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Research Article

Taxonomic Assessment and New Reports of Freshwater *Chlorophyta* and *Charophyta* algae from Benghazi, Libya

Munay A. Alteerah*, Jumana A. M. El-orofy

Department of Botany, Faculty of Science, University of Benghazi, Libya

*Correspondence: munay.abdulqadir@uob.edu.ly

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Abstract. A comprehensive survey of 400 freshwater samples was performed in and around Benghazi, Libya, for taxonomic study of *Chlorophyta* and *Charophyta* at the species level. Samples were collected from different water sites and resources: ponds, rain ponds, sewage ponds, artificial lakes, manmade reservoirs, water tanks, wet soils, and wet walls. During the period from February 2023 to January 2025, samples were randomly collected and preserved by 4% formalin. A total of 66 species belonging to 43 genera, 21 families, and 7 orders of *Chlorophyta* were recorded, and 54 species are newly reported in Libya. A total of 14 species belonging to 8 genera, 6 families, and 4 orders of *Charophyta* were recorded, and 12 species are newly reported in Libya. These findings underscore the rich and previously underexplored diversity of *Chlorophyta* and *Charophyta* in Benghazi and Libya.

Keywords: Desmids; Microalgae; Cosmarium; Phacomyxa; Freshwater *Chlorophyta*; *Charophyta*

1. Introduction

Freshwater microalgae play a vital role in aquatic ecosystems, contributing to primary productivity, nutrient cycling, and the overall health of freshwater habitats (Rao et al., 2024). Among the most abundant and ecologically significant groups of these microalgae are members of the phyla *Chlorophyta* and *Charophyta*. These taxa exhibit wide morphological diversity and are often used as bioindicators for water quality monitoring due to their sensitivity to environmental changes (Shikhaleyeva et al., 2023).

The *Viridiplantae*, or green plants, diverged into two major evolutionary lineages: the chlorophytes (green alga) and the *streptophytes* (including *Charophyceae* and *Embryophyceae*) (Becker & Marin, 2009). This split is estimated to have occurred between 725 million years ago, based on various molecular clock analyses (Leliaert et al, 2012). Among streptophytes, the earliest branching lineages are represented by the flagellated orders *Mesostigmatales* and *Chlorokybales* (Bierenbroodspot et al., 2024). Beyond these basal groups, filamentous and unbranched forms are found in *Klebsormidiales* and *Zygnematales*, while Charales and *Coleochaetales* exhibit more complex multicellular structures, including branched filaments and apical growth. Charales and *Coleochaetales* have long been regarded as close relatives of land plants. This view is supported by molecular phylogenetic studies, as well as by shared biochemical traits—such as glycolate oxidase activity, the presence of superoxide dismutase, and sporopollenin (a polymer constituting the outer walls of zygotes, spores, and pollen grains)—along with ultrastructural features like phragmoplast-mediated cell division. Collectively, these lines of evidence support the hypothesis that land plants evolved from a charophytic ancestor (Donoghue et al., 2021).

Chlorophyta species are highly adaptable and inhabit a wide range of freshwater habitats including rivers, lakes, ponds, wetlands, and even transient water bodies such as rain pools and ditches (Jana, 2024). They can be found as free-floating planktonic forms, attached (periphytic) species on submerged substrates, or within benthic communities (Zhang et al., 2020). Their ecological success is attributed to their high photosynthetic efficiency and tolerance to variable light, temperature, and nutrient conditions (Celewicz et al., 2022). Some genera, such as Scenedesmus, Chlorella are frequently used as bioindicators due to their sensitivity to eutrophication and other environmental stressors.

In contrast, *Charophyta*—a group more closely related to land plants—are commonly found in oligotrophic to mesotrophic freshwater bodies with low to moderate nutrient levels. Many species prefer clear, still or slow-moving

waters where they form dense submerged meadows (Pukacz et al., 2024). These algae are important ecosystem engineers; they stabilize sediments, oxygenate the water column, and provide habitat and spawning grounds for invertebrates and fish (Casanova & Nairn, 2016). Due to their sensitivity to pollution and habitat disturbance, *Charophyta* are increasingly recognized as valuable indicators of ecological integrity in freshwater systems (Farooq et al., 2024).

Understanding the distribution and ecological preferences of *Chlorophyta* and *Charophyta* is critical for freshwater biodiversity assessments and environmental monitoring. (Bellino & Baldantoni, 2023). Their presence, abundance, and community composition reflect water quality and ecosystem health, making them important subjects of taxonomic and ecological research (Shikhaleyeva et al., 2023).

Libya, with its diverse freshwater habitats ranging from ephemeral ponds to permanent lakes and wadis, provides a unique opportunity to study microalgal biodiversity. However, due to limited field surveys and taxonomic expertise in the region, comprehensive documentation of freshwater microalgal communities remains scarce. In particular, the area around Benghazi, located in northeastern Libya, has received little attention in terms of algal biodiversity assessments. This study aims to conduct a taxonomic assessment of freshwater *Chlorophyta* and *Charophyta* species collected from various freshwater bodies in and around Benghazi. By identifying and documenting new or previously unreported taxa, this research contributes to a better understanding of the region's microalgal diversity, biogeography, and ecological status. Furthermore, the findings provide a baseline for future ecological monitoring and may support the development of freshwater conservation strategies in Libya.

