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# Floating Islands for Urban Resilience Aquatic Resources Management in the Tropics: Win-Win-Win Strategies for Eutrophication Control, Aquafarming and Waterborne Green Transport System

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## Abstract

Various wastes from ever rising populations, widespread use of fertilizers, pesticides, antibiotics, pharmaceuticals, hormones for intensified agriculture, aquaculture, livestock farming, direct sewage discharge have been the major drivers of excess phosphorus responsible for eutrophication in inland freshwaters. Reduction of nitrogen did not prove effective for eutrophication control, while multiple lines of evidence indicate that phosphorus control works best to mitigate eutrophication in freshwaters. More specifically, it is the N:P ratio that modulates the types of algal bloom as NP ratio > 16:1 favours the bloom of harmful blue green algae and the reverse for green algae. Although there are different physical, chemical and biological methods used for phosphorus removal, the constructed floating islands have proved immense potentials to remove phosphorus mediated through plant-microbe uptake mechanism to restore clean habitat for sustainable development. The current challenge of the conversion of numerous valuable lakes, reservoirs, wetlands, rivers into wastewater systems unacceptable for fish farming and other economic driven activities can be confronted with win- win- win strategies of environmentally safe and sustainable solutions of floating landmass for agriculture, bio-reclamation of eutrophic lakes and rivers, a farming in these water and urban resilience waterborne green transport system across small to medium scale rivers. It is that floating islands made of selective powerful plants and microbes can be installed not only in the confined polluted lakes and reservoirs, but this facility can be extended to rivers of different dimensions for clean up as well as a network of waterborne public transport in the form of environmentally- safe passage boat, water taxi across the rivers. This is of special significance in small to medium scale rivers in India, Bangladesh and other rich countries in Asia not only for public transport and fish farming as well. However, multidimensional technological approaches and strategies with innovative cutting edge technical nature based solutions are most welcome to achieve the success of such giant holistic functionality project.

**Keywords:** Floating Islands; Tropical Rivers; Eutrophication Control; waterborne Green Transport; Aquaculture

**Abbreviations:** EPA: Eicosapentaenoic Acid; DHA: Docosahexaenoic Acid; PUFA: Polyunsaturated Fatty Acids; LED: Light-Emitting Diodes; PAR: Photosynthetically Active Radiation; FTW: Floating Treatment Wetlands.

## Introduction

Eutrophication in water bodies is strongly modulated by nutrient cycling [1]. While the common ecosystem functions with production of benign phytoplankton are the manifestations of cycling of different nutrients that are commensurate. Any deviation from this proportional input of nutrients can drastically alter ecologically fairly balanced populations resulting in manifestation of harmful algal bloom or cyanobacteria. For instance, in terrestrial environment, nitrogen from fertilizers sinks into soils, often create conditions that favor the growth of weeds rather than native desired plants. Similarly, in aquatic habitats surplus nitrogen or phosphorus cause a situation called eutrophication with development of harmful algal bloom of cyanobacteria that are able to outcompete green algae and diatom at tropical temperature.

Eutrophication in global phenomenon especially in tropical lentic lakes and wetlands due to overabundance of phosphorus and nitrogen caused by uncontrolled discharge of sewage effluents, excessive agricultural fertilizers, untreated industrial wastes, exponential population growth, urbanization, surface and urban runoff and other pollutants from point and non-point sources. The natural factors blamed for the eutrophication include autochthonus and allochthonous decay of animals, vegetation, plants, silt, clay as well as all kinds of organic matter. Recently, climate related environmental threats such as heavy precipitation, flood, landslides, land use pattern, etc. have been identified to accelerate the eutrophication process with dominant cyanobacterial bloom that can be accurately assessed by Satellite Remote Sensing in lakes and reservoirs [2].

