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Effects of aquatic ecological indicators of sustainable green energy landscape facilities

Yuan-Hsiou Chang[a,*], Chen-Ruei Ku[b], Hsiao-Ling Lu[c]

[a] Department of Landscape and Architecture, MingDao University, Changhua, Taiwan
[b] College of Design (Master of Arts Program), MingDao University, Changhua, Taiwan
[c] Department of Entomology, National Taiwan University, Taipei 10617, Taiwan

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ABSTRACT

This study investigated the impacts of the green energy artificial floating island (GAFI) on indicator species to determine the water-quality improvement by using GAFI. We analyzed the amounts and biological characters of living organisms found in water samples. These organisms serve as the biological indicators of water quality. The results indicated that GAFI can effectively break water stratification, make water homogenized, and inhibit the growth of algae. Algae functioning as water indicators mainly include *Synedra ulna* (Nitzsch.) Her. and *Spirogyra*; and aquatic insects and other indicator species are mainly *Libellulidae*, *Coenagrionidae*, *and Leptophlebiidae*. The results showed that a module using GAFI is from unpolluted to moderately polluted, while a module not using GAFI is moderately polluted to heavily polluted. GAFI can quickly improve water quality and increase biodiversity in waters, as well as the quantity and size of species, thus, it has merit for being applied and promoted in the field of water landscaping and ecological engineering.

1. Introduction

The artificial floating island has the functions of reducing the dispersion of pollutants, wave dissipation revetment, biological inhabitation and conservation, water cleaning, and landscaping (Nakamura and Mueller, 2008; Zhu et al., 2011). The emergent plants are planted on artificial islands floating on the water surface, but not on earth (Fonder and Headley, 2010). Nitrogen in wastewater exists in the forms of Org–N, NH_3–N, NO_2^-, NO_3^-, and nitrogen gas, and untreated sewage flowing into clean waters will cause severe eutrophication of water and have adverse effects on the aquatic ecosystem (Korkusuz et al., 2005; Li et al., 2007). Aquatic plants can directly absorb nutrients from water, which shows the effect of biological purification of water quality (Stewart et al., 2008; Bankston et al., 2002). After biological filtering by aquatic plants, the eutrophic elements, such as nitrogen and phosphorus, can be eliminated. Aquatic plants absorb nutrients from wastewater and substrates; however, for organic substances, the effect of absorption and biological degradation by aquatic plants is insignificant as compared with using environmental engineering facilities (Nahlik and Mitsch, 2006; Sheng and Masaaki, 2008; Watson et al., 1989).

The root system of aquatic plants provide a surface area for enormous growth of microorganisms, and such microorganisms on the surfaces of stems and roots of plants can enhance the removal of organic substances and secrete compounds to eliminate the pathogen (Tanner, 2001; Sooknah and Wilkie, 2004; Brix, 1994; Decamp and Warren, 2000). These effects are related to the DO (dissolved oxygen) furnished by the root system of plants (Brix and Schierup, 1990). Furthermore, the root system can decrease water flow speed, which improves the results of sedimentation and filtering (Tanner, 2001). The growth rate of aquatic plants is relevant to the temperature and pollution level of the waters where the plants are growing, and the more serious the pollution, the higher the salinity of nutrient salts, and the faster the growth rate (Kao, 2008). Moreover, it has low risk and low cost to remove, degrade, or adsorb hazardous chemicals in polluted waters by plants (Deng et al., 2004; Weis and Weis, 2004; Shankers et al., 2005). Mixed planting can increase the plant absorption rate of nitrogen by 48–99%, of phosphorus by 63–90%, and can stimulate the activity of microorganism to further raise the decomposition rate of phosphorus in water by 36–81%, and of nitrogen in water by 50–53%; for mixed planting, different populations of aquatic plants compete and promote the purification of nitrogen and phosphorus in water (Chang, 2006).

* Corresponding author. Tel.: +886 937523685; fax: +886 4 8782134.
E-mail address: f89622050@ntu.edu.tw (Y.-H. Chang).

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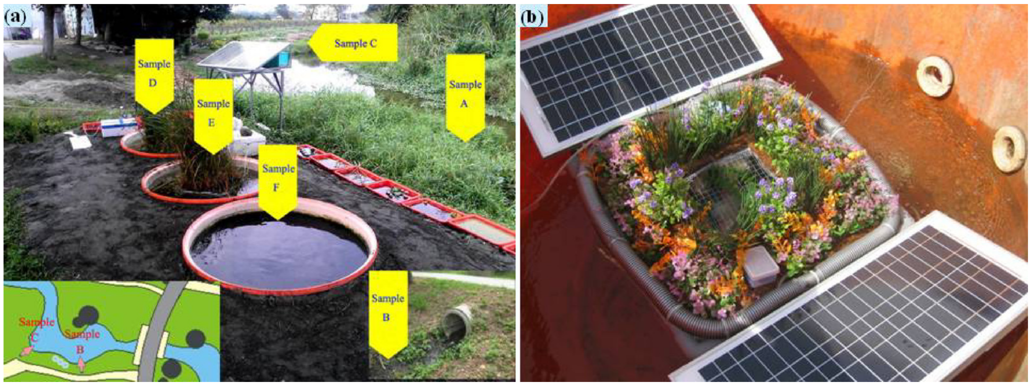

Fig. 1. Experimental location of water samples and green energy artificial floating island.

