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A Study of Some Physicochemical Properties and Non-diatomic Algae in Industrial Wastewater a Leather Factory, Baghdad, Iraq

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Abstract
The study included the ecology and classification of non-diatom phytoplankton in the biological treatment ponds of a leather factory in the tannery in Baghdad. Water and algae samples were taken from three ponds within the factory during the autumn of 2025, with three replicates per site. Some properties (chemical and physical) were measured: water temperature, pH, total suspended solids, and nutrients, including phosphates, nitrates, and two heavy metals: chromium and lead. The results showed slight variations in temperature and pH (27.277-29.177°C and 8.200-7.267, respectively); total suspended solids were recorded at 47.000-80.467 mg/L, while the nutrients showed high concentrations. Phosphate ranged from 2056.600 to 4521.600 mg/L, and nitrates from 1424.333 to 688.533 mg/L. Heavy metals, particularly chromium and lead, were recorded at elevated concentrations, especially in the final treatment pond. The study diagnosed 19 genera, including 29 species of planktonic algae. Cyanophyta constituted the largest percentage (13 genera, 22 species), followed by Chlorophyta (3 genera, 4 species), while Pyrrophyta, Chrysophyceae, and Cryptophyta algae recorded a percentage of represented by one genus and species. The study demonstrated that blue-green algae were the dominant species, owing to their higher tolerance to pollutants present in the treatment basins. These dominant species can potentially be isolated and cultured for use in biological treatment applications.
Keywords: Physicochemical properties, non-diatomic algae, heavy metals, wastewater, leather industry.

1. Introduction

According to the 2021 World Water Development Report (WWDR) published by the United Nations Educational, Scientific, and Cultural Organization (UNESCO), the rate of increase of freshwater use worldwide has increased by more than six times (600 percent) in the last century, along with the rate of consumption, which has increased by nearly 1 percent annually since the 1980s.[1]. Increased usage of freshwater is creating serious water quality issues due to environmental pollution and degradation caused primarily by industrial and agricultural production as well as urban growth. Pollution and degradation of freshwater resources have severely affected aquatic ecosystems and have therefore had direct negative impacts on humans, the prospects of sustainable development, and the properties (including physical, chemical, and biological) of freshwater resources. [2,3].

The leather industry is essential to the global economy and produces various types of durable, valuable merchandise, including apparel, automotive accessories, and furniture. To create leather products, one must undergo a tanning process that stabilizes collagen fibers through a chemical reaction, making them more resistant to damage from the elements and degradation over time. Although there are many different methods of tanning leather, chrome tanning has always been the dominant method for about one and a half centuries, as chrome provides leather with many protection and durability properties that allow it to perform so well under high-temperature and humidity extremes. It is estimated that approximately 90% of all leather produced globally is chrome-tanned and involves the bonding of trivalent chromium ions (Cr^{3+}) to both carboxyl and amino groups of collagen fibers. Chromium is considered one of the major sources of hazardous pollutants that could be released into wastewater from industrial processes[4, 5].

Synthetic dyes released from tanneries such as these contain environmentally damaging contaminants in the form of complex chemical compounds with toxic characteristics, making them difficult to remove from the environment. Recently, bioremediation methods, particularly the use of living organisms such as algae, have been developed and implemented to help reduce environmental contamination caused by
dyes[6, 7].

Algal treatment (phycoremediation or algae-based remediation) is a low-cost, environmentally friendly, and sustainable method for tackling dyes using an algae plant (algae). The metabolic pathways of algae allow for the absorption, biodegradation, and/or transformation of the dye pollutants into less harmful compounds. Additionally, the process of using algae to treat wastewater contributes to the production of oxygen and nutrient cycling in the lake environment, making algae a good option for treating contaminated water through an integrated approach.[8].

Algae are water-based organisms that can store plants' nourishment, in addition to keeping toxic elements such as pesticides and organic/inorganic substances, which is why they are regarded as an option to refine waste biologically.[9]. Algae have been shown to effectively filter synthetic dyes from contaminated bodies of water due to many parameters, including accumulation, adsorption, enzymatic action, and the sun's rays.[10]. In addition, they also have been shown to accumulate heavy metal ions and degrade triglyceride compounds and xenobiotics in the environment. Recently, researchers are looking to microalgae to treat wastewater because of how they absorb CO_2 and their use in biomass for energy and their use in the production of antibiotics[11-13].

