The role of cyanobacteria in freshwater ecosystems of Kurdistan (Gheshlagh, Gaveh, and Sirvan rivers)

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Abstract

Cyanobacteria play a key role in water quality assessment and ecosystem monitoring. Their study provides essential insights for sustainable water management, optimal utilization, and potential socioeconomic benefits. In this study, samples were collected from six stations: upstream of Qeshlaq (under the bridge), Qeshlaq branch before the refinery, Qeshlaq branch after the refinery, Qeshlaq branch, Gavehrood branch, and Sirvan branch. A total of 13 species from the phylum Cyanobacteria were identified. Seasonal variation was pronounced: 8 species from 6 genera in spring, 11 species from 5 genera in summer, 7 species from 4 genera in autumn, and 14 species from 12 genera in winter. Relative abundance fluctuated markedly, increasing from spring to summer, peaking in July with rising temperatures, and declining from November through early spring. The Shannon–Wiener diversity index ranged between 2.25 and 3.33. Oscillatoria was the most dominant genus in most months, while in January, Microcystis pulvera prevailed with a density of 8,666,667±702,377 individuals per cubic meter. Variations in cyanobacterial composition within the Sirvan–Sanandaj River ecosystem appear to be influenced by hydrological conditions, seasonal temperature shifts, and anthropogenic pollution.

Keywords: Cyanobacteria, Freshwater ecosystems, Kurdistan rivers, Seasonal variation, Water quality, Oscillatoria, *Microcystis pulvera.*

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Introduction

Cyanobacteria are among the oldest organisms, dating back more than 3 million years. Their annual blooms cause the death of many aquatic animals and livestock. Cyanobacteria is a group of prokaryotic organisms that exist in all aquatic ecosystems, including saltwater, freshwater, and brackish water. This phylum has a high potential for planktonic blooms in lakes, and many of its species are toxic and capable of causing toxic algal blooms and Cyanobacteria are capable of producing toxins that are harmful to humans, animals, and aquatic life. Increased phosphorus, climate change, and non-native species are important factors in causing algal blooms, which are caused by excessive and uncontrolled growth of algal cells. Algal bloom can be seen as foam on the surface of the water in green, blue-green, brown, or red colors and with an unpleasant odor. According to studies, more than 100 species of cyanobacteria, mostly in 40 genera, have the ability to produce toxins that the most important groups of algal toxin producers include Microcystis, Nodularia, Anabaena, Aphanizomenon, Planktothrix and Cylimdraspermopsis.

Cyanobacteria are of great importance and they are capable of producing toxins that are all harmful to humans, animals, and aquatic life. It is also possible to exploit these resources with the cooperation of fishermen through the formation of fishing cooperatives, which will greatly contribute to creating employment in the region. The presence of plankton often affects the growth, reproductive capacity, and population characteristics of other aquatic organisms (Mohsenpour Azary *et al.,* 2010). One of the most important factors related to plankton is the rapid response of Cyanobacteria communities to convective changes. The structure of Cyanobacteria populations depends on the concentration of nutrients and other factors such as physical factors, temperature, salinity, turbidity, electrical conductivity, etc and biological factors such as growth and population changes of Cyanobacteria, parasites, predators, and chemical factors such as nitrate, phosphate, vitamins, and antibiotics also play an important role (Heinonen, 2004).

In general, plankton communities are not constant in different places and times and change with seasonal changes (Lepisto, 1999).

Materials and methods

To conduct this research, 6 stations were located upstream of Qeshlaq (before the Refinery - under the bridge), the Qeshlaq River branch (downstream of the Refinery), the Qeshlaq River branch (about 3 km downstream from station 2), The Gavehrood and Sirvan branches were sampled monthly. Sampling and identification methods were based on standard methods and valid identification keys. The geographical location of the sampling stations along with the names of the stations are given in Table 1. Sampling was carried out at 6 stations. Table 1 shows the location of the stations which includes Station 1 (upstream of Qeshlaq under the bridge), Station 2 (Qeshlaq branch before the Refinery), Station 3 (Qeshlaq branch after the Refinery), Station 4 (Qeshlaq branch), Station 5 (Gaveh Rood branch) and Station 6 (Sirvan branch).

