Evaluation of *Spirulina platensis* for organic load reduction and water quality improvement in wastewater systems

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Abstract

This paper discusses the performance of an integrated aerated photobioreactor system in treating organic waste for enhanced wastewater quality using Spirulina platensis. Photosynthetic operations of Spirulina shifted pH from 9.01 to 9.42. The wastewater treatment resulted in the removal of BOD_5 up to 82.08%, indicating that organic matter has been effectively removed. The wastewater treatment with Spirulina removed ammonia (98.57%), nitrate (87.99%), and phosphate (88.49%) at different rates within the first five days of operation. ORP increased from –120 to 201 mV, indicating better oxidative conditions. Biomass concentration increased gradually until the fourth day, depicting efficient nutrient assimilation. Treated wastewater quality parameters reached levels that allowed agricultural water reuse for crop irrigation in areas facing water shortage. Harvested algal biomass contains nutrients and organic matter; it acts as a biofertilizer for the improvement of soil fertility toward sustainable crop production. These findings confirm that *Spirulina platensis* represents an environmentally sustainable option for wastewater treatment and reuse—particularly in hot and semi-arid regions—while simultaneously generating valuable algal biomass.

Keywords: *Spirulina platensis*, wastewater treatment, organic load, bioremediation

Introduction

Among all natural resources, water is one of the most essential. However, rapid population growth, urban expansion, and the increase of industrial and agricultural activities have made the treatment of wastewater a considerable challenge. Wastewater contains organic loads and nutrients such as nitrogen and phosphorus, as well as suspended solids and various ion. Water quality deterioration, oxygen depletion, eutrophication, and the spread of algal blooms occur as a result of this [1]. Currently, the application of microalgae for bioremediation of wastewater is seen as an environmentally friendly approach. Microalgae can remove excess nutrients, carry out photosynthesis, and produce commercially valuable biomass that can be converted into fertilizers or used in the bioenergy sector. For instance, studies showed the efficiency of *Spirulina platensis* SP4 in removing ammonia, nitrate, and phosphate from domestic wastewater and enhancing its reuse for irrigation purposes [2]. Likewise, other studies demonstrated that *S. platensis* was able to remove TN, TP, and DOC even from high-salinity aquaculture wastewater [3]. A study evaluated *S. platensis* as a biocoagulant in domestic wastewater, effectively reducing turbidity and total suspended solids to about 63% and 85%, respectively [4]. Another study used *S. platensis* in an oxidation ditch reactor for the removal of nitrates in domestic wastewater with a nitrate removal efficiency of 73.7% under intermittent aeration [5]. For instance, [6] demonstrated the effectiveness of *Spirulina platensis* SP4 in removing ammonia, nitrate, and phosphate from domestic wastewater, thereby enhancing its potential for reuse in irrigation. Likewise, [1] reported that *S. platensis* was capable of removing total nitrogen (TN), total phosphorus (TP), and dissolved organic carbon (DOC) even from high-salinity aquaculture wastewater [2, 3]. A study conducted by [4] evaluated *S. platensis* as a biocoagulant in domestic wastewater, successfully reducing turbidity and total suspended solids by approximately 63% and 85%, respectively.

Likewise, it was demonstrated that *S. platensis* used in an oxidation ditch reactor for nitrate removal in domestic wastewater accomplished 73.7% nitrate removal efficiency during intermittent aeration [5]. For sustainable biomass feedstock for water remediation, agricultural or poultry residues can be used as *Spirulina's* growing medium [6].Previously, the concentration of ammonia in airlift photobioreactors was moderated to maximize *S. platensis* growth and treatment efficiency and to increase the growth as an ammonia removal strategy [7].Microalgae contribute to improving the physicochemical properties of water through photosynthesis, nutrient uptake, and sedimentation of biomass. Aerated photobioreactors enhance algal growth and nutrient removal through continuous aeration and even light distribution. This increases the efficiency of organic and nutrient removal, particularly in warm and semi-arid environmental conditions [3, 4, 5]. Therefore, the objective of the present work is to assess the efficiency of *Spirulina platensis* in reducing organic loads and improving wastewater quality using an integrated aerated photobioreactor system. Changes in pH, biochemical oxygen demand, and algal biomass will be monitored in this study. The foreseen results are supposed to yield a practical model for sustainable treatment of wastewater using microalgae and to support environmental protection with water reuse in the hot and semi-arid regions.

Materials and Methods

A continuous wastewater treatment system was designed and constructed to evaluate the efficiency of *Spirulina platensis* for organic load reduction and water quality improvement. The experimental setup consisted of four sequentially connected tanks, each serving a specific treatment function:

Mechanical Filtration Tank (60 L)

The first tank was designed to remove suspended solids and coarse impurities from the raw wastewater. It contained three vertically arranged layers—gravel, sand, and fine gravel—each approximately 25 cm in height, to ensure gradual and effective filtration. The filtered water then flowed by gravity through a connecting PVC pipe into the next tank.

