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A New Soil Infiltration Technology for Decentralized Sewage Treatment: Two-Stage Anaerobic Tank and Soil Trench System*1

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ABSTRACT

The low removal efficiency of total nitrogen (TN) is one of the main disadvantages of traditional single stage subsurface infiltration system, which combines an anaerobic tank and a soil filter field. In this study, a full-scale, two-stage anaerobic tank and soil trench system was designed and operated to evaluate the feasibility and performances in treating sewage from a school campus for over a one-year monitoring period. The raw sewage was prepared and fed into the first anaerobic tank and second tank by 60% and 40%, respectively. This novel process could decrease chemical oxygen demand with the dichromate method by 89%–96%, suspended solids by 91%–97%, and total phosphorus by 91%–97%. The denitrification was satisfactory in the second stage soil trench, so the removals of TN as well as ammonia nitrogen (NH_4^+-N) reached 68%–75% and 96%–99%, respectively. It appeared that the removal efficiency of TN in this two-stage anaerobic tank and soil trench system was more effective than that in the single stage soil infiltration system. The effluent met the discharge standard for the sewage treatment plant (GB18918-2002) of China.

Key Words: decentralized treatment, nitrogen removal, soil trench system, subsurface infiltration

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INTRODUCTION

As one of the soil treatment technologies, subsurface infiltration system has been used as an on-site treatment alternative to conventional intensive sewage treatment technology in many countries (US EPA, 2002; Zhang *et al.*, 2004). Conventional subsurface infiltration system consists of a septic tank and a soil absorption field where wastewater is treated prior to its discharge to the ground water. There are over 22 million typical subsurface infiltration systems in operation in the US now (Van Cuyk *et al.*, 2001). However, it is still one of the contributors of pathogens and nutrients to ground water, which can lead to health problems if the ground water is directly used as a drinking source.

Recently, an improved subsurface infiltration system, referred to as soil trench system, has been developed. It has been proven to be an effective method for treating dispersed sewage, especially in developing countries (van Buuren *et al.*, 1999; Kong *et al.*, 2002; Inamori *et al.*, 2003). Its main treatment frame is the soil absorption unit, which is enclosed by a waterproof material. The depth of the infiltration layer usually varies from 0.6 to 1.2 m. The treated effluent is collected at the bottom of the gravel layer. With this set-up, construction and operating costs are reduced by about one-third to half that of the active sludge technology. In addition, the effluent can be reused for non-drinking

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purposes (Sun *et al.*, 1998; Kong *et al.*, 2003). During the last four years, over 100 full-scale, on-site soil trench systems have been set up and put into successful operation in different climatic zones in China. These systems operate at a flow rate between 5 and 500 m^3 day^{-1} (Kong *et al.*, 2002; Hu *et al.*, 2004).

Soil trench filter combined with an anaerobic tank in the single-stage soil trench process has been found to achieve chemical oxygen demand (COD), total phosphorus (TP), suspended solids (SS), and NH_4^+-N removals of 80%–92%, 80%–96%, 80%–86%, and 70%–81%, respectively. However, one limitation of single-stage soil trench system lies in its low total nitrogen (TN) removal, which is only around 23%–55% (Kong *et al.*, 2002, 2004; Sun *et al.*, 1998). During the percolation process of the traditional single stage soil infiltration system, both nitrification and denitrification occurred within the same soil infiltration unit. As the carbon content decreased when the organic substances were removed along the soil depth from the top to the bottom, it was found that the carbon source was not enough for the denitrification that followed the nitrification stage. This led to a low level of TN removal. Therefore, further research to increase the efficiency of denitrification is important for biological nitrogen removal in soil trench systems.

The use of soil mixed with peat and plastic foam as filter materials arranged in a multilayer fashion, is one approach to improve the nitrogen removal efficiency. By this system, a mean removal of 75.5% for TN has been attained at certain period (from the thirtieth to fiftieth day) during a lab-scale operation (Zhang *et al.*, 2004). A previous study also proposed the use of a sand filter plus a post-positioned denitrification tank, where a carbon source such as grey water or ethanol was fed into the denitrification tank for increasing nitrogen removal efficiency (van Buuren *et al.*, 1999). However, up to now, very little attention has been paid to the combination pattern of the multistage anaerobic tank and soil trench filter for improving the TN removal efficiency, especially in practice, for treatment of decentralized domestic wastewater. Therefore, such a system was evaluated in this research for improving TN removal. The raw sewage was distributed into two stage anaerobic tanks separately. The aim of the process configuration was to utilize the raw sewage fed into the second stage as a carbon source for denitrification of the nitrate and nitrite in effluent that came from the first stage soil trench.

In this article, a full-scale, two-stage anaerobic tank and soil trench system for the treatment of sewage was designed and operated to evaluate the feasibility and performances in treating sewage from a school campus for over a period of one year.

MATERIALS AND METHODS

System description

The full-scale system was located in a new middle school campus, which is around 8 km from Wenzhou City, China. It was set under the ecological lawn around the dormitory building. The raw sewage was collected from the dormitory and refectory with a population of 1 000–1 200 people, produced by toilets, bathing, laundry, cooking, and washing dishes. The system had a treatment capacity of 60 m^3 day^{-1} in winter and about twice that in summer. The hydraulic loading rate was 100 L m^{-2} day^{-1}. The raw sewage stayed in the anaerobic tank with a retention time of 24 h.

The treatment facility consisted of two anaerobic tanks and two soil trench filters (Fig. 1). In this process, 60% of the raw sewage was fed into the first stage anaerobic tank and the other 40% was fed into the second stage anaerobic tank. The effluent from the first stage anaerobic tank was transported into the first soil trench filter, where the liquid was dispersed evenly by a branched tube distributor. The sewage flowed uniformly within the constructed soil filtration system by capillary action. The effluent of the first-stage soil trench filter was then allowed to flow into the second anaerobic tank, where it was mixed with 40% raw sewage. Finally, the effluent from the second anaerobic tank was fed into the second-stage soil trench filter for further treatment.