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ISSN (Online) 2394-6849

International Journal of Engineering Research in Electronics and Communication Engineering (IJERECE)
Vol 4, Issue 2, February 2017

Artificial Floating Islands as Eco-Engineered Remedy: A Review

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Abstract: - **In present years, water pollution has become one of the most critical environmental challenges. The Artificial Floating Islands (AFIs) are an innovative variant of wetlands with substrates-rooted plants and free-floating aquatic plant systems, which consist of aquatic or terrestrial plants growing in a hydroponic manner with buoyant frames floating on the surface of water bodies. Eco engineered remedy such as floating wetland is commonly presented as an important strategy for maintaining and improving water quality and aesthetic appearance of water bodies. Literature review indicates that previous works are carried out at different scales using different design parameters. Artificial Floating Islands (AFIs) are vegetated floating platforms applied in lakes, ponds and reservoirs to improve the aquatic environment. AFIs have four functions: water purification, habitat enhancement shoreline erosion protection, and improved landscape features. This paper reviews the studies carried out by earlier researchers on AFI. The primary advantages of AFIs are that they float and adjust to water level variations in reservoirs and reduce predation risks by providing safe protections for nesting birds. The paper presents the type, structure, function, and developing history of AFIs. By analyzing the social-economic benefits, advices are given for applying AFIs technology to improve the water environment and to improve crops thereby creating a "win-win" model for both environmental protection and agricultural development in rural places. Based on the review it can be concluded that AFI technology is promising and acceptable even indigenously.**

Keywords:— **Artificial Floating Island (AFI), Nutrient Removal, Wastewater Treatment.**

I. INTRODUCTION

Covering over 70% of the Globe's surface, water is certainly the most exclusive ecological resource. Although we as humans recognize this fact, we overlook it by polluting our rivers, lakes, and oceans. After, we are slowly but surely spoiling our planet to the point where organisms are dying at a very frightening rate. With regard to our human beings, one fifth of the world's population is without access to safe drinking water and half of the population is without access to suitable sanitation. These facility deficits predominantly afflict the poorest areas of the population in developing countries. Floating islands are nothing but floating treatment wetlands (FTW). Floating islands comprise a mat of synthetic matrix at the water surface into which macrophytes are planted. While water passes through the synthetic matrix, it gets purified due to various mechanisms. Floating islands are being used for agriculture in some place in the world. Documentary records suggested that about 1700 years ago (China's Three Kingdoms Era), Chinese farmer started to adapt AFIs for planting rice and vegetables. This floating aquatic cultivation is still applied in some Asian countries such as Myanmar, India, Bangladesh and China (Zhaohua et al. (2013)). FTWs employ rooted, emergent macrophytes (similar to those used in surface and subsurface flow wetlands) growing as a floating mat on the surface of the water rather than rooted in the sediments. The plant roots hanging beneath the floating mat provide a large surface area for biofilm growth and entrapment of fine suspended particulates in water. Because the plants are not rooted in the sediment, they are forced to acquire their nutrition directly from the water column, which enhances potential rates of nutrient and element uptake.

FTWs have been used for the treatment of: Combined storm water-sewer overflow, Sewage, Acid mine drainage, Piggery effluent. Poultry processing wastewater, Water supply reservoirs. Constructed treatment wetlands have usually involved the use of free-floating aquatic plants, or sediment-rooted emergent wetland plants, either with water flowing through the root zone (subsurface flow) or amongst the stems (surface flow). Floating treatment wetlands (FTWs) are innovative alternatives that employ rooted, emergent plants (similar to those used in surface and subsurface flow applications) growing as a floating mat on the surface of the water rather than rooted in the sediments. Attempts for exploring FTWs as an eco-engineered remedy to water pollution are being put together in the present paper.

II. REVIEW OF WORKS ON FTW

Ash and Truong(2004) have presented a case study wherein in situ preliminary treatment of the pond

ISSN (Online) 2394-6849

International Journal of Engineering Research in Electronics and Communication Engineering (IJERECE)
Vol 4, Issue 2, February 2017

effluent was accomplished by floating platforms placed in the ponds (Figure 1). The 21 floating pontoons were designed so Vetiver plants sitting on the pontoons and the roots suspending in the effluent. The size of each pontoon is 2.4m x 2.4m with about 300 individual plants placed on each pontoon. The number of pontoons required was based on the level of nutrient load. Maintenance program included replacement of dead plants, regular harvest to encourage new growth and the export of absorbed nutrients.

Figure 1- Vetiver pontoons Vietnam (Source: Ash and Truong (2004))

The Vetiver grass plants established and flourished (up to 1.5m in 3 months) under hydroponic conditions. Vigorous growth has been seen in the Vetiver grass plants that were placed onto the 21 pontoons indicating effective primary treatment. The pontoons then served as the source of Vetiver grass for the project. The Vetiver Grass wetland with primary treatment by FTWs indicated itself to be a suitable alternative to more expensive solutions to upgrade existing sewerage treatment plants. It has been commented that a high technology solution is not necessarily the best available option.

