Research Article

Evaluation of Phytoremediation Potential of Vetiver Grass (*Chrysopogon zizanioides* (L.) Roberty) for Wastewater Treatment

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Water pollution is one of the most critical global issues. Meanwhile, the problem of water pollution of rivers especially in Iran is rising due to expansion of agricultural and industrial applications. Due to a large number of sewer catchments, there are some dam reservoirs like ZHAVE in Iranian state of Kurdistan that have not been able to collect significant amount of water since last 10 years. Removal of heavy metals as contaminants from runoffs and recycling of water is a necessity and a vital issue in the world. Various methods and standards are invented and used to isolate and remove all types of pollutants. This study focuses on the purification and removal of contaminants in water sources using the phytoremediation method by introducing Vetiver grass species in the case of floating treatment wetland (FTW). This study's preliminary purpose is to investigate a practical remedial solution and improvement methodology for the water quality of reservoirs and rivers by growing the floating Vetiver island method. The results show that following parameters such as COD by 97%, TN by 90%, phosphorus by 66%, TDS by 26%, and evapotranspiration by 40% were reduced. Therefore, we concluded that for a wastewater with varying neutrient concentrations such as in ZHAVE dam, concentration of nutrients N and P was controlled and consequently inhibition and prevention of the eutrophication of water resources in the medium and long term became possible due to reduction in the rate of evaporation from reservoirs.

1. Introduction

Floating treatment wetland (FTW) is a suitable wastewater treatment system for developing countries in the tropics, which requires access to land and high temperatures for biodegradation [1]. These wetlands can treat municipal, domestic, industrial wastewater, aquaculture wastewater, and so on [2–4]. In particular, many practical studies and various purification methods have been conducted to investigate the possibility of reusing wastewater to irrigate agricultural lands [5–9]. Plant-based water treatment methods are effective, cost-effective, and sustainable [10]. One of the crucial factors in applying the phytoremediation method is choosing the right plant [11].

The use of aquatic plants in phytoremediation is beneficial because they have an extraordinary capacity to absorb and destroy pollutants [12]. For example, removal efficiency of NO_3^--N, NH_4^+-N, and P in *Typha Angustifolia* are 51.6%, 56.5%, and 9.1%, respectively [13]. In particular, Vetiver has been studied and used by various researchers to treat different types of wastewater [13–18]. The Vetiver system (VS), as a new phytoremediation method based on Vetiver grass, was recognized for the first time in 1995 due to its "super absorbent" properties suitable for leachate and effluent produced disposal from landfills and wastewater treatment plants in Australia [19].

Vetiver is a hydrophilic plant with physiological properties such as absorbing soluble nutrients such as N and P,

reducing BOD, COD, TSS, heavy metals, and high resistance to pesticides [20]. In the research study done by Kabata, the concentration of lead in Vetiver is considered toxic to the plant if roots and leaves exceed 30 ppm [21].

According to Ash and Truong, the results show that Vetiver has the highest percentage of nitrogen and phosphorus removal than other plants. Vetiver can remove 13,688 kg/ha of nitrogen per year in hydroponic environments, which is even 6 times better than potted conditions and 12 times better than conditions planted in dry soil. It is also 6 times more efficient than the other two media in terms of nitrogen removal in hydroponic environments [22]. Plant growth depends on physical properties such as temperature, soil texture, soil moisture, and chemical properties such as pH, salinity, and heavy metals concentration. Still, this plant can grow in harsh environmental conditions and tolerate these conditions [23, 24].

Although Vetiver has a high tolerance range, it is susceptible to lack of light and does not tolerate shade. However, if the shade is removed from the plant, it returns to its normal state and begins to grow and take root. However, the plant dries out and dies if the lack of light continues [25]. Vetiver grows relatively fast. Its crown is 1 to 2 meters high, and its root has a depth of 3 to 4 meters, which is branched and intertwined and can penetrate different layers of soil and weave them together [26]. Wang tested three species of Vetiver plants with different genotypes at different temperatures. In the presented results, the Vetiver shows the best growth rate at a temperature between 25 and 35 degrees Celsius. Research has shown that the plant has the fastest root growth rate of 4 cm per day at 25°C soil. In other words, in 75 days, the Vetiver's root can reach a length of 3 meters in the best situation [27]. The leaves and stems of Vetiver can be dried to a dark brown color. Its compost can be used. This compost is very nutritious and beneficial for the soil. Leaves are also used for livestock, but it is better to use them in combination because the crude protein in these leaves is less than other plants [24].

Alsghayer et al. investigated PAHs' removal efficiency from wastewater using a constructed wetland where Vetiver was planted. Removal efficiencies of phenanthrene and benzo and pyrene have been reported to be 67%, 66%, and 73%, respectively [28].

Koupai et al. investigated the efficiency of phytoremediation using Vetiver in the Isfahan landfill's leachate quality. According to the results obtained in this study, the removal efficiencies of COD, BOD_5, phosphate, and nitrate using Vetiver after 21 days were 68, 60, 82, and 83%, respectively [29]. Ky et al. evaluated the efficiency of nutrient removal by floating treatment wetland using Vetiver some studies, by using the floating treatment islands system in containers. Darajeh et al. investigated the treatment of palm oil plant effluent (POME), a pollutant produced by the palm oil industry, using vetiver system (VST) technology. This technology was first used to treat POME to reduce biochemical oxygen demand (BOD) and chemical oxygen demand (COD). The results showed that vetiver was able to reduce BOD up to 90 at low POME concentration and 60 at high POME concentration, while control sets (plant-free) were only able to reduce 15 BODs. The reduction in COD was 94% at low POME concentrations and 39% at high concentrations, while the control showed only 12% reduction [30, 31].

