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STUDY OF CONSTRUCTED WETLAND: A CASE STUDY

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ABSTRACT

This manuscript evaluates the quality of effluent for irrigation purposes, highlighting the significance of water sources for this application. The study focuses on the presentation of a constructed wetland designed to harness natural processes, such as wetland vegetation, soil, and activity for wastewater treatment. Specifically, the research compares the cleansing efficiency of a vertical constructed wetland (VCW) using charcoal as a bedding medium, applied to sites contaminated with both organic and inorganic pollutants. The primary objective of this study is to assess the sewage treatment capabilities of a VCW pilot-scale system and determine its pollutant removal efficiency. The water samples were analyzed after treatment in the VCW, where charcoal served as the filtration medium. The research also examines the role of different plants, including Colocasia esculenta (Elephant Ear), Brassica juncea (Indian Mustard), Canna indica (Canna), and Eichhornia crassipes (Water Hyacinth), in combination with the charcoal bed, in improving treatment efficiency. The study underscores the potential of charcoal in enhancing wastewater treatment performance.

Keywords: Constructed Wetland, Vertical Constructed Wetland (VCW), Colocasia esculenta plant, Brassica juncea (Indian Mustard), Canna Indica and Eichhornia crassipes

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1.0 General Introduction

Earth is supported by several natural resources which can be useful to humans. Though the global economy has been expanding, these important resources are being consumed at an explosive rate, with a marked deterioration of overall quality. Through the overuse of natural resources, planet earth is undergoing environmental degradation which is damaging the ecosystem. Further, the theme of environment essay emphasizes a lot on these aspects.

Wetlands are widely considered one of the world's most at-risk and ecological vulnerable ecosystems. Wetlands most productive ecosystems on the planet. They play a crucial role in providing food, capturing and storing carbon, controlling floods, and replenishing groundwater. Additionally, the vegetation found in wetlands is used for multiple purposes such as constructing mats and houses, serving as a refuge for wildlife, and even as a source of food an alternative method which is gradually assuming attention is the use of Constructed Wetlands for waste recovery. The name is derived from the natural processes occurring in wetlands involving biological, physical, chemical, and ecological processes, which together are the basis for cleaning and treating wastewater using wetland media (soil, rock, plants) and the microbial assemblages living on or within them. The latter plants provide a less controlled treatment process, exploiting natural treatment mechanisms. Constructed Wetlands are artificial environments designed to replicate the processes of natural wetlands, with an increased treatment efficiency for pollutant removal. Although traditional and high-level processes for the treatment of wastewater, including activated sludge followed by chemical reaction, are common. Such systems tend to be costly, high-maintenance and service intensive. By contrast, natural-treatment systems are typically lower cost and sustainable, particularly in developing countries. These natural systems rely on physical, chemical, and biological processes to purify wastewater.

1.2 Description of Study Area

Area chosen for the study in Constructed wetlands in Darbhanga. The geographical location of study area is 26O08’33.56” N latitude and 85O57’39.05” E longitude and has an average elevation of 70.40 m. This location is a map of Laheriasarai, Darbhanga BIHAR.

Data of the study is collected from DIVA-GIS, this is free and open-source Geographic Information System (GIS) software developed for analyzing spatial data. It was originally conceived to help with research on the geographical distribution of plants in the case of crop wild relatives or wild potatoes, this study examines the identification of Bihar Darbhanga Constructed Wetlands Wetland Extent and Distribution: Bihar possesses more than 21,998 wetlands covering 403,209 hectares in area. Biodiversity is supported in these wetlands, they recharge groundwater, help to control floods and regulate water flow. However, wetlands of Bihar have been undertreated due to pollution. Particularly in agriculture, fishing and the gathering of forest resources other than timber, local livelihoods are supported through the use of wetlands. Wetlands in the region also play a significant role in income generating human activities such as the crop including cultivation of aquatic food plants and fish farming. These wetlands provide both direct resources and ecosystem services on which communities rely. Bihar’s wetlands have many ecological services such as biodiversity conservation and flood control. They support various birds and various aquatic species and water filters. They find that while South Bihar contributes quite significantly to wetland areas, North Bihar has a disproportionate contribution to the overall wetland extent, emphasizing the need for region specific conservation policies threats such as change in water inflow, pollution and spread of invasive species are the other important issues that need to be addressed through robust conservation measures emphasizing the need for region specific conservation policies. Conservation is critical: the threats encompass changes in water inflow, pollution, and spread of invasive species that must be addressed through robust measures

1.3 Objectives

Based on the literature evaluation and identified research gaps following are the aims of the present study.

1. To use natural process to treat water and remove pollutants.
2. To evaluate the effectiveness of planted Wetlands created by vertical flow in wastewater treatment.
3. To find the plant's total efficiency.
4. To treat wastewater using vertical flow constructed wetland. (VFCW)

2.0 METHODOLOGY

2.1 What is a Constructed Wetland.

A shallow basin that has been filled with filter media, such sand or gravel, and planted with plants that can survive in saturated circumstances is called a constructed wetland. After entering the basin and either flowing over the surface or through the substrate, wastewater is released through a device that controls the wetland's water depth. There are five primary components of a constructed wetland

1. Basin -A shallow basin or cell that contains the other components
2. Substrate- A filtering medium, typically sand or gravel, that is placed in the basin
3. Vegetation- Plants that can tolerate saturated conditions
4. Liner- An impermeable material, like clay or foil, that is lined on one side of the basin to keep wastewater in and groundwater out
5. Inlet/Outlet arrangement system-A system for managing the flow of water into the wetland and its exit

2.2 Classification of Wetlands

1. Natural Wetlands: These are semi-aquatic ecosystems the location of the land periodically or permanently submerged in water. Natural wetlands support diverse plant and animal species and are considered among the most productive ecosystems globally. They play a vital role in water purification, flood management, and preserving biodiversity.
2. Man-made Wetlands: These wetlands are engineered systems designed to utilize natural processes involving vegetation, soil, and microbial activity to enhance water quality.

2.3 Types of Natural Wetlands

1. Surface Flow Wetlands- In these wetlands, water flows above the ground, with wastewater moving horizontally across the plant roots rather than vertically.
2. Subsurface Flow Wetlands- These systems maintain the water level below the substrate surface, using a bed or channel filled with sediment to filter out pollutants from the wastewater.

