Comparative analysis of Rootzone Treatment (Phytorid Technology) in Domestic Sewage Treatment System

Harsh Kumar Saimar[1], Yash Bhadula[2], Abdul Khaliq[3], Gaurav Panwar[4] and Shalini Jaiswal[5]

[1]*Student, Dept. of Civil Engineering, Amity University, Uttar Pradesh, India*
[2]*Student, Dept. of Civil Engineering, Amity University, Uttar Pradesh, India*
[3]*Student, Dept. of Civil Engineering, Amity University, Uttar Pradesh, India*
[4]*Assistant Professor, Dept. of Civil Engineering, Amity University, Uttar Pradesh, India*
[5]*Associate Professor, Dept. of Chemistry, Amity University, Uttar Pradesh, India*

Abstract - *At present, the global disposal of sewage is a major issue due to increased levels of pollutants and the diverse composition of sewage water. Sewage is generated from various sources, such as residential societies, industrial areas, and commercial zones, each containing specific sewage compositions. However, instead of segregating the sources, we still mix everything and send it to sewage treatment plants, resulting in lower treatment efficiency, water body pollution, and high waste generation. Due to a shortage of land, disposal itself is a problem, and to address this, we should encourage decentralization of sewage treatment. The Rootzone Treatment (Phytorid technology) is a type of system that can reduce the impact of sewage and convert it into useful water for gardening and irrigation purposes. To Compare the characteristics of the Phytorid bed, a prototype was built in the Hydraulics lab at Amity University, Greater Noida, Uttar Pradesh, and the quality check process was carried out in the Environmental lab.*

Key Words: **Rootzone Treatment, Phytorid Technology, Decentralization Waste Water Treatment, Domestic Sewage Treatment, Waste Water Treatment, urbanization, Disposal of Sewage**

1.INTRODUCTION

Over the past few decades, India has experienced a significant increase in its urban population. To meet the growing demand for water, all towns and cities are enhancing their water supplies. However, the insufficient wastewater treatment facilities have led to untreated sewage being disposed of into lakes, rivers, and other water bodies, which has had negative effects on both human health and ecosystems. Despite the limited revenue generated by local taxes, including water and sewerage charges, pollution control is crucial, but it is challenging. Nonetheless, Indian cities have the chance to adopt new ways of dealing with wastewater, such as Decentralized Waste Water Treatment (DWWT), which can help conserve resources and provide sanitation to unsanitary areas in Indian towns and cities. Additionally, the reuse and recycle of treated wastewater holds immense potential for overall urban environmental [1]

sustainability, given the socio-economic context of urbanization. Unfortunately, the discharge of harmful substances into primary water sources has led to extensive pollution. Various studies have shown that for every cubic meter of polluted water discharged into water bodies, 8 to 10 cubic meters of clean water can become further contaminated. This is concerning, as contaminated water is responsible for 21 out of the 31 major diseases that cause death in developed countries.[2] These facts underscore the pressing need for improved water treatment methods to address challenges related to food security, water availability, and efficient water use. With energy set to become a major concern in the coming years, it is crucial to identify and adopt appropriate technologies to mitigate these pressures. The goal of sewage treatment is to stabilize the organic matter in sewage and produce a liquid effluent and sludge that can be safely disposed of without posing health risks or causing inconvenience. To achieve maximum user satisfaction and value for money, modern and cost-effective technologies and equipment should be adopted. While septic tanks that use pure anaerobic processes can serve as preliminary sewage treatment plants, better treatment methods are needed, such as those that utilize aerobic processes. However, conventional sewage treatment plants require energy to achieve optimal results, particularly for the aerobic process, which requires oxygen to be supplied to bacteria. Moreover, the lifespan of sewage treatment plants can decrease when heavy pollutant loads are present in the sewage water. Therefore, in modern times, an eco-friendly approach is preferred, one that is efficient, cost-effective, and highly effective. Constructed wetland systems are an example of an eco-friendly approach to sewage treatment, as much of the treatment is conducted near the source itself, making it a decentralized approach to sewage treatment. [3]

2. DECENTRALIZED WASTE WATER TREATMENT

Decentralized water treatment involves treating water at its source to some degree, requiring public involvement and a more comprehensive approach to various ecosystems. Decentralized wastewater treatment (DWWT) follows the principle of decentralization, enabling sewage treatment to be conducted at a more affordable cost, reducing the need for long-distance pumping, and promoting local reuse of treated sewage. By implementing suitable treatment technology at the community, institutional, and individual building levels, DWWT can contribute to achieving equity and sustainability objectives. In a decentralized system, wastewater collection networks are shorter and smaller, and the amount of wastewater to be treated at the end of the network is relatively small, allowing for simpler and more natural treatment methods to be employed. In essence, sewage can be managed at its point of origin.[4][5]

