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EFFICACY OF THE VETIVER GRASS SYSTEM IN TREATING TEXTILE INDUSTRY WASTEWATER IN GAZIPUR, BANGLADESH

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Graphical abstract

Abstract

Industrial wastewater, characterized by a complex mixture of organic and inorganic pollutants including heavy metals, nutrients, suspended solids, and high levels of biochemical oxygen demand (BOD) and chemical oxygen demand (COD), poses significant environmental and public health challenges. Undoubtedly, understanding the properties of industrial wastewater is crucial for designing effective treatment systems to mitigate environmental impacts and protect public health. The objective of this research is to investigate the efficacy of the Vetiver Grass System, a nature-based phytoremediation approach, for the treatment of textile dyeing industry effluents in Bangladesh. The study of industrial wastewater treatment using the Vetiver System encompasses a wide range of aspects, including ecological, engineering, economic, and social dimensions. The Vetiver System utilizes the unique properties of the Vetiver grass (*Chrysopogon zizanioides*) to treat wastewater effectively. The experiment included two systems: one with Vetiver plants placed in industrial wastewater and another without plants as a control. Over 90 days, both systems were kept under the same conditions while key water quality parameters, such as pH, turbidity, COD, BOD, TSS, TDS, heavy metals, nitrogen, phosphorus, and temperature, were tested every 10 days. The Vetiver roots grew by about 116.7%, showing strong absorption of pollutants. Results revealed that the treated water had much lower levels of BOD, COD, TSS, TDS, and nutrients, with no trace of heavy metals, and met the permissible limits set by the Department of Environment (Bangladesh). In contrast, the untreated water remained polluted. Overall, the Vetiver Grass System proved to be an effective, natural, and affordable method for treating industrial wastewater.

Keywords: Vetiver grass system, wastewater, treated water, non-treated water, treatment

1.0 INTRODUCTION

Industrial wastewater treatment is a crucial process in maintaining environmental health and ensuring sustainable industrial practices. It involves the removal of contaminants and pollutants from wastewater generated during various industrial processes. The background of industrial wastewater treatment can be traced back to ancient civilizations, where simple methods were employed to treat water for human consumption and irrigation purposes. However, the modern concept of treating industrial wastewater began in the early 20th century with the development of advanced treatment technologies (Nathanson & Ambulkar, 2025). The treatment of industrial wastewater is a critical environmental concern due to the potentially harmful effects it can have on ecosystems and human health. Traditional wastewater treatment methods can be costly and energy-intensive. Various methods have been employed to treat wastewater, including physical, chemical, and biological processes, to preserve ecological balance and protect human health. In recent years, there has been a growing interest in using phytoremediation techniques to treat industrial wastewater (Yuliasni, et al., 2023). Phytoremediation is the use of plants to remove, degrade, or contain contaminants in soil and water (Raman & Gnansounou, 2017).

Among recent innovative approaches, the use of Vetiver grass has emerged as a promising natural solution for wastewater treatment (Valderrama, Tapia, Penailillo, & Carvajal, 2013). Vetiver grass, scientifically known as *Chrysopogon zizanioides*, is a perennial grass species widely used for soil and water conservation, phytoremediation, and wastewater treatment (SUELEE, 2016). The Vetiver System is a sustainable and eco-friendly approach to wastewater treatment, particularly in industrial settings. This system utilizes the Vetiver plant due to its unique characteristics that make it effective in phytoremediation processes (Dorafshan, 2023).

The Vetiver System has gained attention for its ability to treat various types of industrial wastewater, including those contaminated with heavy metals, organic pollutants, and other harmful substances. The effectiveness of the Vetiver System in industrial wastewater treatment lies in the plant's root system. Vetiver plants have dense and deep roots that can grow up to several meters long. These roots have a high surface area and contain specialized tissues that can absorb and accumulate contaminants from the water. As the wastewater flows through the root system, pollutants are trapped and either taken up by the plant or degraded through various biological, physical, and chemical processes (Truong & Danh, 2015). One of the primary processes is phytoextraction, wherein the plant absorbs heavy metals and translocates them into its tissues for accumulation and eventual removal (Danh, Truong, Mammucari, Tran, & Foster, 2009). Rhizofiltration plays a crucial role through the plant's extensive fibrous roots, which absorb dissolved metals and nutrients while trapping suspended solids (Chen, Shen, & Li, 2004). Additionally, rhizodegradation, also known as phytostimulation, enhances microbial activity in the rhizosphere through root exudates, thereby facilitating the biodegradation of organic contaminants.