Placing charcoal in water can reduce toxic organic compounds, improve suitability for drinking, and remove any odors (AWWA (American Water Works Association), 1999). Charcoal is delicate and odorless, with adsorption effects for toxic heavy metals, toxins, gases, drugs, fats, and liposoluble substances (Pehlivan and Kahraman, 2011). Most charcoal materials have the ability of water purification, and are generally used in ditches, household drainage, and kitchens (Mitsuyoshi, 1997). Sano (1987) proposed the essential advantages of filter materials, for example, the larger the growth area of microorganisms, the better; as water flowing through the filter materials is uniform and turbulent, the water has good effects in contact with microorganisms. The filter materials must have sufficient strength, be lightweight, and operation should be simple, easily cleaned, and repeatedly used. The brush has the advantages of filter material. Aeration can purify water and provide oxygen for the oxidative degradation of microorganism by forcing the water to flow; moreover, the surface tension of air bubbles is utilized for adsorption and air floatation to remove particles in water (Hou and Yeh, 2007).

Kou et al. (2005) pointed out that, microcystis appears in most reservoirs of Taiwan, and leads to algal bloom that may multiply in waters with organic pollutants, especially at high temperatures, which occurs seasonally and often from late spring to early fall, blooming in summer; the cells with air bubbles inside float on the water surface at about 1 M, and is at its most dense within 1 M of the water surface. As suggested by Kou et al. (2005), to reduce nutrient sources of total phosphorus at the bottom layer of a reservoir, and referring to effective means of controlling eutrophication among experiential cases of lake and reservoir regulation abroad, the items that can be improved by aeration and artificial floating island are comprised of the following: keeping the toxic state at the bottom layer; increase the sedimentation rate of biological substances; break stage aeration that may reduce eutrophication in reservoirs; and wind force and solar energy used as power sources. Biological indicators can detect pollutants lower than the limit of the general analysis method, detect long-term changes of pollution concentrations in monitored environments, and determine pollution distribution in surveyed areas and changes to physiological gradient (Ravera and Riccardi, 1997). The indicator organism, a concept proposed by Kolkwitz and Marson from Germany, does not depend on precision instruments to monitor water quality and can make up for the deficiency of physico-chemical analysis.

The method has the following features: long-term intervention of reactive pollutants on organisms and interactions between the same species or populations; is more easily understood and accepted by common people than physico-chemical analysis; algae, zooplanktons, and phytoplankton are microorganisms that are widely distributed and can quickly adapt to environmental changes; it is easily sampled and observed, and is more representative of river water quality (Tien and Wang, 2004). Representative environmental indicator organisms are selected to explore possible reactions and impacts, which can further estimate the state of environmental quality, are widely available, easily observed, and measurable, and most importantly, are sensitive to the reactions of pollutants (Jou, 1996). Tien and Wang (2004) suggested that microorganisms, algae, aquatic insects, benthic invertebrate, and fishes can be used as indicator organisms.

2. Materials and methods

2.1. Study area

The experimental site is located at Lize Lake of MingDao University in Changhua, Taiwan E23°86′79′′, N120°49′33′′ (Fig. 1a). Sample A (SA) is the water of Lize Lake, Sample B (SB) is the drainage outlet for domestic sewage from dormitories, and Sample C (SC) is the water discharged from the wastewater treatment plant of the university. Three round water tanks are placed about 2.5m from the lakeshore, with a diameter of 1.3 M and depth of 1.65 M. SA lake water is filled into the Sample D (SD) tank; SB water is filled into the Sample E (SE) and Sample F (SF) tanks; GAFI is added to SD and SE tanks, but not to the SF tank, which is the reference group.

2.2. Materials

2.2.1. GAFI

The area of GAFI is 60 cm × 60 cm and the opening area of the net cage in the middle is 20 cm × 20 cm. The floating island is comprised of PVC pipe, coconut fiber mat, plastic mesh, plastic hose, aquatic plants, net cage, solar power supply device, and aeration equipment. Submerged and floating plants are placed the net cage, with brush and charcoal as the filter material for water purification. The charcoal is strip-shaped with the total weight of 1 kg, and 4 brushes are hung in the net cage. Charcoal is staggered on the cage bottom for water to flow through, and 3 points are set around the floating island by an aeration device, which extends to 5 cm above the bottom by silicone hose to connect to the air stone for aeration and improve water purifying efficiency by microorganisms in the filter material (Fig. 1b).

GAFI plants are mixed, with the net cage as the center, from the center to the peripheral, and from tall plants to short plants, i.e. *Typha orientalis Presl*, *Eleocharis dulcis*, *Juncus effuses*, *Bacopa monnieri*, *Ludwigia taiwanensis* (8 plants each), the floating plants in the net cage are *Eichhornia crassipes* and *Hydrocharis dubia* (1 plant each), the submerged plants are *Ceratophyllum demersum*