Quantitatively, eutrophication is strongly related with the phosphorus concentration of 20 μg/l; the total phosphorus threshold concentration of 15 μg/L causes an ecological imbalance in algae, macrophyte and macro-invertebrate communities, and hence, a threshold zone (12~15 μg/l) of TP has been believed to be more realistic and protective for all trophic levels [3]. Since the ratio of nitrogen to phosphorus in freshwaters tends to be greater than the ratio in freshwater phytoplankton, phosphorus most often limits the growth of phytoplankton in inland waters. Further, evidences showed that reducing nitrogen input did not reduce eutrophication in inland freshwaters. Consequently, phosphorus enrichment of freshwater has been the major cause of eutrophication in freshwater lakes [4]. Recent investigations based on 464 lakes covering a 14,000 km north-south gradient in the Americas and three lake depth categories, it was revealed that nitrogen was most relevant in shallow lakes (< 3 m depth) at high total phosphorus and high pH, and temperature was not a significant factor in predicting cyanobacterial biomass in America [5]. However, in marine system, both nitrogen and phosphorus have been claimed to be responsible for marine eutrophication [6]. Mounting evidences indicated that phosphorus control is the best to mitigate eutrophication. Farther, it means that the ratio of nitrogen to phosphorus modulate the eutrophication process to a greater extent. Nonetheless, in some studies, nitrogen was also found to play a powerful eutrophication-regulating factor than did phosphorus [7].

## Algal Bloom Defined

Algal blooms may be defined as the bloom when the chlorophyll concentration of algae exceeded > 5μg g/L and the cell density > 1000 cells/ml [8]. The bloom may be either due to benign green algae and diatoms or harmful blue green algae cyanobacteria. In freshwaters, the algal blooms are predominantly caused by harmful blue green algae or cyanobacteria, while in oceans the blooms are contributed mostly by diatom Chaetocerosconvolutus and dinoflagellates and cyanophytes to a lesser extent. The red or brown tides of the oceans caused by dinoflagellates are highly detrimental to fish gills; even whales may be killed by these harmful algae in the oceans.

Since blue green algae are able to grow much faster than green algae, they have some selective edge over others especially in well illuminated shallow tropical water bodies where blue green algae can assimilate dissolved atmospheric nitrogen when combined nitrogen fails [9].

## Differences between Tropical and Temperate Waters

The regulatory factors of algal growth are quite different between low and high altitude lakes. While the algal growth in temperate lakes was primarily due to phosphorus [4], the tropical lakes exhibit a wide range of nutrient limitation regimes showing considerable heterogeneity of the dominant limiting nutrient within an individual lake. Therefore, nitrogen is unlikely to consistently limit algal productivity in tropical lakes Fadum JM, et al. [10] despite it was thought earlier [11].

### N: P Ratio

The N: P ratio of the water bodies plays an important role in the formation of algal bloom in water bodies. Blue-green algae often experience a population explosion when the N: P ratio of pond remains 16:1 which is the guideline at which limitation by one nutrient switches over to another within the phytoplankton community. The average nitrogen-to phosphorus ratio in plankton (N: P = 16) and in deep oceanic waters N: P ratio is 15. This ratio was neither a coincidence, nor the result of the plankton adapting to the oceanic stoichiometry, but rather that phytoplankton adjust the N: P stoichiometry of the ocean to meet their requirements through nitrogen fixation. However, the canonical Redfield N: P ratio of 16 is not a universal biochemical optimum, as N: P ratio is plastic and can vary on a large scale from 8.2 to 45 or more (50) depending on species and the nutrient status of the algae including diel changes [12,13]. However, the canonical Redfield C:N:P ratio for algal biomass may not be achieved in inland waters due to higher C and N content and more variability when compared to the oceans. The results reinforced the role of microorganisms in shaping the chemical environment in aquatic systems particularly at long water residence times and highlights the importance of this factor in influencing ecological stoichiometry in all aquatic ecosystems [14]. The elemental composition of individual species of phytoplankton grown under N or P limitation can vary from around 6:1 to 60:1 (N: P ratio) [15-17]. The optimal N: P ratios for the growth of Mychonastes, Microcystis, and Synechococcus were found to be 64, 32, and 32 for, respectively [18]. In a shallow hypertrophic lake in China, Microcystis bloom predominated within the N: P ratio between 13 and 46, but rapid growth occurred with N:P ratios < 30. Further, it has also been documented that N: P ratio manipulation is an effective strategy for changing the biochemical composition of algae. A study revealed that the N:P ratio of 20:1 favoured growth, protein content and eicosapentaenoic acid (EPA) production in marine algae Nannochloropsis oculata, while 30:1 N:P ratio docosahexaenoic acid (DHA) production in Tisochrysis lutea an important marine algae fed to oyster and shrimp larvae. This leads to indicates that N:P ratio manipulation is an effective strategy to change biochemical composition in algae and N or P limitation tends to lower polyunsaturated fatty acids (PUFA) contents in algae [19].

