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The effect of a green energy landscape fountain on water quality improvement

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ABSTRACT

Obtaining clean water from limited water resources has become very important issue in modern society. The subject is also the main focus of this study. The study site was located on the shore of open water within the campus of Mingdao University. The study site consisted of three water tanks, dug 1.5 m away from the shoreline. Comparison analysis on water quality improvement between waters with green energy landscape fountains (GLF) and waters without GLF was performed. GLF is a floating island equipped with solar panels supplying electricity. Its size is approximately 60 cm × 60 cm, made of PVC pipes. Six different bodies of water (A–F) and twelve indicators of water quality improvement were studied during a 12-month period. The study results revealed that waters with GLFs all showed improvement in water quality. Temperatures and pH levels among top, middle and bottom layers of water were not significantly different. The rates of removing EC, TN, PO_4, and COD from waters were all above 50% while removal rates for NH_3–N, NO_2, and NO_3 all reached 100%. The findings demonstrate the benefits of GLF on improving the quality of water. This study also provides information which can be applied in landscape architecture, architecture and ecology design and engineering in the future.

1. Introduction

The growth of plants in aquatic environment tends to reach from land onto the water surface. Subsequently when the part of the plant connected to land dies or breaks off, a floating island is formed (Hsi Liu Environmental Greening Foundation, 2009). Nakamura and Mueller (2008) indicated that floating islands help contain the spread of pollution at water entry points. It also reduces the speed of water flow allowing pollutants to be intercepted and settled through its plant roots and overall body. Floating islands on water surfaces protect shorelines from erosion by reducing energy and water dissipation from water waves (Takagi, 1996). When a floating island is disconnected from land, a separate ecosystem with its own food chain, including from flying insects, insect-trapping spiders, fishes, amphibians, and amphibian-feeding fishes and birds is established (Hsi Liu Environmental Greening Foundation, 2009). Artificial floating islands (AFIs) were placed in lakes in New Hampshire, USA as early as 1900 to provide nesting grounds and habitat for birds of the Gaviidae family (AFI Study Group, 2000). In Asia, the earliest artificial floating structure was recorded in Japan in 1920. Branches were tied together and placed in lakes, providing grounds for fish to lay eggs (Hirose, 1997). According to Environmental Protection Administration, R.O.C (2013), the Thao tribal people residing in Sun Moon Lake area were pioneers in building artificial floating islands in Taiwan. They used bamboos covered with grass sheets as floating frames to grow paddy, known as "floating farmland".

Fonder and Headley (2010) and Environmental Protection Administration, R.O.C (2013) both pointed out that one way to construct an artificial floating island is to grow plants on top of floating masses. During plant growth, carbon-based organic compounds, nitrogen, phosphorous and other nutrients are absorbed through plant roots below the water surface. Concentrations of nitrogen and phosphorus are lowered and plants can be manipulated to maximize absorption rate within the island (Stewart et al., 2008). Small land requirement and low costs are among the advantages of AFI listed in the studies by Wen and Recknagel (2002) and Zhao et al. (2012).

Other benefits of AFIs included providing habitats for living organisms and ecological conservation. AFIs increase habitat areas for water organisms, and act as sanctuaries for fishes, birds, insects, and amphibians. Successful examples of using AFIs to restore bird population have been reported in Canada (Will and Crawford, 1970; Fager and York, 1975; Payne, 1992; Hiraoka, 1996; Mueller et al., 1996; Momose et al., 1998). Cheng (2006) indicated that in acting as shoreline protection to dissipate water waves, AFIs are

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not affected by depth of water. They are easy to construct and cost is low. At the same time, they easily blend in with surrounding landscape. Ohsima et al. (2001) explained that AFIs can suppress growth of phytoplanktons and algae, and prevent eutrophication. They also enrich the aquatic ecosystem. Furthermore, they elevate the overall landscape aesthetic, while removing pollutants from the water.

Aquatic plant is one of the components of AFI. According to Environmental Protection Administration, R.O.C. (2013), a total of 48 different species of floating, emerged and submerged aquatic plants are commonly found in wetlands. *Bacopa monnieri* (L.) *Wettst.* is the most suitable for AFI. Environmental Protection Bureau of Yi-Lan County (2005) pointed out that plants should have a high adaptability to the environment and strong tolerance and adsorption to pollutants. Environmental Protection Administration, R.O.C. (2013) mentioned that floating ability of *B. monnieri* (L.) *Wettst.* can provide the needed supports for plants whose growth requires adherence to ground, to migrate from land to water surface to form a floating island Shih (2006). *B. monnieri* (L.) *Wettst.* along has 5.1% and 7.6% adsorption rate of nitrogen and phosphorous, respectively. Through its breathing roots, *Ludwigia (x) taiwanensis* allows adherence of micro-organisms and prevents overgrowth of algae while purifying water. Taipei Expo Foundation (2011) explained that soil required for growing *Ruellia brittoniana* does not have to be rich. Whether as wetland plant or aquatic plant, it can be grown to sculpt beautiful landscape along the shoreline. Also Dai and Chiang (2008) revealed that *R. brittoniana* has 56.49% nitrogen and 15.58% phosphorous average removal rate. *Angelonia angustifolia* is very suitable for AFI and easy to grow because it prefers an environment that is warm, wet, sunny, and with good water drainage. Oxygen aerator also has the ability to purify water. The main purpose of aerator in commercial fishpond is to improve the overall water quality. Water with low dissolved oxygen (DO) level not only interrupts fish migration, in some cases it causes death (Horne, 2001). An aerator forces water flow. It provides oxygen needed by mirco-organisms to decompose organic compounds. Dissolved oxygen concentration is an important indicator for overall wellbeing of an aquatic ecosystem. Particles are adsorbed through surface tension of water bubbles.

