Model evaluation and optimisation of nutrient removal potential for sequencing batch reactors

N Artan[1]*, P Wilderer[2], D Orhon[1], R Tasli[1] and E Morgenroth[3]

[1]Environmental Engineering Department, Istanbul Technical University, I.T.U. Insaat Fakültesi, 80626 Maslak, Istanbul, Turkey

[2] Institute of Water Quality Control and Waste Management, Technical University of Munich, D-85748 Munich, Germany

[3] Department of Civil and Eniron. Engineering, University of Illinois at Urbana-Champaign, 3219 Newmark Civil Engineering Lab., 205 North Mathews Avenue, MC-250, Urbana, IL, 61801, USA

Abstract

Performance of sequencing batch reactors for simultaneous nitrogen and phosphorus removal is evaluated by means of model simulation, using the activated sludge model, ASM2d, involving anoxic phosphorus uptake, recently proposed by the IAWQ Task group. The evaluation includes all major process configurations with different aerobic, anoxic, anaerobic sequences, and fill conditions. Basic relationships between modelling and design based on overall process stoichiometry are established for the interpretation of nutrient profiles associated with different operation modes. A similar approach is also used for the assessment of the effect of major operating parameters on system performance.

Introduction

The SBR technology, despite its simplicity as a batch reactor, offers a great flexibility of operation where the sequence of successive phases can be adjusted to sustain any desired combination of growth conditions for different biochemical processes (Irvine et al., 1997; Ketchum, 1997; Morgenroth and Wilderer, 1998). This feature is particularly significant for simultaneous nitrogen and phosphorus removal, now a prerequisite for most wastewaters. The process is an attractive research tool as the batch operation is most suitable for the observation and interpretation of transient responses of any selected process component. It is also used in practice at an increasing pace, as an effective biological treatment technology for a large spectrum of various wastes, ranging from simple domestic sewage to different industrial effluents (Goronszy, 1995; Artan et al., 1996; Wilderer et al., 2001).

Biological nutrient removal involves an intricate array of biochemical processes to be sustained in an appropriate sequence of aerobic, anoxic and anaerobic conditions. The number of processes and components together with the complexity of SBR hydraulics makes it impossible to come up with an accurate prediction of effluent quality, without the use of appropriate modelling. Simulation programs based on models reflecting microbial behaviour with reasonable accuracy are now regarded as valuable tools to systematically assess various design and operating strategies, thus allowing for system optimisation. In the last years, a number of modelling approaches has been proposed for this purpose. For example the IWA (formerly IAWQ) Task Group has developed the Activated Sludge Model No.2 (ASM2) incorporating EBPR (Henze et al., 1995). These models, while providing an acceptably reliable description for nitrogen transformations, generally lacked sufficient credibility for the fate of phosphorus, mainly because they did not incorporate sufficient experimental support, and also, the behaviour of phosphate accumulating organisms (PAOs) did not always appear quite predictable (Sorm et al., 1996; Kuba et al., 1997; Ekama and Wentzel, 1999). In the light of recent research (Mino et al., 1995; Artan et al., 1998; Barker and Dold, 1997), ASM2 was modified as ASM2d to include denitrification by PAOs with reduced anoxic P uptake (Henze et al., 1999).

Model simulation of SBR performance provides information for a selected set of different operating conditions. Interpretation of the simulation results for process design is only meaningful when support is provided in terms of relevant process stoichiometry and mass balance relationships for related model components. The basic stoichiometry of nitrogen oxidation and removal is well understood; it was recently translated into a rational design procedure for SBR systems (Artan et al., 2001). A similar approach is yet to be developed for excess biological phosphorus removal (EBPR), due to the complexity of processes and the excessive number of process components involved. Therefore, evaluation of the fate of nitrogen and phosphorus forms competing for the same organic carbon source in the anoxic/anaerobic phases, within the simultaneous N/P removal systems, still requires model simulation.

The objective of this study was to evaluate the performance of SBRs for simultaneous nitrogen and phosphorus removal by means of model simulation, using the activated sludge model, ASM2d. The evaluation included all major process configurations with different aerobic, anoxic, anaerobic sequences, and fill conditions. Basic relationships between modelling and design based on overall process stoichiometry were established for the interpretation of nutrient profiles associated with different operation modes. A similar approach was used for the assessment of the effect of major operating parameters on system performance. The impact of anoxic P uptake on process performance was also reviewed by comparing ASM2d with ASM2.

Conceptual approach for model simulation

Reactor kinetics

Mechanistic understanding of the SBR process is best secured by identifying significant operational parameters and by interpreting

* To whom all correspondence should be addressed.
☎ 90 212 285 65 47; fax 90 212 285 37 93; e-mail: nartan@srv.ins.itu.edu.tr
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