Assessing The Efficiency of Phytoremediation For The Treatment of Domestic Waste Water

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Abstract- *This study evaluates the efficiency of a designed phytoremediation system in treating domestic wastewater, focusing on pollutant removal, optimal hydraulic retention time (HRT), potential reuse of treated water, and associated ecological benefits. The system's performance was assessed over three sets of treatments for two samples, with effluent quality compared against Tamil Nadu Pollution Control Board (TNPCB) standards. Results indicated that pH levels remained within permissible limits (5.5–9), suggesting neutral conditions. Total Suspended Solids (TSS) decreased across treatments but remained above the TNPCB limit of 30 mg/L, with Sample 1 reducing from 105 mg/L to 71 mg/L and Sample 2 from 111 mg/L to 80 mg/L. Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) levels showed significant reductions; however, initial sets exceeded TNPCB limits, highlighting the need for further treatment. Total Nitrogen (TN) levels met standards in the final set of treatments, while Total Phosphorus (TP) levels remained within permissible limits throughout. These findings suggest that while the phytoremediation system effectively reduces certain pollutants, optimization is required to meet all regulatory standards, thereby enhancing the potential for water reuse and environmental benefits.*

I. INTRODUCTION

DOMESTIC WASTE WATER

Domestic wastewater, also known as sewage, refers to the water that is discharged from residential homes, businesses, and small industries. It contains a mixture of organic and inorganic substances, including human waste, food residues, soaps, and chemicals from household cleaning agents. If left untreated, domestic wastewater can pose significant environmental, public health, and social problems. The treatment of domestic wastewater is therefore crucial for a number of reasons, whichcanbegroupedintoenvironmental,health,economic,andregulatoryaspects.

Environmental Protection

One of the most critical reasons for treating domestic wastewater is to protect the environment from pollution. Wastewater contains organic matter, nutrients, pathogens, and chemicals that can disrupt natural ecosystems if discharged untreated into rivers, lakes, or oceans. Untreated domestic wastewater can lead to the contamination of water bodies with nutrients such as nitrogen and phosphorus. These nutrients promote the excessive growth of algae (eutrophication), which depletes oxygen levels in water, killing aquatic life and disturbing the balance of aquatic ecosystems. The release of harmful chemicals and heavy metals from untreated sewage can poison fish and other wildlife, causing biodiversity loss and Negatively affecting food chains. Many of the contaminants in domestic wastewater, such as ammonia, chlorine, and detergents, are toxic to aquatic organisms. Wastewater treatment removes or reduces these substances, protecting aquatic life and maintaining biodiversity in water bodies. Excess nutrients in untreated wastewater cause algal blooms, which block sunlight from reaching aquatic plants and reduce oxygen levels. This process, known as eutrophication, can lead to the death of fish and other marine life. Treating wastewater ensures that nutrients like nitrogen and phosphorus are kept at levels that do not disturb aquatic ecosystems.

Public Health Protection

One of the primary reasons for treating domestic wastewater is to prevent thespread of diseases. Untreated sewage contains harmful pathogens, including bacteria, viruses, and parasites that can contaminate drinking water sources and spread infectious diseases. Domestic wastewater can carry pathogens that cause diseases like cholera, typhoid, dysentery, and gastroenteritis. These diseases can spread rapidly in communities that lack proper sanitation and wastewater treatment, leading to public health crises. Wastewater treatment processes remove or kill harmful microorganisms, preventing the spread of these diseases and protecting human health. Properly treated wastewater can be reused for agricultural irrigation, industrial processes, and even as drinking water (in advanced treatment systems). This reduces the strain on freshwater resources, especially in regions facing water scarcity. However, this is only safe if the water has undergone thorough treatment to remove pathogens, heavy metals, and other contaminants that can pose health risks. In areas without proper sewage treatment systems, wastewater can infiltrate the ground and contaminate groundwater supplies. Groundwater is a crucial source of drinking water for millions of people, and contamination can have severe health consequences. Wastewater treatment helps protect groundwater resources from contamination by reducing pollutants before they can percolate into the soil.

Economic Benefits

Investing in wastewater treatment can provide substantial economic benefits, both directly and indirectly. Preventing waterborne diseases by treating wastewater reduces healthcare costs associated with disease outbreaks. In regions without proper sanitation, the costs of treating illnesses caused by contaminated water can be immense. A healthier population translates into higher productivity and fewer resources spent on medical treatment. Clean water bodies support fisheries, which are a major source of livelihood for many communities. Untreated wastewater can damage aquatic ecosystems, reducing fish populations and harming the fishing industry. Tourism, particularly eco-tourism and beach tourism, depends on clean water. Polluted rivers, lakes, and coastal areas deter tourists, leading to economic losses for local businesses. By treating wastewater, communities can preserve their natural attractions and maintain a strong tourism industry. Treated wastewater can be reused for various purposes, reducing the need for fresh water. In agriculture, for instance, treated water can be used for irrigation, saving valuable freshwater for drinking and other critical uses. Wastewater treat ment plants can also recover valuable resources from sewage, such as biogas from organic matter, which can be used as an energy source, and nutrients like phosphorus, which can be used in fertilizers.

Compliance with Legal and Regulatory Standards

Governments and environmental agencies have established regulations and standards for wastewater discharge to protect public health and the environment. Compliance with these standards is essential for maintaining sustainable development. India have laws that regulate the discharge of wastewater into the environment. Failure to meet these regulations can result in heavy fines, legal action, and reputational damage for municipalities and businesses. Wastewatertreatmentensuresthattreatedeffluentmeetsregulator ystandards,avoid ing legal penalties and protecting the environment. The United Nations Sustainable Development Goal 6 aims to ensure availability and sustainable management of water and sanitation for all. Treating domestic wastewater is a key component of achieving this goal, as it ensures that water quality is maintained and access toclean water is safeguarded. Many countries are working to align their policies and infrastructure with these global objectives, and proper wastewater treatment is a central part of these efforts.

Conservation of Water Resources

Wastewater treatment plays a crucial role in the conservation of water resources, which are becoming increasingly scarce due to population growth, urbanization, and climate change. In many parts of the world, freshwater is becoming scarce due to over-extraction, pollution, and climate change. Treating and reusing wastewater helps reduce the demand for freshwater, preserving natural water bodies for future generations. By treating domestic wastewater and recycling it for non-potable uses (e.g., irrigation, industrial processes), communities can reduce pressure on limited freshwater supplies. Effective wastewater treatment is a critical component of sustainable water management. By treating wastewater and returning it to the environment in a clean state, we help maintain the natural water cycle and ensure that freshwater resources remain available for future use.