2.4 Configurations of Constructed Wetlands

Constructed wetlands can be created in numerous ways, and these designs are classified based on several variables (Haberl, 1999)

1. Dominant Macrophyte Life Forms: This refers to whether the plants are free-floating, emergent, or submerged.

2. Flow Pattern: Wetland systems can either have free water surface flow or subsurface flow, which can be either horizontal or vertical.
3. Wetland Cell Configuration: Wetlands can be one-stage, multi-stage, or hybrid systems.
4. Wastewater Type: The system is classified based on the type of wastewater it treats, whether primary, secondary, or tertiary.
5. Pretreatment Type: The type of treatment applied before the wastewater enters the wetland, as well as influent and effluent structures.
6. Substrate Type: Wetlands may use various types of substrates, such as gravel, soil, or sand.
7. Loading Type: Wetlands can be designed for continuous or intermittent loading of wastewater.
8. Among these various classifications, this manual focuses primarily on subsurface flow constructed wetlands, which utilize two main types of flow directions

2.5 Horizontal flow

In Horizontal flow wastewater enters the system at one end of horizontal built wetlands and passes slowly **through the porous in a horizontal path. A system of anaerobic, anoxic, and** aerobic zones is traversed by the flow. The marsh vegetation's rhizomes and roots create aerobic conditions that allow oxygen to be released into the substrate. By decomposing contaminants, microbial processes aid in the treatment of wastewater as it passes through the rhizosphere.

2.6 Vertical Flow

In vertical flow constructed flatbed covered in sand and gravel, with more sand/gravel and flora on top, is what makes up a vertical flow-built wetland. A drainage system at the base collects wastewater that is introduced from the top and slowly seeps into the bed. The surface of these wetlands is first flooded by big batches of intermittent feeding

2.7 Working Flow chart

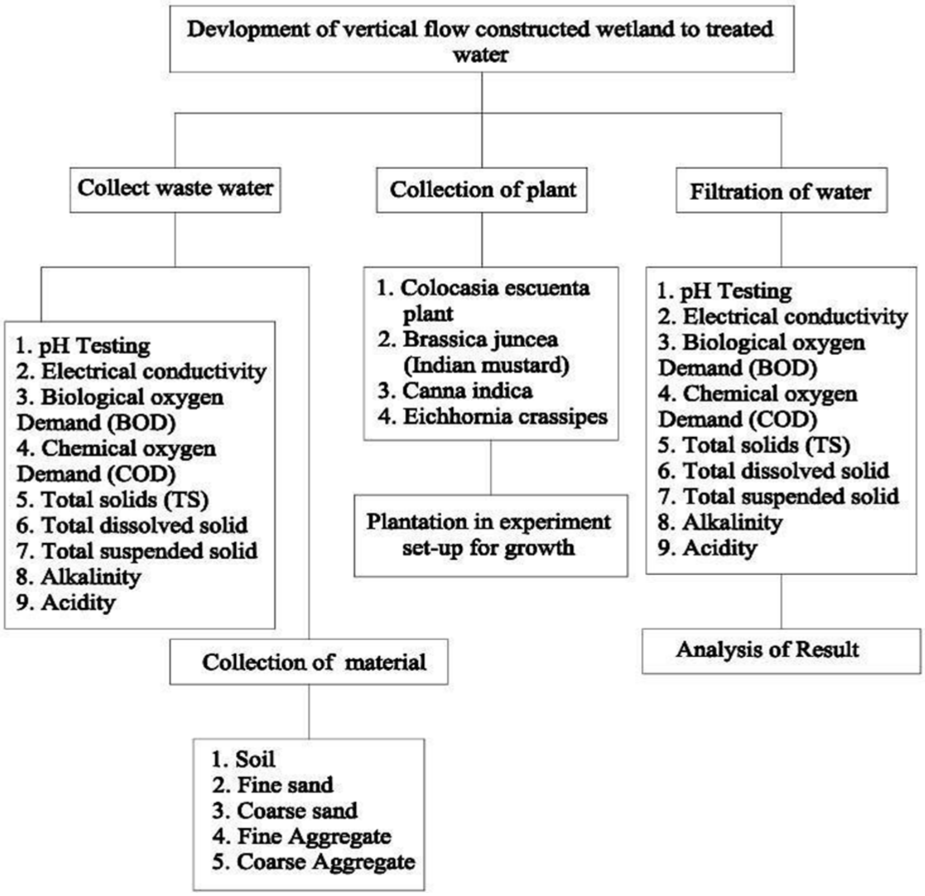


Figure 1. Flow Chart of Methodology

2.8 The idea of treating wastewater with a wetland constructed with vertical flow

A wetland is a designed system containing several bodies of water for the remediation of stormwater runoff or wastewater. The flora in these wetlands provide a substrate for microbes to live and break down an organic substrate of roots, stems and leaves. To this microbial community it is referred to as periphyton. The plants are very important in removing pollutants, and breaking the plants down with microbes into a carbon source. Plant selection for constructed wetlands for water treatment is an important part of that since different aquatic plant species undergo a varying absorption of heavy metals. Constructed wetlands are of two main types. These are the phytoremediation and nature-based remediation systems. To improve plantations of these wastewater treatment beds, constructed wetlands are part of a pair of carefully designed habitats that mimic natural soil, plant and microbe interactions in wetlands. The flow patterns, microbial composition and appropriate plants species are used to maximise the treatment process.

Figure 2. Vertical Flow Construction Wetland Prepared Model

2.8.1 Planning and designing Components of constructed wetlands

1. Components of constructed wetland -A constructed wetland is made up of a substrate, usually vascular plants, and a properly planned basin that retains water. These components can be changed while the wetland is being built. Furthermore, with time, other crucial elements like aquatic invertebrates and microbial populations organically establish themselves inside the system. Water - Wetlands typically develop in areas where an impermeable subsurface layer keeps water from leaking into the earth and landforms direct surface water into shallow basins. Domestic wastewater generated in residences or commercial buildings is referred to as greywater, excluding toilet wastewater, and is free from fecal contamination. It originates from sources such as sinks, showers, bathtubs, washing machines, and dishwashers.

Figure 3. Waste Water Stored in Tank

2. Material Used - The materials used in Soil (2 micrometres in size), fine sand (300 micrometres in size), and coarse sand (600 micrometres in size) are among the materials utilised in the setup. fine-grained aggregate, River pebbles (30–50 mm), crushed stones (10 mm), coarse aggregate (20 mm), 1,000-liter drums, pipes (1-inch and 2-inch sizes), and taps (8 units).

Figure 4. Material Used

The constructed wetland was constructed with a tub, which contains an arrangement of various materials in layers in support bed: the top 10 cm layer of sand is used as the primary filtration zone, removed suspended fine particles, microbial activity to breakdown organic matter. The 15 cm layer of fine gravel lies beneath it for water percolation and nutrient removal by microbial action and adsorption. This is followed by a 10 cm layer of medium gravel to maintain steady water flow, avoid clogging and help provide structural support to the system. The drainage bed containing the cobbles at the base collects effluent and aerates, but without water locking. Together these layers make up a balanced and natural filtration environment.

