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Enhanced nitrogen removal in a wastewater treatment process characterized by carbon source manipulation with biological adsorption and sludge hydrolysis

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ABSTRACT

An innovative adsorption/nitrification/denitrification/sludge-hydrolysis wastewater treatment process (ENRS) characterized by carbon source manipulation with a biological adsorption unit and a sludge hydrolysis unit was developed to enhance nitrogen removal and reduce sludge production for municipal wastewater treatment. The system presented good performance in pollutants removal, yielding the effluent with average COD, NH_4^+-N, TN and TP of 48.5, 0.6, 13.2 and 1.0 mg/L, respectively. Sixty percent of the total carbon source in the influent was concentrated and separated by the quick adsorption of activated sludge, providing the possibilities of reusing waste carbon source in the denitrification tank and accumulating nitrobacteria in the nitrification tank. Low temperature of 6–15 °C and high hydraulic loading rate of 3.0–15.0 m^3/d did not affect NH_4^+-N removal performance, yielding the NH_4^+-N of lower 1.0 mg/L in the effluent. Furthermore, 50% of the residual sludge in the ENRS system could be transformed into soluble COD (SCOD) by alkaline thermal hydrolysis with temperature of 60 °C and pH of 11, and the hydrolyzed carbon could completely substitute methanol as a good quality carbon to support high efficient denitrification.

1. Introduction

With the rapid-development of city, industry and agriculture, increasing amount of nitrogen and phosphorus along with wastewater and farmland runoff has been discharged into water bodies, which has resulted in serious eutrophication in lakes, reservoirs and even rivers, especially city' rivers in China. In recent year, large scale cyanobacteria blossom have broken out more frequently in the Taihu Lake, one of the biggest fresh water lake in China, which not only seriously damages the scenery, but also more seriously threatens the drinking water safety to the people living in this area. To cope with this problem, the local government issued a more-stringent discharge standard for treated wastewater for the Taihu Lake basin. Consequently, most of the wastewater treatment plants in this area need to further upgrade the treatment processes and performance. The common problems facing the treatment plants there include carbon shortage for denitrification (Qiu et al., 2006; Hui et al., 2010), instability of nitrification in winter (Wei et al., 2010; Wang et al., 2009), and high cost in waste sludge disposal (Xiang et al., 2004).

Carbon shortage for biological denitrification is a common phenomenon in wastewater treatment plants, more serious in south cities of China (Zhu and Shu, 2005) where pre-denitrification processes were widely adopted to directly use the carbon source in influent for denitrification (Chen and Cheng, 2010; Zeng, 2009). Based upon current applications, pre-denitrification process shows some deficiencies. Firstly, it is still difficult to realize a satisfactory nitrogen removal when the influent COD/TN ratio is less than 4.0 (Her and Huang, 1995; Liu et al., 2008), where supply of external carbon source, such as methanol, sodium acetate, become necessary and common practice (Natuscka and Thomas, 1996; Oskar et al., 2007; Peng et al., 2007), which not only elevate the operation cost, but might also deteriorate the effluent quality. Secondly, the efficiency of influent carbon utilization is very low since the complex organic matters in influent wastewater would be difficult to be directly utilized by denitrifying bacteria. Thus, in the degradation and transformation processes, most of the carbon source would be consumed by other microbial organisms that use dissolved oxygen as the electron acceptor.

Instability of nitrification in winter is another major problem in wastewater treatment plants in the Taihu area. The nitrifying bacteria could partially and totally lose activity at temperature of lower 15 °C and of 5 °C, respectively (Henze et al., 1997). Moreover, in pre-denitrification processes, a large volume of nitrified wastewater, as much as 2–4 times of the influent flow, should be recycled to the denitrification zone (Huang et al., 2007; Baeza et al., 2004; Teck and How, 2008), which not only greatly increases operation cost, but also results in mixed culture of microorganisms with distinct habits. Especially, the mixed culture of nitrobacteria

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