Biological Treatment Tank (Aerated Photobioreactor, 25 L)

The second tank represented the main treatment stage. It was operated as an aerated photobioreactor inoculated with ***Spirulina platensis***. Continuous aeration was supplied using an air pump to ensure uniform mixing and efficient gas exchange, while artificial illumination of approximately 3500 lux was provided to sustain photosynthetic activity. The temperature was maintained at 20–24 °C, and pH was adjusted between 7.5 and 9.0, representing optimal conditions for *Spirulina* growth this alga had been previously cultured in the Department of Fish and Marine Resources. A nutrient medium containing a low concentration of NPK (20:20:20) fertilizer was added to enhance algal metabolism and nutrient uptake from the wastewater.

Sedimentation Tank (25 L)

This tank received the effluent from the photobioreactor and was used to allow gravitational settling of the suspended solids and excess algal biomass. Settled biomass was collected for quantification and further analysis of growth performance.

Treated Water Collection Tank (25 L)

The final tank collected the clarified effluent from the sedimentation tank. Samples from this tank were analyzed to evaluate the improvement in water quality and the overall efficiency of the treatment process.

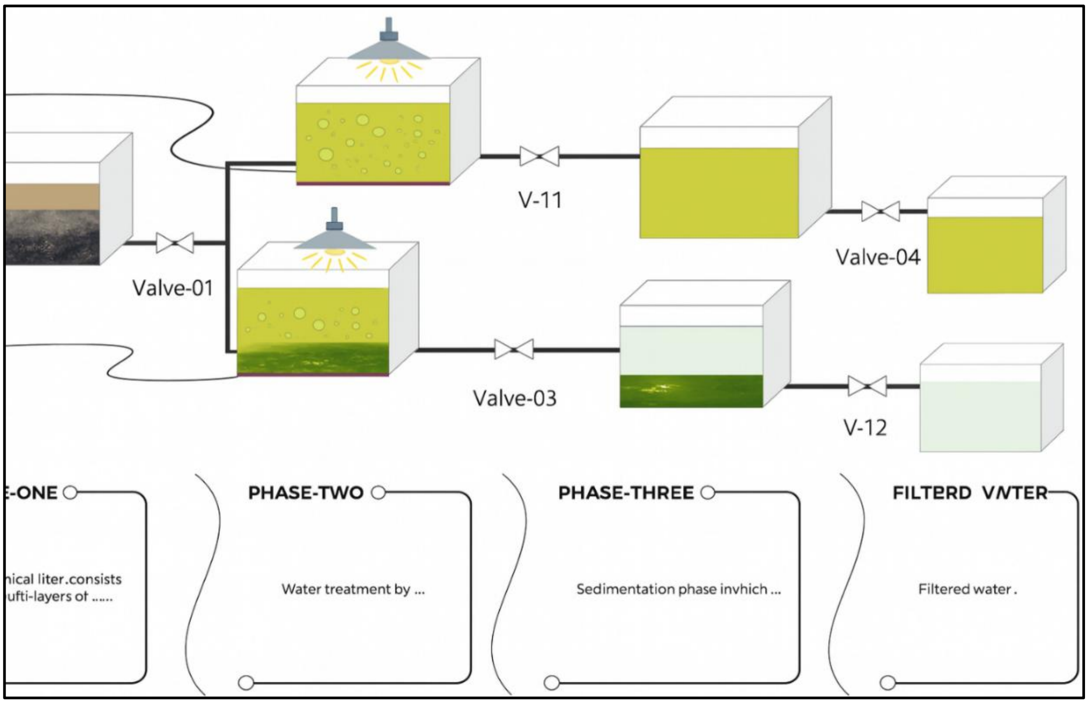

Figure (1): System treatment

The system was operated for five consecutive days as one treatment cycle. Samples were taken daily to measure temperature, pH, and salinity using calibrated electronic meters, and dissolved oxygen (DO) was determined using a digital DO meter. Biochemical oxygen demand (BOD_5), ammonia (NH_4^+), nitrate (NO_3^-), and phosphate (PO_4^{3-}) were analyzed at the beginning and end of the experiment, according to the Standard Methods for the Examination of Water and Wastewater [20].

The biomass concentration of *S. platensis* was determined by filtration through 0.45 µm filter papers and drying to constant weight [20]. The **removal efficiency** of each parameter was calculated using the following equation:

$$\text{Removal efficiency (\%)} = \frac{C_i - C_f}{C_i} \times 100$$

where C_i and C_f represent the initial and final concentrations, respectively [21].

Results and Discussion

The observations from the experiment indicate that the pH levels of the wastewater treated with *Spirulina platensis* gradually increased from 9.01 to 9.42 within five days, whereas in the control treatment the pH decreased from 8.95 to 8.20. The two treatments exhibited highly significant differences ($p < 0.05$) all through the process Figure (2).