PHYTOREMEDIATION

Phytoremediation is an eco-friendly and cost-effective technique that uses plants to remove, degrade, or stabilize pollutants in soil, water, or air. In the context of wastewater treatment, particularly for domestic wastewater, phytoremediationharnessesthenaturalabilityofcertainplantstofil terandpurifycontaminatedwater. This green technology has gained increasing attention due to its potential to address water pollution while contributing to biodiversity and ecosystem restoration. Domestic wastewater, generated from households, is a complex mixture of organic and inorganic pollutants. It contains nutrients such as nitrogen and phosphorus, harmful pathogens, organic matter, heavy metals, and trace contaminants like pharmaceuticalsand personal careproducts.If nottreated properly, this wastewater can severely pollute natural water bodies, leading to eutrophication, oxygen depletion, and public health hazards. Conventional treatment methods, although effective, often have high operational costs, energy requirements, and potential chemical byproducts. Phytoremediation offers a sustainable alternative for wastewater treatment that is both energy-efficient and environmentally beneficial.

Mechanisms of Phytoremediation in Wastewater Treatment

Phytoremediation of domestic waste water involves several mechanisms through which plants improve water quality. These mechanisms include:

A. Phytoextraction:

Certain plants have the ability to absorb contaminants such as heavy metals,organic pollutants, and nutrients (nitrogen and phosphorus) from wastewater through their roots. These contaminants are then either stored or transformed into less harmful compounds within the plant tissues. Phytodegradation:

Some plants, in association with microorganisms present in the root zone (rhizosphere), can break down complex organic pollutants like pesticides, pharmaceuticals, and hydrocarbons into simpler, less toxic compounds. This process occurs through enzymatic activity or through microbial symbiosis in the rhizosphere.

B. Phytostabilization:

This mechanism involves the use of plants to immobilize pollutants in the soil or water, preventing their migration into groundwater or the broader environment. While the pollutants are not removed, they are rendered less bioavailable and less harmful. Phytodegradation:

Some plants, in association with microorganisms present in the root zone (rhizosphere), can break down complex organic pollutants like pesticides, pharmaceuticals, and hydrocarbons into simpler, less toxic compounds. This process occurs through enzymatic activity or through microbial symbiosis in the rhizosphere.

C. Phytostabilization:

This mechanism involves the use of plants to immobilize pollutants in the soil or water, preventing their migration into groundwater or the broader environment. While the pollutants are not removed, they are rendered less bioavailable and less harmful.

D. Rhizofiltration:

Plants can filter wastewater through their roots, trapping suspended solids and precipitating heavy metals. This mechanism is particularly useful for removing toxic metals like lead, cadmium, and mercury from water.

E. Phytovolatilization:

In some cases, plants can take up volatile pollutants and release them into the atmosphere through transpiration. While this can reduce the concentration ofcertain contaminants in water, it requires careful management to prevent air pollution.

F. Oxygen Release in the Root Zone:

Many aquatic plants release oxygen into their root zones (rhizosphere), which helps aerobic bacteria thrive. These bacteria break down organic matter in wastewater more efficiently, contributing to the overall treatment process.

PHYTOREMEDIATION SYSTEMS FOR WASTEWATER TREATMENT

Phytoremediation can be implemented in various systems designed to treat domestic wastewater. The choice of system depends on the scale of wastewater production, the types of pollutants, and the environmental context. Some common phytoremediation systems include, Constructed wetlands are engineered systems that mimic the natural processes of wetlands to treat wastewater. These systems involve shallow basins filled with substrate (gravel or soil) and planted with wetland vegetation. Wastewater flows through the wetland, where pollutants are removed through sedimentation, filtration, and biological processes involvingplants and microorganisms.

Constructed wetlands are effective at removing suspended solids, organic matter, nutrients, and heavy metals. They can be classified into two types:Surface-flow wetlands: Wastewater flows over the surface of the wetland.

Subsurface-flow wetlands: Wastewater flows through the substrate below the surface, allowing for better control of odors and insect breeding. FTWs consist of floating platforms that support wetland plants, with their roots submerged in the wastewater. These systems are particularly useful in treating polluted water bodies like ponds, lakes, or reservoirs. FTWs can reduce nutrient levels, suspended solids, and certain organic pollutants. Wastewater lagoons, also known as stabilization ponds, are shallow basins designed for wastewater treatment. When combined with phytoremediation plants, lagoons can enhance pollutant removal. Floating or rooted plants, such as water hyacinth or cattails, are used to absorb nutrients and organic pollutants, while their root systems provide a habitat for beneficial bacteria. Green filters are systems where wastewater is filtered through soil planted with trees or grasses. These systems rely on the natural filtering capacity of soil and plants to remove pollutants. Green filters are often used for the final polishing of treated wastewater.In hydroponic systems, plants are grown in a soil less environment,with their roots suspended in nutrient-rich wastewater. These systems can be designed to treat domestic wastewater by using plants thatabsorb pollutants directly from the water.Hydroponic systems can be effective a tremo ving nutrients, organic matter, and heavy metals.

ADVANTAGES OF PHYTOREMEDIATION FOR WASTEWATER TREATMENT

Phytoremediation offers several benefits in the context of domestic wastewater treatment

A. Cost-Effectiveness

Compared to conventional wastewater treatment methods, phytoremediation requires lower capital and operational costs. It utilizes natural processes and requires minimal energy inputs.

B. Environmental Sustainability

Phytoremediation is a green technology that supports ecosystem restoration. It promotes biodiversity, enhances the aesthetic value of the landscape, and reduces the need for chemical treatments.

C. Nutrient Recycling

Plants used in phytoremediation can absorb nutrients such as nitrogen and phosphorus from wastewater. These nutrients can be harvested and returned to agricultural systems, contributing to nutrient cycling and reducing the demand for synthetic fertilizers.

D. Low Maintenance

Once established, phytoremediation systems require relatively little maintenance compared to mechanical or chemical treatment systems. They are also resilient to fluctuations in pollutant concentrations and environmental conditions.

E. Pollutant Diversity

Phytoremediation can target a wide range of pollutants, including organic matter, nutrients, heavy metals, and emerging contaminants such as pharmaceuticals and personal care products.