2. Method

2.1. The Study Area

Benghazi is the second-largest city in Libya and serves as a major economic and cultural center in the eastern part of the country (Figure 1). Geographically, the city is situated along the Mediterranean coast at approximately 32.1°N latitude and 20.1°E longitude. It lies within the Cyrenaica region, which is characterized by a mix of coastal plains, upland plateaus, and interior desert landscapes.

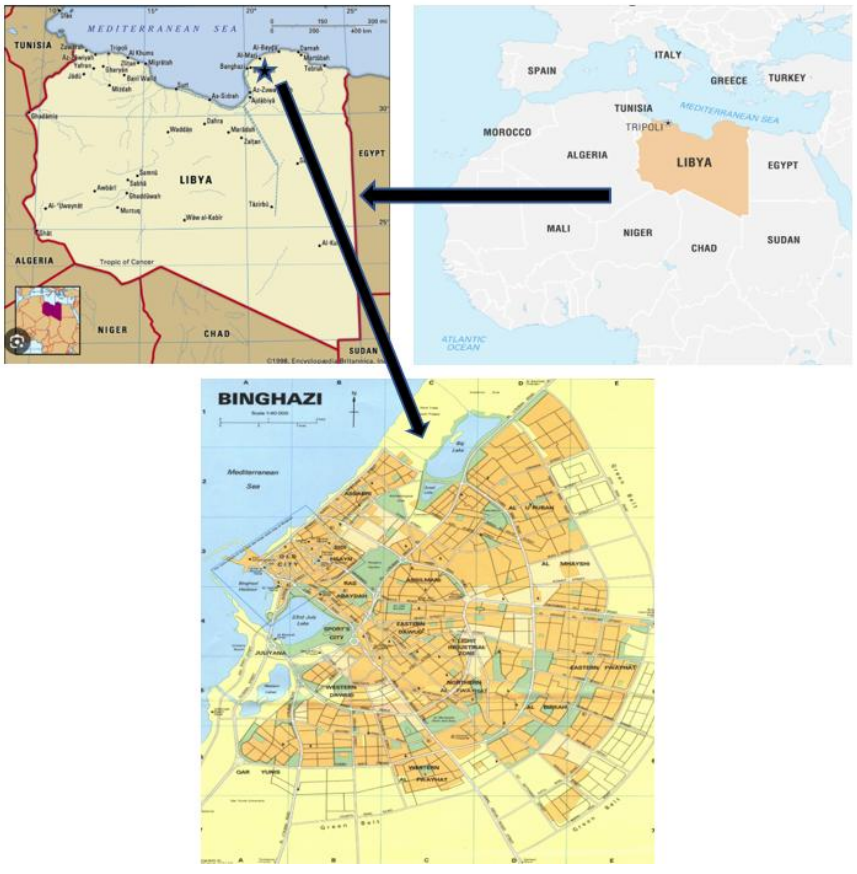


Figure 1. Map of the Study area

2.2. Algae Samples Collection and Identification

A total of 400 freshwater samples were collected during the period between February 2023 and January 2025. The samples were collected at various locations, including ponds, rain ponds, sewage ponds, artificial lakes, manmade reservoirs, water tanks, wet soils, and wet walls, in and around the city of Benghazi. The algal specimens were collected manually using forceps. Some specimens were obtained from the surface of moist soil, stones, wet walls, tubes of air conditioners, and other solid substrata. The samples were stored in plastic bottles or plastic bags. The preservation of the collected samples was conducted using 4% formalin, as previously described by Francoeur et al. (2013). The specimens were stored in the phycology laboratory at the Department of Botany, University of Benghazi. Each sample was assigned a voucher number and date of collection. The observation and identification of algae was conducted in the phycology laboratory of the University of Benghazi, Department of Botany. Microscopic examinations were conducted at a magnification of 40x using a light microscope, and photographs of algae were taken by cell phone. Taxonomic identification was conducted using various reference materials, including keys, monographs, and references (Krienitz et al., 2004; Van Vuuren et al., 2006; Hindák & Hindáková, 2008; Bellinger and Sigee, 2015; Baweja & Sahoo, 2015; Sheath & Wehr, 2015; Wehr et al., 2015; Matthews, 2016). Additionally, the Algae Base website (Guiry and Guiry, 2013; Guiry and Guiry, 2014; Guiry and Guiry, 2024) was consulted for further information.

3. Result and Discussion

From the comprehensive sampling of freshwater algae that was done during the period between February 2023 and January 2025, a total of 65 species belonging to 43 genera, 20 families, and 7 orders of *Chlorophyta* were recorded (Figure 2), and 54 species are newly reported in Libya (Figure 3). A total of 14 species belonging to 8 genera, 1 family, and 1 order of *Charophyta* were recorded, and 12 species are newly reported in Libya (Figure 4). The new reported species are indicated by (*) symbol as presented in Table 1.

