



# IJIRSET

International Journal of Innovative Research in  
**SCIENCE | ENGINEERING | TECHNOLOGY**

e-ISSN: 2319-8753 | p-ISSN: 2320-6710



# INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 10, Issue 7, July 2021

**ISSN** INTERNATIONAL  
STANDARD  
SERIAL  
NUMBER  
INDIA

Impact Factor: 7.569



9940 572 462



6381 907 438



ijirset@gmail.com



www.ijirset.com

# A Review of Lake Water Treatment Using Submerged Aquatic Plants

Dr.Arif Khan<sup>1</sup>, Snehal Bhaskar Thamke<sup>2</sup>

Registrar, National Institute of Technology Raipur, Raipur, Chattishgarh, India<sup>1</sup>

PG Student, Department of Civil Engineering, Nuva College of Engineering & Technology, Kalmeshwar, Nagpur, Maharashtra, India<sup>2</sup>

**ABSTRACT**—Increasing urbanization, industrialization and over population are the factors mainly responsible for adding hazardous components in lake water, which mainly constitutes heavy metals and chemicals etc. Water bodies are the main targets for disposing the pollutants directly or indirectly. In this paper illustrating the role of plants to assist the treatment of wastewater. The prevailing purification technologies used to remove the contaminants are too costly and sometimes non-ecofriendly also. Therefore, the research is oriented towards low cost and eco-friendly technology for waste water purification, which will be beneficial for community. The paper discusses the potential of different process and utilization of terrestrial and submerged aquatic plants (Hydrilla) in purifying water and wastewater from different sources. Present study was conducted by off-site experiment, where HydrillaverticillataCasp was cultured in a tub for subsequent seven days over one year. Second one of the tub was used as control. The quality of domestic wastewater was assessed before and after the experiment by analyzing physicochemical parameters. . The results of the present experiment revealed the significant improvement in the quality of municipal wastewater, as indicated by the decrease in values of most physicochemical parameters studied. That showed efficiency and potentiality of aquatic plant for the purpose.

**KEYWORDS:** Hydrillaverticillata Casp, Submerged Aquatic Plants, Constructed Wetlands, Lake Water

## I. INTRODUCTION

### 1.1 HYDRILLA SUBMERGED SPECIES

Hydrilla (waterthyme) is a genus of aquatic plant, usually treated as containing just one species, Hydrillaverticillata, though some botanists divide it into several species. It is native to the cool and warm waters of the Old World in Asia, Africa and Australia, with a sparse, scattered distribution; in Australia from Northern Territory, Queensland, and New South Wales. The stems grow up to 1–2m long. The leaves are arranged in whorls of two to eight around the stem, each leaf 5–20 mm long and 0.7–2 mm broad, with serrations or small spines along the leaf margins; the leaf midrib is often reddish when fresh. It is monoecious (sometimes dioecious), with male and female flowers produced separately on a single plant; the flowers are small, with three sepals and three petals, the petals 3–5 mm long, transparent with red streaks. It reproduces primarily vegetatively by fragmentation and by rhizomes and turions (overwintering), and flowers are rarely seen. They have air spaces to keep them upright. Hydrilla is a hardy, fast-growing, herbaceous perennial with long, slender stems that can grow to some 7 metres (23 feet) in length. The leaves grow in pairs or in whorls of three to eight and are small, lance-shaped or oblong, and distinctly toothed. It has a high resistance to salinity compared to many other freshwater associated aquatic plants.