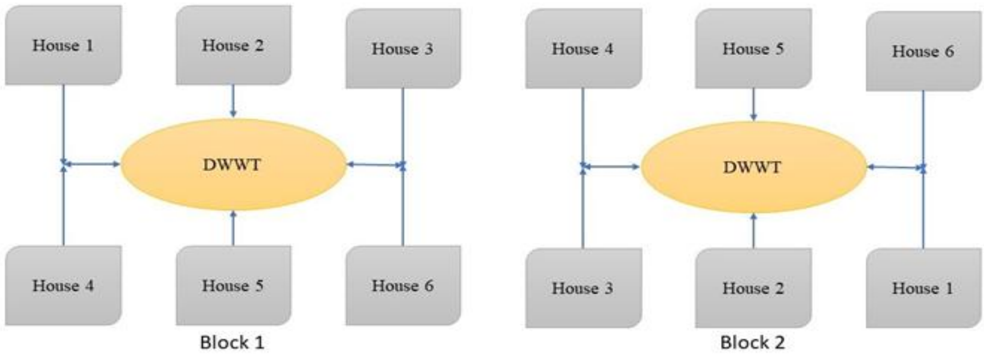

Fig -1: DWWT Layout for Two Residential Blocks

3. CONSTRUCTIVE WETLANDS

Constructed wetlands (CWs) are a natural and sustainable wastewater treatment technology that use plants, soil, and microorganisms to remove pollutants from wastewater. CWs have been used extensively in India as a low-cost and effective solution for the treatment of domestic and industrial wastewater. One type of CW that has gained popularity in India is the Phytorid technology, which was developed by the National Environmental Engineering Research Institute (NEERI) in 2007 after five years of research and development, followed by seven years of field experimentation on various plants. Phytorid technology is a CW system that is designed to treat domestic wastewater using a combination of vertical flow and horizontal flow systems. The system consists of an inlet chamber, a vertical flow bed, a horizontal flow bed, and an outlet chamber. The vertical flow bed is filled with coarse gravel and planted with wetland plants such as Canna, Colocasia, and Typha. The wastewater flows down through the vertical flow bed, where it is treated by the plants and microorganisms. The treated water then flows into the horizontal flow bed, which is planted with grasses and sedges. The treated water then passes through a layer of sand and gravel before it is discharged into the environment.

NEERI has implemented several Phytorid technology systems in India, including the one in the city of Nagpur. The Nagpur system is designed to treat 1.5 million litres of wastewater per day and serves a population of around 50,000 people.[6] The system has been effective in removing organic matter, nutrients, and pathogens from the wastewater, and the treated water is suitable for irrigation and other non-potable uses.

NEERI has also conducted research on the performance of Phytorid technology and developed guidelines for its design, construction, and operation. The guidelines recommend the use of specific wetland plants, such as Canna, Colocasia, and Typha, and the use of specific substrates, such as gravel and sand. The guidelines also recommend the use of appropriate inlet and outlet structures to ensure proper flow and treatment.[7]

Phytorid technology has several advantages over other wastewater treatment technologies. First, it is a low-cost and sustainable solution that uses natural processes to treat wastewater. Second, it can be implemented in both rural and urban areas, making it a versatile solution for wastewater treatment. Third, it has a small footprint, which makes it suitable for areas with limited space. Fourth, it can be easily adapted to local conditions and needs, making it a flexible solution for different types of wastewaters. constructed wetlands, and Phytorid technology, are an effective and sustainable solution for the treatment of wastewater in India. NEERI has played a significant role in the development and implementation of these technologies, conducting research, providing guidelines, and implementing systems across the country. The use of CWs and Phytorid technology for the treatment of wastewater has the potential to provide a sustainable and cost-effective solution for the management of wastewater in both rural and urban areas.