Headley and Tanner (2008) reviewed the FTW concept, structure and function of FTP, and discussed some of the potential advantages of this emerging technology for storm-water applications. They have earmarked that FTWs can tolerate the wide water depth fluctuations typical in storm-water systems, without the risk of the plants becoming inundated and stressed. FTW combines aspects of a pond and a wetland; they behave hydraulically similar to a storm-water detention pond, whilst imparting similar treatment processes to that of a wetland. The plant roots hang beneath the floating mat and provide a large surface area for biofilm growth which forms the central part of the treatment. Headley and Tanner (2008) have provided a list giving main purpose of various studies on FTWs (Table 1). Based on the review, Headley and Tanner (2008) have concluded that FTWs have the key advantage, in terms of storm water management, of being able to accommodate variable water depths. They have recommended further work to assess the long-term performance and process dynamics of full-scale systems under field conditions and to develop robust sizing and system design approaches to optimise the desired treatment processes and reliably achieve water quality objectives. In this regard, it will be particularly important to gain a more thorough understanding of the degree of passive aeration that can be achieved by manipulating the ratio of open water to floating mat coverage.

Table1: Reported Applications of FTWs

Storm-water	Headley and Tanner,(2007) Kerr-Upal et al., (2000) Revitt et al.,(1997)
Combined storm-water and sewer overflow	Van Acker et al., 2005
Sewage	Ash and Truong, (2003) Ayaz and Saygin, (1996) Todd et al.,(2003)
Acid mine drainage	Smith and Kalin, (2000)
Piggery effluent	Hubbard et al., (2004) Ash and Truong, (2003).
Poultry processing Wastewater	Todd et al., (2003)
Water supply reservoirs	Garbutt, (2004)

Headley and Tanner (2008) have presented a conceptual design of a storm water treatment train incorporating a FTW as shown in Figure 2

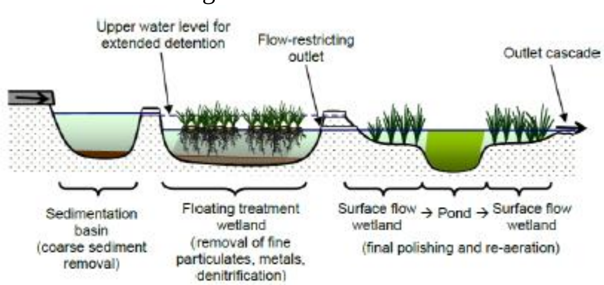

Figure 2- Conceptual Design of Storm Water Treatment (Source: Headley and Tanner (2008))

Nakamura and Mueller (2008) have put forth significance of FTWs as a Restoration Tool for Aquatic Environments. They specified four functions of artificial floating islands (AFIs) as: 1) water purification, 2) habitat enhancement, 3) shore line erosion protection, and 4) improved landscape features.

Figure 3 - AFI in Lake Kasumigaura (Source: Nakamura and Mueller (2008))

It is reported that in Japan more than 70,000 square m of AFI structures are present. AFIs are also found in China, England, Germany, Korea, and Taiwan. AFI provides critical habitat for birds and provide important substrate for spawning fish. According to Nakamura and Mueller (2008), 10 to 30 % surface area of water bodies such as lakes and reservoirs covered by AFIs mitigates the effect of eutrophication.

Yao et.al (2011) identified significant types of AFI plants. Artificial floating island (AFI) with soft stem bulrush (Scirpus validus Vahl), spiked loosestrlfe (Lythrum salicaria Linn.), yellow-flowered iris (Iris wilsonii) and dwarf cattail (Typha minima) were monitored on an experimental scale. It is reported that AFI with plants had a strong capacity for the removal of nitrogen and phosphorus. Particularly, soft stem bulrush (S. validus Vahl) and spiked loosestrlfe (L. salicaria Linn.) were found to be excellent aquatic plants in Beijing wetland restoration.

Faulwetter et.al (2011) evaluated two matrix materials for treating domestic wastewater, recycled plastic and recycled carpet fibres, for COD and nitrogen removal. These materials were compared to pea gravel or open water (control). Experiments were conducted in laboratory scale columns fed with synthetic wastewater containing COD, organic and inorganic nitrogen, and mineral salts. Columns were operated in batch mode with continuous recirculation and aeration. COD was efficiently removed in all systems examined (>90% removal). Ammonia was efficiently removed by nitrification. Removal of total dissolved N was ~50% by day 28, by which time most remaining nitrogen was as NO3-N. Complete removal of NO3-N by denitrification was accomplished by dosing columns with molasses. Shifts in the denitrifying community were observed post-molasses addition, when nitrate levels decreased. The conditioning time for reliable nitrification was determined to be approximately three months. These results suggest that floating treatment wetlands are a viable alternative for domestic wastewater treatment.

