Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 13 Issue 11, November 2024

Application of Green Technologies for Rejuvenation of an Urban Lake: Case Study of Pipliyahana Lake, Indore, India

Eshna Agrawal, Priyanshu Kumath, Sonam Mandani
Clean-Water (Sustainable Water Technologies Private Limited), Indore, Madhya Pradesh, 452001, India

ABSTRACT
Anthropogenic activities have led to extreme pollution of water bodies. One of the leading causes of destruction of many freshwater and marine ecosystems is nutrient pollution which creates hypoxic conditions deteriorating the quality of water and suffocation of aquatic life in it. In this paper, we have reported our application of green technologies such as artificial floating wetlands, microbial cultures and aerators for rejuvenation of a polluted urban waterbody, Pipliyahana Lake, located in Indore, India.

***KEYWORDS*: Green Technologies, Nature Based Solutions, Artificial Floating Islands, Aerators, Eutrophication**

INTRODUCTION

Urban water bodies, such as lakes and ponds, play a vital role in maintaining the ecological balance of cities, offering numerous environmental, social, and economic benefits. These water bodies act as natural reservoirs for rainwater, help regulate urban temperature, support biodiversity, and provide recreational spaces for residents. Historically, urban lakes and ponds have been integral to the cultural and social fabric of cities, serving as hubs for community gatherings and essential sources of water. Yet, in recent decades, these water bodies have been subjected to unchecked pollution, encroachment, and neglect, leading to loss of biodiversity, poor water quality, and the depletion of their natural functions. Challenges such as eutrophication, illegal dumping of waste, and the inflow of untreated sewage further exacerbate the deterioration of these lakes, making their revival increasingly difficult but necessary for the well-being of urban populations. Rapid urbanization, coupled with industrial and domestic pollution, has significantly degraded these ecosystems, making their restoration and sustainable management a crucial urban planning priority.
Management of water bodies has evolved significantly over time, particularly in response to human-induced degradation. Historically, early lake management focused on natural processes such as water level control, fish stocking, and sediment management. For example, restoration projects in the Great Lakes have focused on hydrology, sedimentology, chemistry, and biology to mitigate human-induced degradation. The shift towards integrated, science-based lake management approaches gained momentum in the mid-20th century. Over time, management practices have increasingly emphasized holistic and sustainable approaches, with significant focus on ecological, economic, and social dimensions. These approaches can be broadly divided into three categories: physical, chemical and biological methods (1). Treating polluted water bodies by physical methods involves application of practices like sedimentation, filtration, aeration, screening, mechanical removal of algae etc. (2) These methods aim to remove contaminants without altering their chemical composition but they do not generally work on the underlying causes of pollution. The chemical methods comprise of processes like enhanced flocculation, chemical precipitation, chemical oxidation, and chemical algae removal (3). Many of the chemicals used can be toxic to aquatic life and ecosystems, leading to further environmental degradation if not managed properly (4). The biological methods of water treatment utilize living organisms, primarily microorganisms and plants, to degrade pollutants and improve water quality (5, 6). The biological methods can be effective for treating a wide range of pollutants and are often more sustainable and environmentally friendly compared to chemical methods.
In this paper, we have described the rejuvenation of Pipliyahana Lake through the use of artificial floating wetlands (AFIs), microbial cultures and aerators. Pipliyahana Lake which spreads around an area of 10 acres sits in the heart of one of Indore's fastest developing areas. Years of neglect and dumping of waste had left the lake in a dilapidated state. With its natural channels for water blocked, this rain fed lake had been shrinking in size and

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 13 Issue 11, November 2024

would dry up completely in the summer. The Indore Municipal Corporation (IMC) attempted to remedy this by constructing a Sewage Treatment Plant (STP) near the lake that now releases treated water into the lake year round. This helped mitigate complete drying of the lake in the summer, however the lake still faced severe challenges. The treated water contains many nutrients which over time built up and caused eutrophication at the lake. This led to rampant algal blooms, and duckweed and azolla infestations. Along with the problem of eutrophication, the hush-hush dumping of waste matter such as plastics, religious materials, wet waste etc. by people further exacerbated the water pollution. As a result the lake became an eyesore with the water exhibiting a thick “spinach soup” like consistency and emitting a strong odour. It also led to dying of native aquatic species and reduction in the number of birds flocking to the lake. By installing a total of 12 floating islands and 4 sub-surface floating aerators on the lake and regularly dosing beneficial microbes, we were able to enhance the aesthetic beauty of the lake, improve its water quality and bring about a vibrant ecosystem.