Despite the ecological importance of phytoplankton in wastewater treatment systems, limited studies have focused on the environmental and taxonomic characteristics of non-diatom phytoplankton in biological treatment ponds of leather industries in Iraq. Therefore, the present study aims to evaluate the physicochemical characteristics of treatment ponds and to investigate the diversity and taxonomic composition of non-diatom phytoplankton, as well as to assess their relationship with environmental variables and their potential role as bioindicators of industrial wastewater pollution.

2. Materials and Methods

In order to measure the physicochemical variables[14], samples of water and algae were obtained (to a limited extent) from three different locations of the biological treatment ponds located at the tannery site (associated with a particular leather factory), one of several factories owned by the General Company for Textile and Leather Industries based out of Baghdad, Zaafaraniya (**Figure 1**). Samples were collected in tightly closed sterile polyethylene containers with a one-liter capacity on one occasion during October 2025, using three separate containers at each location. The sample located within the first container of each site was the water sample intended for analysis. Physicochemical parameters were measured according to 14 standard methods. In the case of the second and third bottles, the algae samples were collected with the aid of a plankton net of 20 µ in diameter and were accumulated after they had been thrown and collected into a column. Each of the biological treatment basins in each refinery contained water that had been through several rounds of biological treatment to maximize the collection of as many species of phytoplankton as possible. Before placing the samples into the second bottle, to conserve the algal samples, we added several drops of Lugol's to the second bottle for all of the sites, while the third bottle remained untreated. When the samples were returned to the laboratory, they were treated to ultraviolet sterilization to destroy any remaining microorganisms (bacteria and fungi) and were incubated at acceptable growth temperature within dedicated incubators in order to allow the algal cultures to expand. Slides were created from the algal samples preserved temporarily in order to be able to identify the phytoplankton species using some type of light microscope and to sort through the various types of phytoplankton present in each sample[15-17].

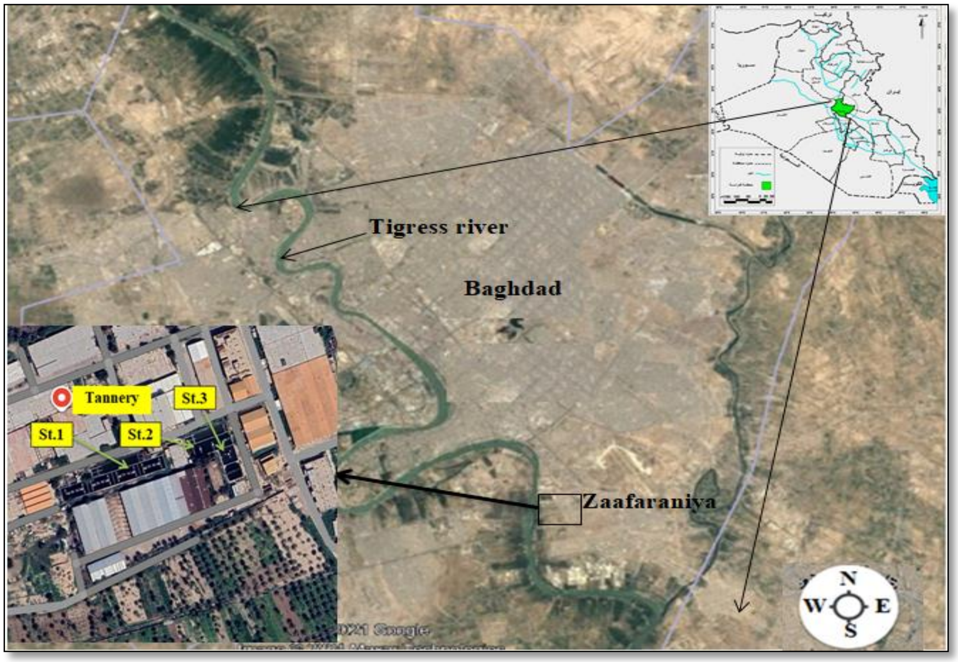

Figure 1. Satellite image of Iraq marked with the locations of collected algae from biological treatment pond from tannery site, Zaafarania, Baghdad.

Statistical analysis was performed using SPSS software (version 19). One-way ANOVA was used to evaluate differences among sampling sites at a significance level of $p \leq 0.05$. Mean values and standard deviations were calculated for all variables. Duncan's multiple range test was applied to determine significant differences among sites. All measurements were conducted in triplicate.

