The effect of substrate composition on the nutrient removal potential of sequencing batch reactors

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Abstract

Experimental results suggest that sequencing batch reactors (SBR) are not efficient for enhanced biological phosphorus removal from domestic sewage with low/medium organic carbon content when denitrification preferentially competes for available carbon. Total COD is not a meaningful parameter to reflect available substrate for N and P removal; COD fractionation and identification of the readily biodegradable COD fraction are required for an accurate assessment of system performance. The degree of soluble COD removal in the non-aerated phase is observed to be much higher than what may be calculated from stoichiometric relationships for N removal and P release, indicating the existence of competing mechanisms such as organic carbon storage by non-polyP bacteria under anaerobic conditions.

Introduction

It is well-known that enhanced biological phosphorus removal (EBPR) requires an anaerobic/aerobic sequence. In the anaerobic stage, phosphorus release is associated with storage of organic substrate within biomass. During the aerobic stage, excess phosphorus uptake takes place at the expense of stored organics which also serve as carbon source for the growth of micro-organisms which have the ability to accumulate polyphosphates (polyP bacteria).

The nature of the organic substrate available plays a key role for effective phosphorus removal which selectively requires the existence of short-chain fatty acids. It is now commonly agreed that the major function of the anaerobic stage is to generate the necessary fermented substrate which can be utilised by polyP bacteria. In all the kinetic models so far proposed, acetate is referred to as the sole external substrate which is taken up and stored as polyß hydroxybutyrate (PHB) during anaerobic conditions. The question of how a reducing power is created for PHB synthesis constitutes the main distinction between various biochemical models (Comeau et al., 1986; Wentzel et al., 1986; Mino et al., 1987). It has been shown that other short-chain fatty acids may also be used to a limited extent for the same purpose and in such cases, other polyhydroxyalkanoates are synthesised besides PHB (Satoh et al., 1992).

Currently, the sequencing batch reactor (SBR) technology is a well promoted and tested alternative with distinct advantages over the conventional activated sludge process. Basically, the SBR is a very simple system involving a single tank (Orhon and Artan, 1994). As it is temporally controlled, as contrasted to spatially controlled conventional continuous-flow processes, it offers a major advantage for the observation and the interpretation of different phenomena associated with the anaerobic/aerobic sequence of the EBPR process.

The magnitude of the available organic substrate and its readily biodegradable fraction is likely to have a decisive impact on the extent of EBPR from domestic sewage and such an impact can best be visualised within an SBR. EBPR may also be severely affected by simultaneous nitrogen removal which is often desired in systems treating domestic sewage. The presence of nitrate at the beginning of the anaerobic phase is detrimental to EBPR, since oxidised nitrogen will preferentially consume organic substrate for denitrification and this will create an anoxic phase before true anaerobic conditions can be sustained. In this case, the amount and the nature of substrate will have to be sufficient both for denitrification and PHB storage for EBPR.

The main objective of this experimental study was to investigate the effect of different substrate conditions and simultaneous nitrogen removal on the EBPR efficiency of an SBR system treating domestic sewage with a fluctuating organic content.

Materials and methods

The experimental work was carried out in a timer-controlled, laboratory-scale sequencing batch reactor with a total volume adjustable up to 8.8 ℓ. The reactor was equipped with both mechanical mixing and diffused aeration devices to create a sequence of anaerobic/anoxic and aerobic conditions. Wastewater feeding during the fill period was secured by an adjustable-flow Watson-Marlow type peristaltic pump and three different exit ports, each controlled by a solenoid valve, which provided discharge of the treated effluent.

The laboratory SBR unit was operated for around 200 d in four different consecutive runs. The operation was adjusted to four cycles a day (cycle time, t_c = 6 h) with the exception of run III where the cycle time was extended to 8 h (three cycles a day). Each cycle involved the regular consecutive sequence of anoxic/anaerobic fill and mixing phase, the aerated reaction phase and the settle/idle phase where the treated effluent was discharged. The operation conditions and the characteristics of the laboratory SBR unit are outlined in Table 1. The sludge age was controlled and the mixed liquor volatile suspended solids (MLVSS) concentration was kept constant for each individual run, by wasting the required amount of activated sludge, once a day, at the end of the aerobic period of the same cycle.

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