MATERIALS AND METHODS

(i) Design of the floating islands
We design our own unique highly engineered floating islands. For this project, we had made the islands using materials such as fibre reinforced plastic (FRP) and steel which make them mechanically strong and durable. The size of each island is 2m x 2m and there are 100 holes in it. Plants such as Canna indica (Indian shot), Cyperus alternifolius (Umbrella palm), Chrysopogon zizanioides (vetiver) and Morning glory were planted in these holes.

(ii) Sub-surface aeration: We deployed 4 submersible aerators in the lake. These aerators have a motor of power 2 HP and were purchased from the market. Each aerator is reported to have an oxygen generation capacity of about 3.5 kg/hour. The aerators were run for 4 hours on a daily basis.

(iii) Dosing of microbial cultures: 1 kg of our own blend of microbial cultures was dosed four times a week during the study period by simply sprinkling the powder over the water.

(iv) Water quality analysis: Water samples were collected from the lake from time to time and these samples were sent to a lab for analysis.

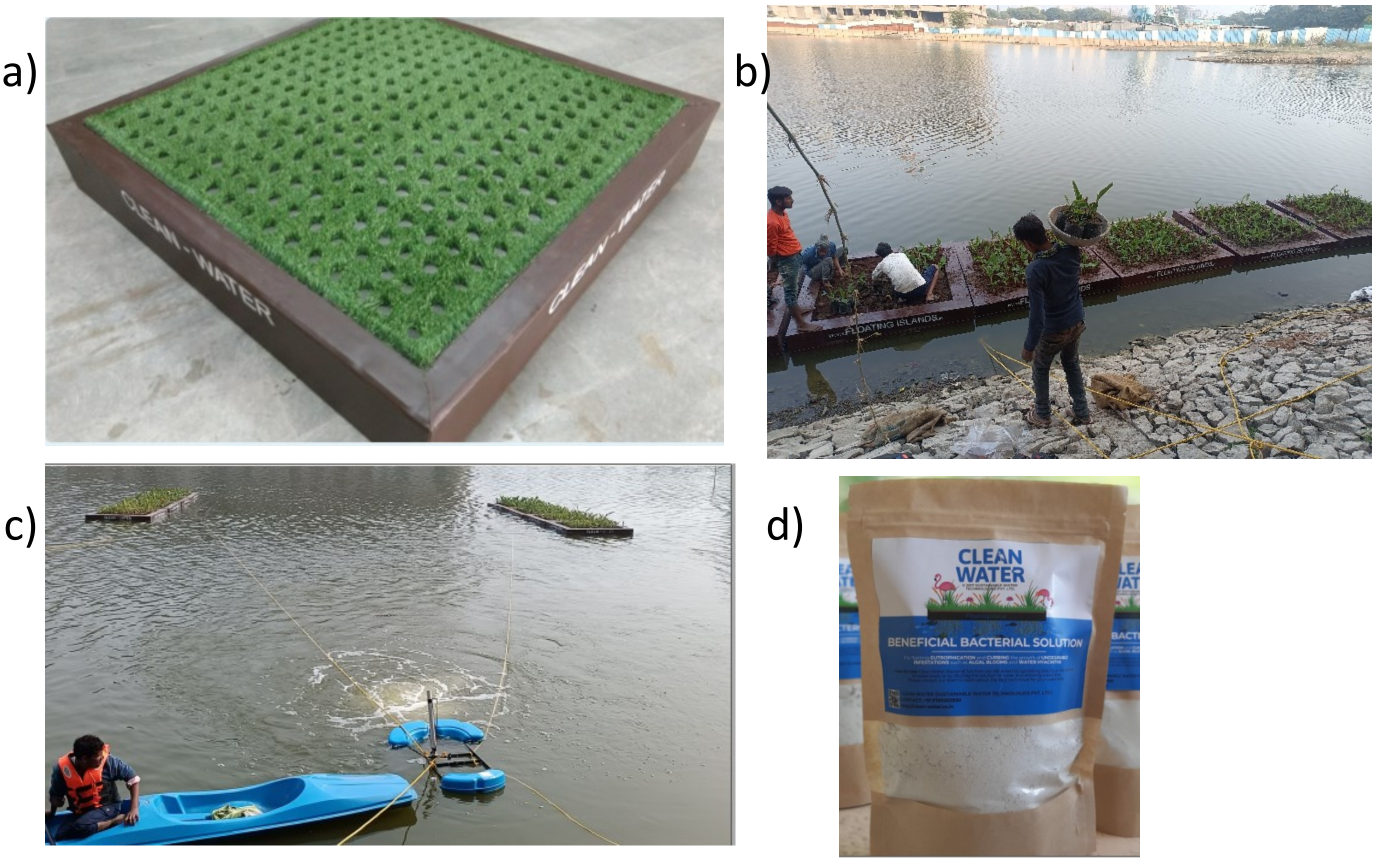

Figure 1: (a) A 2m x 2m floating island, (b) Planting in the islands at the lake, (c) submersible aerator and (d) A packet of our microbial culture

