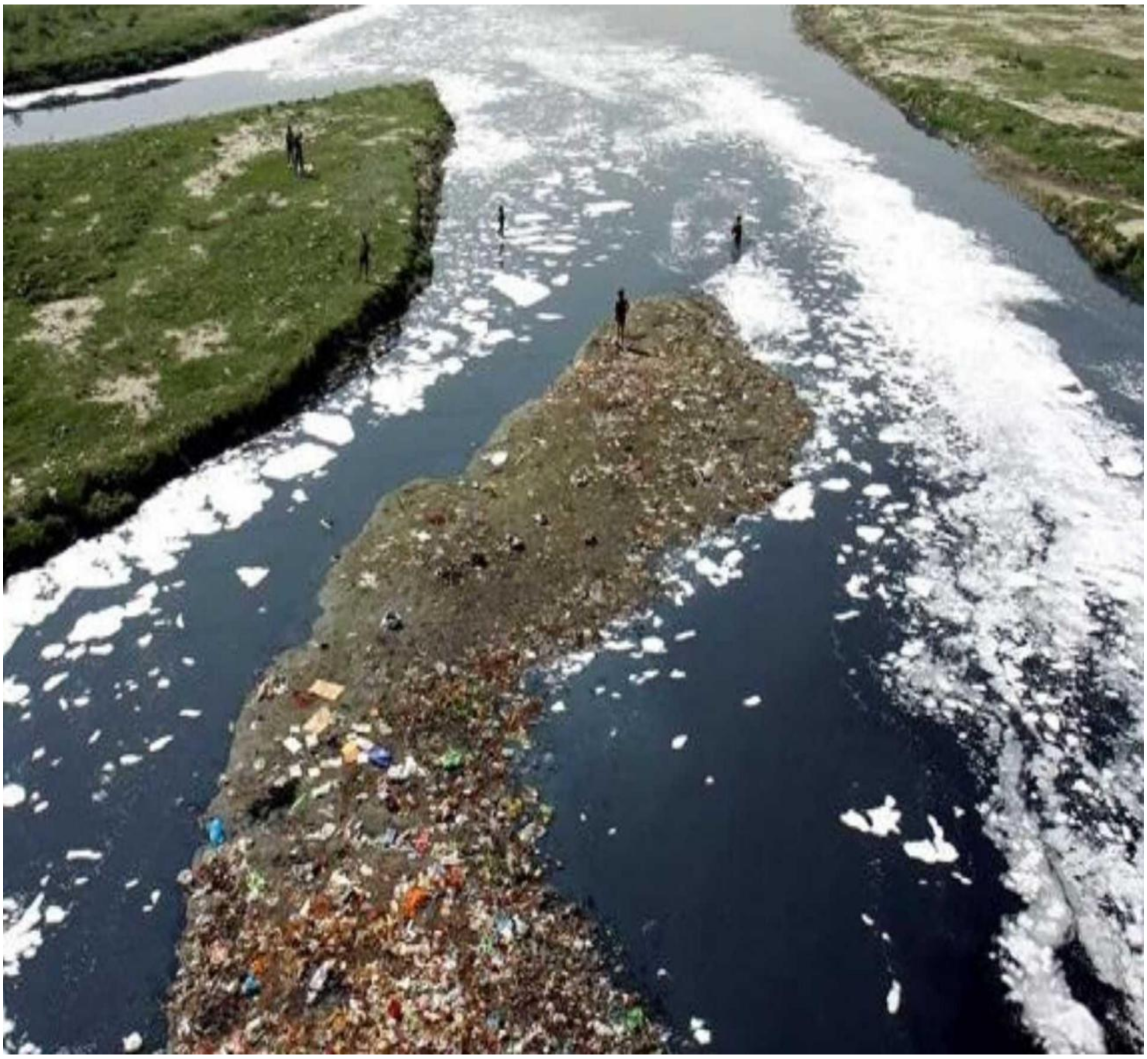
Remediation of River Eutrophication



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Executive Summary

Water eutrophication is one of the most serious global issues as water quality and scarcity become more common. Most research, conducted to date, have focused on eutrophication linked with lake, wet land and ocean ecosystems or other zones with little movement of water into and out of the system, largely because algal blooms, which are associated with eutrophication grow quickly water zones where the water. becomes anoxic. In contrast, the river ecosystem is a complex and unique area of concern, in terms of eutrophication moving waters are dynamic systems, with continuous mixing that maintains toxic conditions, not a condition for eutrophication. Although river eutrophication is common in regions dense populations and industries river eutrophication is becoming a more common and serious problem as these regions often rely on the river for potable water. Thus, river water remediated has received little scientific attention and at present the focus has been on either controlling sources of the where pollution is entering the river or by treating the polluted water as an effluent, an expensive alternative, especially in lesser developed countries. However, it is better to control the sources rather to treat the polluted water. The systematic review was conducted to find innovative approaches to resolve this problem. As a case study, the Sutlej River of Punjab, India was selected as a case which is a good example of river eutrophication. The River is experiencing rapid eutrophication as the result of rapid industrialization, and urbanization. The review resulted in three major source sites responsible for affecting the river water. The analysis led to the suggestion that phycoremediation and the application of ecosystem activation system technology could serve as an effective management option to address this serious condition. However, it is important and the responsibility of the state government, the general public, industries, and water management societies to collaborate on this developing issue and to take appropriate actions.

Introduction

In human history, with the unplanned rapid urbanization and industrialization, aquatic resources are being used as dumping grounds for sewage, industrial, and technological wastes. These kinds of activities create a harmful environment for water bodies and in addition to making many water systems unsuitable for human needs, - cause numerous aqueous species to become extinct. (Earth eclipse, n.d.) Eutrophication is a process in which water is contaminated as a result of excessnutrient enrichment, mainly nitrogen and phosphor~~o~~us resulting in algal blooms,make the water hypoxic., that is low levels of oxygen. This issue not only depleteswater quality but also becomes a threat to aquatic life. And thus, many species arereported to have become extinct (Nutrients and Eutrophication | U.S. GeologicalSurvey, 2019).

