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Treatment of artificial secondary effluent for effective nitrogen removal using a combination of corncob carbon source and bamboo charcoal filter

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ABSTRACT

Nitrogen from secondary effluents has endangered the aquatic environment and human health. A new experimental setup combining a corncob carbon source and bamboo charcoal filter (BCF) was used to effectively purify artificial sewage treatment plant tail water that had high nitrate and nitrogen content, and a low carbon to nitrogen (C/N) ratio. The nitrogen concentration in the reactor's effluent was below the limit of 15 mg/L when the influent COD concentration was 20 mg/L–60 mg/L, the influent NO_3^--N concentration was 15 mg/L–30 mg/L, and the hydraulic retention time (HRT) was 1 h–4 h. The reactor's maximum volumetric load of total nitrogen was 0.585 kg/(m^3 d). The COD and NO_3^--N balances of the reactor indicated that 4.77 g corncob was required to remove 1 g NO_3^--N and 2 g corncob was required to release 1 g COD.

1. Introduction

Restriction on nitrogen and phosphorus effluent concentrations is critical for prevention of eutrophication in lakes (Abell et al., 2010). Regulations regarding nutrient concentrations in wastewater have been enforced in China (Paerl et al., 2011). However, several conventional sewage treatment plants need to be extended or upgraded to satisfy more stringent nutrient discharge standards (Jeong et al., 2006). This is a difficult task as it requires additional land, money, and time (Jokela et al., 2002).

Although frequent fluctuations in water quality can cause an excess of carbon sources in the effluent water, organic matter content is normally low in sewage in China. Consequently, carbon source required for denitrification during secondary processing is insufficient resulting in high nitrate and nitrogen levels, and a low carbon to nitrogen (C/N) ratio in the sewage tail water (Chiu et al., 2007; Guo et al., 2010; Her and Huang, 1995; Ryu et al., 2008). Commonly, carbon sources can be divided into two broad categories: traditional and new. Traditional carbon sources contain low molecular organic matter and sugars (Karanasios et al., 2016). Liquid organic matter, such as glucose, methanol, ethanol, and acetic acid, are preferred as they are easily used by denitrifying bacteria (Bu et al., 2015; Lim et al., 2006). Sugars such as glucose and sucrose are already in use as additional carbon sources. New carbon sources are solid sources that contain natural plant cellulose materials and biodegradable polymers (Ines et al., 1998; Luo et al., 2014, 2016; Volokita et al., 1996a,b).

In recent years, intensive research has been conducted on solid carbon sources primarily consisting of cellulose. Fibre carbon sources can be easily acquired at a low cost and mainly include cotton (Volokita et al., 1996a), paper (Volokita et al., 1996b), straw (Ines et al., 1998), and reed rod. Corncobs are an attractive external carbon source for denitrification (Wang et al., 2013; Xu et al., 2009; Yang et al., 2015). Additionally, in view of high nitrate and nitrogen levels, and low C/N in the tail water of sewage treatment plants, effective denitrification needs new adsorption materials to serve as fillers in biological filters (Jia et al., 2013; Ryu et al., 2009). Bamboo charcoal can be used as a filler for adsorption packing to enable microbial degradation (Chen et al., 2012). A combination of corncob carbon source and bamboo charcoal filter (BCF) may be a feasible solution.

This study aims to utilize a cheap agricultural waste as the solid carbon source and bamboo charcoal as fillers of denitrifying

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biological filter to purify sewage treatment plant tail water effectively. In view of high nitrate and nitrogen content, and a low C/N, the optimization parameters for continuous operation at different water loads, hydraulic retention time, height of packing reactor, and running effect of the denitrifying biological filter were investigated to ensure effluent compliance with the GB18918-2002 1A discharge standard (MOEP, 2002). It expands the application of new, cheap, and harmless materials and provides a theoretical and design basis for the denitrification process in sewage treatment plants.