RESULTS

The AFIs and aerators were deployed in the lake in the December 2022. AFIs are made in a workshop and then brought to the site where they are planted with saplings of the selected plants and then installed in the lake (figure 2). The islands and aerators were anchored from sides.

Figure 2: Artificial floating islands installed in the centre of Pipliyahana Lake.

There are several parameters which determine the quality of a water sample. Since our focus was to reduce the algal blooms, infestations by harmful species and improving the overall quality of water for aquatic life, we finalized on parameters such as pH, DO (dissolved oxygen), BOD (biological oxygen demand), NO_3^- (nitrate) and PO_4^- (phosphate) for analysis. The period of investigation was from December 2022 to September 2023. The pH remained in the range 7.4 ± 0.5 throughout the study period. Since the main source of water in the lake is the treated domestic wastewater coming from the STP, the pH is more or less neutral and good enough for aquatic life to thrive.

Dissolved oxygen is the amount of free oxygen dissolved in water which is a key indicator of water quality and its concentration should be at least 5 ppm for optimum aquatic health. When there is excess amount of organic content in a waterbody such as dead algae, plants, etc. microbes in water can consume oxygen for its decay and lead to low DO levels. Also, the concentration of DO is inversely proportional to temperature and therefore, the DO levels are lowest in the summer season. In the present case, the DO was reported to be 4.8 ppm in December 2022 which improved to values above 7 ppm in the subsequent months with only a slight decline to 6.8± 0.1 in the summer months (fig. 3a).

Biochemical oxygen demand (BOD) measures the amount of oxygen required by microorganisms in decomposing the organic matter present in a water sample. Unpolluted natural waters have a BOD OF 5 mg/L or less. The BOD of Pipliyahana lake in December 2022 before deployment of floating islands and aerators was 22 mg/L suggesting presence of excessive organic matter. These values then decreased drastically to 2.8, 3 and 6 mg/L in the subsequent months implying the effectiveness of our methods in curbing the growth of blooms and invasive species, thus leading to reduction in the amount of organic content (fig.3b). The BOD peaks again in the summer month of April due to rapid degradation of organic content and then declines.

The two main nutrients which apart from being essential for aquatic life, can also harm it when present in excess are nitrate and phosphate. These nutrients when present in abundance promote the growth of algal blooms and invasive aquatic species resulting in depletion of oxygen levels of the waterbody. It was observed that the concentration of nitrate and phosphate reduced to below detection levels after about 6 months' time (fig. 3c and d).

