Open Access **Baghdad Science Journal** **P-ISSN: 2078-8665**
Published Online First: January, 2023 **2023, 20(4): 1218-1227** **E-ISSN: 2411-7986**

DOI: https://dx.doi.org/10.21123/bsj.2023.7457

Using microalga *Coelastrella* sp. to remove some nutrients from wastewater invitro

Muzhda Qasim Qader* ***Yahya Ahmed Shekha***

Environmental Science and Health Department, College of Science, Salahaddin University, Erbil, Iraq.
*Corresponding authors: mzhda.qadir@su.edu.krd
E-mail address: yahya.shekha@su.edu.krd

Received 26/3/2022, Revised 25/7/2022, Accepted 27/7/2022, Published Online First 20/1/2023, Published 1/8/2023

Abstract:

Microalgae have been increasingly used for wastewater treatment due to their capacity to assimilate nutrients. Samples of wastewater were taken from the Erbil wastewater channel near Dhahibha village in northern Iraq. The microalga *Coelastrella* sp. was used in three doses (0.2, 1, and 2g. l^{-1}) in this experiment for 21 days, samples were periodically (every 3 days) analyzed for physicochemical parameters such as pH, EC, Phosphate, Nitrate, and BOD_5, in addition to, Chlorophyll *a* concentration. Results showed that the highest dose $2g.l^{-1}$ was the most effective dose for removing nutrients, confirmed by significant differences ($p \leq 0.05$) between all doses. The highest removal percentage was recorded for ammonium pass 96% followed by NO_3 with 95%, while BOD_5 ranged from 88.7 to 93.5%. Decreases in nutrients coincided with an increase in chlorophyll-*a* content with the highest biomass on the 17th day of the experiment reaching 1.43 mg. l^{-1}.

Keywords: Algal bio-indication, Biomonitoring, Microalgae, Nutrient removal, Water quality, wastewater treatment.

Introduction:

Overuse of water in Erbil Governorate as a result of overpopulation, urbanization, industrialization, and water misuse resulted in a deficiency of this valuable resource, prompting the search for an alternate resource, which turned out to be wastewater [1]. Domestic and industrial wastewater, as well as runoff rainwater, make up urban wastewater [2]. Appropriate treatment of urban wastewater is required to protect human health and the environment. Erbil's wastewater system is a combination of sanitary sewage and stormwater [3]. The amount of sewage discharge changes depending on the season; on average, during the dry season, it reaches 77760 $m^3.day^{-1}$, while during the rainy season, it reaches 108000 $m^3.day^{-1}$ [4].

To prevent eutrophication, wastewater contains high quantities of nitrogen and phosphorus, which are routinely removed from the water. Nitrogen is released into the atmosphere by phosphorus precipitation and nitrification-denitrification processes, while phosphorus is wasted to the sludge [5].

Algae are common and necessary part of all stream ecosystems [6, 7]. They are the main source of energy for many food web streams, carbon fixing from the atmosphere by photosynthesis and transporting it through the web via consumer pathways. Due to their ecological importance and distinguishing characteristics, algae are suitable as indicators of nutrient pollution and also as assessment endpoints for developing numeric nutrient criteria for water quality management purposes under the Clean Water Act [8, 9]. Using microalgae for wastewater treatment is an old idea, and several researchers have devised methods for taking use of the algal rapid growth and nutrient-removal capabilities. The nutrient removal is due to the algae's assimilation of nutrients, although other nutrient stripping events, such as ammonia volatilization and phosphorus precipitation as a result of the algal high pH, also occur [10]. The appropriate nutrient concentration in any system is influenced by a number of factors, including microalgae species, current environmental conditions (light/temperature), the nature of the pilot system, and so on [11].

Treatment methods that combine carbon capture and wastewater treatment while emitting little or no carbon can be considered the most sustainable option [12]. Photosynthesis allows microalgae to produce biomass from light, CO_2, nutrients, and water [13]. Microalgae cultivation often generally requires a large number of nutrients that are readily available in home wastewater [14], and might potentially be obtained for free from wastewater. This can significantly lower the cost of microalgal cultivation, while also reducing pollution and conserving freshwater resources. Microalgal biomass, as a result, is more of a resource than a waste. As a result, utilizing microalgal biomass to treat household waste minimizes the need for sludge disposal and enhances the benefits of using microalgae to treat domestic waste. In order to develop an eco-friendlier wastewater treatment technique, this study attempts to analyze the efficacy of using golden microalga-*Coelastrella* sp. for nutrient removal in wastewater as a biological treatment.

Material method:

Cultivation of microalgae *Coelastrella* sp.

The microalga, *Coelastrella* sp., were isolated from Environmental Science and Health Department laboratory according to a previous investigation conducted by [15]. After identification microscopically depending on [16, 17]. The cells were coccoid, and elliptical until citriform. They appeared as unicellular microalgae or in few-celled aggregations. Cell size ranged between 8-10 µm in width and 9-14 µm in length [18]. Molecular identification was conducted through algal DNA extraction, amplification, sequencing, and comparing to the GenBank database, it was identified as *Coelastrella* sp. (MZ801742) [15]. The cells of *Coelastrella* sp. were cultured in BG11 broth medium in distilled water with light-emitting diode (LED) lamps at ambient temperature.

Experimental design of batch Cultivation

The water sample collection took place in Dhahibah village wastewater channel in Erbil north of Iraq. The wastewater samples were autoclaved for 15 minutes to eliminate bacteria and protozoa. The experiments were carried out in a batch reactor using 2L conical flasks. Each series of experiments began with 1200 mL of wastewater inoculated in flasks with pre-cultured *Coelastrella* sp. Three different fractions were prepared with different concentrations of air dried *Coelastrella* sp. to assess the efficiency of nutrient removal by *Coelastrella* sp. Wastewater with 0.2 g. l^{-1} *Coelastrella* sp. (run 1), wastewater with 1 g. l^{-1} *Coelastrella* sp. (run 2), wastewater with 2 g. l^{-1} *Coelastrella* sp (run 3). The experiments were carried out using municipal wastewater for 21 days at neutral and constant pH (7.5 ± 0.3), constant temperature of 25 ± 1°C, and at constant light intensity (3000 lux) [19].