3. Results

Significant spatial variations were observed among the three treatment ponds in physicochemical characteristics and phytoplankton diversity. The temperature of the water at these sites did vary slightly. Site 2 had the highest mean temperature of 29.177°C, and the lowest mean temperature was recorded at site 3, where the mean was 27.277°C. All three treatment ponds contain alkaline waters. The pH values from each site were very similar to each other, but Site 3 did have the highest pH of 8.200, and Site 2 had the lowest pH of 7.267.

Liquid effluents from tannery and leather manufacturing activities are often heavily polluted with materials that have a large number of soluble ionic constituents, which increases the TSS levels in biological treatment ponds[22-24]. The highest concentration of TSS noted during this study occurred at Site 3 (80.467 mg/L) while the lowest occurred at Site 1 (47.000 mg/L). There were significant statistical differences in TSS concentrations across the sites.

The highest amounts of phosphates (4521.600 mg/L) and nitrates (1424.333 mg/L) were found at site three, while site one had the lowest (2056.600 mg/L for phosphates & 688.533 mg/L for nitrates). Statistically, there were considerable differences among the three sites when compared with each other.

Industrial wastewater contains many different types of heavy metal pollutants, most notably lead and chromium. The majority of chromium and lead were released from leather tanneries in degrees Celsius; the first group was collected from all sites, and Site 3 had 132.400 mg/L of chromium and 65.533 mg/L of lead, while Site 1 had 104.400 mg/L of chromium and 33.400 mg/L of lead[27,28]. Statistical analysis demonstrated that each individual site contained significant differences in chromium concentration (**Table 1**).

Table 1. Rates of physicochemical variables measured in water from three biological treatment ponds for tannery site belonging to the leather factory, Baghdad / Iraq.

Factor	**St1 (Mean ± SE, Min–Max)**	**St2 (Mean ± SE, Min–Max)**	**St3 (Mean ± SE, Min–Max)**	**p-value**	**Sig**
Water Temp °C	28.167 ± 0.726 (27.0–29.5)	29.177 ± 0.608 (28.0–30.03)	27.277 ± 0.534 (26.5–28.3)	0.182	NS
pH	7.400 ± 0.416 (6.6–8.0)	7.267 ± 0.467 (6.4–8.0)	8.200 ± 0.493 (7.3–9.0)	0.363	NS
TSS (mg/L)	47.000 ± 0.577 (46.0–48.0)	66.333 ± 0.441 (65.5–67.0)	80.467 ± 0.393 (79.7–81.0)	0.001	*
PO_4(mg/L)	2056.600 ± 0.351 (2055.9–2057.0)	3202.533 ± 0.371 (3201.8–3203.0)	4521.600 ± 0.351 (4520.9–4522.0)	0.001	*
NO_3(mg/L)	688.533 ± 0.371 (687.8–689.0)	985.053 ± 0.554 (984.08–986.0)	1424.333 ± 0.441 (1423.5–1425.0)	0.001	*
Cr(mg/L)	104.400 ± 0.416 (103.6–105.0)	120.400 ± 0.416 (119.6–121.0)	132.400 ± 0.416 (131.6–133.0)	0.001	*
Pb (mg/L)	33.400 ± 0.416 (32.6–34.0)	42.400 ± 0.416 (41.6–43.0)	65.533 ± 0.371 (64.8–66.0)	0.001	*

*Significant differences at a probability levels $p \leq 0.05$.
NS: Non-significant.

The study diagnosed 19 genera including 29 species of non-ditomic algae, Chyanophyta constituted the largest percentage (13 genera, 22 species), followed by Chlorophyta (3 genera, 4 species), while Pyrrophyta, Chrysophyceae and Cryptophyta algae recorded a percentage of represented by one genus and species (**Figure 2, Table 2**).
The highest number of species was recorded at site three, with 19 species, followed by site one with 10 species, while the fewest species were recorded at site two, with only 4 species **Table 2**.

