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Optimal strategies of fill and aeration in a sequencing batch reactor for biological nitrogen and carbon removal

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Abstract−A modified version of the IAWQ activated sludge model No. 1 (ASM 1) is adopted for the simulation of a sequencing batch reactor (SBR) to optimize the removal of nitrogen (T-N) and organic matters (COD) from wastewater. Since the removal of nitrogen requires both aerobic nitrification and anaerobic denitrification, we seek to find the optimal strategies of substrate fill and aeration. Substrate filling strategy critically influences the removal efficiency of T-N and COD; one fast discrete fill in the beginning of a cycle leads to the best result, while a slow continuous fill results in poor nitrification. In addition, the total aeration time is more important for the removal efficiency than the aeration frequency. A short aeration is beneficial for T-N removal, while a long aeration is beneficial for COD removal as expected. As a result, there is an optimal condition of aeration for the simultaneous removal of T-N and COD.

Key words: Wastewater Treatment, Nitrogen Removal, Sequential Batch Reactor, Optimization Strategy

INTRODUCTION

The sequencing batch reactor (SBR) is a fill-and-draw activated sludge system for wastewater treatment. The SBR system usually consists of more than two reactors that are operated in a sequential mode in order to treat wastewater continuously. A reactor is filled with wastewater during a discrete period and then operated like a batch reactor. After treatment, aeration and mixing are discontinued to settle down activated sludge, and the clear supernatant is drawn or decanted from the reactor. A cycle for a typical SBR consists of the following five distinct phases: fill, react, settle, draw (or decant), and idle. During the reaction phase, the reactor can be operated in aerobic, anoxic, and anaerobic conditions to achieve a certain goal of removing organic matter, nitrogen, and phosphorus [1]. The SBR system has the same unit processes as the conventional activated sludge (CAS) system that has been the most applied method for wastewater treatment.

The major difference of two systems is that the SBR performs equalization, biological treatment, and secondary clarification in a single tank using a timed control sequence, while the CAS system accomplishes those unit processes in separate tanks. The SBR system has many advantages over the CAS system, such as operating flexibility, easy adaptation to nutrient removal, better resistance to sludge bulking, nearly ideal quiescent solid-liquid separation, ability to meet effluent limitations (organic and nutrients), and potential savings of capital cost and space by eliminating separate clarifier and equalizer. However, the SBR requires a higher level of maintenance due to timing units and controls [2,3].

Biological nitrogen removal has been adopted as the most economical method of controlling nitrogen in wastewater effluents. Nitrification is governed by autotrophs which aerobically oxidize ammonium nitrogen to nitrite mainly by *Nitrosomonas* sp., and subsequently nitrite is further oxidized to nitrate mainly by *Nitrobacter* sp. [4]. Nitrate formation is usually considered as the rate-limiting step in whole nitrification [5]. Nitrate is converted to molecular nitrogen by heterotrophic bacteria under an anoxic condition during denitrification step. Therefore, the removal of nitrogen requires both aerobic nitrification and anoxic denitrification sequentially or simultaneously.

$$NH_4^+ \rightarrow NO_2^- \rightarrow NO_3^- \rightarrow N_2(\text{gas})$$

Mathematical models provide meaningful insights for the design and prediction of complex biological processes. A general activated sludge model 1 (ASM1) was initially developed for wastewater treatment systems [6] and has been widely used. Oles and Wilderer modified the ASM1 to simulate the performance of nitrogen removal in an SBR system and suggested the most optimal strategy to be the triple repeated symmetric pulses of anoxic fill and anoxic/oxic react phases [7]. Coelho et al. also applied the ASM1 for an SBR system to find the optimal batch scheduling and filling strategy for biological nitrogen removal, and found that a discrete fill strategy of wastewater and oxygen was much efficient than other fill types [3]. However, there is no investigation for individual effects of fill and aeration on the removal efficiencies of total nitrogen (T-N) and organic matter (COD).

The purpose of this work was to optimize the performance of an SBR system for the simultaneous removal of T-N and COD by investigating the separate effects of substrate fill type and aeration type on the removal efficiencies of T-N and COD with the aid of computer simulation based on a modified ASM1.

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