Wastewater Treatment in Constructed Wetlands by Phytoremediation Technique

Hemadri Prasad Raju[1], *Mamilla* Vijaya Kumar[2] , and *Pachaivannan* Partheeban[3]

[1]Department of Civil Engineering, Mohan Babu University (Erstwhile Sree Vidyanikethan Engineering College), Tirupati, Andhra Pradesh, India.
[2]Department of Civil Engineering, Sri Venkateswara Institute of Science and Technology, Kadapa, Andhra Pradesh, India.
[3]Department of Civil Engineering, Chennai Institute of Technology, Chennai, Tamil Nadu, India.

Abstract. Water is the most required element next to air for terrestrial living being. Though the water is everywhere but no direct use is possible as the fresh water is getting contaminated through various human activities. The conventional treatment methods using activated sludge process, attached growth systems such as trickling filters, rotating biological contactors, aerated lagoons and stabilization ponds are normally practiced in many places with each one having its own merits and demerits depending on space availability, energy requirements etc. An alternative solution called phytoremediation method can save energy requirements to the great extent but space required will be more and it can be used advantageously where space is not a constraint. This method involves using plants to absorb and metabolize pollutants found in wastewater, including nutrients such as nitrogen and phosphorus, heavy metals and other organic and inorganic contaminants. In this study, sewage is passed through a bed of plants, which takes up nutrients and contaminants while releasing oxygen during their photosynthesis process. This promotes the growth of beneficial bacteria that further break down pollutants. In the present work, Spider lily (Hymenocallis littoralis) and Heliconia (Heliconia psittacorum) are two species of tropical plants used in constructed wetlands and that have shown potential in the treatment of sewage. Conducted the performance studies on both plants separately. The efficiency achieved with spider lily plants Heliconia plants are 87.2% and 79.6% in BOD removal respectively. These systems are also relatively low-cost and require minimal maintenance, making them a viable option for wastewater treatment in areas where conventional treatment systems may be too expensive or impractical.

KEY WORDS: Treatment of Sewage, Treatment Potential, Constructed wetlands, Spider Lily, Heliconia, BOD removal.

1. Introduction

Supply of clean and affordable water to fulfill the human needs of the ever-growing population is a great challenge for Indian government. The Central Pollution Control Board (CPCB) provided effluent disposal standards for discharge of environmental pollutants from industries. In order to satisfy it, a variety of wastewater treatment

--- Corresponding Author: hemadriprasadraju@vidyanikethan.edu

processes are employed which includes physical and physico-chemical, biological process and demineralisation processes. In addition, the joint treatment of industrial and municipal waste waters can be economically and environmentally beneficial to both the industry and the municipality **[1].** Numerous water resources have been contaminated as a result of rapid population increase and expanding industrial development in various nations throughout the world because of the continual discharge of organic and inorganic wastes from human activities into natural water bodies [2,3,4]. Untreated home and industrial sewage discharge into water bodies caused water pollution and a decline in water quality [5]. Waste and residue discharge into natural water bodies has catastrophic effects on aquatic ecosystems and poses major risks to human health and natural environments [6].

Urban India produces about 73 billion liters of sewage every day **[7].** Out of this huge amount of sewage the installed treatment capacity is about 37%. The remaining 63% untreated sewage is polluting surface and groundwater quality in India. This situation is aggravated if this sewage is mixed up with industrial wastewater. So, an increase in domestic and industrial wastewater treatment plants shall be a solution, at the same time the economic feasibility is the main obstacle to its implementation **[8].** The conventional treatment plants require a centralized sewage collection network, which may not be feasible in sparsely populated rural areas. Hence, in these cases, phytoremediation is found to be an alternative wastewater treatment technology that is being researched worldwide. It has great potential to treat wastewater when compared to conventional treatment methods such as activated sludge processes, trickling filters, sequential batch reactors, up-flow anaerobic sludge blankets etc. **[9].**

Phytoremediation is fundamentally plant-based (aquatic, semi aquatic and terrestrial) and related associated enzymes, microorganism and water consumption, uptake, remove, retain, transform, degrade or immobilize contamination (organic and/or inorganic) with different origin, from soil, sediment and aquatic media or atmosphere [10, 11, 12, 13, 14, 15]. Phytoremediation is also known for green remediation, agricultural remediation and vegetative remediation [16].

