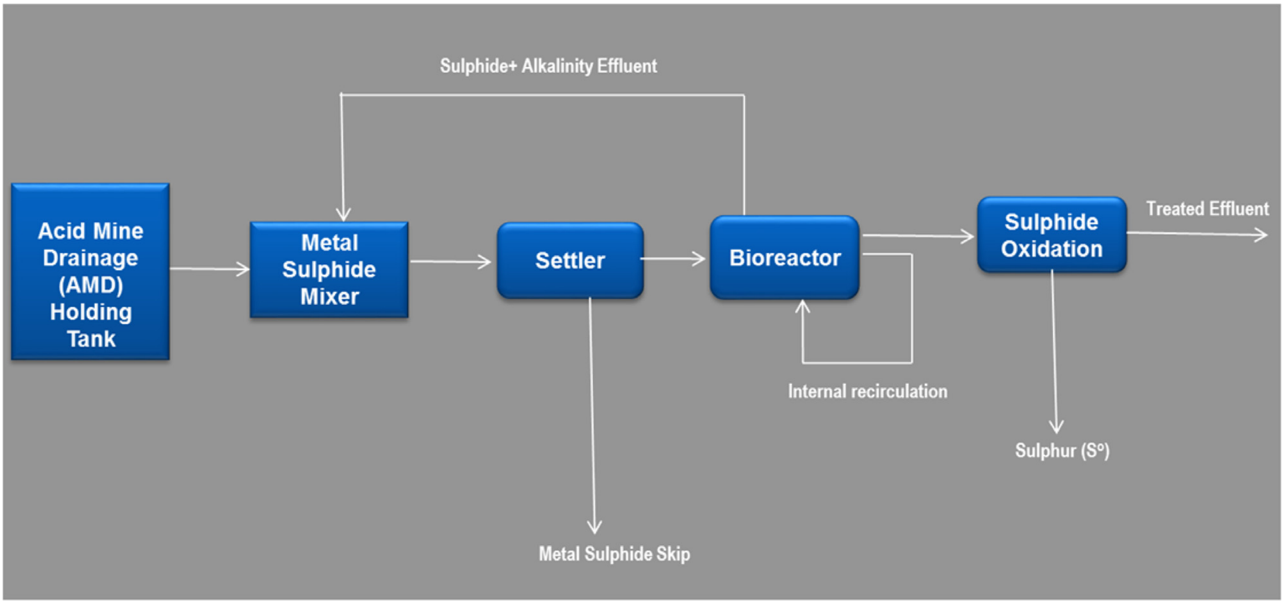

**Fig. 1.** Schematic of the biological sulphate reduction and sulphide oxidation technology.

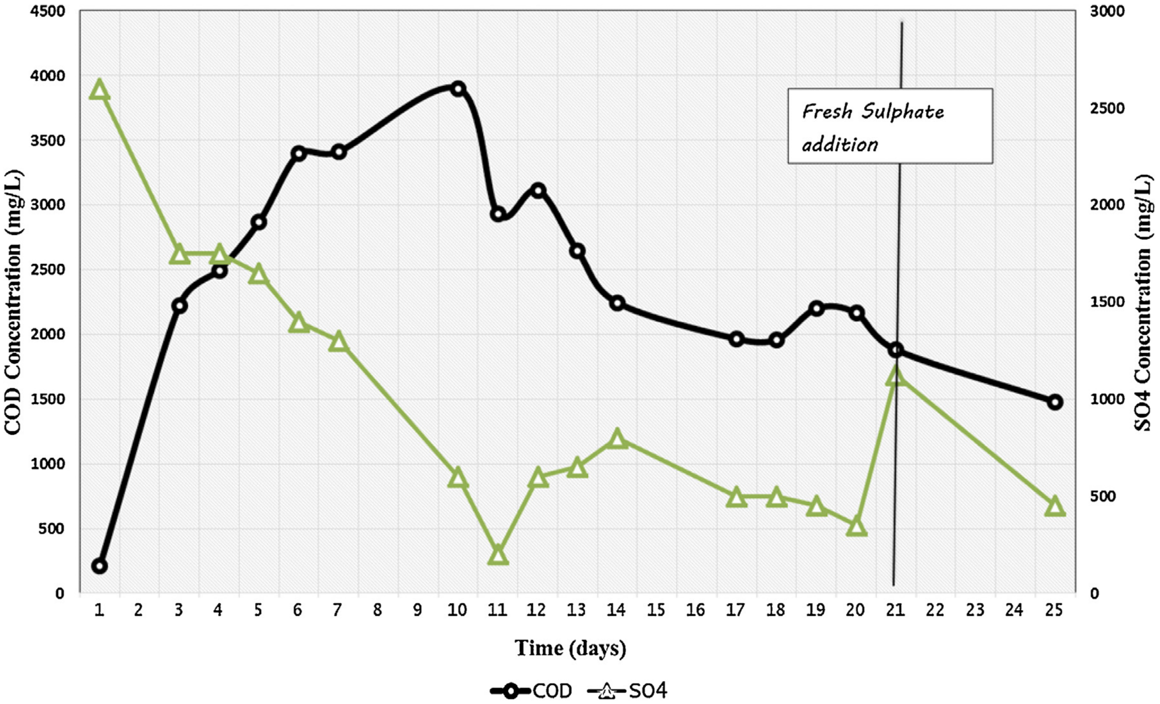

**Fig. 2.** The COD and Sulphate concentrations during the batch operated period (Day 1–25).

generated during the process to sulphur. In this technology degradation products of grass-cellulose are used as cost-effective carbon and energy sources for the sulphate reducing bacteria (SRB) [8]. Due to the alkalinity and sulphide production, the pH of the AMD can be increased to neutral and the metals in the AMD can precipitate as metal-sulphide which may be preferable for the stabilisation of metals as the solubility product of metal sulphide is lower than that of most metal hydroxides [5]. When applying the biological sulphate removal technology described above, a biological hybrid reactor is used, Sulphate Reducing Bacteria (SRB), cellulose-rich grass cuttings and rumen bacteria (RB) obtained from rumen fluid from cattle, provided by slaughterhouses. The RB degrades the grass-cellulose to produce organic acids (acetic, propionic and butyric acids) and hydrogen ($H_2$), which function as the carbon and energy sources for the SRB to reduce the sulphate to sulphide [9]. In this way a true symbiotic relationship exists between the microorganism's consortia dominated by the RB which produces the carbon and energy sources at the rate that the SRB require for sulphate reduction [7,8,16]. The advantage of operating the hybrid reactor is that all relevant microorganisms to the system are in one reactor, thereby stimulating a perfect syntrophy: the RB provides the carbon and energy sources, especially hydrogen for the SRB, which keeps the partial pressure low of the hydrogen, thereby stimulating the RB to supply more hydrogen. Although all stages in the full process are important for total AMD treatment, the core of the technology occurs during the anaerobic hydrolysis and fermentation processes,