1.5 OBJECTIVE

- To analyze the pollutant removal efficiency ofdesigned phytoremediation setup for treating domestic wastewater.
- To determine the optimal conditions (hydraulic retention time) for maximizing the efficiency of phytoremediation in treating domestic wastewater.
- To evaluate the potential reuse of treated water for irrigation or other purposes following phytoremediation and determine its compliance with regulatory standards for water quality.
- To explore the ecological and environmental benefits of usingphytoremediation in wastewater treatment.

SAMPLE COLLECTION

Samples were collected from common sewarage systemof residentialarea whichis combined grey and black water from Kitchen, Bathrooms and Toilets etc. Sampleis collectedin sterile plastic canand 1 litre of eachsampled water used for analysis of untreated Domestic water. Where, remaining 9 litres of each samplewill be used for treatment of water using phytoremediation.

Figure4.1Collected Sample

SAMPLE ANALYSIS

The analysis of untreated Domestic waste water is carried out to determine the initial contaminants of untreated Domestic waste water. The parameters analysed were pH, TSS, TDS, BOD, COD, Total Nitrogen, Total Phosphorous.

pH

Take 250 ml beaker rinse with distilled water. Take 200 ml amount of sample intoa beaker. Measure the temperature of the sample. Measure the Temperature using temperature probe control to the measured value of the temperature of the sample. Keep the sample beaker on base plate of the electrode stand. Immerse the electrode properly in the sample. Allow the sufficient time for electrode to attain the temperature of the solutions. Press the pH mode and read the value of pH after display the ready mode.

TSS

Place the glass fibred filter on the filter apparatus and apply the vacuum, washthe dishwith threesuccessive20ml volume of distilled water. Remove the filter from filter apparatus and dryinanovenat103-105oC for 1 hour. Transfer to a desiccators and weigh after half an hour. Weigh immediately before use(W1). After weighing, handle the filter with force ps only. Filter sufficient sample so that suspended solidsis 50 to 100mg. Assemble the filtering apparatus and begin suction. Wet the filter with a small volume of distilled water to seat it against the fitted support. Shake the sample vigorously and quantitatively transfer predetermined sample volume (approx:100ml) into filter using graduated cylinder.Filter the sample through continuing applying of vacuum. Wash the graduated cylinder, filter suspended solids with portion of distilled water allowing complete drainage between washings. Remove all the traces of water by applying vacuum after the wash water has passed through. After filtration, transfer the filter along with contents to an oven and dry at 103 – 105oCfor 1 hour.Coolin desiccators and weigh(W2).

TotalSuspendedSolids,mg/l=(A-B)X106/V
Where,
W1=WeightoftheFilterPaper,g
W2=Weightofthedriedresidue+FilterPaper,g V = Volume of sample, ml

TDS

Placethe glass fibre filterdiskinto the filtration apparatuswithwrinkled surfaceup& Heatthecleanevaporatingdishto1800Cforonehour.Coolandstoreinthedesiccatorsuntilfortheuse.Filteraportionofthesamplethroughfilterassembly.Volumeof sample takenesteemedfrom valueofspecificconductance.Preferablythishasresiduebetween25to250mg.Stirvolumeofsamplewithmagneticstirrerorshakeit vigorously,pipettethe required volumeof samplefromfiltrateintoweighedevaporatingdish.Evaporatethesampleusingsteambathor dryingovenat980C(approx.)Afterevaporation,transferthedishtoanovenat180°C±2°Cdrytoconstantmass(usually1hto2h).Cooltthedishindesiccatorsandweighassoonaspossible,avoidthelongtimestorage.
TotalDissolvedSolids,mg/l=(A-B)X106/V

Where, llBOD bottleswithsample water,leavingno air bubbles.The standard volumeis usually300 mL.Determineinitial DissolvedOxygen (DO)forone bottleand keeptwobottlesfor incubationat 27oC± 1oCfor72h(3 days).To determine Initial DO, fill the 300 ml bottle withoutturbulently exposingthesampletotheair,andstopperit.Add2mlmanganous Sulphate,2 ml alkali- iodide reagent,Add 2ml of concentratedH2SO4, Mix thoroughlyto dissolvetheliberatediodine. Take200mlofthe solution& titrateimmediatelyagainststdsodiumthiosulphatesolution, Adding34dropsofstarchindicatorsolution.Theendpointispalebluetocolorless. Notethereading After72h(3 days)incubationat 27oC±1oC, determine finalDOinincubatedbottlesassameasinitialDOnotethereading.
Bio ChemicalOxygenDemand, mg/l = ((S1-S2) X 300)/V
Where,Place0.4g HgSO4ina refluxtube.Add20mlorand aliquotof sample dilutedto20ml withdistilledwater.Mix well,sothat chloridesare convertedintopoorlyioinized mercuricchloride.Add10mlstandard K2Cr2O7solutionand thenadd slowy30 ml sulphuricacid whichalready containingsilversulphate.Mix well,if the colour turns green, take fresh samplewithsmaller aliquot.Finalconcentrationof concentrated.H2SO4 shouldbealways18N.Connectthetubestocondensersandrefluxfor2h at 150 ±2oC.Cool and wash downthe condenserswith60 ml distilled water.Cooland titrate against standard ferrousammoniumsulphateusing ferroin as indicator.

Neartheendofthetitrationcolourchangessharplyformgreenblueto winered.Refluxa reagentblanksimultaneouslywiththe sample under identical condition.

Where

COD,mg/l =(B–S)Nx8000
V

B=Volume ofFAS requiredfor titrationagainsttheblankinml; S=VolumeofFAS requiredfortitrationagainstthesample,inml; N = NormalityofFASand V=Volumeofsampletakenfortesting,inml.

TotalNitrogen

TotalNitrogen=TotalKjeldhalNitrogen+Nitarate+Nitrite Total Kjeldhal Nitrogen

Placea measured volumeof samplein 800mlKjeldahl flask,add 50ml digestionreagenttoKjeldahlflask.Addfewglassbeadsafter mixing,heatundera hoodto removeacidfumes.Boilbriskly,untilthe volume reducedto 25-50mland copiouswhite fumesare observed, Continue the digestion,coloredor turbidsamples willbecome transparent and palegreen.Letcooland diluteto300ml withwaterandadd50ml

SodiumHydroxide-Thiosulfatereagentto forman alkalinelayerat flask bottom.Andsetthe flaskinto distillation apparatus.Ifthe sample containingresidual chlorine, removethe chlorineusingDechlorinating reagent.Use 1 ml of dechlorinatingsolutionto remove1mg/lof residual chlorine. Collectthe distillatein 500 ml flaskcontaining50 ml indicating boricacid. Carryoutthe blank usingdistilledwateras samemanner.Titratethe distillate against0.02NH2SO4untilthe solutionbecomes pale Pinkcolor.