RoyChowdhury et al. (2021) used the vetiver plant to treat wastewater containing insensitive ammunition such as 3-nitro-1,2,4-triazol-5-one (NTO). Various NTO treatment technologies are being developed for wastewater treatment of industrial ammunition facilities. This is the first study to discover the potential plant treatment of industrial NTO wastewater using Vetiver grass (*Chrysopogon zizanioides* L.). The results showed that vetiver can effectively remove NTO from wastewater and also transfer NTO from the root to the stem [32, 33].

Panja et al. reviewed the removal efficiency of antibiotics and nutrients from the secondary effluent. Removal efficiencies of antibiotics, nitrate, phosphate, TOC, and COD from secondary effluents using Vetiver have been reported to be more than 90, 40, 60, 50, and 40%, respectively [34]. Maharjan and Pradhanang investigated the ability of Vetiver to treat wastewater. The results showed that, after one month, the removal efficiencies of BOD_5, chloride, nitrate, phosphate, hardness, and alkalinity were reported to be 71.03%, 42.9%, 93.93%, 88.4%, 46.4%, and 22.2%, respectively. Based on these results, Vetiver seems to be very effective in wastewater treatment with high phosphate and nitrate amounts [35]. Mathew et al. investigated the efficiency of Vetiver in wastewater treatment of an organizational kitchen. In this study, the removal efficiencies of BOD_5, COD, and total coliform were reported to be 85%, 90%, and 85%, respectively [36]. The present study focuses on the purification and removal of contaminants in water sources using the phytoremediation method by introducing Vetiver grass species in the case of floating treatment wetland (FTW). This study's preliminary purpose is to investigate a practical remedial solution and improvement methodology for the water quality of reservoirs and rivers by growing the floating Vetiver island method.

2. Materials and Methods

For preparation of synthetic wastewater, chemicals used were purchased. Pepton (Sigma Aldrich CAS number 91079-40-2), $FeSO_4$ (Sigma Aldrich CAS number 7720-78-7), KH_2PO_4 (Sigma Aldrich CAS number 7778-77-0), NaCl (Sigma Aldrich CAS number 7647-14-5), CaCl (Sigma Aldrich CAS number 7720-78-7), $MgSO_4.7H_2O$ (Sigma Aldrich CAS number 10034-99-8), $Ca(NO_3)_2$ (Sigma Aldrich CAS number 13477-34-4), and (NH_4NO_3 CAS number 6484-52-2) were purchased from Sigma Aldrich. In this study, plant samples were obtained from a greenhouse with a 37.2682° N, 49.5891° E coordinate position located in Rasht city, Iran.

2.1. Pilot Preparation. The pilot was made using three polyethylene containers of 126 liters. The container perimeter was covered with black plastic to reduce the penetration of sunlight as much as possible and to prevent the production of moss and algae that cause errors in the test

results. The first container contains 12 floating plants with the addition of dilute and nonaerated sewage. The second container has 12 floating plants with dilute and aerated wastewater equipped with an aeration pipe. The tube is placed in a spiral with a distance of 5 cm from the container's bottom. Holes in the pipe's surface were drilled at intervals of 5 to 8 cm to completely disrupt the wastewater and perform adsorption and treatment operations at a higher speed. The third container has 12 floating plants with concentrated wastewater = (5 times dilute wastewater) and without aeration. The floating surface was made of compressed ionolite with 5 cm thickness and a 25 density to have more strength and continue to float on the water's surface, taking into account the plant's weight. The ionolithic plate containing Vetiver seedlings with the same root and stem length was placed floating on the aqueous medium so that more than 99% of the water surface was covered.

2.2. Preparation of Artificial Sewage. Three 126 liter containers containing 100 liters of synthetic wastewater were selected in the laboratory to evaluate the purification power of Vetiver in ambient air conditions. According to Table 1, synthetic materials were chosen separately, and 100 liters were added to each container. Preliminary data after adding artificial wastewater are shown in Table 1 and Figure 1.

According to Figure 1, all three pots have the same physical and visual conditions (similar number of plants, container, ionolite, cover, and so on) and also the height of taller plants using cutting operations is considered equal to 30 cm, which all plants should be 30 cm high.

The amount of the adsorbed (mg) per unit mass of Vetiver (g) q_e was obtained by mass balance using the following equation [37]:

$$q_e = \frac{C_i - C_e}{m} V, \tag{1}$$

where C_i and C_e are the initial and equilibrium concentrations of the nitrogen and phosphate (mg/L), m is the mass of Vetiver (g), and V is the volume of the solution (L).

3. Results and Discussion

Seven tests have been performed on each container during one month, in which a total of 21 wastewater samples were tested. Table 2 shows the preliminary results of qualitative experiments obtained from the cultivation of Vetiver. The changes of T, pH, EC, TN, TP, and COD parameters in 30 days are presented in Table 2.

3.1. Evaporation and Transpiration. The percentage of water consumption (total evaporation and transpiration) in the samples of Vetiver culture medium in Figure 2 is considerable. Accordingly, the aerated container has the most evaporation due to the rising air pressure. While in the sample of wastewater with higher concentration, it has the least evaporation. Calculations show that during a week in one square meter of free water surface in September, approximately 48 liters of evaporation have been done.