Vetiver also contributes to phytostabilization by immobilizing pollutants in the root zone, effectively reducing their mobility and bioavailability (Chantachon, et al., 2004). While filtration and sedimentation mechanisms further support the removal of particulate matter, there is also limited evidence of phytovolatilization, where certain volatile contaminants may be taken up and released into the atmosphere through transpiration (Pilon-Smits, 2005). Collectively, these integrated phytoremediation mechanisms make Vetiver grass a highly efficient and sustainable approach for industrial wastewater treatment.

Vetiver grass (*Chrysopogon zizanioides*) was chosen for this study due to its superior tolerance to pollutants, salinity, and variable pH, making it ideal for industrial wastewater treatment under Bangladesh's climatic conditions. Compared to other phytoremediation plants such as *Phragmites australis*, *Typha latifolia*, and *Eichhornia crassipes*, vetiver demonstrates higher efficiency in removing suspended solids, heavy metals, and organic pollutants due to its extensive root system and strong pollutant adsorption capacity (Danh, Truong, Mammucari, Tran, & Foster, 2009). Unlike invasive species like water hyacinth, vetiver is non-invasive and easy to maintain. Although conventional methods such as activated sludge or membrane filtration achieve faster and more complete treatment, they are costly and energy-intensive (Ali, 2013). Vetiver offers a sustainable, low-cost, and eco-friendly alternative, but performs best as part of a hybrid system combining physical, chemical, or biological processes. Its long-term stability and adaptability make it a promising phytoremediation tool for industrial wastewater management.

2.0 METHODOLOGY

2.1 Materials and Specimen Preparation

The industrial wastewater was obtained from the inlet point of the Effluent Treatment Plant (ETP) of a renowned textile dyeing mill in Gazipur, Bangladesh. Wastewater characteristics can change over time due to variations in the mill's production or operational cycles. Hence, following a standard sampling method, the sample was collected six times over a period of six hours to get a more accurate representation of the overall wastewater quality of the industry (Kato & Kansha, 2024).

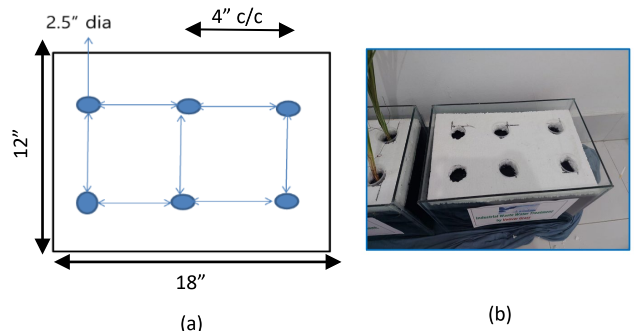

Figure 1 (a) Schematic representation of holes in the cork sheet with a diameter of 2.5 inches @ 4" c/c, and (b) the cork sheet with holes placed over the tank.

To prepare the experimental systems, two glass tanks with dimensions of 18" x 12" x 18" and two Cork Sheets with a size of 12x18 inches were collected. Both sheets were modified to include six holes, each with a diameter of 2.5 inches, spaced 4 inches apart from center to center, as shown in Figure 1 (a) & (b). The Vetiver grass was collected from the local area at Gazipur. Initially, the root size of the grass was kept to 6 inches and the shoot size was adjusted to 24 inches. At first, each hole of the cork sheet was occupied with three vetiver plants as Figure 2 (a). The treatment tank was filled with 12 Liters of industrial wastewater, and the cork sheet was placed above it.

Since this is a hydroponic system in which plants grow without soil and rely on a nutrient-rich water solution instead (Shilpa, Sharma, & Bansuli, 2024), the Vetiver grass roots were ensured to be fully submerged in the water. On the other hand, the non-treatment tank contained 12 Liters of raw industrial wastewater without any treatment and was covered with another piece of cork sheet. It was maintained under the same conditions as the treatment tank, to serve as a control tank.