Table 1: Geographical location of the studied sampling stations of the Sirvan River-Sanandaj

Station number	Station	Geographical location
1	Upstream of Qeshlaq (under the bridge)	"36‘ 22° 35 N "12' 01° 47 E
2	Qeshlaq rood Branch Before the Refinery (airport)	N 35. 22'. 86 E 47. 6291
3	Qeshlaq rood Branch (Downstream of the Refinery)	"12' 12° 35 N "33' 59° 46 E
4	Qeshlaq rood Branch (Located about 3 km downstream from Station 2)	"08' 08° 35 N "59' 53° 46 E
5	Gavehrood branch	"04' 05° 35 N "21' 55° 46 E
6	Sirvan branch	"52' 03° 35 N "51' 49° 46 E

Figure 1 shows Station 1 with a gravel and sand bed, this station is located before the city of Sanandaj. It has clear and relatively clean water. The water depth is about 70 cm with a relatively strong current. On the banks of the river, scattered gardens and agricultural activities take place. The riverbed is relatively natural and has the least impact of human activities compared to other stations.

Figure 1: Station 1 with gravel and sand bed.

Figure 2 shows Station 2 of the Qeshlaq River branch, before the Refinery and adjacent to the airport runway. It is not possible to sample benthic and fish due to the type of substrate and the difficult path, as well as the high pollution. This issue was agreed upon in coordination with the project supervisor.

Figure 2: Station 2 before the refinery adjacent to the airport.

Figure 3 shows Station 3 with a dredged gravel bed located one kilometer downstream of the Refinery. Water depth about 50 cm with a relatively strong current and there are scattered gardens and agricultural activities along the riverbank. Various types of industrial, urban, and domestic wastewater enter the river.

Figure 3: Station 3 with gravel bed after the refinery.

Figure 4 shows station 4 with a mud bed combined with rocks, about 3 km away from station 2. There are scattered gardens and agricultural activities along the riverbank. The water depth is more than 1.20 meters with a relatively strong water velocity. Although the pollution and turbidity of the water at this station is less than at Station 1, it is still high and contaminated with various types of sewage.

Figure 4: Station 4 with mud bed combined with rocks.

Figure 5 shows Station 5 with a bed of gravel and sand with boulders. This station is located on a branch of the Gaveh River and is less disturbed. About 10 kilometers downstream from this station, this branch merges with the Qeshlaq branch and forms the main branch of Sirvan. The riverside vegetation at this station is more than all other stations, and the water depth is more than 80 cm with a relatively high velocity. The water is relatively clear, and there are scattered gardens and agricultural activities along the riverbank.

Figure 5: Station 5 with rubble bed.

Figure 6 Station 6, with a bed of boulders and rubble, is less modified and is located about 7 kilometers downstream of the confluence of the two branches which forms the Sirvan branch. The riverbed is a valley (mountainous with high walls), steep slope, water depth of about 2 meters with high speed and the water turbidity is relatively low and the river in this location has a high degree of self-purification. To study Cyanobacteria, water sampling was carried out directly at designated stations (6 stations) and in such a way that 3 samples were taken at each station and mixed together, and then 500 cc of it was transferred to a glass bottle and fixed with formalin to a final volume of 0.5-2%. Immediately after transferring the samples to the glass bottle, a label with the relevant information (station name and sampling time) was attached to each sample based on predetermined codes.

Figure 6: Station 6 with rocky and rubble bed (after dam crest structure.)

