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Evaluating The Potential of Hibiscus Rosa-Sinensis in Floating Wetland for The Remediation of Water Bodies Polluted with Domestic Sewage

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Abstract
The inadequate infrastructure for wastewater treatment in many regions has led to the contamination of surface water bodies and groundwater degradation. To address this issue, floating wetland treatment systems have emerged as a viable alternative for effective wastewater remediation. This study focuses exclusively on utilizing Hibiscus rosa-sinensis, a tropical ornamental plant, within the context of floating wetland treatment techniques for the remediation of domestic wastewater. The primary objective is to assess the nutrient and pollutant removal efficiency of Hibiscus rosa-sinensis in a laboratory-scale floating wetland system. Healthy Hibiscus rosa-sinensis plants were cultivated on identical floating rafts and placed in plastic tanks filled with domestic sewage for experimental investigation. Water quality analyses were conducted regularly, spanning 0, 3, 5, 10, 15, 20, and 25 days HRT. The results of this experimental investigation revealed that Hibiscus rosa-sinensis, when used in floating wetland treatment, exhibited significant removal efficiencies for various parameters, including turbidity, total suspended solids (TSS), total phosphorus (TP), ammonia, and dissolved oxygen (DO).These findings highlight the potential of Hibiscus rosa-sinensis plants as a practical component of floating wetland systems for removing nutrients and pollutants from domestic wastewater. This research underscores the viability of Hibiscus rosa-sinensis as a sustainable and environmentally friendly solution to address water pollution challenges, particularly in the context of floating wetland treatment.

Keywords: *Magnetic Levitation, Maglev Technology, Material Handling, Contactless Transportation, Electromagnetic Repulsion and Efficient Logistics*

1. Introduction

In pursuing sustainable solutions for wastewater treatment, floating wetland systems have emerged as a promising innovation [1], [2]. These systems, characterized by using buoyant platforms hosting vegetation, offer a nature-inspired approach to mitigate the harmful effects of wastewater pollution[3]– [6]. Among the various plant species suitable for this purpose, Hibiscus rosa-sinensis has gained attention for its remarkable phytoremediation capabilities[7]. This research aims to evaluate the efficacy of Hibiscus rosa-sinensis in a unique floating wetland system for domestic wastewater treatment. This study delves into applying Hibiscus rosa-sinensis in floating wetland systems, supported by a polystyrene sheet with a thickness of 5 cm. The system utilizes plastic net pots and repurposed gunny bags tailored to accommodate 8 cm diameter plastic net pots, facilitating the growth of plants in the soil medium[8]– [11]. This research not only explores the potential of Hibiscus rosa-sinensis as an effective phytoremediation agent but also investigates the efficiency of the entire floating wetland setup in treating domestic wastewater. The controlled system, which follows a similar schedule of water sample collection, allows for a comparative analysis of the treatment performance. The findings of this study offer valuable insights into the viability of floating wetland systems, guided by the remarkable qualities of Hibiscus rosa-sinensis, as an

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eco-friendly and sustainable approach to address the pressing challenges of wastewater treatment [12]–[14].

2. Material And Methods

2.1 Experimental Setup

This experimental segment establishes the unique setup used in this study, emphasizing the innovative use of materials and the systematic approach to data collection and analysis. The following features will present the findings and their implications for domestic wastewater treatment.This study employed a specially designed floating wetland system to treat domestic wastewater. The core component of this system was a 10 cm thick polystyrene sheet that served as the buoyant platform; polystyrene offers an efficient means of ensuring buoyancy [11], [15]. Healthy Hibiscus plants were vegetated on the polystyrene raft using 8 cm diameter net pots, enabling the secure placement of Hibiscus rosa-sinensis plants and the establishment of roots[15]– [17]. An innovative aspect of this system was using repurposed gunny bags tailored to fit the plastic net pots, thereby supporting the soil growth medium used in this study to facilitate plant growth [18], [19].The experimental arrangements were done on a laboratory scale and consisted of a high-density polyethylene (HDPE) tank with a 56 cm diameter and 30 cm height[20]– [22]. An essential element of this setup is the inclusion of a tap positioned 5 cm above the tank's bottom, facilitating the convenient collection of water samples at various hydraulic retention times and for solid particle settlement [23], [24].

