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Optimization of selective sludge discharge mode for enhancing the stability of aerobic granular sludge process

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HIGHLIGHTS

- The selective sludge discharge mode is studied in an aerobic granular sludge reactor.
- Long SRT of granular sludge is the main reason for deterioration of reactor performance.
- The stability of granular reactor can be strengthened by selective discharge of aging granular sludge.

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ABSTRACT

The selective sludge discharge mode was studied in the aerobic granular sludge reactor for improving the long-term stability of aerobic granular sludge process. Results showed that the nitrogen removal performance was obviously improved with the preliminary granulation of the bioreactor at sludge settling time of 1 min after 15 days. After the formation of fine granular sludge, 5–10% volume of the total granular sludge was discharged for the sludge retention time (SRT) controlling, and the removal efficiencies of NH_4^+–N and TN reached 95.9 ± 2.0% and 75.3 ± 3.0% at the SRT_{Total} of 5.3 ± 0.4 days, $SRT_{Granules}$ of 9.9 ± 0.9 days and SRT_{Flocs} of 2.7 ± 0.5 days, respectively. The granular rate and average granular diameter of the bioreactor were stabilized at 80 ± 5.0% and 2.3 ± 0.3 mm, respectively. The results demonstrated that a long SRT of granular sludge leads easily into the deterioration of aerobic granule, and an appropriate selective sludge discharge mode favors the stability of aerobic granular sludge process via the discharge of proportional aging granular sludge and retention of enough new-born flocs.

1. Introduction

Aerobic granular sludge is a kind of compact microbial self-immobilized aggregates. Compared to conventional sludge flocs, aerobic granular sludge has a compact physical structure which favors the excellent sludge settlement and high biomass retainment to simplify the separation of mixed liquor and reduce space demand [1–5]. In recent years, extensive attention has been paid to the aerobic sludge granulation technology in the fields of granular structural quantification, model simulation, functional microorganism analysis and EPS function [4,6–8]. Sludge granulation is a complex physicochemical and biological process. Studies have shown that the formation and stability of granular sludge are closely related to the bioreactor's operating parameters, such as substrate type, loading rate, hydraulic shear stress and sludge settling time [6,9–12]. However, the instability issue of aerobic granule is still existed during long-term operation [9].

It is generally believed that fast settling sludge with compact structure could be enriched by controlling a short settling time, thus, the relative slow settling biomass is discharged selectively in the effluent [13–15]. The selection pressure was firstly put forward to prevent uncontrolled outgrowth of biomass using batch feeding in the bioreactor, and then the functional microbial population with a low growth rate enriches and granular sludge forms [4]. At the same time, conditions like hydraulic shear stress and organic loading rate are also identified as important selection pressures for the formation of aerobic granular sludge. However, researchers have neglected that actually segregation of sludge with different size may offer different biological niches for different microorganisms [15]. The importance of sludge retention time (SRT) controlling via excess biomass discharge in bioreactors has been experimentally discussed [16]. Sheng et al. [15] used a fixed daily sludge discharge ratio of around 10% of slow-settling sludge in granular sludge reactor, and found that this selective sludge discharge facilitated the growth and accumulation of denser sludge in

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