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 13 Issue 11, November 2024

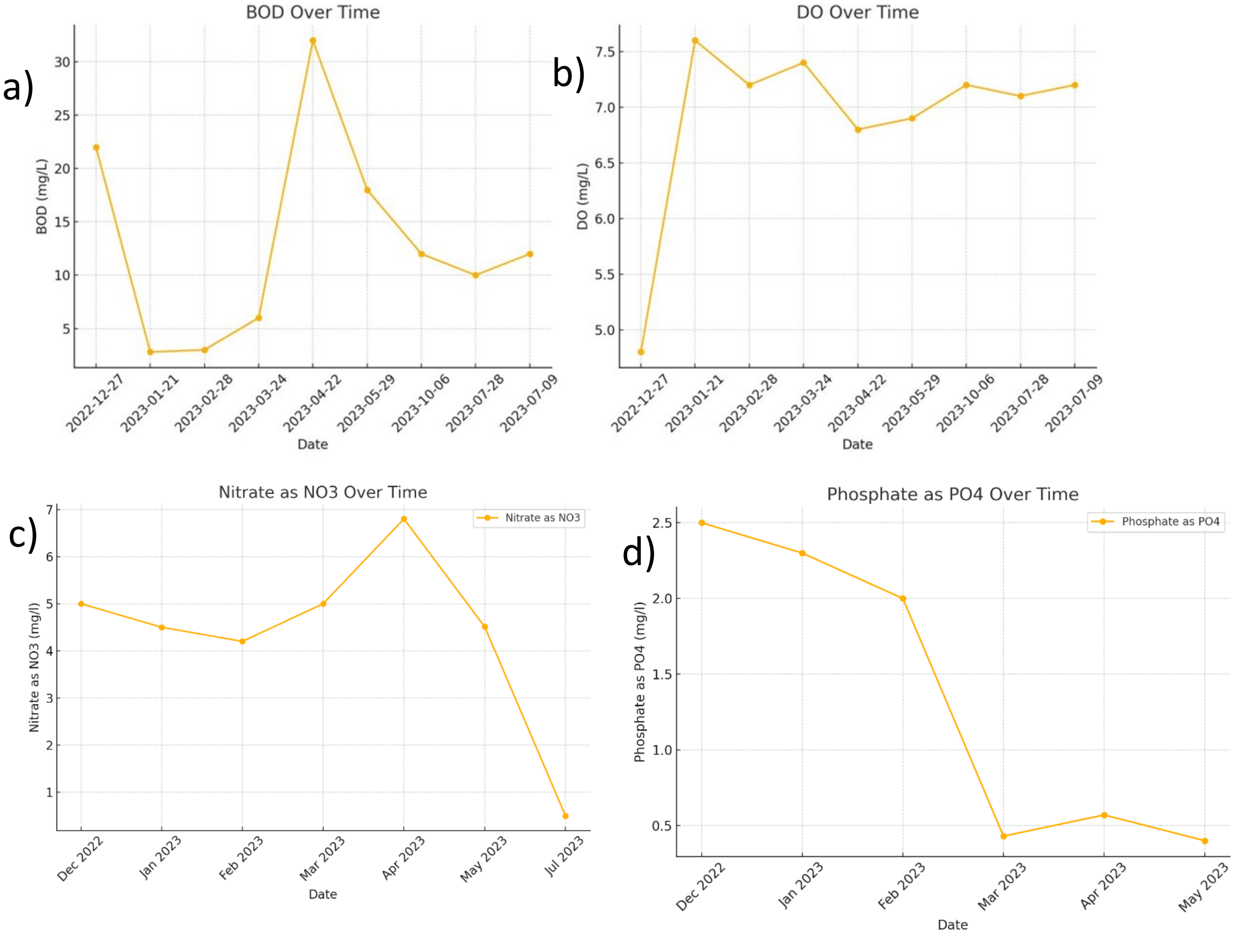

Figure 3: Variation in the levels of (a) BOD, (b) DO, (c) Nitrate and (d) Phosphate over the period of investigation.

The improvement in the water quality which curbed the algal blooms and prevented growth of invasive species is clearly evident from figure 4.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 13 Issue 11, November 2024

Figure 4: Before and after pictures of Pipliyahana Lake

DISCUSSION

The processes of phytoremediation and bio augmentation work synergistically which has resulted in bringing the water quality parameters under optimal levels. The following purposes have been served through the use of floating islands, microbial cultures and aerators:

(i) Decomposition of sludge in the lake: One of the two major problems in the lake was the accumulation of sludge which is basically dead plants (like algae, water hyacinth) and animals and other organic debris from various sources. The natural decomposition of sludge is a slow process and requires lot of oxygen, thus increasing the BOD/COD of the lake. The sludge also acts as store-house of nutrients like nitrogen and phosphorous which are released upon its decomposition and lead to algal bloom. As the sludge levels accumulate, oxygen is not able to reach the bottom layers and this turns the conditions anaerobic. This means that aerobic, beneficial bacteria are unable to consume this sludge, the layers begin to smell and can release potentially harmful substances like H_2S which has a rotten egg like smell. We can treat the sludge directly using methods such as aeration and use of our microbial cultures. The microbes feed on the organic matter/pollutants and convert them to energy that they use to grow and reproduce. In the process, harmless and acceptable end products such as CO_2 and H_2O are produced. The process involves the following reactions:

(a) Oxidation: In this step, the microbes oxidize the organic compounds to produce energy which they require for their metabolic processes.

$COHNS + O_2 + bacteria \rightarrow CO_2 + H_2O + NH_3 + \text{other end products} + energy$

(b)Synthesis of new cell tissue: In this step, microbes multiply by feeding on the organic matter.

$COHNS + O_2 + bacteria \rightarrow C_5H_7NO_2$ (new cell tissue)

(c)Endogenous decay: In this step, there is death and degradation of the microbes themselves.