Most studies have been done upon water, that is left sitting for long periods of time. With no movement and aeration, stagnant water becomes ideal collection of bacteria or fungi such as wetlands, lakes, estuaries. However, rivers have moving water which is aerated and hence unique system. However, eutrophication is not about oxygenated or anoxic system instead, it is about enrichment of nutrients like nitrogen and phosphorous which leads to growth of plants and algal community and hence affecting the aquatic life present there. Eutrophication of rivers is best managed by reducing inputs to the river system, rather than any in situ remedial action. Point source pollutants are easily managed, but diffuse pollution from agriculture, industry, urbanization and others is less easily controlled. Significant reductions in nutrients arethose that have the capacity to alter plant community and population structure (Newman, JR, 2005).

Eutrophication also creates issues for biodiversity or aquatic health and it is also affecting the businesses and economic sectors in a negative manner (*Eutrophication: Causes, Consequences, and Controls in Aquatic Ecosystems | Learn Science at Scitable*, 2014). Moreover, this issue is more threatening for developing countries like India, where there are less resources for management and remediation for water. Also, there are fewer studies reported in the literature on river eutrophication than on lakes, wetlands and estuaries, this study focusses on eutrophication remediation of river water. Generally, eutrophication is controlled by reducing the availability of nutrients in the current freshwater system. It is important to monitor, sample, and apply a suitable methodology in order to reduce eutrophication. (The Open University, 2021) Although, it is a global issue, as eutrophication is present in almost every lake andriver due to human activities, the problem seems to be more severe in developingcountries and their specific water bodies. Therefore, as a case study this report focuseson the longest river in Punjab, India - the Sutlej River.

Eutrophication is a pollution indicator which represents the imbalance of nutrients especially N and P in water. There are several ways to detect it in water resources. Most studies have been done on fresh water of lake ecosystem, however rivers presentmore complex issues.

As my main goal is focused upon the Sutlej River, an actively running water system, rather than a more stagnant system such as a wetland, observing and calculating the eutrophication is a bigger challenge as compared to stagnant water because algal blooms are spread with the flow of the river.

Eutrophication on lakes will stay on one place but river eutrophication is like a conduit pipe as everything that happen on land impacts the river and eventually the ocean and to some extent vice versa.

As river water is used for irrigation purposes it also may eventually become a land issue. Moreover, river water is affected by a diverse landscape with a range of land uses, including agriculture, cities, industrial activities which may also contain heavy metal contamination along with sediments and siltation which further degrades the water quality.

The aim of project is to conduct a comprehensive analysis and synthesis of effective management as well as remediation practices and their ability to reduce eutrophication in a river system. This will provide a scientific basis to support wastewater management societies and the State Pollution Control Boards to develop a science-based water quality strategy.