2. Literature review

Tolu and Atoke have done Phytoremediation study on wastewater in Nigeria by using water Hyacinth plants. After a 5-week experimental study, it was discovered that water hyacinths effectively removed an average of 53.03%, 64.41%, 65.4%, 47.22%, 94.67%, and 30.30% of the pollutants total suspended solids, biochemical oxygen demand, dissolved oxygen, nitrate-nitrogen, cadmium, and iron, respectively. Patil et al., had used Duckweed, water hyacinth plants in Phytoremediation technology to treat domestic wastewater. It was found that this plant reduced chemical oxygen demand, biochemical oxygen demand, total dissolved solids & chloride content of wastewater about 50% with 48 hrs Hydraulic Retention Time (HRT) **[18]**.

Nurul et al., was conducted phytoremediation study to examine the capacity of five aquatic plants, namely Salvinia molesta, Eichhornia crassipes, Pistia stratiotes, Centella asiatica, and Ipomoea aquatica, and also to remove three contaminants from aquaculture effluent, namely phosphate, total suspended solids (TSS), and ammoniacal nitrogen (NH3-N). The results showed a drastic decline in the concentration of pollutants, where Salvinia molesta was efficient in removing 89.3% of TSS and 88.6% of phosphate, but only removed 63.9% of NH3-N with 14 days HRT, Centella asiatica was able to remove 98% of NH3-N, 90% of TSS, and 64% of phosphate, while Ipomoea aquatica showed the potential to eliminate up to 73% of TSS and 73% of NH3-N, and 50% of phosphate, and Eichhornia crassipes drastically removed 98% of phosphate, 96% of TSS, and 74% of NH3-N, while P. stratiotes was able to eliminate 98% of TSS, 78% of NH3-N, and 89% of phosphate [19].

Layana and Reena studied effectiveness of plant species of Canna indica, Heliconia psittacorum and Reedless bed in horizontal subsurface flow constructed wetlands for removing pollutants from domestic wastewater. Various physio-chemical parameters are analyzed like pH, Conductivity, DO, BOD, COD, TSS, TDS and chloride with 1, 3, and 6 days HRT. Result showed more reduction of parameters in constructed wetlands unit having Canna indica plant species with 6 day HRT than the other two units [20].

Abhijit had conducted phytoremediation study by growing aquatic plant culture in cement tank. Sewage was filled in this cement tank for specified interval of seven days. Before and after the growth of aquatic plant culture quality of domestic wastewater was analyzed to check improvement of quality of wastewater. The result of analysis indicated that phytoremediation process improved the quality of wastewater. In this phytoremediation study colocasia Arabica, Typha, Canna, water Hyacinth etc. aquatic plants were used. From their study they concluded that the plants are efficient in removing the BOD, COD and Turbidity etc. from domestic wastewater. But on the contrary Chloride, Sulphates, Hardness were increased, but this is within permissible limit [21].

Arivukkarasu and Sathyanathan had studied the treatment of home wastewater utilizing a floating raft made of naturally buoyant bamboo, along with terrestrial plants including Hibiscus, Chrysopogon zizanioides, Ocimum tenuiflorum and Canna. At intervals of 0, 3, 5, 10, 15, and 25 days the analysis of the water quality was done on a regular basis. The contaminants such as TSS, TP and ammonia had the maximum removal efficiency according to the experimental FWT results utilizing C. indica, that is about 96%, 98% and 95% respectively. In the study by Ch. Zizanioides, the maximum removal efficiency for turbidity (90%), TDS (48%), TN (85%), salt (53%), potassium (74%), TP (92%), EC (27%), COD (93%), BOD (95%), and E. coli (47%), were demonstrated [22].

Zahra and Maryam had reviewed the phytoremediation technology for wastewater treatment. Due to their extremely considerable capacity for digesting and degrading pollutants (such as nitrates, phosphates, and heavy metals), it has been determined that the use of aquatic plants in wastewater phytoremediation is particularly effective. Additionally, they came to the conclusion that the implementation of this innovation on a broad scale is still limited. As a result, they suggested to have accurate data should be made available to the public to increase its effectiveness as a workable solution on a global scale. From their perspective, the phytoremediation process is a relatively new technology and still in the early stages of research and optimization. It is seen as efficient, new, and environmentally beneficial technology and has been assessed as a distinct low-cost tech and green alternative to the available methods [23].