## Strategies of Eutrophication Control

There are several methods ranging from very simple to advanced technologies involved in physical, chemical, biological or integrated system approach for the removal of phosphorus or nitrogen from urban eutrophic pond or wastewater in general or from animal wastes [20-23].

Strategically, these methods include A) Preventive measures dealing with i) early detection, ii) water shade management, iii) hydrological maintenance; B) In-lake or reservoir treatment that includes i) harvesting the floating cells and ii) hydro physiological and physical control (buoyancy regulation); C) Chemical treatment handling with i) oxidative stress based methods and ii) other algicides and cyanides; D) Removal of cyanoHAB biomass by chemical treatment; E) Approaches toward biological treatment. However, it can be highlighted as: prevention of bloom development, physical, chemical, biological and integrated holistic approach (Figure 1). Different innovative and intensive management actions can be taken to improve the eutrophication status of lakes [24-26].

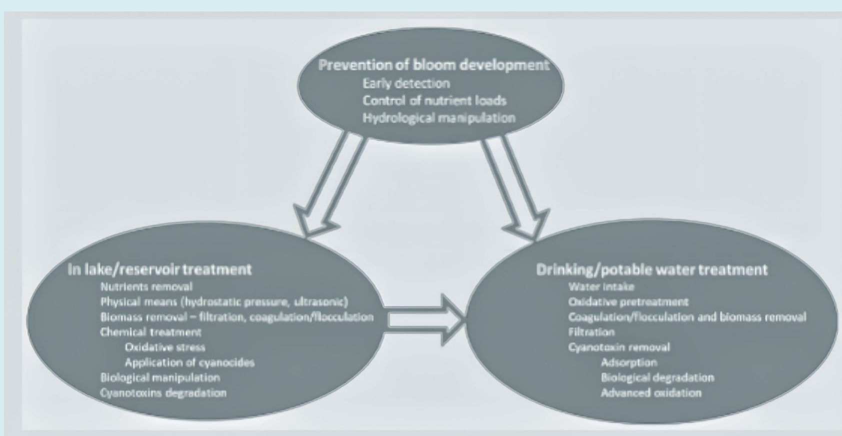


**Figure 1:** Schematic presentation of strategies and techniques implemented to the development of cyanoHAB and to mitigate potential impacts on aquatic ecosystem and potable water [26].

Although there are different methods employed for eutrophication control, not a single method is effective, since every method has its advantage and disadvantages. The physical and chemical methods have quick effects in the short term and are more suitable for small lakes, but cannot absolutely solve the problem due to incomplete removal performance and for non-economic reasons. The biological method, on the contrary, is environment-friendly, cost-effective and sustainable, but needs a long-term period for solution. A combination of these three management techniques (Figure 2) was used in a Chinese lake [27,28] to synthesize short-term and long-term management strategies that control current cyanobacterial blooms and restore the lake ecosystem.