Total Kjeldahl Nitrogen=(Sample – Blank)XNof H2SO4X 14000(as N) mg/l VST

Nitrate

TakeSampleof50ml,add1mlof0.1M1:1Hcltothesample.Measure the absorbanceat 220 nm 275nmread. Preparea blankas samemanner. Calculate the concentration fromthe linear graph.

Nitrate(mg/l)=SampleconcXMakeupvolume
Samplevolume

Nitrite

Prepare a serialdilutionof nitriteinthe rangeof2to25µg/l(2,4,10,17 &25)bydilutingappropriatequantitiesofstandardnitritesolutionto50 ml. Add 1 ml of sulphanilamidesolution.Let the reagentreactfor 2 to 8 minutes.Add1mlofNEDAdihydrochloridesolutionandmix immediately.Letstandforatleast10minutes.Measuretheabsorbanceat 543 nm. Preparea blankas samemanner.Plotthe calibrationcurve, absorbance versus concentration.
Take50mlofclearsampleandadd1mlofsulphanilamidesolution.Let the reagentreactfor 2 to 8 minutes.Add 1 ml of NEDAdihydrochloride solutionandmiximmediately.Letstandforatleast10minutes.Measure theabsorbanceat543nm.calculatetheconcentrationfromthelinear graph.
Nitrite(mg/l)=SampleconcXMakeupvolume
Samplevolume

Total Phosphorous

To 100 ml sample that does not contains more than 200µg (P) and is free from colour and turbidity. Add 1 drop phenolphthalein indicator. If sample turns pink, addstrongaciddropbydroptodischarge the colour.Ifmore than5drops ofacidis required, take a small amount of sample and dilute 100ml with distilled water after first discharging pink colour with acid. After sample treatment add 4 ml molybdate reagent and 10 drops stannous chloride reagent. The colour development is depend on temperature, hold samples, standards, and reagents in the temperature range between 20°C and 30°C. After 10 min but before 12 min, using the same equal intervals for all determinations, measure colour photometrically at 690 nm and compare with calibration curve.
phosphorous,mg/l=SampleconcXMakeupvolume
Samplevolume

Parameters	Sample 1	Sample 2	Effluent discharge Standard (TNPCB)
pH	7.9	7.7	5.5-9
TotalSuspendedsolids	121	115	30
Total Dissolved Solids	1250	1265	-
Biochemical Oxygen Demand	82	84	20
Chemical Oxygen Demand	219	227	100
Total Nitrogen	150	158	15
Total Phosphorous	1.7	1.8	1

Table4.1.AnalysisReportofuntreatedDomesticWastewater

RESULTS AND DISCUSSION OF DOMESTIC WASTEWATER SAMPLE ANALYSIS

The analysis of two domestic wastewater samples was performed to assess their suitability for discharge and reuse based on various key parameters. The following results were obtained:

pH

ThepH valuesofbothsamples were withintheneutraltoslightlyalkalinerange,at 7.9 and 7.7. This is suitable for general discharge and irrigation purposes, as pH valuesbetween5.5and9aregenerallyconsideredacceptable formostapplications.

Total Suspended Solids(TSS)

TSS values were 121 mg/L and 115 mg/L, slightly above the typical discharge standards of ≤30 mg/L for surface waters. Elevated TSS levels can cause turbidity, reduce light penetration, and negatively impact aquatic life in receiving water bodies. Further treatment may be necessary to lower these levels for direct discharge.

Total Dissolved Solids (TDS)

The TDS values were measured at 1250 mg/L and 1265 mg/L. High TDS levels indicate significant dissolved substances, which may affect soil and crop health if used for irrigation.

Biochemical Oxygen Demand(BOD)

BOD values were 82 mg/L and 84 mg/L, indicating substantial levels of organic matter. These values are above the common effluent standards of ≤20 mg/L for surface water discharge. This suggests a high microbial demand for oxygen, which could lead to oxygen depletion in receiving waters, impacting aquatic ecosystems. Additional biological treatment might be necessary.

Chemical Oxygen Demand(COD)

COD values were 219 mg/L and 227 mg/L, which are also higher than the general permissible limit of ≤100 mg/L for discharge. High COD levels indicate the presence of organic and possibly inorganic pollutants. The values are within discharge limits but could benefit from reduction to avoid potential ecological impacts.

Total Nitrogen

Total nitrogen concentrations were 150 mg/L and 158 mg/L, indicating elevated nutrient levels, which could lead to eutrophication in natural water bodies, causing algal blooms and oxygen depletion. Additional treatment to reduce nitrogen levels may be recommended, especially if the effluent is to be discharged into sensitive water bodies or used for irrigation of crops sensitive to nitrogen.

Total Phosphorus

Total phosphorus levels were 1.7 mg/L and 1.8 mg/L. These values are slightly higher than typical discharge standards of ≤1 mg/L for sensitive water bodies. Excessive phosphorus contributes to eutrophication, similar to nitrogen.Phosphorus levels should be monitored closely if the effluent is released into aquatic environments.

The wastewater samples analyzed showed values exceeding the standard permissible limits for several parameters, including TSS, BOD, nitrogen, and phosphorus. This suggests the need for additional treatment measures to meet discharge standards, especially for direct release into surface waters or use in sensitiveapplications.LoweringTSS,BOD,nitrogen,andphosphoruslevelswould improve the water quality, making it more suitable for safe discharge or reuse.

SELECTION OF PLANT FOR PYTOREMEDIATION

The plant Vetiver Grass (Vetiveria zizanioides) is selected for the treatment of domestic wastewater.

Vetiver (Vetiveria zizanioides), a deep-rooted grass species, has been widely recognized for its ability to remediate contaminated soils and treat wastewater through a process called phytoremediation. Its use in wastewater treatment has gained attention due to its high tolerance to a wide range of environmental conditions and its ability to remove pollutants efficiently.