3. Materials and methodology

3.1 Plant Selection

Spider lily (Hymenocallis littoralis) and Heliconia (Heliconia psittacorum) are selected for sewage treatment because they have been found to be effective at removing pollutants from wastewater. These plants are known as "constructed wetland" plants, which mean they can thrive in environments with high levels of nutrients and organic matter.

 https://doi.org/10.1051/e3sconf/202345503023

Fig. 1. Spider lily plants

Fig. 2. Heliconia plants

3.2 Collection of Sewage

The first step in collecting sewage for treatment by spider lily and heliconia is to identify the source of the sewage. The source of sewage has been identified and a representative sample of the sewage has been collected from the sewerage system leading to treatment plant in the campus for testing and treatment by phytoremediation technique. This is done using a clean and sterile container.

3.3 Planting

Initially soil up to 15 cm thick filled and then plants of two different types of plants spider lily and heliconia were planted in each tank and poured water up to soil became wet and left for 3 days to acclimatize the plants to show initial growth. The Space between the plants was evenly maintained with 30cm distance from each plant as shown in the Figure 3. Then the tank was filled with sewage water until it reaches a depth of 15cm above the soil.

3.4 Pouring of sewage

After 3 days of planting of trees, the tanks were filled with the sewage upto 15cm height above the soil for experimental study, performance of plants in removal of pollution load. The plants were regularly monitored and the water quality analyzed for various parameters such as temperature, pH, Turbidity, Total Dissolved Solids, Chlorides, BOD, Alkalinity and Acidity. At every three days interval samples were collected for analysis.

https://doi.org/10.1051/e3sconf/202345503023

Fig. 3. Heliconia plants with sewage water

Fig. 4. Tanks with heliconia and spider lily plants with sewage

3.5 Testing of Sewage

The sample of sewage collected at every 3 days once and tested to determine its characteristics, such as the pH, temperature, Turbidity, TDS, BOD, Chlorides, Acidity and alkalinity.

3.6 Monitoring plant growth

The growth of the plants monitored regularly. This includes measuring the height and spread of the plants, as well as checking for any signs of disease or pest infestations. Any abnormal growth or discoloration be noted and addressed as soon as possible.

3.7 Nutrient supply

The plants require nutrients for growth, which are provided by the sewage water. The nutrient levels in the sewage water monitored regularly, and adjustments made as necessary to ensure that the plants have access to the required nutrients. Quality of the water in the treatment tank monitored regularly to ensure that the plants are growing in a healthy environment. This includes monitoring the pH, temperature, dissolved oxygen, and nutrient levels in the water.

 https://doi.org/10.1051/e3sconf/202345503023

Fig. 5. Condition of plants heliconia and spider lily on 9th day growth

4. Results and discussion

4.1 Results

The samples of sewage were tested to determine its characteristics, such as the pH, temperature, Turbidity, TDS, BOD, Chlorides, Acidity and alkalinity. Tests were performed with 3 days interval within the span of 15 days.

Table 1. Overview of physico-chemical parameters waste water treated with Spider Lily

Parameters	Day-1	Day-3	Day-6	Day-9	Day-12	Day-15
pH	7.72	7.9	7.76	7.7	7.6	7.6
TDS(mg/l)	253.1	237.5	230	228	227	225
Turbidity(NTU)	15.2	13.9	7.2	0.	0.1	0.1
Alkalinity(mg/l)	290	160	145	105	100	95
Acidity(mg/l)	Nil	Nil	Nil	Nil	Nil	Nil
Chlorides(mg/l)	269.9	244.9	230	227	220	219
BOD(mg/l)	49.5	25.2	18	11.7	7.2	6.3

