

Improved sulphate removal rates at increased sulphide concentration in the sulphidogenic bioreactor

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Abstract

The product of the biological sulphate reduction is sulphide. High concentrations of molecular H₂S (g) can be inhibitory for microbial activity, especially at a reactor pH of 6 to 7. This paper focuses on the effect of high sulphide concentrations on the sulphate reduction rates. The results of three investigations operating a continuous reactor, a column reactor and batch-test reactors have shown that increased sulphide concentrations have resulted in improved biological sulphate reduction. In all instances the reactor pH was kept at 7.5 to 8.5. It was shown that when the sulphide concentration was 700 mg/l in a continuously operated reactor, the sulphate reduction rate was 12 gSO₄/l·d. When operating batch-test reactors the results showed that when the sulphide concentration increased, to 1 400 mg/l, the volumetric and specific sulphate reduction rates correspondingly increased to 4.9 gSO₄/l·d and 1.5 gSO₄/gVSS, respectively. Thirdly, operating a tall column reactor using H₂ and CO₂ as the energy source, showed that when the initial sulphide concentration of the feed water was 0, 100 and 268 mg/l, the average biological sulphate removals were 650, 1 275 and 1 475 mg/l, respectively. These obtained results indicated that the addition of sulphide to the feed water to the reactor had a positive effect on sulphate removal. Improved sulphate removal results in increased alkalinity production and in an increased reactor pH, which in turn is favourable for a decrease in the redox potential, when a dominant redox couple, like sulphate: sulphide, is present in a reactor.

Keywords: alkalinity, pH, Redox value, sulphate reduction rate, sulphide toxicity

Introduction

Acid mine drainage (AMD) is the result of mining activities, due to bacterial oxidation and exposure to oxygen and water of sulphide minerals (pyrite) by a group of acidophilic iron reducing micro organisms. Because of the salinisation properties of AMD and the associated scaling and bio-corrosion problems, as well as increased environmental awareness among the general population, methods are being investigated to remove the high sulphate concentration of AMD. Sulphate-rich effluents can be treated biologically when sulphate reducing bacteria (SRB) and organic matter are present. The products of the biological sulphate removal technology are sulphide and alkalinity, which contribute to the pH increase of the treated water. The advantage of the sulphide formation is that the metals present in the AMD precipitate as metal-sulphide (MeS). The disadvantage of the formation of hydrogen sulphide is its toxicity for both the methanogenic activity of granular sludge (Koster et al., 1986) as well for the sulphidogenic bacteria, e.g. *Desulfovibrio desulfuricans* (Okabe et al., 1995). Moreover, it has been reported that the produced sulphides are fatally toxic to humans at gaseous concentrations of 800 to 1 000 mg/l (Speece, 1996). Because of its toxicity, it is forbidden in most industrialised countries to drain sulphide-containing effluents into sewer pipes or surface waters (Janssen, 1996). When no metals are present, sulphide accumulation can result in a severe inhibition of the purification process and in some cases might even cause total process failure. Many studies have been dedicated to the effect of sulphide toxicity on the biological sulphate reduction efficiency. In gen-

eral, these studies demonstrated that, under mesophilic conditions, both granular and suspended sludge are more tolerant to sulphide inhibition at a pH of around 8, when the sulphide is in the HS⁻ form. At neutral pH values, free H₂S (sulphide in gas form), which is more toxic than HS⁻, accounts for 50% of total dissolved sulphide, whereas at pH 8 it is only around 10% (Lens and Hulshoff Pol, 2000). Speece (1996) listed the sulphide toxicity levels investigated by different researchers, which showed that 100 to 150 mg/l sulphide is toxic for lactate- and glucose-utilising SRB in a continuously stirred tank reactor (CSTR). Moreover, 60 to 75 mg/l sulphide was not tolerated by acetate- and propionate-utilising SRB (in a CSTR), while Parkin et al. (1990) reported that when the sulphide concentration was 60 to 70 mg/l, in an acetate- and propionate-fed chemostat, it resulted in process failure.

The aim of this investigation was to demonstrate that high sulphide concentrations (700 to 1 400 mg/l) in the biological sulphidogenic reactor can be beneficial for biological sulphate removal, operating:

- A completely mixed demonstration reactor
- A tall column reactor
- Four small-scale laboratory test reactors.

Materials and methods

Operating a pilot-scale completely-mixed biological sulphate removal reactor

Feed water

The feed water to the sulphate removing reactor consisted of AMD of which the composition is given in Table 1. It was supplemented with macronutrients (25 mg/l ammonia-N and

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