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A New Wetlands Technology for Wastewater Treatment

Floating Islands as a Remediation Tool

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Floating islands, also known as floating treatment wetlands (FTWs), are a relatively new technology for improving water quality and creating habitat. More than 5,400 floating islands have been installed around the world in the past decade. Island sizes range from small, decorative units to some that are larger than football fields and can be made in any shape or buoyancy. Islands have withstood numerous freeze/thaw cycles, as well as typhoons, tornadoes, hurricanes and major snowfalls.

Primary uses for FTWs include water quality improvement for lake water, wastewater or stormwater; fishery enhancement; destratification or dissolved oxygen enhancement; and creation of waterfowl and riparian edge wildlife habitat. The typical duty of FTW technology is to rapidly cycle nutrients for appropriate biota within target waterways. Secondary uses for FTWs include erosion control, wave dampening and structural platforms, stemming from the product's materials and construction design. Removal rates have been developed in field-scale applications for contaminants such as ammonia, nitrate, phosphorus, metals, total suspended solids (TSS) and biochemical oxygen demand (BOD). FTWs may have application at industrial sites for such contaminants.

FTW demonstration projects have been completed in collaboration with the USACE, USGS, NRCS, U.S. Forest Service, the Government of Singapore, New Zealand's National Institute of Water and Atmospheric Research and others. FII's research team and collaborators includes individuals associated with biofilm and wetland studies in North America and internationally

Case Studies

Numerous case studies have been developed around municipal wastewater treatment, stormwater, lakes and agricultural runoff, "living shorelines" and erosion control. Applications for landfill leachate, propylene glycol, endocrine disruptors and metals have also been explored.

• Landfill leachate is a problematic water stream to treat, but initial results indicate that the original floating island product developed 10 years ago (Figure 1), can effectively improve its quality. The islands were installed to cover about 20 percent of the surface area of an existing lagoon system in New Zealand. Removal of color (Figure 2) and TSS (89 percent compared with upstream samples) were exceptional, and FTWs also substantially removed total nitrogen and BOD.

• Propylene glycol is a deicing agent commonly used at airports. An island installed to remove propylene glycol from airport stormwater in Bangor, Maine, thrived during harsh weather, but its efficacy was not measurable due to its small size and low glycol concentrations. However, glycol concentrations were reduced from greater than 500 mg/L to less than 1 mg/L in subsequent lab-scale tests.

• The studies show that FTWs will remove contaminants such as nitrogen, phosphorus, BOD, TSS and propylene glycol from water. Another lab-scale test indicates that FTWs can also reduce dissolved concentrations of the endocrine disruptor Bisphenol-A (BPA), a chemical commonly used in production of plastics and epoxy resins. BPA has been directly linked to gender ambiguity in fish. BPA is one of many man-made chemicals that have been recently detected in the nation's waterways through use of more sensitive analytical techniques. Along with pharmaceuticals, concentrations of estrogens and their mimickers have been detected well above background levels. Due to significant changes in behavior of the marker fish that were studied, it appears likely that a microbial biofilm growing on and around the island in this study degraded BPA to below the initial concentration of 50 ng/L.

• A FTW installed in the Billings, Mont., Metra Park stormwater pond has effectively removed nutrients, metals and other contaminants, with average removal percentages ranging from 41 percent to 80 percent. In November 2008, the city personnel constructed a pond to treat a portion of stormwater discharges originating from a 174-acre drainage dominated by light industrial and commercial properties. A large island was installed in the Metra pond shortly after its construction, along with a smaller system in the channel preceding the pond. The FTWs were planted with native grasses and other vegetation in May 2009.

The Metra pond results agree with a detailed scientific study recently performed with FTWs in New Zealand. In that study, a stormwater pond with an FTW significantly outperformed a pond without an FTW, with removal of

TSS, particulate zinc and particulate copper improving by 41 percent, 40 percent and 39 percent, respectively. It was theorized in the New Zealand study that biofilm attached to the plant roots provides a significant removal pathway for TSS and particulate metals. Due to changes in pH and dissolved oxygen induced by the FTW, adsorption and precipitation of dissolved metals also increased.

FTWs for Nutrient Removal

Nutrients in water are problematic in North America and around the world. Under current best management practices, nitrogen and phosphorus tend to cycle into algae, cyanobacteria, aquatic plants or benthic organic matter poised to return to the waterway given appropriate conditions. Most waterways in the United States also experience at least occasional hypoxic (low oxygen) conditions. An estimated 25 percent of lakes in the United States seasonally experience even worse dissolved oxygen conditions and become anoxic. This factor greatly limits such waterways, preventing them from sustaining biota that could otherwise continue cycling nutrients out of the water.

Nature's wetland effect provides an alternative. Given sufficient biofilm reactive surface area in combination with circulation, biofilm-generating bacteria can cycle nutrients into periphyton at levels sufficient to keep up with inflow and inventoried nutrients. Periphyton is the viable microfloral community attached to the surfaces of submerged objects in water; it comprises biofilm, algae, fungi, zooplankton and larger invertebrates.

