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Study on the application of integrated eco-engineering in purifying eutrophic river waters

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A B S T R A C T

Eutrophication has become the primary water quality issue for most of the freshwater in the world. An integrated ecological engineering was applied to treat the eutrophic water of the Shuangqiao River (SQ River), one of the most heavily polluted rivers inflowing to the Chaohu Lake, China. A multi-pond constructed wetlands system was built up to treat the external loading of wastewater. Meanwhile, an in situ purification system consisted of sediment dredging, hydrophytes restoration and artificial floating islands was constructed to purify the internal loading and the river course water. By monitoring the river water quality and analyzing the samples of sediments and plants, the treatment effects and efficiencies of single and integrated ecological technique were studied. Our results indicated that the implement of ecological project notably enhanced the river's capacity of reducing total phosphorus (TP), total nitrogen (TN) and potassium permanganate index (COD), which had increased from 2.49, 33.69 and 40.32 tons per year to 3.75, 58.28 and 74.36 tons per year, respectively. As a result, the concentrations of TP, TN and COD in the river water were dropped by 10.5%, 11.8% and 8.2% respectively. The monitoring data also showed that the removal efficiency of the in situ purification system varied with the seasons, while that of the wetlands system remained at a high level throughout the year, indicating the feasibility of a combination of different techniques to reduce the impact of season on water purification. In summary, this research indicated that single ecological technique produced no satisfying results due to the limits of technique features and environmental conditions, while the integrated engineering techniques could overcome those restrictions and had the potential to remediate heavily polluted rivers.

1. Introduction

Globally, aquatic ecosystems are being impaired by human activities (Gleick, 2003; Zamparas and Zacharias, 2014). The shortage of river water and the discharge of relative large quantities of wastewater directly into watercourses led to significant water pollution. Eutrophication and algal blooms, which appeared as a result of excessive input of inorganic nutrients (particularly nitrogen and phosphorus) to freshwater rivers, lakes, streams and reservoirs, have been considered as two of the most common and serious threats to the safety and security of water resources around the world (Ghadouani and Coggins, 2011; Sierp et al., 2009; Vareli et al., 2009; Zhu et al., 2011). In China, up to 27.8% and 57.4% of the lakes were eutrophic and mesotrophic respectively, and 19.3% and 9.0% of the water quality of the river monitoring sections belonged to IV–V and inferior to V grade (*Surface Water Quality Standards of China*) in 2013 (Ministry of Environmental Protection, 2014).

As nitrogen (N) and phosphorus (P) are directly responsible for water eutrophication, removing N and P from water is an effective approach to mitigate or prevent this issue. However, conventional wastewater treatment systems, which are known to be efficient in removing COD, cannot reduce the negative impacts of nutrient pollution effectively (de-Bashan and Bashan, 2004; Paerl et al., 2011; Yin et al., 2013). Therefore, other appropriate measures should be taken to lower the impacts of nutrient pollution. Ecological technologies, such as hydrophytes restoration, artificial floating island (AFI) and constructed wetlands system (CWs), representing innovative and emerging solutions for environmental protection and restoration, have been developed worldwide (Babatunde et al., 2008; Vymazal, 2011; D.Q. Zhang et al., 2014; Zhao et al., 2012).

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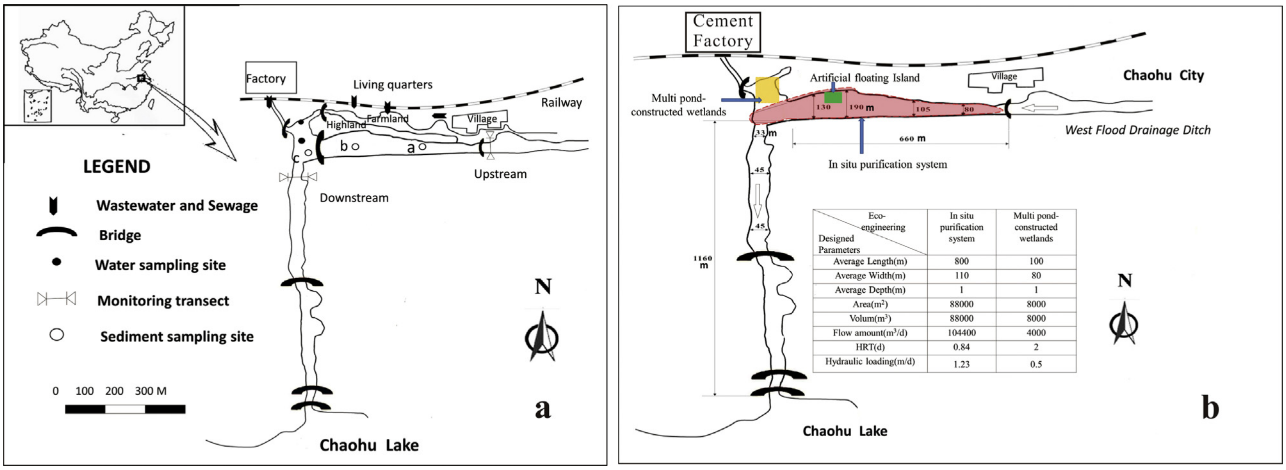

Fig. 1. Locations of sampling sites (a) and eco-engineering project (b).