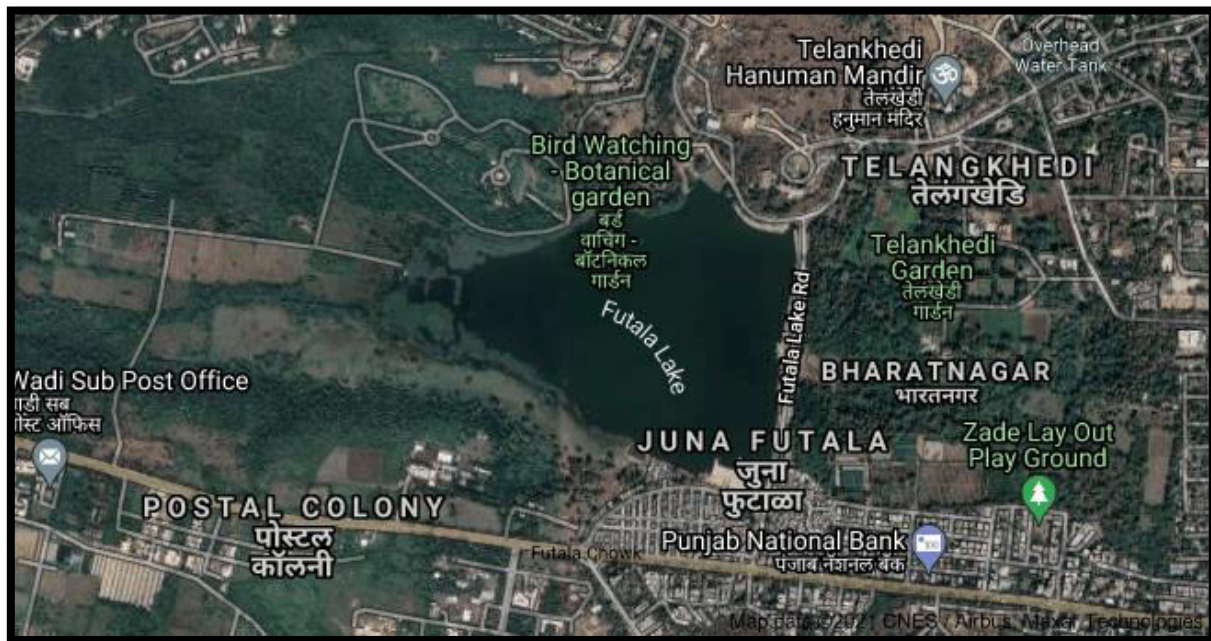
### 1.2 SAMPLING LOCATIONS

According to a survey by ABP News-Ipsos, Nagpur has been identified as the best city in India by topping the liveability, greenery, public transport, and health care indices. It is famous for the Nagpur Orange and is known as the “Orange City” for being a major trade center of oranges cultivated in the region.

Nagpur city with coordinates of 21°8'55" and 79°4'46"E is second capital of Maharashtra state. Nagpur city is popularly known as orange city, also city of lakes. The city had 10 lakes in the past, but unfortunately only 7 of them are there now. The Futala Lake with a coordinate of 21°8'44"N and 79°03' 48"E is closed water body. The Fulatalake is spread



over 60 acres. The Futala Lake is located at the western side of the Nagpur city. The catchment area of dam is 6.475 sq. km. The length of west weir is 8.0m. Futalalake is having capacity to irrigate an area of 34.42 hectors of cultivated agriculture land and Telenkhedi Garden. The initial purpose for irrigating nearby agricultural land was prominent amongst the utilization of Futalalake.



(Figure 1: Satellite Image of Futala Lake)

### 1.3 Problem on hand

The Futala lake water is unpotable and now-a-days used for irrigation purpose and for commercial fisheries. It doesn't have self cleaning capacity; hence continuous addition of nutrients through many polluting sources is leading. The watershed of Futalalake is a part of Nag river watershed. Nag River is completely polluted on account of incoming sewage into it. The Four streams are prominent within catchment. The Futala Lake and its environs near Telankhedi Garden on Amravati road, Nagpur, is a picnic spot. It is rainwater impoundment with an area of 26.3 hectors and 5-6 meters deep during monsoon. Futala Lake, too, is facing the threat of eutrophication with weeds covering almost half the lake area already. The sewage is released into Futala Lake without treatment therefore the Futala lake water is polluted at moderate level. In Futala Lake, eutrophication was first seen in some portion towards west, but, almost half of the lake area is covered by weeds, especially on south and north side. Species inside the water start to diminish due to lack of sunlight, even oxygen level in lake water already drastically dropped. Another worry for the lake was, collapse of large portion of embankment towards the bund embankment, constructed with black stone in some time ago, raising the needs for inspection of remaining portion of the embankment. Futala Lake was chosen in this study, since it is heavily influence by human actions leading to domestic and partially agricultural pollution sources. The basic objective of present study is to treatment of Futala lake water using submerged aquatic plants.

### 1.4 U.S. EPA Guidelines

There are no federal regulations governing reclaimed water use, but the U.S. EPA (2004b) has established guidelines to encourage states to develop their own regulations. The primary purpose of federal guidelines and state regulations is to protect human health and water quality. To reduce disease risks to acceptable levels, reclaimed water must meet certain disinfection standards by either reducing the concentrations of constituents that may affect public health and/or limiting human contact with reclaimed water.

*Based on the U.S. EPA inventory*, current regulations can be divided into the following reuse categories: unrestricted urban reuse (irrigation of areas with unrestricted public access), restricted urban reuse (irrigation of areas with

controllable access), agricultural reuse on food crops, agricultural reuse on non-food crops, unrestricted recreational reuse, restricted recreational reuse, environmental reuse (wetland or sustain stream flows), industrial reuse, groundwater recharge, and indirect potable reuse. Based on the study objectives, the regulations on “unrestricted urban reuse” and “agricultural reuse on food crops” should be considered in this research. Table 1 lists the U.S. EPA guidelines for urban reuse and agricultural reuse water quality.