3.2. COD Results. Floating islands were very effective in reducing COD. At the end of the one month, COD decreased about 33% in a container containing concentrated wastewater, even though the plant had almost given up and lost its efficiency. This reduction is very significant in the other two containers, which include more dilute wastewater.

It turns out that in a container containing dilute nonaerated wastewater, after about three weeks, we observed 0.90% removal rate according to the numbers and graphs related to COD removal (Figure 3). However, in a container containing dilute wastewater with aeration, the system quickly began to reduce COD so that after ten days, the rate of COD reduction reached more than 0.90%. Furthermore, in both cases, one month after the start of the test, the removal percentages of 0.93% and 0.97% were obtained for nonaerated and aerated containers, respectively. Therefore, these results demonstrate very desirable effect of the system and justify using of this method to reduce COD in polluted waters (Figure 3).

3.2.1. Results of Statistical Analysis with RSM for the First Response (COD). According to Table 3, parameters A, C, and D are effective in the study response.

The correlation coefficient (R^2) was 0.99, which indicates that the fitting model follows the data very well. The equation of the first-order polynomial model resulting from the analysis of the test results is as follows:

$$COD = 161.97 - 83.5A + 159.66B + 456.36C + 201.43D. \tag{2}$$

In the above equation, the parameters A, B, C, and D are temperature, pH, EC, and time, respectively. Figure 4 shows the interaction of independent parameters affecting the COD response from data analysis. According to the figure, the COD value decreases with increasing temperature at pH 7.5. The lowest COD value was obtained at 26.2°C and EC = 500 cm/μs over 31 days.

3.3. TN Results. Many researchers have found that nitrogen removal efficiency in treatment using plants is always higher than without plants in studying plants' role [38, 39]. In the TN removal test, except for the container containing concentrated wastewater, we saw a 65% increase in nitrogen sources. As shown in Figure 4, in the following two samples, we see a favorable reduction of total nitrogen from the wastewater source.

In a container containing dilute nonaerated wastewater, 50% of the total nitrogen was removed from the beginning of the experiment until the tenth day. However, after that, the reduction operation was slower, and finally the removal percentage reached 55 at the end of the experiments, which is nonsignificant compared with the first days of the investigation. In the aerated container, the nitrogen removal operation had a better process so that on the seventh day, more than 50% of the total nitrogen was removed by the system. In the second week, the removal percentage reached 80%, but after that the graph's slope gradually decreased, and the rate of nitrogen removal decreased (Figure 4).

TABLE 1: Concentration of synthetic materials (based on OECD) in samples of Vetiver medium.

Row	Type of composition	Container a Dilute sewage x (g/100 L)	Container b Dilute sewage x (g/100 L)	Container c Concentrated sewage x5 (g/100 L)
1	Pepton	25.6	25.6	128
2	$FeSO_4$	1	1	5
3	$Ca(NO_3)_2$	16.4	16.4	82
4	NH_4NO_3	0.16	0.16	0.8
5	KH_2PO_4	0.28	0.28	1.4
6	NaCl	0.07	0.07	0.35
7	CaCl	0.4	0.4	0.2
8	$MgSO_4.7H_2O$	0.02	0.02	0.1

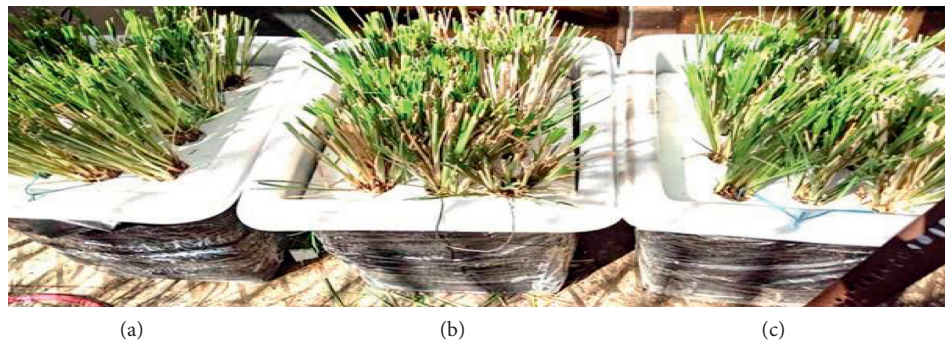(a)   (b)   (c)

FIGURE 1: Comparison of floating Vetiver in water of Khajeh Nasiruddin University laboratory: (a) dilute sewage with aeration; (b) dilute sewage without aeration; (c) concentrated sewage without aeration.