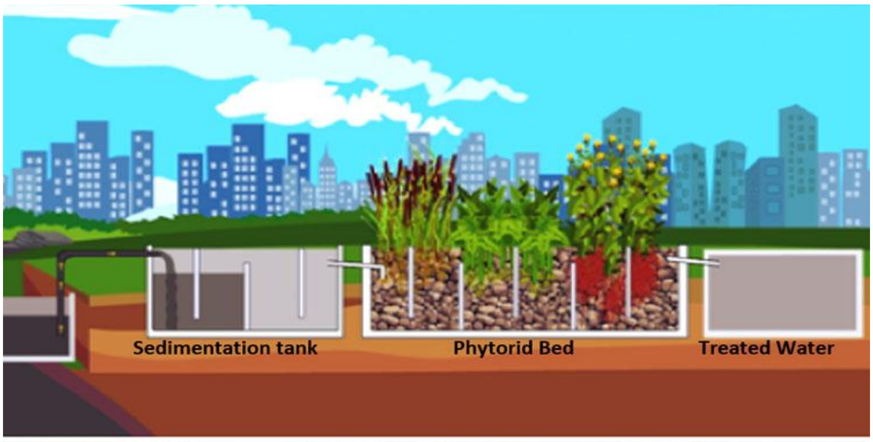

Fig 2: Phytorid Treatment System [8]

4. METHODOLOGY

This section details the materials and procedures involved in the project's Investigation of phytorid technology. A prototype was built in the Hydraulic Laboratory to process 40 litres of water per day. The prototype's dimensions were measured to accommodate a volume of 100 litres, with rough dimensions of {0.6 m X 0.5 m X 0.5 m}, equivalent to 0.012 m^3.

Following guidelines from the central pollution control Board, the prototype was maintained with a top freeboard of 0.20 m and the surface is placed at 0.15 m from the model's top to ensure subsurface flow. The maximum revised capacity was determined to be 0.09 m^3 for the prototype.

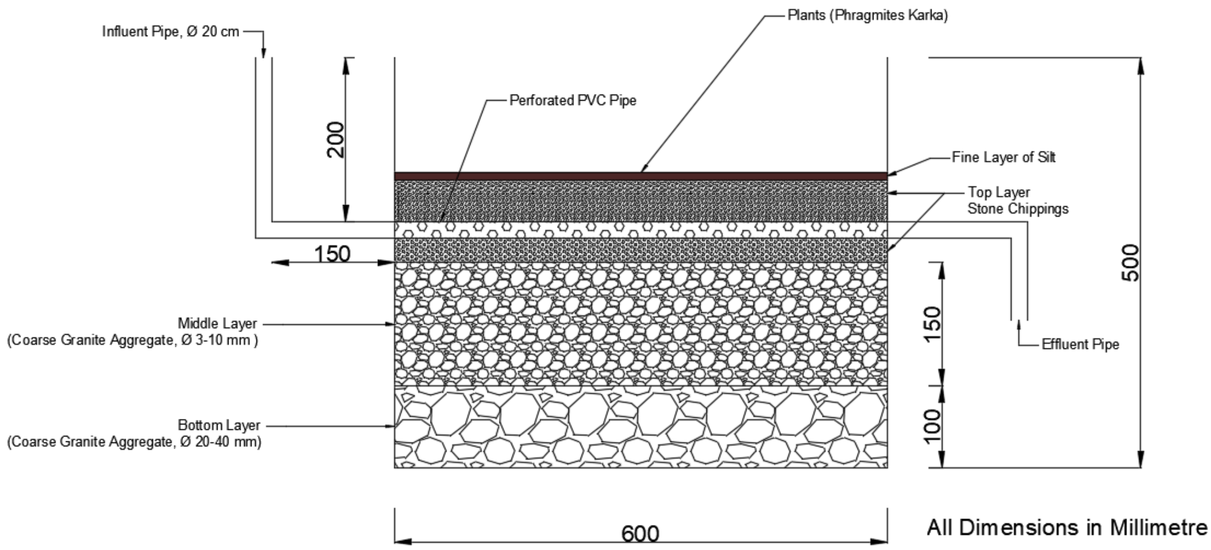

Fig 3: Design of Phytorid Bed (Elevation of Prototype)

After accounting for the volume occupied by the aggregates and roots, a sample was poured into the prototype to assess its maximum capacity. Approximately 40 litres of sample were drained to reach its capacity, indicating that the prototype's maximum capacity is 40 litres per day.