Project Objectives

- To identify the challenges of remediating eutrophication in rivers,
- To present two case studies to demonstrate the challenges in populated watersheds, and
- To present and evaluate innovative microbial based remediation of eutrophication in rivers.

Image 1- Sutlej river of Punjab, India; source- Google Earth

Note- My focus is Sutlej river represented by Image1. However, the example of Chinese remediation strategy will be discussed as the recommendation due to to some similarities between India and China in terms of population, weather conditions, and also both are developing countries. So, it will be easy for India to adapt the remediation strategy of China.

Background and Location of Sutlej River-

Sutlej River is the longest river in Punjab, India, and a major source of water supply for irrigation, drinking, washing, and bathing in the region. In the Punjab region, the River Sutlej receives a large amount of effluents from various industries and city sewage drains. (Sharma et al., 2017)

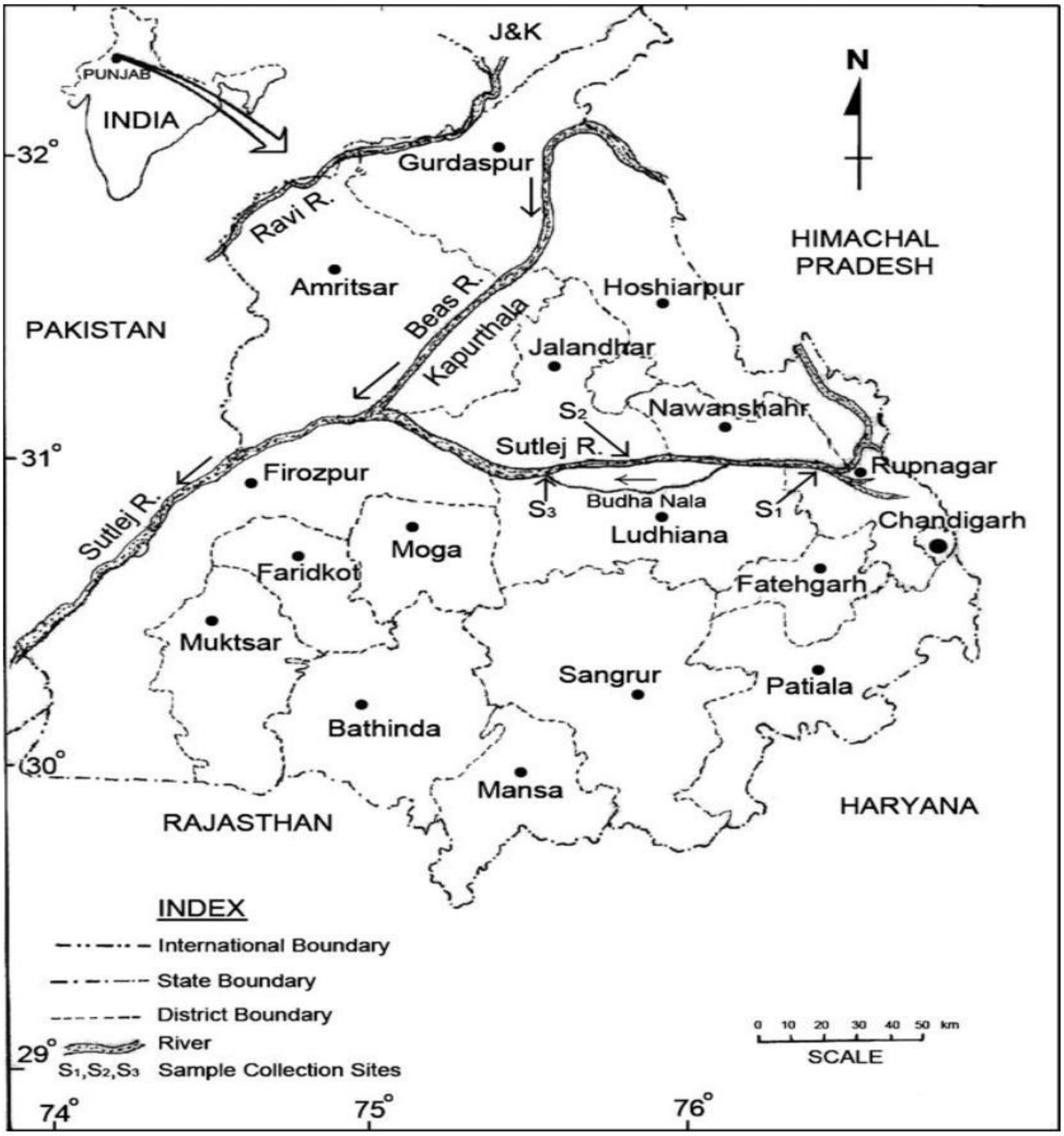


Fig 1- Sutlej river map; source- https://www.researchgate.net/profile/Rajinder-Jindal/publication/264385769/figure/fig1/AS:295835880443908@1447544178986/Map-showing-observation-sites-S-1-S-2-and-S-3-on-river-Sutlej-S-1_Q640.jpg

The Sutlej River originates from Mansarovar Lake in Tibet at an elevation of about 4572 m and is a major tributary of the River Indus. Satluj (Figure1) plays a key role in the economy of northern India where two out of three persons depend upon agriculture and allied activities for their livelihood. The entire Satluj basin lies between latitudes 30 and 33°N and longitudes 76 and 83°E. The Satluj River enters the Indian state of Himachal Pradesh at Shipkila at an altitude of 6,608 meters. It flows in a southwesterly direction through Kinnaur, Shimla, Kullu, Solan, Mandi, and Bilaspur districts. The total length of the river is 1,448 km. The Sutlej leaves Himachal Pradesh to enter the plains of Punjab at Bhakra, where India's highest gravity dam has been constructed. The catchment area of the Satluj to Bhakra dam is about 56,876 km^2 of which 36,900 km^2 lies in Tibet and 19,975 km^2 in India. The total installed capacity is 1325 MW – 5 x 108 MW + 5 x 157 MW Francis turbines. Finally, the Satluj drains into the Indus in Pakistan (Husain, 2017).