2.2 Experimental Groups

Two distinct experimental groups were employed to evaluate the effectiveness of the Hibiscus rosa-sinensis floating wetland system. The first group, known as the "Experimental Group," featured the Hibiscus rosa-sinensis floating wetland system, which included the plants vegetated on the raft [17]. In contrast, the second group, calledthe "Control Group," consisted of a setup without any plants or a raft. Both experimental configurations were filled with domestic wastewater, forming the basis for comparative analysis to assess the performance and efficiency of the floating wetland system in treating wastewater. This experimental design systematically evaluated the Hibiscus rosa-sinensis floating wetland's impact on pollutant and nutrient removal [25], [26].

Figure 1 Floating Wetland Treatment System with Hibiscus Rosa-Sinensis Plants

2.3 Raw Municipal Wastewater

The experimental phase of this study was carried out during the timeframe spanning from February to April 2021. The source of the raw domestic sewage was the sewage treatment plant located in

Arakkonam, Tamilnadu, India. It was during the installation of the floating wetland system that this raw sewage was collected. Within the controlled laboratory environment, a comprehensive analysis was conducted to determine the initial concentration and assess the physico-chemical parameters of the raw sewage. The experimental investigation, conducted between April and June 2021 in Arakkonam, Tamil Nadu, India, occurred during a transitional period from spring to early summer. This period is characterized by increasing temperatures, with average daily highs ranging from approximately 27°C to 38°C. Understanding the prevailing environmental conditions, particularly temperature variations, is crucial when assessing the performance of biological systems like the floating wetland treatment [27], [28].

2.4 Water Quality Analysis, And Statistical Analysis

The sample collection process from the FWT system involved drawing a 500 ml water sample from the tap provided at the bottom of the tank, which allowed for collecting water with free-settled particles. Water samples from both the experimental and control groups underwent a thorough water quality analysis, covering physical parameters (turbidity and color), chemical parameters (pH, TDS, TSS, BOD5, COD, EC, Ammonia, phosphate, sodium, potassium, total hardness, total nitrogen, total phosphorus), and biological parameters (E-Coli)[17], [22], [29]. The collected data was then analyzed to evaluate the efficiency of pollutant and nutrient removal by the Hibiscus rosa-sinensis floating wetland system and to compare its treatment performance with the control group, providing a comprehensive assessment of its suitability for domestic wastewater treatment. To enhance the reliability of the results, experiments were replicated, and data were subjected to statistical analysis. Data normality was assessed utilizing both the Kolmogorov-Smirnov and Shapiro-Wilks tests. Nonparametric Mann-Whitney U tests were employed for comparing treatments in cases where the data did not meet the parametric assumptions ($p < 0.05$)[22], [30].

3. Result And Discussion

This section offers a comprehensive analysis of the collected data and an exploration of the research implications. The goal is to provide insights into the system's efficiency in pollutant and nutrient removal and its potential for sustainable domestic wastewater treatment. Through the discussion of the results, this study contributes to the understanding of innovative solutions for environmental preservation and wastewater management.In the study, we evaluated the wastewater quality parameters at different time intervals [31](0, 3, 5, 10, 15, 20, 25, and 30 days) for both the control (no plants) and the Floating Wetland Treatment (FWT) with Hibiscus rosa-sinensis plants[17], [32]. The domestic wastewater characteristics and their lowest and highest removal rates are furnished in Table 1. Escherichia coli are a crucial indicator of water contamination. Over the study period, the E. coli counts in the control and FWT-Hibiscus groups reduced, reflecting the system's ability to reduce bacterial contamination. The floating wetland system with Hibiscus rosa-sinensis plants demonstrated consistent performance, with E. coli levels gradually decreasing, which is promising for wastewater treatment efficiency[33].The initial E. coli concentration at 0 days was 2110 MPN/100mL for the control and FWT-Hibiscus. Over 30 days, the FWT-Hibiscus achieved a maximum removal efficiency of 28.01%, significantly reducing E. coli to 1519 MPN/100mL, demonstrating its efficacy in E. coli removal from domestic wastewater[17].The Mann-Whitney U test revealed a significant difference in E. coli removal between the two group's control and FWT-HIB, with a mean rank of 6.19 and a sum rank of 49.50. This revealed that FWT-HIB treatment has a statistically significant impact on E. coli compared to the control treatment with a p-value of 0.050.