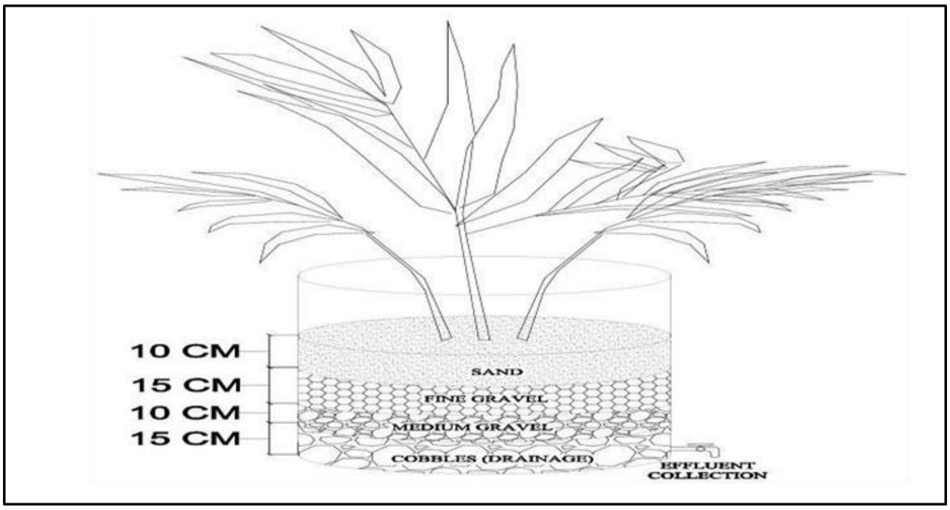


Figure 5. Layers of Vertical Flow Construction Wetland

2.8.2 Working Mechanism of Vertical Constructed Wetland

Physical processes

The two most commonly used physical procedures to purify wastewater in artificial wetlands are sedimentation and filtration Depending on the independence of all the treatments mechanisms biological and chemical and on the hydraulic retention time—the amount of time the water is in the system—the efficiency of the processes is greatly influenced. In general, a longer retention time will produce better contaminant removal but excessive retention can produce negative effects. Mechanical straining is mostly used for the elimination of floating debris. Sedimentation is especially useful for removal of microbiological pathogen and suspended particles, e.g. coliform and other bacteria. This process also partially reduces organic matter. Sedimentation operates under the influence of gravity, which is affected by the particle size, shape, density, and the consistency of the medium. Sedimentation may occur in two forms: discrete settling (without particle interaction) and flocculent settling (with particle interaction).

The base of the wetland becomes the settled solids that build up into the layer of deposition material. Another important process is sorption, i.e. adsorption and absorption. Physical (weak molecule) and chemical (stronger ionic) are two types of sorption. Adsorption or adherence of gases, liquids, or suspended substances in solids arises from the importance for the removal of phosphorus. Soil particles combine with insoluble inorganic phosphate; this binding is enhanced in soil with high clay content because the former have greater cation exchange capacity than sandy soils. In addition to phosphorus, Adsorption onto organic materials in soil and water is another method of removing heavy metals. Since ammonium ions are charged, can attach to the filter media, and their adsorption efficiency can be improved using specialized media like zeolite.

Absorption refers to the uptake of contaminants by plant roots and microbial populations. Inorganic phosphorus is absorbed by plants in wetlands, with roots being important for its removal. Even though total uptake capacity of microbes is limited by their small size, they also absorb phosphorus at rapid rates, as a result of their fast reproduction rates. Each of the pollutant types is removed from the wastewater using a series of process that involves a combination of physical settling, chemical binding and biological uptake.

Biological processes

This process is carried out in constructed wetlands through the use of biological processes to remedy or treat wastewater in a natural way. Some of the main organic reactions found are photosynthesis, fermentation, microbial, ammonification, nitrification, etc.

Ammonification is the first step in the nitrogen cycle of wetlands dealing with wastewater rich in organic nitrogen. The breakdown of organic nitrogen compounds is done by microbes through extracellular enzymes so that they can turn these into ammonium ions (NH_4^+). One such reaction is that of the oxidative deamination of amino acids by the release of energy results in the production of ammonia (NH_3). In this reaction the oxygen increases reaction rate in higher layers of water and decreases reaction rate in deeper layers as facultative to obligate conditions. Ammonification is most efficient at a pH of 6.5 to 6.8, and almost doubles with every 10°C increase in temperature.

Nitrification occurs when ammonium is present in the system following the ammonification. This is a two-step process where nitrate specific autotrophic bacteria oxidize NH_4^+ to NO_2^- and NO_2^- to NO_3^-. In the first stage, microbes like Nitrosomonas, Nitroso coccus, and Nitro Spira convert ammonium to nitrite. In the second stage, bacteria such as Nitrobacter and other Nitro Spira species convert nitrite to nitrate. These microbes need enough oxygen, an alkaline pH, appropriate micronutrients and a temperature between 25–40°C. However, autotrophic bacteria are primarily responsible for this transformation, and heterotrophic bacteria may contribute further at a lesser rate.

Nitrogen removal through denitrification is a major process for discarding nitrogen in constructed wetlands, converting nitrate (NO_3^-) to nitrogen gases (N_2, N_2O, or NO) that are lost into the atmosphere. Anoxic (low oxygen) conditions are very favourable to this process, which is naturally restricted in vertical flow systems by decreased oxygen availability. Species of Bacillus, Pseudomonas, Enterobacter, Spirillum and Micrococcus are microorganisms involved in denitrification. Factor such as dissolved oxygen levels, redox potential, organic matter availability, and the type of substrate control whether or not denitrification will be successful. Denitrifying bacteria should be able to use dissolved oxygen around 0.3 to 0.5 mg/l, otherwise if oxygen is available, they will use it before nitrates.

Aquatic plants and algae also carry out photosynthesis that help oxygenize the wetland environment and supply carbon. It enhances the conditions for nitrification by releasing oxygen into the root zones (rhizosphere). Respiration is the universal biological process, whereby organism's breakdown organic carbon into carbon dioxide and water utilising energy. Bacteria, fungi, algae and protozoa are common microorganisms to constructed wetlands, all of which play a role in biological transformations.

Chemical processes

Metals present in wastewater can undergo chemical transformations and settle out of the water column as insoluble precipitates. Sunlight and interaction with atmospheric gases can degrade organic pesticides and help eliminate disease-causing microorganisms. The pH levels of both water and wetland soils play a critical role in governing numerous chemical and biological processes. These include the solubility of solids and gases, cation exchange processes, the transformation of substances, and the equilibrium between ionised and non-ionized forms of acids and bases.