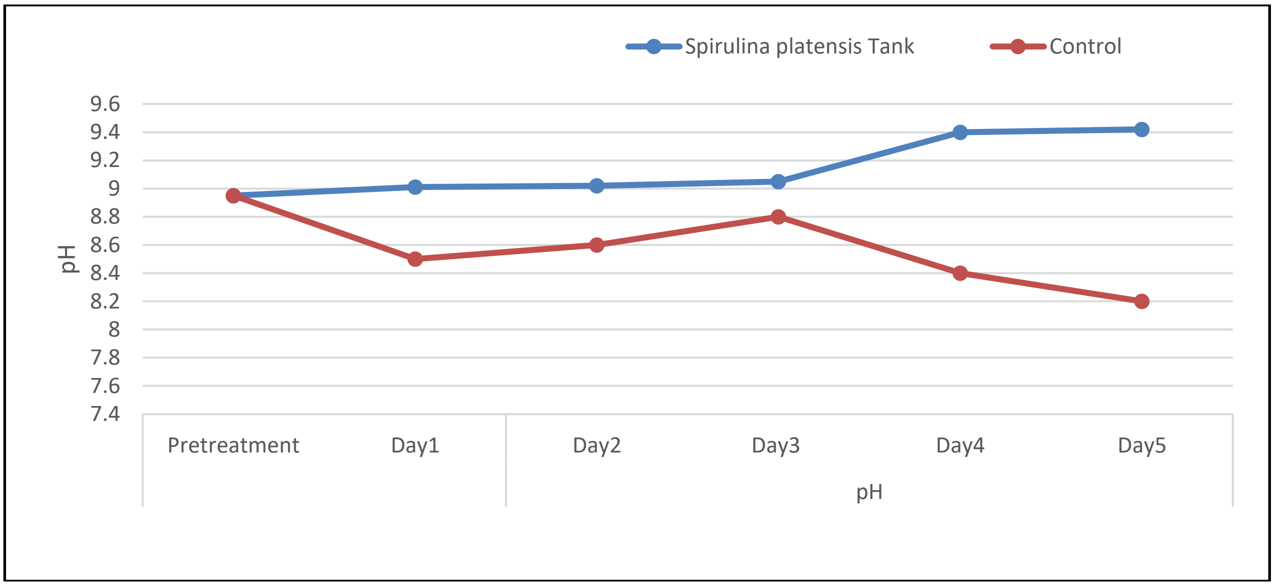

Figure (2): pH values during the experimental period

The increase in pH could have resulted from the metabolic activities linked to the algal growth plus the uptake of carbon dioxide during photosynthesis, which raises the medium's alkalinity [1, 2]. The pH drop in the control may, however, be ascribed to the decomposition of organic matter and the simultaneous release of acids and carbon dioxide [3]. These findings are in strong agreement with previous studies, such as those being [4] and [5], who validated that the algae do help in the enhancement of water properties and consequently increase the pH values during the biological treatment process.

The outcomes indicated an undoubted lowering of the biochemical oxygen demand (BOD_5) values in the sewage treated with *Spirulina platensis* (26.5 to 4.75 mg/L) in five days, and a removal efficiency of 82.08% was noted, while the control only recorded 44.34%, showing significant differences ($p < 0.05$) among the treatment's Figure (3).