2.2 Testing Procedure

The experiment had been executed for 90 days at room temperature. This test instrument has an accuracy rate of ±0.05 pH and ±2% EC/TDS of the full scale. Figure 2 (b) presents the sample water preparation for colorimetric analysis and the HACH DR 3900 Spectrophotometer as shown in Figure 2 (c) was used to determine the levels of heavy metals, nutrient levels (nitrogen and phosphorus), and color in the wastewater during the experimental period. To ensure accuracy, with the help of a HI98193 portable dissolved oxygen (DO) meter, the levels of dissolved oxygen and BOD have been tested in the wastewater. The device in Figure 2 (e) is a COD Reactor, HI839800 model from

Figure 2 (a) Vetiver plants inside the holes, and Total Dissolved Solids (TDS) test apparatus, (b) Water Sample Preparation, (c) Colorimetric Analysis using Spectrophotometer, (d) Dissolved oxygen (DO) meter, (e) COD Reactor, (f) Vetiver Plant Growth Observation, and (g) pH, Temperature, Electrical Conductivity (EC).

Hanna Instruments was utilized to measure Chemical Oxygen Demand (COD). Finally, using a filter apparatus, the Total Suspended Solids have been determined. The initial and final growth of the vetiver plant was observed as shown in Figure 2(f), the test results were collected, and eventually, the water quality parameters of both tanks were compared to reach a conclusion on the utilization of the Vetiver system to treat industrial wastewater. Every 10 days, the wastewater from both tanks was collected and tested for different water quality parameters. The wastewater's pH, Temperature, Electrical Conductivity (EC), and Total Dissolved Solids (TDS) have been determined using a multiparameter water quality tester, Hanna Instrument HI98129, as shown in Figure 2(g). The tests were conducted in the chemical lab of the mill industry in Gazipur.

2.3 Root and Shoot Growth Rate

To measure how fast the roots grew:

$$\text{Growth Rate} = \frac{Final\ Size - Initial\ Size}{Time\ (days)}$$

The change in root and shoot size indicates the potential of vetiver grass to absorb and stabilize pollutants from the wastewater.

2.4 Root-to-Shoot Ratio (RSR)

To determine biomass distribution between roots and shoots:

$$\text{RSR} = \frac{Root\ Size}{Shoot\ Size}$$

The removal capacity of heavy metals from wastewater can be obtained from the Root-to-shoot ratio. The higher the ratio, the higher the removal capacity (Poorter & Garnier, 2007).

2.5 Relative Root Growth

Relative Root Growth (%) quantifies the percentage increase in root size over a specific period which offers insights into a plant's root development dynamics.