Table 1. Classification of the micro-algal species reported from Benghazi, North of Libya

Kingdom –Plantae			
I-Phylum: *Chlorophyta*			
Class	**Order**	**Family**	**Genus and Species**
I-Chlorophyaceae	Sphaeropleales	Neochloridaceae	**Botryosphaerella sudetica* (Lemmermann) P.C. Silva
			**Golenkinia radiata* Chodat
		Schizochlamydaceae	**Planktosphaeria gelatinosa* G.M. Smith
		Selenastraceae	*Selenastrum capricornutum* Printz
			Chlorolobion braunii (Nägeli) Komárek
			**Monoraphidium contortum* (Thuret) Komárková-Legnerová
			**Monoraphidium litorale* Hindák
			**Monoraphidium arcuatum* (Korshikov) Hindák
			**Monoraphidium irregulare* (G.M. Smith) Komárková-Legnerová
			**Monoraphidium caribeum* Hindák

		**Kirchneriella obesa* (West) West & G.S. West
		Ankistrodesmus falcatus (Corda) Ralfs
	Hydrodictya-ceae	**Tetraëdron minimum* (A.Braun) Hansgirg
		Pediastrum tetras (Ehrenberg) Ralfs
		**Pseudopediastrum boryanum* (Turpin) E.Hegewald
	Scenedesmaceae	**Coelastrum indicum* W.B. Turner
		**Coelastrum microporum* Nägeli
		**Coelastrum rugosum* (Rich) P.M. Tsarenko
		**Westella botryoides* (West) De Wildeman
		Scenedesmus quadricauda (Turpin) Brébisson
		**Scenedesmus incrassatulus* Bohlin
		**Scenedesmus bijuga* (Turpin) Lagerheim
		**Desmodesmus armatus* (Chodat) E.H. Hegewald
		**Desmodesmus bicaudatus* (Dedusenko) P.M. Tsarenko
		**Desmodesmus abundans* (Kirchner) E.H. Hegewald
		**Tetradesmus dimorphus* (Turpin) M.J. Wynne
		**Coelastrella vacuolata* (I. Shihira & R.W. Krauss) Hegewald & N. Hanagata
	Radiococcaceae	**Gloeocystis gigas* (Kützing) Lagerheim

Kingdom –Plantae			
I-Phylum: *Chlorophyta*			
Class	**Order**	**Family**	**Genus and Species**
	Chlamydomona-dales	Goniaceae	**Gonium pectorale* O.F. Müller
		Tetrasporaceae	**Phacomyxa sphagnicola* Skuja
		Chlamydomona-daceae	*Chlamydomonas reinhardtii* P.A. Dangeard, nom. cons
			**Heterochlamydomonas uralensis* Novakovskaya, Boldina, Shadrin & Patova
			**Gloeomonas tecta* (Skuja) Ettl
		Volvocaceae	*Pandorina morum* (O.F. Müller) Bory
			Eudorina elegans Ehrenberg
			Eudorina unicocca G.M. Smith
		Chlorococcaceae	**Chlorococcum acidum* P.A. Archibald & Bold, nom. inval.
			**Chlorococcum amblystomatis* (F.D.Lambert ex N.Wille) N.Correia, J.Varela & Leonel Pereira
		Sphaerocystidaceae	**Sphaerocystis schroeteri* Chodat

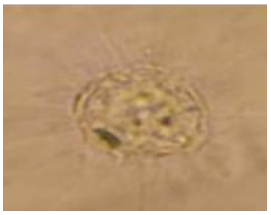
		Haematococcaceae	*Haematococcus pluvialis* Flotow
			**Chlorogonium euchlorum* (Ehrenberg) Ehrenberg
		Spondylomoraceae	**Pyrobotrys stellatus* (Korshikov) Korshikov
	Chaetophorales	Fritschiellaceae	**Stigeoclonium tenue* (C. Agardh) Kützing
		Chaetophoraceae	**Chaetophora elegans* (Roth) C. Agardh
			**Gongrosira papuasica* (Borzì) Tupa
II-Ulvophyceae	Ulotrichales	Ulotrichaceae	**Ulothrix aequalis* Kützing
			Ulothrix zonata (F. Weber & Mohr) Kützing
			**Ulothrix tenerrima* (Kützing) Kützing
			**Ulothrix subconstricta* G.S. West
			**Ulothrix consociata* Jónsson
	Oedogoniales	Oedogoniaceae	**Oedogonium pusillum* J.P. Keshri
			**Oedogonium virceburgense* Hirn ex Hirn
			**Oedogonium richterianum* Nayal, nom. inval.
III-Trebouxiophyceae	Chlorellales	Oocystaceae	*Oocystis borgei* J.W. Snow
			**Oocystis solitaria* Wittrock
			**Lagerheimia genevensis* (Chodat) Chodat

