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Climate Changes and Their Impact on Phytoplankton and Physicochemical Properties of the Tigris River, Baghdad, Iraq

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ABSTRACT

The study was conducted in the Tigris River in Baghdad during May 2021 until March 2022 to follow the impact of climate change, rising temperatures, and the presence of pollutants on the dynamics of phytoplankton and some physicochemical variables from four sites. The results showed that the climatic conditions during different seasons, in addition to the nature of the sampling sites, have a clear and significant impact on the studied traits and, in turn, affect the phytoplankton community. The highest average temperature (30.67 ˚C) was recorded; the pH values ranged between 8.70 & 6.75; the electrical conductivity (1208.18-770.11 µS/cm) and the total dissolved solids (TDS) (778.95- 439.49 mg/L) were evaluated. Upon measuring the total hardness and turbidity, a significant increase was detected at the third site during winter, amounting to 67.26 NUT and 775.46mg/ L, respectively. The dissolved oxygen concentration (DO) was recorded at the fourth site during winter (10.08- 4.67 mg/L), while the BOD ranges were 4.87- 2.51mg/ L. A benefit in the average values of plant nutrients was detected at the third site affected by the waste liquid disposal area of the Medical City Hospital Complex compared to the nutrient concentration at the other three sites, which was 3.43, 4.87, 13.50 & 409.00mg/ L for NO3 PO4 and SiO2 and S04, respectively, The study was able to classify 161 species of phytoplankton belonging to 69 genus, the largest percentage of which was Baciliariophyceae (42%), followed by Cyanophyceae (27%), Chlorophyceae (24%), Euglenophyceae (4%) and 1% for Chrysophyceae, Xanthphyceae, and Cryptophyceae. Recent years have witnessed severe climatic conditions affecting various environmental factors in the study area. The phytoplankton community has been vulnerable to their impact altering the physical and chemical properties of the river water. This indicates that the aquatic environment responds to climatic conditions.

INTRODUCTION

Iraq is one of the Arab countries affected by climate change, including Djibouti, Egypt, Morocco and Somalia, and is one of the countries most exposed to the negative effects of climate change. Studies elucidated that temperatures are going to increase by more than 3 degrees at the end of the current century **(Sieed*et al*., 2021)**. Research

evidence suggests that global climate change will lead to general adverse effects worldwide. Ocean warming affects vertical mixing of water and stratification patterns, thus changing the nutrient cycle and phytoplankton production **(Azani *et al.*, 2021)**. The greenhouse effect poses a serious threat to both aquatic and terrestrial ecosystems that can endanger marine food webs by changing the basis, composition, quality and function of primary producers. Microalgae play an essential role in regulating the earth's system, especially in aquatic ecosystems **(Chen, 2021)**.

Many studies on the impact of environmental factors on the dynamics of phytoplankton evaluated the level of influence of different factors on the presence and appearance of these algae species with different physical factors, especially temperature and light intensity, as well as chemical factors such as pH, total hardness, electrical conductivity (EC) and nutrient level, although they are less important than the previous two factors **(Reynolds, 1984; Smith, 2004)**.

Phytoplankton serves as the basis for the aquatic food web and the functioning of ecosystems. Although phytoplankton accounts for less than 1% of the photosynthesis of Earth's biomass, they are considered the primary element and source of productivity in the aquatic environment and accounting for nearly 50% of the world's main net production. The accumulation of organic pollutants, algae and aquatic plants at the bottom of the water body with low water levels can cause the flowering of phytoplankton algae resistant to organic pollution that regulate the proportion of carbon dioxide in water **(Fernandes *et al.*, 2019)**. This means that the presence and diversity of algae in the aquatic environment has a role in atmospheric carbon dioxide fluctuations and climate patterns **(Basu & Mackey, 2018)**.

Most studies indicate that the effects of warming on river systems are the strongest in wetlands, as the flows are few and biological interactions control the availability of living organisms, and the decrease in water levels as a result of high temperatures can lead to a decrease in the productivity of the ecosystem and thus a decrease in water quality through lack of oxygen, increased concentration of pollutants and high acidity; this leads to the proliferation of harmful algae **(Gobler, 2020)**.