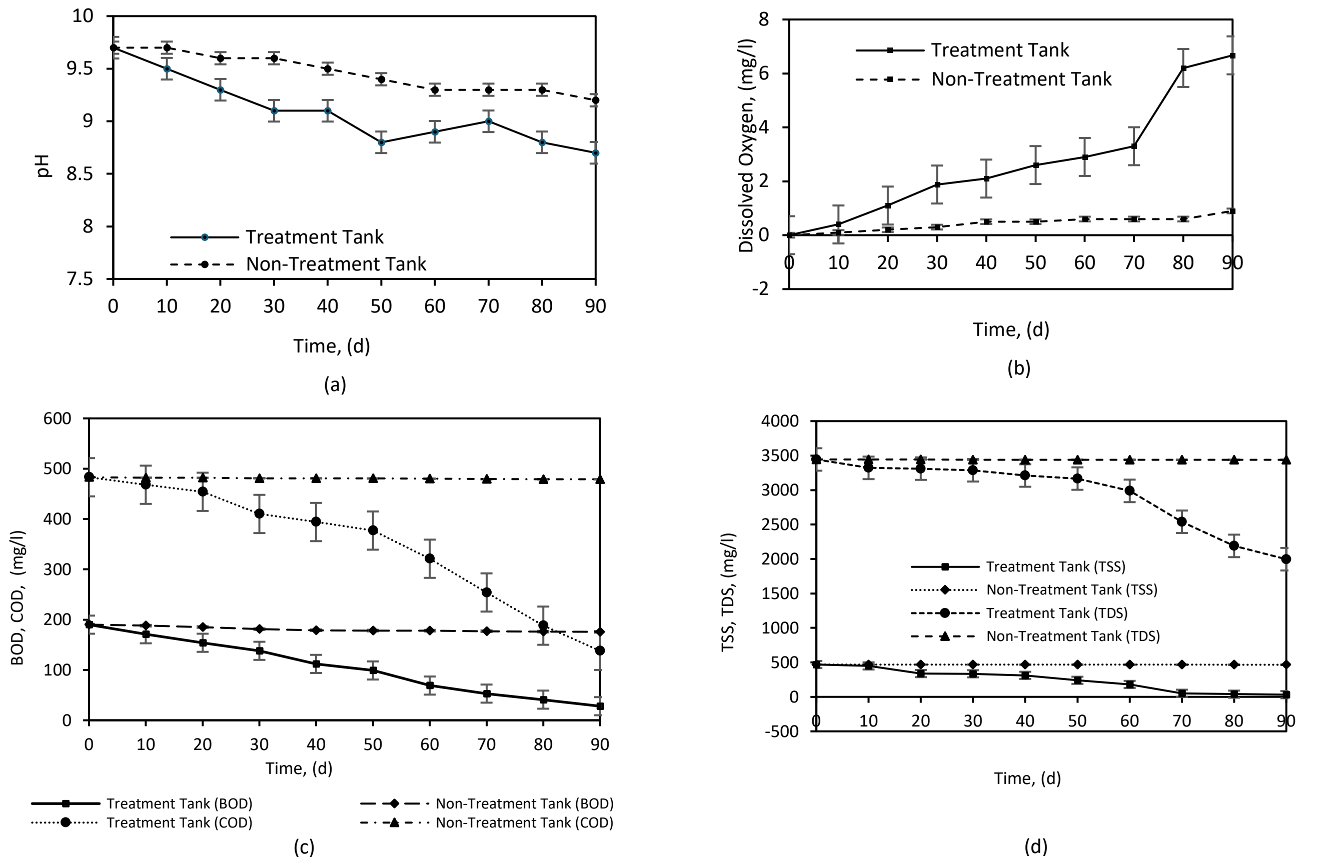

Figure 3 (a) Relationship between Time and pH of treated and raw wastewater, (b) Variation in the concentration of dissolved oxygen with time, (c) Effect of vetiver system on BOD and COD of the industrial wastewater and (d) Change in TSS and TDS level of industrial wastewater during the experiment

It's calculated using the formula:

$$\text{Relative Root Growth (\%)} = \frac{\text{Final Root Size} - \text{Initial Root Size}}{\text{Initial Root Size}} \times 100$$

This metric is valuable for assessing how environmental factors, such as nutrient availability or pollutant presence, influence root expansion. A significant increase in root size may indicate enhanced nutrient uptake or a response to specific soil conditions.

2.6 Pollutant Removal Efficiency (%)

For each parameter (pH, Turbidity, COD, BOD, TSS & TDS), the removal efficiency can be calculated as:

$$\eta = (C_i - C_f) \times 100 / C_i$$

where:

- η = Removal efficiency (%)
- C_i = Initial concentration (before treatment)
- C_f = Final concentration (after treatment)

3.0 RESULTS AND DISCUSSION

3.1 Effect of Root and Shoot Growth

The daily average root growth rate was 0.078 inches/day.

However, no growth could be attained in the Shoot size. This suggests that nutrient allocation was focused on root development rather than shoot expansion. The increase in RSR from 0.25 to 0.54 suggests that roots are expanding more than shoots, ultimately indicating higher pollutant absorption from wastewater.

3.2 Wastewater Parameter Analysis

The comparative analysis of water quality parameters between the treatment and non-treatment tanks over a 90-day monitoring period reveals the effectiveness of the applied treatment process. The pH level shown in Figure 3 (a) in the treatment tank gradually shifted from an initial alkaline range (~9.7) to a more neutral state (~8.6), suggesting a stabilization of the water chemistry likely due to microbial activity. In contrast, the pH in the non-treatment tank remained relatively constant, staying around 9.6 throughout the observation period, which reflects the absence of any significant biological or chemical processes affecting the water composition. Dissolved Oxygen (DO) levels in the treatment tank as shown in Figure 3 (b) showed a marked increase from zero to approximately 7 mg/l, which is indicative of improved aerobic conditions suitable for aquatic organisms. Conversely, the non-treatment tank exhibited negligible DO improvement, remaining under 1 mg/l.
From Figure 3 (c), a significant decline in Biochemical Oxygen Demand (BOD) was observed in the treatment tank, with values