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Table 1 Floating Wetland Treated Domestic Wastewater Parameters with Min and Max Removal Efficiencies

Floating wetland system		E-coli	BOD	COD	EC	DO	NH3	PO4	K
Control	Min Conc.	2013	70	233	2194	3.40	22.5	8.5	15.40
	Max Conc.	2110	86	262	2230	4.30	27.5	10.2	18
	Mean	2057.25	78.12	251.37	2214.1	3.76	24.87	9.35	16.76
	Std. Dev.	37.38	5.76	10.36	12.21	.29	1.71	.60	.99
	Min Eff. %	0	-1	-1	0	7	-6	-2	0
	Max Eff. %	5	18	10	2	21	13	16	14
FWT Hibiscus	Min Conc.	1519	33	95	2120	4.0	13.7	4.2	8.20
	Max Conc.	2110	86	262	2230	4.30	27.5	10.2	18
	Mean	1817.87	58.16	184.16	2176.1	4.48	20.31	7.30	13.85
	Std. Dev.	223.25	18.72	60.25	38.23	.35	4.28	2.04	3.56
	Min Eff. %	1	8	2	1	-16	5	3	0
	Max Eff. %	28	61	63	5	7	47	58	54
Floating wetland system		**TH**	**TN**	**TP**	**pH**	**TDS**		**TSS**	**Turbidit**
Control	Min Conc.	419	15.6	4.2	7.6	1434		76	30
	Max Conc.	440	18.5	5.7	8.5	1526		88	38
	Mean	429.87	17.11	4.91	8.07	1488.5		82.43	33.92
	Std. Dev.	7.47	1.03	.442	.305	33.25		4.11	2.79
	Min Eff. %	0	-3	-14	-4	0		-1	-3
	Max Eff. %	5	13	16	7	6		13	19
FWT Hibiscus	Min Conc.	352	9.3	2.1	7.35	1133		27	14
	Max Conc.	440	18.5	5.7	8.34	1526		88	38
	Mean	395.87	13.47	3.57	7.86	1348.8		60.25	25.83
	Std. Dev.	33.08	2.97	1.11	.370	144.35		22.44	8.18
	Min Eff. %	2	8	2	-2	1		3	5
	Max Eff. %	20	48	58	10	25		69	62

Biochemical Oxygen Demand (BOD) indicates the amount of biodegradable organic matter in water. The FWT-Hibiscus system consistently outperformed the control group in reducing BOD levels[17]. As the hydraulic retention time increased, the reduction in BOD levels became more apparent, demonstrating the system's efficiency in organic matter removal.At the outset, BOD concentrations were 85 mg/L initially. The FWT-Hibiscus showed maximum removal efficiency of 61.18% at 30 days, reducing BOD levels to 33 mg/L[33], [34]. This result highlights the system's ability to enhance the removal of biodegradable organic matter.Mann-Whitney U test was employed to compare the ranks of a control group and an FWT-HIB group. The analysis yielded a mean rank of 11.06 for the control group and a sum of ranks of 88.50, while the FWT-HIB group had a mean rank of 5.94 and a sum of ranks of 47.50. These results suggest that FWT-HIB significantly differed from the control group forBiochemical Oxygen Demand (BOD) with P .028 < P0.05[31]. Chemical Oxygen Demand (COD) measures the oxygen required to oxidize organic and inorganic substances in water[35]. The FWT-Hibiscus system consistently significantly reduced COD levels compared to the control group, indicating its effectiveness in removing organic and inorganic pollutants from the wastewater[17].Initial COD concentrations were 260 mg/L, and FWT-Hibiscus achieved a remarkable maximum removal efficiency of 63.46%, reducing COD to 95 mg/L at 30 days HRT.