**Table 1 U.S. EPA Guidelines for Water Reuse**

Reuse types	Treatment	Reclaimed water quality	Setback distance	Monitoring
<b>Urban reuse (landscape irrigation, vehicle washing, fire protection, commercial air conditioners, etc.)</b>	Secondary Filtration Disinfection	pH=6-9, BOD≤10mg/L, ≤2 NTU, No detectable fecal coli/100mL, 1 mg/L CL2 residual(minimum)	50 feet to potable water wells	pH: weekly, BOD: weekly, Turbidity: continuous, Coliform: daily, Cl2 residualcontinuous
<b>Agricultural reuse on food crop</b>	Secondary Disinfection	pH=6-9, BOD ≤30mg/L, TSS ≤30mg/L, < 200 fecal coli/100ml, 1mg/L CL2 residual(minimum)	300 feet to potable water wells 100 feet to areas accessible to the public (if spray irrigation)	pH: weekly, BOD: weekly, TSS: daily, Coliform: daily, Cl2 residualcontinuous
<b>Agricultural reuse nonfood crop</b>	Secondary Filtration Disinfection	pH=6-9, BOD≤10mg/L, ≤2 NTU, No detectable fecal coli/100mL, 1 mg/L CL2 residual(minimum)	50 ft (15 m) to potable water wells	pH: weekly, BOD: weekly, Turbidity: continuous, Coliform: daily, Cl2 residualcontinuous

## 1.5 SELECTION OF WETLAND PLANTS

Floating and submerged plants are used in an aquatic plant treatment system. A range of aquatic plants have shown their ability to assist in the breakdown of wastewater. The Hydrilla, Tape Grass and Pondweed are common submerged aquatic plants which have shown their ability to reduce concentrations of BOD, TSS and Total Phosphorus and Total Nitrogen. However prolonged presence of Hydrilla, Tape Grass and Pondweed can lead to deterioration of the water quality unless these plants are manually removed on a regular basis. These submerged plants will produce a massive mat that will obstruct light penetration to the lower layer of the water column that will affect the survival of living water organisms. This system is colonised rapidly with one or only a few initial individuals. The system needs to be closely monitored to prevent attack from these nuisance species. Loss of plant cover will impair the treatment effectiveness. Plant biomass should be regularly harvested to ensure significant nutrient removal. Plant growth also needs to be maintained at an optimum rate to maintain treatment efficiency.



(Figure2 :Hydrilla submerged aquatic plant)



(Figure3 : Tape Grass submerged aquatic plant)



(Figure 4: Pondweed submerged aquatic plant)

## 1.6 ROLE OF PLANTS

The main role of the aquatic plants (please be sure to select only aquatic plants because of the always water saturated environment that is a fundamental aspect in constructed wetlands) is to act as catalyzers in the purification process. This process, as seen before, is a combination of microbiological, chemical and physical processes. The plants haven't a significant action as direct removal (for some substances, like N and P or organic matter, we can talk of a contribution in the order of 10-20% during the vegetative season); they offer instead a very efficient support for the growth of aerobic bacteria colonies on their rhizomes. Air is pumped towards the root zone by several mechanisms, like convection. Another important plant's function is the maintenance and continuous re-establishment of the hydraulic conductivity inside the beds.

**Table 2: Role of plants**

Macrophyte property	Role in treatment process
<b>Aerial plant tissue</b>	<ul style="list-style-type: none"> <li>• Light attenuation – reduced growth of phytoplankton</li> <li>• Reduced wind velocity – reduced risk resuspension</li> <li>• Aesthetic pleasing appearance of system</li> <li>• Storage of nutrients</li> </ul>
<b>Plant tissue in water</b>	<ul style="list-style-type: none"> <li>• Filtering effect-filter out large debris</li> <li>• Reduced current velocity –Increase rate of sedimentation, reduced risk of suspension</li> <li>• Provide surface area for attached biofilms</li> <li>• Excretion of photosynthetic oxygen –Increases aerobic degradation</li> <li>• Uptake of nutrients</li> </ul>
<b>Roots and rhizomes in the sediment</b>	<ul style="list-style-type: none"> <li>• Stabilizing the sediment surface-less erosion</li> <li>• Prevents the medium from clogging in VFS</li> <li>• Release of oxygen increase degradation(nitrification)</li> <li>• Uptake of nutrients</li> </ul>

