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New Records of Non-Diatom Algae in Aquatic Habitat along Greater Zab River Path from Bekhma to Gwer District in Erbil Province, Iraq

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Abstract:

A study of non-diatom algal species composition in twelve sites from Greater Zab River path within Erbil Province, was carried out from April 2021 to January 2022 with monthly sample collection in twelve studied sites. Among them site 4,5,6,7 and 9 are the first for algal study in this area. The 112 different species of algae belong to 33 genera, 25 families, 13 orders and 4 divisions have been identified. The predominant genera included *Spirogyra* and *Cosmarium* 17, 8 taxa respectively. 13 taxa were new recorded to Iraqi Kurdistan algal flora and 9 of them were new recorded to Iraqi algal flora: *Botryosphaerella sudetica, Muriella magna, Gloeotaenium loitlesbergianum, Apiocystis brauniana, Anabaena oscillarioides, C. distentum, C. tutum, C. contractum* var. *minutum, kirchneriella irregularis, Oedogonium suecicum f. australe, Coelastrum indicum, Oocystis lacustris,* and *Pediastrum braunii*. Also, there were three new genera for Iraqi algal flora which including: *Botryosphaerella, Muriella* and *Apiocystis.* A brief description as well as the measurement is given for each species. Water temperatures ranged from 17.3 to 20.08 ºC, hydrogen ion concentration and electrical conductivity value ranged from 7.44 to 7.88 and 433.20 to 721.56 $\mu S.cm^{-1}$ for all studied sites respectively. The aim of this study is to identify algal taxa in studied sites.

Keywords: Erbil Province, Greater Zab River, Iraq, New records, Non-diatom algal taxa, Ponds, Springs

Introduction:

Aquatic algae are extremely diverse creatures that live in all types of natural settings where there is water, food, and light, aquatic environment, algae show a clear response to changes in the characteristics of the water. Freshwater algae are frequently used for assessment and monitoring water quality [1]. Algae, like other microorganisms, are regarded as cosmopolitan due to their tiny size, great abundance, rapid population growth, and long-range migration since they occur in a variety of habitats and are distributed globally [2]. Due to its high biomass productivity, Chlorophyta, popularly known as sea lettuce, has been suggested as a model species for land-based aquaculture [3]. Algal growth rates are accelerated by warming, and algal species with high temperature growth maxima are favored [4]. In Iraq there are numerous research papers on algal identification and classification [5-9]. In the Kurdistan Region of Iraq, studies on algal flora have attracted more attention, although there are numerous research papers on algal identification and classification [10]. Up to date, according to final algae check list for the Iraqi Kurdistan Region [11], 1812 taxa of the algal flora in all were recorded. Also, in Iraq a total of 2647 taxa were reported[12]. Algal content of this study's samples was three springs, three ponds and six rivers within Erbil province were considered. The goal of the current study is to have advance knowledge of the distribution of algae in these aquatic habitats. More recently, a number of algal new record study was added to Iraqi algal flora [13-19]. Algae depend on a variety of environmental parameters, including temperature, pH, and others, to grow and reproduce [5]. Benthic algae are those that grow on submerged surfaces and are present at the water's surface bottom [6].

Material and Methods:

1- Description of Studied Sites

This work was carried out in Erbil Province which is locates between the latitude of 35º 40' and 30 º 30' N, and longitude 43º 20' and 44º 20' E. Greater Zab River is a large river in Kurdistan

Region of Iraq. Erbil Province is situated between 36 °-37° north latitudes and 43°-44° east longitude. Many authors provide descriptions of the geology, water resources and climate in the studied area of Erbil Province [20-21]. Twelve sites (rivers, springs and ponds) along Greater Zab River were selected to algal abundance, distribution and classification from from Bekhma to Gwer district in Erbil province. All the studied sites are about 95 km long (Table. 1, Fig. 1).

Table 1. Location of sampling site within studied area.

