Journal of Biotechnology 285 (2018) 1–5

Contents lists available at ScienceDirect

Journal of Biotechnology

journal homepage: www.elsevier.com/locate/jbiotec

Short communication

Effects of return sludge alkaline treatment on sludge reduction in laboratory-scale anaerobic–anoxic–oxic process

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ARTICLE INFO

Keywords:
Alkaline treatment
Anaerobic–anoxic–oxic process
Return sludge
Sludge reduction
Sludge volume index

ABSTRACT

Three alkaline treatments (pH 10, 11, and 12 for 1 h) were used to treat return sludge alone to reduce sludge production in laboratory-scale anaerobic–anoxic–oxic processes. After 99 days of operation, alkaline treatments at pH 10 and 11 led to accumulative excess sludge production and sludge yield reduction of 18.8%–31.7% and 14.7%–27.8%, respectively. However, alkaline treatment at pH 12 led to system breakdown because of sludge bulking. The alkaline treatment at pH 10 did not affect the chemical oxygen demand and NH_4^+-N removals of the system and sludge volume index (SVI) of aerobic activated sludge. However, alkaline treatments at pH 11 and 12 obviously deteriorated the wastewater treatment efficiencies and sludge SVI. Although the three treatments increased the effluent pH by 0.08 to 0.38, the effluent pH of three systems were all lower than 9.00. The treatments at pH 10 and 11 increased the specific oxygen uptake rate of activated sludge, whereas the treatment at pH 12 decreased this rate.

1. Introduction

Excess sludge is an unpleasant byproduct of wastewater treatment because of its large volume, offensive odor and high pollutants content. Untreated excess sludge may significantly affect the environment (Li et al., 2015; Guo et al., 2013; Semblante et al., 2016). The widespread application of sewage and wastewater treatment processes to satisfy increasing stringent legislation concerning aqueous discharges into surface waters resulted in increased excess sludge production. For instance, the amount of dewatered sludge in China was more than 3.0×10^7 tons (with 80% water content) (Zhang et al., 2016). Accounting for approximately 50%–60% of the total operational cost of wastewater treatment plants (WWTPs) (Guo et al., 2013), the treatment and disposal of excess sludge is one of the serious problems in WWTPs. Meanwhile, the substantial production of excess sludge has exacerbated the problems of sludge treatment and disposal (Guo et al., 2013; Niu et al., 2016). The prohibitions of conventional sludge disposal methods, like land filling and dumping at sea, have been proposed by economic, environmental, and legal regulations (Yang et al., 2011). Therefore, sludge production should be reduced in the wastewater treatment process, and such reduction is regarded as an ideal way to solve the sludge-associated problems rather than post-treatment of the produced sludge (Wei et al., 2003; Uan et al., 2013).

Currently, the methods for sludge reduction are based on four mechanisms, lysis–cryptic growth, uncoupling metabolism, maintenance metabolism, and predation on bacteria (Wei et al., 2003; Guo et al., 2013). In the method based on lysis–cryptic growth, the sludge grows on the lysates that dissolved on their own. When sludge microbial cells lysis or disintegrate, the microbial cellular matters are released into the liquid, and these organic autochthonous substrates are reused by the sludge microorganisms for metabolism (Uan et al., 2013). Because it is convenient, highly efficient, and easy to operate (Foladori et al., 2010; Guo et al., 2013; Romero et al., 2013), the method based on the lysis–cryptic growth has attracted the interest of many researchers. The sludge disintegration technologies, such as ozonation, ultrasound, and thermal-alkaline treatment, have been developed and are now widely applied to reduce sludge production in wastewater treatment processes (Foladori et al., 2010; Guo et al., 2013; Romero et al. 2013). Alkaline treatment, a simple disintegration technology, has been traditionally applied, alone or combined with other treatments, to solubilize or hydrolyze sludge and enhance anaerobic sludge digestion (Li et al., 2016a; Neumann et al., 2016; Shao et al., 2012). Given its simplicity, low cost, and high cell solubilization, alkaline treatment can be also applied to lysis–cryptic growth-based sludge reduction. To date, alkaline treatment had been combined with other treatments, such as thermal treatment, ozone treatment, and ultrasonic treatment, to reduce sludge production (Banu et al., 2011; Ma et al., 2012; Kumar et al., 2015). However, few studies exist on the use of alkaline treatment alone

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https://doi.org/10.1016/j.jbiotec.2018.08.018
Received 24 April 2018; Received in revised form 24 August 2018; Accepted 27 August 2018

Table 1
Characteristics of influent of wastewater.

Parameter	Range	Mean
COD(mg/L)	78–536	421
pH	6.9–7.9	7.7
SS(mg/L)	36–353	156
NH_4^+-N(mg/L)	34.7–59.5	40.1
TN(mg/L)	37.6–79.6	59.3
TP(mg/L)	4.9–12.1	8.1

in the sludge reduction based on lysis–cryptic growth.

Additionally, the anaerobic–anoxic–oxic (A2O) process, which is used to remove COD, nitrogen, and phosphorus in wastewater, is a more widely used treatment in WWTPs (Grady et al., 2011; Li et al., 2016b). For instance, 31% of WWTPs in China use the A2O process (Zhang et al., 2016). Hence, sludge reduction in the A2O process should be studied. Thus, the object of this study is to investigate the effects of alkaline treatment on sludge reduction in the A2O process.

