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Water quality improvement with artificial floating islands

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ABSTRACT

As the natural purification of the traditional artificial floating island is very slow, the purpose of this research is to explore the efficiency of the green energy artificial floating island (GAFI) to improve water quality. We constructed experimental models near the bank of Lize Lake at MingDao University in Taiwan, where the surrounding waters and wastewater from the dormitories served as the sources for water purification and treatment. In the field of the experimental model, three water tanks, each of which is 165 cm in depth and 130 cm in diameter, with 2 tons of water in total, were buried as the experimental containers. The GAFI area is 60 × 60 cm equipped with three kinds of aquatic plants: *Typha orientalis* Presl, *Eleocharis dulcis* and *Juncus effuses*, as the vegetation purification plants, and an aerator device powered by solar power. According to our experimental results, GAFI can effectively break down stratified water into homogenized water and inhibit algae growth. The dissolved oxygen and oxygen reduction potential were increasing when the GAFI was used, and the NH_3–N, NO_3–N and NO_2–N were effectively decreased. As GAFI can quickly enhance water quality, it is worth promoting its application for water landscapes and environmental conservation in the future.

1. Introduction

Artificial floating island (AFI) technology, also known as FTWs (floating treatment wetlands), is a variation of wetland treatment systems. The emergent aquatic plants applied in the two systems have commonality (Mallison et al., 2001; Chua et al., 2012). Nakamura and Mueller (2008) and Zhu et al. (2011) argued that AFI has various functions, including reducing the spread of contamination, clipping revetment, habitat conservation, water decontamination, water purification and green landscaping. AFI can remove suspended solids (SS) in the water through physical operation, as well as realize absorption and utilization through the biosynthesis of the contaminants, while providing biofilm adhesion medium (Chang et al., 2012). Moreover, as it can reduce light penetration, and competition for water nutrients, it can inhibit the growth of algae (Zhao et al., 2012). Hu et al. (2010) built the ecological sludge floating-bed (ESFB) composed of 72.5% of the recycled sludge, 12.5% of slag and 15% of expanded perlite. According to the experimental results, the removal efficiency was 36% in total nitrogen (TN), 35.7% in total phosphorus (TP), 44.3% in ammonium nitrogen (NH_4^+–N), 38.1% in total dissolved phosphorus (TDP) and 47.9% in chlorophyll-a (Chl-a). Piper et al. (2002) used soil and moist vegetation to construct 1 m^2 floating nest platforms. The platforms were placed in 26 lakes and were surveyed for the reproduction of common loon (*Gavia immer*). Compared to natural nests, the hatching success and fledging success increased by 69% and 32%, respectively; these results were assumed to reduce the chance of predation when using the platform.

Apart from the benefit of artificial floating island in reducing contamination and habitat conservation, the aquatic plants could be used for water decontamination and purification. It is reported that the aquatic plants can absorb excessive nitrogen nutrients, reducing nitrate nitrogen and phosphate phosphorus in wastewater; some plants could even degrade toxic chemicals, ex trichloroethylene (Bankston et al., 2002; Nahlik and Mitsch, 2006; Sheng and Masaaki, 2008). The roots of aquatic plants provide a space for microorganisms to grow on the plant stems and root surface, which can improve the removal of organic matter; these effects are related to the dissolved oxygen (DO) released from plant roots (Watson et al., 1989; Tanner, 2001; Sooknah and Wilkie, 2004; Brix and Schierup, 1990). The use of vegetation removes, degrades and sequesters contaminated water, rendering harmful chemicals as low risk and cost-effective (Deng et al., 2004; Weis and Weis, 2004; Shankers et al., 2005).

To construct the AFI, some materials were discussed in previous studies. Most carbonized materials with the function of water

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purification are generally used in ditches, drainage and family kitchens (Yatagai, 1997). Sano (1987) proposed that the filter should have characteristics like sufficient strength of the filtering medium, lightweight, simple operation with good cleaning effect and reusable. The choice of brush should also have the same characteristics like the filtering materials. Oxygen aeration has water purification effects by forcing the flow of water through aeration; it can provide oxygen for microbial oxidation decomposition of organic substances, and absorb the particles suspended in water by the surface stress of bubbles (Hou and Yeh, 2007). Based on the foregoing descriptions, we generated the green energy artificial floating island (GAFI), which combined the advantageous components for AFI, in addition to an aerator device powered by a solar system, and used it to monitor the efficiency of water purification. Our design and experimental data provide future applications of AFI in lakes and reservoirs to help solve the problems caused by conventional devices, and without consuming extra energy sources.