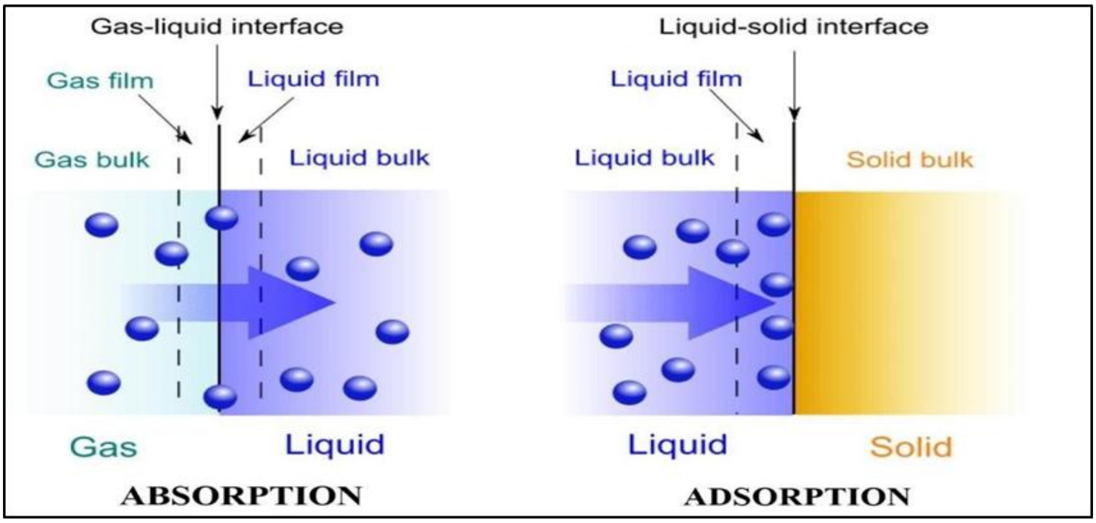


Figure 6. Experimental vertical constructed wetland

Absorption

1. Absorption refers to the integration of molecules throughout the entire volume of a solid or liquid.
2. It is considered a bulk phenomenon, as the molecules are distributed uniformly within the material.

3. Temperature typically does not have a significant effect on absorption.

Adsorption

1. Adsorption involves the accumulation of molecules specifically at the surface of a solid or liquid rather than throughout its volume.
2. It is classified as a surface phenomenon.
3. This process is generally enhanced at lower temperatures.

Table 1. Properties of removal material

Pollutant	Main removal mechanism
Suspended solids	**1. Filtration**
	2. Sedimentation
Nitrogen	**1. Ammonification followed by nitrification and denitrification**
	2. Ammonia volatilization
	3. Plant uptake and export through biomass harvesting
Phosphorous	**1. Retention in the soil by adsorption and precipitation reaction facilitated by filter media**
	2. Precipitation with calcium, aluminium and iron
	3. Plant uptake
Pathogens	**1. Sedimentation**
	2. Filtration
	3. Natural die-off due to long retention time
	4. Predation
	5. UV irradiation
	6. Excretion of antibiotics from roots of macrophytes
Heavy metals	**1. Precipitation and adsorption**
	2. Plant uptake
	3. Cation exchange
	4. Complexation
	5. Microbial Oxidation or reduction
Organic matter	**1. Settling or filtration**
	2. Microbial
Organic contaminates	**1. Microbial adsorption and clay particles**
	2. Decomposition by aerobic

2.8.3 Study of plants used in construction wetland.

1. **Colocasia esculenta plant -** It belongs to a genus of tall-growing plants within the family Araneae. These plants regions of Africa, Southeast Asia, and the Indian subcontinent. Commonly referred to as "elephant ear, the name comes from the large, broad leaves that resemble the ears of an elephant in both shape and size.

Weather required- The temperature sticky climate with consistent moisture and average temperature ranging from 21°C to 27°C

Cultivation period- The cultivation period of Colocasia esculenta plant is 70- 80 days

Importance of plant- Colocasia has robust root growth and unique qualities that make it perfect for treating wastewater, namely its large surface area and high porosity which enhance its ability to aid in pollutant removal.

Figure 7. Colocasia esculenta plant.

2. **Brassica juncea (Indian Mustard)-** It is a flowering plant in the mustard family is used as a vegetables, oilseed and spice. This is also originated in Central Asia.

   Weather required- Mustard prefers a low temperature range of 10°C to 25°C

   Cultivation period- The cultivation period of Brassica juncea is 65- 75 days

Importance of plant- Brassica juncea (mustard) is an important plant due to its economic, agricultural, nutritional, and environmental contributions. It chains sustainable farming practices, improves food security, and provides valuable properties for the food commerce

Figure 8. Brassica juncea plant.

3. **Canna Indica -** Nowadays, Canna indica works by using surfactants to remove phosphates, other waste particles, and high organic load colour.

   Weather required- The warm and tropical climates average range of 18°C to 30°C

   Cultivation period- The cultivation period of Canna Indica is 50- 60 days

   Importance of plant- Its attractive beauty, edible rhizomes, medicinal uses, soil conservation, and cultural import. It is used in outmoded medicine, phytoremediation.

Figure 9. Canna indica plant

4. **Eichhornia Crassipes -** This free-floating aquatic plant, commonly referred to as water hyacinth, is indigenous to the Amazon Basin. It is well-known for its quick growth,

stunning purple blooms, and capacity to thrive in freshwater environments like ponds, lakes, rivers, and wetlands.

Weather required- Warm, tropical, and subtropical environments and slow-moving water for optimal growth of 22°C to 30°C

Cultivation period- The cultivation period of Eichhornia crassipes is 50- 60 days

Importance of plant- Water purification, biomass making, and composting, but it is also an aggressive type that waterways and disrupts ecosystems. It has economic uses in biofuel and animal feed

