Influence of the COD to sulphate ratio on the anaerobic organic matter degradation kinetics

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Abstract

The influence of the COD to sulphate ratio on the substrate consumption kinetic parameters was evaluated using a differential reactor filled with polyurethane foam matrices, taken from a horizontal-flow anaerobic immobilised biomass (HAIB) reactor. Experiments were carried out with synthetic substrate containing glucose, ammonium acetate and methanol, besides sodium bicarbonate. Micronutrients were provided by adding salts and trace metals from a stock solution. The influent chemical oxygen demand (COD) was maintained as constant as possible around 2 000 m$g \cdot l^{-1}$ in all the experiments. The reactors were subjected to increasing sulphate concentrations from 100 to 2 800 mg$\cdot l^{-1}$. First-order apparent kinetic parameters (K_1^{app}) decreased from 1.96 x 10^{-4} to 1.55 x 10^{-4} l$\cdot$mg $VSS^{-1} \cdot h^{-1}$ as the COD to sulphate ratio decreased from 22.6 to 0.8. The progressive but moderate inhibition of the organic matter conversion observed indicates that high sulphate concentrations can be accommodated in HAIB reactors even at very low COD to sulphate ratios.

Introduction

The presence of sulphate in wastewaters can sometimes represent a serious problem when the anaerobic treatment process is used. Sulphide generation may cause problems such as odour and corrosion, besides toxicity in an aquatic medium. In addition, the anaerobic treatment of sulphate-rich wastewaters deserves special attention, since several interactions between methane-producing archaea (MPA) and sulfate-reducing bacteria (SRB) take place in the anaerobic reactor. The result of these synthrofic or competitive interactions can compromise the successful application of anaerobic biotechnology.

Sulphate emissions are not a direct threat to the environment, but high sulphate concentrations can cause an imbalance in the natural sulphur cycle. Sulphide production can present serious operational problems in anaerobic reactors used for the treatment of wastewaters containing high sulphate concentrations (Lens et al., 1998).

Hydrogen sulphide (H_2S) in aqueous and gaseous solution causes chemical (corrosion, odour, increase of the effluent COD) and biological (toxicity, inhibition) problems that can affect the wastewater treatment process. These factors have been a barrier to the wider application of anaerobic processes for the treatment of wastewaters containing high sulphate concentrations generated in several types of industries. Therefore, it is necessary to elucidate the factors governing the interactions among the different types of micro-organisms involved in the process, and to develop technologies and strategies to guarantee the successful application of the anaerobic process for the treatment of sulphate-containing wastewaters (Colleran et al., 1995).

The problems of odour and corrosion have been conveniently solved by the collection and treatment of the biogas and the use of materials resistant to corrosion. However, maintaining methanogenic stability is only possible under favourable conditions for process self-control. Among other conditions, an effective management of the factors that interfere in the equilibrium of the microbial community in anaerobic reactors is required. Such factors include pH, temperature, hydraulic retention time (HRT), organic and sulphate loading rates and the relationship between chemical oxygen demand (COD) and sulphate.

The main current problems related to the presence of high sulphate concentrations in the influent of anaerobic reactors are recognised as: competition between sulphate-reducing bacteria (SRB) and methane-producing archaea (MPA) for the same substrates (H_2, acetate); sensitivity of MPA to sulphide, leading to methanogenesis inhibition when the sulphide concentration surpasses certain limits; precipitation of trace metals, causing nutritional deficiencies in the reactor. Competition between MPA and SRB in an anaerobic consortium is based on subtle inter-relationships still not clarified (Speece, 1996).

Verstraete & Vandevivere (1999) and Silva et al. (2002) reported on the use of anaerobic processes for sulphate removal. Such technology has been optimised in order to recover sulphur, thus avoiding its emission as pollutant and recycling it as raw material.

The COD to sulphate ratio is a parameter widely used to control biological sulphate reduction, as well as the methanogenic process leading to organic matter consumption. Wastewaters with a COD/sulphate ratio of 0.67 contain enough sulphate available to completely remove the organic matter via sulphate reduction. This is a theoretical ratio based on stoichiometry and assumes that all the COD is in a form that can be utilised by SRB. However, several factors can influence the microbial competition between MPA and SRB and an oversimplified analysis can lead to contradictory results (Speece, 1996).

The kinetic approach can be useful to elucidate some aspects of sulphate reduction and methanogenesis in anaerobic reactors. Thus, biochemical reaction rates and kinetic parameters can be used to investigate the effect of sulphate in an anaerobic reactor. Evaluation of organic substrate consumption rates in a reactor

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