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Research article

Effect of air flow rate on development of aerobic granules, biomass activity and nitrification efficiency for treating phenol, thiocyanate and ammonium

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ABSTRACT

The impact of air flow rate on aerobic granulation was evaluated for treating toxic multiple pollutants; phenol (400 mg L^{-1}), thiocyanate (100 mg L^{-1}) and ammonia nitrogen (100 mg L^{-1}) by using three lab scale sequencing batch reactors (SBRs) (R1, R2 and R3). Larger granules (2938.67 ± 64.91 μm) with higher biomass concentration (volatile solids of 4.17 ± 0.09 g L^{-1}), higher granule settling velocity (55.56 ± 1.36 m h^{-1}) and lower sludge volume index (35.25 ± 1.71 mL $gTSS^{-1}$) were observed at optimal air flow rate of 2.5 L min^{-1} (R2). Confocal laser scanning microscopic images illustrated the extended fluorescence for extracellular polymeric substances in R2. In R2, partial nitrification was achieved. Phenol was completely removed in all the reactors while partial removal of SCN^- and no nitrification were observed with a decrease (1.5 L min^{-1}) and an increase (3.5 L min^{-1}) in air flow rates (R1 and R3, respectively). This study provides an experimental contribution to examine the effect of optimal combination of aeration and toxic multiple pollutants, governing characteristics and nitrification efficiency of granules along with SBR performance in an economic way in terms of optimal air supply.

1. Introduction

Aerobic granulation has been emerged as a novel technology for treating wastewaters using sequencing batch reactors (SBRs). Aerobic granules grow without any support and have a regular, denser, stronger microbial structure, good settling behavior and ability to tolerate toxic and high organic loading (Marques et al., 2013). Many factors such as substrate loading, substrate type and operational parameters like cycle time, settling time, feeding strategy, upflow liquid velocity and aeration intensity, affect aerobic granulation (Lee et al., 2010; Tomar and Chakraborty, 2018).

In a column type biological reactors, hydraulic turbulence and hydraulic shear force mainly resulted from aeration, are one of the important parameters responsible for granulation and are determined in terms of superficial upflow air velocity (Chen et al., 2008). It enhances the contact possibilities among the flocs by particle-particle collision and maintains the stability and structural integrity of the granules (Liu and Tay, 2002). High air flow rate provides high shear force that trigger the secretion of bacterial extracellular polymeric substances (EPS), which enhances the microbial aggregation by promoting the stability and communication of cells (Kong et al., 2015). Higher hydraulic shear force contributes to smoothness of granule by eroding the granule surface and suppress the filamentous growth by providing adequate oxygen (Show et al., 2012).

Most of the previous literature works illustrating the effect of air flow rate on aerobic granular sludge (AGS) were mainly carried out with simple carbon sources such as acetate, propionate and glucose (Chen et al., 2008; Gao et al., 2011; Tay et al., 2001a; Zhang et al., 2015) and few with toxic carbon sources like phenol (Adav et al., 2007). Phenol is found with the other toxic compounds like ammonia-nitrogen (NH_4^+-N) and thiocyanate (SCN^-) in the wastewaters generated from liquefaction and gasification of coal etc. (Vázquez et al., 2006). The conversion of ammonium to nitrate (nitrification) is generally an obstacle for nitrogen removing biological reactors because of sensitivity of nitrifiers to various factors such as inhibition due to aromatic compounds (Ramos et al., 2016).

When ammonia is found with phenol and thiocyanate, the latter compounds inhibit nitrifiers, therefore is essential to be removed prior to nitrification (Kim et al., 2008). Nitrification is carried out by autotrophic microorganisms which require more amount of

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aeration, therefore dissolved oxygen for nitrification. Thus enhancing the operational cost of the treatment plant by more power consumption required for more aeration.

The present research work provides a better experimental explanation for the formation of aerobic granules with the combination of optimal aeration and toxic multiple pollutants like phenol, thiocyanate and ammonia nitrogen, governing characteristics and nitrification efficiency of granules along with SBR performance in an economic way in terms of optimal air supply.