This underscores the system's effectiveness in lowering organic and inorganic pollutants in wastewater[33], [34].Statistical analysis for two groups,the control, and the FWT-HIB, were compared using the Mann-Whitney U test.Following analysis, the control group's mean rank was 11.19 with a sum of ranks of 89.50, whereas the FWT-HIB group's mean rank was 5.81 with a sum of ranks of 46.50. According to these findings, the hibiscus floating wetland treatment (FWT-HIB) was significantly different from the control group's Chemical oxygen demand (BOD) with a p-value of .021 < P 0.05[31]. Electrical Conductivity (EC) is associated with the concentration of dissolved ions in water. The FWT-Hibiscus system demonstrated stable EC levels similar to the control group, indicating that the system did not significantly impact the ion concentration in the water. This suggests that the system primarily affects organic and bacterial contaminants[17], [32].Electrical Conductivity initial levels were 2230 µS/cm for the control and FWT-Hibiscus groups. The FWT-Hibiscus maintained stable EC levels, with a maximum removal efficiency of 4.93% at 30 days, indicating that the system primarily targeted organic and bacterial contaminants while preserving ion concentrations[33].The FWT-HIB and the control groups' statistical analysis were compared using the Mann-Whitney U test. After analysis, the FWT-HIB group had a mean rank of 6.06with a sum of rankings of 48.50, while the control group had a mean rank of 10.94 with a sum of ranks of 87.50. These results showed that, with a p-value of.038< P 0.05, the chemical oxygen demand (BOD) of the floating wetland treatment with Hibiscus Rosa sinensis(FWT-HIB) was statistically significant from the control[31], [36]. Dissolved Oxygen (DO) is essential for aquatic life and indicates the water's oxygen content. The FWT-Hibiscus system exhibited a decrease in DO levels compared to the control group. This could be due to increased microbial activity in the wetland, which consumed oxygen[32], [37]. However, the levels remained within acceptable limits, indicating that the system maintained a suitable oxygen level for aquatic organisms.Initial DO concentrations were 4.3 mg/L for the control and FWT-Hibiscus groups. Despite a reduction in DO levels for the FWT-Hibiscus, it remained within acceptable limits, with a minimum removal efficiency of -16.28% at 30 days, ensuring a suitable oxygen level for aquatic organisms[33], [34].Using the Mann-Whitney U test, statistical analysis was performed for the control and the FWT-HIB groups. After analysis, a sum of ranks of 39.50 and 4.94 of mean rank for the control group, while 12.06 was the mean rank and sum of Rank of 96.50 for the FWT-HIB group. These results showed a significant difference (p-value of.001< P 0.05) in the Dissolved (DO) between the hibiscus floating wetland treatment (FWT-HIB) and the control group[31]. Ammonia levels decreased consistently in both the control and FWT-Hibiscus groups. The floating wetland system demonstrated a slightly higher reduction rate, suggesting its potential to enhance ammonia removal from the wastewater[17], [20]. This is a positive outcome, as high ammonia concentrations can harm aquatic ecosystems.Initial ammonia concentrations were 26 mg/L. Over 30 days, the FWT-Hibiscus achieved a maximum removal efficiency of 47.31%, reducing ammonia levels to 13.7 mg/L. This outcome underscores the system's potential to enhance ammonia removal[20].The Mann-Whitney U test was used to compare the statistical analysis for the control and the FWT-HIB groups. After analysis, the mean rank of the FWT-HIB group was 5.88, with a sum of rankings of 47.00, while the mean rank of the control group was 11.13, with a sum of ranks of 89.00. These results showed that the chemical oxygen demand (BOD) of the hibiscus floating wetland treatment (FWT-HIB) was significantly different from that of the control group (p-value =.028< P 0.05). Phosphate concentrations decreased in both groups, with the FWT-Hibiscus system consistently achieving a higher reduction rate. This indicates the system's ability to effectively remove phosphates, which can contribute to eutrophication and water quality degradation.Initial phosphate concentrations were ten mg/L for the control and FWT-Hibiscus. The FWT-Hibiscus consistently outperformed the control, with a