Aquatic systems are exposed to numerous environmental factors depending on climate changes, morphology and geology of the water body and human activities, and the presence and distribution of phytoplankton algae is related to the chemical and physical properties of water and depends on each other and is affected by climate changes, which in turn affects the stability of the aquatic food web **(Al-Husseini & Al-Salman, 2020)**.

The study aimed to detect the impact of climate change, high temperatures and the presence of pollutants on the dynamics of phytoplankton in addition to some physicochemical variables at some sites within the Tigris River in Baghdad and compare them with previous studies.

MATERIALS AND METHODS

The Tigris River enters Baghdad City at the North of Baghdad, which flows to the South, dividing Baghdad into two sections: Risafaand Karkh, which has a slope of 6.9cm/km and a width that ranges from 160- 400 meters in twisted areas. Four sites were selected for the present investigation (Fig. 1). The first site is located at the northern side of the Tigris River, the al-Muthanna Bridge; the second site is Al-Sarrafiya Bridge; the third site is opposite to the liquid waste disposal area of the Medical City Hospital Complex, and the last site is located in the Bab al-Muadham area (Table 1). Water and phytoplankton samples were monthly collected from the selected sites in the Tigris River in Baghdad during the period from May 2021 to March 2022. Some physiochemical parameters as water temperature (˚C), pH, electric conductivity (µS/cm), the turbidity (NUT), total hardness, dissolved oxygen (mg/L), biological oxygen requirements (mg/L), total dissolved solids (mg/L), total phosphate, nitrogen, silicate and sulfate (mg/L) were measured during the study, and all these parameters were estimated by the methodology of **APHA (2017)**.

1. Phytoplankton sample

A volume of 250ml of each sample was preserved by a Lugol's solution (1:100) ml by special net light compound microscope model GX-140106 that was used to identify phytoplankton species. The permanent slides were prepared using a concentrated nitric acid for diatoms clarification and then classified by utilizing permanent slides. While other algae were diagnosed via preparing temporary slides and were examined at 40x according to guidelines of **Desikachary (1959)**, **Prescott (1969)**, **Nural-Islam and Zaman (1975)**, **Furet and Benson-Evans (1982)**.

Table 1. Global position system (GPS) of the study sites

Site	Longitude (eastward)	Latitude (northward)
S1	44 °19'47.4 E	33° 22'366 N
S2	44°22' 20.6"E	33°20' 50.4"N
S3	44°22' 45.5"E	33°20'33.08"N
S4	44°22' 46.6"E	33°20' 32.7"N