2. Materials and methods

2.1. Study area and materials

Our study area and GAFI (Fig. 1) instruments are the same as in a previous study (Chang et al., 2014). Briefly, our study was performed in Lize Lake at MingDao University in Taiwan. Sample A (SA) is Lize Lake water body; Ssample B (SB) is the drainage outlet of domestic sewage from the dormitories; Sample C (SC) is the water discharged from the wastewater treatment plant; Sample D (SD) is the same water from SA but treated with GAFI; Sample E (SE) and Sample F (SF) are the same water from SB but SE treated with GAFI. SF thus serves as the reference group for SE. The details of GAFI structure are the same as previously reported (Fig. 1). For this study, we detected the water quality with YSI-Pro Plus multi-parameter water quality analyzer HACH and DR-890 portable water quality spectrophotometer. Suspended solids were tested with a magnetic filter funnel (300 ml), suction device (flow rate of 13 LPM; vacuum of 600 mm Hg; horsepower of 1/8HP), glass fiber filter (47 mm, 100 pcs), ceramic evaporating dish and oven.

2.2. Methods

This survey was conducted during the period of 2012/03/22–2012/07/26, 127 days in total. In six water quality monitoring sites, SA, SB and SC were tested at the upper water layer (5 cm below the water surface) due to their short water depth. SD, SE and SF, on the other hand, were tested and recorded at the upper layer, the middle water layer (80 cm below the water surface) and the bottom water layer (5 cm above the tank bottom). Data collected from SA, SB and SC served as the original water quality information. Data collected from the SD and SE tanks were the water quality when GAFI was applied. SF was the reference group of SE without the help of GAFI. We collected the water samples according to the announcement of NIEA W104.51C No. 0950043953 of the Environmental Protection Administration (EPA), Executive Yuan, Taiwan.

The water quality was tested and recorded in 13 items. Water temperature (WT), pH values, dissolved oxygen (DO), electrical conductivity (EC) and oxidation–reduction potential (ORP) were tested by a YSI-Pro Plus multi-parameter water quality meter on the site between 10:00 and 12:00 every Friday. The total nitrogen (TN), total phosphorus (TP), chemical oxygen demand (COD) and suspended solids (SS) were monitored at the end of each month. Ammonia nitrogen (NH_3–N), nitrite–nitrogen (NO_2–N), nitrate nitrogen (NO_3–N) and phosphates (PO_4) were monitored on Friday between 10:00 and 12:00 at the middle and the end of each month using a DR-890 portable water quality spectrophotometer. We collected the water samples according to the regulations issued by the Environmental Analysis Laboratory, EPA, Executive Yuan, Taiwan.

3. Results

3.1. WT, DO, EC, pH and ORP

It is worth noting that SF had no apparent stratification in WT, DO, EC, pH or ORP before April 19th. However, after April 19th, the

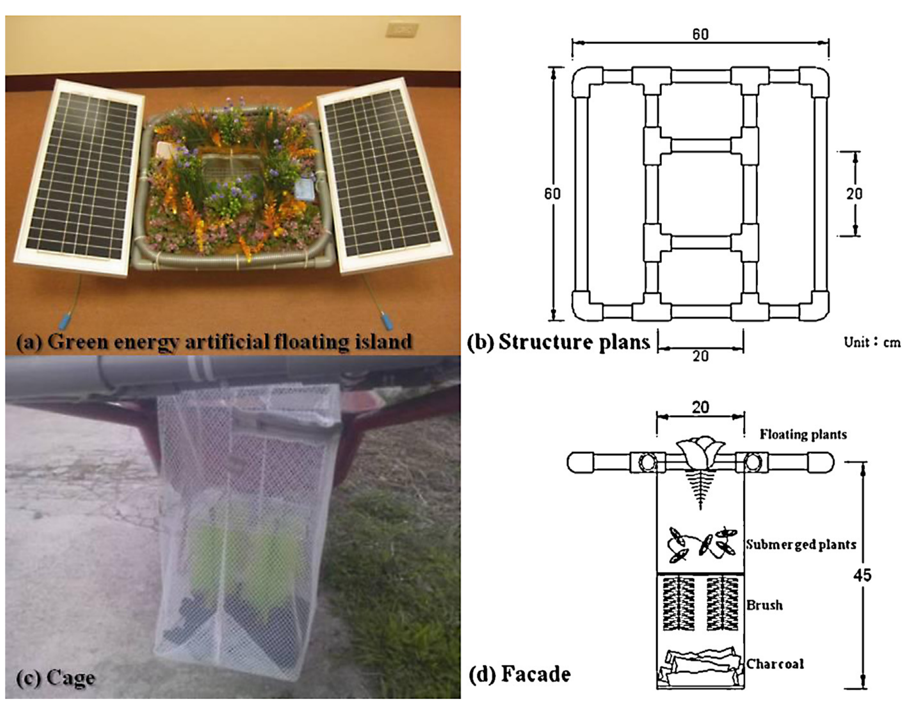

Fig. 1. Green energy artificial floating island.