Figure4.2Vetiverplant

Mechanisms of Vetiverin Waste water Treatment

Vetiver primarily uses the following mechanisms for treating wastewater:

Phytoextraction:Vetivercanabsorbnutrientslikenitrogenandphosphorus,as\wellasheavymetals(suchaslead,cadmium,mercury,andarsenic)from contaminated water through its extensive root system. The absorbed contaminants are either stored in the plant tissues or converted into less harmful forms.

Rhizofiltration: Vetiver’s fibrous root system acts as a natural filter, trapping suspended solids and absorbing dissolved pollutants directly from the water. This mechanism is particularly effective in reducing sediment, heavy metals, and nutrient load from wastewater.

Phytodegradation: Vetiver’s root zone (rhizosphere) supports microbial activity, whichhelpsbreakdowncomplexorganicpollutantslikehydrocarbonsandpesticides into simpler, less toxic compounds. The plant also releases enzymes that aid in the degradation of certain pollutants.

Phytostabilization: Vetiver can stabilize contaminants in wastewater, especially heavy metals, reducing their mobility and bioavailability. This prevents them from leaching into groundwater or being further transported within the water system.

Oxygenation: Vetiver's roots release oxygen into the surroundingwater,enhancingtheactivityofaerobicbacteria,whichfurtherdegradeorganicpollutants.

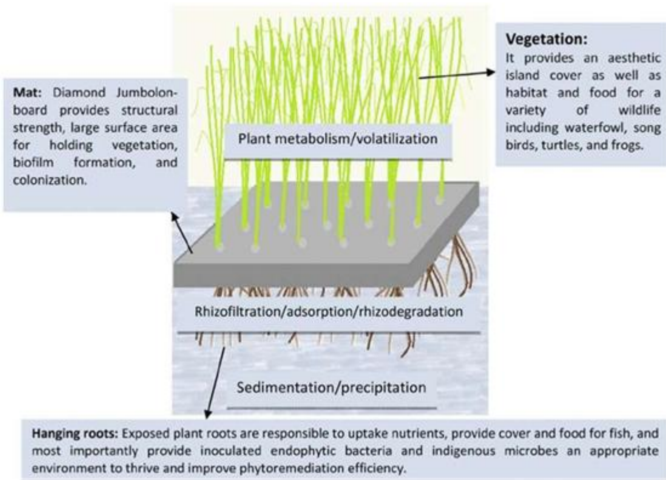

Figure4.3Phytoremediationdesign

DESIGN AND WORKING OF PHYTOREMEDIATION PROCESS

We describe the design and operation of the phytoremediation process used to treat domestic wastewater. The process employs Vetiver Grass (Vetiveria zizanioides) plants grown on floating rafts, which are transferred to a controlled experimental setupcontainingamixtureofdomesticwastewateranddemineralizedwater.This design simulates the conditions for efficient phytoremediation, with careful monitoring of water quality over a specified period.

Experimental Setup

Containers: The experimental setup consists of containers with dimensions of 20 cm x 10 cm. Each container holds a mixture of domestic wastewater and demineralized water in a 4:1 ratio. This dilution ensures that the concentration of pollutants in the wastewater is manageable for the phytoremediation plants, allowing them to effectively absorb and remove contaminants.
Floating Rafts: Rafts made of jute cloth with holes supported by wooden frame. These rafts allow the plants' roots to be submerged in the wastewater, facilitating nutrient uptake, pollutant absorption, and microbial interactions in the root zone.

Water Mixture: The containers are filled with a mixture of 90% domestic wastewater and 10% demineralized water. Demineralized water is used to prevent the buildup of excess salts that could inhibit the plants growth and phytoremediation efficiency.

Environmental Conditions: The containers arekept in partial sunlight to optimize the growth of the plants while minimizing water loss due to evaporation and evapotranspiration. By maintaining partial sunlight exposure, the plants have sufficient energy for photosynthesis without causing rapid water depletion, which could distort the experimental results.

Operational Process

Initially theSelectedhealthy plantsofsamesizeswereplacedonFloatingraftinthe container of size 20 cm X 10 cm containing freshwater to grow for 10 days.

Sampling Schedule: Two samples of 10 L is collected for the period of a month, 1 liter of water sample is collected from each container for analysis. This allows for regularmonitoringofthetreatmentprocess,includingthemeasurementofkey water quality parameters such as biological oxygen demand (BOD), chemical oxygen demand (COD), and total suspended solids (TSS) etc.

In each trial, of two sets, the sample is pored in the pytoremediation setup at the ratio of 4:1 of domestic wastewater and Distilled water. Set 1, 2, 3 of each sample has the retention time of2, 4, 6 weeks.

Monitoring and Analysis: The collected samples are analyzed to determine the effectiveness of the phytoremediation process in removing pollutants from the domestic wastewater. The water quality parameters are measured and compared over time to assess the performance of the plants in reducing contamination levels

RESULTS AND DISCUSSION

The analysis of the effluent discharge quality for the given samples was conducted against the standard limits prescribed by the Tamil Nadu Pollution Control Board (TNPCB). The results of the parameters measured are as follows:

pH

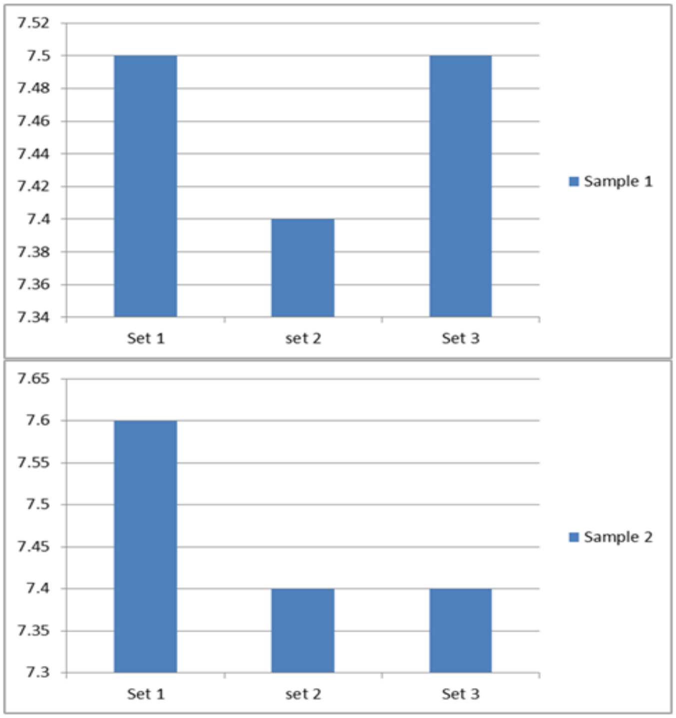

Figure5.2ComparisiongraphonpH

The pH values for all sets in both Sample 1 and Sample 2 fall within thepermissible range of 5.5 - 9 set by TNPCB. The values remain relatively stable, with minor variations between 7.4 to 7.6, indicating neutral conditions. This suggests that the effluent discharge does not pose a significant risk of acidity or alkalinity.

