Ecological Engineering 77 (2015) 363–372

Contents lists available at ScienceDirect

Ecological Engineering

journal homepage: www.elsevier.com/locate/ecoleng

Remediation effect of pond–ditch circulation on rural wastewater in southern China

Lin Ma [a,b], Feng He [a,*], Jian Sun [a,b], Long Wang [a,b], Dong Xu [a], Zhenbin Wu [a]

[a] State Key Laboratory of Freshwater Ecology and Biotechnology, Institute of Hydrobiology, Chinese Academy of Sciences, Wuhan 430072, China
[b] University of Chinese Academy of Sciences, Beijing 100049, China

ARTICLE INFO

Article history:
Received 5 June 2014
Received in revised form 29 October 2014
Accepted 25 November 2014
Available online 17 February 2015

Keywords:
Water circulation
Zooplankton community structure
Water quality
Redundancy analysis

ABSTRACT

To mitigate water pollution caused by rapid urbanization in the rural areas of China, it is urgent to develop suitable wastewater treatment technologies, which are socio-economic, environmentally sustainable and easily maintained. This study investigates the remediation effect of a pond–ditch circulation system on water quality. This system is composed of connected ponds and ditches in rural areas. We constructed the treatment systems as follows: system I (S1) was circulated 24 h/day (13.2 L/h), system II (S2) was static with macrophytes, and system III (S3) was circulated with macrophytes. Our results indicated that after 60 days of treatment, the levels of the total nitrogen, total phosphorus, ammonia nitrogen, chemical oxygen demand, chlorophyll *a* and turbidity of water significantly decreased in the ponds/ditches of S1 and S3. Similar significant decreases of these parameters were observed in the water of the ditch in S2, whereas the concentrations of TN, TP and NH_4^+-N of water from the two ponds in S2 increased. Moreover, the increase of the species numbers and the diversity index of zooplankton and the decrease of heterotrophic index in three ponds/ditches of S1 and S3 and the ditch of S2 demonstrated the improvement in water quality. The significant relationship between the zooplankton community structure and the environmental variables was confirmed by redundancy analysis (RDA) and Pearson's correlation analysis. In conclusion, the pond–ditch circulation system can effectively remove excessive nutrient loads and improve water quality and hence represents a simple and economical solution for the restoration of a degraded rural water environment.

1. Introduction

The rapid urbanization of rural areas in China causes serious water pollution, which severely threatens water safety, as well as human health. Domestic sewage of approximately 96% of all villages is discharged directly into the receiving waters without any treatment because of the lack of drainage channels and wastewater treatment facilities (Zou et al., 2012). The sewage quantity far exceeds the self-purification capacity of natural water, causing serious aquatic environment damages. Moreover, the polluted water threatens the safety of more than 100 million people in Chinese rural areas (Dong et al., 2012). To ensure the security of water resources and the health of people, it is urgent to establish a suitable domestic wastewater treatment system in rural China.

Conventional centralized systems and onsite decentralized systems are the two primary approaches widely used for wastewater treatment in urban areas. The former approach consists of large-scale pipeline networks for sewage collection and sewage treatment plant, which are not suitable for treating rural wastewater in China because of the high cost, complex maintenance and high volume of the residual sludge (Hellström and Jonsson, 2003). Additionally, the characteristics of rural wastewater often change in quantity, composition and spatial distribution (Ho, 2005; Wang et al., 2011). By contrast, the latter approach is preferable for treating rural wastewater because of its high removal efficiency of pollutants, low costs and easy maintenance (Ichinari et al., 2008). The extensively used onsite decentralized systems include constructed wetlands (Wu et al., 2002; Yu et al., 2012; Zou et al., 2012), high-rate algal ponds (Evans et al., 2005; Kim et al., 2002; Zhou et al., 2006), a septic tank (Liang et al., 2009) and aerobic biological treatment units (Nakano, 2006; Nakano and Yasumoto, 2012). These systems have been developed and applied in many rural areas of China based on their own special characteristics. Currently, however, the effluent quality of these single onsite centralized systems fails to satisfy the sewage discharge standards because of the increasingly complex composition of rural domestic wastewater and higher effluent standards.

* Corresponding author. Tel.: +86 27 68780832.
E-mail address: hefeng@ihb.ac.cn (F. He).

http://dx.doi.org/10.1016/j.ecoleng.2014.11.036
0925-8574/

To solve this problem, there have been considerable efforts to integrate existing decentralized treatment systems. These integrated decentralized treatment approaches include compound media filter bed combined systems (Wang et al., 2010; Zhang et al., 2009), constructed wetland combined systems (He et al., 2014; Vera et al., 2013) and bio-ecological combined systems (Gao and Hu, 2012; Liang et al., 2009; Wu et al., 2013). These combined wastewater treatment methods have significantly improved water quality in many rural areas of China.