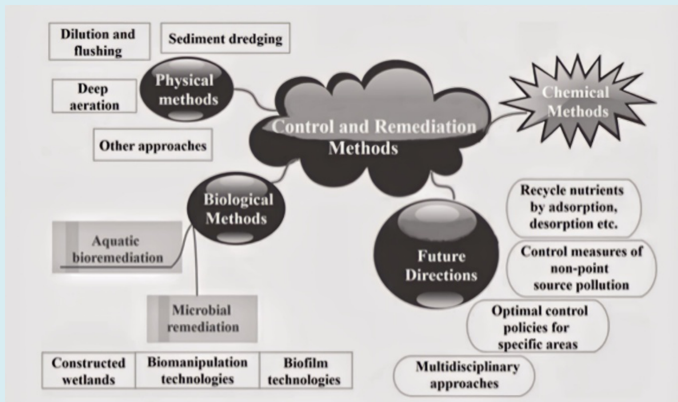


**Figure 2:** Key treatment technology for cyanobacterial bloom control in a Chinese lake [28].

## Floating Islands

Natural floating islands, sometimes referred to as tussocks, floatons, or suds, are composed of vegetation growing on a buoyant mat of plant roots or other organic detritus. It is a mass of floating aquatic plants, mud, and peat that range in thickness from several centimeters to a few meters. Floating islands occur as a common natural phenomenon, and they exist less commonly as an artificial phenomenon. They are generally found on marshlands, lakes, and similar wetland locations As decaying mass decomposes it releases gases which keep the bog floating. Three types of the aquatic macrophyte vegetation such as submerged, emergent, and free floating plants are associated with natural floating islands responsible for bioremediation.

### Floating Island and Hydroponics

Hydroponics is the technique of growing plants without soil using a water-based nutrient solution, and have an aggregate substrate bed or growing media including vermiculite, coconut coir, or perlite. The floating rafts contain small pots in which the plants grow and their roots reaching through the bottom and into the nutrient-rich water below or directly into the eutrophic waters. Traditional hydroponics has been primarily used for increasing crop production under controlled conditions by supplying balanced nutrients in solutions. There are different types of hydroponic systems used for commercial production of cereal crops, crops, and vegetables such as beets, radishes, carrots, potatoes, fruits, ornamentals and seasonal flower as a value addition for human consumption or human aestheticism. The floating islands are larger dimensions of hydroponic systems where all kinds of vegetations, crop, fruits, valuable medium size trees can be cultivated acting as biodiversity hotspot or even used for huts of the villagers as well as for luxurious tourism on water boat. Seemingly, the hydroponic system is the miniature model of well planned wise designed constructed large floating islands. The basic principles remain the same in two being involved in nutrient uptake by plant microbe association. In a miniature model of hydroponic system Rana S, et al. [29] were successful in the bioreclamation of municipal domestic wastewater using tomato plants (*Lycopersicum esculentum*). The study revealed that $PO_4$-P was removed by 58.14–74.83%, while removal of $NO_3$-N exceeded 75% in all treatments. Reduction of COD and BOD from non-diluted wastewater was 61.38% and 72.03%, respectively. Ammonium-N concentration was subsided below the toxic level in all the treatments. The population of coliform bacteria (*Escherichia coli*) was reduced by 91.10–92.18% over the control. Production of tomato plant tended to increase with more nutrient levels of water being highest in non-diluted wastewater. The bioaccumulation of Cd and N in tomato crop was far below the threshold level, but the bioaccumulation of Pb and Cr was above the safe level by 80 times and 660 times, respectively. It was concluded that the aquaponically reclaimed water can be reused in agriculture, aquaculture and industries [29].

### Distribution of Natural Floating Islands

The natural floating islands are widespread across the world. They do exist on six of the seven continents and sometimes in the oceans between them. The floating islands have attracted the attention of the ecologists since ancient times. They supported the theory that floating islands have been evolved for the dispersal of plant and animal species across the oceans.

There are three natural floating islands in India. The floating island in Loktak Lake in tropical India spans approximately 240 square kilometres and appears to be dotted with numerous small islands from above. The main attraction of the high altitude Khajjiar Lake in Himachal Pradesh is the floating island which is actually a cluster of grass and weed growing on the surface of the lake. Floating islands in a wetland system in tropical Kerala, India have extensively been used for rice cultivation. However, floating islands are experiencing with abandoned rice fields, proliferation of exotic invasive plants and less salinity and tidal flow [30]. In tropical Brazilian Amazon, the natural floating islands can vary in size from a few square meters to a few hectares in. In tropical Lake Titicaca, Peru, floating islands are huge raft usually made of bundled totora reeds used by the local people who build their huts for living due to effect huge rafts of bundled reeds.