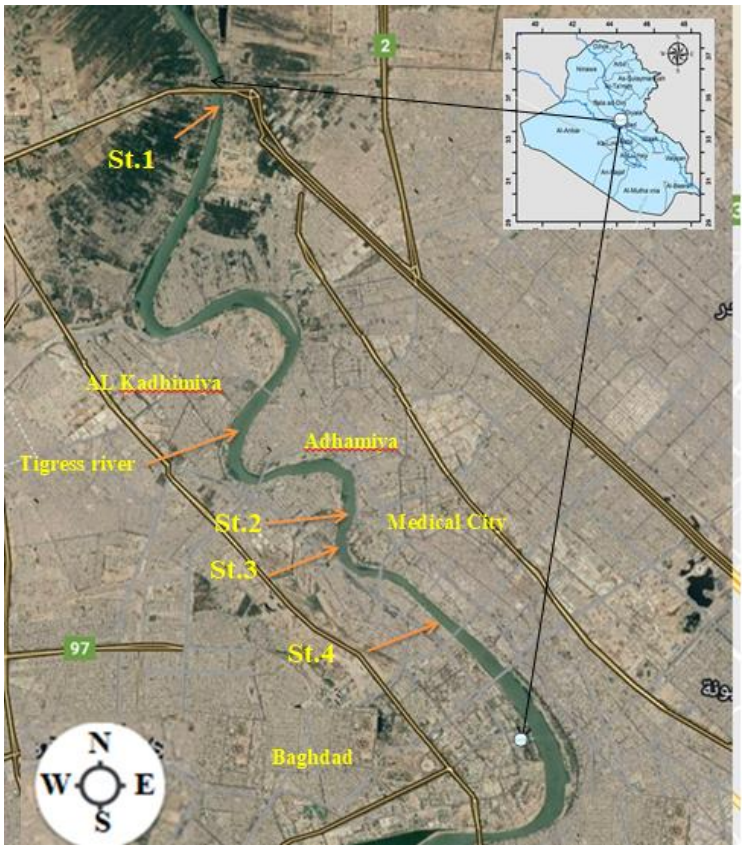

Fig. 1. The study area at four sites from the Tigris River within Baghdad City

RESULTS AND DISCUSSION

The physical and chemical properties of water play a major effective role in the nature and behavior of various aquatic organisms, including phytoplankton algae, because they are indicators for assessing the water quality and are greatly affected by climatic variables in addition to the waste of human activities **(Azani *et al.*, 2021)**. The study dealt with the environmental factors represented in Table (2) and the results showed clear differences between the study sites.

Table 2. Physicochemical parameters (mean values) of water from different sites during the studied period.

Stations / Variable	Mean ± SD			
	ST.1	**ST.2**	**ST.3**	**ST.4**
Water temperature °C	30.67± 0.33	19.67± 0.88	10.67 ±5.24	17.42±1.42
pH	7.80±0.31	8.10±0.31	6.75 ±0.22	8.70±0.15
Electrical conductivity(µs/cm)	916.31±22.84	770.11±28.84	1208.18±131.58	1052.67±28.04
TDS(mg/l)	439.49±33.12	680.67±10.6	778.95 ±48.89	605.08±12.12
Turbidity(NUT)	32.26 ±0.85	10.68±0.85	67.26 ±0.85	18.03 ±0.66
Total hardness	625.72 ±20.47	630.72 ±21.37	775.46 ±60.07	697.55 ±17.78
DO(mg/l)	7.87± 0.53	7.13± 0.57	4.67 ±0.14	10.08±1.1
BOD(mg/l)	2.51± 0.22	3.10 ±0.15	4.87 ±0.37	3.54 ±0.32
PO_4(mg/l)	0.646± 0.32	0.007± 0.003	3.43 ±0.20	0.017± 0.001
$NO_{3(mg/l)}$	6.37 ±0.17	0.54±0.057	13.50 -18.90	0.740±0.140

SiO2(mg/l)	3.35 ±0.57	3.01 ±0.57	4.35 ±0.45	4.11 ±0.30
SO_4(mg/l)	190.65±23.27	287.13 ±29.77	409.00-550.11	320.33 ±23.04

The water temperature recorded the highest rate of 30.67°C for the first site during summer and the lowest rate of 10.67ºC at the third site during winter. This difference is due to the nature of Iraq's climate characterized by high temperatures in summer and low in winter, besides the variation between night and day **(Al-Ghurairy, 2014)**. Higher temperatures affect the effectiveness of the photosynthesis of algae, and the seasonal variability of the phytoplankton algae community is highly associated with seasonal temperature variations **(Singh & Singh, 2015)**.

pH affects the physical and chemical properties of water, and it has a correlation with the presence of different types of organisms **(Lind, 1979)**. The pH values were close at all sites, and the extent of change was small. This may be due to the regulatory capacity of water hardness as the water contain bicarbonate and carbonates ions and tends to basal. This is consistent with previous and present studies conducted on the Tigris River **(Lami, 2002; Al-Janabi, 2011; Moussa & Al-Magdamy, 2023)**.

The slight decrease in pH values at the third site is due to the rise in organic matter and the production of dissolved carbon dioxide gas as a result of wastewater released from the Medical City directly into the river **(Al-Magdamy & Al-Salman, 2021)**.

Turbidity represents the presence of suspended substances in water, including silt and alluvium, as well as bacteria, microorganisms and floating plants **(Abbawi & Hassan, 1990)**. Turbidity is affected by many factors, the most important of which are climate changes in the region, the nature and composition of the river bed, and the amount of plants and algae within the region **(Manseaua*et al*., 2022).**

The high turbidity in the Tigris River may be due to the entry of a large amount of suspended material into the river, especially from sewage, and continuous dredging operations **(Antoine, 1977; Sabri *et al*., 1989)**. Electrical conductivity is the conductivity of water to an electric current and depends on temperature, type of ions and their concentrations, and the reason for the increase in electrical conductivity may be due to the tons of sand sediment carried by rivers and various salt-laden elements **(Dudgeon, 2006)**. The highest rate of electrical conductivity values was 1208.18µS/ cm during spring at the third site, while at the second site, the lowest rate was 770.11 µS/cm during summer. By comparing the electrical conductivity values with the previous studies, it was found that it recorded high values, this increase may be related to the increase in total dissolved solids in the water owing to the rain and soil erosion in the river **(Moussa & Al-Magdamy, 2023)**.

