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Seasonal Variations of Attached Cyanophyta Algae on Concrete Bridges in Tigris River from Baghdad

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Abstract

The attached Cyanophyta community is a model for monitoring aquatic systems and interpreting environmental change in aquatic systems. The present study aims to conduct a seasonal study on Cyanophyta attached to the concrete abutments of three bridges (Al-Jadriya Bridge, Bab Al-Moadam Bridge, and Al-Muthanna Bridge) in the Tigris River within the city of Baghdad, central Iraq (from October 2021 to June 2022). The study included the quality of Cyanophyta and, the eleven environmental parameters (water temperature, electric conductivity, salinity, pH, total alkalinity, Calcium, Magnesium, dissolved oxygen, total dissolved solids, total phosphorus, and total nitrogen). Monthly samples were taken from the water under each bridge from three sampling sites in the river, and the results were presented as four seasons. A total of 45 Cyanophyta taxa were identified in the three orders. Order: Chroococcales 11%; Order: Oscillatoriales 64%; Order: Nostocales 25% dominance of Oscillatoriales from the second site, and the highest number of species recorded in the autumn. The study showed clear differences in the total number of algal species attached to different sites. The study was able to add a new record species to the Iraqi algae flora, which is *Lyngbya sordida* Gomont.

Keywords: Attached Algae, Environmental parameters, Cyanophyta.

1. Introduction

Algae are considered primary producers of organic matter and oxygen, as byproducts, in aquatic habitats to stimulate their ability for photosynthesis and also their benefits for other organisms. Benthic algae is a name given to all types of prokaryotic and eukaryotic algae attached to the bottom or attached to objects immersed in water. Some sources refer to another term, periphyton, as it represents small plants growing on various media. Periphyton is a complex mixture of algae, fungi, and bacteria. They are linked to each other through of a cover consisting of a sticky substance secreted by algae and bacteria. Therefore, this term may not refer to algae alone. In newer sources, the mixture of algae, bacteria, and fungi is called Biofilms [1, 2, 3].

[4] explained that attached algae are all groups of algae that have transformed submerged surfaces into their home by adding sticky, mucilaginous substances or adhesive molecules by secreting special enzymes that help them to seize and stick the organic and inorganic matter spread within the water column. Benthic algae play an important role in the environment and its regulation, such as sediment stability, primary productivity, and the circulation of nutrients and energy between the sediment and the water column [5]. Thus, it leads to the stability of the aquatic medium in which it is found, and its life cycle is characterized as being very short, but its reproduction rate is rapid. Because it is attached , therefore affected by the chemical, physical, and biological changes that occur in the water column, the presence of any type of algae is greatly affected by environmental factors and the seasons of the year, and the most important factors that affect the distribution of algae are light, temperature, humidity, pH, and nutrient availability. Differences in environmental factors determine the type of algae that can be obtained after collecting samples [6].

Bridges play an important role in connecting cities and governorates and facilitating the transportation process, as well as contributing significantly to reducing the time required to travel long distances to reach any place. They are not only important in the transportation process for people but also in the transportation of goods, gas, oil, and water, so they are considered one of the most important pivotal and important structures that are closely related to the transportation process. Therefore, preserving the structure of bridges and reducing the causes that may damage bridges is an important matter [7].

Bridges are based on concrete abutments, parts of which are immersed in water when the bridge passes through the course of the river. These abutments and the structure of the bridge itself are affected by several factors, including environmental and other biological influences. Human influences also play a major role in the erosion of the bridge structure [8]. Resulting from climate or pollutants and climatic conditions are more important than those resulting from pollutants, which are represented by changes in temperature, winds, water flow velocity, and the presence or absence of ice [9]. As for the effects resulting from the pollutants, they may be carbon dioxide, sulfur dioxide, nitrogen gas, ozone gas, or hydrocarbons. As for the biological effects, they include bacteria, fungi, algae, water weeds, and plant roots [10]. The most important reason for biofilm, concrete Biofilm (i.e., stains, discoloration, etc.) is the growth of microorganisms on its surface as a result of the presence of moisture. Lichens on concrete surfaces and their multiplication cause deterioration of concrete, and this is called bio-contamination of concrete [11, 12].

Concrete corrosion: It is intended to deteriorate the constituent material of concrete as a result of influencing factors that may be internal or external, with the presence of what helps corrosion, which is heat and moisture that occurs between the components of concrete such as calcium oxide, iron oxide, or silicon oxide with water components such as chlorides, sulfates, or silica. These materials, whose source may be from living organisms present in the water, such as algae and others, as a result of their death overtime and the decomposition of their bodies in the water, in addition to the entry of gases into the concrete cracks or the entry of the resulting salts after the evaporation of water during the high temperature Also, the pouring of concrete at high temperatures leads to the formation of air gaps inside the concrete and thus the cracking of the concrete [13]. The research aims to follow up on the seasonal changes of blue-green algae attached to the concrete abutments of some bridges within the city of Baghdad.