TABLE 2: Results as soon as synthetic wastewater is added to each of the test containers.

| The average of the measured parameter	Day	T (ºC)	pH	EC (μs/cm)	TDS (mg/l)	DO (mg/l)	TN (mg/l)	TP (mg/l)	COD (mg/l)
Container a dilute sewage x, aerated	0 (before phytoremediation)	24.2	7.02	554	350	1.7	34.32	0.47	344
	7	24.9	7.9	488	300	4.5	16.21	0.3	99
	10	26.5	8.01	488	300	4.7	13.49	0.25	28
	4	25.3	7.86	478	290	5.1	7.11	0.23	20
	19	25.4	7.9	467	280	5.9	5.2	0.19	16
	24	25.9	8.1	458	270	5.4	4.1	0.17	12
	31	26.2	8.15	446	260	5.9	3.5	0.16	11
Container b diluted wastewater x nonaerated	0 (before phytoremediation)	24.2	7.02	554	350	1.7	34.32	0.47	344
	7	24.8	6.86	489	310	1.3	22.84	0.45	166
	10	26.6	7.03	484	300	0.9	18.5	0.4	84
	14	25	7.17	464	290	1.2	16.25	0.38	46
	19	25.2	7.1	427.4	270	1.1	16	0.34	35
	24	25.8	7.2	395.7	250	1.2	15.5	0.32	27
	31	26	7.1	379.9	240	1.2	15.3	0.27	24
Container c concentrated wastewater 5x nonaerated	0 (before phytoremediation)	24.3	6.89	1270	840	0.5	117.8	1.92	760
	7	24.8	7.03	1529	1020	0.4	138.41	2.83	622
	10	25.9	7.15	1623	1030	0.4	171.46	3.15	642
	14	23.4	7.2	1540	1050	0.5	183.4	3.41	572
	19	23.7	7.1	1588.96	1060	0.45	188	3.7	550
	24	23.9	6.9	1633.93	1090	0.35	192	3.9	520
	31	24	6.9	1678.90	1120	0.38	195	3.95	510
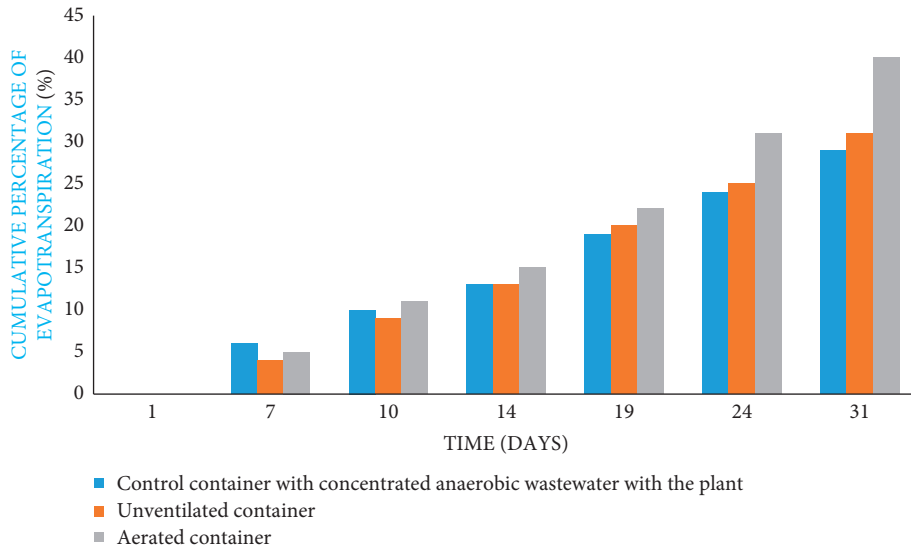
Figure 2: Results of cumulative percentage of evapotranspiration in the water container with Vetiver sampling by days.
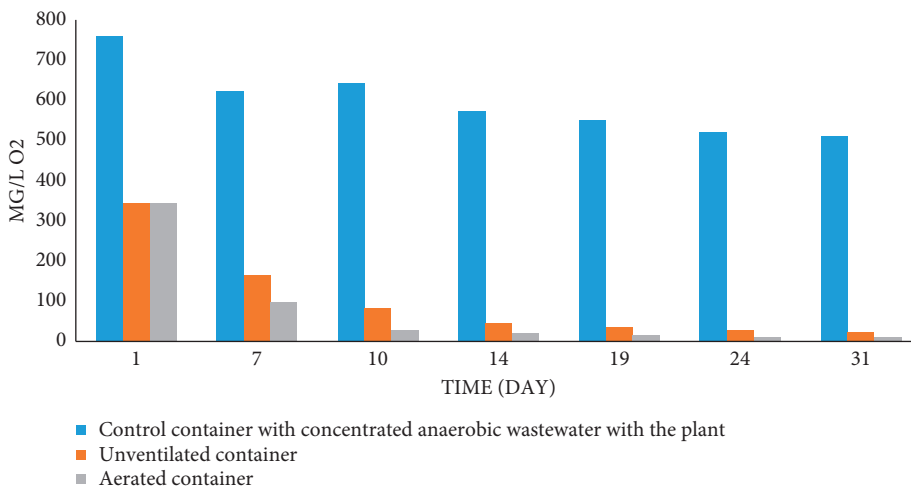

Figure 3: Results of mean COD in water container with Vetiver sampling by days.

Table 3: ANOVA analysis of variance for the first answer.

Source	Sum of squares	Degrees of freedom	Average of squares	F value	P value	Significant
Model	88257.30	4	22064.32	157.48	0.0062	Significant
A: temperature	2201.97	1	2201.97	15.92	0.05	Significant
B: pH	893.87	1	893.87	6.46	0.1261	Significant
C: EC	4715.25	1	4715.25	34.08	0.0281	Significant
D: time	4954.47	1	4954.47	35.81	0.0268	Significant

As shown in Figure 4, this removal process continued until the last day, and at the end of the month, we achieved a 90% removal rate. However, the removal percentage is not expected to increase significantly with the continuation of the experiment.

3.3.1. Result of Statistical Analysis with RSM for the Second Response (TN). Parameters C and D are effective in the study response, according to Table 4.