Analytical Methods

All of the sampling and measurements took place at the same time of day. The dry weight (air dried) of microalgae produced per liter (g. l^{-1}) was used to compute biomass. The following approach was used to calculate the dry cell weight of the microalgal biomass: Before conducting the experiment, untreated wastewater was analyzed for physicochemical parameters. Once a day, 100 mL samples were taken and centrifuged at 3000 rpm. At a 21-day interval, the percentage of NO_3, NO_2, NH_3-N, PO_4-P, BOD_5 elimination, and growth rate were calculated. Samples were taken from flasks every day at the same time and centrifuged to separate algae. The BOD_5 was measured using standard methods at a certified laboratory [20]. All of the other analyses were used photometrically with a spectrometer (UV-Visible 1240; Tecator, Rodgau, Germany). The result of treatment measured as percentage according to this equation [21].

% Treatment=before treatment value- after treatment value/before treatment value×100

Estimation of chlorophyll-*a* concentration

To calculate chlorophyll-*a* concentration, 10 mL of culture was centrifuged at 3000 rpm for 5 minutes. The pellet was mixed with 5 mL of diethyl ether. The mixture was centrifuged at 3000 rpm for 5 minutes, and the absorbance of the supernatant was measured with a UV spectrometer (UV-Visible 1240; Tecator, Rodgau, Germany) at 660 and 643 nm [22].

Chlorophyll-*a* = $(9.92 * A_{660}) - (0.77 * A_{643})$

Statistical analysis:

Factorial analysis for parameters was performed by using (SPSS version 25) program and Excel spreadsheets.

The data were subjected to standard analysis of vari ance (Two-way ANOVA) and the Duncan test was used to compare means at a significant ($P \leq 0.05$) level [23].

Result and discussion:

The micro-alga, *Coelastrealla* sp. was used for the treatment of wastewaters collected from the Erbil wastewater channel near Dhahibha village. Some physicochemical parameters such as pH, EC, BOD_5, NO_3, NO_2, and PO_4 of wastewater were analyzed before treatment as control and after treatment with algae species for 21 days.

Before treatment (Control), the mean of initial values of pH, EC, BOD_5, PO_4, NH_4, NO_3, and NO_2 were 8.09, 912 µS/cm, 775, 23.7, 42.23, 23.7, and 8.94 mg. l^{-1}, respectively (Figs. 1-6). The pH value of wastewater at all doses (0.2g.l^{-1}, 1g.l^{-1}, and 2g.l^{-1}) was steadily increased by utilizing *Coelastrealla* sp., reaching 8.45, 8.52, and 8.65 (Fig. 1) after 21 days of treatment. The enhanced photosynthetic activity of algae or the chemical composition of water may both contribute to the alkaline tendencies [24-26]. Photosynthesis-induced increases in pH can accelerate the removal of nutrients via ammonia stripping or phosphorous precipitation, [27] showed that the pH of the wastewater sample treated with *Chlorella minutissima* was altered from 8.01 to 8.82, while the pH of the wastewater sample treated with *Scendesmus* sp. was changed from 8.01 to 9.09. pH changes can have a variety of effects on algal metabolism and growth, including changing the equilibrium of inorganic carbon species, modifying the availability of nutrients, and impacting cell physiology directly [27]. High pH values during the treatment period and interpreted the research that the values of the exponent of hydrogen of the medium increase if the ratio of phosphorus absorption into energy that is derived from the process of photosynthesis or respiration as influenced by the absorption of phosphorus by many factors most important of pH, temperature, and light intensity as it was observed that the pH increase by precipitating phosphorus as influenced by the absorption of phosphorus by precipitating phosphorus [28, 29]. Highest applied dose ($2 g.l^{-1}$) was more effective role for rises pH values than other doses.

The amount of substances (salts, minerals, metals, calcium, and other organic and inorganic compounds) that have been dissolved in the liquid is referred to as total dissolved solids (TDS). Total solids levels that are too high or too low can reduce the efficiency of wastewater treatment plants as well as the operation of process industries that use raw water. TDS concentration levels in wastewater typically ranged from 250 to 850 $mg.\ l^{-1}$. TDS variations have the same pattern as EC variations [30]. Salt ions typically affect microalgal cells via the ion homeostasis mechanism [31]. Conductivity is a general indicator of water quality, especially as the number of dissolved salts changes during wastewater treatment processes; changes in total salt concentration cause a change in conductivity [32]. As shown in Fig. 2, the EC values decreased to 353, 368, and 373.5 $\mu S.cm^{-1}$ which comprised (59.04, 59.64, and 61.2%) of removal percent respectively on the 21st day of treatment. TDS ratio decreased from 668 $mg.\ l^{-1}$ to 199.16 $mg.\ l^{-1}$ run1, 185.7 $mg.\ l^{-1}$ runn2, and 173.9 $mg.\ l^{-1}$ run3 on the 21st day. Generally, low level of salts may be facilitated photosynthesis by inorganic nutrient uptake and alkalinity tolerance [31]. The maximum reduction of TDS and EC by *Coellastrela* sp. occurred at the highest dose ($2 g.l^{-1}$) (Table 1).

On the 21st day of treatment, the maximal removal percentages of BOD_5 were, 93.54, 90.32, and 88.70 % respectively [33], found that BOD_5 removal was 61.38 % on the 10th day and 78.64 % in natural wastewater, and that percent removal with different algal doses (20g, 40g, 60g, 80g, 120g, and 140g) was 12, 69, 68, 44, 24, and zero, respectively. In contrast to [34], for pure wastewater the maximum removal of BOD_5 by *C. vulgaris* was 21.63%, while for 50% diluted wastewater, the maximum removal of BOD_5 was 30.36%. The lowest dose of algae, $0.2 g.l^{-1}$, is the most effective amount for removing BOD_5 (Fig. 3). As a result, even a small dose of *C. vulgaris* is sufficient to efficiently reduce BOD_5 in wastewater.

The most oxidized form of nitrogen compounds is nitrate. Nitrate determination aids in determining the nature and degree of oxidation in biological processes, as well as enhanced wastewater treatment [35]. In incubation of *Coelastrealla* sp. in wastewater showed that the minimum and maximum removal of NO_3 was occurred on 3rd day and 21st day respectively. The lowest reduction of NO_3 could be attributed to the nitrification process; algae prefer to assimilate N in the form of ammonia because it is a more passive and energy-efficient method of assimilation than nitrate uptake [26], or maybe because some nutritional elements, such as nitrate, are gradually consumed as *Coelastrealla* sp. grows, nitrate concentrations reduce. Results came in accordance with [36], which showed that *Monoraphidium* sp. removed NO_3 in wastewater by 51% and 95% in 5 days ; [37], determined that *Isochrysis zhanjiangenesis* removed 78% active phosphorous and 84.7% nitrate nitrogen in wastewater within 11 days; [38], showed that *Scenedesmus dimorphus*, *Selenastrum minutum*, and *Scenedesmus* sp. removed phosphate between 91% to 99% in mixed municipal and industrial wastewater ; [25], who reported that NO_3 and PO_4 removal were 87.6 %, and 90 %, respectively by *Chlorella* sp. in wastewater.