The total length of river Sutlej in the state of Punjab is approximately 440 km. The average discharge of the River Sutlej in the State of Punjab, as measured at Ropar, is approximately 500 m3/ sec. At Ropar, there is a Head-Works for canal system to provide irrigation to large parts of the State. The total catchment area of River Sutlej in the state of Punjab is approximately 20303 $km.^2$(Central Pollution Control Board, 2019)

Data Interpretation-

The below tables clearly indicate the presence of eutrophication. In table 1, from the year data of 2015- 2018, it is clear that the overall fecal coliform population is increasing which is indicates the presence of sewage and hence organic compounds in the water.

Overall, The B.O.D and the fecal coliform values are increasing which promotes algal growth and hence indicating the presence of eutrophication, bad water quality and suffocating environment for the aquatic life.

Year	Location	pH	DO mg/l	COD mg/l	BOD mg/l	Total Coliform MPN/100ml	FecalColiform MPN/100ml	Class as per DBU
2015	Sutlej at U/S Budha Nallah (Upper)	7.5	6.3	5.9	1.3	500	228	B
2016		7.9	7.3	9.2	<1	895	324	C
2017		7.5	6.7	12.3	<1	2286	1119	C
2018		7.6	6.8	9.3	<1	2550	1053	C
2015	Sutlej at 100m D/S Budha Nallah Confl., Ludhiana	7.2	4.2	54	17	56000	38250	D
2016		7.5	4.1	69	21	41100	17140	D
2017		7.4	3.0	251	75	123083	71167	E
2018		7.3	3.0	218	54	535000	235556	E
2015	Sutlej at D/S East Bein	7.5	3.0	35	6.1	8750	4125	E
2016		6.8	2.3	49	9	2430	838	E
2017		7.2	1.1	54	12	2353	1145	E
2018		7.5	3.1	50	11	24742	15208	E

Table 1- Sutlej river condition; source- (Central Pollution Control Board, 2019)

In Table 2, it can be noticed that in the given locations, both nitrate and phosphate values increase in summers and winters. From the Table 3 standard values, clearly shown that Buddah Nullah (Image 2) is the concerned location. Furthermore, phosphate is the nutrient which we need to reduce as compared to nitrate in order to control eutrophication.