The correlation coefficient R^2 was 0.98, which indicates that the fitting model follows the data very well. The first-order polynomial model equation resulting from the experimental results' analysis is given in the following relation:

$$TN = 17.37 - 6.26A + 22.76B + 45.76C + 12.22D. \quad (3)$$

In the above equation, the parameters A, B, C, and D are temperature, pH, EC, and time, respectively. Figure 5 shows the interaction of independent parameters affecting the TN
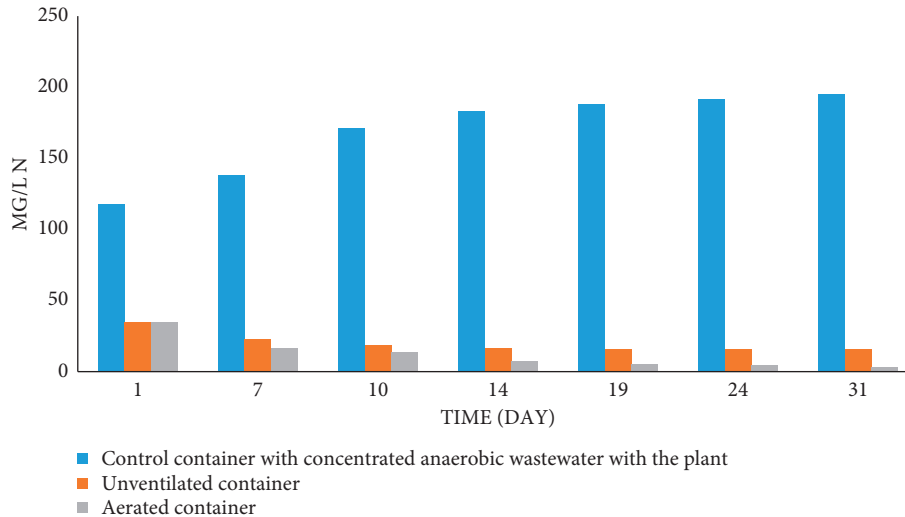
FIGURE 4: Results of the average total TN nitrogen in the water container with Vetiver sampling by days.

TABLE 4: ANOVA analysis of variance for the second answer.

Source	Sum of squares	Degrees of freedom	Average of squares	F value	P value	Significant
Model	711.35	4	177.84	36.11	0.0271	Significant
A: temperature	12.38	1	12.38	2.51	0.2537	Nonsignificant
B: pH	18.34	1	18.34	3.73	0.1934	Nonsignificant
C: EC	47.40	1	47.40	9.62	0.0901	Significant
D: time	18.25	1	18.25	3.71	0.0941	Significant

response resulting from data analysis. TN value decreases with increasing temperature at pH 7, according to the figure. The lowest TN was obtained at 26.5°C and EC = 500 cm/μs during 31 days.

3.4. TP Results. According to the study of Wang et al., the decomposition of phosphorus by microorganisms in treatment using plants is more than without plants [40]. It should be noted that in addition to adsorption, phosphorus can also be removed by chemical precipitation [41]. In phosphorus-related experiments, we eventually encountered a decrease in total phosphorus in both containers over one month. In a container containing dilute, aerated wastewater, aerobic bacteria begin to absorb and remove phosphorus, and the trend is a decreasing graph as shown in the figure. Phosphorus value decreases by up to 50% within 10 days, and by the end of one month, this reduction reaches 66%. Phosphorus values increase by 80% after a week in an anaerobic container and then decrease so that at the end of one month, the total phosphorus rate drops to 42%. The reason for the initial increase is that the polyphosphates are not detected in the experiments, and anaerobic-friendly polyphosphate bacteria begin to break down these polyphosphates because the anaerobic state occurs in this sample and mineral phosphorus is released as a result of their activity. In this time, mineral phosphorus is determined in experiments. This problem is the reason for this increase in phosphorus in Figure 5. In the next step, phosphorophilic bacteria absorb and consume the produced phosphates, and

they chart a downward trend from this point. The floating system with Vetiver works well as it is known, and the total phosphorus is reduced in wastewater with this concentration.

3.4.1. Results of Statistical Analysis with RSM for the Third Response (TP). Parameters A, B, C, and D are effective in the investigated response, according to Table 5. The correlation coefficient of R^2 was 0.99, which indicates that the model fits well.

The first-order polynomial model equation resulting from the experimental results' analysis is given in the following equation:

$$TP = 0.2991 - 0.0757A + 0.1956B + 0.3809C + 0.0901. \tag{4}$$

In the above equation, the parameters A, B, C, and D are temperature, pH, EC, and time. Figures 6–9 show the interaction of independent parameters affecting COD, DO, TN, and TP responses resulting from data analysis. According to the figures, the TP value decreases with increasing temperature at pH 7. The lowest TP value was obtained at 36.5°C and EC = 500 cm/μs over 31 days.