The GLF in this study utilized 4 emerged plants for experiment: *Scrophulariaceae, L. (x) taiwanensis, R. brittoniana*, and *A. angustifolia*. In this study, 12 different indicators were used to determine the effects of water purification by GLF, which offers an alternative to ecological conservation effort.

2. Materials and methods

2.1. Study area

The location of this experiment was in the orchard of Mingdao University campus in Xizhou Township of Changhua County in Taiwan, E23°86′79″, N120°49′33″.

2.2. Materials

2.2.1. GLF structure

The 60 cm × 60 cm outer frame of GLF was made of PVC pipes with a diameter of 3 in. At the bottom of the middle portion of the GLF, *Scrophulariaceae,L. (x) taiwanensis*, *R. brittoniana*, *A. angustifolia* were planted atop three layers of 50 cm × 50 cm palm fiber mat. Inside the filtering chambers were charcoal, hairbrush, pebbles and other filtering agents. Solar panels provided electricity for the water pump below, which supplied water for the water fountain above.

Black plastic netting was attached to the bottom of GLF to prevent palm fiber mats from sliding off. Clamps were used to reinforce the structural stability. GLF is made mostly from recycled materials. In addition to the water pump, a pipe aerated air to water below to increase DO level for water quality improvement (Fig. 1).

2.2.2. Measuring apparatus and materials

2.2.2.1. Water quality measuring apparatus. 12 water quality experiments were conducted. A YSI-Pro Plus Multichannel CTD was used to measure water temperature (WT), electrical conductivity (EC), pH, oxygen reduction potential (ORP), and DO levels in water. A portable HACH DR-890 spectrophotometer was used to measure NH_3–N, nitrite (NO_2), nitrate (NO_3), orthophosphate (PO_4), total nitrogen (TN), total phosphorus (TP), and chemical oxygen demand (COD).

2.2.2.2. Physical environment monitoring. A microclimate monitor (VS7LOGGER) was installed at the experiment site to record physical environment data such as solar radiation, illumination, rainfall, temperature, and humidity every 10 min for a 12-month period.

2.2.2.3. Solar power equipment. The equipment was mounted close to the water edge within the experiment site. Solar panels were angled at 23° facing south. Other related equipment was installed underneath the panels supplying electricity for GLF D and E. The specifications of solar panels and other equipment are as follow: two 100 W monocrystalline solar panel measuring 160 cm × 108 cm; solar panel control box (12V20A); solar deep cycle battery (EVX): 12V100A, 2 extra slots for spare batteries.

2.3. Methods

2.3.1. Water sampling and water quality research

1.5 m away from the edge of the water, 3 water-holding holes measuring 1.7 m in diameter and 2 m in depth spaced 20 cm apart were dug. Equal-size water tanks were placed in the holes to prevent water seepage. Readings from 6 Samples of water from A to F were compared. The six water bodies (A–F) are as follows. A: water from water purification station; B: water from Lize Lake (on campus); C: wastewater from student dormitory (non-stagnant water); D is injected with water from Sample B and GLF is installed for comparing results with Sample B; E is injected with water from Sample C and GLF is installed for comparing results with Samples F (stagnant water) and C. Sample F and Sample E served as the control samples. Waters in D–F were further divided into three layers: top (5 cm below water surface); middle (20 cm below water surface); and bottom (5 cm below bottom surface) for testing purposes. Based on the water quality testing guidelines released by EPA of Executive Yuan, readings of 6 Samples of water from A to F were recorded weekly on friday morning between 10am and 12pm from November 2012 to November 2013 (Fig. 2).

During the 12-month period, a multichannel CTD model YSI-Pro Plus was used to collect measures of WT, EC, pH, ORP, DO from the top, middle and, bottom layers of water, respectively. Portable spectrophotometer model DR-890 was employed to collect measures of NH_3–N, NO_2, NO_3, PO_4, TN, TP, and COD in waters on a monthly basis. Analysis was then performed utilizing the data collected above to evaluate the change over the course of the year.

2.3.2. Physical environment monitoring

Physical environment monitoring was carried out by the microclimate monitoring station installed on site. Data on solar radiation, illumination, rainfall, air temperature, and humidity were gathered every 10 min during the 12-month experiment.