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Issue: 04 April 2024
Page No: 598-608

maximum removal efficiency of 58% at 30 days, reducing phosphate levels to 2.1 mg/L and preventing eutrophication[33], [34].The FWT-HIB and the control groups' statistical analyses were compared using the Mann-Whitney U test. The analysis showed that the FWT-HIB group had a mean rank of 6.06 with a sum of rankings of 48.50, while the control group had a mean rank of 10.94 with a sum of rank 87.50. These results revealed that, with a p-value of.038< P 0.05, the phosphate (PO4) of the floating wetland treatment with Hibiscus (FWT-HIB) was statistically significant from that of the control group[31]. Potassium levels in the FWT-Hibiscus system remained relatively stable, with a maximum removal efficiency of 54.44% at 30 days. This suggests that the system effectively maintained potassium ion concentrations within acceptable limits. Stable potassium levels are essential for various water uses, and the system's ability to achieve this while treating wastewater is a positive outcome, indicating its capacity to maintain ion balance[19]. Potassium levels remained relatively stable, with initial concentrations of 18 mg/L for both the control and FWT-Hibiscus. The system achieved a maximum removal efficiency of 54.44% at 30 days, reducing potassium levels to 8.2 mg/L, indicating the system's consistent performance in maintaining ion concentrations[37].The statistical analyses of the control groups and the FWT-HIB were compared using the Mann-Whitney U test. The FWT-HIB group had a mean rank of 6063 with a sum of rankings of 53.00, according to the analysis, while the control group had a mean rank of 10.38 with a sum of ranks of 83.00. These findings determined that the potassium (K) of the floating wetland treatment with hibiscus (FWT-HIB) was statistically not significant from the control group at a p-value of.130 > P 0.05[31]. Sodium concentrations in the FWT-Hibiscus system exhibited reductions over the study period, with a maximum removal efficiency of 38.46% at 30 days. The system's potential to reduce sodium levels is crucial for water quality improvement, as excessive sodium can harm aquatic ecosystems and human consumption. The system contributes to better water quality and ecosystem health by achieving these reductions[37]. Initial sodium concentrations were 91 mg/L forthe control and FWT-Hibiscus. FWT-Hibiscus achieved a maximum removal efficiency of 38.46%, reducing sodium levels to 56 mg/Lover 30 days, showcasing its potential in sodium removal[19].The Mann-Whitney U test was used to evaluate the statistical analyses between the FWT-HIB and the control groups. The analysis resultsrevealed that the control group had a mean rank of 9.44 with a sum of rank 75.50, but the FWT-HIB group had a mean rank of 7.56 with a sum of rank of 60.50. The Sodium (Na) of the floating wetland treatment with hibiscus (FWT-HIB) was found to be statistically not significant from that of the control group, with a p-value of.130 > P 0.05[31]. The study observed consistent reductions in total hardness levels over the test period in the FWT-Hibiscus system. The maximum removal efficiency of 20% at 30 days and reducing total hardness to 352 mg/L, emphasizing its effectiveness in improving water quality. It indicates the system's effectiveness in mitigating hardness and improving water quality. Reduced hardness is beneficial for various domestic and industrial water uses, as it minimizes scale formation and enhances water's suitability for consumption and industrial processes.The statistical analyses of the control groups and the FWT-HIB were compared using the Mann-Whitney U test. According to the analysis, the FWT-HIB group had a mean rank of 6.31 with a sum of rankings of 50.50, while the control group had a mean rank of 10.69 with a sum of ranks of 85.50. Based on these findings, it was determined that the Total Hardness (TH) of the floating wetland treatment with hibiscus (FWT-HIB) was statistically not significant from the control group at a p-value of.065> P 0.05. Total nitrogen concentrations exhibited significant reductions in the FWT-Hibiscus system, highlighting its potential for nutrient removal[17]. The system achieved a substantial removal efficiency of 48.33% at 30 days. Effective reduction in total nitrogen is vital for preventing water body eutrophication and maintaining ecological balance, emphasizing the system's positive environmental impact[35]. Initial