In the laboratory, the samples underwent preparation steps (siphoning and centrifugation), qualitative and quantitative analysis and in the sedimentation stage, the water bottles were kept in a dark and still place for at least two weeks, after which the supernatant water of the samples was siphoned off under the hood (on a stable surface that would not cause water to splash) so that the sample volume was almost halved (250 cc). Then the samples were centrifuged for 5 minutes at 3000 rpm until a final volume of 40-50 cc was obtained. After initial preparation, the samples were kept in a static place for at least 24 hours for qualitative examination. In the qualitative study, the surface water was transferred to a glass container and 1-2 drops of the bottom water were qualitatively examined with a 22×22 slide and a binocular microscope and 24 hours after qualitative examination, the samples were subjected to quantitative examination. In this way, based on the density results in the qualitative study (low, medium, and high), the groundwater sample was brought to a certain volume and then 0.1 cc was removed from it using a grooved piston pipette and they were examined with a 22×22 slide and a microscope with a magnification of 400×, and finally, according to the dilution factor, the density in cubic meters was calculated (Wetzel and Likens, 2000; APHA, 2017).

The speciments were identified in the laboratory based on the relevant identification keys. Species identification was performed based on valid identification keys such as: Tiffany and Britton (1971), Habit and Pankow (1976). Hartley *et al.* (1996), and Wehr and Sheath (2015).

Shannon dversity index

Shannon Diversity index is also called Shannon-Wiener and Shannon-Weaver, and is widely used in ecological studies. It provides a rough estimate of the amount of variation and is insensitive to the number of samples and its range of variation is between 1 and 3. The advantage of this index is that it considers the number of species along with their population (uniformity). In polluted environments with high stress, the index decreases because the number of species decreases or the population of less resistant species decreases, and conversely, the population of resistant species increases.

Results

Based on the results of the table below, a total of 6 genera and 8 species of cyanobacteria were identified and counted in the spring, of which 6 species were present in Farvardin, 5 species in Ordibehesht, and 3 species in Khordad and in all three months of spring, the genus Oscillatoria was dominant, and in Ardi Behesht, the cyanobacterium species Microsystis pulvera also had high growth with an average density of 400,000±0 (Table 2).

Table 2: Density (Number per Cubic Meter± SD) of different cyanobacterial species in different months of spring season in Sirvan River – Sanandaj- 2023.

Species	Spring		
	April	May	June
Oscillatoria limosa	666667±461880	320000±268328	350000±100000
Oscillatoria sp.	466667±305505	400000±0	200000±0
Osillatoria tenuis	1000000±0	200000±0	200000±0
Aphanizomenon sp.	300000±141421		
Lyngbya sp.	200000±0		
Microsystis pulvera		400000±0	
Anabaena spiroides	200000±0		
Johannesbaptistia pellucida		200000±0	

In the summer season, the genus Oscillatoria was dominant in all three months of July, August, and September, with the highest density in July (1,750,000±1,482,116 individuals per cubic meter) and then decreased in August and September (Table 3).

Table 3: Density (number per cubic meter + SD) of different cyanobacterial species in different months of the summer season of Sirvan River- Sanandaj- 2023.

Species	Summer		
	July	August	September
Oscillatoria limosa	1650000±1569501	2760000±3623258	1400000±1019804
Oscillatoria sp.	1750000±1482116	500000±258199	1400000±673300
Oscillatoria. sp.2		6600000±0	
Osillatoria tenuis		200000±0	650000±443471
Scenedesmus quadricauda		600000±0	200000±0
Scenedesmus acuminatum			600000±0
Dactylococcopsis acicularis			200000±0
Oocystis borgi	266667±115471		
Dactylococcopsis irregularis			200000±0

In the autumn season, a total of 7 species from 4 genera of Cyanobacteria were observed, and in this season, the genus Oscillatoria had the highest density in each of the three months of October (1925271±2400000 individuals/m^3), November (848528±1200000 individuals/m^3), and December (3964425±5650000 individuals/m^3) (Table 4).

Table 4: Density (number per cubic meter + SD) of different cyanobacterial species in different months of autumn season in Sirvan River-Sanandaj- 2023.