Image 2- Condition of Buddah Nullah; source- https://englishtribuneimages.blob.core.windows.net/gallarycontent/2020/5/Desk/2020_5$largeimg_155656314.jpeg

Location	*Season*	*NO_3 (mg L^{-1})*	*PO_4 (mg L^{-1})*
Ropar head works	Winter	0.32–0.43	0.10–0.02
	Summer	0.40–0.62	0.22–0.27
	Monsoon and post Monsoon	0.53–0.82	0.20–0.32
Budha Nullah at Phillaour	Winter	0.38–0.62	0.21–0.31
	Summer	0.80–1.05	0.33–0.50
	Monsoon and post Monsoon	0.82–1.26	0.33–0.57
Budha Nullah at Wallipur (Industrial area of Ludhiana)	Winter	0.80–1.30	0.52-0.70
	Summer	1.10–1.35	0.67-0.98
	Monsoon and post Monsoon	1.16–1.62	0.76-1.10

Table2- Seasonal nutrient concentration; source- (Prasad et al., 2019)

Parameters	WHO	ISI	ICMR
pH	6.5–8.5	6.5–8.5	7–8.5
Total alkalinity	120	–	–
Total hardness	500	300	300
Chloride	250	250–1,000	250–1,00(
Nitrate	50–100	50–100	20–100
Phosphate	0.1–1	0.5–1	–
BOD	5.0	–	–
DO	5.0	3.0	–
TDS	500	–	500

All parameters are expressed in mg L^{-1} except pH

Table 3- water quality standards by world health organization (WHO), indian standards institution (ISI), indian council of medical research (ICMR);

Source- Jindal and Sharma (2011)

Action Plan for Clean River Sutlej

According to the action plan by the state government of Punjab, Punjab Pollution Control Board (CPCB) and other environmental stakeholders focused on the polluted water of Sutlej river and identified different causes. Taking into account the rapid urbanization and industrialization, all the stakeholders had regular meetings and planned the certain actions which were crucial for the River remediation and cleanliness (Central Pollution Control Board, 2019).

In 2019, they decided to establish a total of 101 STPs (sewage treatment plants) around the Sutlej River. Moreover, a total of 59 STPs were already established and 8 were under installation whereas they were planning to build the rest of the STPs within the upcoming years (Central Pollution Control Board, 2019).

Ludhiana City falls within the catchment area of River Sutlej and is contributing significantly to the water pollution of River through Buddha Nallah, which passes through the heart of Ludhiana City. Ludhiana City which was declared critically polluted areas by the Ministry of Environment & Forests and thereby restricted the setting up of new / expansion of existing projects (Central Pollution Control Board, 2019).

Therefore, Punjab Pollution Control Board developed a comprehensive remedial environmental action plan titled "Ludhiana Action Plan regarding abatement of Environmental Pollution in Critical Polluted Areas of Ludhiana" prepared in consultation with all the stakeholders, including Industrial Associations.

Cleaning and monitoring of Buddha Nallah were considered as the priority issues subject under these actions.

On the other hand, CPCB categorized the water classes for monitoring the river water as follows-

Class A: Drinking water sources without conventional treatment but after disinfection

Class B: Organized outdoor bathing

Class C: Drinking water sources with conventional treatment followed by disinfection

Class D: Propagation of wildlife and fisheries

Class E: Irrigation, Industrial cooling, and controlled water disposal

Status of river water quality-

(i). Class-B quality of water enters the State, which becomes Class-C while crossing Nangal-Ropar Belt and District Hoshiarpur.

(ii). It remains Class-C before point of confluence of Budha Nallah with river Sutlej.

(iii). It becomes Class-E after the confluence of the Budha Nallah with River Sutlej.

(iv). After reaching at Dharamkot Nakodar Road, Jalandhar (which is upstream of point of confluence of East Bien with River Sutlej) its quality becomes Class-D.

(v). At the downstream point of confluence East Bein with River Sutlej, its quality becomes again Class-E

Major Sources of Pollution

(i). Sewage/ sullage generated from Urban Areas

(ii). Sewage/ sullage generated from Rural Areas

(iii). Industrial sources

(iv). Discharge of wastewater from dairies

(v). Waste water from carcass handling unit

The government installed CCTV cameras for monitoring the river pollution. The government also made strict rules for preventing the river source pollution ~~and~~ established laws/ punishments were enacted for the people/ industrialist polluted the river water. Also risk assessment was done to monitor f~~or~~ the success of this action plan.(Central Pollution Control Board, 2019)

However, this plan was not completely successful due to time, money and electricity issues. The government is still looking for the alternative approaches.