dropping from approximately 190 mg/l to below 30 mg/l, while the non-treatment tank remained consistently high at around 185–190 mg/l. Similarly, the Chemical Oxygen Demand (COD) in the treatment tank decreased from about 490 mg/l to 140 mg/l, indicating a substantial reduction of oxidizable organic matter, whereas no notable changes occurred in the untreated system. Additionally, Total Suspended Solids (TSS) and Total Dissolved Solids (TDS) concentrations in the treatment tank were significantly reduced from initial values of 470 mg/l and 3450 mg/l to under 50 mg/l and 2000 mg/l, respectively, as presented in Figure 3 (d), whereas these parameters remained unchanged in the non-treatment tank.

The nutrient concentrations as presented in Figure 4 (a) & (b), particularly nitrogen (N) and phosphorus (P) showed a substantial decline in the treatment tank. Nitrogen levels decreased from approximately 27 mg/l to 15 mg/l, while phosphorus levels dropped from about 27 mg/l to 14 mg/l. In contrast, the non-treatment tank showed only minimal changes, with nutrient concentrations remaining consistently high. Similarly, electro-conductivity (EC) as presented in Figure 4 (c), which reflects the presence of dissolved ions, demonstrated a marked reduction in the treatment tank, from around 6100 µS/cm at the start to 5000 µS/cm by the end of the study period, while the EC values in the non-treatment tank remained nearly unchanged.