A correlation was detected between the values of conductivity and the values of total dissolved solid; the highest rate of total dissolved solid materials during spring was recorded with a value of 778.95 mg/L at the third site and decreased during winter to record the lowest rate of 439.49 mg /L at the first site. Additionally, there is a significant difference among the sites during the seasons of the year. Besides, high conductivity values were noticed at the third site throughout the study period, and this is due to the

large quantities of wastewater released from the Medical City Hospital Complex loaded with different ions **(Wahhab and Hassan, 2023).**

The conductivity and TDS recorded high values compared to previous studies on the Tigris River at the same sites, as the high temperatures and increased evaporation rates help increase the concentration of salts and ions within the water column, but the high values of conductivity and TDS were not affected by the high temperatures. The highest rate recorded during spring is ascribed to the impact of the large amounts of ion-rich organic pollutants **(Al-Ani *et al*., 2019; Hassan *et al*., 2023)**.

In addition, high values of total hardness were observed at all sites, and the reason may be related to the high temperatures, the impact of human activities and the impact of wastewater, while its rise during winter is attributed to the fall of a quantity of rain that helped wash away the edges of the river adding to the rainwater carrying different ions, and this is consistent with previous studies addressing the same sites **(Luo *et al*., 2016)**.

The highest rate of dissolved oxygen was recorded during winter at 10.08mg/ L at the fourth site and decreased during summer reaching the lowest rate of 4.67 mg/L at the third site. Whereas, the highest rate of biological oxygen demand for winter was 4.87mg/ L at the third site, and the lowest rate for summer was recorded at the first site with a value of 2.51mg/ L.

The high concentration of dissolved oxygen was registered during winter and its decrease was in summer, which is caused by the difference in temperatures since its rise reduces the concentration of dissolved oxygen **(Wetzel, 2001)**. However, the high value of the biological demand of oxygen during winter may be due to the increase in organic matter, resulting from sewage as well as the presence of some species of bacteria resistant to temperature, and their activity increases when rain falls leading to an increase in dissolved oxygen, thus increasing the biological demand of oxygen **(Al-Asadi, 2015)**.

Sedimentary rocks are the main source of sulphates **(Langmuir, 1997)**; the studies indicate that Iraqi waters are rich in sulphate ion **(Al-Fatlawi, 2011)**. The highest rate of sulphate was recorded with 409.00mg/ L at the third site during the fall season, while the lowest rate was 190.65mg/ L at the first site during summer. From Table (2), high sulphate values were determined at the third and fourth sites during the seasons, except for a slight decrease during summer. This is explained by the increase in the amount of sewage waste reaching the river at the third site, and its effect continues to the fourth site since the sewage waste is rich in sulfate ion **(Hassan *et al*., 2018; Al-Magdamy & Al-Salman, 2021)**.

The results revealed a significant increase in the values of plant nutrients represented by nitrates, phosphates and wires, and a variation was recorded between sites affected by human activities more than environmental changes. The highest rate of nitrates, phosphates, and wires during the winter within the third site was determined (13.50, 3.54, 4.35) mg/L respectively, while the lowest rate was recorded (0.54, 0.007, 3.01) mg/L during summer covering the second site (Table 1). The reason for the increase in nutrients

at the third site is due to the richness of waste discharged from the Medical City Hospital Compound with organic materials and detergent residues, so its increase causes nitrates and phosphates, while the wires result from the presence of sand grains whose concentration increases within the water column as a result of erosion processes resulting from the force of sewage flow, and this is consistent with many sources **(Rasheed, 2017; Abdul Majeed, 2022)**.