Rural wastewater consists mainly of crop residue, animal urine/feces, domestic sewage, aquaculture wastewater and atmospheric deposition. In rural areas, most wastewater is discharged directly, with little or no treatment, into rivers, ditches and ponds. Worse yet, the mobility of the polluted water is weakened because of such factors as drought and/or overuse of water. Furthermore, rural villages usually lack economic resources and trained personnel in wastewater treatment. Therefore, it is imperative to develop an effective rural wastewater treating system that has low cost, is easily maintained and is energy efficient (Cameron et al., 2003). Previous studies have shown that water mobility, a characteristic of a healthy aquatic ecosystem, plays an important role in inhibiting the formation of eutrophication (Acuña et al., 2010). The faster the water flows, the more difficult it is for the suspended algae to grow and form bloom (Acuña et al., 2010; Mitrovic et al., 2011). In this study, we hypothesize that the self-purification ability of rural polluted water in a pond–ditch circulation system can be effectively improved by increasing the mobility of wastewater to an ideal level. Compared to other integrated decentralized treatment systems, the advantages of this pond–ditch circulation system are: (1) lower cost and land consumption, (2) simple operation and easy maintenance and (3) an in situ remediation technology. To test this hypothesis, we constructed a pond–ditch circulation system composed of two ponds and one ditch to simulate the condition in rural areas of southern China and investigated the effects of circulation on the quality of rural wastewater.

Moreover, zooplankters are the microscopic, free-swimming animalcule components of an aquatic ecosystem. Zooplankters are the primary consumers of phytoplankton and are the main food source for fish (Hulyal and Kaliwal, 2008; Rodrigo et al., 2013). Therefore, zooplankton is usually used as an indicator of the trophic status of a water body (Zhao et al., 2013). In the study, these small-scale experiments, which lasted two successive months, primarily investigate (1) the critical role of circulation in improving water quality; (2) the effect of circulation on the zooplankton community structure; and (3) the correlations between the environment variables and the zooplankton community structure.

2. Materials and methods

2.1. Experimental water and sediments

The experimental water was collected from four sites (A, B, C and D) (Fig. 1). Sampling sites A and C were located along the bank of Guanqiao Lake (30°31′N, 114°22′E), a part of Donghu Lake in the northeastern outskirts of Wuchang district, Wuhan, Hubei province, China. Site B was situated in the drainage channels of a village near the bank of Guanqiao lake, and a pond in this village was chosen and named site D. The sediments used in the experiment were collected from the top 0 to 10 cm of the sediment at sites A and D in June 2013 and thoroughly mixed prior to experiments.

2.2. Treatment systems

Three small-scale circulation systems (S1, S2 and S3) were set up next to site B. As shown in Fig. 2, each system was composed of one plastic water distribution bucket and four aquariums (I, II, III

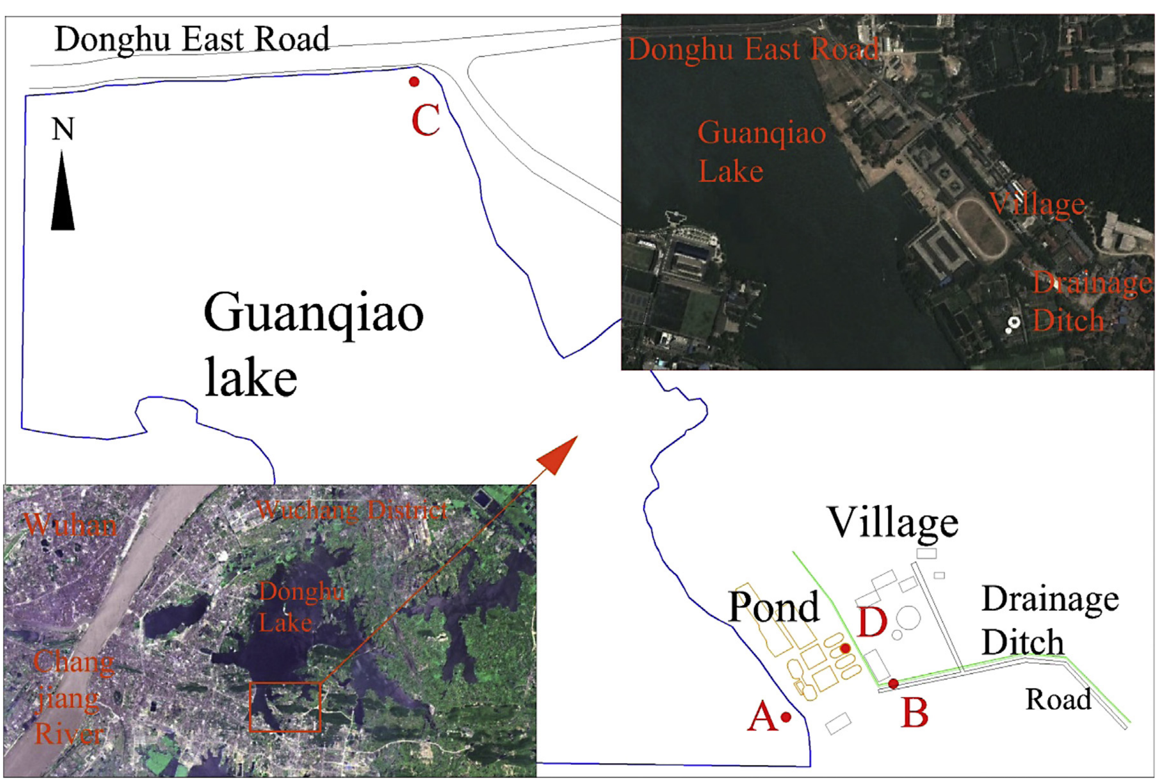

Fig. 1. Location of the four sampling sites (A–D).