TotalSuspendedSolids(TSS)

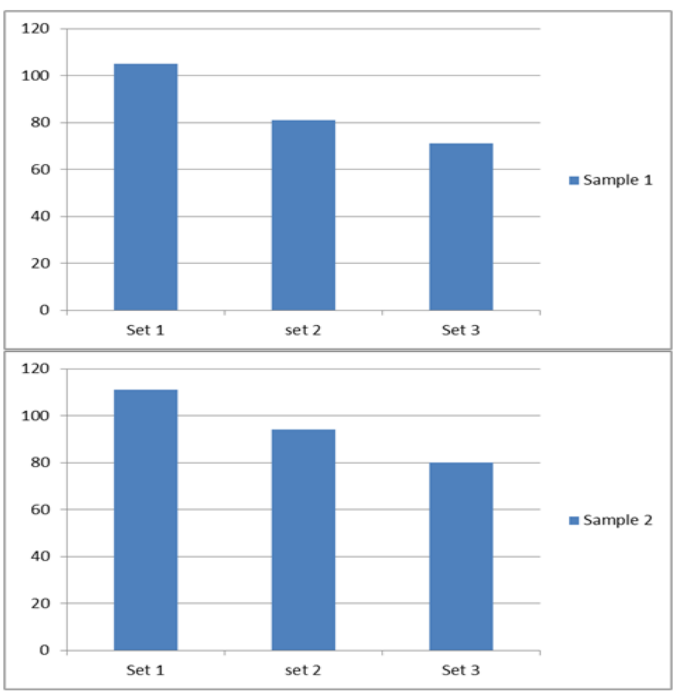

Figure5.3ComparisiongraphonTSS

For Sample 1, the TSS levels decrease from 105 mg/L in Set 1 to 71 mg/L in Set 3, while in Sample 2, it reduces from 111 mg/L to 80 mg/L. However, all values remain significantly higher than the TNPCB limit of 30 mg/L, indicating that the effluent contains excessive suspended solids even after treatment, which could impact water clarity and aquatic life.

TotalDissolvedSolids(TDS)

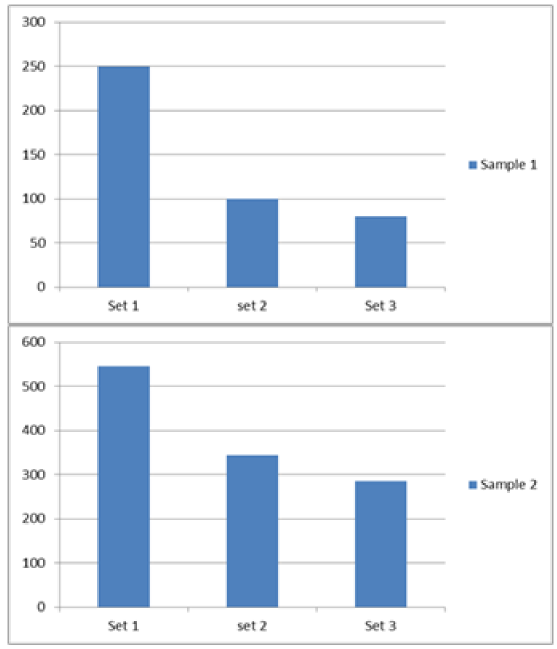

Figure5.4ComparisiongraphonTDS

TDS levels in Sample 1 range from 250 mg/Lin Set 1 to 80 mg/L in Set 3, whereas in Sample 2, it reduces from 546 mg/L to 285 mg/L. Although there is a notable reduction across the sets, there is no specific standard set by TNPCB for TDS. The significant difference between Sample 1 and Sample 2 indicates that Sample 2 contains more dissolved salts, potentially affecting water salinity and usability.

BiochemicalOxygenDemand(BOD)

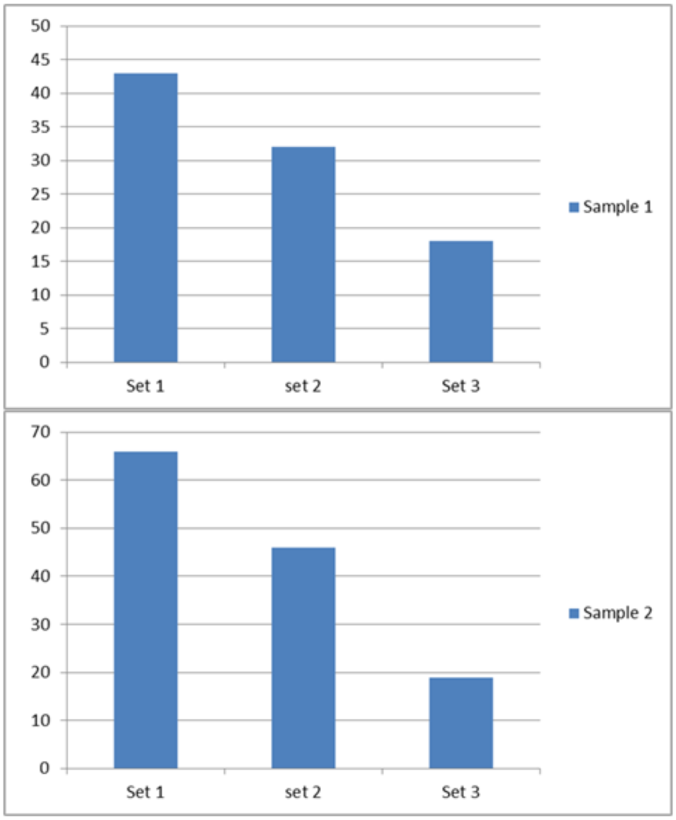

Figure5.5ComparisiongraphonBOD

The BOD values in Sample 1 decline from 43 mg/L in Set 1 to 18 mg/L in Set 3, while in Sample 2, the reduction is from 66 mg/L to 19 mg/L. However, TNPCB's permissible limit is 20 mg/L, meaning that Set 1 and Set 2 for both samples exceed this threshold. This suggests that the effluent still contains a high organic load in early treatment stages, requiring further treatment to meet environmental discharge standards.