1.Qualitative study of phytoplankton

The qualitative study showed the presence of 161 species of phytoplanktonic algae belonging to 69 genera (Table 3), the largest percentage of which was Bacillariophyceae (42%), followed by Cyanophyceae (27%), Chlorophyceae (24%), Euglenophyceae (4%) and the rest of the other divisions (1%) for Chrysophyceae, Xanthphyceae and Cryptophyceae (Fig. 2).

Table 3. Distribution of the number of genera and species diagnosed within the sites during the study

Station / Division	Sites								TOTAL	
	St.1		St.2		St.3		St.4			
	G.	Sp.	G.	Sp.	G.	Sp.	G.	Sp.	G.	Sp.
Bacillariophyta (Centrales)	1	1	3	6	4	11	5	13	6	13
Bacillariophyta (Penales)	11	26	20	55	9	30	19	45	26	55
Cyanophyta	5	16	15	34	17	44	12	32	17	44
Chlorophyta	8	10	17	38	12	34	15	30	15	39
Euglenophceae	2	2	2	6	2	5	2	3	2	6
Chrysophyceae	-	-	0	0	0	0	1	2	1	2
Xanthphyceae.	1	1	0	0	0	0	0	0	1	1
Cryptophyceae.	-	-	1	1	1	1	1	1	1	1
TOTAL	28	56	58	140	45	125	55	126	69	161

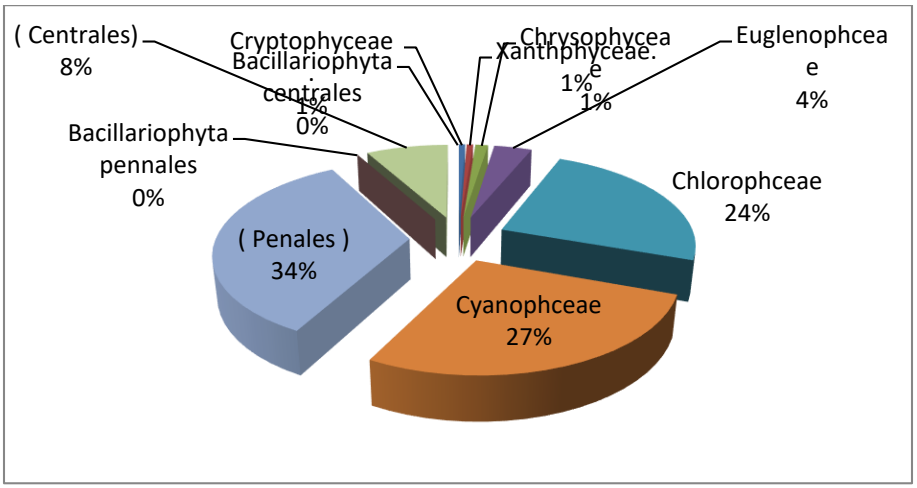

Fig. 2. Percentages of algae groups diagnosed at all sites in the Tigris River during the study period

Environmental factors directly affect the density and diversity of the algae community, as the plankton diatoms in rivers are mainly affected by temperature, pH, nutrients, current velocity and predators, and are spatial and temporal dominance of certain species **(Moura *et al*., 2007)**. Furthermore, environmental factors, in turn, are affected by the climate of the region, its geological nature, and the released remnants of human activities from nearby areas, affecting the algae community in general **(Pan *et al*., 1996)**.

The Iraqi environment is characterized by high concentrations of silicates in all types of water, whether lakes or rivers, and this is indicated by the current results (Table 2) and this leads to an increase in the number of diatoms species diagnosed at all study sites (Fig. 2). This fiding matches those of various Iraqi studies **(Al-Hassany & Al-Bayati, 2017; Al-Tammie & Al-Mersomy, 2018; Al- Saeedi, 2022)**.

The highest number of species was recorded at the fourth site, while the lowest number was recorded at the first site in all seasons (Table 3). The third site is the most contaminated with organic compounds dumped from the Medical City **(Gobler, 2020)**, indicating that hospital's waste released into riverbeds leads to an increase in nutrients that stimulate the growth of phytoplankton, and this coincides with the high concentrations of nutrients found at the third site (Table 2).

However, the presence of antibiotics and drug residues causes disruption of the growth of some species of algae at the expense of other species, represented by blue-green algae resistance of some types to high concentrations of antibiotics, unlike diatoms, which affect the presence of acceptable environmental concentrations of antibiotics in the construction of structures of their bodies from silica, and thus stopping reproduction and reducing the types of diatoms **(Griffith & Gobler, 2020)**. Therefore, there was a decrease in the species number of diatoms within the third site (Table 3).