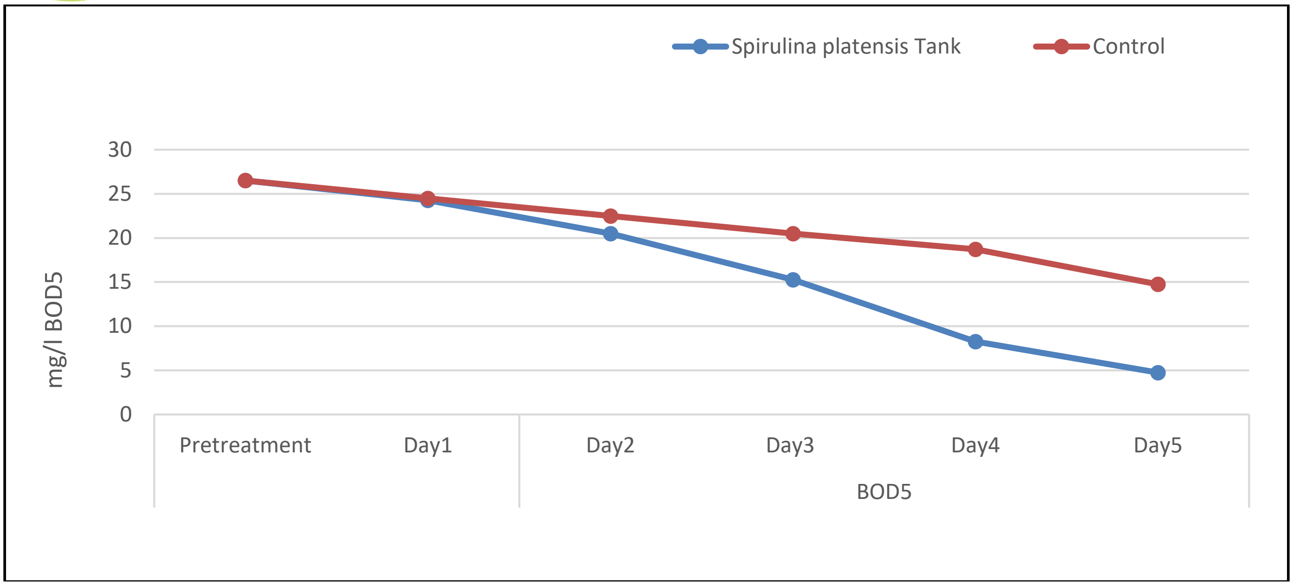

Figure (3): BOD5 values during the experimental period

This marked reduction is attributed to the ability of *Spirulina* to absorb and utilize dissolved organic matter as a carbon and energy source, in addition to releasing oxygen through photosynthesis, which enhances the biological oxidation of pollutants [3, 6]. These findings agree with those reported in [5,4], who indicated that microalgae—particularly *Spirulina*—are effective in reducing BOD levels and improving water quality by lowering the organic load in biological treatment systems.

The results showed a sharp decrease in ammonium (NH_3–NH_4^+) concentration in the wastewater treated with *Spirulina platensis*, from 3.5 mg/L before treatment to 0.05 mg/L on the fifth day, achieving a removal efficiency of 98.57%. In contrast, the control treatment recorded a lower reduction of 71.43%, with significant differences ($p < 0.05$) between the two treatments Figure (4).

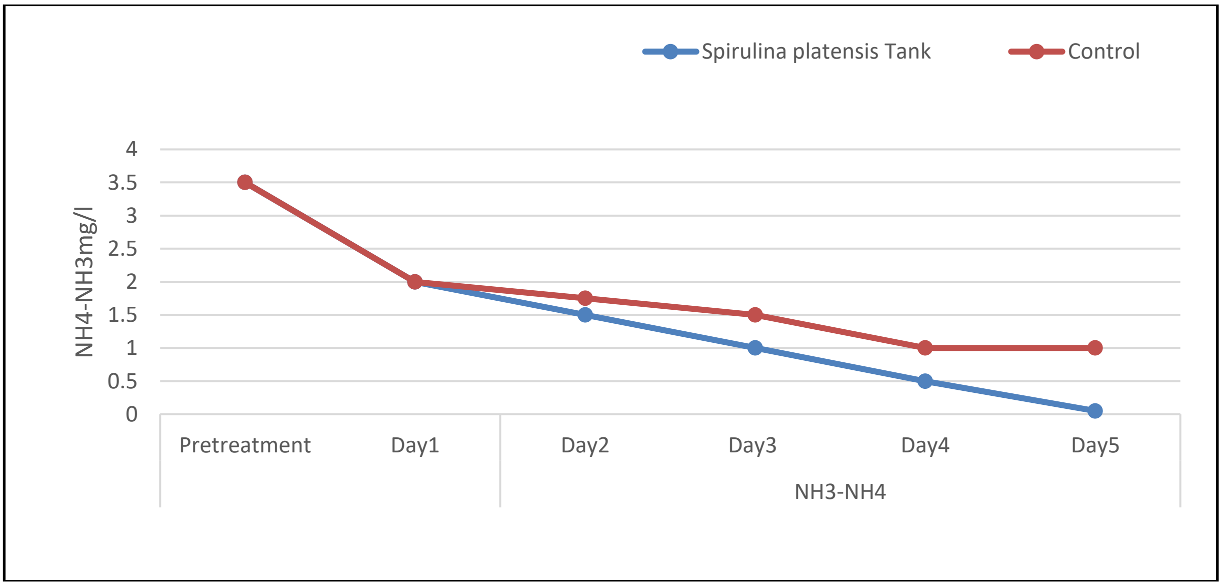

Figure (4): NH4-NH3 values during the experimental period

This high removal efficiency is attributed to the strong ability of *Spirulina* to assimilate ammonium as a nitrogen source for protein synthesis and cell growth, as well as to the increase in pH caused by photosynthetic activity, which promotes ammonia volatilization [2, 3]. Similar findings were reported in [5,4], who confirmed that *Spirulina platensis* effectively removes ammonium and other nitrogenous compounds from wastewater through biological uptake and enhanced oxidation processes.