On the 21st day of treatment, the highest removal percentages of nutrients NO_2, NH_4, and PO_4 were 83.9, 96.6, and 93.1 %, respectively, at a $2 g.l^{-1}$ dose (Fig. 7). The maximum removal of NO_2 occurred on the 21st day, possibly due to an increase in pH values caused by photosynthesis, which can accelerate the removal of nutrients via ammonia stripping or phosphorous precipitation, which increases phosphate adsorption on microalgal cells [39-43], In wastewater, NH_3-N, nitrate, nitrite, and simple organic nitrogen such as urea, acetic acid, and amino acids can be assimilated by microalgae [44, 45]. Because microalgae cells require nitrogen for protein, nucleic acid, and phospholipid synthesis, microalgae growth is thought to be required for nitrogen removal via uptake, degradation, and sedimentation [46], also the micro-algal denitrification and nitrification processes [47]. Ammonia was the most preferable form of nitrogen used by microalgae with removal percent pass 96%. Same results were obtained by [48].

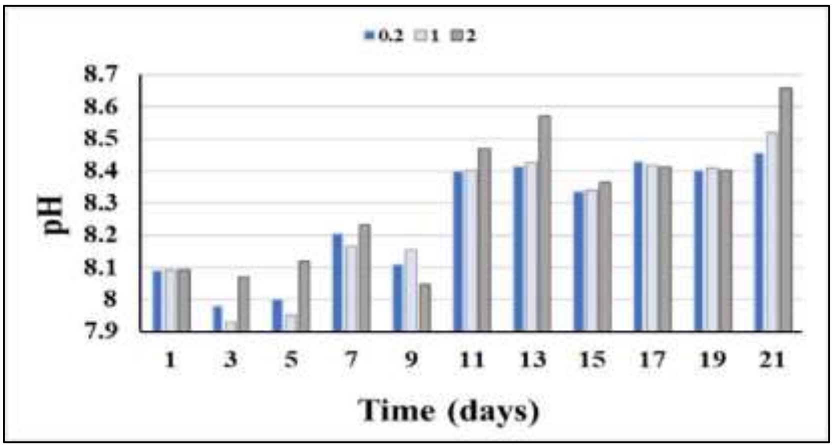

Figure 1. Effect of adding different doses of micro-algae *Coelastrella* sp. (0.2, 1, and 2 g. l^{-1}) on pH values of wastewater.

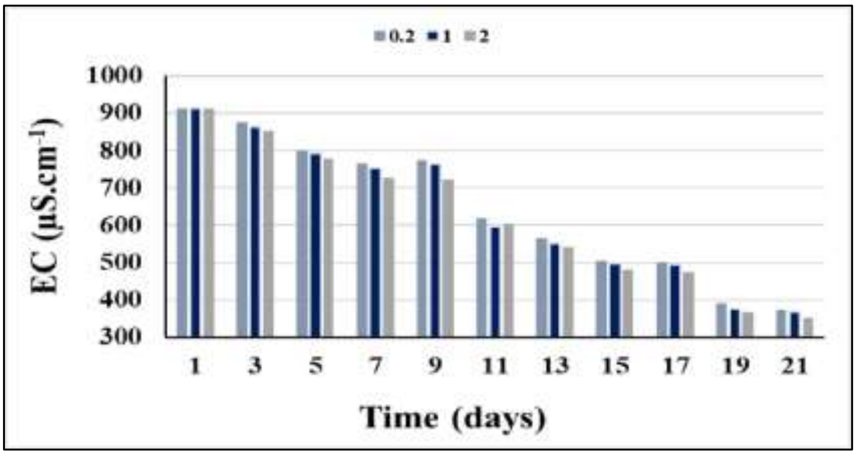

Figure 2. Effect of adding different doses of micro-algae *Coelastrella* sp. (0.2, 1, and 2 g. l^{-1}) on electrical conductivity values of wastewater.

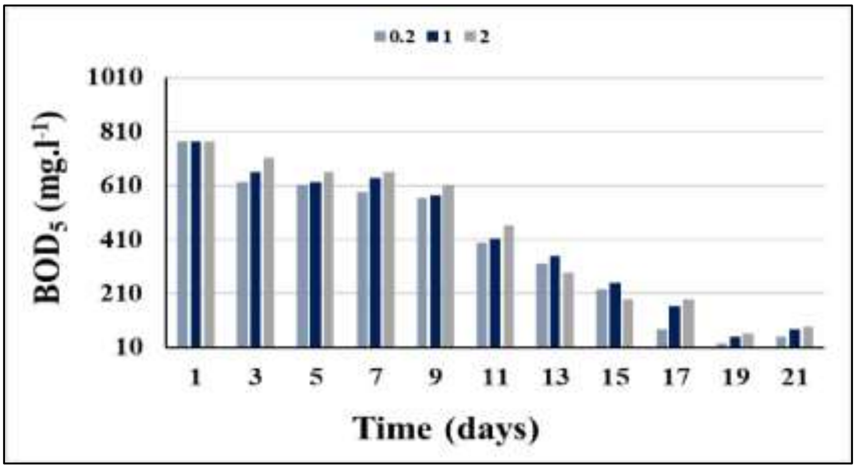

Figure 3. Effect of adding different doses of micro-algae *Coelastrella* sp. (0.2, 1, and 2 g. l^{-1}) on BOD_5 values of wastewater.