2. Materials and Methods

2.1. Study area:

The study area is located in the Tigris River within the city of Baghdad. The location was determined by a GPS device at longitudes for the three sites (**Table 1**). The river is affected by human activities because there are many Casinos and restaurants on the riverside in this area. The study included the collection of seasonal samples of water and algae attached to the concrete abutments of three bridges built on the Tigris River. The first is the Al-Jadriya Bridge in the Al-Jadriya region, the second is the Bab Al-Muadham Bridge within the Al-Shaljiyeh region, and the last is the Al-Muthanna Bridge, north of Baghdad (**Figure 1**).

Table 1. Global Position System (GPS) of the study sites

Site	Longitude (eastwards)	Latitude (northwards)
S1	44° 22’28.56 E	33 °17 ’00.91 N
S2	44° 22’45.30 E	33 °20’33.08 N
S3	44 °20’44.14 E	33° 25’42.59 N

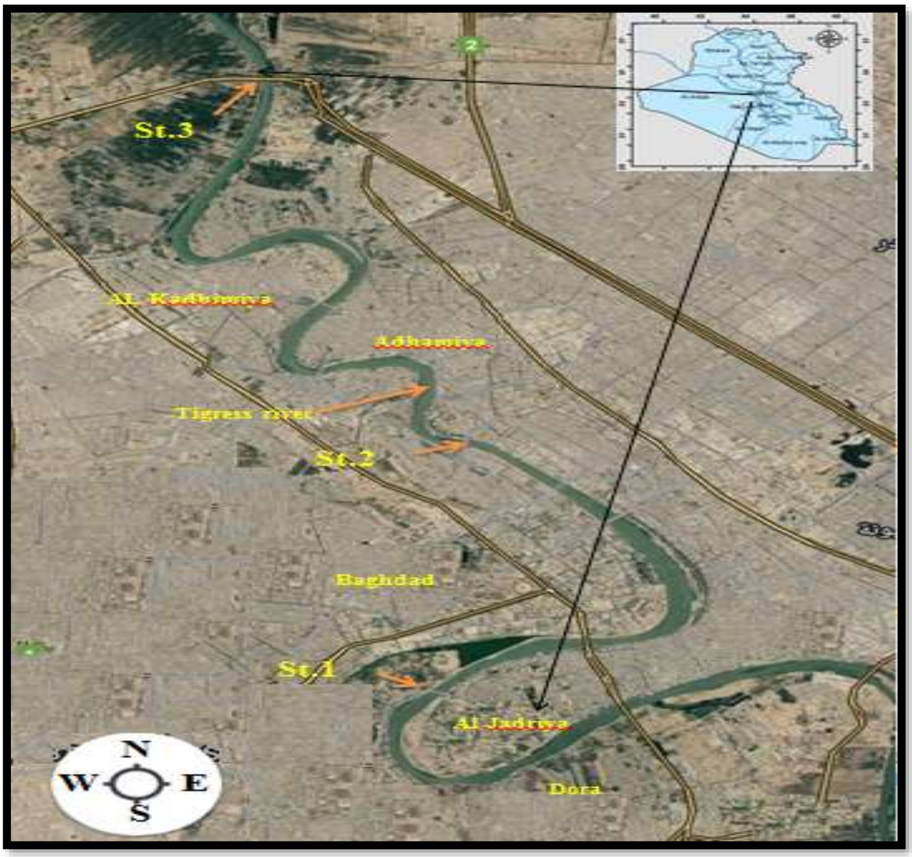

Figure 1. Map the studied area with sampling sites :1. Al-Jadriyah Bridge 2. Bab Al-Mu'adam Bridge 3. Al-Muthanna Bridge

2.2. Sample collection:

Samples were collected monthly from three sites in the study area (**Table 1**) from October 2021 to May 2022 and represented four seasons. The physicochemical analysis of the Tigris River is represented by the field measurements, which are water temperature (C), pH, and electric conductivity (µS/cm) measured by the digital portable multimeter, whereas the laboratory measurements included the dissolved oxygen (mg/l), total dissolved solids (mg/l), total alkalinity (mg $CaCO_3$/l), magnesium (mg $CaCO_3$/l), Calcium (mg CaCO3/l), salinity (S‰), total phosphate (mg/l), and total nitrogen (mg/l), estimated by the methodology of [14].