## II. PROPOSED METHODOLOGY

### 2.1 MATERIALS AND METHODS

#### 2.1.1 Materials

1. Submerged Aquatic Plants (Hydrilla)
2. Wastewater Sample
3. Tube
4. PVC Pipe
5. Valve



(Figure5 : Collection of Submerged Aquatic plants)



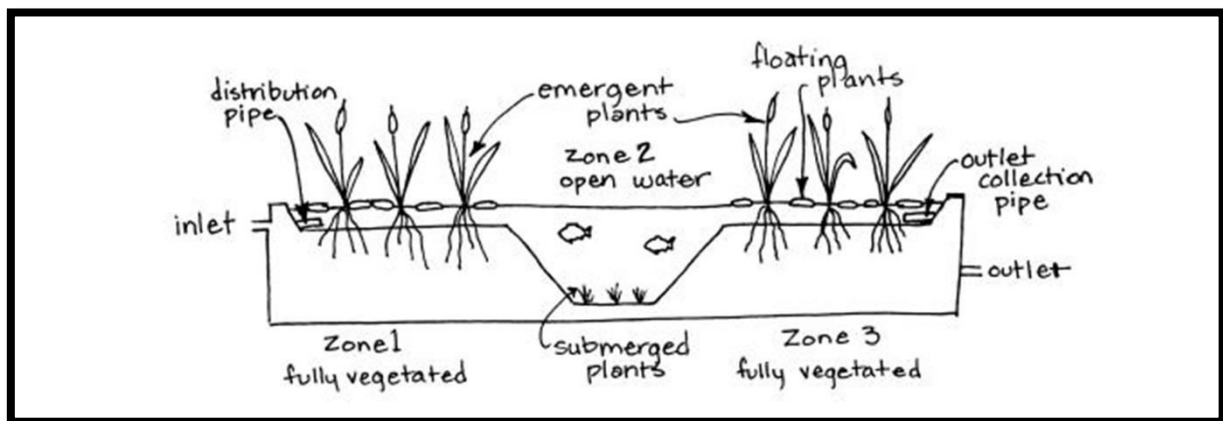


(Figure 6: Wastewater Sample and Hydrilla plants)

### 2.1.2 Experimental technique

Experimental aquatic plant (*Hydrilla verticillata* Casp.) is a submerged aquatic plant, native of Africa, Australia and parts of Asia, which can quickly overcome other plant species because of the ability to grow with less light and more efficiently take-up nutrients from aquatic system.

Remediation of nutrients from lake water (wastewater) was studied by using a *Hydrilla verticillata* Casp. A fixed amount of 100gms of this aquatic plant was cultured in a plastic tub of 0.173 m diameter, six inches deep and 20 Liter capacities containing domestic wastewater, for a week interval.

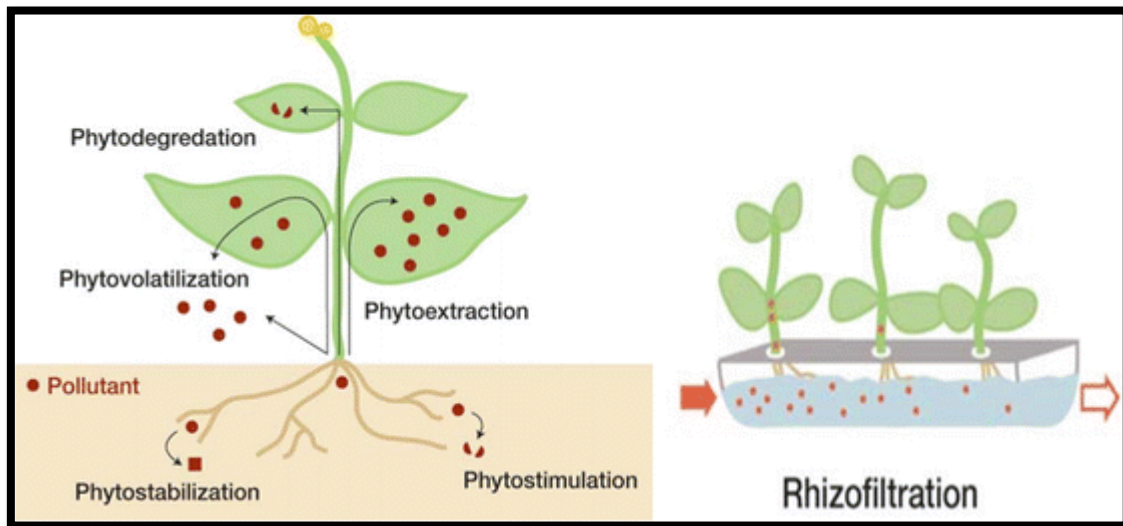


(Figure 7: Constructed Wetland Process)