Sites	Places	Habitat type	X - Field	Y - Field
1	Ruwandiz	River	436082	4063343
2	Ble-Barzan	River	435941	4063509
3	Behkma	River	434498	4060141
4	Gomi Gali	Pond	434390	4060135
5	Chami Raza	Spring	431080	4057123
6	Qandil	Spring	428770	4054650
7	Prdisarkawr	Spring	425862	4052589
8	Ifraz	River	386628	4020974
9	Aski Kalak	Pond	378459	4016213
10	Aski Kalak	River	377990	4014307
11	Gwer	Pond	369444	3999202
12	Gwer	River	368132	4000218

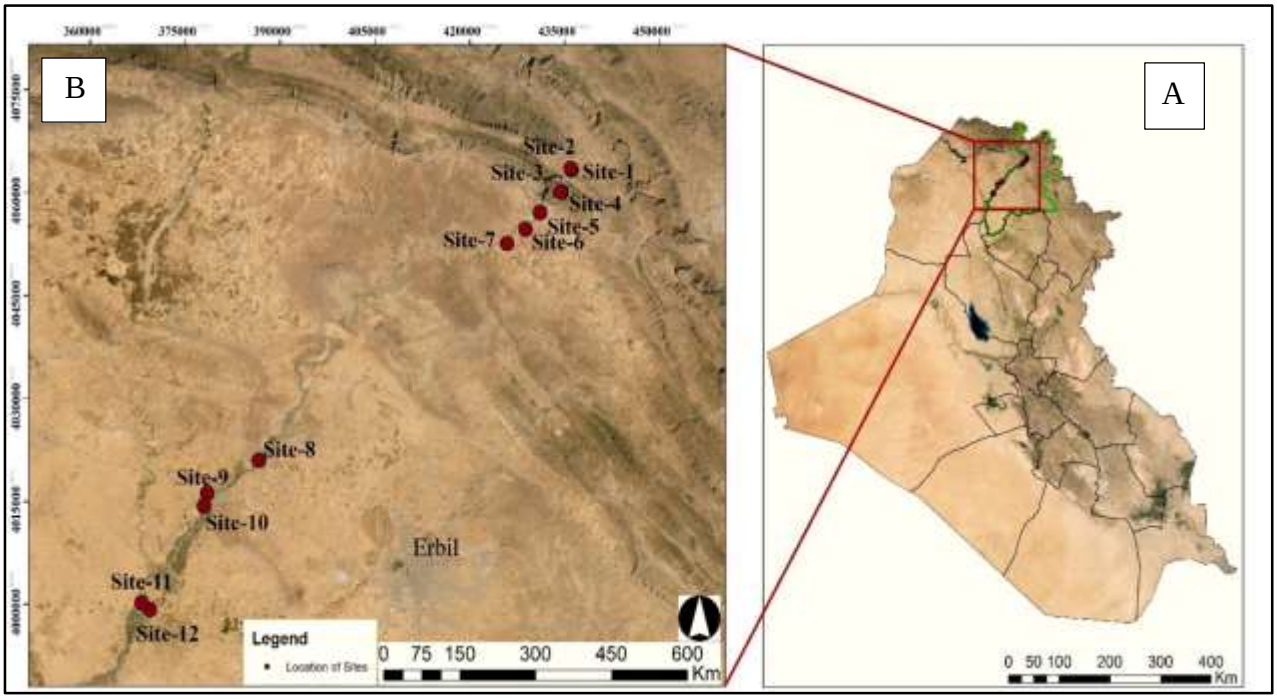

Figure 1. Shows: A) Map of Iraq and Erbil province; (B) Map of studied area and the sampling the site of study in greater Zab river (Basemap in ArcGIS).

2-Algal Collection, Preservation and Identification

Samples of planktonic or floating microalgae were collected with phytoplankton mesh net 20 µm, stored in vials 50-100 ml, while benthic algae which includ epilithic algal samples were collected by removing stone and scrape surface by spatula, forceps and tooth brush, and algae which live on surface macrophytes (epiphytic algal taxa) for example *Oedogonium suecicum f. australe* was collected on macrophytes by scrape algae then placed in a tube with water and preservative of algal samples. The collected samples at each site were added to two airtight polylab vial. One of them was preserved with 1 ml Lugol's solution. Flagellated forms of algae were identified before algal fixation as soon as possible because of their loss of taxonomic characters [22]. Then each sample was labeled and then brought to the laboratory[23]. Different species were taken using a microscope digital camera (Model Number: SCMOS05100KPB). The new records based on the most recent checklist of the algae in

Iraqi Kurdistan Region by [11]. A precise glass mercury thermometer 0-100 ˚C was used in the field to monitor the water's temperature. A portable pH meter (JENWAY 3505) and a portable EC meter were used to electrometrically measure pH and EC in the field (HANNA instruments, HI98303).