The findings revealed that there was a steady decline in the concentration of nitrates (NO_3^-) in wastewater that had been treated with *Spirulina platensis*, which went from 6.986 mg/L prior to treatment to 0.839 mg/L on the fifth day; thus, the removal efficiency reached up to 87.99%. The control, on the other hand, only showed a reduction of 49.90%, and there were significant differences ($p < 0.05$) between the treatments Figure (5).

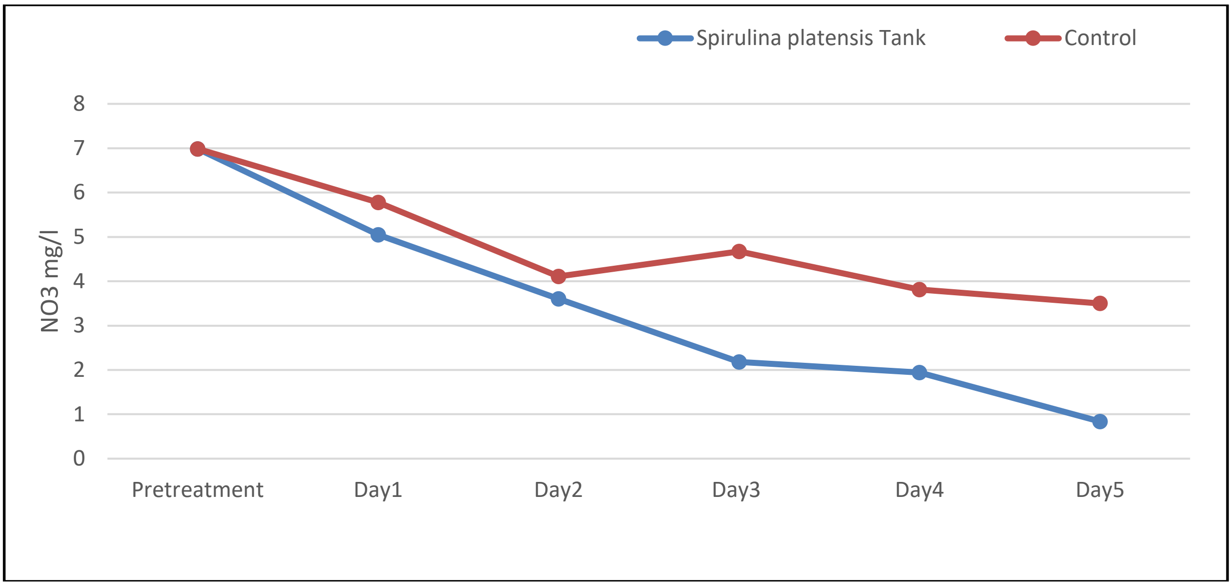

Figure (5): NO3 values during the experimental period

The capacity of the removal of nitrates at such a high rate is due to *Spirulina* cells taking in the nitrate ions as a nitrogen source for their protein and pigment synthesis while the bacterial denitrification is taking place with more efficiency since the bacteria are being supported by the oxygen released during the process of photosynthesis [7, 8]. These findings are consistent with [9,10], who reported that *Spirulina platensis* and other cyanobacteria play a key role in nitrogen removal from wastewater through nutrient assimilation and bio-oxidative mechanisms.

The phosphate (PO_4^{3-}) concentration in wastewater treated with *Spirulina platensis* decreased sharply from 35.87 mg/L to 4.13 mg/L within five days, achieving a removal efficiency of 88.49%, compared with only 31.42% in the control. This significant difference ($p < 0.05$) indicates that *Spirulina* effectively assimilated phosphate for metabolic processes and promoted precipitation through the pH increase caused by photosynthesis. Such high removal efficiencies are also observed by [11, 12] who found that the absorption capacity of S. platensis for phosphorus is fast by bioassimilation and chemical precipitation. In control, the slight increase in phosphate indicates mineralization and re-release from organic matter. 262 Overall, it is concluded that Spirulina platensis holds a great promise in support of sustainable phosphate removal and nutrient recovery (Figure 6).