Rather interesting study is published by Floating Island International Inc. USA (2011) entitled as, “Floating Islands Outperform Constructed Wetlands”. The study projects are located Rehberg Ranch Residential Subdivision, Billings, Montana USA and McLean’s Pit Landfill, Greymouth, New Zealand. The project used branded FTWs named as BioHaven® floating islands. Promising pilot studies with BioHaven® floating islands or floating treatment wetlands (FTWs) showed superior results when compared to constructed wetlands. In comparing municipal wastewater and landfill leachate treated with both systems, BioHavens had higher removal rates and percentage removal for ammonia, total nitrogen, biochemical oxygen demand (BOD) and total suspended solids (TSS) as presented in Table 2 and Table 3. The Rehberg Ranch residential subdivision was built beyond the reach of the city’s municipal sewer system. So, developers constructed an aerated lagoon domestic wastewater treatment system engineered and designed to meet US EPA secondary standards for BOD and TSS. Subsequently in November 2009 Floating Island International installed an experimental FTW design in one of the subdivision’s two aerated lagoons. The City implemented a rigorous monitoring regime to measure efficacy of the FTW system in comparison to the control lagoon with no FTW. Both lagoons received the same wastewater. There was considerable enhanced performance of the lagoon having AFI as seen from Table 2. Figure 4 gives the photograph of the aerated lagoon with AFIs. Further, FTW treatment was tried successfully for Landfill Leachate in New Zealand for South Island town Greymouth. Water-clean Technologies constructed and installed 288 m2 of BioHavens to cover approximately 20% of the lagoon surface in half of the lagoons, in November 2009. The wetland plants being utilized are Carex virgata and Cyperus ustulatus. The improved performance is evident from Table 3.

Table 2: Comparative Performance for municipal waste water

	Removal percentage	
Parameter	FTW	Constructed Wetlands
BOD	89%	81%
Total Nitrogen	69%	39%
NH_4-N	83%	21%
TSS	53%	68%
Size, Sq. m	214	1197

Table 3: Comparative Performance for Landfill Leachate

	Removal percentage	
Parameter	FTW	Constructed Wetlands
BOD	46%	33%
Total Nitrogen	40%	33%
TSS	89%	55%
Size, Sq. m	288	877

Figure 4 – Aerated lagoon with AFIs at Rehberg Ranch, USA (Floating Island International Inc. USA (2011))

Zhaohua et al. (2013) analysed the social-economic benefits of AFIS, and they gave suggestions to China applying AFIs technology to improve the water environment and to cultivate crops thereby creating a "win-win" model for both environmental protection and agricultural development in rural places. The AFIs are classified as shown in Table 4. Wet type AFIs are deployed for water purification as plant roots come in direct contact with waste water. In dry AFIs as there is no direct contact, they are more useful for providing habitat for birds as well as aesthetic purpose.

Table 4 - Type of AFIs

Wet Type	Mat-with-frame
	Mat-without frame
	Floating log type
	Waste tire type
Dry Type	Box type
	Floater type

Yeh et al. (2015) appraised the artificial floating island (AFI) concept, structure, and functions. The applications of AFI technology for a variety of applications such as nutrition removal, biomass production, aquaculture and agriculture, as well as wastewater and storm water treatment are reported. Further, it is pronounced that certain efficient water purification plants (such as water peanuts and water hyacinth) can be harmful to the native ecosystem when introduced to the areas outside their native distribution areas; and improperly selected and managed AFIs are reported to likely trigger undesirable effect on the local agriculture, aquaculture, and biodiversity due to invasive species. The decayed, long soaked floating materials can also become a source of pollution.

In Pune, Deshmukh et al. (2016) explored use of FTW technique to treat nallah water polluted by sewage. The lab scale experiments were carried out. The Frame of size 0.9 m * 0.8m was made with the help of plastic bottles and pipe with 100mm dia., as plastic bottles would provide buoyancy for floating. Surface of frame was covered by mesh for plantation with the help of nylon rope. For Pilot Scale Experiment a tank of capacity 1000 lt. was filled with nallah water. Floating island was installed in the tank. Indigenous Canna plants were planted on floating mat in the tank treatment covering 60% of area. Based on batch studies it was found that the efficiencies of nitrate and phosphate removal using AFI technique increased with growth and age of the plants. After 21 days, almost 90-95% BOD and COD removal is reported due to the AFI technique adopted.

III. CONCLUDING REMARKS

The AFI technology is definitely eco-friendly, and the same can foster sustainable development. However, there are not as much of scientific studies. So, there is lack of design and operation standards to meet diversified requirements of pollution mitigations. It is essential to bring the issue to notice of researchers. In this view following aspects of AFIs need to be thoroughly investigated, and an appropriate design and operation standard are to be evolved in order to ensure widespread use of the AFI technology.

- Native macrophytes appropriate for specific applications need to be identified.
- Need of passive and artificial aeration to be investigated thoroughly.
- Dependable ratio of area of AFIs to pollution load needs to be determined.
- Construction and maintenance details of AFIs need to be specified to suit indigenous constraints.

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