### 2.1.3 Rhizofiltration Technique

A rhizofiltration system planted with *Hydrilla* was constructed with the sample of Futala lake Nagpur, Maharashtra, and evaluated for its efficiency in removing physical, chemical parameters and enteric pathogens from wastewater. The utilisation of wetlands for remediation of polluted soils and waters via rhizofiltration, phytostabilisation and phytoextraction has been increasing steadily over the past decades. The use of wetlands for quality improvement of wastewater, referred to as rhizofiltration, is the best known and most researched application of constructed wetlands. Rhizofiltration is the process of absorption of contaminants present in the rhizosphere into the root system of plants. This remediation process is used to decontaminate aquatic ecosystems using aquatic or land plants. During the

utilization of this process, plants are grown on the contaminated site (in situ) or in an ex situ environment. Contaminants are absorbed through plant roots until saturation is reached, and finally, the plants are harvested with their roots. As the accumulation of contaminants occurs in the roots without any translocation to the shoots, there is an extremely low chance of atmospheric contamination.



(Figure 8: Rhizofiltration Technique)

### III. CASE STUDY'S

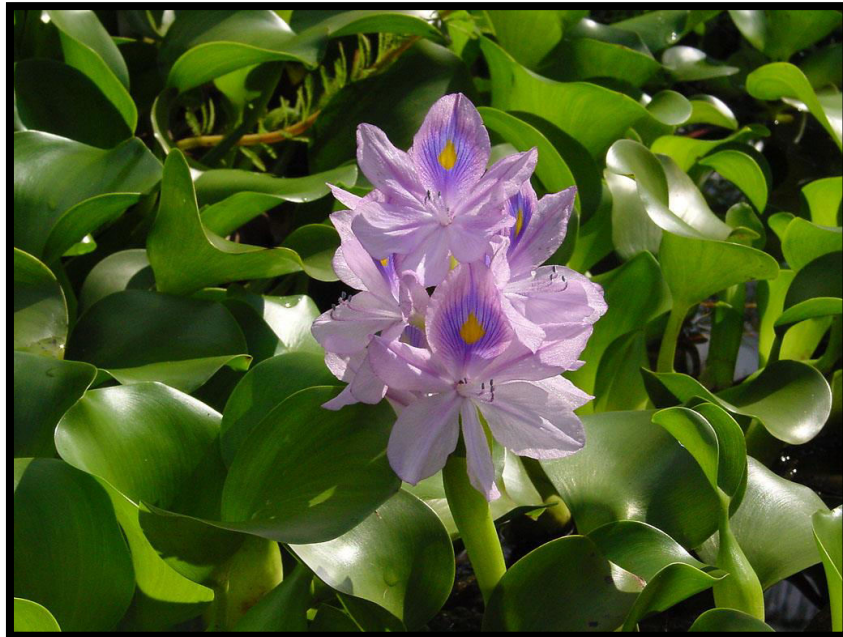
#### 3.1 CASE STUDY 2

##### 3.1.1 EXPERIMENTAL SET UP

Yadav S. B., Jadhav A. S(2011) construct wetland as combined with surface flow and planted with *Eichhorniacrassipes* was built near Technology Department, Shivaji University, Kolhapur. ( Latitude 16° 40' N, Longitude 74° 15' S). Maharashtra situated in western part of India. The climate of this region is tropical with an average annual rainfall of 1025 mm. The mean minimum and maximum temperatures during the study period were 15° C and 34°C respectively.

The integrated subsurface flow artificial wetland constructed with brickwork of size 3 m × 1.25m having a depth of 0.6 m. The tank is plastered in cement mortar on both sides. The bottom of the tank is made up of 1:4:8 concrete portions to make it watertight. The necessary slope is provided at the bottom of the tank for sludge removal. The constructed wetland cell is of 3.06 sq m area and length to width ratio 2.45:1.25. The depth of the bed is 0.6 m. The bed has regular rectangular shape and a necessary slope is provided at the bottom of the tank for sludge removal. The inlet and outlet chambers are made up of PVC pipe of 12.5 m in diameter with a control valve. At the base of the wetland unit two pipes of 10 cm diameter having inward holes at every 0.9 m distance run parallel in longitudinal direction from inlet chamber to outlet chamber to facilitate the drainage.





(Figure9 :Eichhorniacrassipes)

### 3.1.2 OPERATIONS

The campus wastewater was let into the constructed wetland intermittently over 30 days. The plants were monitored for general appearance, growth and health. The length of the plant was found to be similar to that of wetland plants in natural wetlands. Any invasive plants like ordinary grass were uprooted and removed immediately. The plant density spread vigorously within 2 months.