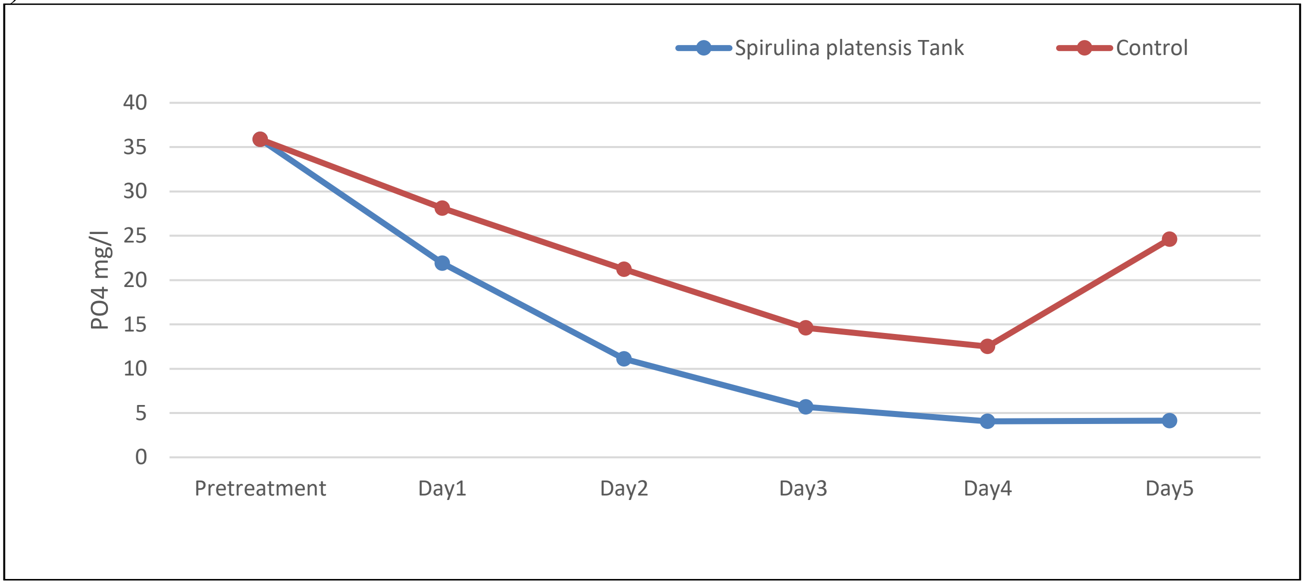

Figure (6): PO4 values during the experimental period

The oxidation-reduction potential (ORP) of wastewaters treated with Spirulina platensis increased from –120 mV to 201 mV after five days treatment, a 267.5% increase compared to the pretreatment value; control incubations recorded only an ORP gain of up to 112 mV (193.3%). This marked improvement ($p < 0.05$) may be due to the improved oxidative situation caused by photosynthetic production of oxygen, as well as microbial activity promoted by by Spirulina. An increase in ORP implies transfer of reducing to oxidizing state, contributing the degradation of organic matter and stabilization of the water. Similar results were obtained in [11,13], which proved that S. platensi increased significantly the ORP and dissolved oxygen during waste-water treatment.

Similarly, [14] found that algal–bacterial consortia based on *Spirulina* markedly enhance redox potential and overall treatment efficiency Figure (7).

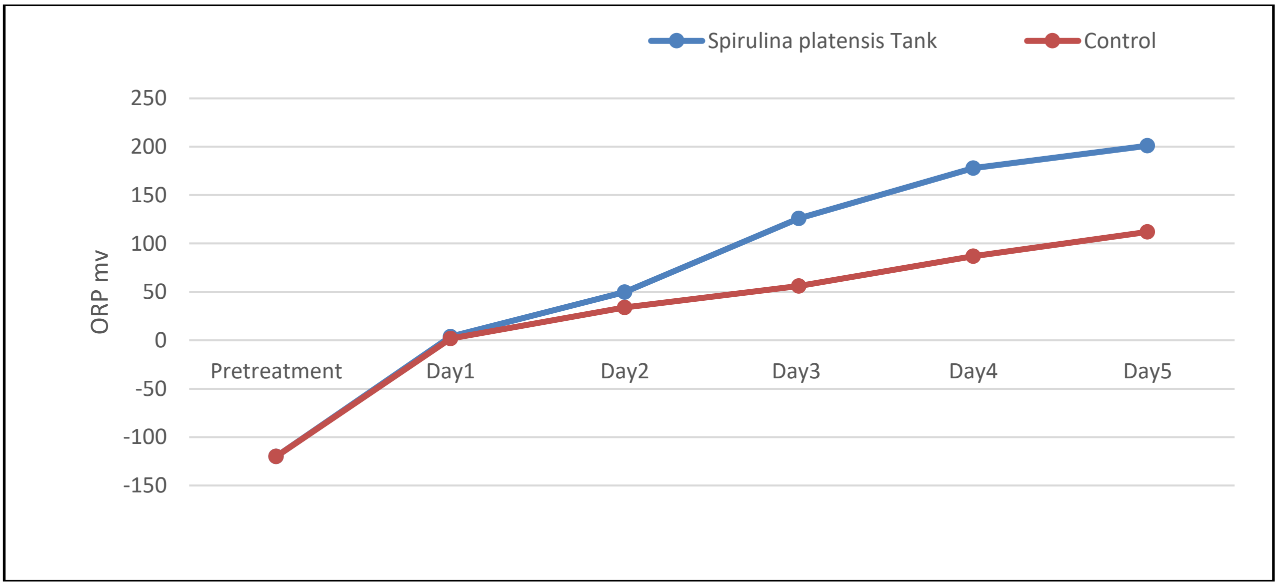

Figure (7): ORP values during the experimental period

The biomass of *Spirulina platensis* cultivated in wastewater showed a substantial increase over the five experimental days. The initial biomass concentration before treatment was 2.324 mg/L, which gradually increased to 2.443 mg/L on the first day and 2.61 mg/L on the second day. The third day recorded the most pronounced increase (3.567 mg/L), followed by the fourth day, which reached the maximum value of 4.245 mg/L. A slight decrease to 3.541 mg/L was observed on the fifth day (Figure 8).