Figure 10. Eichhornia Crassipes plant

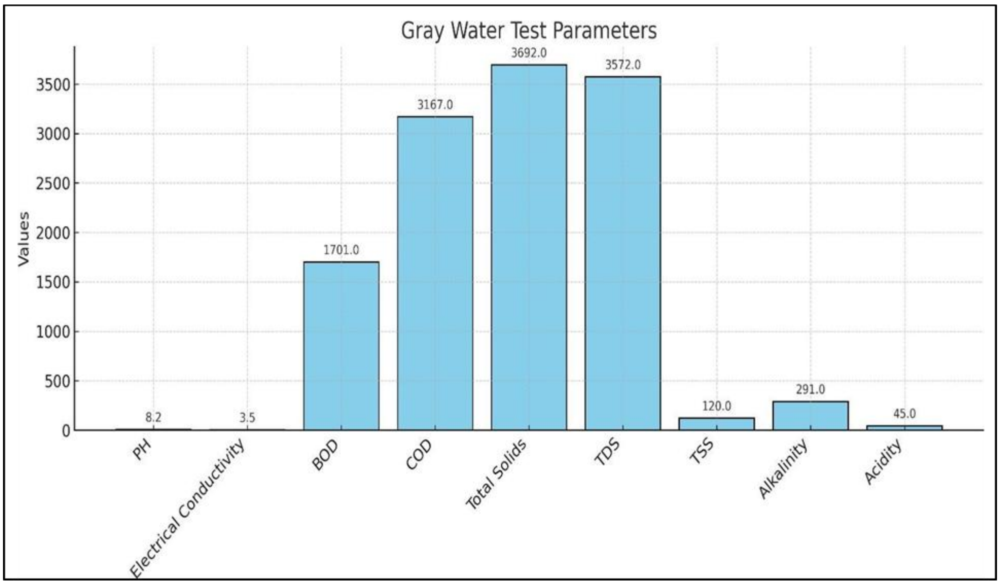
3.0 RESULTS AND DISCUSSIONS

The Constructed wetlands offer a natural, eco-friendly solution for treating domestic graywater, especially in resource-constrained regions. This study investigates the performance of four plant species Colocasia esculenta, Brassica juncea, Canna indica, and Eichhornia crassipes in graywater treatment using constructed wetlands. Given Bihar's tropical climate and growing sanitation needs, the development of a scalable, low-cost treatment system is crucial.

Table 2. Test on Gray Water

Test on Gray Waters			
Sr.no	**Parameters**	**Units**	**Values**
1	**PH**		**8.2**
2	**Electrical Conductivity**	**mS/cm**	**3.5**

3	**Biological Oxygen Demand (BOD)**	**mg/l**	**1701**
4	**Chemical Oxygen Demand (COD)**	**mg/l**	**3167**
5	**Total Solids (TS)**	**mg/l**	**3692**
6	**Total Dissolved Solid (TDS)**	**mg/l**	**3572**
7	**Total Suspended Solid (TSS)**	**mg/l**	**120**
8	**Alkalinity**	**mg/l**	**291**
9	**Acidity**	**mg/l**	**45**

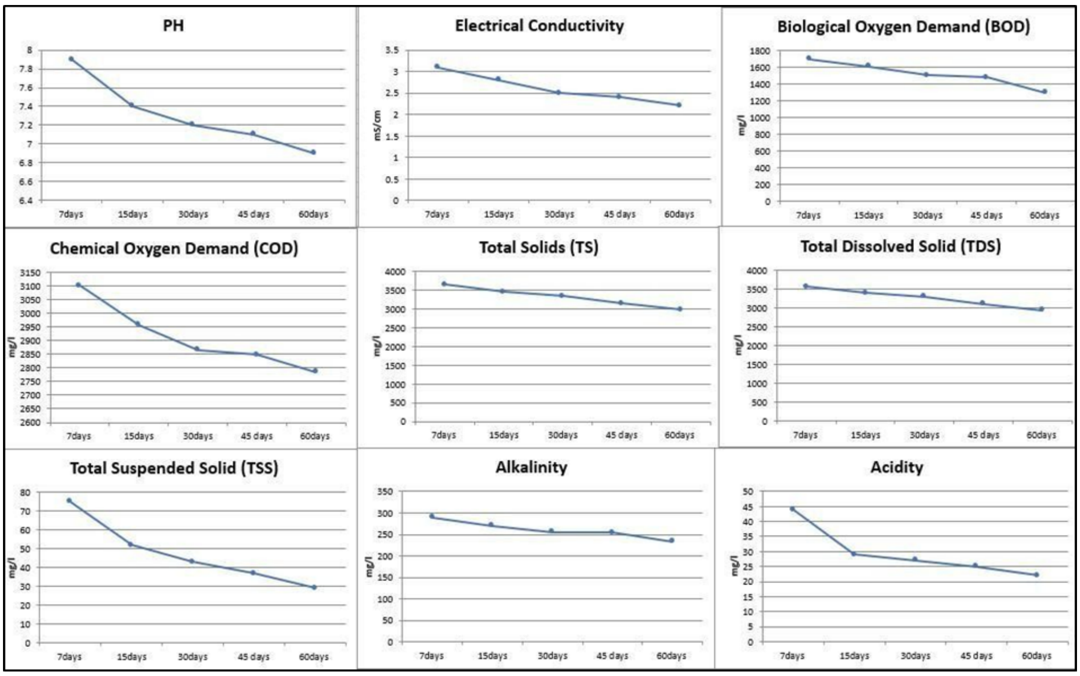


Graph 1. Gray Water Test Results

In this test of the gray water sample indicates in which a pH of 8.2, which places it above the neutral level of 7 and suggests a basic composition. The electrical conductivity, measured at 3.5 mS/cm, points to a significant number of dissolved salts or ions, likely introduced by common household products such as soaps and detergents. Much to the level of biodegradable organic matter, the Biological Oxygen Demand (BOD) is 1701 mg/l, far beyond typical domestic gray water ranges of 100 to 300 mg/l. Similarly, the Chemical Oxygen Demand (COD) is 3167 mg/l, markedly above the normal range of 250 to 800 mg/l, indicating a high amount of chemicals pollution, which could be the resultant of the synthetic materials. The Total Solids (TS) level is 3692 mg/l, the majority of which comprises Total Dissolved Solids (TDS) at 3572 mg/l, while the Total Suspended Solids (TSS) are relatively minimal at 120 mg/l. This reveals that most pollutants are in dissolved form, necessitating advanced treatment methods for effective removal. Moreover, the sample's alkalinity (291 mg/l) is considerably greater than its acidity (45 mg/l), reinforcing the observation of its slightly alkaline nature.

Table 3. Water Quality Analysis of Constructed Wetland Basin Treated After 7 days to

Test on Collected Water from waste water Wetland Basin on Colocasia Plant (Arbi)							
Sr.no	**Parameters**	**Units**	**7days**	**15days**	**30days**	**45days**	**60days**
1	**PH**		7.9	7.4	7.2	7.1	6.9
2	**Electrical Conductivity**	**mS/cm**	3.1	2.8	2.5	2.4	2.2
3	**Biological Oxygen Demand (BOD)**	**mg/l**	1697	1612	1503	1480	1301
4	**Chemical Oxygen Demand (COD)**	**mg/l**	3101	2956	2865	2847	2784
5	**Total Solids (TS)**	**mg/l**	3641	3444	3335	3138	2970
6	**Total Dissolved Solid (TDS)**	**mg/l**	3566	3392	3292	3101	2941
7	**Total Suspended Solid (TSS)**	**mg/l**	75	52	43	37	29
8	**Alkalinity**	**mg/l**	290	270	256	254	233
9	**Acidity**	**mg/l**	44	29	27	25	22



Graph 2. Water Quality parameter over time (Colocasia Wetland Treatment)

This test is conducted on a 60 days period and the Colocasia (Arbi) Plant based constructed wetland improved steadily and representations in the quality of gray water. There was a significant decrease in Biological Oxygen Demand (BOD) with a time reduction from 1697 mg/l on 7day to 1301 mg/l on 60 days, representing a substantial decrease of organic pollutants via natural bio degradation processes.