Species	Autumn		
	October	November	December
Oscillatoria limosa	2400000±1925271	500000±424264	5650000±3964425
Oscillatoria sp.	800000±848528	1200000±848528	1600000±1562050
Osillatoria tenuis	300000±141421		333333±230940
Scendesmus bijuga	600000±0		
Scenedesmus quadricauda	200000±0		
Aphanizomenon sp.		200000±0	400000±0
spirulina sp.	600000±200000		

A total of 14 species from 12 genera of cyanobacteria were observed and counted in the winter season. At the beginning of this season, Microsystis pulvera was the dominant species with a density of (702377±866667). However, in February and March, the genus Oscillatoria limosa was dominant with densities of (1150000±900000) and (206666667±1331666), respectively (Table 5).

Table 5: Density (number per cubic meter + SD) of different cyanobacterial species in different months of winter season in Sirvan River-Sanandaj- 2023.

Species	Winter		
	January	February	March
Oscillatoria limosa	5440000±7003428	1150000±900000	20666667±1331666
Oscillatoria sp.	3900000±3252691	733333±611010	12666667±702377
Osillatoria tenuis	533333±416333	400000±282843	1400000±0
Scendesmus bijuga	500000±424264	200000±0	
Aphanizomenon sp.		200000±0	
Stigonema sp.	600000±0	400000±0	600000±0
Gloeotrichia sp.		200000±0	
Gloeocapsa turgida		200000±0	
Gallionella sp.		300000±141421	
Dactylococcopsis acicularis		200000±0	
Lyngbya sp.	300000±141421	200000±0	400000±0
spirulina sp.			200000±0
Chroococcus turgidae			1600000±0
Microsystis pulvera	8666667±702377		

As can be seen in Figure 7, the percentage of presence of the Cyanobacteria phylum fluctuated significantly in different months and they started to grow in the spring and gradually increased, and then began to decline in the months of January, February, and March. They also experienced a very large percentage drop in November (Fig. 7).

Shannon-aweinraz index

The Shannon-Wiener index is the most common, simplest, and most understandable index of species diversity, indicating the number of species present in the ecosystem under study. The higher the amount, the healthier the water body is biologically (Table 6).

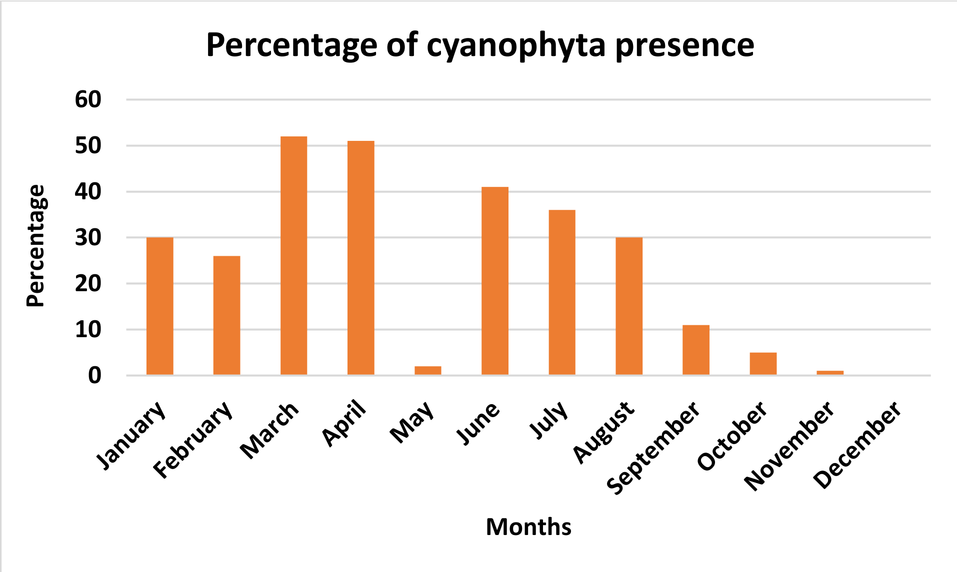

Figure 7: Percentage of Cyanobacteria density of the Cyanobacteria phylum observed in different months in this study.

Table 6: Shannon-Wiener index values of phytoplankton in different months studied.