Kingdom –Plantae			
I-Phylum: *Chlorophyta*			
Class	**Order**	**Family**	**Genus and Species**
			Eremosphaera viridis De Bary
		Chlorellaceae	*Chlorella vulgaris* Beijerinck
			**Chlorella ellipsoidea* Gerneck
			**Parachlorella kessleri* (Fott & Nováková) Krienitz, E.H. Hegewald, Hepperle, V. Huss, T.Rohr & M.Wolf
			**Dictyosphaerium pulchellum* H.C. Wood
	Trebouxiales	Trebouxiaceae	**Crucigenia tetrapedia* (Kirchner) Kuntze
			**Neochlorella semenenkoi* Krivina, Temraleeva, Bobrovnikova & Sinetova
			**Lobosphaera incisa* (Reisigl) Karsten & al.
			**Dictyochloropsis asterochloroides* Skaloud, Friedl, A. Beck & Dal Grande
II. Phylum –*Charophyta*			
I-Class-Zygnematophyceae	Spirogyrales	Spirogyraceae	*Spirogyra varians* (Hassall) Kützing
			**Spirogyra affinis* (Hassall) Petit
	Desmidiales	Desmidiaceae	**Euastrum elegans* Ralfs
			**Cosmarium moniliforme* Ralfs
			**Cosmarium depressum* (Nägeli) P. Lundell, nom. Illeg
			**Cosmarium granatum* Brébisson ex Ralfs
			**Cosmarium laeve* Rabenhorst
			**Cosmarium margaritatum* (Lund.) Roy & Bisset
			**Spondylosium desmidiiforme* (Borge) G.S. West
		Closteriaceae	**Closterium incurvum* Brébisson
			**Closterium dianae* Ehrenberg ex Ralfs
		Gonatozygaceae	**Gonatozygon monotaenium* De Bary

	Zygnema-tales	Zygnemataceae	**Mougeotia scalaris Hassall*
II-Class –Klebsormidiophyceae	Klebsor-midiales	Klebsormidiaceae	*Klebsormidium flaccidum* (Kützing) P.C.Silva, Mattox & W.H.Blackwell