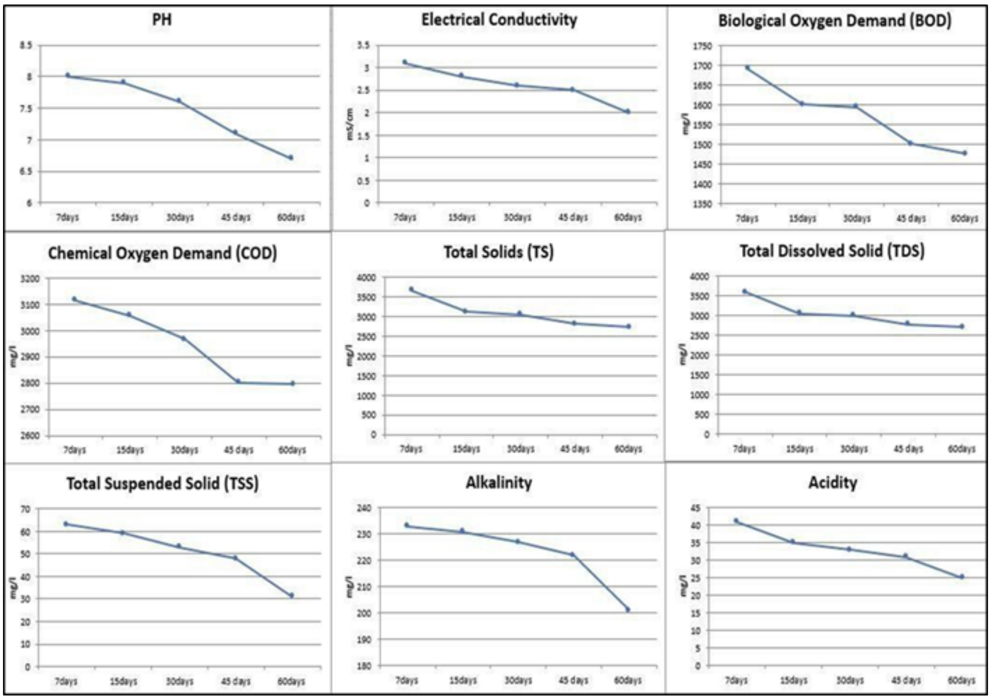
This is through comparisons on the Chemical Oxygen Demand (COD), which went down from 3101 mg/l to 2784 mg/l as chemical contaminants disappear within the system. This showed elimination of dissolved substances Total Dissolved Solids (TDS) reduced from 3566 mg/l to 2941 mg/l. Total Suspended Solids (TSS) also marked reduced down from 75 mg/l to 29 mg/l, indicating the wetland was effective in removing particulate matter.

The pH decreased from 7.9 to 6.9 slowly moving closer to neutral. The alkalinity as well as the acidity declined from 290 mg/l to 233 mg/l and from 44 mg/l to 22 mg/l, respectively.

The Colocasia based wetland system performed successfully to stabilize the overall chemical composition of the water making the grey water less organic as well as inorganic pollutant. Although the 60-day period has resulted in lower pollution levels than acceptable limits, continued reduction of all main pollutants supports the ability of this natural treatment approach. Nevertheless, additional post treatment steps may be needed for complete safety in reuse or discharge phytoremediator in constructed wetlands for treating wastewater.

Table 4. Water Quality Analysis of Constructed Wetland Basin Treated After 7 days to 60 days on Brassica juncea

Test on Collected Water from waste water Wetland Basin on Brassica juncea (Indian Mustard)							
Sr.no	**Parameters**	**Units**	**7days**	**15days**	**30days**	**45days**	**60days**
1	**PH**		8	7.9	7.6	7.1	6.7
2	**Electrical Conductivity**	**mS/cm**	3.1	2.8	2.6	2.5	2
3	**Biological Oxygen Demand (BOD)**	**mg/l**	1692	1601	1594	1501	1475
4	**Chemical Oxygen Demand (COD)**	**mg/l**	3115	3056	2967	2801	2796
5	**Total Solids (TS)**	**mg/l**	3651	3107	3041	2812	2729
6	**Total Dissolved Solid (TDS)**	**mg/l**	3588	3048	2988	2764	2698
7	**Total Suspended Solid (TSS)**	**mg/l**	63	59	53	48	31
8	**Alkalinity**	**mg/l**	233	231	227	222	201
9	**Acidity**	**mg/l**	41	35	33	31	25



Graph 3. Water Quality parameter over time (Brassica juncea Wetland Treatment)

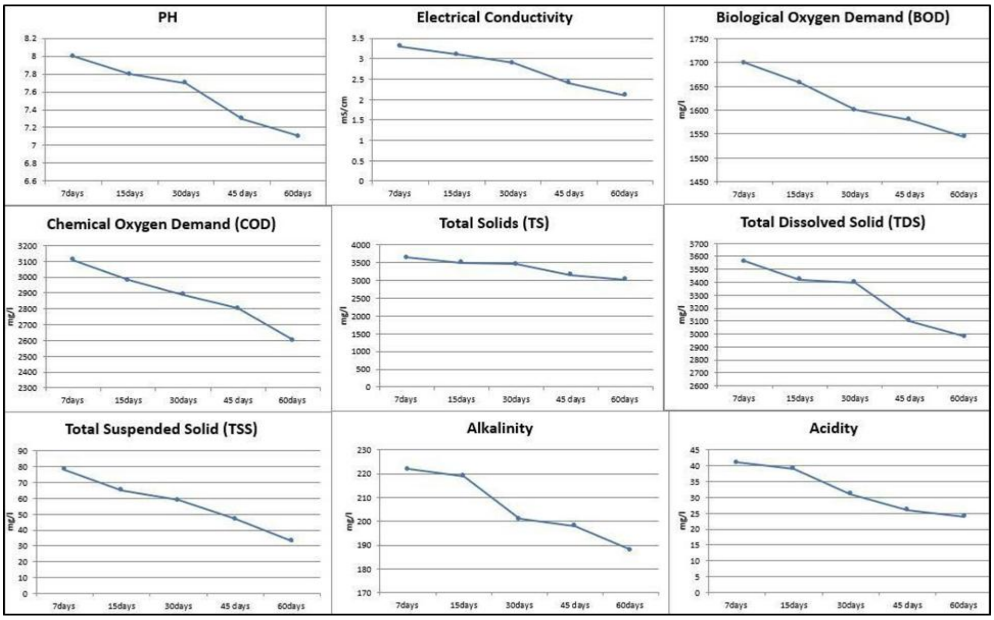
Test on Collected Water from waste water Wetland Basin on Brassica juncea (Indian Mustard) This necessarily means that the chemical balance is improved and that the environment is more conducive to biological processes. Values were also observed for the electrical conductivity which decreased from 3.1 to 2.0 mS/cm. This trend indicates that the dissolved ions and salts are disappearing from the water as the water is getting purer and salinity is becoming less and less of a stressful issue. Beside this, the reduction in the amount of biodegradable organic pollutants was evidenced from the decrease in Biological Oxygen Demand (BOD) from 1692 mg/l to 1475 mg/l. This indicates that active microbial degradation processes are occurring, which is essential for biological treatment of water.