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Volume: 02
Issue: 04 April 2024
Page No: 598-608

total nitrogen concentrations were 18 mg/L for the control and FWT systems[20], [37]. Over a 30-day hydraulic retention period, the FWT-Hibiscus demonstrated a maximum removal efficiency of 48.33%, reducing total nitrogen to 9.3 mg/L. This highlights the system's potential to reduce nitrogen levels significantly, which is crucial for preventing water body eutrophication[19], [32], [33].The statistical analyses of the control groups and the FWT-HIB were compared using the Mann-Whitney U test. The FWT-HIB group had a mean rank of 5.56 with a sum of rank 44.50, according to the analysis, while the control group had a mean rank of 11.44 with a sum of ranks of 91.50. Based on these findings, it was determined that the Total Nitrogen (TN) of the floating wetland treatment with hibiscus (FWT-HIB) was statistically significant from the control group at a p-value of.010 < P 0.05[31], [36]. The FWT-Hibiscus system consistently demonstrated substantial reductions in total phosphorus concentrations, with a maximum removal efficiency of 58% at 30 days. These results are crucial for preventing nutrient-driven water pollution, which can lead to eutrophication[35]. By efficiently removing phosphorus, the system plays a pivotal role in safeguarding water bodies and aquatic ecosystems from excessive nutrient loading. Initial total phosphorus concentrations were 5 mg/L for the control and FWT-Hibiscus. The FWT-Hibiscus consistently outperformed the control, with a maximum removal efficiency of 58% at 30 days, reducing total phosphorus to 2.1 mg/L. This result underscores the system's effectiveness in removing phosphorus, a key contributor to water body pollution[20].The Mann-Whitney U test was used to compare the statistical analyses of the control groups with the FWT-HIB. By comparison, the control group had a mean rank of 11.31 with a sum of rank 90.50; on the other side, the FWT-HIB group had a mean rank of 5.69 with a sum of rank 45.50, according to statistical analysis. With a p-value of.015< P 0.05, these findings showed that there was a significant difference in potassium (K) between the control group and the floating wetland treatment with hibiscus (FWT-HIB)[19], [36]. The control and FWT-Hibiscus group's pH levels were generally stable, remaining within acceptable limits. The slight fluctuations in pH were within the permissible range, underscoring the system's capacity to maintain pH stability during wastewater treatment. This stability is essential for preserving water quality and the health of aquatic ecosystems[32]. Initial pH levels were 8.2,and FWT-Hibiscus achieved a maximum removal efficiency of 10.37%, raising the pH to 7.35. The system's impact on pH levels was minimal and remained within the acceptable range, ensuring water quality suitability[33].The statistical analyses of the control groups and the FWT-HIB were compared using the Mann-Whitney U test. According to the analysis, the FWT-HIB group had a mean rank of 7.25 with a sum of rank 58.00, while the control group had a mean rank of 9.75 with a sum of ranks 78.00. These findings demonstrated that the pH of the floating wetland treatment with hibiscus (FWT-HIB) was not significant from the control group at a p-value of.328> P 0.05[31], [36]. TDS (Total Dissolved Solids) concentration in the FWT-Hibiscus system consistently demonstrated removal efficiencies. The maximum removal efficiency of 25.46% at 30 days indicates the system's capacity to reduce dissolved solids, enhancing water quality. Lower TDS levels are desirable for various water uses, as they reduce the risk of scaling and improve taste and safety for consumption. Initial TDS concentrations were 1520 mg/L for both treatment systems. The FWT-Hibiscus consistently demonstrated greater removal efficiency, with a maximum of 25.46% at 30 days, lowering TDS levels to 1133 mg/L. These results indicate the system's capacity to reduce dissolved solids, contributing to improved water quality[34].The Mann-Whitney U test was used to compare the statistical analyses of two floating wetland treatment groups; the statistical results showed no significant difference between the control and FWT-HIB. According to the results, the TDS of the floating wetland treatment with hibiscus (FWT-HIB) was insignificant from the control group, with a p-value of .065> P 0.05. Themean rank for FWT-HIB as 6.25 with a sum of rank 50.00 was reported in the analysis, compared to a mean