The samples of the attaching algae were collected using a PVC delimiter device [15] from the study sites and preserved by adding Lugol’s solution. Attached algae were diagnosed by preparation of temporary and [14, 16, 17, 18].

3. Results and Discussion

The water temperature recorded seasonal differences between the sites, and within the seasons of the year, the highest average was 29.0 °C at the second site during the summer season, while the lowest average was 14.0 °C at the first site during the winter season. The pH highest average of 8.70 was recorded at the third site during the summer season, while the lowest average of 6.70 was recorded at the second site during the summer as well. It is due to the presence of organic waste in that area, resulting from bird droppings, which, when decomposed, leads to the liberation of carbon dioxide (CO_2), which, when dissolved in water, combines with water and forms carbonic acid, which leads to a decrease in the acidity of the water [19].

There is a strong relationship between electrical conductivity (EC) and the rate of sodium chloride salts (NaCl), dissolved salts, and various ions such as chlorides, sulfates, carbonates, sodium, calcium, and potassium. The lower Electrical Conductivity and Salinity were 1052.67µS/cm, 2.23S‰ in the third station during the winter, but the highest was 1280µS/cm, 2.42 S‰ in the second site during the spring. The increase in electrical conductivity in this season may be caused by soil erosion and human activity at site 2 [20].

The results showed clear seasonal differences between the total dissolved substance (TDS) values, where the highest rate (680.67 mg/L) was recorded in the second site during the spring, while the lowest rate (605.08 mg/L) was recorded in the third site during the summer. The highest rate of TDS in the second site during the spring may be caused by irrigation effluent reaching the river during this period, which leads to the dissolution of a lot of suspended materials in the river. The total relationship was in the summer and in all study sites without any significant differences, and the reason for that is the decrease in the river water level due to the lack of rain and the increase in the evaporation process.

The highest dissolved oxygen concentration was 10.08 mg/l. In the first and third locations during the winter, the reason for this is the decrease in temperatures as well as the increase in wind speed when collecting samples, while the lowest rate of 7.13 mg/l was recorded in the second site during the spring, and the reason is due to the high percentage of pollutants expelled from the site of Khader Elias, located on the river. It was also noted that the sewage pipes of the Medical City discharged their effluent to the river when the sample was taken, which caused an increase in organic waste within the river, as the increase in organic waste reduced the levels of dissolved oxygen in the water as a result of the increase in the activity of microorganisms, which led to the consumption of oxygen in the process of organic decomposition despite the low temperatures [21, 22]

The third site recorded the highest value of water alkalinity, which was 144 mg $CaCO_3$/l during the summer, whereas the lowest values in the first and second sites converged at the water alkalinity during the autumn, as it was recorded at 132.5 and 133.17 mg $CaCO_3$/l, respectively. The high alkalinity may be caused by a high concentration of CO_2 from the atmospheric air into the water, or it may result from the respiration of living organisms that are found in the water. It helps convert calcium carbonate into soluble bicarbonate. Low alkalinity levels in the autumn can be caused by the deposition of carbonates at the bottom of the water due to a lack of rain. These results are consistent with the study of [23, 24].

The concentration of magnesium ions is less than that of calcium because carbon dioxide interacts more easily with calcium than magnesium [25]. Magnesium values were between 27.92 and 29.17 mg $CaCO_3$/l. while Calcium was between 71.33 and 109.5 mg $CaCO_3$/l. The highest rate of nitrates (1.351 µg/g) was recorded in the first site during the winter and the lowest rate (0.540 µg/g) in the second site during the spring, while the highest rate of phosphate (0.079 mg/L) was recorded in the first site during the spring, while no significant differences for phosphate were recorded in the third site during all seasons and the second site during winter, spring, and summer.

The reason for the high rate of phosphate in the spring and at the first site of the study is due to the exposure of the river water to sewage water, industrial waste, and detergents [26]. Or because of the movement of boats within the same site, which works to move the bottom, which leads to an increase in phosphate within the water column, and this is consistent with [27]. As for the decrease in phosphate values during the summer, it is due to the large consumption of phosphate by aquatic plants and algae, and this is consistent with the studies of [28].