Other specifications of the model are:

- Total dimensions of the model: 0.9m×0.9m×0.5m
- Dimensions of the pipes:
    - For Influent & effluent 20mm Dia PVC pipes of 150 mm length.
    - 600 mm length for Aerator Connections.
- Location of the aerator pipe: 0.30 m from the top level of prototype.
- Building material used for prototype:
    - 10 mm thick glass
    - 12 mm thick plyboard

4.1 Building Material Used

The following materials were used in the development of the phytorid bed:

Coarse Granite Aggregates: Granite aggregates are a type of crushed hard rock that is commonly found on Earth and is often used as a building material due to its desirable properties. Granite is known for being solid (with grades ranging from 800-1200) and highly solid (with grades ranging from 1,400-1,600), as well as frost-resistant (with grades ranging from 300-400) and having a low flakiness index (5-23%). Additionally, it falls into the first class in terms of radionuclidity (with A (eff) <370nBq/kg), meaning that harmful components and additives are either absent or do not exceed norms. Certificates and research conclusions can confirm this fact. Granite is often used as a high-grade aggregate for concrete. The stone is mostly composed of feldspar, quartz, and mica crystals, and the content of each influences the stone's colour and shades. The types of coarse aggregate used in the phytorid bed project included:[9]

Coarse Aggregate (Effective dia 20-40 mm): It is typically utilized as a foundation layer beneath asphalt surfaces in road construction. It is also used for both small-scale and large-scale projects. This fraction is commonly employed as sub-base material for the construction of highways and railways, as well as in the production of concrete and reinforced concrete structures. It is also used as a filler for parking areas and foundations of work areas where heavy construction machinery operates, as well as in the production of concrete with higher strength.

Coarse Aggregate (Effective dia 3-10 mm): The primary use of aggregates of this fraction is in the production of paving slabs and other construction products that require this particular size of aggregate.

Small stone chippings: Granite aggregates in the smallest sizes are utilized not only in road construction, but also for decorative purposes and to pave paths, cover sports grounds, and create safe surfaces for children's playgrounds. These small aggregates are also used to manufacture reinforced concrete structures and improve the slip resistance of surfaces. Additionally, granite sand is an effective material for landscape architecture and gardening.[10]

Fig 4: Coarse Granite Aggregate (Effective Dia 20-40mm)

Fig 5: Coarse Granite Aggregate (Eff Dia 10-20mm)

Fig 6: Coarse Granite Aggregate (Eff Dia 10-20mm)

Aerator: A perforated PVC pipe connected to a fish tank aerator was utilized to supply air to the bed.

Reed plant (Phragmites Karka): Phragmites Karka, commonly known as Indian Reed or Common Reed, has long, green leaves that can grow up to 60 cm in length. The leaves are flat, smooth, and narrow, with a pointed tip. They are arranged alternately along the stem and can be up to 2 cm wide. The leaves play an important role in the plant's photosynthesis, which is crucial for its growth and survival. Phragmites Karka leaves are widely used in wastewater treatment due to their unique ability to remove pollutants from water.[11] The leaves have a large surface area, which allows for the absorption and retention of contaminants such as heavy metals, organic pollutants, and nutrients. The roots of the plant also provide an environment for beneficial microorganisms, which help to break down and remove pollutants from the water. In addition to their use in wastewater treatment, Phragmites Karka leaves are also used for thatching and as a source of fiber for papermaking.[12] The plant's ability to remove pollutants from water makes it an important tool for environmental management and conservation efforts.[13]

Fig 7: Coarse Granite Aggregate (Effective Dia 10-20mm)

4.1 Building Material Used

A sample of approximately 45 litres of wastewater was Collected from the Chauganpur Lake, Chauganpur , Knowledge Park V, Greater Noida, Uttar Pradesh. During the initial sampling, the wastewater was found to have low oxygen levels, resulting in little to no aquatic life being present. The collection of the sample was done using a collector mug & the opening was sealed with a bottle cap

4.3 Parameter Tested

Turbidity: Turbidity is a measure of the clarity or cloudiness of water, caused by the presence of suspended particles such as sediment, algae, or other organic and inorganic materials.[14] In treated wastewater, high turbidity levels can indicate the presence of pathogens and other contaminants that can be harmful to the environment and human health. Therefore, turbidity is an important parameter that must be monitored to ensure the safety of treated wastewater discharge. To reduce turbidity levels in treated wastewater, various processes such as settling, filtration, and disinfection can be used. By maintaining low turbidity levels in treated wastewater, the environmental impact of wastewater discharge can be minimized.

pH: pH is a measure of the acidity or basicity of a solution, and it plays a critical role in wastewater treatment. The pH of wastewater can affect the solubility, speciation, and toxicity of various contaminants present in the water. It also has a significant impact on the performance of various chemical and biological treatment processes. In wastewater treatment, the pH range should be maintained within specific limits to ensure efficient treatment and safe discharge of treated water pH plays a crucial role in ensuring that treated wastewater is safe for discharge into the environment or reuse. Treated wastewater often has a different pH than natural water, and a shift in pH can affect the ecosystem in the receiving water bodies. Therefore, it is important to monitor and control pH levels in treated wastewater to ensure environmental safety. The optimal pH range for treated wastewater discharge depends on the characteristics of the receiving water body. For example, a pH range of 6.5 to 8.5 is typically acceptable for discharge into freshwater bodies, while a pH range of 7.5 to 8.5 is typically acceptable for discharge into marine environments. If the pH of the treated wastewater is outside of the acceptable range, it can cause ecological harm, such as altering the acidity of the water, killing aquatic life, and promoting the growth of harmful algae. To ensure that the pH of treated wastewater is within the acceptable range, pH controllers can be used to continuously monitor and adjust the pH of the treated wastewater before discharge. [15]