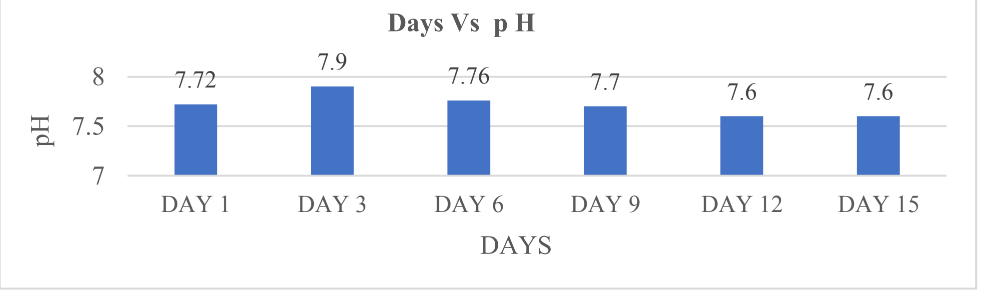

Fig. 6. Graph showing the pH values at 3 days interval of time of treatment by Spider Lilly plants

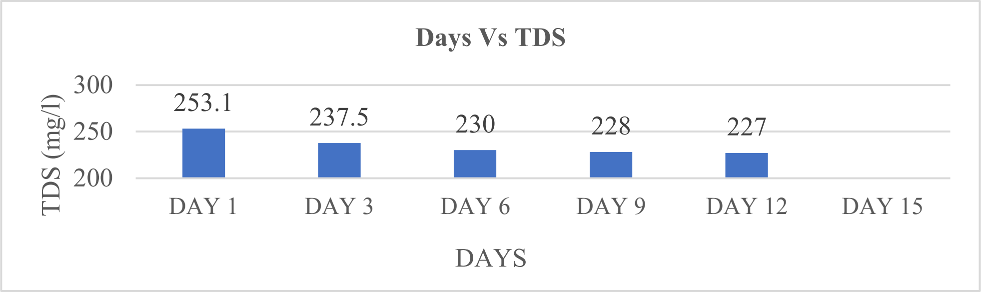

Fig. 7. Graph showing the TDS values at 3 days interval of time of treatment by Spider Lilly plants

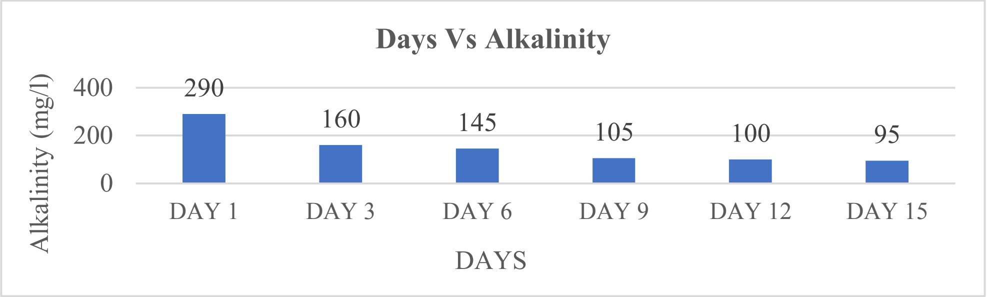

Fig. 8. Graph showing the Alkalinity values at 3 days interval of time of treatment by Spider Lilly plants

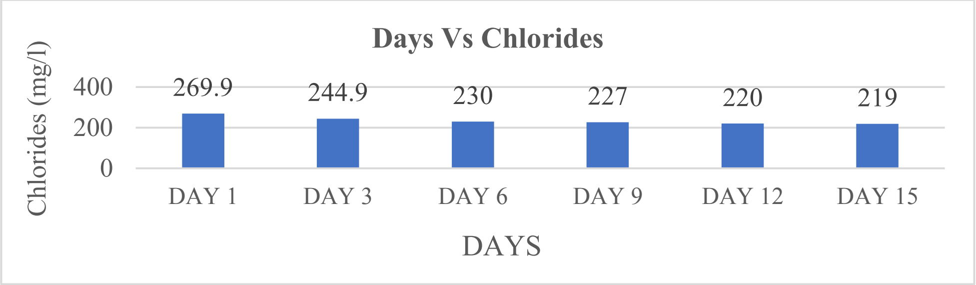

Fig. 9. Graph showing the chlorides values at 3 days interval of time of treatment by Spider Lilly plants