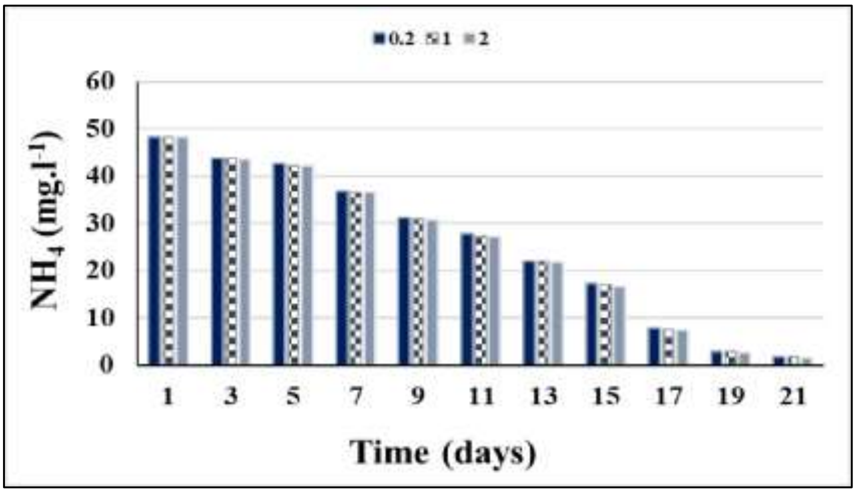

Figure 4. Effect of adding different doses of micro-algae *Coelastrella* sp. (0.2, 1, and 2 g. l^{-1}) on ammonium content values of wastewater.

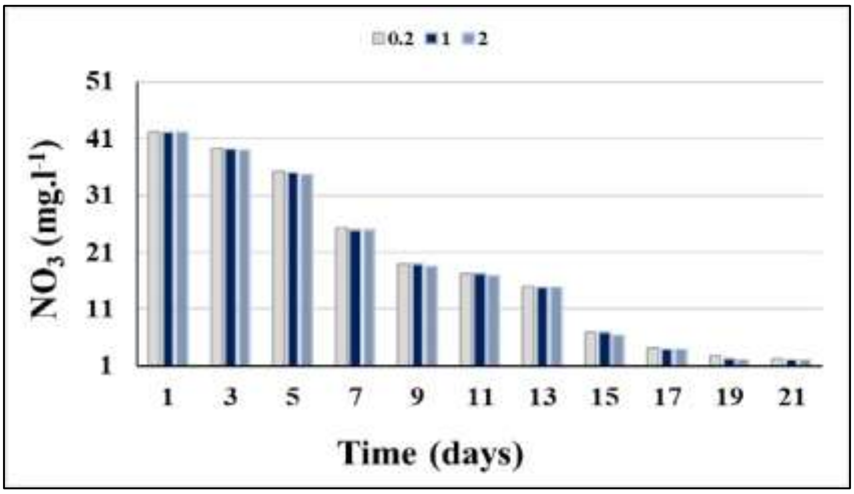

Figure 5. Effect of adding different doses of micro-algae *Coelastrella* sp. (0.2, 1, and 2 g. l^{-1}) on nitrate content values of wastewater.

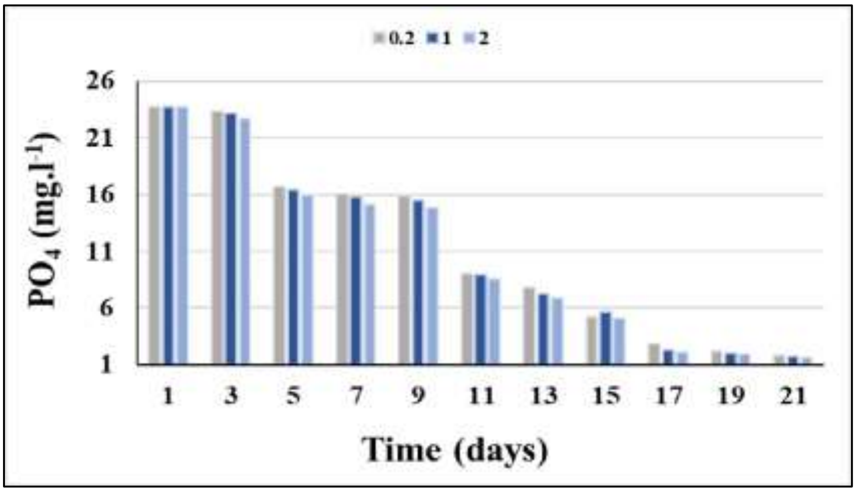

Figure 6. Effect of adding different doses of micro-algae *Coelastrella* sp. (0.2, 1, and 2 g. l^{-1}) on phosphate content values of wastewater.

Table 1. Effect of adding different doses (0.2, 1, and 2 g. l^{-1}) of micro-algae *Coelastrella* sp. on some tested wastewater variables, data represented as (Mean± S.E).

Parameters	D1(0.2g. l^{-1})	D2(1g. l^{-1})	D3(2g. l^{-1})
pH	8.25 ± 0.008^{b}	8.25 ± 0.008^{b}	8.31 ± 0.008^{b}
EC (µS.cm^{-1})	643.7 ± 0.82^{a}	632.7 ± 0.82^{b}	619.36 ± 0.82^{c}
TDS (mg. l^{-1})	409.9 ± 0.24^{a}	405.7 ± 0.24^{b}	398.49 ± 0.24^{c}
K (mg. l^{-1})	5.610 ± 0.13^{a}	5.480 ± 0.13^{b}	5.38 ± 0.13^{c}
NH_4(mg. l^{-1})	25.67 ± 0.1^{a}	25.47 ± 0.1^{b}	25.31 ± 0.1^{c}
NO_3 (mg. l^{-1})	19.07 ± 0.006^{a}	18.86 ± 0.006^{b}	18.65 ± 0.006^{c}
NO_2 (mg. l^{-1})	4.680 ± 0.009^{a}	4.12 ± 0.009^{c}	4.2 ± 0.009^{b}
PO_4 (mg. l^{-1})	11.32 ± 0.025^{a}	11.13 ± 0.025^{b}	10.79 ± 0.025^{c}
BOD_5 (mg. l^{-1})	386.9 ± 1.5^{c}	415.9 ± 1.5^{b}	427.27 ± 1.5^{a}
Chlorophyll *a* (mg. l^{-1})	0.631 ± 0.003^{c}	0.77 ± 0.003^{b}	0.981 ± 0.003^{a}

Note: Values in each column with different letters are significantly different at P<0.05. Values in rows with same letters are not significantly different.