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Volume: 02
Issue: 04 April 2024
Page No: 598-608

rank of 10.75 with a sum of ranks 86.00 for the control group[31]. The FWT-Hibiscus system consistently exhibited significant removal efficiencies for Total Suspended Solids, with a maximum of 68.97% at 30 days. The remarkable reduction in suspended solids is pivotal for improving water clarity and reducing particulate matter in the treated water. The system's efficiency in removing TSS contributes to enhanced water quality and aquatic habitat preservation. Initial TSS concentrations were 87 mg/L for the control and FWT-Hibiscus. The FWT-Hibiscus consistently showed significant removal efficiency, with a maximum of 68.97% at 30 days, reducing TSS levels to 27 mg/L[34]. These findings highlight the system's robust performance in removing suspended solids from wastewater.When the statistical analyses of the two floating wetland treatment groups were compared using the Mann-Whitney U test, the statistical findings showed that there was no significant difference between the control and FWT-HIB. The results showed that, with a p-value of.050> P 0.05, the TSS of the floating wetland treatment with hibiscus (FWT-HIB) was not significant from the control group. The analysis showed that the FWT-HIB group had a mean rank of 6.19 with a sum of rankings 49.50, while the control group had a mean rank of 10.81 with a sum of ranks 86.50[31]. The FWT-Hibiscus system exhibited remarkable removal efficiencies for turbidity, with a maximum of 62.16% at 30 days. The system's ability to significantly enhance water clarity and reduce suspended particles is crucial for water quality improvement. Reduced turbidity contributes to better light penetration, benefiting aquatic flora and fauna. Initial turbidity was 37 NTU for the control and FWT-Hibiscus[36]. The FWT-Hibiscus consistently demonstrated a remarkable removal efficiency, with a maximum of 62.16% at 30 days, reducing turbidity to 14 NTU. This underscores the system's efficiency in removing suspended particles and improving water clarity[17].When the statistical analyses of the two floating wetland treatment groups were compared using the Mann-Whitney U test, the statistical findings showed that there was a significant difference between the control and FWT-HIB. The results showed that, with a p-value of.0.038< P 0.05, the Turbidity of the floating wetland treatment with hibiscus (FWT-HIB) was not significant to the control group. The analysis showed that the FWT-HIB group had a mean rank of 6.06 with a sum of rankings 49.50, while the control group had a mean rank of 10.94 with a sum of ranks 87.50.

Conclusion

In conclusion, the Hibiscus rosa-sinensis floating wetland system has demonstrated exceptional capabilities in enhancing water quality by removing various pollutants. The study's standout results are characterized by the maximum removal efficiencies achieved by this innovative treatment approach. E. coli reduction reached a remarkable maximum efficiency of 28.01%, highlighting the system's proficiency in mitigating bacterial contamination. Equally noteworthy are the maximum removal efficiencies observed for crucial parameters such as BOD (61.18%), COD (63.46%), ammonia (47.31%), phosphate (58.00%), total hardness (20.00%), total nitrogen (48.33%), and total phosphorus (58.00%), all exceeding expectations and underscoring the system's robust performance.The system's consistent maintenance of electrical conductivity within acceptable limits and dissolved oxygen levels suitable for aquatic life is a testament to its holistic approach to water quality improvement. The impressive maximum removal efficiencies for TDS (25.46%) and TSS (68.97%) demonstrate the system's ability to significantly enhance water clarity and reduce suspended solids, further improving water quality. Moreover, the system effectively maintained stable potassium levels while substantially reducing sodium concentrations (38.46%), reinforcing its positive impact on ion balance and overall water quality.These concrete findings, underpinned by the maximum removal efficiencies achieved, firmly establish the Hibiscus rosa-sinensis floating wetland system as a potent and sustainable solution for domestic wastewater treatment. Its exceptional performance across a spectrum of water quality parameters underscores its potential to address water pollution challenges comprehensively while

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Volume: 02
Issue: 04 April 2024
Page No: 598-608

preserving the equilibrium of aquatic ecosystems.Top of Form

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