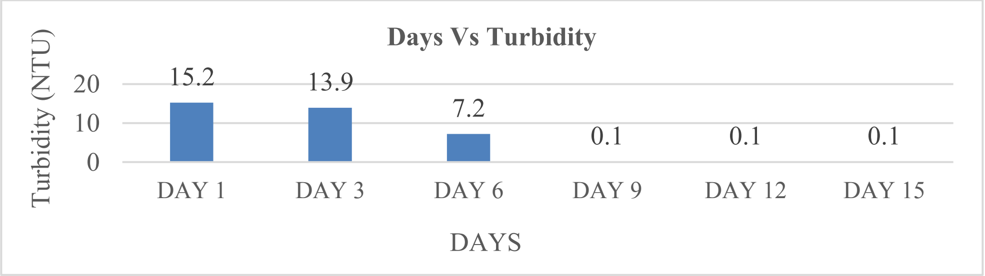

Fig. 10. Graph showing the Turbidity values at 3 days interval of time of treatment by Spider Lilly plants

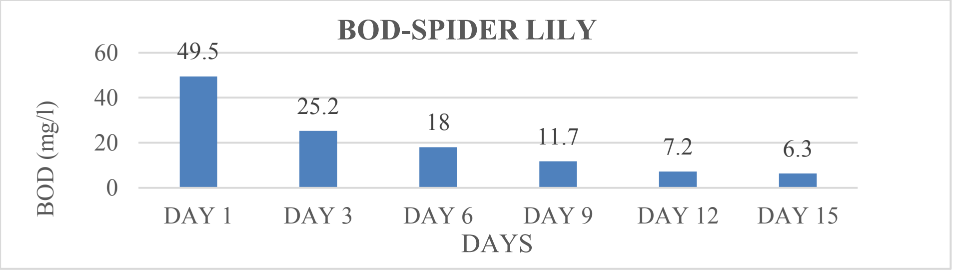

Fig. 11. Graph showing the BOD values at 3 days interval of time of treatment by Spider Lilly plants

Table 2. Over view of physico-chemical parameters wastewater treated with Heliconia Plants.

Parameters	Day-1	Day-3	Day-6	Day-9	Day-12	Day-15
pH	7.72	8.6	8.4	7.7	7.6	7.6
TDS(mg/l)	253.1	201	182.1	205	192	185
Turbidity(NTU)	15.2	12.7	18.6	3.2	2.3	0.7
Alkalinity(mg/l)	290	100	95	50	40	40
Acidity(mg/l)	Nil	Nil	Nil	Nil	Nil	Nil
Chlorides(mg/l)	269.9	279.9	269	249	264.9	246.9
BOD(mg/l)	56.8	38.5	31.5	27.5	26.5	21.5

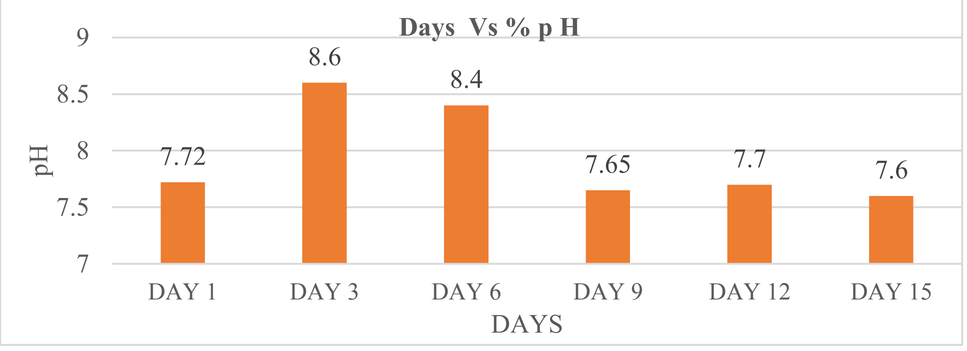

Fig. 12. Graph showing the pH values at 3 days interval of time of treatment by Heliconia plants