The floating forests in central Brazilian Amazon started with the agglomeration of aquatic vegetation, and gradually accumulate organic matter sufficient to form large forest patches of several hectares in area and up to 12 m in height. The local people use the traditional ecological knowledge for interacting with matupás in different stages of the matupá life cycle [31]. The benefits of floating islands include nutrient removal, transformation of pollutants, and reduction in bacterial contamination mediated through plant uptake, plant-bacteria association involved in biotransformation and stabilization of pollutants. Nutrient uptake by plants is crucial in the removal of nitrogen and phosphorous from waste water. The removal efficiency was estimated as 74% for total nitrogen and 60% for total phosphorus [32,33]. Additionally, the floating islands are able to provide valuable wetland habitats for diversified native plant species including benthic and sessile macro-invertebrates, green algae and zooplankton Rome M, et al. [34] and thereby transforming into a stable environment.

## Constructed Floating Islands

Constructed floating islands are based on the principle of ecological engineering aimed at developing a sustainable ecosystem that uses the nature based ecosystem components of aquatic plants, macrophytes, trees and associated microbes. They are kept buoyant by the light spongy tissues of certain aquatic plants, by gases released into their soils by the decomposing vegetation or by both these forces. Artificial islands may vary in size from small islets to large ones depending on purpose to support a single pillar or the entire communities and cities. Building artificial islands can provide additional land area that can be used for housing, industry, tourism, and agriculture.

The world's largest vegetated floating islands of 1.6 hectares in size were installed in Lake Tai, China. This was made of a combination of polyurethane open cell filter foam, closed cell polyethylene flotation foam, bamboo and coconut fiber, filter foam mix with wicking ability to supply water to plant roots. Traditionally, the most common macrophytes used in flating treatment wetlands are *Carex fasicularis, Cyperus articulatus, C. papyrus, Schoenoplectus validus, Scirpus californicus, S. lacustris, Paspalum pennisetum, Phragmites australis., Vetiveria zizanioides and Typha sp., T. dominguensis, T. latifolia*. A constructed floating wetland using macrophytes *Typha domingensis* has been found to be highly effective in the treatment of raw sewage in a municipal sewage treatment plant in Brazil where the removal efficiency of COD, $BOD_5$ and TSS was about 55, 56 and 78% respectively [35]. In general, the removal efficiency of phosphorus and total nitrogen was found to be higher than natural floating islands; the removal efficiency for phosphorus and total nitrogen was 86 – 93% and 90.3%, respectively [36].

## Working Mechanism

The underlying synergistic mechanism of reclamation through floating island is the nutrient uptake of macrophytes-plants- microbial associations under ambient aerobic and light conditions. The plant- microbe association collectively trap excess N and P and at the same time, the decomposition of organics is accelerated by the attached microbes. Estimates show that the phosphorus removal concentration was 16.5 g·m−2a−1. Installations of floating islands in three rivers in the USA showed the annual phosphorus removal rate by above-ground vegetation to be around 2 g-P m−2 [34]. Removal is not only limited to nitrogen and phosphorus, it was equally effective for organics measured by chemical oxygen demand (COD) [27]. Thus, the plants can be considered as the direct "tools" and the indirect "medium" that provide shelters for microbes that work together [37].

