Int. J. Aquat. Biol. (2022) 10(6): 537-542
ISSN: 2322-5270; P-ISSN: 2383-0956
Journal homepage: www.ij-aquaticbiology.com

Original Article

Cyanobacteria diversity in various waterbodies of Mosul, Iraq

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Abstract: Cyanobacteria are photoautotrophic bacteria that can adapt to various environments due to their extensive physiological adaptability. These bacteria are naturally distributed in diverse ecosystems, including freshwater, marshes, groundwater, lakes, brackish water (estuaries), salt water, moist soils, and dry land. This study was conducted to enlist cyanobacteria isolates in different waterbodies in Mosul, Iraq. For this purpose, 16 sites were selected and sampled. Based on the results, the *Gloeocapsa* nigrescens was the dominant species (10.34%), followed by *Microcystis robusta* (6.69%), *Oscillatoria nigro-viridis* (6.69%), and *Oscillatoria* sp. (6.69%). Mosul Dam Lake (station 12) was the most diverse one with six cyanobacteria species, including *Schizothrix* sp., *Aphanocapsa koordesii*, *G. crepidium*, *O. trichoides*, *M. flos-aquae*, and *Plectonema tomasinianum*.

Article history:
Received 21 October 2022
Accepted 22 December 2022
Available online 25 December 2022

Keywords:
Algae
Bacteria
ASM-1 medium
Microcystis
Oscillatoria

Introduction

Cyanobacteria are ancient negative Gram-stain microorganisms that emerged during the volcanic age approximately 3.5 billion years ago (Sergeev, 2018). They play a crucial role in transforming the earth's atmosphere to an aerobic condition (Demoulin et al., 2019). They are known as blue-green bacteria or algae because of their blue-greenish hue (Matheron and Caumette, 2015; Zahra et al., 2020). Water and land are both suitable habitats for cyanobacteria (Svirčev et al., 2019). They are found in various environments, including saltwater, freshwater, cold, hot, and terrestrial ecosystems (Fitri et al., 2021; Kostryukova et al., 2021). Cyanobacteria have approximately 2,000 species in 150 genera in five orders (Vincent, 2007). They are important primary producers playing a significant role in carbon and nitrogen cycles (Vincent, 2007). Cyanobacteria can be found in oil fields and oil pools around oil wells (Radwan and Al-Hasan, 2000; Chaillan et al., 2006; El-Sheekh and Hamouda, 2014) and in moist, shady atmospheres with heavy rainfall (Wiśniewska et al., 2022). In addition, Makhalanyane et al. (2015) reported these bacteria in the northern and southern polar, where environmental conditions are extremely harsh. In addition, they are a renewable energy source known as Third Generation Biofuel (TGB) (Teta et al., 2020; Filatova et al., 2021; Forchhammer and Selim, 2022; Sánchez-Baracaldo et al., 2022).

The cyanobacteria have distinct shapes, such as unicellular, colonies, and filamentous (Tamulonis and Kaandorp, 2014; Herrero et al., 2016). They contain various cell types, e.g. the heterocysts are characterized by thick walls, particularly in Nostocales and Stigonematales, which bear the nitrogen enzyme for nitrogen fixation and converting nitrogen gas into ammonia and amino acids. The akinete type can reproduce new filaments under inconvenient conditions (Kaushik and Sharma, 2017). In recent years, interest in blue-green bacteria (cyanobacteria) has increased rapidly due to their ability to produce various materials such as vitamins, amino acids, fatty acids, proteins, various dyes,

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DOI: https://doi.org/10.22034/ijab.v10i6.1783
DOR: https://dorl.net/dor/20.1001.1.23830956.2022.10.6.10.3

Table 1. Sampling stations and collection results Cyanobacteria.