3.5. Plant Root Growth Results. The presence of plants increases the biofilms formed around the roots, which play an essential role in oxidation, absorption, and so on. In floating treatment wetland with higher biomass growth rates, better nitrogen transfer has been observed [41]. A set of
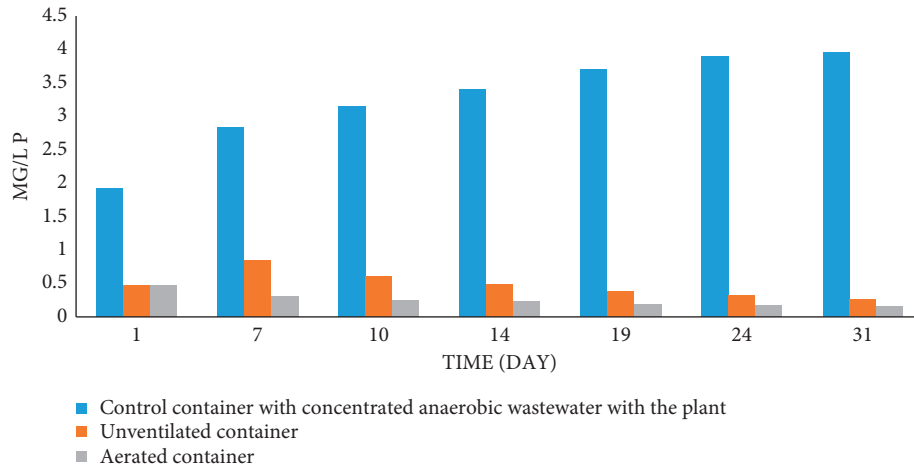
FIGURE 5: Results of the average total TP phosphorus in the water container with Vetiver sampling by days.

TABLE 5: ANOVA analysis of variance for the third answer.

Source	Sum of squares	Degrees of freedom	Average of squares	F value	P value	Significant
Model	0.0684	4	0.0171	2515.80	0.0004	Significant
A: temperature	0.0018	1	0.0018	255.56	0.0039	Significant
B: pH	0.0013	1	0.0013	189.61	0.0052	Significant
C: EC	0.0033	1	0.0033	464.45	0.0021	Significant
D: time	0.0010	1	0.0010	140.04	0.0071	Significant

microorganisms interactions are involved in treating wastewater in artificial ponds, which attach to plant roots and decompose contaminants to survive [42, 43].

In this study, the root growth diagram shows that the container with lower contaminants concentrations has grown more without aeration. The root material has taken a diverse and thicker shape. This difference may be due to the plant trying to gain more nutrients. In an aerated container, the roots easily reach these sources and grow naturally because the movement of food is done by the pressure of air bubbles. They are mixed continuously, and they do not precipitate. However, in the case of aeration, the roots have to go deep to reach food sources.

As shown in Figures 10–12, the roots are still growing normally after 2 weeks because the nutrients are water-soluble, and there is no competition. However, the roots quickly start to grow vertically and do not branch after absorbing these substances. This problem is beneficial for using in water reservoirs of dams with a low or medium concentration of nutrients because nutrients are absorbed by root growth. The rate of root growth, as it is known, during 30 days of research for the Vetiver plant in an unaerated container with diluted wastewater and aerated container with diluted wastewater is on average equal to 25 and 20 cm, respectively.

However, various researchers have conducted several studies on the effectiveness of Vetiver, for example, Kirti et al. compared the phytoremediation efficiency of vetiver and lemongrass in pots against compared simulation of Ni-Cd battery electrolyte waste (EW). They observed that the accumulation of nickel (μgg-1) in shoots (36.8) and roots

(252.9) of Vetiver was higher than that of lemongrass 12.5 and 7.79, respectively. Therefore, Vetiver was more resistant to EW toxicity than lemongrass because it had fewer morphological parameters and lower rise in TBARS against the doses of EW. Also Vetiver roots had higher Niel accumulation than Cd in EW-contaminated soil in comparison with lemongrass [44].

In another study, Siyar et al. evaluated the use of Vetiver grass in plating real contaminated soils around a smelter. The studied parameters including voltage gradient (1-2 V/cm), different electric field (AC-DC), saturated and unsaturated state, and Eh-pH changes for plating Vetiver performance were investigated. Vetiver grows for 21 days. Then, three different voltage gradients (1, 2DC V/cm and 2AC V/cm) were applied to the soil for 8 hours a day for 21 days and were compared with control cells without electric field (PR). The results showed that the use of DC current significantly changes the values of Eh-pH, and this is in contrast to the use of AC current, which causes minor changes. Absorption of total metals in the stems of plants treated with AC with BCF > 1 was much higher than PR and DC. Due to the speed of movement and plant health, if AC current is applied for a long time, it can have better results in electrical treatment of Vetiver plant through the plant extraction process [45]. Ng et al. evaluated the growth performance, accumulation process, and adsorption skills of Vetiveria zizanioides (Linn.) Nash. In both single and mixed heavy metals (Cd, Pb, Cu, and Zn)-disodium EDTA-enhanced contaminated soil. Results showed that all accumulation of heavy metals were significantly higher ($p < 0.05$) in both lower and upper roots and tillers of Vetiver grass for Cd + Pb + Cu + Zn + EDTA
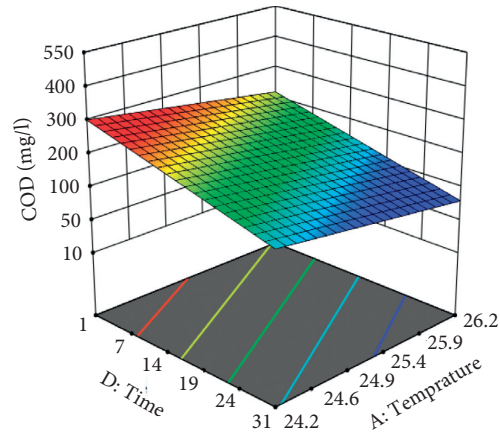
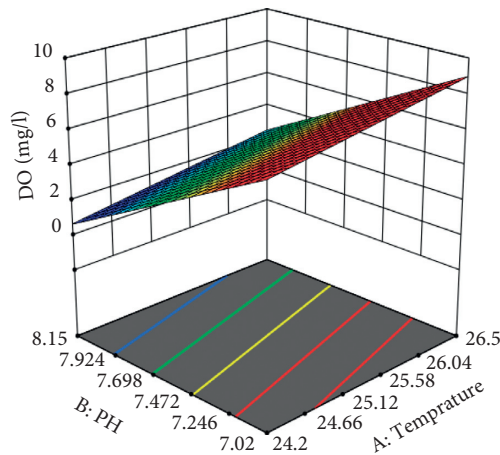FIGURE 6: The effect of independent parameter interaction on COD response.