### 3.1.3 RESULTS

The overall system treatment performance was high and stable during the observation period

**Table 3: Physico-chemical parameters and percent removal at inlet and outlet of Set A.**

Sl.No	Parameter	Inlet		Outlet		Average removal	%
		Range	Average	Range	Average		
1	pH	7.1-7.4	6.3	7-7.3	7.2	-	
2	DO	0	0	3.4-7.1	5.56	-	
3	BOD	122-1	163.2	14-21	21.9	86.19%	
4	COD	169.2-176.40	171.9	18-25	23.10	87.35%	
5	TSS	135-142	167.1	20-59	41	76%	
6	TDS	465-505	537	99-120	199.1	69.95%	
7	TN	13.8-14.95	17.3	6.95-7.98	9.08	43.33%	
8	Total phosphorus	3.14-3.9	4.4	1.6-2.01	1.99	45%	

Table 4: Physico-chemical parameters and percent removal at inlet and outlet of Set

Sl.No	Parameter	Inlet		Outlet		Average removal %
		Range	Average	Range	Average	
1	pH	7.2-7.8	7.6	7.1-7.6	7.3	-
2	DO	0-0.1	0	4.9-6.2	7.1	-
3	BOD	132.4-141.8	136.9	9-24	22.6	95.8%
4	COD	167.4-178.8	173.45	10-28	24.9	97%
5	TSS	136.80-139.6	138.54	14-55	32.45	82%
6	TDS	467.4-486	433	90-110	109.81	71%
7	TN	14.01-14.42	14.20	7.12-7.82	6.79	43.07%
8	Total phosphorus	3.45-3.66	3.25	1.42-1.92	1.5	49.03%



(Figure : Fig.2: Water Weed: *Eichhorniacrassipes*; Fig.3: Filling the C.W. by sewage; Fig.4: Placing the *Eichhorniacrassipes* in the C.W.; Fig.5: Growth of *Eichhorniacrassipes*)

#### IV. RESULTS AND DISCUSSION

##### 4.1 Physico-chemical examination of Futala Lake Water

Macrophytes / aquatic plants grow normally in water bodies polluted by nutrients of varied sources and utilized the nutrients to produce large amount of biomass. The results of physico-chemical analysis of lake water before & after the remediation by using a submerged aquatic plant *Hydrilla verticillata* Casp shown in (Table - 1). Physical parameter Temperature plays an important role in change of various chemical parameters and physiological process of aquatic plant. pH Value was recorded around 7.0 before culture but after the culture (ending of the experiment) little increase was noticed due to reaction of aquatic plant in water.

Turbidity and Salinity values were decreased after the culture during the entire study period.

**Table 5: Physico-chemical characteristics of Lake water before & after the culture of "Hydrillaverticillata"**

S.No.	Parameters	Unit	Initial Value	Final Value
1.	Temperature	Celcius	24.8	22.9
2.	pH	.	6.98	7.63
3.	Turbidity	NTU	18.1	10.1
4.	Salinity	‰ (permil).	0.553	0.469
5.	Electrical Conductivity	Mmhos	835.10	720.30
6.	Total Oxygen Demand	Ppm	538.10	468.90
7.	Total Alkalinity	mgCaCo/L	260	155
8.	Chloride	mg/L	108.45	103.10
9.	Dissolved Oxygen	mg/L	2.6	7.5
10.	Oxygen Saturation	%	33.3	82
11.	Chemical Oxygen Demand	mg/L	144	100.8
12.	Total Hardness	mg/L	335.62	256.08
13.	Calcium Hardness	mg/L	184.14	140.58
14.	Calcium	mg/L	73.80	56.34
15.	Magnesium	mg/L	36.46	27.68
16.	Ammonical -N	mg/L	12.89	6.74
17.	Nitrite-N	mg/L	0.362	0.242
18.	Nitrate-N	mg/L	57.04	29.11
19.	Total Phosphate	mg/L	1.657	1.154
20.	Organic Phosphate	Mg/L	0.795	0.593

A minor variation was observed in chloride contents due to its non-utilization by the aquatic plant. In domestic wastewater Dissolved oxygen and Percentage oxygen saturation values were increased significantly, after the experiment, as HydrillaverticillataCasp played a vital role in oxygen transfer in to water system. Nitrogen contents were examined as Ammonical, Nitrite and Nitrate form. As Nitrate nitrogen is the stable product of oxidation.