No.	Site	Results
1	Water from the waterfall that pours into Lake Al-Qusour	-
2	Soil from the house garden	-
3	Al-Qusour Lake Basins of the Animal Resources Laboratory / College of Agriculture	+
4	Subtrahends of the industrial area	+
5	Khoser Al-Kharazi near the College of Environment	+
6	Al-Qusour Lake at a certain depth	-
7	Lake of the presidential palaces at a depth	+
8	The discard of the Hammam Al-Alil cement plant	-
9	Litter from the Khosr estuary, which flows during the day in the Tigris	+
10	Edge of the right side of the Mosul Dam Lake	+
11	The left edge of the Mosul Dam Lake	+
12	The middle of the Mosul Dam Lake (from the surface)	+
13	The middle of the Mosul Dam Lake (from the depth)	+
14	Subtrahends of Wadi Akab Estuary	+
15	Karasaray site	+
16	Khoser Al-Muthanna district (sewage water)	+

enzymes, phenols, and alkaloids, which are applied in diverse fields including medicine, industry, and agriculture. For instance, in agriculture, they used to produce biological fertilizers and nitrogen fixation from the atmosphere by transforming the nitrogen to ammonium, which is necessary for plant growth and dissolving the phosphate and consequently enhancing and improving the production of the crop (Kumar et al., 2019; Kini et al., 2020). Cyanobacteria can also remove crude oil, heavy minerals, and pesticides from wastewater (Mona et al., 2020). Furthermore, they possess secondary metabolic compounds used as anti-fungal, anti-bacterial, and anti-cancer agents (Singh et al., 2016; Kumar et al., 2019). Despite the importance of cyanobacteria, there is little information available regarding cyanobacteria in Iraqi natural ecosystems. Hence, the current study aimed to survey and identify cyanobacteria isolates in different waterbodies in Mosul, Iraq.

Materials and Methods

From February to April 2020, water samples were collected from different water bodies (Table 1). For transitional culture, liquid and solid assimilated medium-1 (ASM-1) was used to isolate Cyanobacteria. The solid ASM-1 was prepared by adding agar at a concentration of 1% per 100 ml of liquid medium. The water samples were inoculated using the streaking method and incubated at 26±2°C under constant lighting of 2500 lux for four weeks. Following the growth of the cyanobacteria colonies, the developing colonies were identified using a light microscope, according to Waterbury (2006) and Hossain et al. (2020). To obtain a pure culture, the identified colonies were transferred to new Petri dishes containing the medium mentioned above and cultured in the incubator as mentioned above (Waterbury, 2006; Hossain et al., 2020).

Results and Discussion

Based on the results, most samples were positive for the presence of cyanobacteria (Table 1). Previous studies have confirmed the presence and blue-green bacteria in the Nineveh Province (AL-Shakarchi and AL-Shahery, 2020), showing the diversity of Cyanobacteria in these areas due to suitable conditions e for their growth. In addition, since Cyanobacteria can accumulate pollutants, they are crucial indicators for environmental pollutants (Paerl et al., 2011; Mona et al., 2020; Lu et al., 2021).

The inventory of Cyanobacteria species in the studied area is shown in Table 2. Based on the results, *Gloecapsa nigre-scens* showed the highest percentage (10.34%), followed by *Osillatoria nigro-viridis*, *Microcystis robusta*, and *Osillatoria* sp. (6.89%), and the remaining taxa each consists 3.44% of the richness. Six cyanobacteria were found in the

Table 2. Sampling stations and collection results from various waterbodies of Mosul.

