

Biological sulphate reduction with primary sewage sludge in an upflow anaerobic sludge bed reactor – Part 6: Development of a kinetic model for BSR

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Abstract

A 2-phase (aqueous-gas) kinetic model for biological sulphate reduction (BSR) using primary sewage sludge (PSS) as carbon source is presented. The methanogenic anaerobic digestion (AD) model of Sötemann et al. (2005) is extended by adding the biological, chemical and physical processes associated with BSR, i.e. propionic acid degrading sulphate-reducing bacteria (SRB), acetoclastic SRB and hydrogenotrophic SRB, the aqueous weak acid/base chemistry processes of the sulphate and sulphide systems and an aqueous-gas sulphide exchange process. The model is validated with experimental data from 2 upflow anaerobic sludge bed (UASB) reactors fed various PSS COD/SO₄²⁻ ratios under constant flow and load conditions at 35°C and 20°C. The kinetic model results, including the reactor pH (within 0.1 pH unit) compare well with the experimental results and with those calculated from a steady-state BSR model. The kinetic model confirms that: (1) at ambient temperature (20°C), the hydrolysis rate is significantly reduced compared with that at 35°C, which requires a longer sludge age (larger bed volume) in the UASB reactor; (2) the hydrolysis rate of the PSS biodegradable particulate organics (BPO) is the same under methanogenic and sulphidogenic conditions; (3) the PSS BPO are carbon deficient for BSR in that more electrons are donated than carbon supplied for the required alkalinity increase, with the result that the sulphide system supplies the alkalinity deficit; and (4) due to (3) there is zero CO₂ gas generation and in effect the sulphide system establishes the reactor pH. This observation allows the carbon content of the utilised organics to be determined from the H₂CO₃* alkalinity increase in the reactor, which can be simply measured by titration methods.

Keywords: biological sulphate reduction, primary sewage sludge, upflow anaerobic sludge bed reactor, dynamic model, kinetics, stoichiometry, mixed weak acid/base chemistry