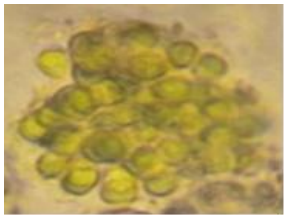
Selenastrum capricornutum



Golenkinia radiata



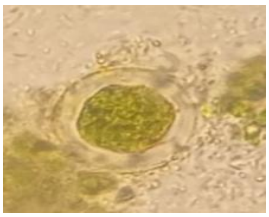
Chlorolobion braunii



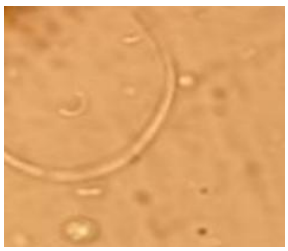
Botryosphaerella sudetica



Monoraphidium litorale



Planktosphaeria gelatinosa



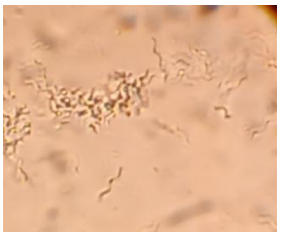
Monoraphidium arcuatum



Monoraphidium contortum



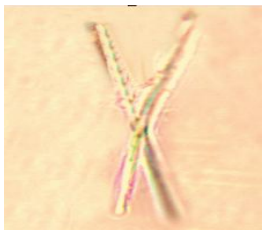
Monoraphidium caribeum



Monoraphidium irregulare



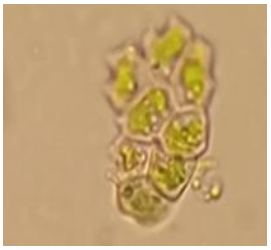
Kirchneriella obesa



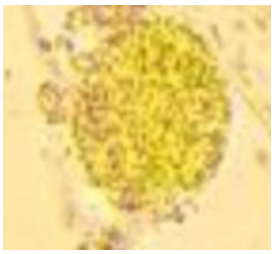
Ankistrodesmus falcatus



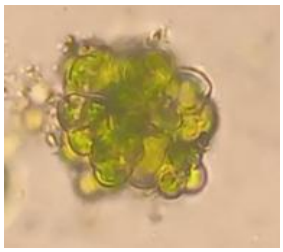
Tetraëdron minimum



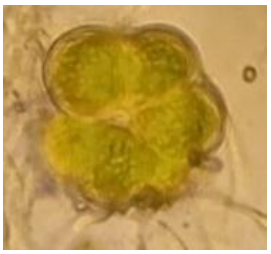
Pediastrum tetras



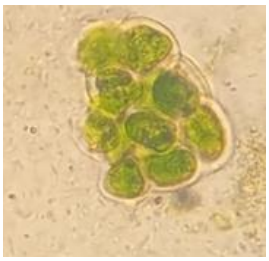
Pseudopediastrum boryanum



Coelastrum rugosum



Coelastrum microporum



Coelastrum indicum



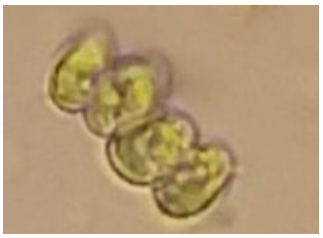
Scenedesmus quadricauda



Scenedesmus incrassatulus



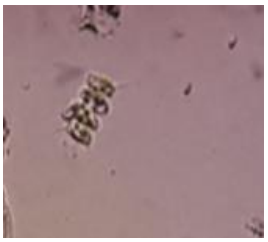
Scenedesmus bijuga



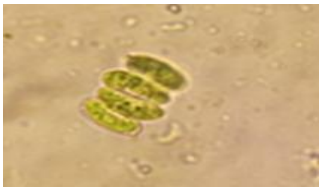
Desmodesmus communis



Desmodesmus abundans



Desmodesmus bicaudatus



Tetradesmus dimorphus



Desmodesmus armatus



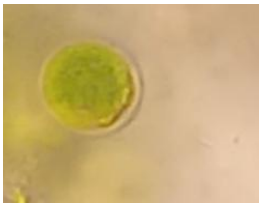
Westella botryoides



Chlamydomonas reinhardtii



Heterochlamydomonas



Gloeomonas tecta

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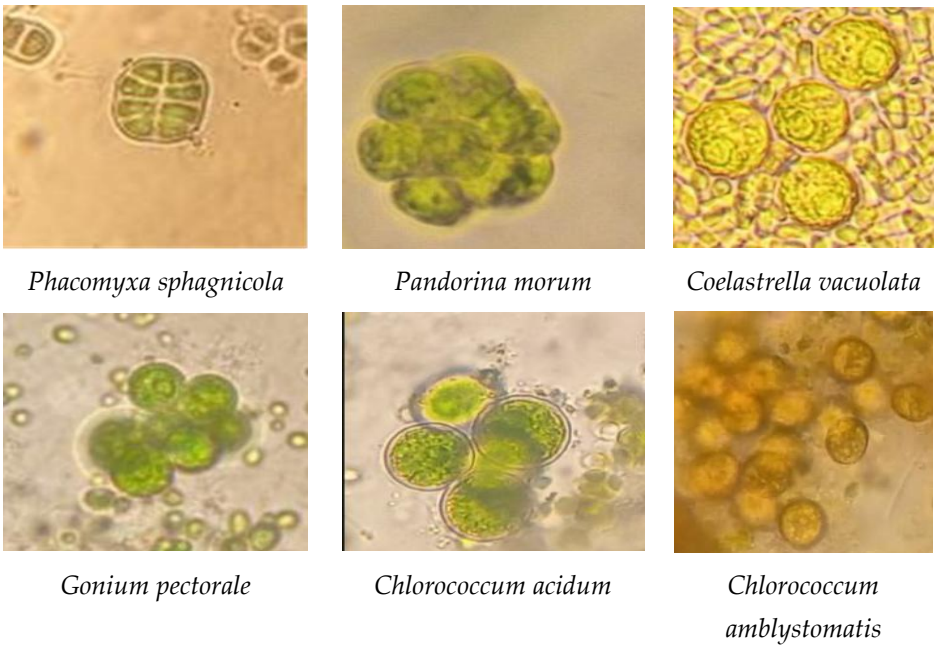
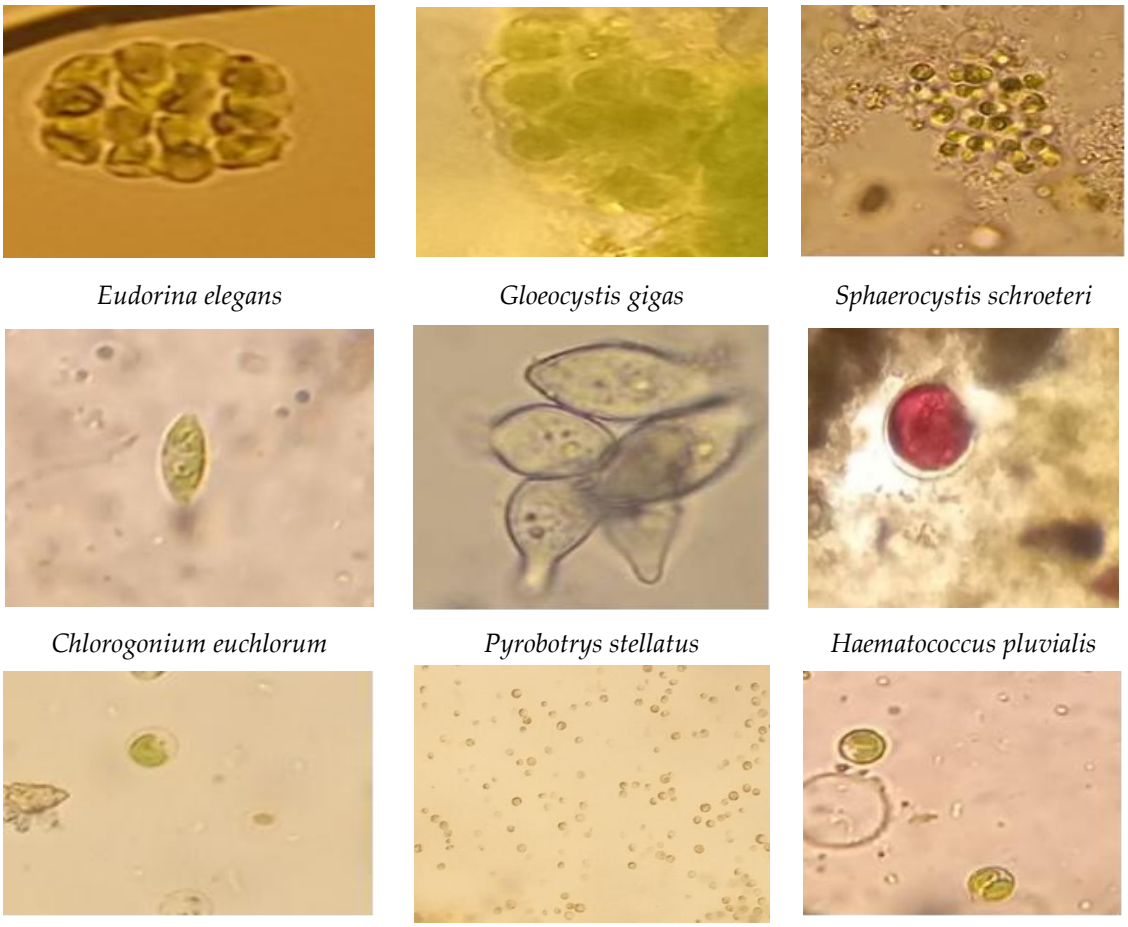
uralensis