#### 4.2 Percentage changes in physico-chemical parameters

##### Physical changes:

Temperature minimized 9.89 percentage and pH shifted above of 6.58 %. Reduction in Turbidity, Salinity noticed 37.00 and 17.42 %. Due to ionic absorbing tendency of HydrillaverticillataCasp in experiment, Electrical conductivity and Total dissolved solids were deducted in 15.66 and 15.80 % relatively.

##### Chemical changes:

34.50 % Reduction was found for Total alkalinity. Remarkable utility of Carbon dioxide in photosynthetic activity Total and Free carbon dioxide reduced in 51.56 and 36.91 %. Because of significant release of oxygen in water by HydrillaverticillataCasp Dissolved oxygen values increased to 140.1 % and Oxygen saturation 113.0 %. Little change in Chloride (4.38%) was found. Chemical oxygen demand decline average of 36.14 %. Total hardness, Calcium hardness, Calcium, Magnesium values were reduced by percentage of 28.71, 24.96, 24.39 and 37.16 individually. More





than 39.00 % reduction rate was noticed for Nitrogenous and Phosphorous compounds like Ammonical – N (39.45 %), Nitrite – N ( 47.59 %), Nitrate – N ( 50.35 %) and Total ortho phosphate (52.58% ), Acid hydrolysable phosphate (42.85 %) and 44.69 % for Total phosphate. Organic phosphate reduction value in percentage was 36.41 after the experimentation in lake water with HydrillaverticillataCasp.

## V. CONCLUSION

It is noted that CWs are now being increasingly used for environmental pollution control. Constructed wetlands were implemented in a wide range of applications, such as water quality improvement of polluted surface water bodies, wastewater on-site treatment and reuse in rural areas, campuses, recreational areas and green architectures, management of aquaculture water and wastewater, tertiary treatment, and miscellaneous applications.

Water monitoring results obtained from several demonstrations show that CWs could achieve acceptable wastewater treatment performances in removing major pollutants, including suspended solids, organic matters, nutrients, and indicating microorganisms, from wastewater influent. The results indicate that if constructed wetlands are appropriately designed and operated, they could be used for secondary and tertiary wastewater treatment under local conditions, successfully. Hence constructed wetlands can be used in the treatment train to upgrade the existing malfunctioning wastewater treatment plants, especially in developing countries. During hydraulic retention study, it was found that the BOD, COD was best removed in planted wetland than unplanted wetland. It is because of the oxygen diffusion from roots of the plants and the nutrient uptake and insulation of the bed surface. It is also found that the increases in the detention period of the wastewater the removal rate also increases.

## ACKNOWLEDGMENTS

The authors are grateful to the NUVA COLLEGE OF ENGINEERING & TECHNOLOGY, for providing guidance and resources to carry out this work.

## REFERENCES

1. Dr. Arif Khan, 2019, Quantify impact on water Environment by Using Fuzzy set Theory INTERNATIONAL JOURNAL OF CIVIL STRUCTURAL ENVIRONMENTAL AND INFRASTRUCTURE ENGINEERING RESEARCH DEVELOPMENT (VOLUME 9, ISSUE PP-1-11, AUG 2019)
2. Dr Arif Khan Bai V Raman Reinier Bouwnmeester and S Mohan 2017 INTERNATIONAL JOURNAL of Civil Structural, Environmental and infrastructure Engineering Research Department Volume 7, issue 4: pp-15-20, august 2017
3. Dr. Arif Khan, 2017, INTERNATIONAL JOURNAL of innovative Research in Science Engineering Volume 6, Issue 7, pp-13258-13263, July 2017
4. Dr Arif Khan Venkatesh Uddameri 2017, International Journal of Engineering Research and Application Volume 7, Issue 6. (Part II), pp-01-06, June 2017
5. Dr Arif Khan 2017 To fuzzy Logic Approach Quantify Water Pollution, International Journal of Engineering Science and Computing Volume 5, Issue 5, pp-12227-12233, May 2017
6. Md Shahjada Alam, Dr. Arif Khan, 2020, To minimize Vehicular Emissions of Nagpur, India, INTERNATIONAL JOURNAL OF ENGINEERING RESEARCH & TECHNOLOGY (IJERT) Volume 09, Issue 11 (November 2020)
7. Md Shahjada Alam, Dr. Arif Khan, 2020, The Impact Study of Vehicular Pollution On Environment, International Journal for Science and Advance Research In Technology (IJSART) Volume 6 Issue 12 – DECEMBER 2020.
8. Bastian, R. K., & Hammer, D. A. (1993). The use of constructed wetlands for wastewater treatment and recycling. In G. A. Moshiri (Ed.), Constructed wetlands for water quality improvement (pp. 59–68). Boca Raton, FL: CRC Press.
9. Batzer, D. P., & Sharitz, R. R. (2006). Ecology of freshwater and estuarine wetlands. Berkeley, CA: University of California Press.
10. Brix, H. (1994). Use of constructed wetlands in water pollution control: historical development, present status, and future perspectives. Water Science and Technology, 30(11), 209–223.
11. Byung, J. K., Sherwood, C. R., Thomas, A., & Patrick, D. S. (1997). Development of constructed wetlands for the reuse of wastewater in semi-arid regions (All U.S. Government Documents, Utah Regional Depository, Paper 591). Retrieved April 10, 2012, from <http://digitalcommons.usu.edu/govdocs/591/>