Just like the aforementioned, the Chemical Oxygen Demand (COD) followed a similar course of falling from 3115 mg/l to 2796 mg/l, meaning that chemically oxidizable material has been reduced. Such implies the wetland's increasing ability to eliminate complex and organic and inorganic pollutants. In addition, Total Dissolved Solids (TDS) and Total Solids (TS) were lower from 3651 to 2729 mg/l and 3588 to 2698 mg/l, respectively, because both suspended and dissolved materials were filtered and assimilated by the system and the Total Suspended Solids (TSS) also dropped noticeably from 63 to 31 mg/l, which could be attributed to trapping of suspended particles physically in plant roots and associated microbial activity. Water buffering strength decreased modestly from 233 mg/l to 201 mg/l as measured by alkalinity. For all concentrations, the buffering capacity was still reduced, but acceptable to maintain pH stability. At the same time, acidity dropped from 41 to 25 mg per liter in keeping with the better pH levels, therefore reducing free hydrogen ion concentration.

The overall of Brassica juncea in the constructed wetland system was, indeed, effective for treating wastewater in 60 days' indicators, indicating potential of the plant in improving water quality. This confirms that Indian Mustard is also suitable for use in ecofriendly, sustainable wastewater treatment solutions by phytoremediation.

Table 5. Water Quality Analysis of Constructed Wetland Basin Treated After 7 days to 60 days on Canna Indica

Test on Collected Water from waste water Wetland Basin on Canna Indica Plant							
Sr.no	**Parameters**	**Units**	**7days**	**15days**	**30days**	**45days**	**60days**
1	**PH**		8	7.8	7.7	7.3	7.1
2	**Electrical Conductivity**	**mS/cm**	3.3	3.1	2.9	2.4	2.1
3	**Biological Oxygen Demand (BOD)**	**mg/l**	1699	1658	1601	1580	1544
4	**Chemical Oxygen Demand (COD)**	**mg/l**	3110	2980	2888	2804	2602
5	**Total Solids (TS)**	**mg/l**	3639	3486	3458	3148	3014
6	**Total Dissolved Solid (TDS)**	**mg/l**	3561	3421	3399	3101	2981
7	**Total Suspended Solid (TSS)**	**mg/l**	78	65	59	47	33
8	**Alkalinity**	**mg/l**	222	219	201	198	188
9	**Acidity**	**mg/l**	41	39	31	26	24



Graph 4. Water Quality parameter over time (Canna indica Wetland Treatment)

In this test Over a 60-day period, the water quality data collected from a constructed wetland basin planted with Canna Indica revealed a steady and encouraging trend in wastewater purification. The pH levels, initially measured at 8.0, gradually declined to 7.1 by the end of the study. The change suggests a slightly alkaline to more neutral or mildly acidic stabilization of the water's chemical environment. It is very likely that this transformation is due to ongoing biological (and chemical) activity and interactions underway in the wetland ecosystem.

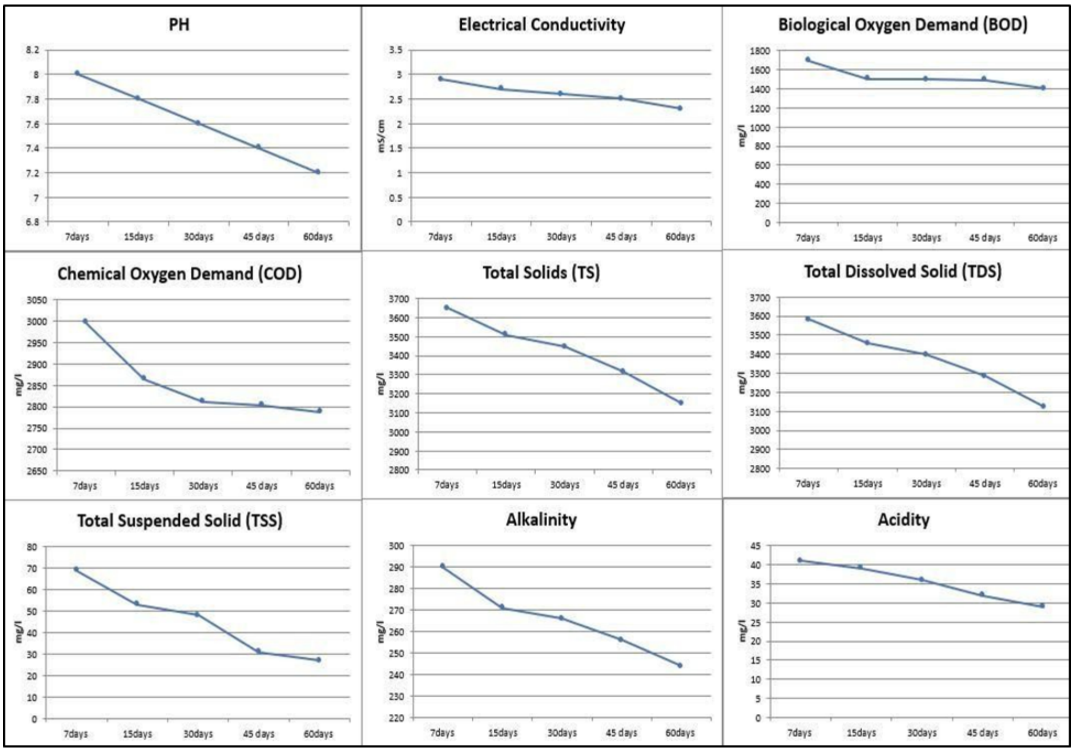
It was also observed that the electrical conductivity was dropping from 3.3 to 2.1 mS/cm. The drop in dissolved ions is a positive indicator of better water quality, as this drop reflects a large decrease. Besides this, both of the Biological Oxygen Demand (BOD) and the Chemical Oxygen Demand (COD) showed downward trends. COD decreased from 3110 mg/l to 2602 mg/l and BOD was reduced from 1699 mg/l to 1544 mg/l. The return of these changes represents effective degradation of organic pollutants and increased amount of oxygen in the water due to improved biological treatment capacity for Canna Indica. The Total Solids (TS) was reduced from 3639 to 3014 mg/l, Total Dissolved Solids (TDS) from 3561 to 2981 mg/l and Total Suspended Solids (TSS) from 78 to 33 mg/l. These indicate an improvement in the efficiency of the wetland in the removal of physical impurities through sedimentation and plant associated filtration processes.