2. Materials and methods

2.1. Experimental devices

The experimental device setup is displayed in Fig. 1. The experimental devices contained a solid carbon source reactor and a denitrification filter that were made of polymethyl methacrylate. The carbon source reactor had an inner diameter of 80 mm and a height of 320 mm with an effective volume of 1206 L. Simulated municipal wastewater was pumped from the bottom to the top through a porous retainer plate and then passed through the solid carbon source using a peristaltic pump. The denitrification filter was a fixed bed reactor filled with bamboo charcoal. The particle size of bamboo charcoal was reduced to 2 mm–4 mm using a special crusher after soaking, cleaning, and passing through a 6 mm–10 mm mesh. The effluent flowed from top to bottom into the denitrification filter with an inner diameter of 80 mm and a height of 650 mm with an effective volume of 0.785 L. The total effective volume was about 2 L when the fill height was 400 mm. The perforation aperture of the porous retainer plate was 1.5 mm. There were four sampling openings every 80 mm above the porous retainer plate. Backwash using water and compressed air was designed to prevent filter clogging.

2.2. Operating conditions

Operating conditions of the experimental devices are shown in Table 1. Different influential concentrations, fluxes, and hydraulic retention times were maintained at different times.

2.3. Experiment analysis

Sampling was arranged every three days to ensure all operating conditions were tested. The glucose, ammonium acetate, potassium nitrate, and potassium dihydrogen phosphate were used to add COD, NH_3-N, NO_3^--N, and TP, respectively. Three water samples were collected each time in the influent, corncob effluent and BCF effluent. The corncob removal rate represented the removal rate between the influent and corncob effluent. The total removal rate represented the removal rate between the influent and BCF effluent. The levels of COD and NH_3-N were analysed according to standard methods (Zhou et al., 2015a). NO_3^--N and NO_2^--N levels were determined using ion chromatography (ICS-900, Thermo, USA).

3. Results and discussion

3.1. Solid carbon source

After the completion of bamboo charcoal hanging membrane, corncob was added to the experimental reactor. The effect of different quantities of solid carbon source on denitrification was compared, as shown in Fig. 2a. The removal rate of NO_3^--N was found to become higher as the quantity of corncob increased. With an addition of 60 g, 140 g, and 200 g of corncob, the removal rate of NO_3^--N was 38.1%, 51.0%, and 67.1%, respectively. The total removal rates of the whole treatment system were 49.1%, 83.2%, and 87.4%, respectively, for these additions. The corncob served as a solid carbon source as well as a carrier of the denitrifying bacteria. The visible natural microbial membrane on the corncob facilitated partial removal of NO_3^--N. There were micro-holes, mid-sized holes, and large holes in the bamboo charcoal, enabling penetration of denitrifying bacteria into the internal pores. Bamboo charcoal, an environmentally friendly and inexpensive biosorbent (Zhou et al.,

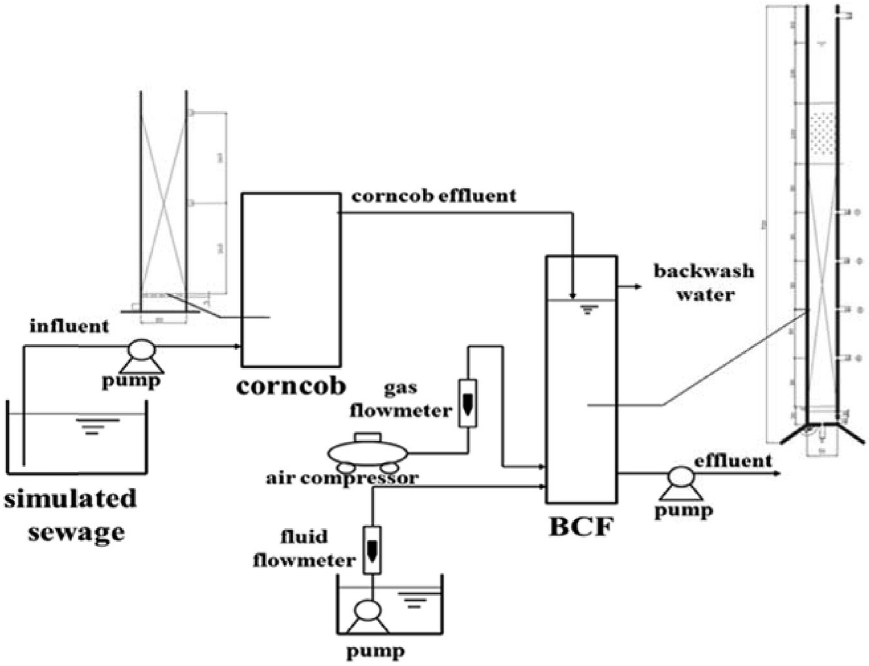

Fig. 1. Scheme of the pilot-scale combination of corncob carbon source and bamboo charcoal filter.