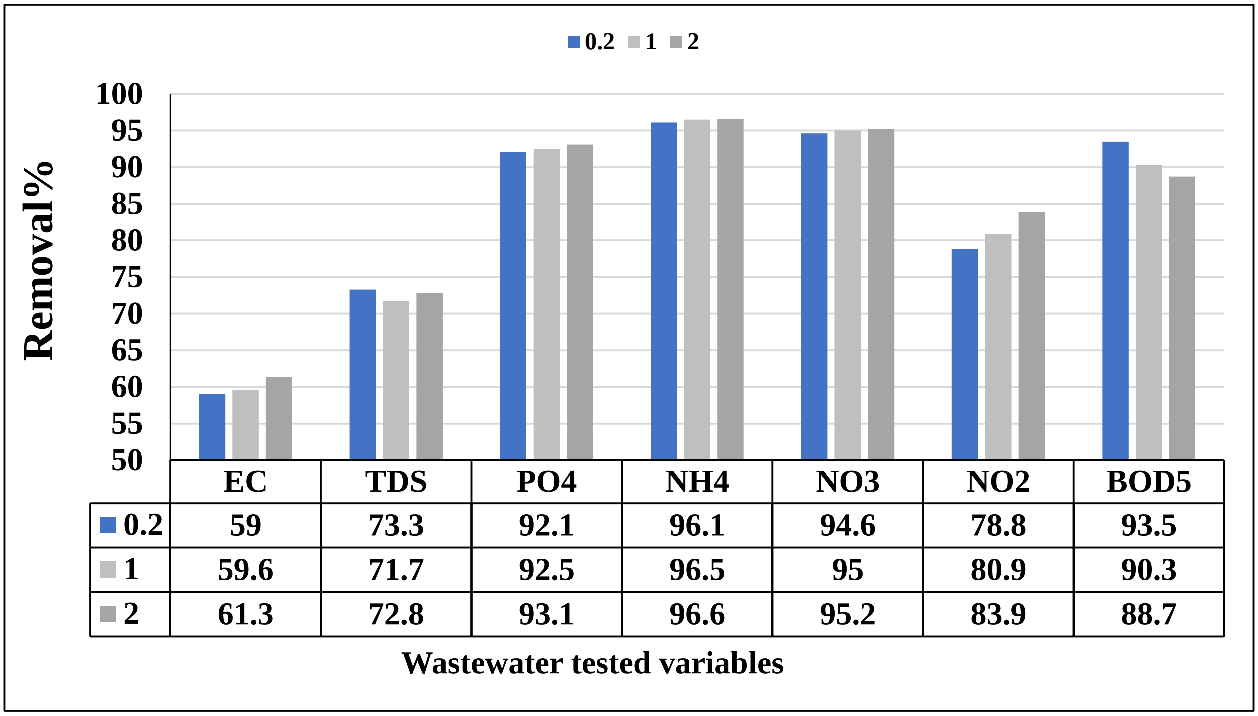

Figure 7. Percent removal from wastewater tested variables after adding three doses of micro-algae *Coelastrella* sp. (2, 1, and 0.2g. l^{-1}).

Algae prefer ammonia to nitrate, and nitrate consumption does not occur until the ammonium has been nearly completely consumed. Previous research revealed a ranking of tolerance to high levels of ammonium/ammonia (39-1.2 mM), with the order of tolerance being: Chlorophyceae > Cyanophyceae, Dinophyceae, Bacillariophyceae, and Raphidophyceae [48]. These findings also demonstrate that ammonical nitrogen removal is preferable to nitrite and nitrate nitrogen removal. In comparison to nitrite, the remaining NH_4-N concentration vanished quickly. After 9 days, the ammonium depletion from synthetic wastewater by *C. vulgaris* and *Scenedesmus rubescens*, respectively was comparable to experiments conducted by [49], who described ammonia elimination between (79 and 100 %) after 188.25 hrs. (about 8 days) , and [50], who recorded ammonium removal efficiencies of 90% from agro-industrial wastewater after 9 days. In the current study, microalgae-*Coelastrealla* sp. removed more than 93% of PO_4 from wastewater, which is a greater removal ratio than that reported by [51], who found that *Chlamydomonas* sp. removed 33% of PO_4 from wastewater.

Because of its critical "light-harvesting" role in photosynthesis, chlorophyll is abundant in nature and critical to the survival of both the plant and animal kingdoms [52]. With increasing doses of algae and treatment durations, nitrogen removal rises, followed by increases in algal biomass via chlorophyll *a* concentration. During the experiment, the amount of chlorophyll-*a* in the *Coelastrella* sp. treatments rose. For all doses, the starting value of chlorophyll *a* was 0.30 mg. l^{-1}, 0.31 mg. l^{-1}, and 0.54 mg. l^{-1} respectively. Then, on the 17th day, all doses 0.98 mg. l^{-1}, 1.08 mg. l^{-1}, and 1.43 mg. l^{-1} reached their maximum value (Fig. 8). On the 21st day of the experiment, all treatments observe a considerable decline in biomass and chlorophyll-*a*, indicating that the algae had reached the stage of death, and the number of algal cells decreased to 0.86 mg. l^{-1}, 1.008 mg. l^{-1}, and 1.25 mg. l^{-1}, accordingly. The maximum chlorophyll-*a* concentration was reported at the end of the treatment period, which could be due to algae's high nutrient consumption for metabolism and growth [53], with increases in pH values [54]. As the algal cell increases, the rate of nutrient increase, so algal biomass simply increases.

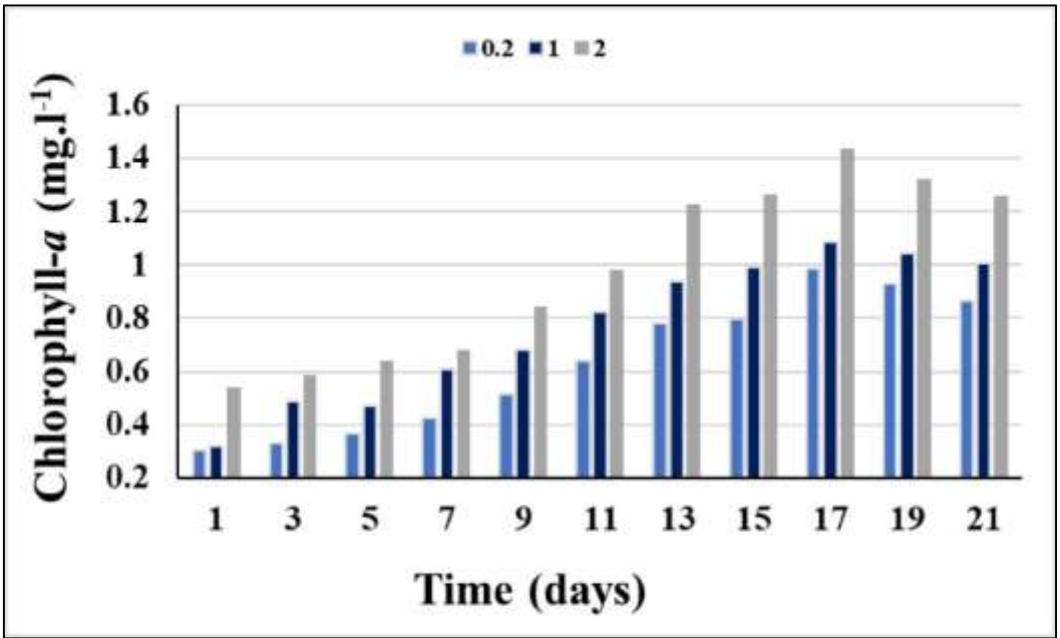

Figure 8. Effect of adding different doses of micro-algae *Coelastrella* sp. (0.2, 1, and 2 g. l^{-1}) on chlorophyll content values of wastewater.