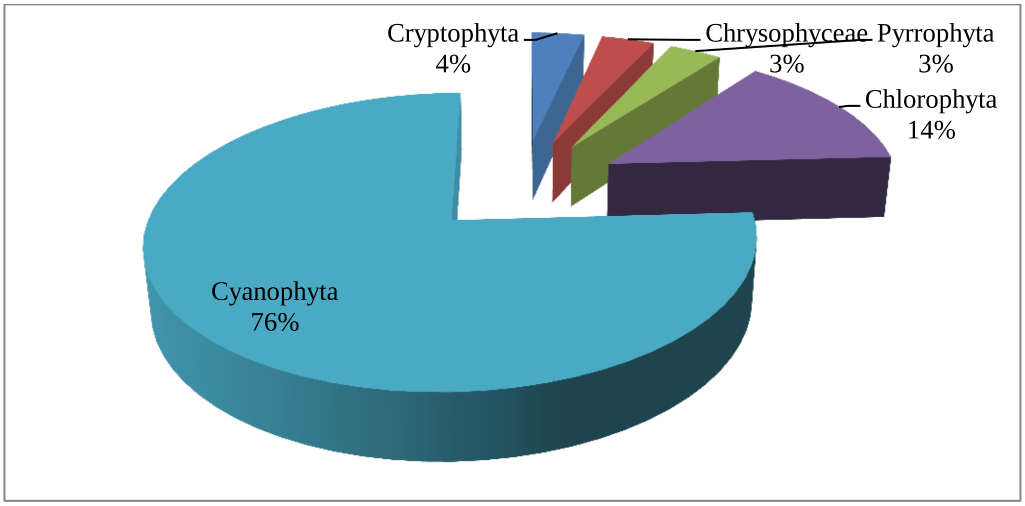

Figure 2. Percentages of algae species diagnosed at the three sites.

Table 2. The number of genera and species in the different study sites.

Station Taxa		St.1	St.2	St.3
Division : CYANOPHYTA 1-Order: Chroococales				
1.	*Aphanothece microscopica* Naegeli			+
2.	*Aphanothece nidularis* P. Richter			+
3.	*Aphanothece stagnina* (Sprengel)	+	+	+
4.	*Chroococcus giganteus* West and West	+		+
5.	*Chroococcus limneticus* var *elegans* G.S.Smith	+		
6.	*Chroococcus turgidus* (Ktz.) Naegeli	+		
7.	*Coelosphaerium dubium* Grunow			+
8.	*Dactylococcopsis acicularis* Lemmermann		+	
9.	*Gloeocapsa* sp	+		
10.	*Gomphosphaeria Lacustris* Chodat			+
11.	*Microcystis aeruginosa* Kuetzing	+		+
12.	*Microcystis inserta* Lemmermann	-	-	+
2-Order Oscillatoriales				
13.	*Arthrospira massarti* Kuffareth			+
14.	*Oscillatoria prolifica* (Grev.) Gomont			+
15.	*Oscillatoria tenuis* Agardh.	+		
16.	*Oscillatoria tenuis* var. *tergestina* Rabenhorst			+
17.	*Phormidium ambiguum* Gomont.			+
18.	*Phormidium mucicola* Huber-pest and Naumann			+
19.	*Phormidium* sp.	+		
3- Order : Nostocales				
20.	*Anabaena affinias* Lemmermann.	+		
21.	*Cylindrospermum majus* Kuetzing			+
22.	*Nodularia spumigena* Martens in Jergens			+
Division Pyrrophyta				
23.	*Glenodinium gymnodinium* Penard	+		
Division : CHLOROPHYTA Class: Chlorophyceae Order: Chlorococcales				
24.	*Chlamydomonas* sp.			+
25.	*Scenedesmus bijuga* var. *alternan* (Reinsch)Borge			+
26.	*Scenedesmus denticulatus* Laghereim			+
27.	*Tetraedron trigonum* (Naeg.) Hansg.			+
DIVISION: Chrysophyceae				
28.	*Mallomonas* sp.		+	
DIVISION: CRYPTONEMALES				
29.	*Cryptomonas*		+	

4. Discussion

The sampling design used in this study, which included three biological treatment ponds representing different stages of wastewater treatment, was appropriate for evaluating the ecological distribution of non-diatom phytoplankton. The selected physicochemical parameters such as nutrients and heavy metals are known to influence algal community composition and therefore were sufficient to achieve the study objectives.