Additionally, the immersed roots of aquatic macrophytes act as a filter for flowing wastewater enabling trapping of suspended particles and thereby improving the quality of water. Increased abundance of large sized zooplankton suggest a viable mechanism by which floating wetlands might contribute to the top-down control of excess algal growth by the removal of phosphorus [34]. Experimental studies of Qin S, et al. [37] showed that all the plant islands with water hyacinth, canna, water spinach, calamus (Figure 3) were highly effective for water purification with sparse concentration of residual contaminants. The synergistic mechanism of the plants and the attached microbes was largely involved in the removal of various contaminants from the habitats. The well-grown roots exhibited a great network structure and acted as the filter to realize the preliminary immobilization of contaminants. N and P could act as the essential components for the growth of plants, and the attached microbes could also realize the transformation through metabolism, such as $NH_4$+-N, $NO_3$−-N, P, etc. Organic matter could be decomposed with the effects of enzymes produced by roots; microbes use organics as the carbon source for the growth, and this facilitates the degradation during the metabolism process. Oxygen could be secreted by roots to form the anaerobic/anoxic/aerobic micro-areas, which provided the microbes with suitable conditions for the removal of N and P. Consequently, the concentrations of COD in wastewater tended to reduce gradually.

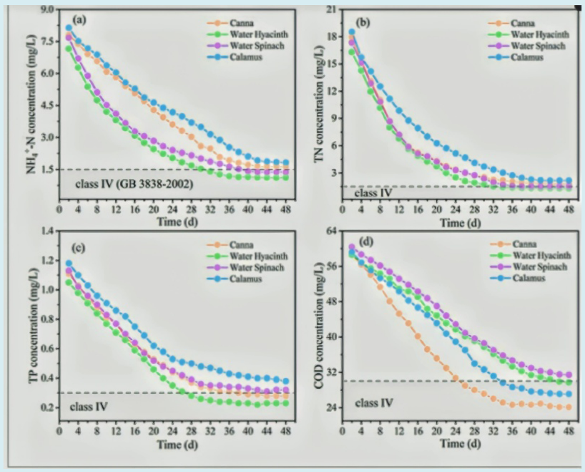


**Figure 3:** Comparison of contaminants removal of plant islands with different plants: (a) NH4+-N, (b) TN, (c) TP, (d) COD [37].

## Ecosystem Services

Constructed floating islands are known to have immense potentials to remove phosphorus while proving enormous ecosystem services via direct and indirect ways to promote sustainable development. The benefits include land mass for agriculture, human settlement and protecting soil erosion and water stabilization in ponds. In hydroponic lagoons, built in the shape of artificial rivers where required temperature and solar radiation are the driving force for plants and microbial activity. Given these conditions favourable the constructed floating island can intensify the nutrients uptake by the macrophytes and quicken the restoration effects. This system is also equally effective in temperate countries of Poland, where the light-emitting diodes (LED) were used to photosynthetically active radiation (PAR) leading to enhance the efficacy of nutrient uptake by macrophytes in biologically treated wastewater fed ponds.

According to WHO [38], currently urban planning, risk governance and resilience have become increasingly important strategies to promote and protect public health at the local level. This is because climate change, ill-planned urbanization and environmental degradation are the drivers that make many cities vulnerable to disasters [38]. This warrants a sustainable urban development and resilient planning that can absorb much of the shocks and stresses on environmental health and to restore safe, healthy and sustainable cities. Apart from unique capacity to absorb all shocks and stresses, floating islands have been positively adapting and transforming towards sustainability by the way of interlinking with urban resilient planning as a sustainable pillar for urban development. Hence, floating islands maintain continuity of benefits within its framework to the urban inhabitants [38].

It is, therefore, universally suggested the wise planned, well conceptualized and well designed ecosystem assemblages focusing on nature based solutions with indigenous plants - microbes associations for pollution abatement. At the urban development scale for easy transport across rivers, the waterborne green transport system can be implemented with the constructed floating islands that have great potentials to enhance urban resilience in the form of land mass for climate resilient agriculture, ecological restoration of polluted and perturbed aquatic systems, eco-tourism, worldwide. However, this is especially pertinent as environmental friendly waterborne public passage boat in many small to medium scale polluted rivers in India, Bangladesh and other river rich Asian countries. A large number of people use conventional ferries as a convenient mode of transport system to cross rivers instead of a few available aero-bridges installed long distances from the residence of local inhabitants. Floating islands are highly efficient to reduce the level of phosphate, root mediated absorption of heavy metals by water hyacinth, scavengers of toxic elements and thereby decreasing the risk of algal bloom mediated through bottom up approach. Additionally, this green transport system can shift the food chain from blue green to green algae and zooplankton as well as benign environment which is essential for fish culture. At the same time, floating islands are well known to increase the habitat diversity by creating pockets of native vegetation and food-web connectivity because they are used by a wide range of species by providing refuge for small fish, a food source for larval insects, phytoplankton, zooplankton and thus form an excellent habitat for fish farming with conducive environment as well as a protective platform against mosquitoes – a danger in tropical countries. Floating islands are visually attractive and eco-tourism; many aquatic and terrestrial birds use them as forage grounds. Seemingly, floating islands are excellent for wetlands in tropical countries.