Harvesting fish and other aquatic life fed by FTWs can be part of this strategy. By harvesting fish at levels that exceed influent nutrient quantities, waterways can be transitioned from a eutrophic or hypereutrophic level to mesotrophic, with corresponding improvement in all standard water quality parameters. When combined with strategic fishery management, biofilm/periphyton can provide a food base for up to 55 pounds of fish per acre-foot of water, based on a year-long study at Fish Fry Lake near Shepherd, Mont. This mass of fish translates to about 0.5 pounds of phosphorus per acre-foot that could be removed from water. If left unattended, that same amount of phosphorus could cycle into about 3,600 pounds per year of aquatic plants or 550 pounds of filamentous algae.

In addition to removing phosphorus via the food web, FTWs can remove it via three other pathways:

• Incorporation into biomass in the FTWs – This mass will grow indefinitely and could be periodically harvested if not incorporated into the food web.

• Incorporation into biomass that will sink to the pond sediments, along with adsorption to sediment – This is one manner in which phosphorus is already sequestered in many ponds; FTWs can enhance this process and make it permanent by maintaining aerobic conditions, if aeration is included. Once phosphorus has been incorporated into biomass and sediment, it should remain precipitated and out of the waterway. Studies conducted at Michigan's Houghton Lake over the past 40 years demonstrated that phosphorus will continue to accumulate within wetland soils. In that large wetland, the phosphorus concentration in treated municipal wastewater is reduced from about 3 mg/L to less than 0.1 mg/L.

• Phosphorus removal via plant uptake – However, studies have shown that plant uptake of phosphorus comprises only 6 percent or less of the total removal. Most of this removal is contained in plant roots rather than above-surface vegetation.

Using public information, Floating Island International (FII) has developed a cost chart comparing FTWs to other technologies for phosphorus removal (Figure 3). FTWs, either with or without aeration, have substantially lower costs than alternative technologies such as alum treatment.

FTWs are scalable by building larger or multiple units. Islands for water treatment of very large water bodies and high nutrient loads, encompassing many acres, have been proposed and are being considered as alternatives to more invasive, costly technologies such as dredging.

Industrial Applications

FII has developed four variations of FTW technology:

- BioHavens – the original product.
- Floating streambeds – a newer product utilizing circulation and aeration.
- Freshwater coral – a completely submerged product attached to BioHavens or floating streambeds, or anchored in place.
- Elevated bioswales – a variation of floating islands placed in irrigation ditches and swales.

Each option represents a method for utilizing nature's concentrated wetland effect. FTWs could be applied to industrial sites:

• They have been shown to remove total metals (as particulate or attached to other suspended solids) and dissolved metals (due to changes in water chemistry).

• Most of their nutrient removal efficacy is due to biofilms – at least 80 percent, according to research, with the other 20 percent coming from plants. Bacteria in biofilms are very resilient and difficult to kill or even inhibit.

• Studies have shown that aerobic, anoxic and anaerobic bacteria can coexist and operate within a single biofilm. This ability makes possible biological processes that may require a range of environmental conditions, such as nitrogen removal. Settings that are too extreme for plant life are frequently conducive to bacterial growth.

• Native bacteria are capable of breaking down hydrocarbons and nearly any other contaminant present at industrial sites, given the proper environmental conditions.

• Hazardous waste takes many forms; however, biofilm is a natural means to biosequester or bioremediate a wide range of heavy metals and toxic compounds. Studies have shown that plants are not required to grow biofilm. Since some hazardous waste settings may be too extreme for plants, a floating "lid" (designed to entirely cover a water body or lagoon) may be appropriate. This approach has been successfully used at a wastewater setting in New Zealand (Figure 4). Benefits to such a system are: 1.) odor control, 2.) a barrier to birds and wildlife and 3.) long-term bioremediation of hazardous materials.

• Some industrial waterways cannot support a fully functional food web, so these systems can become noxious insect breeding grounds. As a strategy to mediate insects that can spread West Nile disease or blue tongue/EHD, FTWs are being used in waterways from the size of livestock tanks to hypoxic lakes. Islands with grid-based or solar-powered circulators can provide a concentrated wetland effect to ensure an active food web (Figure 5).

Summary

By biomimicking nature, FTWs provide the concentrated wetland effect that transitions nutrients through the food web. FTWs and natural floating islands are essentially simple biofilm reactors that can include plants.

FTWs have been used to treat a diverse selection of waters (eutrophic lake water, raw municipal wastewater, treated wastewater, landfill leachate, stormwater) with a variety of contaminants (suspended solids, nutrients, organics, metals). Numerous case studies provide removal rate estimates for these contaminants. It is believed that FTW applications can be expanded to hazardous waste sites and other industrial applications where FTWs could provide a water treatment solution for the site or at least the first stage of treatment.

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