Total Dissolved Solids: Total dissolved solids (TDS) is a measure of the amount of inorganic and organic matter that is present in water.[15] This includes minerals, salts, and other substances that have dissolved in the water. TDS is an important parameter to measure in wastewater treatment as it can affect the quality of the treated water and the efficiency of the treatment process. In wastewater treatment, high levels of TDS can cause issues such as scaling and fouling of equipment, which can lead to decreased treatment efficiency and increased maintenance costs. TDS can also impact the treated water's suitability for reuse, discharge into the environment, or as a drinking water source. To control TDS levels in wastewater treatment, various techniques such as reverse osmosis, nanofiltration, and electrodialysis can be used to remove dissolved solids. Additionally, monitoring and adjusting the influent water quality, such as limiting the discharge of industrial effluent, can also help to control TDS levels.

Chloride Concentration: The chloride ion, denoted by the negatively charged anion Cl^-, can be produced through two ways: either by chlorine gaining an electron or by dissolving a substance such as hydrogen chloride in polar solvents or water. These ions, such as sodium chloride, are extremely soluble in water and have essential functions in regulating cellular fluid, transmitting nerve impulses, and maintaining the acid/base equilibrium. Chloride concentration is a crucial parameter to monitor in treated wastewater, as it can impact the quality of the receiving water body. Chloride can originate from various sources, including industrial wastewater, road salt runoff, and seawater intrusion. High chloride concentrations can lead to corrosion of infrastructure, including pipes and pumps. Reverse osmosis and ion exchange technologies are commonly used to reduce chloride levels in treated wastewater. Additionally, monitoring chloride concentration in treated wastewater is necessary to ensure that discharged water meets regulatory requirements and does not harm the environment or public health.[16]

Dissolved Oxygen: The dissolved oxygen (DO) in a water body like a river, lake, or stream indicates the amount of oxygen available to support the growth of aquatic plants and animals. It is considered the most crucial indicator of the water body's health and its ability to sustain a balanced aquatic ecosystem. Wastewater containing organic pollutants that consume oxygen can reduce the DO levels and result in the death of marine organisms. The level of dissolved oxygen is an important factor in determining the water quality and the water body's ability to support aquatic life. Generally, a higher level of DO indicates better water quality, while low levels may lead to the inability of fish and other organisms to survive. The DO in water mainly comes from the dissolved oxygen in the air and the photosynthesis of aquatic plants. Sunny days with dense algae or plants can increase DO levels due to photosynthesis, and stream turbulence can also increase DO levels as air is trapped under rapidly moving water. Water temperature also affects DO levels, as colder water can hold more oxygen than warmer water.[17]

Phosphate Concentration: Phosphate is an essential nutrient for plant growth and various biological processes in living organisms. However, excessive amounts of phosphates in water bodies can cause eutrophication, leading to the depletion of oxygen and the proliferation of harmful algal blooms. There are two types of phosphates found in wastewater: orthophosphate (soluble) and polyphosphate (insoluble). Orthophosphates are the most common form found in wastewater and are typically removed using chemical precipitation methods, such as adding metal salts to the wastewater to form insoluble compounds that can be removed through sedimentation. Polyphosphates can be removed through biological treatment methods, such as activated sludge. Maintaining proper phosphate concentrations in treated wastewater is crucial for protecting the environment and public health. Excessive phosphate concentrations can lead to eutrophication, which can cause harm to aquatic ecosystems and human health. Therefore, monitoring and controlling phosphate concentrations in treated wastewater is critical for ensuring safe and sustainable wastewater treatment practices.[18], [19]

Hardness: Hardness in water is a measure of the concentration of dissolved minerals, primarily calcium and magnesium. It can cause scaling and damage to water-using equipment, such as pipes, boilers, and cooling towers. There are two types of hardness: temporary hardness and permanent hardness. Temporary hardness can be removed by boiling the water or through the addition of chemicals such as lime or soda ash. Permanent hardness cannot be removed through boiling and requires ion exchange or membrane filtration. Maintaining proper hardness levels in treated wastewater is essential for preventing damage to equipment and ensuring the longevity of the infrastructure. Excessive hardness can lead to scaling, corrosion, and reduced efficiency of water-using equipment, which can result in higher operating costs and increased energy consumption. Therefore, monitoring and controlling hardness levels in treated wastewater is critical for ensuring efficient and sustainable water treatment practices.[20]