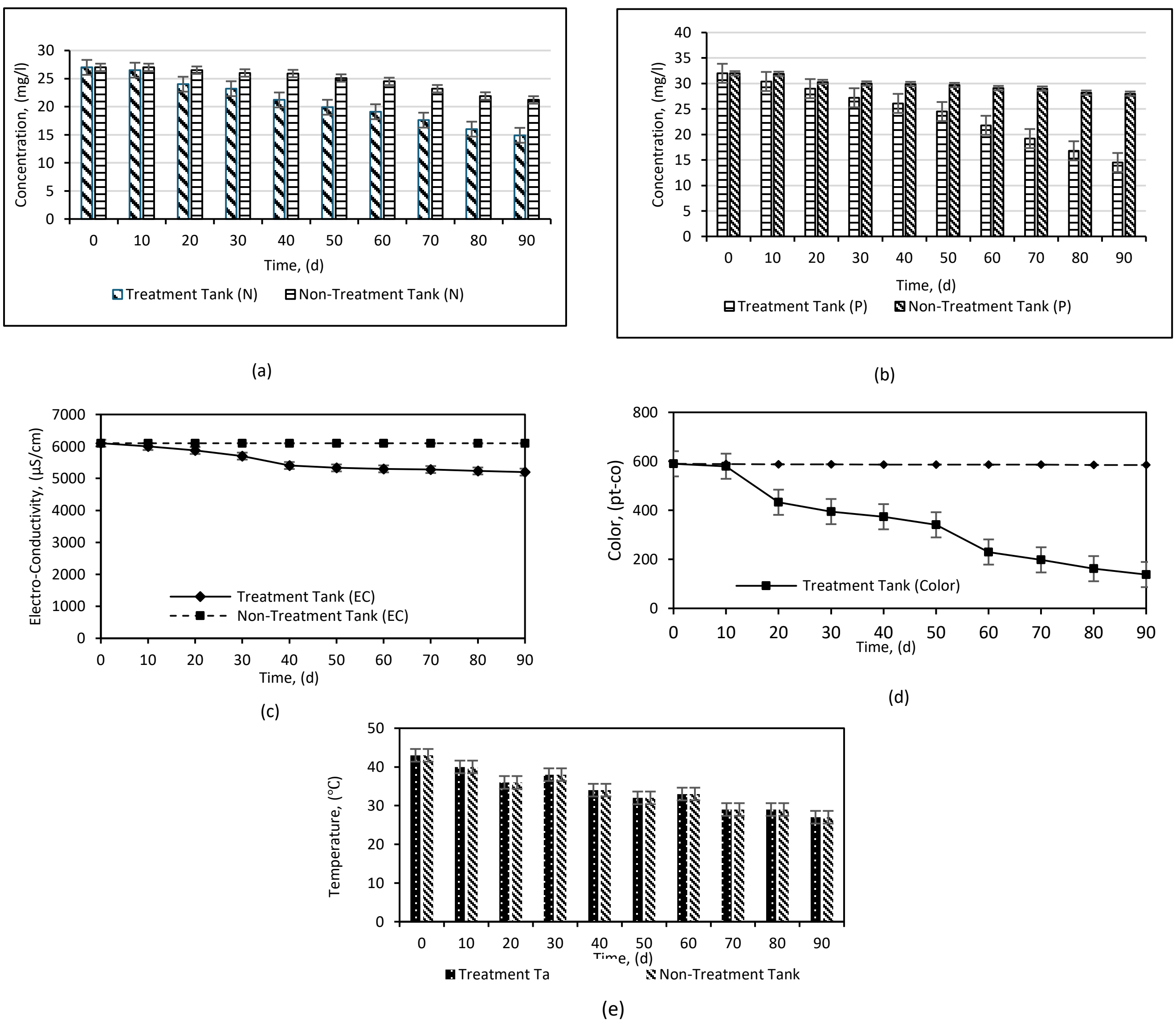

Figure 4 (a) Nitrogen concentration of wastewater with time, (b) Phosphorus concentration of wastewater with time, (c) Electro-Conductivity variations in wastewater, (d) Changes in Color in raw and treated wastewater, and (e) Variation of temperature over 90 days in treated wastewater compared to raw wastewater.

Color, another key indicator of water quality (Figure 4, d), often associated with organic pollutants or dye residues, also decreased significantly in the treatment tank, dropping from roughly 590 Pt-Co units to 140 Pt-Co units. The color levels in the non-treatment tank, however, remained stable at around 590 Pt-Co units throughout the monitoring period. These results collectively suggest that the treatment process effectively improves water quality by reducing nutrient concentrations, EC, and color. However, when compared to the legal discharge standards set by the Department of Environment (DOE), Bangladesh, it becomes evident that while the treated water meets the color standard (below 150 Pt-Co), it still exceeds the permissible limits for nitrogen (10 mg/l), phosphorus (5 mg/l), and EC (1200 µS/cm). When compared with the standard discharge limits prescribed by the Department of Environment (DOE), Bangladesh, the final treated values for BOD, COD, DO, TSS, and TDS were found to be within permissible limits. The bar chart in Figure 4 (e) illustrates the temperature trends of both treatment and non-treatment tanks over a 90-day period, measured at 10-day intervals. The temperature on day 0 was approximately 43°C in both tanks, indicating high initial values, which could be attributed to recent industrial processes or thermal characteristics of fresh effluent.

Over time, the temperature in both tanks gradually decreased. By day 10, the temperature dropped to around 40°C, followed by a further reduction to 36°C by day 20 that the treatment process applied did not significantly influence thermal conditions within the tank.

3.3 Pollutant Removal Efficiency

Table 1 evaluates the performance of vetiver grass (*Chrysopogon zizanioides*) as a phytoremediation agent in treating industrial wastewater over a 90-day period. The removal efficiency of various physicochemical parameters was calculated using the concentration values before and after treatment. The treated water sample represents the actual wastewater that passes through the vetiver system. The results highlight a remarkably high efficiency in removing TSS (93.18%) and BOD (85.26%), reflecting the strong potential of vetiver roots in capturing suspended solids and decomposing organic matter. COD removal was also significant (71.43%), indicating a reduction in oxidizable pollutants. Moderate removal was observed for nutrients such as phosphorus (54.69%) and nitrogen (44.81%), showing that vetiver can contribute to nutrient control, though not as aggressively as for solids and organic matter discharge. The current ECR 2023 guidelines represent the latest national environmental policy framework, aimed at minimizing environmental pollution and protecting public health.

Table 1 Removal Efficiency of Vetiver Grass System in Treating Industrial Wastewater (Based on Treated Water Values)

SL No	Parameter	Initial Value	Final Treated Value (After 90 Days T)	Efficiency (%)
1	Biological Oxygen Demand (BOD)	190	28	85.26%
2	Chemical Oxygen Demand (COD)	483	138	71.43%
3	Total Suspended Solids (TSS)	469	32	93.18%
4	Total Dissolved Solids (TDS)	3444	1997	42.00%
5	Temperature (°C)	43	27	37.21%
6	Nitrogen (N) (mg/l)	27	14.9	44.81%
7	Phosphorus (P) (mg/l)	32	14.5	54.69%
8	Electro Conductivity (EC)	6102	5198	14.81%
9	Color (pt-co)	590	138	76.61%