River contamination and life hazard-

News information in 2021, reported that people living around the Sutlej River, Ludhiana are having serious impacts on their health as well as on their crop yield (Aggarwal, 2021). The river water depollution process has been delayed from the due date due to which the pollution was also spreading to the neighbouring States, like Rajasthan. People living in Rajasthan were getting numerous diseases from the bad quality water of river Sutlej. The black water of Buddah Nullah is disturbing the native people as they are really concerned about their health (Aggarwal, 2021). Furthermore, if this polluted water can impact human life and crops then it could be risk of extinction for aquatic life live inside the water.(Aggarwal, 2021)

Image 2- Toxicity of River water; source- https://images.citizenmatters.in/wp-content/uploads/sites/2/2019/10/29113329/sutlej-banks-ludhiana.jpg

Recommendations-

As one can see the examples in Table 3a, there are many remediation techniques and management strategies that could be applied to the affected water zones in order to reduce eutrophication. However, these techniques have some disadvantages in terms of cost, energy consumption, and self-purification. In contrast, there is another

Table 3a- Eutrophication methods with limitation; source- Chai et al.,2017

METHODS	LIMITATIONS
Sewage interception	• costly • and burdens urban sewage systems and wastewater treatment plants
Deep dredging	• damages the ecology of river bottoms
Phytoremediation	• dependent on local climate conditions and limits its longevity and function
Artificial aeration	• large energy consumption
Water transfer	• can't restore the self-purification capacities of the water ecosystem

technique which is plant based and really effective remediation strategy known as phytoremediation, but the issue is that the growth and nutrient removal potential is affected by many factors such as temperature, water salinity, and the physiological limitations of the plant. So, we still need to look for new strategies that can overcome all the disadvantages of the previous approaches.

A) <u>Ecosystem Activation system (EAS) Treatment-</u>

A new technique based on the principle of water self-purification of polluted water ecosystems is a process where the microbial community plays a key role in the water body self-purification as the microbial community eliminates the deleterious water materials. (Chai et al., 2017)

The benefits of the process are the removal of contaminants as well as hazardous algae. (e.g., two and three-fold decrease in the amount of Flavobacterium and Pseudomonas, typical abundant species of eutrophic freshwater, respectively) (Chai et al, 2017).

The process also creates beneficial conditions for microbiome recovery (Chai et al, 2017) and can restore and maintain ecological integrity. For example, representative phytoplankton of eutrophic freshwater, *Chlorella*, and *Chlamydomonas* were undetectable (Chai et al, 2017).

The location of the case study was 21.539579°–121.539983°E, 31.314243°–31.314806°N, Shanghai, China. The analysis time was 90 days. The total area of the water body is 8000 m2, and the water depth is 2–3 m. The main pollution sources were surface runoff and uncontrolled discharge of domestic wastewater due to the combined sewer. The water surface was initially covered by suspended algae clouds and was blackish green (Chai et al, 2017).

According to Chai et al (2017) this treatment -the EAS technology has 3 reaction stages: anoxic, aerobic, and releasing. Polluted water is pumped into EAS, microorganisms activation is initiated by the addition of a specific activating reagent like Polyhydroxyalkanoate (PHA).

Beneficial microorganisms activated by the system are released into the water body with effluent. As a result, the microbial community structure of the water ecosystem was continuously restored.

During the formal operation stage, the influent and effluent flow was kept at 0.1 m^3/h.The internally recycled water was moved to the influent. The 2 streams of water were completely mixed at the inlet of the self-priming pump. The inner ratio was 100% and the hydraulic cycle of the entire system was maintained by the self-priming pump. DO concentration was maintained at 3.5 ± 0.5 mg/L in the aerobic stage using an online, real-time control device.