Results and Discussion:

This study was conducted on a monthly basis over a period of ten months, from April 2021 to January 2022. Site 4, 5, 6 and 7 are sites taken for the first time for studying algal in this area. A total of 112 algal species belong to 33 genera, 25 families, 13 orders and 4 divisions were identified, among them 13 taxa were new records to Kurdistan region of Iraq and Iraqi algal flora. Each sample site's data on water temperature, EC, and pH have a significant effect on algal growth, also to grow and reproduce [5]. Three *Cosmarium* are new additions and for each of the remaining genera, only one new record was observed with 23.076 % and 7.692 %, Table. 3. It is clear that a total of 13 new algal record were identified in 11 genera, 8 families, 8 orders, 3 classes and 2 divisions, Table. 5. The geology of the region, seasonal fluctuations, and environmental factors such as water temperature, pH and EC might all contribute to the disparities between the numerous species observed in the study sites [24]. The results of the present study of water temperature, pH and EC were in accordance with the result of [25-30]. The cause of the dispersion of algae and one explanation for the occurrence and dominance of a particular population of algae in habitats throughout the year is their capacity for adaptation. Algae are among the organisms that can withstand stress and environmental changes, and some varieties can withstand changes in temperature, pH, and other environmental factors [8]. The findings of this research agree with a study by [25, 26], that highlighted the fact that algae create specialized spores, defensive or tolerant spores, and a variety of chemical compounds to protect them from UV light, high radiation, and desiccation.

Table 2. Some water properties in the studied sites during the studied period.

Site	Places	Aquatic habitat type	Water Temp. °C	pH	EC (μS.cm^{-1}).
1	Ruwandiz	River	17.3	7.75	545.00
2	Ble-Barzan	River	18.08	7.77	721.56
3	Behkma	River	19.04	7.75	648.94
4	Gomi Gali	Pond	20.05	7.44	537.65
5	Chami Raza	Spring	19.54	7.63	615.46
6	Qandil	Spring	19.41	7.70	667.79
7	Prdisarkawr	Spring	20.07	7.79	437.76
8	Ifraz	River	19.73	7.83	433.20
9	Aski Kalak	Pond	19.82	7.85	442.09
10	Aski Kalak	River	20.08	7.88	448.23
11	Gwer	Pond	21.01	8.12	439.91
12	Gwer	River	21.02	7.82	819.50

Table 3. New records with its percentages in the sites during the studied period

Name of Algal genus	New Recorded species	%
Anabaena Bory, 1822	1	7.692
Botryosphaerella P.C.Silva 1970	1	7. 692
Gloeotaenium Hansgirg 1890	1	7. 692
Coelastum Naegeli in kuetzing 1849	1	7. 692
Pediastrum *Meyen* 1829	1	7. 692
Cosmarium Ralfs 1848	3	23.076
Kirchneriella Schmidle 1893	1	7. 692
Oedogonium Link 1820	1	7. 692
Oocystis *Naegeli,* 1845	1	7. 692
Apiocystis Nägeli, 1849	1	7. 692
Muriella J.B.Petersen 1932	1	7. 692
Total	**13**	**100**

Table 4. List of algal taxa identified in the study sites during the studied period

No.	Name of algal taxa new records
1	***Botryosphaerella sudetica*** (Lemmerman) P.C.Silva 1970
2	***Muriella magna*** F.E.Fritsch et R.P.John 1942
3	***Gloeotaenium Loitlesbergereanum*** Hansgirg 1890
4	***Apiocystis brauniana*** Nageli 1849
5	***Anabaena oscillarioides*** (Bory ex Bornet & Flahault) Wacklin, Hoffmann & Komarek 1886
6	***Cosmarium distentum*** (G.S. West) Coesel & Meesters 2015
7	***Cosmarium tutum*** Grönblad (1945)
8	***Cosmarium contractum* var. *minutum*** (Delponte) Coesel 1989
9	***Kirchneriella irregularis*** (G. M. Smith) Korshikov 1953
10	***Oedogonium suecicum f. australe*** (G.S.West) Tiffany 1934
11	***Coelastrum indicum*** W.B.Turner 1892
12	***Oocystis lacustris*** Chodat 1897
13	***Pediastrum braunii*** Wartmann 1862