Conclusion:

Finally, algae are increasingly being used to assess the health and ecological quality of aquatic ecosystems because they are relatively inexpensive and easy to measure, and they are sensitive to nutrient pollution, making them a potentially beneficial indicator of ecosystem change. Therefore, algae participate to a significant reduction in the concentrations of all nutrients, accompanied by an increase in their biomass. Also, ammonium nitrogen is a more preferable form of nitrogen for algae and have higher removable percentage than other form of nitrogen. Considerable removal of BOD_5 and dissolved salts (EC value) are observed.

Authors' declaration:

- Conflicts of Interest: None.
- We hereby confirm that all the Figures and Tables in the manuscript are mine ours. Besides, the Figures and images, which are not mine ours, have been given the permission for re-publication attached with the manuscript.
- Ethical Clearance: The project was approved by the local ethical committee in Environmental Science and Health Department, College of Science, Salahaddin University, Erbil, Iraq**.**

Authors' contributions statement:

Q, M. Q. contributed to collecting the samples, laboratory analyzing of samples and writing the manuscript. S, Y. A. contributed to the research design, statistical analysis, editing the final revision of the manuscript.

References:

1. Shekha YA, Al-Abaychi JK. Assessment of Monthly Variation of Two Water Bodies in Erbil Governorate. J Univ Zakho. 2013; 1(2): 821-31. https://sjuoz.uoz.edu.krd/index.php/sjuoz/article/view/402.
2. Kisser J, Wirth M, De Gusseme B, Van Eekert M, Zeeman G, Schoenborn A, et al. A review of nature-based solutions for resource recovery in cities. Blue-green syst. 2020;2(1):138-72. DOI: https://doi.org/10.2166/bgs.2020.930

3. Ganjo DG, Aziz FH, Shekha YA. An attempt for reuse of the wastewater of Erbil City for irrigation purposes. Erbil, Kurdistan Region of Iraq. I. Typha angustifolia L. macrophyte as a biological waste removal from wastewater. Zanco J Pure Appl Sci . 2006;18(2):148-75. https://www.researchgate.net/publication/271148051_An_attempt_for_reuse_of_the_wastewater_of_Erbil_City_for_irrigation_purposes_Erbil_Kurdistan_Region_of_Iraq_I_Typha_angustifolia_L_macrophyte_as_a_biological_waste_removal_from_wastewater.
4. Shekha YA, Haydar H, Al-Barzingy YOMJBSJ. The effect of wastewater disposal on the water quality and phytoplankton in Erbil wastewater channel. Baghdad Sci J 2010; 7(2): 984-93. https://doi.org/10.21123/bsj.2010.7.2.984-993.
5. Gonzalez-Camejo J, Aparicio S, Ruano M, Borrás L, Barat R, Ferrer J. Effect of ambient temperature variations on an indigenous microalgae-nitrifying bacteria culture dominated by Chlorella. Bioresour Technol. 2019; 290: 121788. https://doi.org/10.1016/j.biortech.2019.
6. Stevenson J. Ecological assessments with algae: a review and synthesis. J Phycol 2014; 50(3): 437-61.
7. Stevenson RJ, Smol JP. Use of algae in environmental assessments. Freshwater Algae of North America. 2003: 775-804. https://doi.org/10.1016/B978-012741550-5/50024-6.
8. USEPA U. Nutrient Criteria Technical Guidance Manual-Lakes and Reservoirs. 2000:8. https://doi.org/doi:10.7282/t3-6mra-wv76.
9. Baker MA, Bauer C, Bothwell M, Charles D, Fetscher B, Findlay S, et al. Nutrient Enrichment Indicators in Streams. US EPA . 2013:16-18 https://wwwepagov/sites/production/files/2013-09/documents/indicatorsworkshoppdf.
10. Hammouda O, Gaber A, Abdelraouf N. Microalgae and wastewater treatment. Ecotoxicol Environ Saf. 1995; 31(3): 205-10.
11. White D, Silkina A, Skill S, Oatley-Radcliffe D, Van Den Hende S, Ernst A, et al. Best practices for the pilot-scale cultivation of microalgae, public output report of the EnAlgae project. EnAlgae. 2015; Swansea. UK. http://dx.doi.org/10.25607/OBP-1046.
12. Mohammed K. Microalgal photobioreactors for carbon-efficient wastewater treatment: PhD (dissertation) School of Civil Engineering and Geosciences Newcastle University, United Kingdom http://hdl.handle.net/10443/2318; 2013.
13. Hsueh H, Li W, Chen H, Chu H. Carbon bio-fixation by photosynthesis of Thermosynechococcus sp. CL-1 and Nannochloropsis oculta. J Photochem Photobiol B Biol. 2009; 95(1): 33-9.
14. Yun YS, Lee SB, Park JM, Lee CI, Yang JW. Carbon dioxide fixation by algal cultivation using wastewater nutrients. J Chem Technol Biotechnol.1997; 69(4): 451-5.
15. Toma JJ, Aziz FH. Antibacterial activity of three algal genera against some pathogenic bacteria. Baghdad Sci J 2022: 7. 1-9. https://doi.org/10.21123/bsj.2022.6818.2022:1-9
16. Wehr JD, Sheath RG, Kociolek JP. Freshwater algae of North America: ecology and classification: Elsevier. 2nd Ed. Academic Press, San Diego. June 5, 2015 https://www.elsevier.com/books/freshwater-algae-of-north-america/wehr/978-0-12-385876-4
17. John DM, Whitton BA, Brook AJ, York PV, Johnson LR. The freshwater algal flora of the British Isles: an identification guide to freshwater and terrestrial algae:second edition. 702. Cambridge University Press.2002. http://assets.cambridge.org/97805211/93757/frontmatter/9780521193757_frontmatter.pdf
18. Uzunov BA, Stoyneva MP, Gärtner G, Kofler W. First record of Coelastrella species (Chlorophyta: Scenedesmaceae) in Bulgaria. Ber Naturwiss.-med Ver Innsb. 2008; 95: 27-34.
19. Razzak SA, Hossain MM, Lucky RA, Bassi AS, De Lasa HJR, Reviews SE. Integrated CO2 capture, wastewater treatment and biofuel production by microalgae culturing—a review. Renew Sust Energ Rev.2013; 27: 622-53.
20. Andrew D Eaton, Lenore S Clesceri, Arnold E Greenberg, Mary Ann H Franson, American Public Health Standard methods for the examination of water and wastewater. American public health association, Washington, DC; 1998. p. https://www.worldcat.org/title/standard-methods-for-the-examination-of-water-and-wastewater/oclc/40733179.
21. Al Ahmed SG. Dairy wastewater treatment using microalgae in Karbala city–Iraq. Int J Env Ecol Family Urban Stud. 2014; 4(2) : 13- 22.
22. Becker EW. Microalgae: biotechnology and microbiology: Cambridge University Press; 1994.
23. Gauvreau K. Principles of biostatistics. 2nd Ed. 584. CRC Press. 2018 https://www.amazon.com/Principles-Biostatistics-Marcello-Pagano/dp/1138593141.
24. Fathi AA, Azooz MM, Al-Fredan MA. Phycoremediation and the potential of sustainable algal biofuel production using wastewater. Am J Appl Sci. 2013; 10(2): 189. https://doi.org/10.3844/ajassp.2013.189.194
25. Hammouda O, Abdel-Raouf N, Shaaban M, Kamal M, Plant B. Treatment of mixed domestic-industrial wastewater using microalgae Chlorella sp. Am J Sci. 2015; 11(12): 303-15. http://www.dx.doi.org/10.7537/marsjas111215.38.
26. Sharma GK, Khan SA. Bioremediation of sewage wastewater using selective algae for manure production. Int J Environ Eng Manag. 2013; 4(6): 573-80. https://www.researchgate.net/publication/346670294_Bioremediation_of_sewage_wastewater_through_microalgae_Chlorella_minutissima.
27. Rawat I, Kumar R, Bux F. Phycoremediation by High-Rate Algal Ponds (H RAPs). Biotechnological Applications of Microalgae: Biodiesel Value-Added Products CRC Press, Boca Raton. 2013:179P. https://www.routledge.com/Biotechnological-