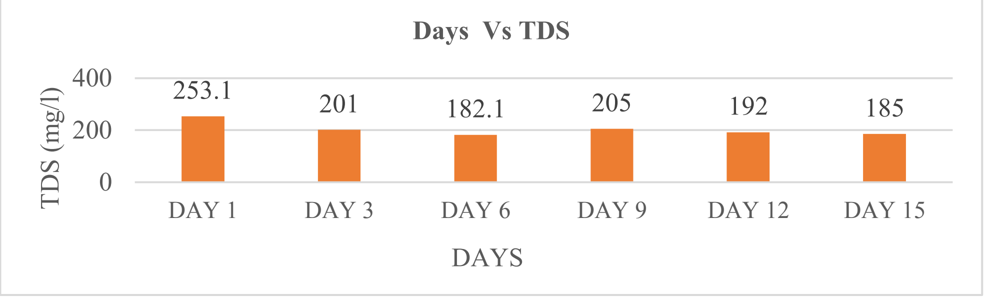

Fig. 13. Graph showing the TDS values at 3 days interval of time of treatment by Heliconia plants

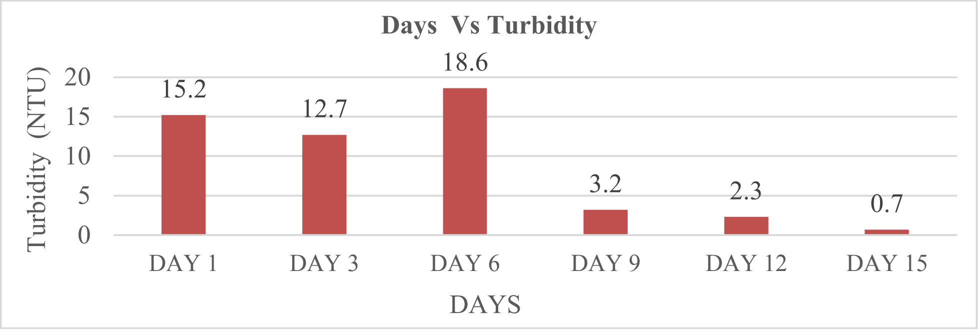

Fig. 14. Graph showing the Turbidity values at 3 days interval of time of treatment by Heliconia plants

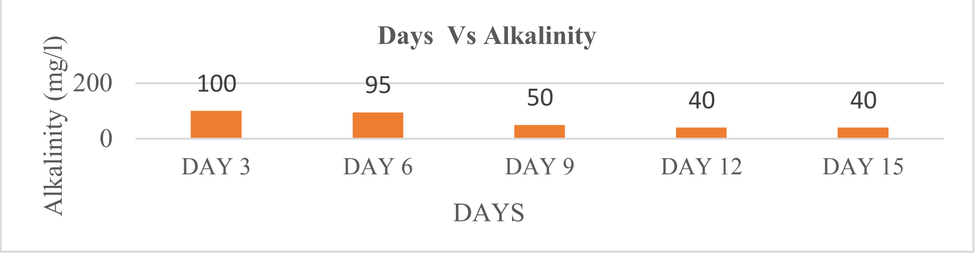

Fig. 15. Graph showing the Alkalinity values at 3 days interval of time of treatment by Heliconia plants

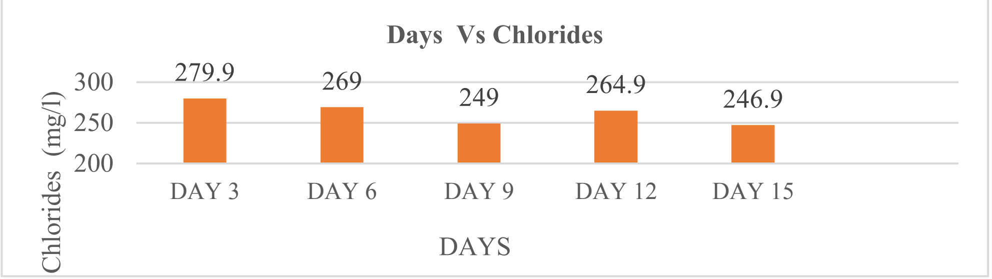

Fig. 16. Graph showing the Chlorides values at 3 days interval of time of treatment by Heliconia plants