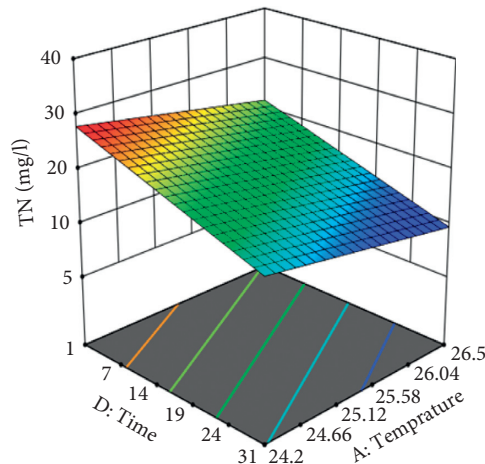FIGURE 7: The effect of independent parameter interaction on DO response.

FIGURE 8: The effect of independent parameter interaction on TN response.

treatments as compared with the control. Only Zn + EDTA treatment collected the highest amount of zinc (8068 ± 407 mg/kg) while the highest accumulation of copper was (1977 ± 293 mg/kg) and lead was (1096 ± 759 mg/kg) in the composition. In general, the accumulation trend of heavy metals in Vetiver was Zn >>> Cu > Pb >> Cd for all treatments, respectively [46]. Nugroho et al. evaluated the uptake and removal of heavy metals by Vetiver (*Chrysopogon zizanoides* L.) in metal—contaminated waters. Vetiver was planted in synthetic plating wastewater containing different
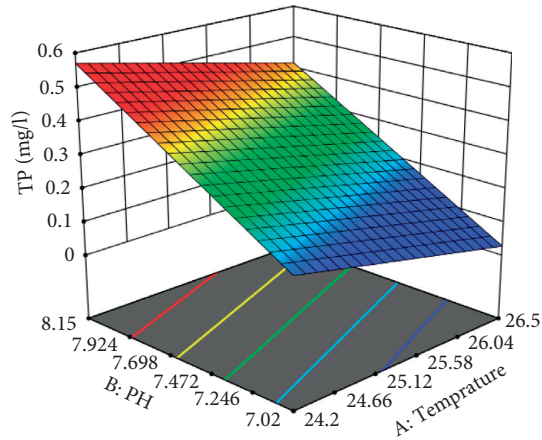
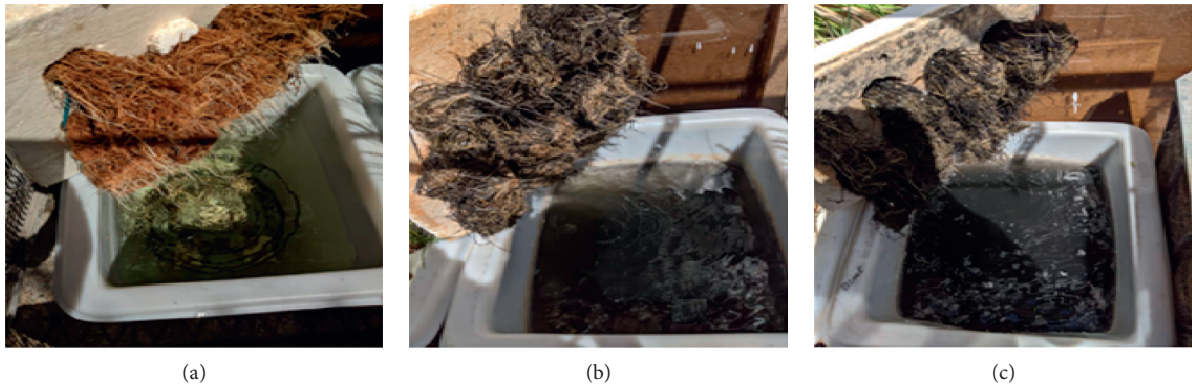FIGURE 9: The effect of independent parameter interaction on TP response.