Applications-of-Microalgae-Biodiesel-and-Value-Added-Products/Bux/p/book/9780367380021.
28. Mostafa SS, Shalaby EA, Mahmoud GI. Cultivating microalgae in domestic wastewater for biodiesel production. Not Sci Biol. 2012; 4(1): 56-65. https://www.notulaebiologicae.ro/index.php/nsb/article/view/7298.
29. Tang EP, Vincent WF, Proulx D, Lessard P, Noüe Jdl. Polar cyanobacteria versus green algae for tertiary waste-water treatment in cool climates. J Appl Phycol. 1997; 9(4): 371-81. https://doi.org/10.1023/a:1007987127526.
30. Delrue F, Álvarez-Díaz PD, Fon-Sing S, Fleury G, Sassi J-F. The environmental biorefinery: Using microalgae to remediate wastewater, a win-win paradigm. Energies. 2016; 9(3): 132. https://doi.org/10.3390/en9030132.
31. Spellman F. Wastewater treatment. Handbook of Water Wastewater Treatment Plant Operations. 2003: 1-115. DOI: https://doi.org/10.1201/b15579.
32. Fallahi A, Hajinajaf N, Tavakoli O, Sarrafzadeh MH. Cultivation of mixed microalgae using municipal wastewater: biomass productivity, nutrient removal, and biochemical content. Iran J Biotechnol. 2020; 18(4): e2586. https://doi.org/10.30498/IJB.2020.2586.
33. Levlin E, Conductivity measurements for controlling municipal waste-water treatment. Proceedings of a polish-Swedish-Ukrainian seminar. Water, Sewage and Waste technology 2010.51-62. http://www2.lwr.kth.se/Forskningsprojekt/Polishproject/rep15/ConductV15.pdf
34. Krishnan A, Neera AL. Waste water treatment by algae. Int J Innov Res Sci Technol. 2013; 2(1): 286-93.Wastewater treatment by algae.Krishnan An/f58a7242cb4a11972c7a2e44acf372a7cc46f3ad.
35. Madadi R, Zahed MA, Pourbabaee AA, Tabatabaei M, Naghavi MR. Simultaneous phycoremediation of petrochemical wastewater and lipid production by Chlorella vulgaris. SN Appl Sci 2021; 3(4): 1-10. DOI:. https://doi.org/10.1007/s42452-021-04511-w
36. Bartram J, Ballance R. Water quality monitoring: a practical guide to the design and implementation of freshwater quality studies and monitoring programs: CRC Press. 1996. 383. https://www.taylorfrancis.com/books/mono/10.1201/9781003062110/water-quality-monitoring-jamie-bartram-richard-ballance.
37. Larsdotter K, Jansen JLC, Dalhammar G. Biologically mediated phosphorus precipitation in wastewater treatment with microalgae. Environ Technol. 2007; 28(9): 953-60. https://doi.org/10.1080/09593332808618855.
38. Zheng J, Hao JM, Wang B, Shui C. Bioremediation of aquiculture wastewater by microalgae Isochrysis zhanjian genesis and production of the biomass material. Key Eng Mater. 2011; 460: 491-495. https://www.tib.eu/en/search/id/BLSE:RN287021068/Bioremediation-of-Aquiculture-Wastewater-by-Microalgae?cHash=2529ba5e73323c8deab4897e00882c3a
39. Gentili FG. Microalgal biomass and lipid production in mixed municipal, dairy, pulp and paper wastewater together with added flue gases. Bioresour Technol. 2014; 169: 27-32. https://doi.org/10.1016/j.biortech.2014.06.061.
40. Bux F. Biotechnological applications of microalgae: biodiesel and value-added products: CRC Press; Boca Raton, Florida. 2013. 239p. https://doi.org/10.1111/jpy.12233
41. Ruiz-Marin A, Mendoza-Espinosa LG, Stephenson T. Growth and nutrient removal in free and immobilized green algae in batch and semi-continuous cultures treating real wastewater. Bioresour Technol. 2010; 101(1): 58-64. https://doi.org/10.1016/j.biortech.2009.02.076.
42. Carrillo V, Fuentes B, Gómez G, Vidal G. Characterization and recovery of phosphorus from wastewater by combined technologies. Rev Environ Sci. 2020; 19(2): 389-418. https://doi.org/10.1007/s11157-020-09533-1.
43. Rajesh Banu J, Merrylin J, Kavitha S, Yukesh Kannah R, Selvakumar P, Gopikumar S, et al. Trends in biological nutrient removal for the treatment of low strength organic wastewaters. Curr Pollut Rep. 2021; 7(1): 1-30. DOI: https://doi.org/10.1007/s40726-020-00169-x.
44. Tao R. Nutrient and organic matter removal from wastewaters with microalgae: 177. Paris Est.; Tampereen yliopisto, 2019. http://urn.fi/URN:NBN:fi:tuni-201906192108
45. Barsanti L, Gualtieri P. Algae: anatomy, biochemistry, and biotechnology: CRC press. J Phycol. 2007; 43(2): 412–414. https://doi.org/10.1111/j.1529-8817.2007. 00335.x; 2005.
46. Huo S, Wang Z, Zhu S, Zhou W, Dong R, Yuan Z. Cultivation of Chlorella zofingiensis in bench-scale outdoor ponds by regulation of pH using dairy wastewater in winter, South China. Bioresour Technol. 2012; 121: 76-82. https://doi.org/10.1016/j.biortech.2012.07.012.
47. Zimmo O, Van Der Steen N, Gijzen HJ. Comparison of ammonia volatilisation rates in algae and duckweed-based waste stabilisation ponds treating domestic wastewater. Water Res. 2003; 37(19): 4587-94. https://pubmed.ncbi.nlm.nih.gov/14568043/.
48. Durai G, Rajasimman M. Biological treatment of tannery wastewater-a review. J Environ Sci Technol. 2011; 4(1): 1-17. DOI: https://doi.org/0.3923/jest.2011.1.17.
49. Ghaidaa H, Al-Hiyaly S. Evaluation of Cyanobacteria efficiency in nutrient removal from Al-Rustamiah wastewater treatment plant, South of Baghdad, Iraq. Plant Arch. 2020; 20 Supplement 1: 3469-3475 http://www.plantarchives.org/SPECIAL%20ISSUE%2020-1/3469-75%20(443).pdf.
50. Martınez M, Sánchez S, Jimenez J, El Yousfi F, Munoz L. Nitrogen and phosphorus removal from urban wastewater by the microalga Scenedesmus obliquus. Bioresour Technol. 2000; 73(3): 263-72. https://doi.org/10.1007/s10811-006-9148-1.