Table 2. Physicochemical parameters during the study period from three sites of Tigris River under the bridges selected

Parameters	Code	S.1	S.2	S.3
		Mean±SD	**Mean±SD**	**Mean±SD**
Water temp. °C	WT	17.75±1.43	19.67± 0.88	17.42±1.42
Electric Conductivity µS/cm	EC	1217±32.79	1208.18±28.84	1052.67±28.04
Salinity ‰	S‰	2.39±0.11	2.42±0.12	2.23±0.08
pH	pH	7.83± 0.38	8.10±0.31	8.70±0.15
Total Alkalinity (mg $CaCO_3$/L)	TA	132.5±5.95	133.17±5.60	144.5±2.22
Calcium (mg $CaCO_3$/L)	Ca	109.5±2.29	95.75±8.57	71.33±1.72
Magnesium (mg $CaCO_3$/L)	Mg	27.92±1.64	29.17±1.84	28.17±0.67
Total dissolved solids (mg/L)	TDS	679.00±12.77	680.67±10.6	605.08±12.12
Dissolved oxygen (mg/L)	DO	10.8±0.85	7.13± 0.57	10.08±1.1
Total Phosphorus (mg/L)	TP	0.079±0.005	0.003	0.00±0
Total Nitrogen (mg/L)	TN	1.351±0.041	0.54±0.057	0.740±0.140

A total of 45 taxa of Cyanophyta were identified at three sites throughout the study period (**Table 3**). The identified attached algae belonged to 16 genera, including three orders of the class Cyanophyceae: Chroococcales 11% (4 genera, 5 species), Order: Oscillatoriales 64% (4 genera 29 species), Order: Nostocales 25% (8 genera, 11 species) (**Figure 2**) The highest percentage was for the order Oscillatoriales from which most of its members are distinguished by having filamentous forms surrounded by a gelatinous envelope that prefers to exist in an attached manner, and among its species, *Oscillatoria and Lyngbya* recorded the highest number of species (21, respectively) [20]. While the lowest percentage was for species of the order Chroococcales, which are characterized by being unicellular cells and aggregate colonial forms, most of their types prefer to exist planktonic within the water column.

Algae tend to be attached to solid surfaces as a survival strategy and to increase their growth. As nutrients within the water column tend to gather near or on solid surfaces [29], organisms attached to these surfaces produce secretions of attached organisms or decomposition products. Other attached dead organisms accumulate on these surfaces and act as attractive materials for living organisms, such as bacteria and fungi [30], this indicates that attached algae include species capable of secreting sticky substances, which are represented by most types of Cyanophyta (blue-green algae). This is what was found in the current study is consistent with local and international studies [31].

Table 3. The number attached Cyanophyta species Cyanophyta identifies concrete bridges during the study period from the Tigris River in Baghdad

Site / Orders Cyanophyta	St.1				St.2				St3				Total
	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	
Chroococcales	0	0	0	0	4	0	1	0	0	0	0	0	5
Oscillatoriales	3	6	6	0	14	10	5	0	2	2	2	6	29
Nostocales	2	3	2	1	5	1	2	1	0	1	0	1	11
Total	5	9	8	1	23	11	8	1	2	3	2	7	45

Clear differences were recorded in the total number of algae species attached to different study sites (**Figure 3**), as the second site recorded the highest number of species from the three orders of Cyanophyta, in which the dominant species are the Oscillatoriales, followed by the Nostocales and Chroococcales, respectively. The difference in the number of species between the sites is due to the different environmental factors, the amount and type of pollution, and the rate of runoff, as the second site is characterized by the abundance of organic waste reaching the river and restaurants near the shrine Khader Elias and the droppings of the Medical City, which help to increase the attached algae, especially the blue-green algae with threadlike shapes, which are a suitable medium for the formation of an algal mat [32].

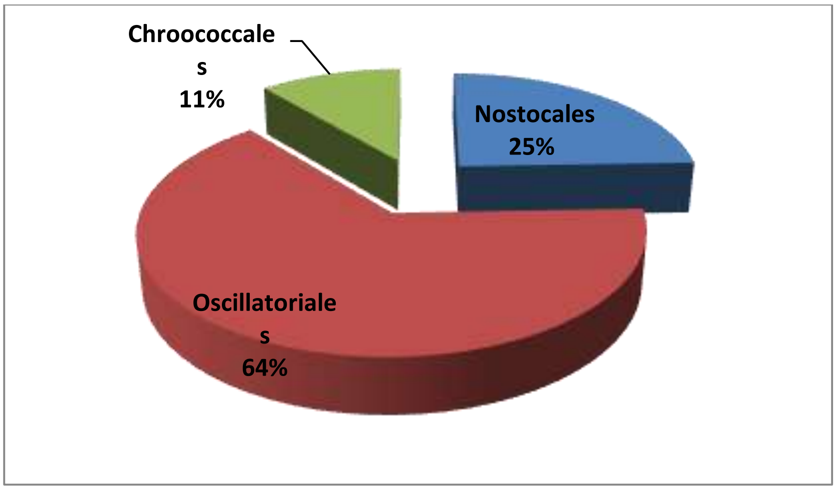

Figure 2. Percentages orders of Cyanophytae Identifies at three sites during the study period

