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Influence of particles properties on biofilm structure and energy consumption in denitrifying fluidized bed bioreactors (DFBBRs)

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HIGHLIGHTS

- Particles sphericity plays a significant role in biofilm morphology and detachment.
- Increasing biofilm thickness does not improve denitrification rate at low C/N.
- Thicker biofilms result in lower biomass yields and effluent VSS.
- Thicker biofilms reduce the operational cost and total annualized cost.
- Lightweight with high sphericity are the optimum attributes of media in DFBBRs.

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ABSTRACT

The influence of particles properties on biofilm structure, reactor performance, and energy consumption for denitrifying fluidized bed bioreactors (DFBBRs) using maxi-blast plastic (MX), multi-blast plastic (MB), natural zeolite (NZ), and lava rock (LR) was investigated. The work showed that the particles with sphericity of 0.9 (MB and NZ) maintained a fluffy protruding biofilm and achieved slightly higher nutrient removal efficiencies as compared to the particles with sphericity of 0.5 (MX and LR) which exhibited a patchy biofilm at low C/N ratio. As a results, lower detachment rate and biomass yields were observed for MB and NZ of 0.12 g VSS/g COD, as compared to 0.19 g VSS/g COD for both the MX and LR. This study showed that increasing the biofilm thickness, though not significantly impacting nutrient removal efficiencies, would decrease the annualized energy costs and therefore reduce the long-term operational cost. Moreover, MB appears to be the superior media.

1. Introduction

Among the biological processes for municipal and industrial wastewater, the fluidized bed bioreactor (FBBR) system is a promising bioreactor for biological nutrient removal (BNR). Recently, several FBBRs had been used and investigated for carbon oxidation, nitrification, denitrification, and anaerobic treatment of municipal and industrial wastewater (Jannette et al., 1997; Cui et al., 2004). Due to its large surface area, denitrifying fluidized bed bioreactor (DFFBR) can maintain very high biomass (biofilm) concentrations of up to 40,000 mg VSS/L (Shieh and Keenan, 1986; Mulcahy and Shieh, 1987).

Biofilm accumulation is a dynamic process that is the net result of growth and the detachment processes and is affected by several external factors, including composition and concentration of the feed (carbon/nitrogen (C/N) ratio), velocity of the liquid phase (shear stress), concentration of particles, particle–particle collisions, and particle–wall collisions (Alves et al., 2002). Retrofit of existing conventional activated sludge plants employing pre-denitrification with fixed-film processes such as moving bed bioreactor (MBBR) and integrated fixed film activated sludge (IFAS) will likely result in biofilm denitrification processes operating under increasingly limiting carbon conditions due to the low food-to-microorganisms ratio. Low carbon during the denitrification process has been proven to increase the detachment rate and reduce the biofilm thickness (Xing et al., 2000; Alves et al., 2002; Islam et al., 2008). Moreover, the C/N and decreases in the concentrations of extracellular polymeric substances (EPS), i.e. carbohydrate and protein production (Li et al., 2008) adversely impacts biofilm attachment (Miqueleto et al., 2010; Ras et al., 2011; Ye et al., 2011). Hence, the right balance between the parameters that contribute to biofilm adhesion and growth and those that affect detachment should be attained.

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