Table 2 Comparison of Treated Wastewater Parameters with Bangladesh DoE Standards (ECR 2023)

SL No	Parameter	Treated Value (After 90 Days)	DoE Standard Limit (ECR 2023)	Compliance Status
1	pH	8.7	6.0 – 9.0	✅ Compliant
2	Dissolved Oxygen (DO) (mg/L)	6.27	≥ 4.5	✅ Compliant
3	Biological Oxygen Demand (BOD)	28	≤ 30	✅ Compliant
4	Chemical Oxygen Demand (COD)	138	≤ 200	✅ Compliant
5	Total Suspended Solids (TSS)	32	≤ 150	✅ Compliant
6	Total Dissolved Solids (TDS)	1997	≤ 2100	✅ Compliant
7	Temperature (°C)	27	≤ 40	✅ Compliant
8	Nitrogen (N) (mg/L)	14.9	≤ 50	✅ Compliant
9	Phosphorus (P) (mg/L)	14.5	≤ 30	✅ Compliant
10	Electrical Conductivity (µS/cm)	5198	≤ 12000	✅ Compliant
11	Color (Pt-Co)	138	≤ 150	✅ Compliant

A slight increase was noted on day 30, reaching 38°C, after which the temperature continued its overall downward trend. By the end of the monitoring period on day 90, the temperature stabilized at approximately 27°C in both tanks. Notably, the temperature profiles of the treatment and non-treatment tanks remained nearly identical throughout the period, suggesting

The treated effluent meets all the DoE standards (as shown in Table 2), indicating full Compliance. This confirms the suitability of the vetiver system solutions are crucial, particularly in rural and industrial zones with limited access to centralized treatment facilities.

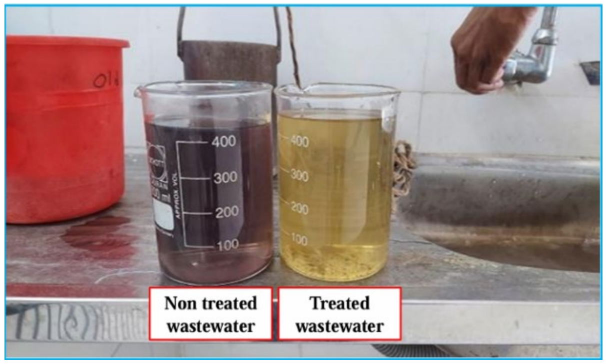

Figure 5 Treated and Non-treated Wastewater after 90 days

Furthermore, this table validates the findings of Table 1, offering a regulatory lens to verify the real-world feasibility of the observed efficiencies. It shows that the vetiver grass system not only improves water quality but also aligns with national discharge standards, thus making it a viable and sustainable treatment alternative. Figure 5 presents a visual comparison between untreated and treated industrial wastewater in two separate 400 mL breakers.

On the left side, the beaker labeled "non-treated wastewater" contains a dark brown, highly turbid liquid, indicating the presence of a high concentration of pollutants, suspended solids, and possibly organic and inorganic contaminants. The opacity and color are visual cues of poor water quality and heavy pollution load. On the right side, the beaker labeled "Treated wastewater" holds a light yellow, semi-clear liquid, demonstrating a significant reduction in color, turbidity, and visible contaminants. The improvement is attributed to the phytoremediation process using vetiver grass, as studied over a 90-day treatment period.

4.0 CONCLUSION

The 90-day laboratory experiment utilizing the Vetiver Grass System demonstrated significant potential in treating industrial wastewater, as reflected in both the visual comparison and the tabulated data. It is evident from the test results that the treated water significantly reduced the amount of dissolved and suspended pollutants when compared to the untreated system. Total Suspended Solids (TSS), Biological Oxygen Demand (BOD), and Chemical Oxygen Demand (COD) were reduced by 93.18%, 85.26%, and 71.43%, respectively. The Vetiver grass system effectively treated industrial wastewater, improving color, pH, electroconductivity, nutrient removal, and maintaining a dissolved oxygen level of 6.27 mg/L. The treated water met Bangladesh DoE (ECR 2023) standards, making it suitable for reuse or discharge. This cost-effective, low-maintenance phytoremediation approach is promising for sustainable wastewater management. However, as the study was conducted under controlled laboratory conditions, real-world factors, such as seasonal variations, larger pollution loads, inconsistent flows, and maintenance challenges, may influence its performance.