Phacomyxa sphagnicola *Pandorina morum* *Coelastrella vacuolata*

Gonium pectorale *Chlorococcum acidum* *Chlorococcum amblystomatis*

Figure 2. Coccoid and colonies Chlorophytes collected from Benghazi.



Eudorina elegans *Gloeocystis gigas* *Sphaerocystis schroeteri*

Chlorogonium euchlorum *Pyrobotrys stellatus* *Haematococcus pluvialis*

Chlorella vulgaris *Chlorella ellipsoidea* at 10x *Parachlorella kessleri*

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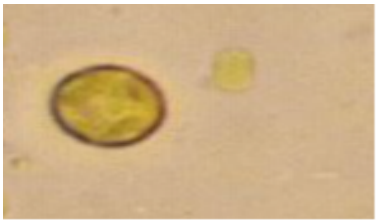
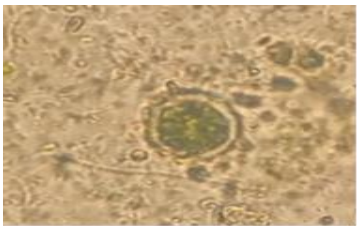
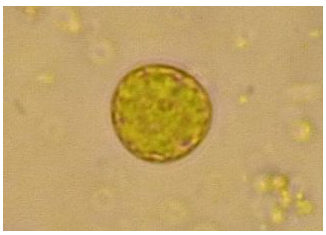


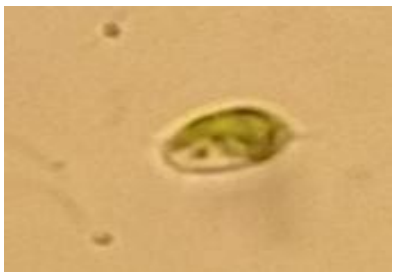
Neochlorella semenenkoi



Dictyochloropsis asterochloroides



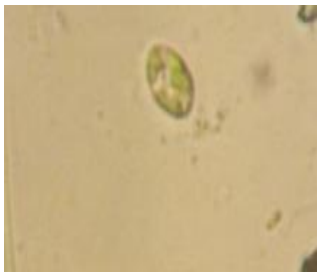
Eremosphaera viridis



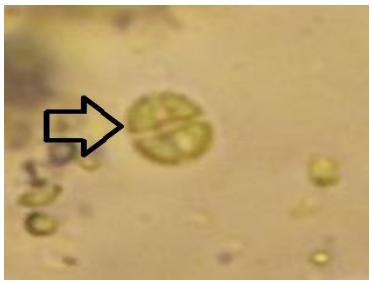
Lagerheimia genevensis



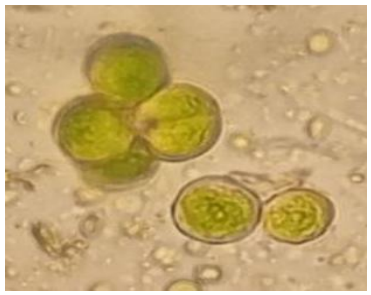
Oocystis solitaria



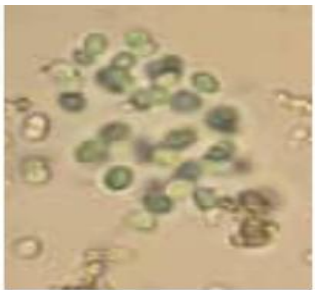
Oocystis borgei



Crucigenia tetrapedia



Lobosphaera incisa



Dictyosphaerium pulchellum



Ulothrix subconstricta



Ulothrix zonata



Ulothrix aequalis



Ulothrix tenerrima

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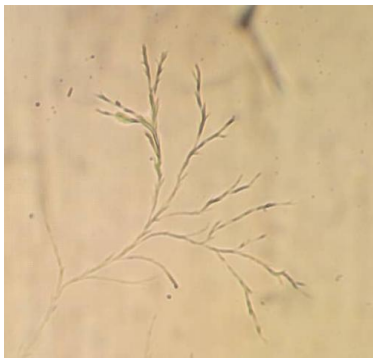
Ulothrix consociate