Table 5. Classification of algal taxa new records

Division: Cyanophyta	
Class: Cyanophyceae	*Cosmarium distentum* (West) Coesel & Meesters
Order: Nostocales	*Cosmarium tutum* Shyndanovina
Family: Nostocaceae	*Cosmarium contractum* var. *minutum* Scott & Prescott
Anabaena Bory, 1822	Order: Chlorococcales
Anabaena oscillarioides Bory ex Bornet & Flahault	*Kirchneriella* Schmidle 1893
Division: Chlorophyta	*Kirchneriella irregularis* (G. M. Smith) Korshikov
Class: Chlorophyceae	Class: Trebouxiophyceae
Order: Chlorococcales	Order: Oedogoniles
Family Dyctiosphaeraceae	Family:Oedogoniaceae
Botryosphaerella P.C.Silva 1970	*Oedogonium* Link 1820
Botryosphaerella sudetica (Lemmerman)	*Oedogonium suecicum f. australe* (G.S.West) Tiffany
Gloeotaenium Hansgirg 1890	Order: Chlorellales
Gloeotaenium Loitlesbergereanum Hansgirg	Family: Oocystaceae
Family: Scenedesmaceae	*Oocystis* Naegeli, 1845
Coelastum Naegeli in kuetzing 1849	*Oocystis lacustris* Chodat
Coelastrum indicum Turn.	Order: Chlamydomonadales
Family: Hydrodictyaceae	*Apiocystis* Nägeli, 1849
Pediastrum Meyen 1829	*Apiocystis brauniana* Nageli
Pediastrum braunii Wartmann	Order: Chlamydomonadales
Order: Zygnematales	Family: Tetrasporaceae
Family: Desmidiaceae	*Muriella* J.B.Petersen 1932
Cosmarium Ralfs 1848	*Muriella magna* F.E.Fritsch et R.P.John

Description of the New Records

Non-diatom algal forms were identified using the references of: [31-32].

Botryosphaerella sudetica (Lemmerman) P.C.Silva 1970

Colonies about 80 µm wide, cells ovoid, up to 10 µm wide, with thin remnants of mother cell wall material persisting within mucilage following autospore release [32]. Forms small colonies, with cells arranged in group (Fig.2A). This species inhabits pond as plankton is obtained in site nine (18 Sep 2021: water temperature 20.4 °C, pH 7.42, EC 631µS.cm^{-1}) Table. 2.

Muriella magna F.E.Fritsch et R.P.John 1942

Cells are up to 20 µm wide, spherical or broadly ellipsoid, chloroplast initially in pairs, later divided into several trough-shaped portions, with age dis-like and polygonal, always densely packed, autospores unknown, akinetes uo to 90 µm wide, with thick, stratified walls [32] (Fig.2B) which was obtained from site seven (18 May 2021: water temperature 20.3°C, pH 7.41, EC 457 µS.cm-1) Table 2, occupies as benthos in the spring.

Gloeotaenium Loitlesbergereanum Hansgirg 1890

It has single cells 25 µm in diameter, 2-celled colonies 70-90 µm in diameter, or in 4-celled colonies [31] (Fig.2C). Information of sampling sites: This type which inhabits in ponds as benthic organisms, was taken from site five, (18 June 2021: water temperature 20.4°C, pH 7.51, EC 530µS.cm^{-1}), Table. 2.

Apiocystis brauniana Nageli 1849

It is a colonial mucilage that has developed and resembles a sack, it is made up of cells and is linked at one end to solid substrates like aquatic plants. 6.8 to 11.3 µm wide cells. The individual cells have smooth walls, are spherical, and have chloroplasts that resemble cups. The cells have lengthy pseudocilia despite not being motile. The cells split into 4-cell subgroups, but because they prefer to spread inside the colonial sack, it is difficult to identify the subgroups (Fig.2D). This species was found in pond as plankton, in site four (18 Oct 2021: water temperature 19.2 °C, pH 7.48, EC 570µS.cm^{-1}), Table 2.