12. Crites, R. W., & Tchobanoglous, G. (1998). Small and decentralized wastewater management systems. New York, NY: McGraw-Hill.
13. David, M. G., James, L. A., Christopherson, S. H., & Axler, R. (2002). A report of constructed wetlands. Minneapolis, MN: University of Minnesota.
14. De Jong, J. (1976). The purification of wastewater with the aid of rush or reed pond. In J. Toutbier & R. W. Pierson (Eds.), Biological control of water pollution (pp. 133–139). Philadelphia, PA: University of Pennsylvania.
15. Kentucky Department of Environmental Protection. (2012). Wastewater treatment plant operator certification manual. Frankfort, KY: Kentucky Department of Environmental Protection, Division of Compliance Assistance.
16. Nelson, J., Bishay, F., Van Roodselaar, A., Ikononou, M., & Law, F. C. (2007). The use of in vitro bioassays to quantify endocrine disrupting chemicals in municipal wastewater treatment plant effluents. *Science of the Total Environment*, 374(1), 80–90.
17. U.S. Environmental Protection Agency (U.S. EPA). (1980). Aquaculture systems for wastewater treatment: Seminar proceedings and engineering assessment (EPA430/9-80-006). Cincinnati, OH: U.S. Environmental Protection Agency, Office of Research and Development. (NTIS No. PB81-156705)
18. U.S. Environmental Protection Agency (U.S. EPA). (1988). Constructed wetlands and aquatic plant systems for municipal wastewater treatment (EPA/625/1-88/022). Cincinnati, OH: U.S. Environmental Protection Agency, Office of Research and Development.
19. A handbook of constructed wetlands volume 1: general considerations; Luise Davis, USDA-Natural Resources Conservation Service and the US Environmental Protection Agency-Region III,
20. Borkar, R. P., Mahatme, P. S. (2011), "Wastewater Treatment with Vertical Flow Constructed Wetland", *International journal of environmental sciences* Vol 2(2), pp 590 -603
21. Asghar Ebrahimi, Ensiyeh Taheri (2013) "Efficiency of Constructed Wetland Vegetated with *Cyperus alternifolius* Applied for Municipal Wastewater Treatment", Hindawi Publishing Corporation *Journal of Environmental and Public Health*, Vol. 2013, pp 1-5
22. Hafez nezami, Jin-Lee Kim (2012) "Evaluating Removal Efficiency of Heavy Metals in Constructed Wetlands", *Journal of environmental engineering* © asce / april 2012, pp 475-482.
23. Atif Mustafa (2013), "Constructed Wetland for Wastewater Treatment and Reuse: A Case Study of Developing Country", *International Journal of Environmental Science and Development*, Vol. 4(1), pp 20-24
24. Yadav S. B., Jadhav A. S. (2011), "Evaluation of Surface Flow Constructed Wetland System by Using *Eichhornia crassipes* for Wastewater Treatment in an Institutional Complex", *Universal Journal of Environmental Research and Technology* All Rights Reserved Eurasian publications, Vol. 1, pp 435-441
25. Chavan B. L., and Dhulap V. P. (2013), "Developing a Pilot Scale Angular Horizontal Subsurface Flow Constructed Wetland for Treatment of Sewage: The Phytoremediation with *Colocasia esculenta*", *International Research Journal of Environment Sciences* Vol. 2(2), pp 6-14
26. Dr. Joachim Schrautzer, Ralph Otterpohl (2009), "Constructed wetlands: potential for their use in treatment of grey water in Kenya", *Environmental Management* Natürlicher Ressourcen, pp 1-77
27. "The use of constructed wetlands for wastewater treatment", Wetlands International - Malaysia-Office (2003)
28. "Constructed wetland manual", United Nations Human Settlements Programme (UN-HABITAT), (2008)



**Impact Factor:  
7.569**



# INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

 **9940 572 462**  **6381 907 438**  **ijirset@gmail.com**



[www.ijirset.com](http://www.ijirset.com)

Scan to save the contact details