## Floating Islands as Urban Resilient Platform

Over population and competing socio-economic demands and the presence of feedback loops within the system exacerbate the over-exploitation of inland water resources in many tropical countries including Brazil, India, Indonesia, Kenya, Malaysia and Mexico causing serious aquatic pollution and degradation of water quality limiting the use of these water bodies for water supply, fisheries, recreation, tourism and wildlife [39].

Water quality plays a critical role in the growth and survival of fish in aquaculture. Poor water quality can have many adverse effects on fish survival, growth, reproduction and diseases. Most farmed fish are highly sensitive to changes in water quality such as pH, toxic substances, temperature and presence of gas. For instance, most cultured fish may die with pH below 4.5 and 10 or above. Reproduction and growth of fish can be greatly affected at pH below 6.5 and above 8.5. Therefore, an optimum condition is always necessary for successful aquafarming.

Installation of ecological floating beds are of substantial importance due to the involvement of nature based novel sustainable cleansing approach to mitigate the water quality abatement in tropical waters. Secondly, the functional activities of all plant microbe associations involved in remediation are accelerated when they are installed in tropical lakes or rivers with relatively high temperature within their range.

However, the performance may vary depending on hydraulic loading rate, size, depth, and hydraulic residence time, plant types, physiology, and density, floating mat types, plant harvesting methods and additional technology [40]. Thick mats of floating morning glory (*Ipomoea spp.*) cultivated as a crop in the natural wetland of Boeng Cheung Ek, Phnom Penh, Cambodia Zhang DQ, et al. [41] reduced *E. coli* and detergents levels by 99.9% and 87% respectively, within 200 m from sanitary sewage point of entry to the wetland. Zhang Q, et al. [42] also showed that morning glory could improve water quality in carp aquaponic pond systems [43]. Zheng CB, et al. [44] found the treatment efficiency of edible spicy water celery was limited, but water celery can be edible since the plant slowly uptakes the nutrients. A review dealing with 67 peer-reviewed articles along with some case studies from tropical climates showed that ecological floating wetlands can provide a positive impact to the urban environment. The tropical Singapore's "Active, Beautiful, Clean (ABC) Water Policy'' was based on innovative visioning despite lake of strong scientific evidence with respect to performance of the green infrastructure [40,45]. As a whole, multidisciplinary approaches are always necessary for better understanding the contaminant uptake rates associated with different plants, required maintenance of the systems, plant robustness, and community appreciation [40].

## Linking With Green Transport Water Taxi

Although floating islands can be installed for eutrophication control and ecological restoration in lentic waters of lakes, wet lands and reservoirs, they are of particular significance in small to medium scale polluted rivers in tropical countries of India where large number of people cross the river using the conventional petrol or diesel powered ferries or steamer causing much pollution to rivers.

Artificial islands are created to mimic nature, help reducing phosphorus, improve water quality and acts as buffer habitats against surges in nutrients and pollution. Buoyancy in artificial floating reed beds is commonly provided by polyethylene or polyurethane foam, or polyethylene plastic containing air voids. Growth media include coconut fibre; mats made of polyester or recycled PET bottles; synthetic geotechnical mat; jute; soil; and sand. Artificial floating islands are sometimes made by planting cattails and other plants on floating plastic rafts in order to reduce phosphorus levels in the water.