No.	Site	Isolates	%
1	Water that flows from the waterfall and into the lake	ND (Not detected)	Nill
2	Residential garden soil	ND	Nill
3	Basins from Al-Qusour Lake of the Animal Resources Laboratory/ College of Agriculture	*Gloeocapsa nigrescens nageli*	10.34
		Phytoeonis sp.	3.44
		Lyngbya birgei	3.44
		Calothrix Parietina	3.44
4	Subtrahends of the industrial zone	*Spirulina subtilisima*	3.44
5	Khoser Al-Kharazi, near the College of the Environment	*Gloecapsa nigrescens*	10.34
		Green algae	6.89
		Fragillaria sp. (Ditoms)	3.44
6	Al-Qusour Lake (depth)	ND	Nill
7	Al-Qusour Lake (surface)	*Osillatoria nigro-viridis*	6.89
		Gloeocapsa nigrescens	10.34
		Anabaena sp.	3.44
		Anabaena spiroides	3.44
8	Hammam Al-Alil cement factory water	ND	Nill
9	Litter from the Khosr estuary, which flows into the Tigris River	ND	Nill
10	The right bank of Mosul Dam Lake	*Chlorogloea fritschii*	3.44
		Green algae	6.89
		Phormidium sp.	3.44
11	The left bank of the Mosul Dam Lake	*Osillatoria nigrouviridis*	6.89
		Osillatoria lemmermann	3.44
12	The middle of the Mosul Dam Lake (surface)	*Schizothrix* sp.	3.44
		Aphanocapsa koordesii	3.44
		Gloeocapsa crepidium	3.44
		Osillatoria trichoides	3.44
		Microcystis flos-aquae	3.44
		Plectonema tomasinianum	3.44
13	The middle of the Mosul Dam Lake (depth)	*Microcystis robusta*	6.89
14	Subtrahends of the Wadi Akab mouth	*Anabaena variabilis*	3.44
		Osillatoria sp.	6.89
15	Karasaray area	*Microcystis robusta*	6.89
16	Khosar Hay al-Muthanna	*Nostoc* sp.	3.44

surface water of Mosul dam lake (station 12), the most diverse site. Temperature and light conditions were optimum in this site along with fall turnover i.e. the circulation of nutrients from the lake's bottom; then it had algae bloom during sampling (Lürling et al., 2018; Jiang et al., 2022).

No cyanobacteria existed in sites 1, 2, 6, and 8, which could be due to unsuitable environmental conditions. In site 8, the cement factory's drainage water was saturated with oil contamination. Despite the report that cyanobacteria that break down hydrocarbons may live in such environments, they did not find in this study. The oils inhibit certain types of cyanobacteria, and it takes resistant species a relatively long time to adapt to these systems (Zutshi and Fatma, 2015; Yadav et al., 2016; Karmakar et al., 2018). In site nine, many microorganisms, including bacteria, fungi, algae, and diatoms, but no cyanobacteria. The absence of cyanobacteria could be attributed because of pollution and containing large waste, and the high NaCl significantly reduces the growth rate of cyanobacteria by ionic (Na^+) stress (Batterton and Van Baalen, 1971; Zahra et al., 2020).

Some collected cyanobacteria had spherical colonies, such as *Microcystis robusta*, *M. flos-aquae*, and *Gloeocapsa nigrescens* (Fig. 1a-d); some branched filament shape, *Plectonema tomasinianum* (Fig. 1e), or unbranched filaments, *Lyngbya birgei* (Fig. 1f), and *Osillatoria trichoides* (Fig. 1g), and some filamentous, such as *Nostoc* sp. and *Anabaena* sp., containing heterocyst vesicles (Fig. 1j, h). The heterocysts vesicles serve as communication elements; they bind together on the surface, and the