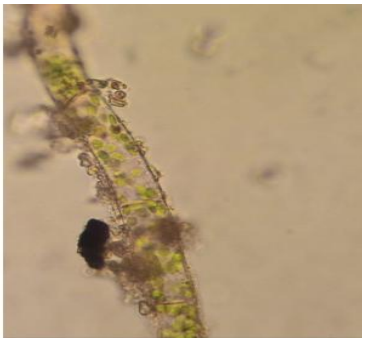
Chaetophora elegans



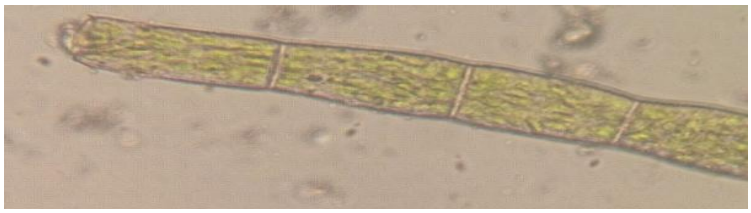
Stigeoclonium tenue



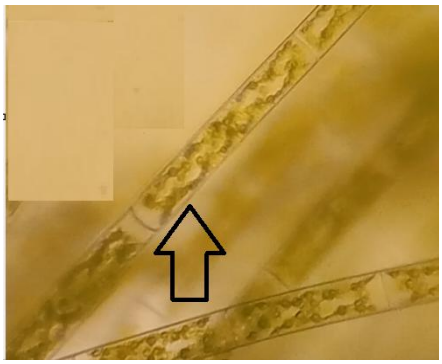
Oedogonium pusillum



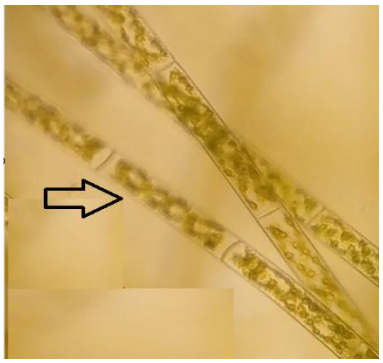
Oedogonium richterianum



Oedogonium virceburgense



Spirogyra affinis



Spirogyra varians

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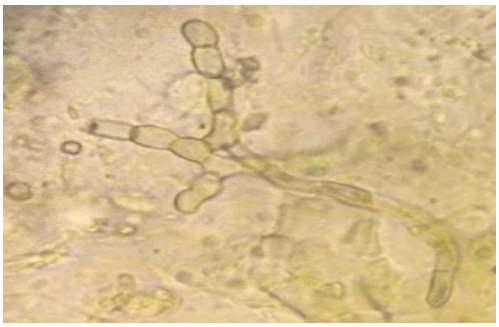
klebsormidium flaccidum

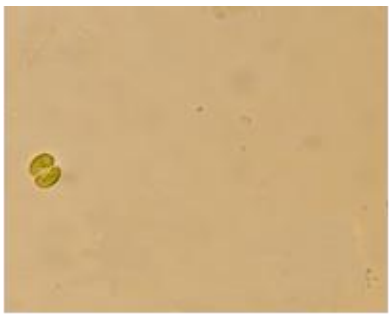


Gongrosira papuasica

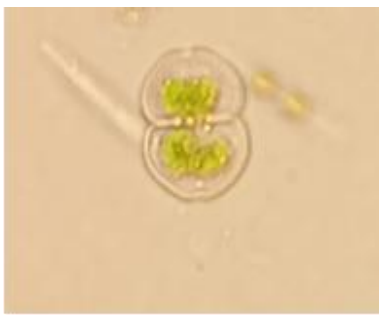
Figure 3. Filamentous Chlorophytes and Charophytes collected from Benghazi.