Hydrophytes have been widely applied in the remediation of rivers and lakes for they are very important component part of a healthy aquatic ecosystem. Besides, the hydrophytes are also efficient in assimilating nutrients, creating favorable conditions for the microbial decomposition of organic matter and increasing water transparency and oxygen availability (Wang et al., 2009, 2010). So far, typical eco-engineering techniques including hydrophytes restoration, AFI, microbial restoration and ecological river bank, are intensively exploited the potential of aquatic plants and microorganisms to treat polluted water. However, the purification efficiency was greatly affected by the season, and the plant biomasses must be removed periodically from the water bodies, otherwise, the nutrients that have been incorporated into the plant tissues may be returned to the water during the decomposition processes (Lu et al., 2010). CW has become an increasingly novel option as the ecological restoration technique, which greatly improve the water quality by substrate adsorption and filtration, microbial assimilation and transformation as well as wetlands plant uptake (Kadlec, 2009; Scholz et al., 2007). Because of the high removal efficiency, low cost, simple operation, and great potential for water and nutrient reuse, CWs are increasingly used worldwide, especially in the developing countries. However, CWs occupy a large area of lands, which is a limiting resource in countries such as China where human population density is high. It was previously reported that the intense and persistent nutrients release from the sediment into the overlying water prevented the water quality from any improvement for a considerable period even after external loading reduction (Sondergaard et al., 2003). Therefore, sediment dredging was an effective remediation method to alleviate eutrophication for it can reduce internal nutrient loading directly, create suitable habitat conditions and promote ecological restoration (Zhang et al., 2014). However, sediment dredging has some shortcomings such as high costs, strict demand of dredging precision and instability of treatment effectiveness (Zamparas and Zacharias, 2014).

As disadvantages of single eco-engineering technique limit the success of large scale applications in river and lake restoration, techniques using combined biotechnological and engineering methods have drawn increased attention. These approaches have superiorities in maintaining the stability and longevity of the remediation effectiveness, and they usually require less time, space and cost. However, there have been only a few reports concerning the application of integrated eco-engineering in remediation of polluted rivers and most of these studies were performed with laboratory, microcosm or mesocosm experiments (Mi et al., 2014; Sheng et al., 2013; Wang et al., 2009, 2010). Particularly, the knowledge about ecological river engineering is still scarce in China and neighboring Korea (Woo, 2010).

To improve future restoration practices, we herein proposed and reported an integrated eco-engineering project with in-depth analysis of results. The integrated project combined sediment dredging, hydrophytes restoration, AFI and CWs, was carried out at SQ River (one of the most heavily polluted inflows of Chaohu Lake, China) in 2010. The objectives of this study were: (1) to characterize the water purification activities and highlight strengths and weaknesses of these approaches; (2) to evaluate the water quality improvements and the removal efficiency of treatment units; (3) to assess the feasibility of applying different treatment units to remediate a polluted river. This study can make recommendations to further the application of river restoration in more broad regions.

2. Methods

2.1. Study site

The Shuangqiao River (SQ River), situated in the east of the north bank of the Chaohu Lake and approximately 1.45 kilometers (km) in length and averagely 32 meters (m) in width, was one of the most heavily polluted rivers inflowing to Chaohu Lake. The major land uses in the region were constructed land and cropland. Due to the increasing human activities, the lake suffered from serious pollution and eutrophication problems. The shortage of river water further exacerbated the problem of pollution, as a result, the water quality of the river was inferior to V grade and the sediment was polluted heavily. In the upstream of the SQ River lay the West Flood Drainage Ditch, that was 3.33 km in length and gathered municipal sewage from the Chaohu City. In addition, the SQ River also received water from farm irrigating catchments.

As the River was located in the suburban regions of the Chaohu city, pollution interception had not been started. In the engineering area, besides the pollutants brought by the upstream water and surface runoff, 4 wastewater inflows receiving domestic sewage and agricultural wastewater from the towns and villages, were situated in the North Bank of the river (Fig. 1a). The Sewage Outlet No. 1 was 30 m away from the downstream of a village and Sewage Outlet Nos. 2, 3 and 4 went through a railway culvert. These four sewage inflows passed farmland and channels separately and finally converged at the northern corner of the crook of the river and together flowed into the SQ River.