Shannon phytoplankton index											
January	February	March	April	May	June	July	August	September	October	November	December
2.39	3.30	3.09	3.18	3.04	3.29	2.39	2.56	3.33	2.28	3.25	2.25

The Shannon-Wiener index values were obtained in the range of 2.25 to 3.33.

Discussion

Water resources form an ecosystem whose components include non-living factors (physical and chemical factors) and living factors (producers, consumers, decomposers) with complex ecological relationships between them and Cyanobacteria, as the first producers of organic carbon, play a fundamental role in the food chain of aquatic ecosystems and are always influenced by abiotic factors, demonstrating the capacity of biological production in aquatic environments that the role of cyanophytes is very prominent. As can be seen in Tables 2, 3, 4 and 5, in total, the observed samples included 13 species belonging to the Cyanobacteria phylum, which are: *Oscillatoria limosa, Oscillatoria* sp., *Osillatoria tenuis, Scendesmus bijuga, Scenedesmus quadricauda, Scendesmus abondans, Aphanizomenon* sp., *Stigonema* sp., *Gloeotrichia* sp., *Lyngbya sp., spirulina* sp., *Chroococcus turgidae, Synechococcus* sp.

Changes in different species of Cyanobacteria in the Sirvan-Sanandaj River ecosystem have been different, which could be due to the increase in this branch as a result of various factors, including water flow and temperature increase, as well as the impact of various pollutants. In this study, the Cyanobacteria phylum began to increase during the months of July with warming weather, and this population growth continued, and then a decrease in population growth was observed from February. In the warm months of the year, the density of Cyanobacteria began to grow, which was due to the increase in temperature.

Oscillatoria were the most dominant genera in most areas, which could be due to water pollution in this ecosystem, and the occurrence of pollution and its increasing trend, for whatever reason, in the ecosystem requires remediation and restoration activities.

Remedial measures include activities that reverse or stop environmental damage and it is divided into physical, chemical, biological (using plants, microalgae, cyanobacteria, bacteria, etc. that consume nutrients, organic compounds, and heavy metals), and ecological types (Sood *et al.,* 2015). According to this study, the Cyanobacteria phylum increased significantly compared to 1400, so that it formed the dominant phylum in winter while, based on studies conducted in 1400 at stations 1, 2, 4, and 5, except for two cases, the first phylum was the dominant Bacillariophyta in all seasons. In two exceptional cases, station 1 in spring (Chlorophyta phylum with similar amounts to Cyanobacteria) and station 3 in winter (Cyanobacteria phylum with similar amounts to Bacillariophyta) were identified as the first dominant phylum. The ability of Cyanobacteria to compete with other freshwater algae under a wide range of conditions, including favorable growth at high temperatures, low light tolerance, and mass algal blooms, is important and prepares Cyanobacteria to survive in unfavorable conditions, tolerating low P/N ratios and allowing continuous growth when N is limited, depth regulation by buoyancy, resisting zooplankton feeding, tolerating pH, low CO2 concentrations and allowing continuous growth of Cyanobacteria only at the lake surface and forming intense blooms (Bellinger, 1986., Bellinger and Sigee, 2010), symbiosis with aerobic bacteria and nitrogen fixation by heterocysts are also an important source of inorganic nutrients in the surface oceans (Shapiro, 1990).

In cyanophytes, in addition to the thin cell wall, a gelatinous membrane also surrounds the cell, which provides high tolerance to adverse conditions in this group, Therefore, the habitats of members of this phylum are very diverse and they are present in almost all aquatic, terrestrial, and even aerial habitats, and the study of cyanobacteria in aquatic ecosystems is of great importance.

On the one hand, they are used as primary products for feeding various aquatic animals, and also as biological indicators (Duker and Palmer, 2009; Brraich and Kaur, 2015). If the Shannon-Wiener index value is more than 3, the environment is clean and ranked excellently, and values less than 3 indicate stress and an environment with moderate pollution levels. Accordingly, the studied area has different conditions in terms of pollution load in different months. Therefore, in the months of April, May, June, September, November, February, and March, this ecosystem contained clean water, and in the months of July, August, October, December, and January, it is considered polluted water.

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