The results of installations of some floating treatment wetlands (FTW) using common reed *Phragmites australis* in a polluted tropical river (Kshipra or Shipra river) in Madhya Pradesh and in polluted Rajkori lake in Delhi showed significant reductions of different water quality parameters including total solids (55–60%), $NH_4$-N ( 45- 55%), $NO_3$-N ( 33- 45%), Kjeldahl Nitrogen (45–50%) and BOD (40–50%) of BOD removal [46].

River floating rafts are made up a base structure supporting native semi-aquatic plants to enhance the biodiversity and to restore fish populations in the area [47,48]. The results of the installation of the large floating island in historic Neknampur lake in Hyderabad revealed significant improvement of water quality particularly the removal of phosphorus and nitrogen from the lake [46,49]. There are 27 rafts joined together to form an island that spreads over 25 00 ft of the historic Neknampur Lake in Hyderabad, India (Figure 4). The island structure is simple, but effective because of the fact that the roots of growing plants reach into the water and remove excess e phosphate and nitrates and thereby cleaning the lake. Tropical climate is quite favourable for the plants to grow in ambient sunlight and temperature. The structures are provided with thermocol on all four sides with plastic bottles attached to ensure that they remain afloat, a plastic mesh, a gunny bag placed on the top and followed by a layer of gravel in which saplings were grown. Each raft is 10ft x 10ft in size, and 27 of such rafts are joined together to form an island which spreads across over 2,500ft$^2$ of the lake. In total, the island is covered by approximately 3,500 saplings of diverse plants and macrophytes including vetivers, canna, bulrush, lemon grass, fountain grass, lillies, khus, flowering plants, and mosquito repelling plant citronella were planted [50]. This bioremediation model has immense potentials to rejuvenate many polluted especially the eutrophic lakes in tropical countries.

**Figure 4:** Installation of the floating treatment in the historic Neknampur Lake in Hyderabad, Indiia (Lakes of India https://lakesofindia.com) [50].

Based on sound background information, it is conjectured that wick- floating islands that mimick the aero-bridge services across the rivers of many crowded cities, can be constructed with innovative designs and installed for environmentally-safe waterborne green transport system that may provide double benefits within the frameworks of public transport teamed with eutrophication control as well as bioremediation abatement. Linking floating islands as a platform of nature solution may open up a new vista for public transport across the rivers that may mimic aero-bridge in many crowded cities and replace electric or fuel generated ferries manifesting negative impacts on aquatic biota in rivers. This can replace or compliment the petrol or diesel powered ferries that cause pollution to rivers from point and non-point sources. The second advantage of the passage boat can be viewed by remediation potentials that enabled to remove phosphorus this can replace or compliment the conventional pollution generating public transport system. Advantages of such installed floating island in the form of water taxi can be further viewed to effectively remediate pollutants from point and non-point sources and particularly remove phosphorus from many tropical rivers mediated through bottom up approach of phosphorus removal by plant-algae- microbe associations that made the floating islands unique [51].

## Conclusion

Anthropogenic pollution from various point and non-point sources resulted enormous loss of valuable water resources turning them into almost wastewaters. Shortage of land mass for agriculture has been steadily rising due ever increasing population. Further disadvantages can be visualized for crossing nearby convenient rivers due to inadequate transport systems in rivers causing unsustainable. This call for environmentally safe and floating solutions for sustainable landmass for agriculture, waterborne green transport and rejuvenation of polluted waters rivers and lakes and wetlands that are likely transform unsustainable to sustainable urban development [52]. Floating cities have been investigated many times across the globe particularly in Netherlands and Japan. It is proposed that deployment of floating islands made of selective powerful plants and microbes in medium to large scale floating islands coupled with well-planned roadmap may explore different dimensions water cleaning strategies, production machinery of agriculture crops as well as a sustainable network of waterborne green transport system passage boat or water taxi across the rivers. This is of special significance in small to medium scale rivers in India, Bangladesh and other river rich countries in Asia public transport and fish farming as well. However, multidimensional, technical solutions have to be considered as a most important component of holistic functionality project.

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