2. Materials and methods

2.1. Reactor and experimental set-up

Three similar acrylic SBRs of 212 cm working height and inner diameter of 6 cm, with 6 L working volume were used in the present study. The schematic diagram of reactor is given in Fig. 1. Aeration was provided as fine air bubbles through an oil free air compressor by the air stones kept at the reactor bottom with the 1.5, 2.5 and 3.5 L min^{-1} air flow rates resulting into a hydraulic shear force, in terms of superficial upflow air velocities of 0.88, 1.48 and 2.07 cm s^{-1}, respectively in R1, R2 and R3. The dissolved oxygen (DO) concentration in the mixed liquor of R1 was 3.0–3.5 mg L^{-1}, while in R2 and R3, it was above 5.0 mg L^{-1}. The superficial upflow air velocity was calculated by using equation (1). The reactors were maintained at room temperature (25–30 °C).

$$\text{Superficial upflow air velocity}\left(cm\ s^{-1}\right) = \frac{\text{air flow rate}\left(L\ min^{-1}\right)}{\text{Cross sectional area of reactor}\ \left(m^2\right)} \quad (1)$$

The solid retention time (SRT) was determined by using equation (2) (Liu and Tay, 2007).

$$SRT = \frac{X_{VSS}V}{X_eV_e/t_c} \quad (2)$$

[X_{VSS}: VSS in the reactor (g L^{-1}); V: reactor working volume (L); X_e: effluent VSS (g L^{-1}); V_e: effluent withdrawal volume (L) and t_c: cycle time of the reactor (day)].

2.2. Seed sludge characteristics and composition of synthetic wastewater

The seed sludge was collected from the wastewater treatment plant of Indian Oil Corporation Limited (IOCL), Noonmati, Guwahati, Assam. The total and volatile suspended solids (TSS and VSS) in the seed sludge were 0.26 ± 0.05 and 0.19 ± 0.03 g L^{-1}, respectively. The seed sludge had a particle size of 49.41 µm. The SVI_{30} value of seed sludge was 208.60 mL $gTSS^{-1}$. 3 L sludge was used as

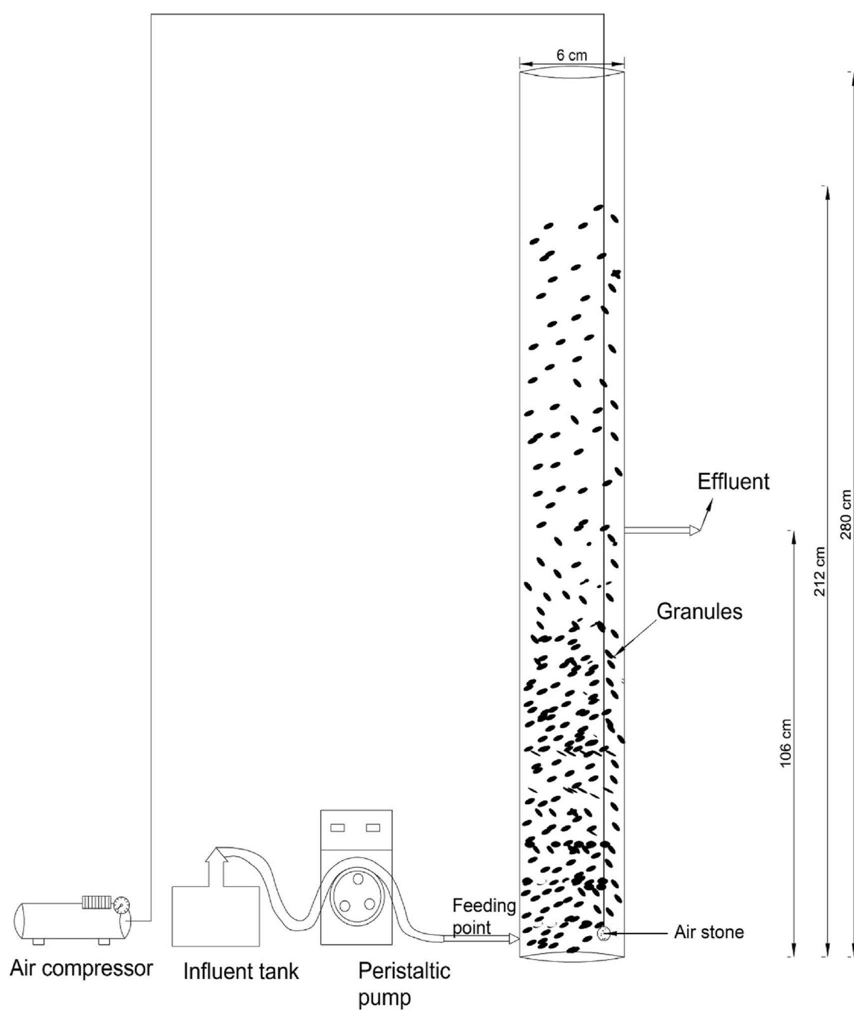

Fig. 1. Schematic diagram of SBR.