ChemicalOxygenDemand(COD)

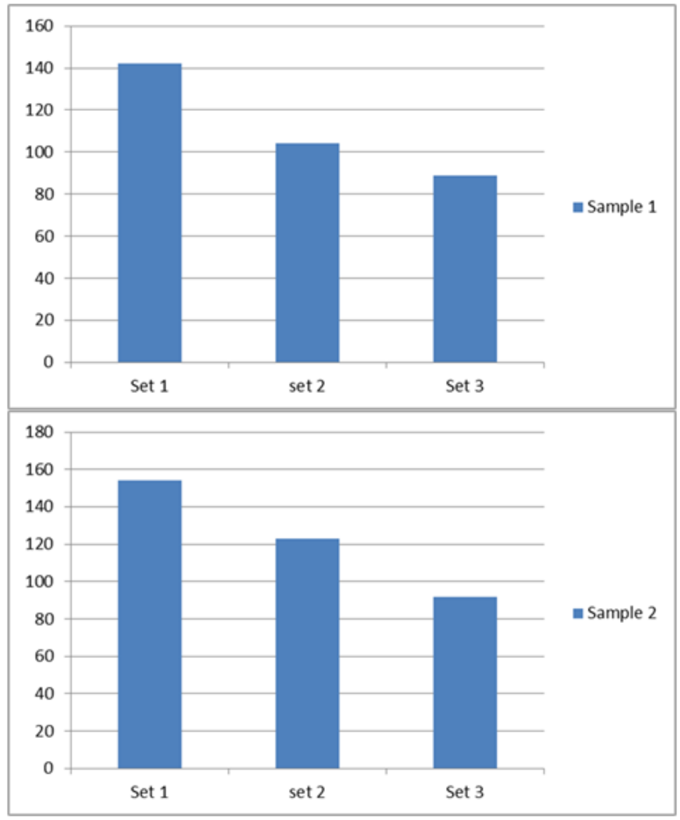

Figure5.6ComparisiongraphonCOD

COD levels for Sample 1 decrease from 142 mg/L in Set 1 to 89 mg/L in Set 3, while for Sample 2, the values drop from 154 mg/L to 92 mg/L. TNPCB's limit for COD is 100 mg/L, meaning that Set 1 and Set 2 in both samples exceed the permissible value, but Set 3 in Sample 1 meets the standard, while Sample 2 is still slightly above the limit. This suggests that Set 3 treatment is more effective in reducing chemical pollutants in Sample 1 compared to Sample 2.

TotalNitrogen(TN)

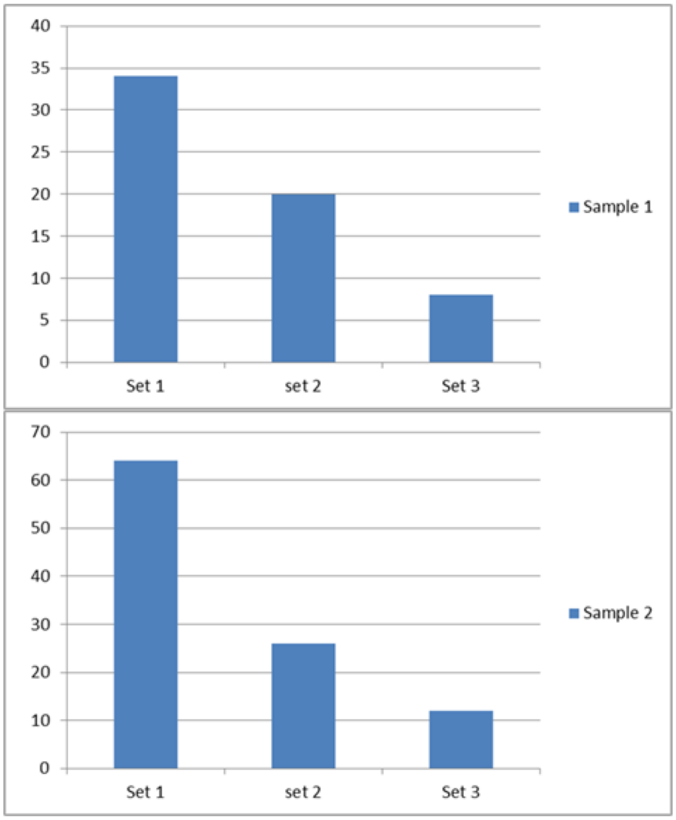

Figure5.7ComparisiongraphonTotalNitrogen

For Sample 1, the total nitrogen reduces from 34 mg/L in Set 1 to 8 mg/L in Set 3, while in Sample 2, it drops from 64 mg/L to 12 mg/L. The TNPCB standard is 15 mg/L, meaning thatSet 1 and Set 2 in both samples exceedthe limit, while Set 3 in both cases meets the standard. This indicates that advanced treatment significantly improves nitrogen removal efficiency.

TotalPhosphorus(TP)

