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Simultaneous carbon and nutrient removal in an airlift loop reactor under a limited filamentous bulking state

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HIGHLIGHTS

- A stable limited filamentous bulking (LFB) state was achieved.
- The LFB promote a well-balanced aerobic and anoxic/anaerobic state.
- The LFB enhanced COD and nutrient removal in the airlift loop reactor (ALR).
- The LFB reduced the ALR height-to-diameter ratios and aeration energy consumption.
- Removal efficiencies of COD, NH_4^+—N, TN and TP were 91%, 92%, 86% and 94%.

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ABSTRACT

Airlift loop reactors (ALRs) are important bioreactors for wastewater treatment. However, few studies have investigated the application of an ALR for simultaneous carbon and nutrient removal, especially for activated sludge systems. This study evaluated the performance of integrated nitrogen, phosphorus and COD removal in an ALR with a low height-to-diameter ratio in a limited filamentous bulking (LFB) state (SVI of 180–220 mL/g). The average removal efficiencies for COD, NH_4^+—N, TN and TP were 91%, 92%, 86% and 94%, respectively. Additional research showed that only under the LFB state, the appropriate distribution of dissolved oxygen inside the ALR was established to promote a well-balanced aerobic and anoxic/anaerobic state. In addition, the macro-gradient of the substrate concentration at the inlet and the heavier bio-P sludge density compensated for the proliferation of filaments. Hence, the stable LFB state was achieved by balancing the floc-forming bacteria and the filamentous bacteria in the ALR.

1. Introduction

The excessive discharge of nitrogen (N) and phosphorus (P) nutrients to rivers and lakes can result in eutrophication. Therefore, the effluent requirements for decreasing N and P discharges are becoming more stringent. In conventional biological nutrient removal (BNR) systems, the removal of N is accomplished by aerobic nitrification followed by anoxic denitrification. In contrast, the removal of P is achieved through enhanced biological phosphorus removal (EBPR), which uses polyphosphate-accumulating organisms (PAOs) to generate alternating anaerobic–aerobic conditions. For the simultaneous removal of N and P, the operating conditions (i.e., anaerobic, anoxic and aerobic) have been achieved by varying space (the A^2O process) or time (the SBR process). However, these processes are problematic because the A^2O process requires a large amount of space and the SBR process is operationally complex.

In recent years, substantial attention has been given to integrated bioreactors. These bioreactors are cost-effective, efficient and small footprint. Thus, the airlift loop reactor (ALR) (a type of integrated bioreactor), which combines anaerobic, anoxic and aerobic conditions in a single reactor, is a valuable alternative for the simultaneous removal of N and P. Previously, ALRs have been used to treat wastewater containing nitrogen (Fujiwara et al., 1998; Guo et al., 2005; Hano et al., 1992; Jin et al., 2008; Meng et al., 2004; Walters et al., 2009), nitrite (Dhamole et al., 2009), nutrients (Bando et al., 1999), chemical fertilizer plant waste (Wen et al., 2005), and landfill leachates (Yang and Zhou, 2008).

To achieve the appropriate anoxic/anaerobic and aerobic zone volume ratios in the ALR (which is important for nutrient removal), a biological membrane system is commonly used. In a biological membrane system, the bacteria responsible for nitrogen and phosphorus removal can be immobilized on fixed materials (Guo et al.,

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