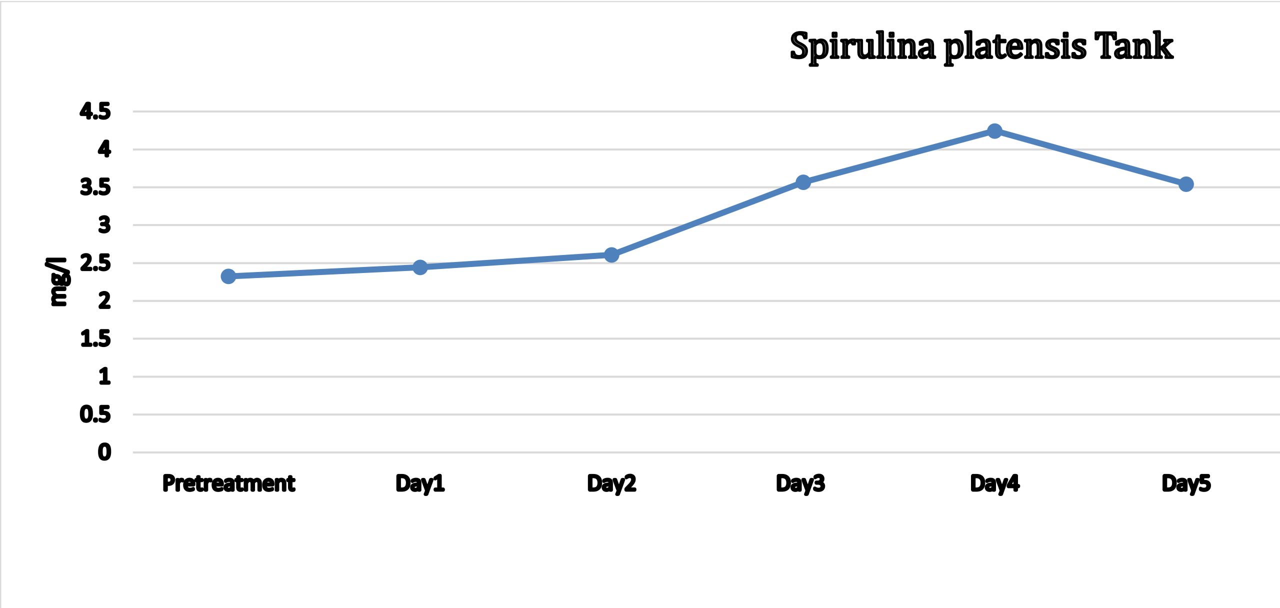

Figure (8): Biomass values during the experimental period

With the increase of treatment days, a simgnificant increase ($p < 0.05$) in biomass was noted, which indicated that *Spirulina platensis* had converted the nutrients in wastewater—especially nitromgen and phosphorus—very well to support its mgrowth and multiplication. This increase is usually accompanied by himgh photosynthetic activity facilitated by the rich nutrient supply. Similar observations were made in [3] and [15], who pointed out that the cyanobacterial mgrowth in wastewater simgnificantly depends on nutrient presence.

The slight decline observed on the last day (from 4.245 to 3.541 mg/L) may be attributed to nutrient depletion following the exponential growth phase or the accumulation of metabolic byproducts, which can inhibit cell growth. Also, the very himgh cell densities can cause the limght in the culture to be limited because the cells will be shadinmg each other. These aspects of limght limitation and nutrient availability due to self-shadinmg are mentioned in [4], who described that very himgh biomass density can lead to reduced mgrowth rates because of limght penetration and nutrition beinmg limited. Overall, the study indicates that wastewater serves as an excellent medium for the cultivation of *Spirulina platensis*, highlighting its potential for environmental remediation with the dual benefit of biomass production and pollutant removal.

Results revealed that Spirulina platensis could be a potential alga based treatment option for organic and nutrient removal from waste water. Significantly, BOD_5, ammonia, nitrate and phosphate contents were reduced in a short time of treatment. The higher value in pH and ORP in this study led to an improved oxidative environment inside the system. There was good algal growth, suggesting that most of the available nutrients were utilized. Therefore, S. platensis could be an alternative for the sustainable and environmentally friendly wastewater recycling. In addition, received treated effluent was of satisfactory levels for reuse as irrigation water especially in dry region. Moreover, the harvested algal biomass (nutrient and organic matter rich biomass) can be used as biofertilizer for enhancing the soil fertility and sustainable crop production.