$C_5H_7NO_2 + 5O_2 \rightarrow 5CO_2 + 2H_2O + NH_3 + Energy$

As can be seen from the above reactions, oxygen is necessary for carrying out the breakdown of the organic matter. If sufficient oxygen is not present, the breakdown can happen through anaerobic route as follows:

Complex Organic Matter $\rightarrow$ Soluble Organic Molecules $\rightarrow$ $3CH_4 + CO_2$

Methane (CH_4) when collected, cleaned and handled properly can used as an energy source. This is possible in closed systems like a wastewater treatment facility but in the situation to be addressed, the lake is an open system and it is not possible to collect the methane gas.

Thus, it becomes imperative to have a continuous supply of oxygen to lower down methane emissions as methane is a more potent greenhouse gas than carbon dioxide. For this, we had deployed aerators which enhance the level of dissolved oxygen in water. An ample and evenly distributed oxygen supply is the key to rapid, economically-viable, and effective water treatment.

(ii) Reduction of nutrients and prevention of eutrophication: Excess of nutrients like nitrogen and phosphorous in a water body leads to growth of algae and plants like water hyacinth. These species take up a lot of nutrients which are then not available for other species. Also, when they die, they contribute to sludge formation which requires a lot of oxygen for decomposition. This depletes the dissolved oxygen level of the lake. The plants and microbial cultures take up these nutrients so that they are not available to algae, thus preventing algal bloom. Removal of nitrogen takes place as follows:

(a) Nitrification

$NH_3 + O_2 \rightarrow NO_2^- + 3H^+ + 2e^-$

$NO_2^- + H_2O \rightarrow NO_3^- + 2H^+ + 2e^-$

(b) Denitrification in this process NO_3^- is converted to nitrogen gas (N_2) by denitrifying bacteria. These are heterotrophic bacteria which need organic matter as a source for carbon.

$$2NO_3^- + 10e^- + 10H^+ \rightarrow N_2 + 6H_2O$$

Biological phosphorus removal primarily occurs via accumulation of phosphorous compounds by microorganisms. Most of the phosphorous is accumulated as polyphosphate which is retained as an energy reserve in the microorganisms.

Thus, the plants and microbes compete the algae for the nutrients in water preventing eutrophication.

(iii) Reduction in BOD: A lot of suspended matter in lakes is organic debris which results in high TSS. This is also referred to as the insoluble component of Biological Oxygen Demand (BOD). Our microbes treat both the soluble and insoluble parts of BOD, thus reducing the overall TSS level. After dosing the microbes, there will be reduction in eutrophication leading to less amount of sludge being produced. This results in lower BOD levels.

(iv) Reduction in odour: The microbes control odour by converting volatile organic compounds, H_2S and NH_3 to odourless end products.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 13 Issue 11, November 2024

CONCLUSION

By the implementation of our strategies of nature based solutions, the quality of the water in the lake was brought under optimal levels. The natural ecosystem of the lake by managing the nutrient and pollutant levels was also restored. The growth of algal blooms and invasive species could be curbed. The floating islands served as habitat for local biodiversity, thus increasing the number of ducks, fish etc. in the lake. The overall aesthetic beauty of the area got enhances, thus creating a peaceful green space for recreation. Thus, it can be concluded that nature based green technologies can be effective, environment friendly and sustainable alternatives for improving the quality of water bodies and wastewater treatment. With the success of this project, similar strategies have been deployed at Jawahar Bal Udyan Lake, Bhopal and the research is underway.

REFERENCES:

1. Simon, Monika, and Himanshu Joshi. "A review on green technologies for the rejuvenation of polluted surface water bodies: Field-scale feasibility, challenges, and future perspectives." Journal of Environmental Chemical Engineering 9.4 (2021): 105763.
2. Y. Wang, W. Zhang, Y. Zhao, H. Peng, Y. Shi, Modelling water quality and quantity with the influence of inter-basin water diversion projects and cascade reservoirs in the Middle-lower Hanjiang River, J. Hydrol. 541 (2016) 1348–1362.
3. X. Ma, Y. Wang, S. Feng, S. Wang, Comparison of four flocculants for removing algae in Dianchi Lake, Environ. Earth Sci. 74 (2015) 3795–3804.
4. G. Crini, E. Lichtfouse, Advantages and disadvantages of techniques used for wastewater treatment, Environ. Chem. Lett. 17 (2019) 145–155
5. J.A. Dunalska, J. Sienska, ´ D. Szymanski, ´ The use of biopreparations in lake restoration - Experimental research, Oceanol. Hydrobiol. Stud. 44 (2015) 500–507
6. S.R. Jing, Y.F. Lin, D.Y. Lee, T.W. Wang, Nutrient removal from polluted river water by using constructed wetlands, Bioresour. Technol. 76 (2001) 131–135