Figure 2. Algal new record in the studied area: A. *Botryosphaerella sudetica*, B. *Muriella magna*, C. *Gloeotaenium Loitlesbergereanum*, D *Apiocystis brauniana* Scale bar: 10µm

Anabaena oscillarioides (Bory ex Bornet & Flahault) Wacklin, Hoffmann & Komarek 1886

Trichomes have spherical or oval heterocysts, small, blue-green barrel-shaped cells, and are straight or slightly curved. Cells are with 3.4-5.5 µm in width and 3.2-4.6 µm in length. The adult akinetes are smooth and elliptical or cylindrical (not spiny). The akinetes have heterocysts near both of their ends, and the trichomes frequently have several akinetes in succession (Fig.3A). The specimens of this species are taken from ponds in site seven where they are free-floating (18 May 2021: water temperature 20.3°C, pH 7.41, EC 457µS.cm^{-1}), Table 2.

Cosmarium distentum (G.S. West) Coesel & Meesters 2015

Cells are 14–18 µm long, 11–15 µm wide, and have an isthmus of 3–4 µm. The stated diagnostic of *Cosmarium laeve* Rabenh has a reduced cell length to breadth ratio. Semi cells are broadly oval from a broad base, with a rounded or slightly truncate tip, and a conspicuous tubercle in the middle. The cell wall has tiny punctures in it (Fig.3B). This species was presented in spring as benthic in site six (18 July 2021: water temperature 19.2 °C, pH 7.34, EC 687 µS.cm^{-1}), Table. 2.

Cosmarium tutum Grönblad (1945)

Cells 72.9-80.7 µm in length, 72.2-80.5 µm breadth with length: breadth ratio of 0.95-1.07, 42.6-46.0 µm thickness, and isthmus of 38.5-42.7 µm, sub-circular, apex slightly truncate, sinus is always closed and moderately deep (isthmus equals half of the cell breadth). Semicell semicircular with broadly rounded basal angles the wall of which is provided with an outer, hyaline). A thickened zone with scattered, large (approx. 1 µm in diameter) scrobicles about 30 in number is to be seen in the centre of the semicell. The surface of this zone looks smooth in optical microscope, and all pore openings are inside scrobicles. Semicell with one dicentric furcate chloroplast (Fig.3C). This species existed in spring from site seven (18 Aug. 2021: water temperature 21.0 °C, pH 7.65, EC 668 µS.cm^{-1}), Table. 2.

Cosmarium contractum* var. *minutum (Delponte) Coesel 1989

Cells are small, less than 28 µm long, 1.3–1.4 times longer than wide, with a deep median constriction, an acutely open sinus, and semicells that are broadly elliptic in the vertical and circular in the lateral views. Cell size is 22–26 µm long, 17–21 µm wide, and 4-5 µm wide at the isthmus (Fig.3D). This species resides as benthos in the spring and was gathered from site five (18 Aug. 2021: water temperature 19.0 °C, pH 7.35, EC 556µS.cm^{-1}), Table. 2

Figure 3. Algal new record in the studied area: A. *Anabaena oscillarioides*, B. *Cosmarium distentum*, C. *Cosmarium tutum*, D. *Cosmarium contractum* var. *minutum* Scale bar: 10µm

Kirchneriella irregularis (G. M. Smith) Korshikov 1953

It features cells that are highly bent into a crescent form, with apices that are almost touching each other. Cells with 3.4-5.4 µm in width and 15.8-27.2 µm in length. The cells are twisted so that their ends are not in the same plane and might be either sharply pointed or very slightly rounded (Fig.4A). These taxa dwelled in spring from site five (18 Apr 2021: water temperature 20.0°C, pH 7.46, EC 480 µS.cm^{-1}), Table 2.

Oedogonium suecicum f. australe (G.S.West) Tiffany 1934

Dioecious and macrandrous, cylindrical, (12)-14-16 µm in diameter, and (46)-56-78-(80) µm in length, describe vegetative cells. There are more than one in same filament with a median pore, measuring 39-40-41(43) µm in diameter and 40-42-43 µm in length. Glogose, thick-walled oospores that almost completely fill the oogonia measure 31-34-35 µm in length and 32-34-31 µm in diameter (Fig.4B). The habitat of this species is river from site ten and twelve (18 Apr 2021: water temperature 18.8°C and 19.3°C, pH 7.70 and 7.73, EC 301 µS.cm^{-1} and 601 µS.cm^{-1}) Table 2.

Coelastrum indicum W.B.Turner 1892

Spherical, free-living, 8-16-32-64-celled colonies. The colony contains spherical cells with an angled undulated border and triangular openings. The cell wall is next to a single chloroplast. Individual cells are 4-6 µm in diameter, with colonies measuring 34–40 µm (Fig.4C). Habitat pond as benthos, and it was located in site seven (18 Sep 2021: water temperature 19.2°C, pH 7.34, EC 737 µS.cm^{-1}), Table. 2.