The few species recorded at the third site (**Figure 3**) Perhaps the lack of species recorded at this site is due to the fact that the Al-Muthanna Bridge was subjected to vandalism, followed by maintenance and restoration work during the years 2014–2016 [27]. Because it contains longitudinal grooves when taking the sample for attached algae, it is not possible to fully reach the algae growing inside these grooves, so the site is distinguished by the lack of species, and the water flow rate is very high compared to the other two sites, in addition to the presence of dredging operations for the river near the bridge most of the seasons of the year.

The study also showed clear differences in the numbers of Cyanophyta species attached to different seasons of the year in the three sites (**Table 3**), as the highest total number of species was recorded in autumn, with 23 species within the second site, while the lowest number of one species was recorded in the summer within the first and second sites. The decrease in the number of species in the summer may be due to the increase in evapotranspiration due to the high temperature and low water level [6].

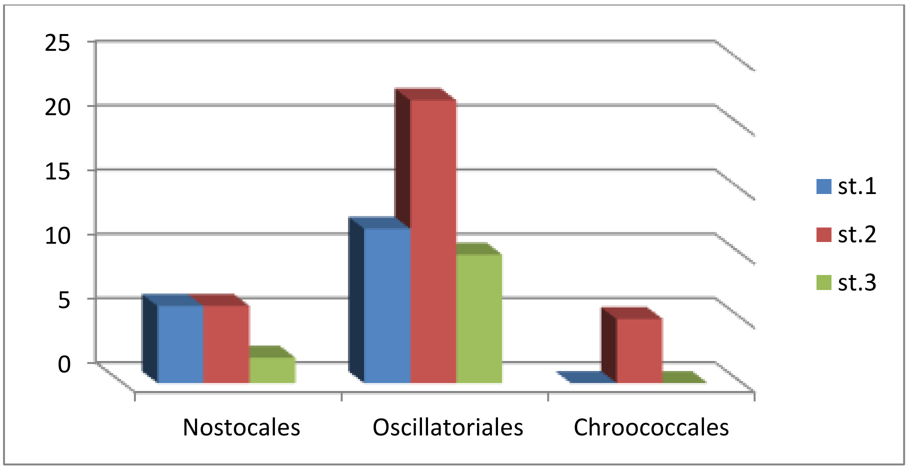

Figure 3. The spatiotemporal variation in numbers of attached Cyanophyta species during study period from three site

One new species was recorded in the current study for the first time in Iraq, based on the Checklist of Algal Flora in Iraq [33]. This type of algae attached to solid bodies, which belongs to the order Oscillatoriales, was detected at the first site only and during the autumn (**Table 3**).

Division:Cyanophyta

Class:Cyanophyceae

Order:Oscillatoiales

Family:Oscillatoriaceae

Genus: *Lyngbya sordida* Gomont

Filamentous in shape, its threads are straight and long, growing in the form of dense tufts (Caespitose) surrounded by a gelatinous sheath consisting of two monochromatic layers and extending clearly forward. The length of the cell ranges from 2.5–3 micrometers, and its width ranges from 9–10.5 micrometers. This type of algae is found in fresh water and attached to surfaces immersed in water. It thrives in aquatic environments if the appropriate conditions are available for it, including the intensity of light, temperature, abundance of nutrients, and pH [34] (**Figure 4**).

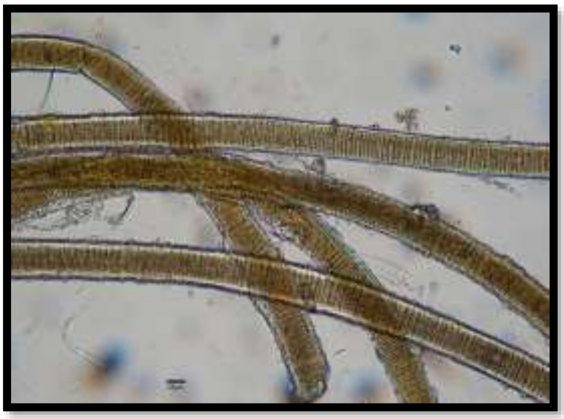

Figure 4. *Lyngbya sordida* Gomont, 40x.

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5. Conclusions

The environmental parameters revealed that the river within the study area is characterized by high salinity and conductivity. The community of attached Cyanophyta varied through places and time and was affected by the different types of pollutants that reached the river water.

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Conflict of Interest

There are no conflicts of interest.

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