The temperature of the aquatic environment is one of the key parameters affecting aquatic ecosystems because it physically changes the water's properties, and it will impact every organism living in aquatic ecosystems. Additionally, temperature impacts all behavioral and physiological functions of organisms, which dictates where those organisms can live around the world; in this way, temperature will affect the distribution of organisms. For example, the temperature oscillation directly impacts the growth rates of algae, and as a general rule of thumb, most algal cells benefit from optimal growth conditions when the temperature is between15 and 25ºC[18, 19]. PH is an important variable that determines the physical and chemical characteristics of a given water body. In addition, pH gives an indication of what organisms can live in that water body or not. Water purity, flow patterns, climatic variations, and human waste production all have an effect on vannature and, therefore, water temp[20]. Climate change may alter water temperature and pH, which directly influence algal metabolism, growth, and distribution. Increased temperatures may enhance Cyanophyta growth due to their higher tolerance to environmental stress. Based on statistical analysis (Table 1), temperature and pH at all three sites were not statistically significantly different due to the close proximity of each pond, as well as their similar environmental conditions and shallow depths. Each pond can be described as a small static water body[18], [21]. Liquid effluents from tannery and leather manufacturing activities are often heavily polluted with materials that have a large number of soluble ionic constituents, which increases the TSS levels in biological treatment ponds[22-23-24.] The increased TSS at site 3 was likely due to the shallower pond depth at this Site coupled with the collection procedure that disturbed the bottom sediments, causing greater suspension of the particles within the water column. The amount of nutrients found in all three biological treatment ponds was higher than average, especially phosphates and nitrates.

Bioreactor studies performed prior to this one has shown that biological treatment ponds at tanneries & oil refineries are typically enhanced by ammonia & phosphate additions, which yield ions in solution that serve as the principal food for algae, leading to a significant increase in algae's ability to grow, multiply, and actively participate in the treatment of contaminated water[25,26].

Industrial wastewater contains many different types of heavy metal pollutants, most notably lead and chromium. The reasons for elevated chromium levels at each site can be attributed to the use of chromium to increase the strength of leather through tanning. Unlike chromium, lead is a contaminant associated with the combustion of fuels that occurs during the operation of machinery used in the leather industry and other types of tanning processes, and eventually all wastewater from tanneries is disposed of in the bioremediation ponds of the sites included in this study[29].

The high concentrations of nutrients such as nitrate and phosphate observed in the treatment ponds contributed significantly to the dominance of Cyanophyta species. These algae are known to tolerate polluted environments and utilize high nutrient levels efficiently. Similarly, elevated heavy metal concentrations, particularly chromium and lead, created stressful environmental conditions that favored pollution-tolerant species, especially Cyanophyta, over other phytoplankton groups.

Consistent with these environmental conditions, the classified algae showed that most genera belong to Cyanophyta. It was observed a clear dominance of Cyanophyta species in terms of the number of genera and species in the study[30 31]. This is due to their physiological nature, as they are able to tolerate different environmental conditions and can live in places with high organic pollution. They also have a high capacity for removing harmful pollutants[30]. The availability of algal growth-promoting factors such as nitrogen and phosphates contributed to an increase in the number of species relative to the number of genera identified in the third site. This site is characterized by its small size compared to the first basin, low water levels, shallow depth, and the presence of algal clumps at the bottom[31]. The second site is characterized by being a small, deep basin, approximately 5 meters long and 2 meters wide, with a very high-water level and oil slicks. These conditions—low light, high depth, and high levels of oil pollutants led to a decrease in algal species. This site serves as a storage unit for treated water transferred from the first basin (the first site) to the last basin (the third site)[32]. These results are consistent with those reported by[33] in their study of the biological treatment basins at the Al-Dura refinery. The result shows that most of the identified species belong to the order Chroococales of Cyanophyta; they are characterized by their gelatinous, clustered colonies, which are more resistant to environmental conditions and high levels of pollution[34]. Dissolved oxygen and BOD were not measured in the present study due to the nature of the treatment ponds and the focus on algal community structure; however, they are recommended for future investigations. Carbon dioxide

concentration was not directly measured; however, the high abundance of phytoplankton, especially Cyanophyta, indicates active CO_2 uptake during photosynthesis. Future studies are recommended to quantify CO_2 removal efficiency in these ponds.
One limitation of this study is that sampling was conducted during a single period. Therefore, the results represent baseline environmental conditions. Seasonal variations may influence physicochemical parameters and phytoplankton distribution. Future studies are recommended to include multi-season sampling.

5. Conclusion

This study demonstrated significant variations in physicochemical characteristics and phytoplankton diversity among biological treatment ponds of tannery wastewater. Cyanophyta showed clear dominance due to their high tolerance to pollution and elevated nutrient levels. Their abundance confirms their usefulness as reliable bioindicators of wastewater quality and highlights their potential role in biological treatment and environmental monitoring of industrial wastewater. Cyanophyta possess physiological adaptations such as tolerance to heavy metals, ability to grow under high-nutrient conditions, and resistance to environmental stress, which allow them to dominate polluted environments and make them suitable for bioremediation applications.

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Conflict of Interest

The authors declare that they have no conflicts of interest.

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