Oocystis lacustris Chodat 1897

Elliptical-oval cells with nicely rounded, unthickened poles. The maternal wall of the chloroplast parietal 1-2 has a globosa pyrenoid. Cells are 6-10 µm in diameter and 11.5-12 µm long (Fig.4D). It resides in spring and was recorded in site five (18 Oct 2021: water temperature 19.2°C, pH 7.63, EC 585 µS.cm^{-1}), Table 2.

Pediastrum braunii Wartmann 1862

Colony has a circular shape, is virtually complete but has a few interstices, has 4-16 quadrate or 5-sided cells, and the periphery cells have 3-4 short, unevenly spaced sharp projections [32]. The walls do not have any projections or incisions. The cells are 9-12 µm in diameter (Fig.4E). It is found in spring and pond and was collected

from site six and elven (18 Sep 2021: water temperature 19.2°C and 22.0°C, pH 7.34 and 7.41, EC 737µS.cm^{-1} and EC 681µS.cm^{-1}), Table 2.

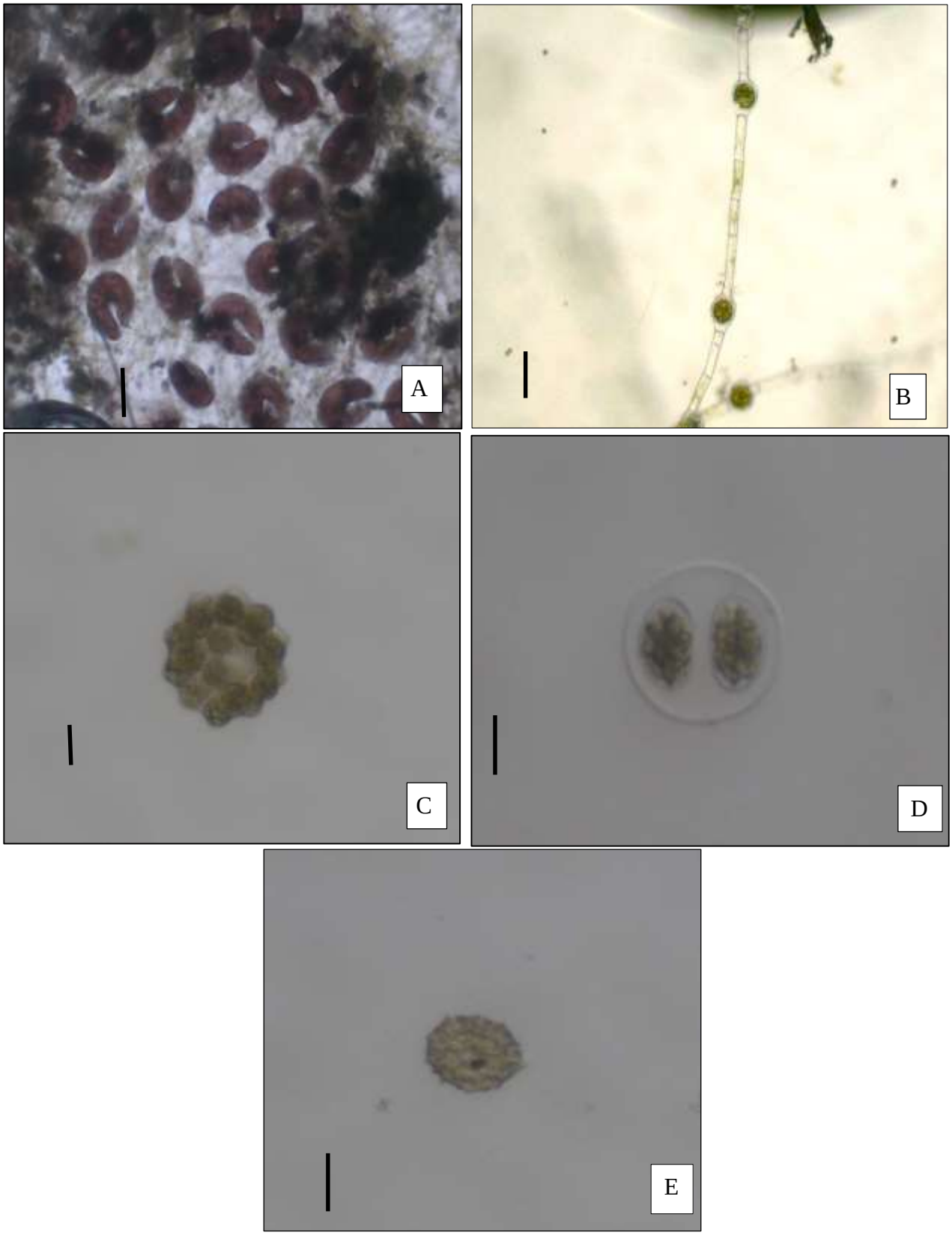

Figure. 4:Algal new record in the studied area: A. *Kirchneriella irregularis*, B. *Oedogonium suecicum f. australe*, C. *Coelastrum indicum*, D. *Oocystis lacustris*, E. *Pediastrum braunii* Scale bar: 10µm

Conclusions:

In the current study, 13 new algal taxa were recorded as new record to the algal flora of Iraq and Iraqi Kurdistan, and 9 of them were first discovered in Iraq. All algal taxa new records were belonging to Chlorophyta and Cyanophyta division. The studied area is open to other kinds of biological beings. The pH of the studied site was fluctuating toward the alkaline side of neutrality.

Authors' declaration:

- Conflicts of Interest: None.
- We hereby confirm that all the Figures and Tables in the manuscript are mine ours. Besides, the Figures and images, which are not mine ours, have been given the permission for re-publication attached with the manuscript.
- Ethical Clearance: The project was approved by the local ethical committee in Salahaddin University.

Authors' contributions statement:

F. H. A. and Ch. M. Sh. both participated in the development of the idea of the search. F. H. A. developed the theory and performance the computation. Ch. M. Sh. did all the identification of algal new records and other physicals and chemicals analysis but with supervising and encouragement by F. H. A. Both authors discussed the results to contribute to the final manuscript to become in better form.

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سجلات جديدة للطحالب غير الدياتوم في الموائل المائية على طول مسار نهر الزاب الكبير من بخما إلى منطقة قوير في محافظة أربيل ، العراق

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الخلاصة:

أجريت دراسة لتكوين أنواع الطحالب غير الدايتومية في اثني عشر موقعاً من مسار نهر الزاب الكبير داخل محافظة أربيل ، من نيسان 2021 إلى كانون الثاني 2022 مع جمع عينات شهرياً في اثني عشر موقعاً مدروساً. من بينها موقع 7،6،5،4 و 9 هو الأول لدراسة الطحالب في هذا المجال. 112 نوعًا مختلفًا من الطحالب كانت تنتمي إلى 33 جنسًا و 25 عائلة و 13 رتبة و 4 أقسام تم تحديدها. شملت الأجناس السائدة *Spirogyra* و *Cosmarium* (17 ، 8) تصنيفات على التوالي. تم تسجيل 13 نوعًا جديدًا من الطحالب في كردستان العراق و 9 منها تم تسجيلها حديثًا في نباتات الطحالب العراقية: *Botryosphaerella sudetica* و *Muriella magna* و *Gloeotaenium loitlesbergianum* و *Apiocystis brauniana* و *Anabaena oscillarioides* و *Cosmarium distentum* و *Cosmarium tutum* و *Cosmarium contractum* var. *minutum*، *Oedogonium suecicum f. australe* ، *Kirchneriella irregularis*، *Coelastrum indicum*، *Oocystis lacustris*، و *Pediastrum braunii*. كما كان هناك ثلاثة أجناس جديدة للطحالب العراقية وهي: *Botryosphaerella* و *Muriella* و *Apiocystis*. يتم إعطاء وصف موجز بالإضافة إلى القياس لكل نوع. تراوحت درجات حرارة الماء من 17.3 إلى 20.08 درجة مئوية. تراوحت قيمة تركيز أيون الهيدروجين والموصلية الكهربائية من 7.44 إلى 7.88 و 433.20 إلى 721.56 ميكرولتر.سم $^{-1}$ على التوالي.

الكلمات المفتاحية: محافظة أربيل، نهر الزاب الكبير، العراق، سجلات جديدة، أصناف الطحالب غير المشطورة، البرك، الينابيع.