FIGURE 10: Comparison of the condition of floating Vetiver roots in the water of Khajeh Nasir al-Din laboratory after 15 days: (a) dilute sewage with aeration to the root of the Vetiver; (b) dilute sewage without aeration; (c) concentrated wastewater without aeration to the Vetiver.
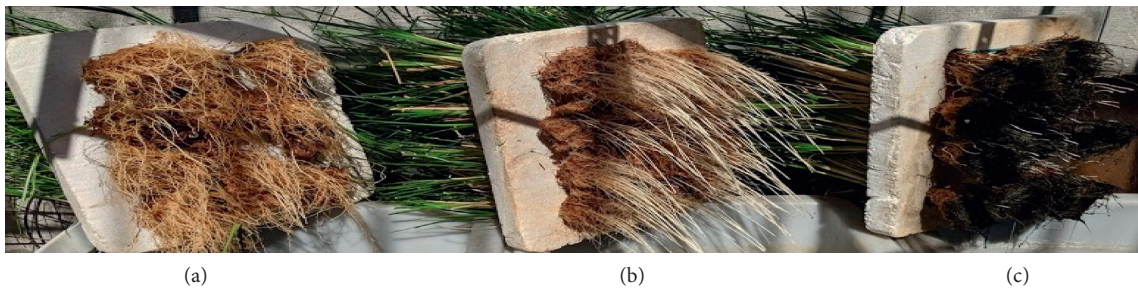

FIGURE 11: Comparison of the condition of floating Vetiver roots in the water of Khajeh Nasir al-Din laboratory after 30 days: (a) dilute sewage with aeration to the root of the vetiver; (b) dilute sewage without aeration; (c) concentrated wastewater without aeration to the Vetiver.

levels (low, medium, and high) of chromium (Cr) and nickel (Ni). Water, roots, and twigs were collected periodically to determine Cr and Ni levels using atomic absorption spectroscopy (AAS). The maximum absorption of Cr and Ni was 127.21 mg/kg/day and 60.15 mg/kg/day, respectively, while the removal of chromium and nickel was 1.09 mg/kg/day and 12.24 mg, respectively. The results show that Vetiver plant has a good efficiency for removing heavy metals from aquatic environments [47]. In another study, Datta et al.

investigated the potential of using Vetiver as a plant purifier to remove tetracycline (TC) from aqueous media. Vetiver plants were grown for 60 days in a greenhouse in a TC-contaminated hydroponic system. Preliminary results indicate that complete elimination of tetracycline occurred within 40 days in all TC treatments. The initial concentration of TC had a significant effect ($p < 0.0001$) on the removal kinetics of tetracycline in roots and stem tissues, which confirmed root uptake and transfer to the stem. In general,
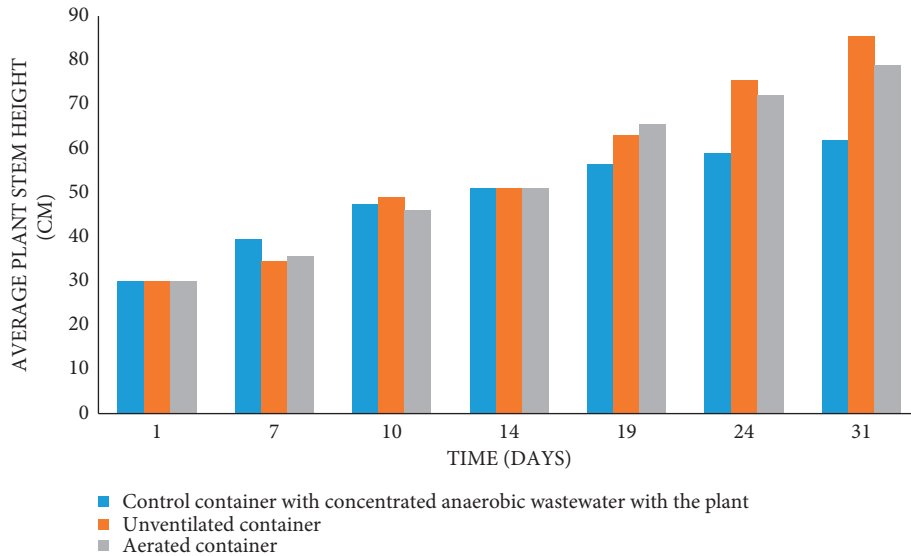
Figure 12: Results of mean plant stem height Vetiver in water except for sampling days.

past and present studies prove the effectiveness of plant phytoremediation, especially Vetiver in water and wastewater treatment of various pollutants [48]. These man-made made structures of floating islands could be further improved in their filtration efficiencies and survival when a chitosan-based filter was added which could reduce the overall heavy metal ion concentration of polluted water [49].

4. Conclusion

According to studies, the use of wastewater treatment by floating islands in developed countries receives more attention. As mentioned, this method is considered more than others, with many benefits, especially its economics. It is better to pay more attention to such practices in undeveloped countries, following the developing and developed countries. Therefore, research has been done to increase its efficiency and apply them to optimize artificial floating islands. We will now briefly review the highlights of this research.

The highest percentage of COD removal was related to the container containing dilute aerated wastewater (97%); the lowest reduction rate was related to the container containing dilute unaerated sewage (93%). The highest TN removal percentage was related to the container containing dilute aerated waste (90%). The lowest rate of reduction was related to the container containing dilute unaerated wastewater (55%). In total phosphorus, the highest percentage of removal was related to the container containing dilute aerated wastewater (66%). The lowest rate of reduction (42%) was related to the container containing dilute unaerated wastewater.

The highest evaporation percentage is related to the container containing dilute aerated wastewater (40%); the lowest evaporation percentage is associated with the container containing dilute unaerated sewage (31%). In general, the efficiency of this project is high and worth the investment. Since the leaves and roots of this plant have economic value, it compensates its initial capital investment and starts

to create profit after a short time. Due to the above results, the aerated system had a higher efficiency in other experiments, except for the evaporation section. However, it is recommended to use an unaerated system on a large scale since both the energy cost of the aerators and evaporation are removed and reduced, respectively.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

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