Nitrite effect on the phosphorus uptake activity of phosphate accumulating organisms (PAOs) in pilot-scale SBR and MBR reactors

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Abstract

Batch tests were performed to investigate the nitrite effect on the P-uptake of biomass grown in pilot-scale SBR and MBR systems. The results showed that the nitrite has an inhibitory effect on the aerobic P-uptake of the SBR and the MBR biomasses. The degree of inhibition was observed to be 65% and 37% at 10 mg NO2-N/l for the SBR and the MBR respectively. Both biomasses were found capable of using nitrate as electron acceptor as effectively as nitrate. Moreover, for the SBR biomass the anoxic P-uptake rate using nitrite was found even higher (60%) than the P-uptake rate with nitrate. From a modelling point of view, the current models require appropriate extensions to describe these various effects of nitrite. Hence, an extension of the ASM2d model has been provided. Prevention of nitrite build-up in full-scale EBPRs will eliminate the nitrite inhibition problem. Alternatively, one can adopt a proactive approach in which the aerobic P-uptake phase is replaced with an anoxic P-uptake phase using only nitrite as electron acceptor. Such an approach offers considerable cost savings and enhanced nitrogen and phosphorus removal. This, however, requires further research for experimental validation and testing.

Keywords: ASM2d, MBR, modelling, nitrogen and phosphorus removal, nitrite inhibition, polyphosphate accumulating organisms, phosphate uptake, SBR

Introduction

Microbiological investigation of the nitrite effect with a variety of physiological types of bacteria (from aerobes to facultative anaerobes) has shown that nitrite interferes with energy generation (e.g. by inhibiting oxygen uptake, oxidative phosphorylation or proton-dependent active transport of substrate) and growth mechanisms (Yarbrough et al., 1980; Rake and Eagon, 1980). In the field of activated sludge, the inhibitory effect of nitrite (its effect is mainly pH dependent and better represented as a function of the nitrous acid concentration, HNO2) on the nitrifying biomass activities have also been long recognised and documented (Anthonisen et al., 1976; Van Hulle et al. (2007); Vadivelu et al., 2006). Moreover, nitrite has also been experimentally observed to inhibit the activity of ordinary aerobic heterotrophic organisms (Musvoto et al., 1999). Nitrite was also hypothesised to cause proliferation of filamentous bulking in activated sludge systems due to its interference with the aerobic respiratory mechanism (Casey et al., 1999).

Several studies with phosphorus accumulating organisms (PAOs) have also confirmed that elevated concentrations of nitrite negatively affect phosphorus uptake activities of PAOs under both aerobic and anoxic conditions (Meinhold et al., 1999; Saito et al., 2004). Note that denitrifying PAOs were also shown to be able to utilise nitrite as an electron acceptor without any adverse effect of course within a certain concentration range.

That said, however, these studies have reported different types of effect (e.g. inhibitory vs. toxic effect) and different threshold values of inhibition by nitrite. For example, Meinhold et al. (1999) found that a nitrite level of 6 to 8 mg NO2-N/l completely halted the anoxic P-uptake and severely inhibited aerobic P-uptake for sludge taken from a pilot BIODENIPHO® plant. Saito et al. (2004) reported that 2 mg NO2-N/l already inhibited the aerobic P-uptake severely while more than 6 mg NO2-N/l completely stopped it. Moreover, they also found that nitrite at 12 mg NO2-N/l level reduced the anoxic P-uptake rate down to 65%. On the other hand, Ahn et al. (2001) and Hu et al. (2003) could not find any severe effect on the anoxic P-uptake rate at elevated nitrite concentrations, even up to 40 and 35mg NO2-N/l respectively. The varying degree of adaptation of biomass to nitrite has been offered as explanation for these wide-ranging threshold values of nitrite inhibition. Saito et al. (2004), however, argued that chemical precipitation may occur if pH is not controlled during batch tests, which may corroborate some of the reported results.

Since the underlying biochemical mechanism of the nitrite effect is still far from being clear, in this study, we investigated and evaluated the effect of nitrite on aerobic and anoxic phosphate uptake by PAOs enriched in nutrient removing pilot-scale...