51. González LE, Cañizares RO, Baena S. Efficiency of ammonia and phosphorus removal from a Colombian agroindustrial wastewater by the microalgae Chlorella vulgaris and Scenedesmus dimorphus. Bioresour Technol. 1997; 60(3): 259-62. DOI:10.1016/S0960-8524(97)00029-1.
52. Wu LF, Chen PC, Huang AP, Lee CM. The feasibility of biodiesel production by microalgae using industrial wastewater. Bioresour Technol. 2012; 113: 14-8. https://doi.org/0.1016/j.biortech.2011.12.128.
53. Humphrey A. Chlorophyll as a color and functional ingredient. J Food Sci. 2004; 69(5): C422-C5. https://doi.org/10.1111/j.365-2621.004.tb10710.x.
54. Samorì G, Samorì C, Guerrini F, Pistocchi R. Growth and nitrogen removal capacity of Desmodesmus communis and of a natural microalgae consortium in a batch culture system in view of urban wastewater treatment: part I. Water Res. 2013; 47(2): 791-801. https://doi.org/10.1016/j.watres.2012.11.006.
55. Lee S-A, Ko S-R, Lee N, Lee J-W, Van Le V, Oh H-M, et al. Two-step microalgal (Coelastrella sp.) treatment of raw piggery wastewater resulting in higher lipid and triacylglycerol levels for possible production of higher-quality biodiesel. Bioresour Technol. 2021; 332: 125081. https://doi.org/10.1016/j.biortech.2021.

استخدام الطحلب *Coelastrella* sp. للتخلص من بعض المغذيات من مياه الصرف الصحي

موژده قاسم قادر **يحيى أحمد شيخه**

قسم العلوم البيئة والصحة، كلية العلوم، جامعة صلاح الدين، أربيل، العراق.

الخلاصة:
تم استخدام الطحالب الدقيقة بشكل متزايد في معالجة مياه الصرف الصحي نظرًا لقدرتها على استيعاب العناصر الغذائية. تم أخذ عينات من مياه الصرف الصحي من قناة الصرف الصحي لمدينة أربيل قرب قرية ذهيبه. *Coelastrella* sp. تم استخدامه في ثلاث جرعات (0.2، 1 ، و 2 غم. لتر $^{-1}$) في هذه التجربة لمدة 21 يومًا ، تم تحليل العينات بشكل دوري (كل 3 أيام) من أجل تقدير خصائص الفيزيائية والكيميائية للمياه مثل الأس الهيدروجيني ، والتوصيل الكهربائي ، والفوسفات ، والنترات ، والمتطلب الحيوي للأوكسجين BOD_5 باستخدام الطرق القياسية ، فضلا عن تحديد كمية الكلوروفيل a. أظهرت النتائج أن أعلى جرعة (2 غم. لتر $^{-1}$) كانت الأكثر فاعلية في إزالة أعلى معدل للعناصر الغذائية ، وأكدتها أحصائيا الفروقات المعنوية ($p \leq 0.05$) بين جميع الجرعات. تم تسجيل أعلى نسبة إزالة الأمونيوم بنسبة تجاوزت 96٪ يليه NO_3 بنسبة 95٪ ، بينما تراوح نسبة ازالة BOD_5 من 88.7 إلى 93.5٪. تزامن الانخفاض في المغذيات مع زيادة محتوى الكلوروفيلي مع أعلى كتلة حيوية في اليوم السابع عشر من التجربة 1.43 ملغم. لتر $^{-1}$.

الكلمات المفتاحية: المؤشرات الحيوية للطحالب ، الرصد الحيوي ، الطحالب الدقيقة ، إزالة المغذيات، جودة المياه ، معالجة مياه الصرف الصحي.