References

1) Fu, Q., Zhanmg, L., Wanmg, Z., & Liu, Y. (2023). *Nutrient removal from aquaculture wastewater by Spirulina platensis: Effect of salinity and limght intensity. Journal of Environmental Manamgement*, 325, 116–128.
2) Afifah, F. N., Nur, F., & Kurniawan, T. (2024). *Evaluation of Spirulina platensis as a biocoamgulant in domestic wastewater treatment. Environmental Technolomgy Reports*, 9(2), 115–126.
3) Phú, N. D., Tran, Q. T., & Le, M. T. (2025). *Optimization of aerated photobioreactors for nutrient removal usinmg Spirulina platensis in semi-arid environments. Environmental Biotechnolomgy Letters*, 12(1), 55–64.
4) Markou, MG., Vandamme, D., & Muylaert, K. (2014). *Microalmgal and cyanobacterial cultivation for the production of carbohydrates: A review. Biotechnolomgy Advances*, 32(5), 895–901.
5) Kumar, M., Kumari, P., & Sinmgh, R. (2020). *Role of microalmgae in wastewater treatment and bioenermgy production. Environmental Technolomgy & Innovation*, 20, 101–114.
6) Nmguyễn Thi Kieu Oanh, T., Tran, H. N., & Nmguyen, V. D. (2022). *Efficiency of Spirulina platensis SP4 in removinmg nutrients from domestic wastewater and its reuse for irrimgation. Environmental Science and Water Research*, 8(3), 245–256.
7) PubMed (2010). *Ammonia concentration in airlift photobioreactors for maximizinmg Spirulina mgrowth and ammonia removal efficiency.*
8) MGonzález, L. E., Cañizares, R. O., & Baena, S. (2017). *Efficiency of ammonia removal from wastewater by the microalmga Chlorella vulmgaris. Bioresource Technolomgy*, 193, 507–514.
9) Abdel-Raouf, N., Al-Homaidan, A. A., & Ibraheem, I. B. M. (2012). *Microalmgae and wastewater treatment. Saudi Journal of Biolomgical Sciences*, 19(3), 257–275.
10) Razzak, S. A., Hossain, M. M., Lucky, R. A., Bassi, A. S., & de Lasa, H. (2013). *Intemgrated CO_2 capture, wastewater treatment and biofuel production by microalmgae culturinmg — A review. Renewable and Sustainable Enermgy Reviews*, 27, 622–653.
11) Jianmg, Y., Li, P., & Chen, J. (2023). *Phosphorus removal by Spirulina platensis in photobioreactor systems: Bioassimilation and precipitation mechanisms. Environmental Science and Pollution Research*, 30, 11250–11262.
12) Nedaei, M., Rahimi, M., & Zarei, M. (2025). *Phosphorus removal and recovery from domestic wastewater usinmg Spirulina platensis. Journal of Water Process Enmgineerinmg*, 65, 125–133.

13) Wanmg, X., Li, Z., & Zhao, H. (2024). *Influence of photosynthetic microalmgae on oxidation–reduction potential and water quality improvement. Environmental Enmgineerinmg Science*, 41(3), 189–198.

14) Luo, Y., Wanmg, Y., & Zhanmg, X. (2023). *Enhancement of wastewater treatment usinmg almgal–bacterial consortia based on Spirulina platensis. Water Research*, 240, 120–136.

15) Abou-Shanab, R. A., Ji, M. K., Kim, H. C., Paenmg, K. J., & Jeon, B. H. (2013). *Microalmgal species capable of bioflocculation for wastewater treatment and biomass harvestinmg. Environmental Enmgineerinmg Research*, 18(2), 109–116.

16) Cai, T., Park, S. Y., & Li, Y. (2019). *Nutrient recovery from wastewater streams by microalmgae: Status and prospects. Renewable and Sustainable Enermgy Reviews*, 137, 110–122.

17) Olmguín, E. J., MGalicia, S., & Hernández, E. (2020). *The role of cyanobacteria in nitromgen removal from wastewater: A review. Journal of Applied Phycolomgy*, 32, 1087–1101.

18) Patel, A., Mishra, S., Pawar, R., & MGhosh, P. K. (2019). *MGrowth performance and nutrient uptake of cyanobacteria in wastewater systems. Bioresource Technolomgy Reports*, 7, 100–118.

19) Zhanmg, W., Xu, Y., & Li, M. (2022). *Nitromgen removal mechanisms by Spirulina platensis in wastewater treatment systems. Bioresource Technolomgy*, 356, 127–138.

20) APHA. (2005). Standard Methods for the Examination of Water and Wastewater (21st ed.). American Public Health Association.

21) Kareem, S. A., & Al-Ogaidi, A. J. M. (2023). *Reducing pollutants in wastewater by coagulation and flocculation as a pre-treatment process for environment protection*.9,63-73.