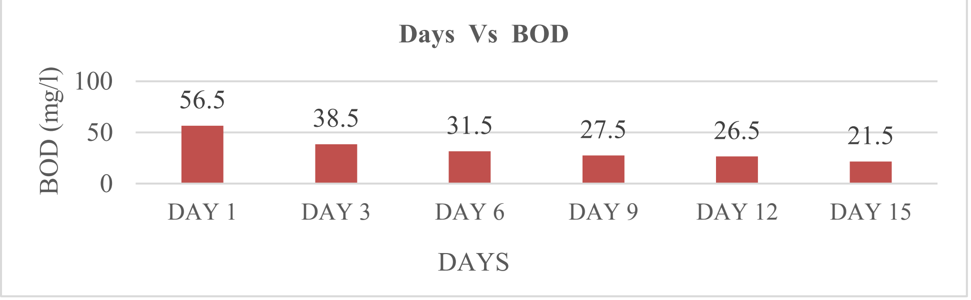

Fig. 17. Graph showing the BOD values at 3 days interval of time of treatment by Heliconia plants

4.2 Discussions

The pH of the treated water by Heliconia plants and Spider Lilly was found to be 7.6,

https://doi.org/10.1051/e3sconf/202345503023

indicating near to the neutral pH. The TDS value for the water treated by Heliconia plants was 185 mg/l, while for Spider Lilly plants, it was 225 mg/l. The turbidity values were 0.7 NTU and 0.1 NTU for Heliconia and Spider lily plants respectively. The alkalinity of the treated water by Heliconia plants was 40 mg/l, and for Spider lily plants, it was 95 mg/l. Chloride concentrations were 246.9 mg/l and 219 mg/l for Heliconia and Spider lily plants respectively. Lastly, BOD values were 21.5 mg/l and 6.3 mg/l for Heliconia and Spider lily plants respectively.

The results obtained indicate that both heliconia and spider lily plants are effective in treating sewage wastewater, as demonstrated by the significant reduction in TDS, turbidity, and BOD values. The pH of the treated water was found to be neutral, indicating that the plants did not significantly affect the pH of the wastewater. The alkalinity values were also significantly reduced by the plants, indicating that they can effectively remove alkaline compounds from the wastewater. The chlorides concentrations in the treated water were higher than the maximum permissible limits set by the World Health Organization (WHO). However, the values obtained are still lower than the initial concentrations of chlorides in the raw sewage wastewater. Therefore, it can be inferred that the plants were able to remove some of the chlorides from the wastewater.

5. Conclusions

Phytoremediation is one of the new cleanup concepts that recently recognized although it was happening naturally. It involves the use of plants to clean contaminated environments. Despite various present technologies available, it seems that foliage plants and trees may be the best means of improving water quality. Because the plants have tremendous capacity of absorbing nutrients and removes heavy metals, this can benefit for wastewater treatment to bring down the pollution load.

The present study investigated the effectiveness of heliconia and spider lily plants in treating sewage wastewater. The study results indicate that both heliconia and spider lily plants are effective in treating sewage wastewater, as demonstrated by the significant reduction in TDS, turbidity, and BOD values. The TDS values for the water treated by heliconia and spider lily were 185 ppm and 225 ppm respectively, indicating a significant reduction in dissolved solids. The turbidity values were also significantly reduced by the plants, with 0.7 NTU and 0.1 NTU for heliconia and spider lily plants respectively. The reduction in TDS and turbidity values indicates the plants' capability to remove organic and inorganic pollutants from the wastewater.

Since the treated sewage was found to be near to the neutral pH in all studies, it indicates that the plants did not significantly affect the pH of the wastewater. The alkalinity values were significantly reduced by the plants, indicating that they can effectively remove alkaline compounds from the wastewater. The reduction in alkalinity values is an essential aspect of wastewater treatment as high alkalinity values can lead to the formation of scale in water distribution systems.

The chlorides concentrations in the treated wastewater were higher than the maximum permissible limits set by the World Health Organization. The removal efficiency achieved is 8.52 % and 18.85 % respectively for heliconia and spider lily plants. Therefore, it can be inferred that the plants were able to remove some of the chlorides from the wastewater. The BOD content was significantly reduced by the plants. The efficiency achieved is 79.6 % and 87.2% respectively for heliconia and spider lily plants. The high reduction in BOD values indicates the plants' capability to remove organic pollutants from the wastewater.

Hence, based on these results and observations it can be concluded that heliconia and spider lily plants can be viable and sustainable options for treating sewage wastewater.

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