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Conflicts of Interest

The author(s) declare(s) that there is no conflict of interest regarding the publication of this paper

References

[1] Ali, H. K. 2013. Phytoremediation of heavy metals—Concepts and applications.. *Chemosphere, 91(7): 869–881*.

[2] Chantachon, S., Kruatrachue, M., Pokethitiyook, P., Upatham, S., Tantanasarit, S., & Soonthornsarathool, V. 2004. Phytoextraction and accumulation of lead from contaminated soil by vetiver grass: Laboratory and simulated field study. *Water, Air, and Soil Pollution*. doi:10.1023/B:WATE.0000022926.05464.74

[3] Chen, Y., Shen, Z., & Li, X. 2004. The use of vetiver grass (Vetiveria zizanioides) in the phytoremediation of soils contaminated with heavy metals. *Applied Geochemistry 9*(10): 1553-1565. DOI: https://doi.org/10.1016/j.apgeochem.2004.02.003

[4] Danh, L. T., Truong, P., Mammucari, R., Tran, T., & Foster, N. 2009. Vetiver grass, Vetiveria zizanioides: A choice plant for phytoremediation of heavy metals and organic wastes. *International Journal of Phytoremediation, 11*(8): 664-691 DOI: http://dx.doi.org/10.1080/15226510902787302

[5] Dorafshan. 2023. Vetiver Grass (Chrysopogon zizanoides L.): A Hyper-Accumulator Crop for Bioremediation of Unconventional Water. *Sustainability, 15*(4): 3529.

[6] Kato, S., & Kansha, Y. 2024. Comprehensive review of industrial wastewater treatment techniques. *Environmental Science and Pollution Research*. DOI: https://doi.org/10.1007/s11356-024-34584-0

[7] Nathanson, J. A., & Ambulkar, A. 2025. *Britannica*. Retrieved April 22, 2025, from wastewater treatment: https://www.britannica.com/technology/wastewater-treatment/additional-info#contributors

[8] Pilon-Smits, E. 2005. Phytoremediation. *Annual Review of Plant Biology*. 56(1): 15–39. DOI: https://doi.org/10.1146/annurev.arplant.56.032604.144214

[9] Poorter, H., & Garnier, E. 2007. Ecological Significance of Inherent Variation in Relative Growth Rate and Its Components. In F. V. Francisco Pugnaire, *Functional Plant Ecology* (2nd Edition ed., p. 774). CRC Press. doi:10.1201/9781420007626-3

[10] Raman, J. K., & Gnansounou, E. 2017. A Review on Bioremediation Potential of Vetiver Grass. In E. G. Sunita J. Varjani (Ed.), *Waste Bioremediation* 1: 13. Singapore: Springer . DOI: https://doi.org/10.1007/978-981-10-7413-4_6

[11] Shilpa, Sharma, P., & Bansuli. 2024. Hydroponics in Vegetable Crops: A Review. In *Encyclopedia of Sustainability Science and Technology Series Springer, New York, NY. doi:https://doi.org/10.1007/978-1-0716-3993-1_2*

[12] Suelee, A. 2016. *The Vetiver Network International.* Retrieved from https://vetiver.org/MAL_contaminated%20water%20.pdf Retrieved on 03 01, 2025,

[13] Truong, P., & Danh, L. T. 2015. The Vetiver System. In *Prevention And Treatment Of.* The Vetiver Network International. Retrieved from https://www.vetiver.org/TVN_Water_quality%202%20ed.pdf Retrieved on 03 01, 2025,

[14] Valderrama, A., Tapia, J., Penailillo, P., & Carvajal, D. E. 2013. Water phytoremediation of cadmium and copper using Azolla filiculoides Lam. in a hydroponic system. *Water and Environment Journal*. *27(3): 293-300.* DOI: 10.1111/wej.12015

[15] Yuliasni, R., Kurniawan, S. B., Marlena, B. M., Hidayat, M. R., Kadier, A., Ma, P. C., & Imron, M. F. 2023. Recent Progress of Phytoremediation-Based Technologies for Industrial Wastewater Treatment. *Journal of Ecological Engineering, 24*(2): 13. DOI:10.12911/22998993/156621