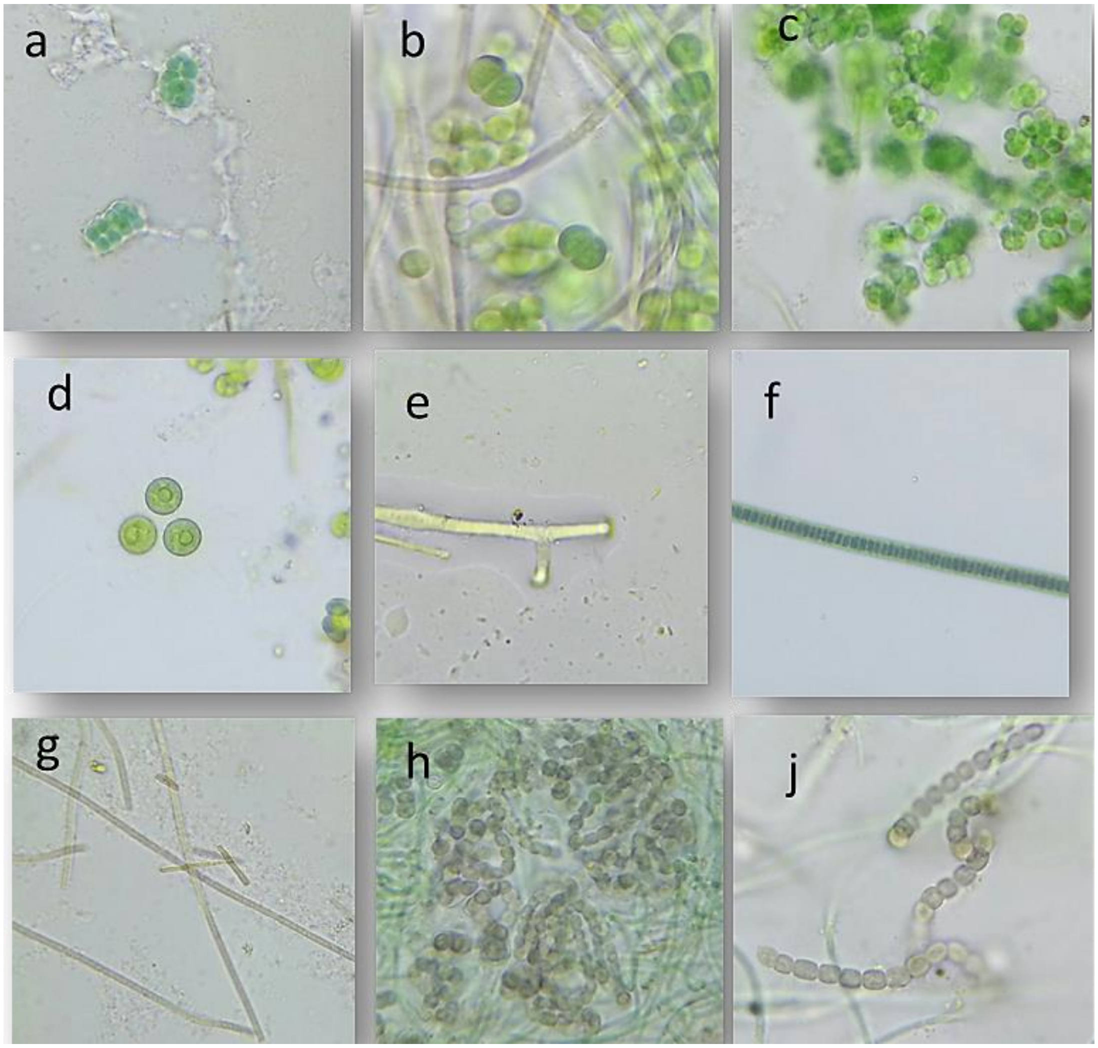

Figure 1. Some isolated cyanobacteria (100X) from the studied area (a) *Microcystis robusta*, (b) *M. flos-aquae*, (c and d) *M. flos-aquae*, (e). *Plectonema tomasinianum,* (f) *Lyngbya birgei*, (g) *Osillatoria trichoides*, (h) *Nostoc* sp. and (j) *Anabaena* sp.

heterocysts are sites for nitrogen fixation to survive in environments with low nitrogen (Burnat et al., 2014; Marino et al., 2020).

According to the results, the identified cyanobacteria at various sites have different adaptations to environmental parameters and also vary in their growth rates (Demay et al., 2019; Filatova et al., 2021). Studies showed that the possibility of isolating diverse cyanobacteria from various sites depends on the proper environmental conditions e.g. temperature, light, pH, and pollution (Wijffels et al., 2013; Ammar et al., 2014; Kaushik and Sharma, 2017). In conclusion, this study showed that *G. nigrescens* was the most common species in the study sites (10.34%) in waterbodies of Mosul, followed by *M. robusta*, *Osillatorio* sp., and *O. nigroviridis* (6.89%). Mosul Dam Lake, with six species, was the most diverse site.

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