Biological Oxygen Demand (BOD): Biological Oxygen Demand (BOD) is a measure of the amount of oxygen required by microorganisms to decompose organic matter in water. There are two types of BOD: carbonaceous BOD and nitrogenous BOD. Carbonaceous BOD is the primary focus in wastewater treatment as it indicates the level of organic matter that needs to be removed to ensure safe and sustainable wastewater treatment practices. container with dissolved oxygen and microorganisms.[21] The container is then incubated for five days at a specific temperature (usually 27°C) to allow the microorganisms to consume the organic matter and oxygen. The initial and final dissolved oxygen levels are measured, and the difference between the two values indicates the amount of oxygen consumed by the microorganisms during the incubation period. The BOD test is an important parameter in wastewater treatment as it provides an indication of the level of organic pollutants present in the wastewater. High BOD levels can lead to a depletion of oxygen in water bodies, causing harm to aquatic life and creating unpleasant odors.[22]

5. COMPARITIVE ANALYSIS

The base model was created according to the design using 10 mm thick glass, PVC pipes, and corks. To ensure adequate stability during loading and transportation, extra glass plates were added at the bottom. The perforations were created by using a heated steel wire, and the dimensions of the base model were verified before all the connections were glued together.

Fig 8: Assembled Prototype Model for phytorid Bed

The construction of the bed in the model began with the placement of a 10cm layer of 20-40 mm granitic aggregate as the bottommost layer. This was followed by a layer of 3-10 mm granitic aggregate up to a height of 15 centimetres, taking care to provide enough space for the perforated pipe without overloading it. After the intermediate layer was placed, a top layer was made using small stone chippings and a small amount of silt, and reed plants were planted on top. The plants were then watered, and the model was left to allow the roots to develop for 24 hours.

Fig 9: Phytorid Bed with Different Layers of Aggregate

Fig 10: Prototype Model with Plats Planted & watered

During this time, tests were conducted on the original sample. Once completed, the sample was introduced into the Phytorid bed through an inlet pipe until it reached the level of the influent pipe. Before the sample was drained into the bed, an aerator was attached to the perforated pipe and turned on. The inlet pipe was then sealed with a cork, and the arrangement was allowed to sit for 24 hours, which is the retention period for batch processing.

Once the retention period had ended, the effluent pipe was used to extract the final sample, which was then subjected to various tests (as mentioned earlier). The results obtained were compared to the initial sample to determine the effectiveness of the Phytorid bed. These results were then compared to the pre-defined efficiencies established by the National Environmental Engineering Research Institute (NEERI).[2]

6. SAMPLE TESTING & RESULT DISCUSSION

The Comparative study yielded values for different parameters, which were then compared to the standard values provided by NEERI. The following outcomes were observed:

Table -1: Comparison of Initial & Final Test Results

S.No	Criteria	Initial Value	Final Value	Unit	Percentage Removal	Remarks
1	pH	7.90	7.10	-	-	Allowable (6.5-8.5 ,as Per BIS & NEERI)
2	Hardness	482.00	243.00	mg/L	-	Allowable (300mg/L, as Per BIS & NEERI)
3	Dissolved Oxygen	1.92	14.50	mg/L	-	Allowable (>6 mg/L ,as Per BIS & NEERI)
4	Biochemical Oxygen Demand (BOD3)	51.00	6.10	mg/L	88.04	Allowable (80-95% ,as Per BIS & NEERI)
5	Dissolved Solids	6589.00	418.00	mg/L	93.66	Allowable (85-95% ,as Per BIS & NEERI)
6	Turbidity	39.50	3.57	NTU	-	Allowable (5 NTU ,as Per BIS & NEERI)
7	Chloride Concentration	282.00	261.00	mg/L	-	Allowable for irrigation (250mg/L ,as Per BIS & NEERI)
8	Phosphate Concentration	0.09	0.03	mg/L	65.56	Allowable (60-70% ,as Per BIS & NEERI)