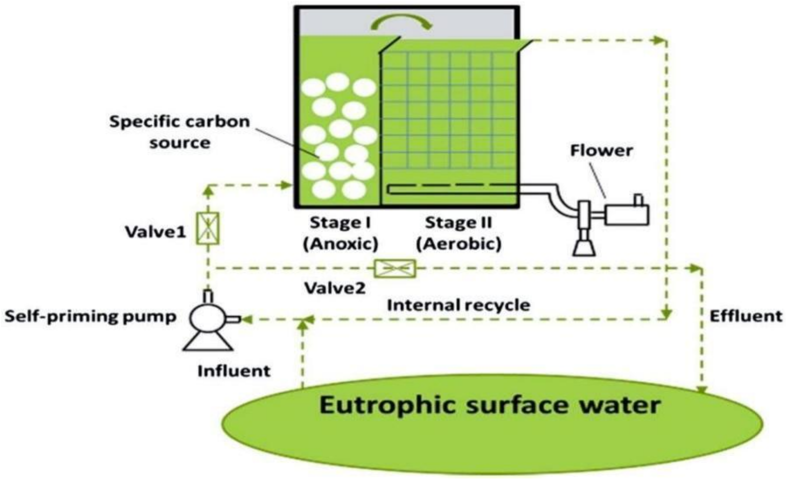
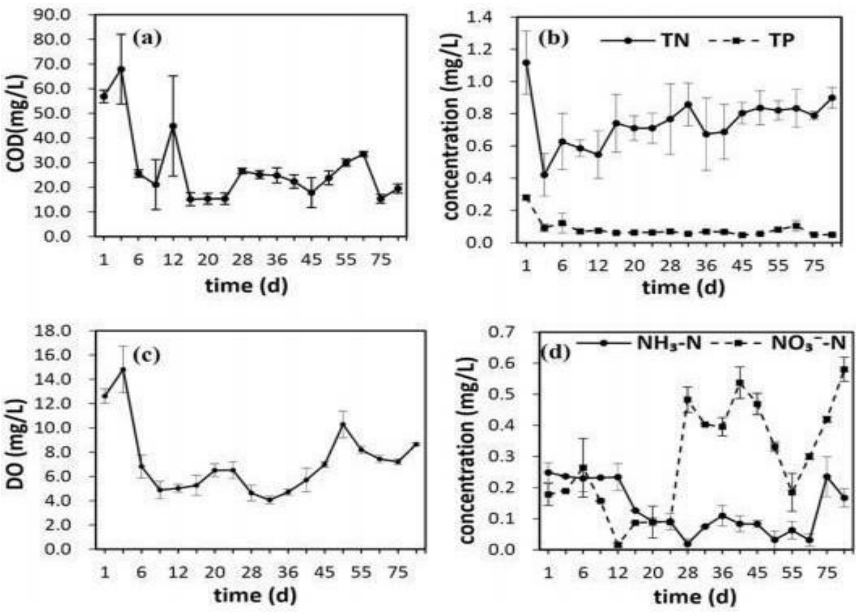


Figure 2- EAS; source- (Chai et al. , 2017)



Graph 1- Result of EAS over a time period of 75 days; source-(Chai et al. , 2017)

B) <u>Phycoremediation-</u>

In phycoremediation, microalgae consume the excess nutrients as well as other heavy metals which also retard the growth of other species of algae and hence improving he water quality (Kiran et al, 2016).

The location of the lake as a case study is Indira Park, Hyderabad (India). The Lake is heavily contaminated with blue-green algae (BGA) mainly *Microcystis sp*. Before treatment, the lake contained insufficient levels of nitrogen, phosphor~~o~~us, COD, and BOD along with a bad odor. The total lake area is around 1.875 hectares with an average depth of 8 m (Kiran et al., 2016).

According to Kiran et al, (2016) in this treatment, diatoms are used to consume nitrates and phosphates along with nutrients like silica, iron, copper, molybdenum, etc. It uses carbon dioxide and produces oxygen along with the accumulation of heavymetals. Furthermore, this algal treatment retards the blue- green algae growth and hence controls the lake pollution. Moreover, Benthic Diatomic algae along with nualgi, an algscide, could help in water restoration as well carbon sequestration.

