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Performance of double-layer biofilter packed with coal fly ash ceramic granules in treating highly polluted river water

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HIGHLIGHTS

- A new double-layer biofilter was developed to enhance denitrification efficiency.
- It had a trickling upper layer and a submerged lower layer.
- Coal fly ash ceramic granules with high porosity were used as packing materials.
- This biofilter was efficient in highly polluted river water treatment.
- COD and nitrogen were mainly removed in upper layer and lower layer, respectively.

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ABSTRACT

To improve trickling filters' denitrification efficiency, a biofilter with a trickling upper layer and a submerged lower layer was developed and applied in treating highly polluted river water. It was packed with porous coal fly ash ceramic granules. Its start-up characteristics, influence of hydraulic loading rates (HLR), carbon/nitrogen (C/N) ratio and filter depth on pollutants removal were investigated. The results indicated this biofilter was started quickly in 16 days with river sediment as inoculum. Alternating nitrification and denitrification were achieved when water flowed downwards. COD and nitrogen were mainly removed in the upper layer and the lower layer, respectively. With HLR of 4.0–5.0 $m^3/(m^2\ d)$, chemical oxygen demand (COD), ammonium (NH_4^+–N) and total nitrogen (TN) in the effluent were below 50, 5 and 15 mg/L, respectively. This biofilter removed more than 80% of COD, 85% of NH_4^+–N and 60% of TN with C/N ratios ranging from 6 to 10.

1. Introduction

Trickling filters have been used in water and wastewater treatment for decades (Sharvelle et al., 2008). Generally, the trickling filters do not require passive aeration (Lahav et al., 2001), and can remove organics and nitrogen simultaneously with high efficiency. In recent years, trickling filters have been used not only in wastewater treatment, but also in gas purification (Kong et al., 2001; Lebrero et al., 2012), surface water treatment (van den Akkera et al., 2008) and aquaculture water recirculation (Chowdhury et al., 2010; Eding et al., 2006). The advantages of trickling filters include: low maintenance, inexpensive installation, and great tolerance to hydraulic and organic shock loads (Lekang and Kleppe, 2000).

Despite the high potential of traditional trickling filters in removing ammonia by nitrification (Almstrand et al., 2011; Evans et al., 2004), their denitrification efficiency is usually low. The high level of nitrate and nitrite in effluent has a negative impact on the aquatic environment, and poses health problems to human being and aquatic organisms (Li et al., 2010). Accordingly, further attention needs to be given to the development of biofilters with high denitrification efficiency in water treatment. The packing material of the trickling filters determines not only their treatment performance but also the amount of capital investment. The production of various packing materials that can be used in trickling filters such as fibrous medium, synthetic plastic materials and ceramic particles inevitably consumes large amounts of natural resources (Qiu et al., 2010; Tsang et al., 2008; Yang et al., 2005), and also large quantities of energy. Since the geometry and physicochemical characteristics of packing materials influence the trickling filters' performance, suitable packing material with high porosity and specific surface area should be utilized to improve the efficiency of trickling filters (Morgan-Sagastume and Noyola, 2008).

Coal fly ash is a by-product from the burning process of coal in fired burning plants and other industrial factories utilizing coal as fuel. The annual production of coal fly ash has continued to

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