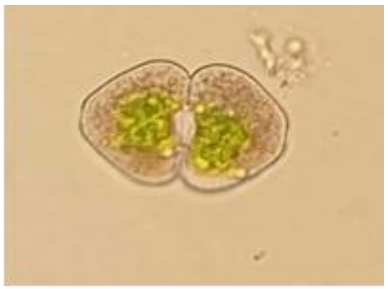
Cosmarium formosulum



Cosmarium depressum



Cosmarium laeve



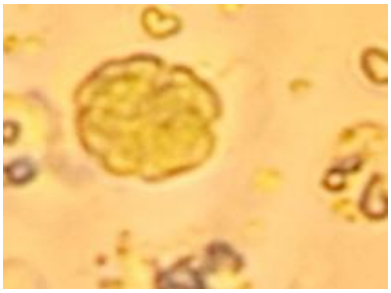
Cosmarium granatum



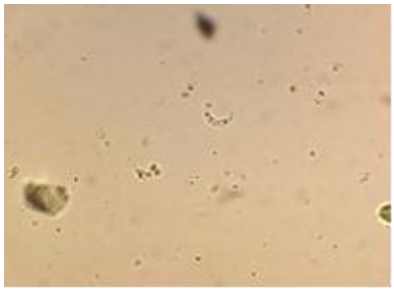
Cosmarium margaritatum



Cosmarium moniliforme



Euastrum elegans



Closterium incurvum



Closterium dianae

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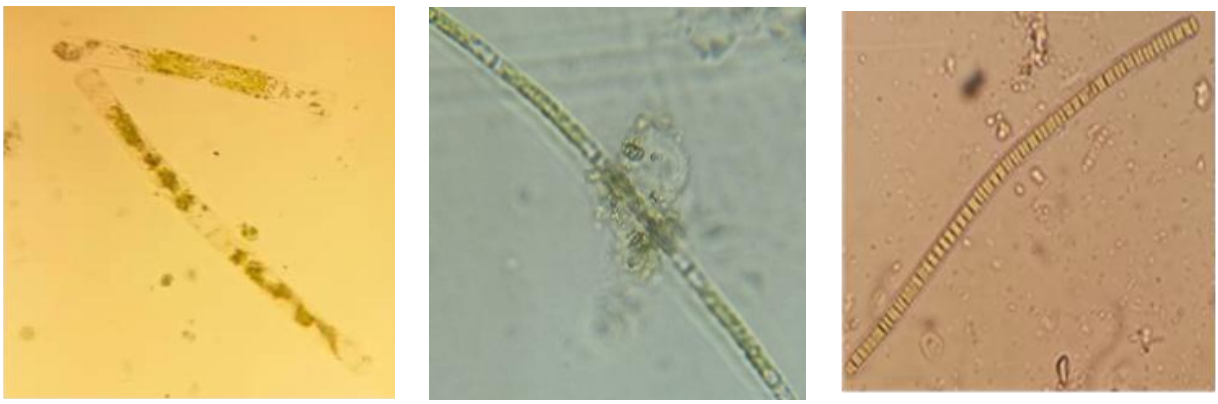

Gonatozygon monotaenium *Mougeotia scalaris* *Spondylosium desmidiiforme*

Figure 4. Charophytes collected from Benghazi.

It is rare to find a source of water or moist area on the earth that is not home to algae. These organisms can be considered as ubiquitous as bacteria, which are possibly the most extensively distributed organisms on the planet. The diversity in form and colour exhibited by algae is seemingly infinite. There are no exclusively freshwater groups of algae, but *Chlorophyta* and *Charophyta* are more abundant and diverse in freshwater (Wehr et al., 2015).

Green algae thrive in diverse inland habitats, with specific groups exhibiting distinct ecological needs. Flagellated chlorophytes are prevalent in nutrient-rich standing waters, while coccoid unicells are found in plankton of high-nutrient, well-lit environments. Most filamentous and plant-like *Chlorophyta* attach to surfaces in water, though some are free-floating or inhabit soils. Filamentous conjugating green algae typically occur in stagnant waters like roadside ditches and can create free-floating mats. Desmids prefer ponds and streams with low conductivity and moderate nutrients, often coexisting with macrophytes and filamentous algae (Wehr et al., 2015); this is what was observed in the current study. Chlamydomonas reinhardtii and Chlorella vulgaris were more common in the current study, which is consistent with Abobaker and Elsalhin (2016) and also with Abobaker (2006). Chlamydomonas reinhardtii remains one of the most useful organisms for the study of basic physiological processes, including photosynthesis and carbon uptake (Hoek et al., 1995; Graham & Wilcox, 2000). Some genera only appeared once, such as Golenkinia, where one species was observed (Golenkinia radiata). Also, Phacomyxa sphagnicola appeared once. Neither of these species has been recorded in previous studies.

Research on freshwater algae in Libya remains relatively limited. One of the earliest studies was conducted by Nizamuddin & Gerloff (1982), who recorded *Chlorophyta* with 21 genera and 35 species and *Charophyta* with 3 genera and 9 species from various regions across the country. Freshwater algae were collected from Suluq Lake by Issa et al. (2012) consisted of 17 genera (29 species) of *Chlorophyta*. Abobaker & Elsalhene (2016) collected freshwater samples from the Green Mountain area, also in the eastern part of Libya, and identified 13 genera (14 species) of *Chlorophyta*. Similarly, 16 species belonged to *Chlorophyta*, and only 1 species from *Charophyta* was recorded from freshwater habitats in the city of Shahat, in north-eastern Libya, by Elsalhene & Abobaker (2018). In southern Libya, Loujanqi et al. (2020) documented 11 species in the city of Kufra. More recently, Abobaker et al. (2023) reported 19 species of class Chlorophyceae from the Derna Waterfall in eastern Libya.

The identification of 66 newly recorded species of freshwater *Chlorophyta* and *Charophyta* in Benghazi, Libya, significantly expands the known algal biodiversity of the region and carries several noteworthy ecological and conservation implications. These findings indicate to shortage in previous studies on freshwater algal flora in Libya. Algae are sensitive bioindicators of water quality and ecological health. Documenting algal diversity in Libyan freshwater bodies provides baseline data that can be used for future environmental monitoring and conservation planning. It may also help detect ecological changes due to climate shifts or anthropogenic impacts in Mediterranean inland waters.

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4. Conclusion

The present study significantly contributes to the understanding of freshwater algal biodiversity in the Benghazi region of Libya by providing a detailed taxonomic assessment of *Chlorophyta* and *Charophyta*. Through systematic sampling and morphological identification, several genera and species were documented, including both commonly reported taxa and previously unrecorded species in the region. These new records not only extend the known distribution ranges of certain taxa but also underscore the underexplored richness of Libyan freshwater ecosystems. This study lays foundational groundwork for future taxonomic, ecological, and conservation-related research in North African freshwater systems. It emphasizes the urgent need for continued biotic surveys and the establishment of a comprehensive algal database for Libya, which could inform environmental management strategies and biodiversity conservation efforts in the region.

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