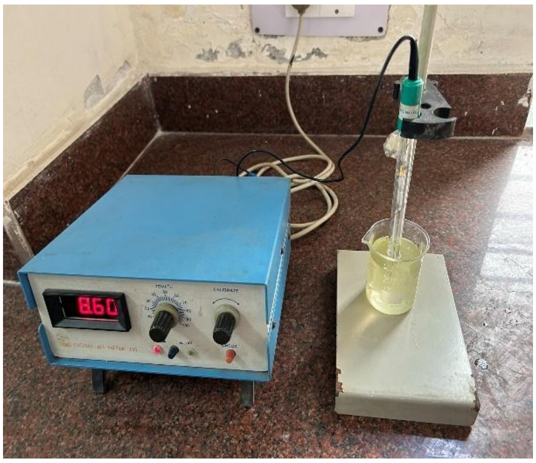

Fig 11: pH test of Sample

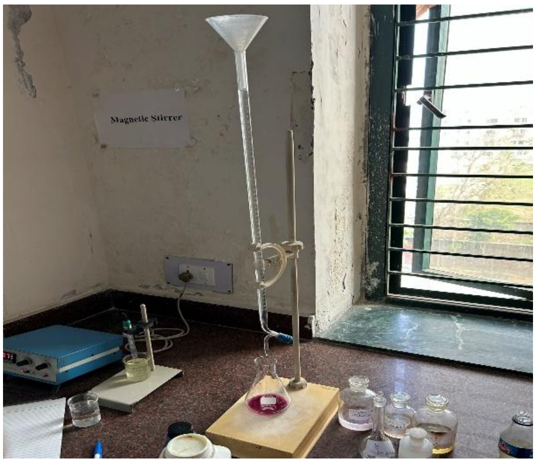

Fig 12: Different tests Performed on Water Sample

7. CONCLUSION

In conclusion, the analysis conducted supports the viability of phytorid technology as an effective decentralized wastewater treatment solution with potential for water reuse. The treated water generated by phytorid systems demonstrates satisfactory quality and can be utilized for various purposes, including irrigation, flushing, river dilution, and gardening. NEERI's recommendation to extend the retention period to 48 or 72 hours is advised to achieve high-quality standards.[22]

One notable advantage of phytorid treatment plants is their relatively low operational and maintenance costs compared to other treatment processes, making them a promising option for future implementation. However, the requirement for larger land areas to accommodate high-capacity treatment systems poses a significant challenge. Ongoing efforts aim to enhance the capacity of these systems within smaller land areas, and it is crucial to raise public awareness about their installation, even in residential settings, with the involvement of untrained workers.[23]

To ensure the continued effectiveness of phytorid beds, it is recommended to replace the arrangement of plants and coarse beds every 18 months. This maintenance practice helps sustain optimal treatment performance over time. Overall, the implementation of decentralized wastewater treatment through phytorid technology holds promise for addressing water scarcity, pollution, and sustainable water resource management. [24]

REFERENCES

[1] S. Bhamare, "Analysis and Design of Sewage Treatment Plant using Phytorid Technology," Int J Res Appl Sci Eng Technol, vol. 8, no. 6, pp. 1557–1563, Jun. 2020, doi: 10.22214/ijraset.2020.6252.

[2] "National Inventory of Sewage Treatment Plants Central Pollution Control Board Parivesh Bhawan East Arjun Nagar , Delhi," 2021.

[3] A. A. Raval and P. B. Desai, "Review Article Root Zone Technology: Reviewing its Past and Present," 2015. [Online]. Available: http://www.ijcmas.com

[4] C. Zaharia, "Decentralized wastewater treatment systems: Efficiency and its estimated impact against onsite natural water pollution status. A Romanian case study," Process Safety and Environmental Protection, vol. 108, pp. 74–88, May 2017, doi: 10.1016/j.psep.2017.02.004.

[5] E. Engstler, D. J. Kerschbaumer, and G. Langergraber, "Evaluating the Performance of Small Wastewater Treatment Plants," Front Environ Sci, vol. 10, Jul. 2022, doi: 10.3389/fenvs.2022.948366.

[6] M. Sawant, K. Aware, and Y. Honrao, "Phytorid Technology," 2020.

[7] Dr. K.R. Ranganathan et al., "Guidelines on Construction, Operation and Application of Rootzone Treatment Systems for the Treatment of Municipal and Industrial Wastewater." [Online]. Available: www.cpcb.delhi.nic.in

[8] Dr. Raman Sharma, "Phytorid Technology," Phytorid technology and implemented projects across India.

[9] R. S. Kumar, H. Mohammed, and M. Haripriya, "An Experimental study on partial replacement for coarse aggregate by Granite Waste," 2016. [Online]. Available: www.ijiset.com

[10] Cescon and J. Q. Jiang, "Filtration process and alternative filter media material in water treatment," Water (Switzerland), vol. 12, no. 12, Dec. 2020, doi: 10.3390/w12123377.