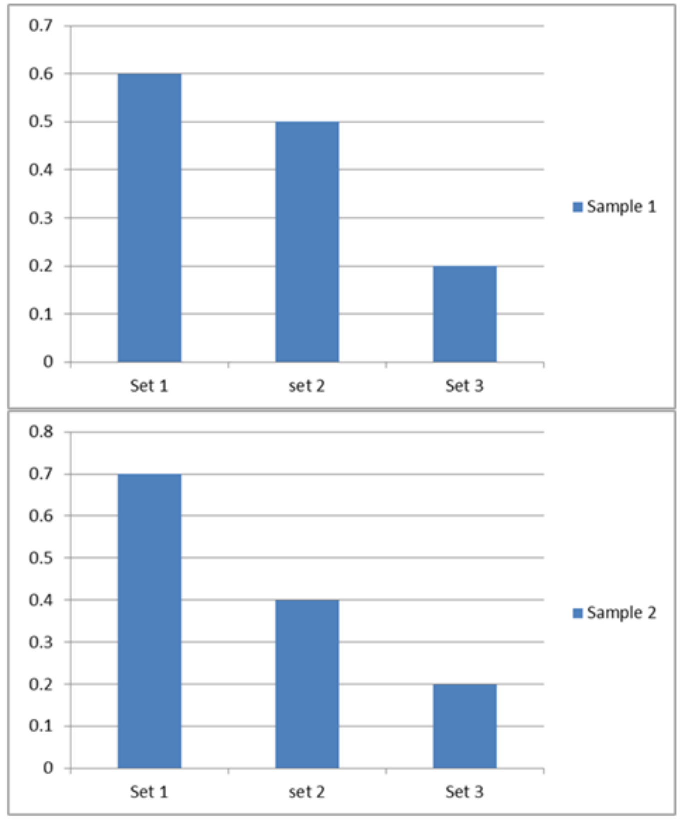

Figure5.8ComparisiongraphonTotalPhosphorous

ThetotalphosphorusvaluesforSample 1range from0.6mg/Lin Set1to0.2mg/L in Set 3, while in Sample 2, the reduction is from 0.7 mg/L to 0.2 mg/L. The TNPCB limit is 1 mg/L, meaning all values are well within the permissible range. This suggests that phosphorus levels in the effluent are not a major concern and remain effectively controlled throughout the treatment process.

Overall, Set 3 demonstrates the best treatment efficiency in both Sample 1 and Sample 2, bringing most parameters within regulatory limits. However, parameters like TSS, BOD, and COD still require improvement, particularly in Sample 2, which has generally higher pollution levels. Further optimization of treatment processes is necessary to ensure compliance with environmental standards.

COMPARISON WITH TYPICAL GARDENING / IRRIGATION STANDARDS

To determine whether the treated effluent meets the standard for gardening use or irrigation, we need to compare the final values (Set 3) of Sample 1 and Sample 2 with typical irrigation water quality guidelines. The key parameters that affect suitability for gardening are pH, Total Suspended Solids (TSS), Total Dissolved Solids (TDS), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Nitrogen (TN), and Total Phosphorus (TP).

Parameter	Set3 (Sample1)	Set3 (Sample2)	TypicalIrrigation Standard(FAO& CPCBGuidelines)	Meets Standard?
pH	7.5	7.4	6.5-8.5	✓Yes
Total Suspended Solids(TSS)(mg/L)	71	80	<50	✕No
TotalDissolvedSolids (TDS) (mg/L)	80	285	<2000	✓Yes
BiochemicalOxygen Demand (BOD) (mg/L)	18	19	<30	✓Yes
ChemicalOxygen Demand(COD)	89	92	<250	✓Yes

Table5.2ComparisonwithTypicalGardening/IrrigationStandards

- pH, TDS, BOD, COD, TN, and TP are within safe limits for irrigation/gardening. These parameters indicate that the effluent does not pose a serious risk of harming soil quality, plant growth, or microbial activity.
- TSS levels (71 mg/L in Sample 1 and 80 mg/L in Sample 2) exceed the irrigation guideline limit of 50 mg/L. High TSS can lead to clogging of irrigation systems and sediment buildup in soil.

Thetreated effluentisalmost suitableforgardening,but furthertreatment isneeded to reduce TSS below 50 mg/L. With some filters used to reduce TSS, the effluent can be safely used for irrigation purposes.

EXPLORING THE ECOLOGICAL AND ENVIRONMENTAL BENEFITS OF USING PHYTOREMEDIATION IN WASTEWATER TREATMENT

Phytoremediation has emerged as a sustainable and eco-friendly approach for treatingwastewater,leveragingplantstoremove,stabilize,ordegrade contaminants. This technique demonstrates significant potential to address the growing challenges of water pollution while delivering multiple ecologicalbenefits. The results obtained from phytoremediation of wastewater (as detailed below) illustrate its effectiveness in meeting effluent discharge standards prescribed by the Tamil Nadu Pollution Control Board (TNPCB).

Performance of Phytoremediation in Wastewater Treatment

The following data reflects key water quality parameters before and after treatment using phytoremediation, compared to TNPCB effluent discharge standards:

Reduction in Contaminant Levels:

Biochemical Oxygen Demand(BOD) and Chemical Oxygen Demand (COD) levels consistently decreased across all sets, meeting the TNPCB standards.

Total Nitrogen and Total Phosphorous concentrations also reduced significantly, highlighting the efficiency of phytoremediation in nutrient removal.
Improved Water Clarity:

A marked reduction in Total Suspended Solids (TSS) and Total Dissolved Solids (TDS) was observed, improving overall water quality.
Sustainable pH Levels:

The pH remained within the acceptable range of TNPCB standards, ensuring that the treated water is neither too acidic nor too alkaline.
Ecological and Environmental Benefits

Eco-Friendly Process: Phytoremediation employs plants, minimizing reliance on chemical treatments and reducing secondary pollution.

Habitat Creation: Wetlands and phytoremediation systems provide habitats for aquatic and terrestrial organisms, enhancing biodiversity.

Carbon Sequestration: The plants used in phyto remediation sequest carbondioxide, contributing to climate change mitigation.
Cost-Effective: This method is less expensive compared to conventional wastewater treatment techniques, making it accessible for resource-constrained a Further research should focuson refining operationalparameters,suchasextendingHRTandintegratingadditionaltreatment stages, to enhance pollutant removal efficiency. Implementing effective phytoremediation systems can contribute to sustainable wastewater management, offering ecological and environmental benefits by reducing pollutant loads and promoting resource recovery. reas.

Theanalysis ofdomesticwastewatersamples revealedelevatedlevelsofpollutants, including TSS, BOD, COD, Total Nitrogen, and Total Phosphorus, indicating a significant organic load that could adversely affect receiving water bodies if discharged untreated. Given these findings, the project advocates for theapplication of phytoremediation as an effective treatment strategy, leveraging the capabilities of vetiver grass. Vetiver is well-known for its robust growth and high nutrient uptake, making it an ideal candidate for reducing pollutants in wastewater.The designed phytoremediation setup demonstrated varying degrees of effectiveness in treating domestic wastewater. Neutral pH levels were consistently maintained,indicatingstabilityinthetreatmentprocess.Notablere ductions inTSS, BOD,COD, TN, andTP wereobserved acrosstreatment sets.However,TSS levels remained above TNPCB standards, and initial BOD and COD levels exceeded permissible limits, underscoring the need for process optimization. Achieving compliance with regulatory standards is crucial for the potential reuse of treated water in irrigation and other applications.