2. Materials and methods

2.1. Wastewater

The wastewater used in the test was obtained from a residential area in Beijing, China. The characteristics of the wastewater are summarized in Table 1.

2.2. A2O systems and their operations

Four identical laboratory-scale A2O systems, which were same as those used in previous study (Li et al., 2016b), were used in the test. The flow diagram of the experimental systems is shown in Fig. 1. The volumes for each part of the A2O systems were set as follows: anaerobic tanks, 4 L; anoxic tanks, 4 L; oxic tanks, 16 L; and settlement tanks, 4 L. The hydraulic retention time (HRT) and dissolved oxygen (DO) of the former three tanks for the four systems were 2 h and < 0.1 mg/L (anaerobic tanks), 2 h and 0.2–0.5 mg/L (anoxic tanks), and 8 h and 1.5–3.0 mg/L (oxic tanks), in accordance with Chinese standards. The internal recycling ratio (mixing liquor recycling) for the four systems was 100%.

A pump (P1), which was used to pump the settled sludge from the settlement tanks to the concentrated tank, was operated for 10 h and then paused for 2 h. The sludge in the concentrated tank (2 L) was further concentrated (once per 10 h). The supernatant of the concentrated tank was regularly discharged with the effluent. Another pump (P2), which was used to pump the concentrated sludge into alkaline treatment tank, was operated for 0.5 h and then paused for 11.5 h. In three systems, the concentrated sludge was alkaline treated for 1 h to attain pH values of 10.0, 11.0, and 12.0 by adding 6 M NaOH, and these systems were termed as pH 10, pH 11, and pH 12 systems. The concentrated sludge was not alkaline treated in the last system, which was used as control (control system). Pump 3 (P3) and Pump 4 (P4) were used to pump the sludge in alkaline treatment tank to the anaerobic tank of the systems and pump the activated sludge from oxic tank to anoxic tank, respectively. To maintain similar sludge concentrations (2–4 g/L) in the oxic tanks of the four systems, the aerobic activated sludge in oxic tanks was regularly discharged as waste-activated sludge. The sludge retention time (SRT) of the four systems was approximately 8–15 days. The test was conducted at room temperature (20–28 °C).

2.3. Analysis and calculation

The influent, effluent, and mixed sludge in oxic tanks (namely aerobic activated sludge) were regularly sampled in the test and the sample volume was 200 ml. The water quality parameters, including chemical oxygen demand (COD), NH_4^+-N, total nitrogen (TN), total phosphorous (TP), pH, and suspended solids (SS), of the influent and effluent were analyzed. The mixed sludge characteristics, including sludge concentration (SS and volatile suspended solids, VSS), sludge volume index (SVI), and specific oxygen uptake rate (SOUR), were analyzed. COD was determined by a COD meter (DR2800, HACH, USA). pH was measured by a pH meter (PB-10, Sartorius, Germany), and DO was measured by an online DO meter (3310, WTW, Germany). Oxygen uptake rate (OUR) was determined using the slope of the linear portion of the DO versus time curve. The specific oxygen uptake rate (SOUR) was calculated by dividing the OUR by the VSS concentration (APHA, 1998). Other parameters (COD, NH_4^+-N, TN, TP, SS, VSS and SVI) were analyzed by standard methods (APHA, 1998). All reported data are the means of three replicate experiments or measurements.

The accumulative sludge production, sludge yield were calculated according to previous study (Guo et al., 2014). The reductions of sludge production and sludge yield were calculated according to Eq. (1).

$$Reduction\ (\%) = \frac{S_{Con} - S_A}{S_{Con}} \times 100\% \qquad (1)$$

Where, S_{Con} is sludge production or sludge yield of control system; S_A is sludge production or sludge yield of alkaline treatment system.

The removals of each water quality parameters were defined as Eq. (2).

$$Removal\ (\%) = \frac{C_{inf.} - C_{eff.}}{C_{inf.}} \times 100 \qquad (2)$$

where, $C_{inf.}$ is the concentration of COD, NH_4^+-N, TN or TP in the influent; $C_{eff.}$ is their concentration in the effluent.

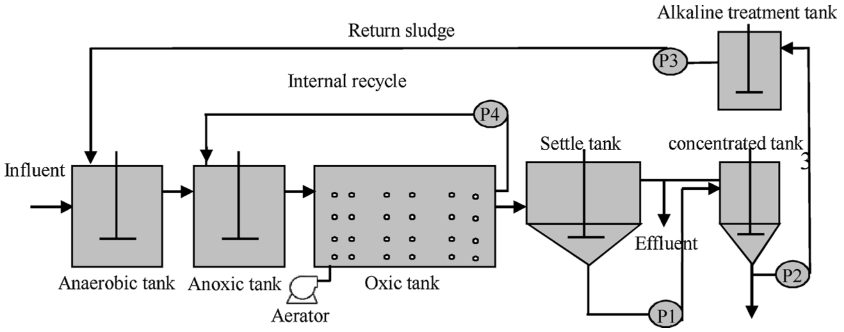

Fig. 1. Flow diagram of the experimental systems.
P1: Pump1; P2: Pump 2; P3: Pump 3; P4: Pump 4.