[11] N. S. M. Said, S. R. S. Abdullah, H. A. Hasan, A. R. Othman, and N. 'Izzati Ismail, "Endurance of Phragmites karka in removing colour and suspended solids from industrial coffee processing effluents in a continuous reed bed system," Journal of Water Process Engineering, vol. 40, p. 101832, Apr. 2021, doi: 10.1016/J.JWPE.2020.101832.

[12] K. Angassa, S. Leta, W. Mulat, H. Kloos, and E. Meers, "Evaluation of Pilot-Scale Constructed Wetlands with Phragmites karka for Phytoremediation of Municipal Wastewater and Biomass Production in Ethiopia," Environmental Processes, vol. 6, no. 1, pp. 65–84, Mar. 2019, doi: 10.1007/s40710-019-00358-x.

[13] A. A. Asaad, A. M. El-Hawary, M. H. H. Abbas, I. Mohamed, A. A. Abdelhafez, and M. A. Bassouny, "Reclamation of wastewater in wetlands using reed plants and biochar," Sci Rep, vol. 12, no. 1, Dec. 2022, doi: 10.1038/s41598-022-24078-9.

[14] A.R. Mhaske and S. M. Taley and R. B. Biniwale, "Removal of tubidity from sewage water by phytorid sewage treatment plant: a study using the response surface methodology.," International Journal of Agricultural Engineering , vol. 7, 2014.

[15] R. K. Kushwah, A. Bajpai, and S. Malik, "Characteristics of waste water in sewage treatment plant of BHOPAL, (India)," J. Chem. Pharm. Res, vol. 3, no. 6, pp. 766–771, 2011.

[16] Yiming Li and Zhongzhu Yang and Kaihua Yang and Jingjing Wei and Zihao Li and Chi Ma and Xu Yang and Tantan Wang and Guangming Zeng and Guanlong Yu and Zhigang Yu and Chang Zhang, "Removal of chloride from water and wastewater: Removal mechanisms and recent trends," Science of The Total Environment, vol. 821, 2022.

[17] Y. Nagvekar, ""Feasibility of Phytorid Technology For Waste Water Treatment "." [Online]. Available: www.ijres.org

[18] J. T. Bunce, E. Ndam, I. D. Ofiteru, A. Moore, and D. W. Graham, "A review of phosphorus removal technologies and their applicability to small-scale domestic wastewater treatment systems," Frontiers in Environmental Science, vol. 6, no. FEB. Frontiers Media S.A., Feb. 22, 2018. doi: 10.3389/fenvs.2018.00008.

[19] A. Cabo, S. Gouveia, C. Cameselle, and K. H. Lee, "Monitoring of phosphorus discharge in a sewage treatment plant with a phosphate automated analyzer," Environmental Science: Advances, vol. 1, no. 4, pp. 483–490, Oct. 2022, doi: 10.1039/d2va00062h.

[20] S. Saikia Kakati, "Assessment of Water Hardness Used for Domestic Purposes in Some Tribal Villages of Dhakuakhana Sub-division, Lakhimpur District, Assam." [Online]. Available: www.neptjournal.com

[21] A. K. Khambete and R. A. Christian, "STATISTICAL ANALYSIS TO IDENTIFY THE MAIN PARAMETERS TO EFFECTING WWQI OF SEWAGE TREATMENT PLANT AND PREDICTING BOD." [Online]. Available: http://www.ijret.org

[22] A. S. Manasi, M. J. Rutuja, P. N. Srushti, P. S. Shrunkhala, P. Sachin, and C. B. Sandeep, "Feasibility Analysis of Decentralized Wastewater remedy systems," International Journal of Advanced Research in Science, Communication and Technology (IJARSCT), vol. 8, no. 1, pp. 207–219, 2021, doi: 10.48175/568.

[23] S. Kumar and M. P. Choudhary, "Performance Assessment of Domestic Wastewater Treatment Plants Operating on Different Technologies," Int J Eng Adv Technol, vol. 9, no. 3, pp. 1649–1653, Feb. 2020, doi: 10.35940/ijeat.C5454.029320.

[24] A. Petkar et al., "58 International Journal for Modern Trends in Science and Technology Treatment of sewage & Industrial Waste Water by using Phytorid Technology," Phytorid Technology. International Journal for Modern Trends in Science and Technology, vol. 8, no. 05, p. 58, 2022, doi: 10.46501/IJMTST0805010.