Regarding chemical parameters, alkalinity slightly declined from 222 mg/l to 188 mg/l, suggesting a modest reduction in the water's buffering capacity. Acidity levels also fell from 41 mg/l to 24 mg/l, indicating fewer corrosive conditions and an improved chemical balance in the treated water.

Constructed wetland system based on Canna Indica overall is highly effective in wastewater treatment of 60-day period. These continuous improvements in all major water quality parameters such as pH, conductivity, organic load and solid content demonstrate that this nature-based solution is low cost and sustainable. Strong potential for wider application of the technology lies in its reliable performance, in particular in rural and semi-urban areas that have wastewater and environmental management challenges.

Table 6. Water Quality Analysis of Constructed Wetland Basin Treated After 7 days to 60 days on Eichhornia Crassipes

Test on Collected Water from waste water Wetland Basin on Eichhornia Crassipes							
Sr.no	**Parameters**	**Units**	**7days**	**15days**	**30days**	**45days**	**60days**
1	**PH**		8	7.8	7.6	7.4	7.2
2	**Electrical Conductivity**	**mS/cm**	2.9	2.7	2.6	2.5	2.3
3	**Biological Oxygen Demand (BOD)**	**mg/l**	1692	1501	1498	1492	1401
4	**Chemical Oxygen Demand (COD)**	**mg/l**	2996	2864	2811	2803	2788
5	**Total Solids (TS)**	**mg/l**	3649	3510	3445	3316	3149
6	**Total Dissolved Solid (TDS)**	**mg/l**	3580	3457	3397	3285	3122
7	**Total Suspended Solid (TSS)**	**mg/l**	69	53	48	31	27
8	**Alkalinity**	**mg/l**	290	271	266	256	244
9	**Acidity**	**mg/l**	41	39	36	32	29



Graph 5. Water Quality parameter over time (Eichhornia crassipes Wetland Treatment)

In this test Over a 60-day period, the water quality data obtained from the wetland basin cultivated with Eichhornia Crassipes (Elephant Ear) demonstrates a continuous and encouraging enhancement in several key parameters, underscoring the efficiency of this natural wastewater treatment approach.

The pH value gradually decreased from 8.0 to 7.2, suggesting a shift toward neutral conditions. Such a change Favors aquatic ecosystems and reflects improved chemical stability in the water, likely resulting from sustained biological and microbial activities within the wetland environment.

Electrical conductivity showed a consistent decline from 2.9 to 2.3 mS/cm, indicating a notable reduction in dissolved ionic substances. This trend confirms the system's effectiveness in removing salts and minerals from the water, contributing to overall water purification. Significant decreases were also observed in both Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD). BOD dropped from 1692 mg/l to 1401 mg/l, and COD reduced from 2996 mg/l to 2788 mg/l. These trends reflect the breakdown of organic pollutants and improved oxygen levels, which are essential indicators of healthy, self-sustaining water bodies. The analysis further revealed substantial reductions in solid contents. Total Solids (TS) decreased from 3649 mg/l to 3149 mg/l, and Total Dissolved Solids (TDS) from 3580 mg/l to 3122 mg/l. Notably, Total Suspended Solids (TSS) declined from 69 mg/l to 27 mg/l, suggesting the effective filtration and settling of particulates facilitated by the plant's root system and microbial interactions. Chemical characteristics also improved. Alkalinity dropped moderately from 290 mg/l to 244 mg/l, indicating a slight reduction in the water's buffering capacity. Additionally, acidity fell from 41 mg/l to 29 mg/l, pointing to a decline in corrosive elements and a more balanced chemical composition.

The overall of Eichhornia Crassipes in a constructed wetland system proved to be an effective, natural solution for wastewater treatment. The continuous improvement in parameters such as BOD, COD, pH, conductivity, and solid contents illustrates the plant's ability to enhance water quality through biological and ecological processes. This nature-based method stands out as a sustainable and economical option, especially valuable for communities in rural and semi-urban areas struggling with water contamination and sanitation issues

3.1 The result of Performance constructed wetland

Based on the analysis of the water test performance in the constructed wetland, the following reductions were observed in quality parameters

$$\text{Reduction Percentage} = \frac{(Initial\ value - Final\ Value)}{Initial\ Value}\ X\ 100$$

Initial value- Gray Water

Final Value- Value after plant treatment

Table 7. Reduction Performance of plant.

Test on Collected Water from waste water Wetland Basin on Eichhornia Crassipes							
Sr.no	**Parameters**	**Units**	**7days**	**15days**	**30days**	**45days**	**60days**
1	**PH**		8	7.8	7.6	7.4	7.2
2	**Electrical Conductivity**	**mS/cm**	2.9	2.7	2.6	2.5	2.3
3	**Biological Oxygen Demand (BOD)**	**mg/l**	1692	1501	1498	1492	1401
4	**Chemical Oxygen Demand (COD)**	**mg/l**	2996	2864	2811	2803	2788
5	**Total Solids (TS)**	**mg/l**	3649	3510	3445	3316	3149
6	**Total Dissolved Solid (TDS)**	**mg/l**	3580	3457	3397	3285	3122
7	**Total Suspended Solid (TSS)**	**mg/l**	69	53	48	31	27
8	**Alkalinity**	**mg/l**	290	271	266	256	244
9	**Acidity**	**mg/l**	41	39	36	32	29

3.2 Best Performance According to Reduction

TSS Reduction Eichhornia crassipes (77.50%)

Best BOD Reduction Colocasia esculenta (23.47%)

Best COD Reduction Canna indica (18.61%)

Best TDS Reduction Brassica juncea (24.47%)

Best Alkalinity Reduction Canna indica (35.40%)

Best Acidity Reduction Colocasia esculenta (51.11%)

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