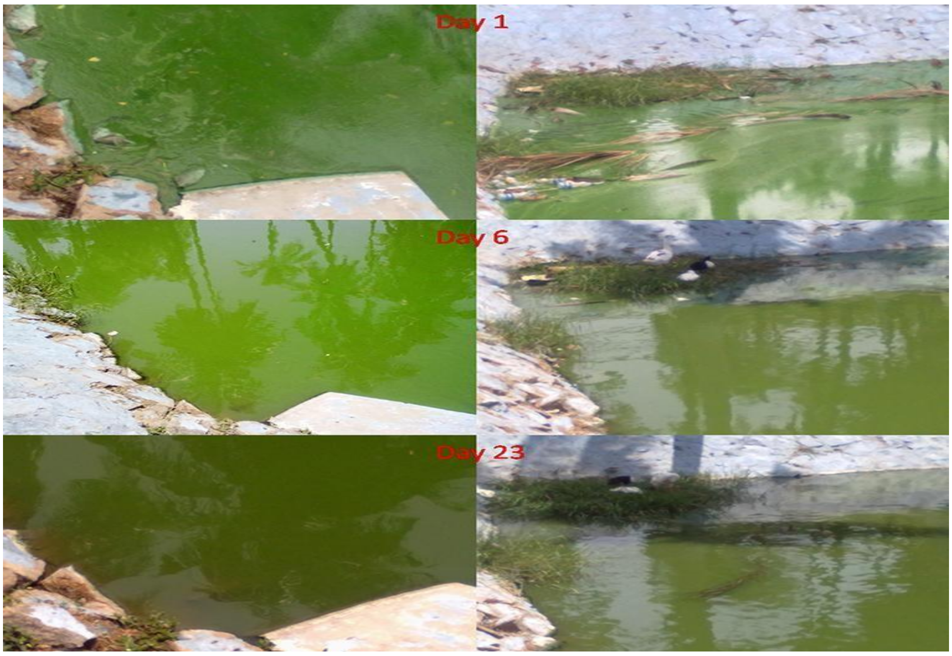


Figure 3- Lake visibility from day(1-23) after treatment; Source- (Kiran et al., 2016)

Figure 3 is the visible proof of the reduction of blue green algae and improvement in water quality.

S. No	Parameter	Inlet	Day 01	Day 06	Day 14	Day 23	Percentage of reduction
	Nualgi dosage		4 l	2 l	2 l	2 l	
1	pH	7.61	6.56	6.98	6.99	7.01	
2	Conductivity, ms/cm	1021	932	856	824	839	
3	TDS, mg/l	935	864	474	948	1079	
4	TSS, mg/l	33	14	<10	<10	<10	
5	COD, mg/l	323	350	212	101	32	94%
6	BOD, mg/l	64	56	14	27	10	89%
7	DO, mg/l	0.3	0.6	0.2	1.2	0.8	
8	TKN, mg/l	33	16	10	18	6	83%
9	Nitrate, mg/l	2.42	1.94	0.86	0.78	0.58	82%
10	Phosphate, mg/l	1.45	1.12	0.88	0.54	0.38	80%
11	Faecal coliform	21	18	8	12	12	

Table 3b- Reduction of contaminants ; Source- (Kiran et al., 2016)

Phytoplankton	Day 1	Day 7	Day16	Day 24
Blue green algae (BGA)	122	63	43	41
Pennate	11	34	54	71
Centric	2	13	16	16

Table 4- Microbial coimmunity (units- cellsx 10^6/ml); Source- (Kiran et al., 2016)

As per Table 3b and Table 4, it may be concluded that this unique methodology actually improves the water condition and also reduces algae growth. Moreover,reduction in chemical contaminants is seems to be very impressive. This technique is unique and a new approach for resolving the eutrophication issues.

Conclusion-

- I consider both Ecosystem activation system and phycoremediation as innovative, affordable, and are energy efficient methodologies. The benefit of self-restoration makes these techniques more valuable. However, there are some knowledge gaps in EAS treatment which could be the limitation of this process.

On the other hand, phycoremediation could be more effective if it could be used as an integrated approach that is if it is used with other wastewater treatment processes (Ricky & Shanthakumar, 2022).

- In a crux, there is a strict need for alternative approaches to clean river water. It is important for Government to generate effective action policies which are affordable and can improve water health because a lot of lives are dependent upon "healthy" water. For water management societies and environmental activists, it is important to be aware of the disadvantages of using the water and its designated use.

On the other hand, Indian youth can come forward and take some actions to motivate people about the right actions. Volunteer activities could be done by the public to take out the garbage from river water. Moreover, people also avoid throwing plastics and other medical wastes into rivers and even into the river water. It is now important for the Industrial association to think about installing sewage treatment plants and phycoremediation for the treatment of wastewater with high chemical content otherwise the banning of industries around the river would be the only solution.

So, combined and innovative approaches are the primary requirement for this river project.

Acknowledgement

I would like to thank my project supervisor Dr. Les Lavkulich who gave me this opportunity to work on this project. I got to learn a lot from this project about remediation strategies about eutrophication, how to differentiate river and lake eutrophication and how to do the critical thinking and writing. I would also like to thank MLWS faculty for every support.

I would also like to extend my heartfelt thanks to your parents because without their help this project would not have been successful. Finally, I would like to thank my dear friends who have been with me all the time.

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