The study recorded differences in the number of phytoplankton species according to the seasons of the year for all study sites, as presented in Fig. (3). Spring recorded the highest total number of species reaching 145 species belonging to 50 genera, while the lowest total number of species recorded during the summer season amounted to 60 species belonging to 30 genera.

The increase in algae species in spring is due to the increase in the concentration of nutrients from phosphate, nitrate and silicate reaching the river aligned with rainwater, as spring was characterized by an increased rainfall and good rates of temperatures, and this finding concurs with that of **Kasim (2011)**.

An increase in the species of algae blue-green was noticed during summer compared to other seasons, and this is traced back to the high potential of the blue-green algae to coexist with various environmental conditions, viz. high temperatures, increased acidity and high concentration of salts **(Wahhab & Hassan, 2023)**. Upon comparing the results with those of previous studies, an increase in the number of species registered in the same locations was assessed **(Al-Hassany & Al-Bayati, 2017).**

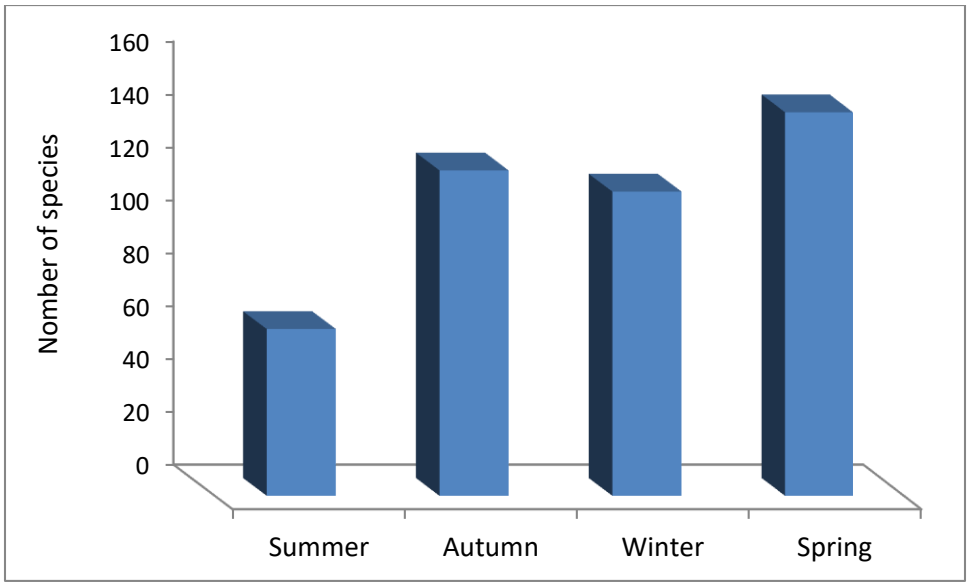

Fig. 3. The number of total species diagnosed during the four seasons at all sites

CONCLUSION

The severe climatic conditions of recent years affected the various environmental factors in the study area, impacting the phytoplankton community altering the physical and chemical properties in the river water, meaning that the aquatic environment responds to climatic conditions and is affected by the nature of the sites and what is added to the riverbed by the remnants of human activities. Besides the natural climatic conditions, some of these activities surrounding the Tigris River affect directly or idirectly the phytoplankton algae community resulting in rising the water level or the increase & decrease of pollution levels. According to this study, the rise in temperatures at all sites during summer and the exposure of the Tigris River water to organic pollution, especially the third site, have increased the nutrient levels in the aforementioned site, and this led to an increase in the types of Phytoplankton that are tolerant to these conditions, represented by Cyanophyceae. In addition to the previous results, the aforementioned factors have reduced the level of elevation, and the sandy bottom of the Tigris River has witnessed an increase in the concentration of silicate within the water column, which led to an increase in the number of Bacillariophyceae species.

REFERENCES

Abbawi, S. A. and Hassan M. S. (1990).Practical environmental engineering - water tests. Dar al-HikmaFor Printing and Publishing, Ministry of Higher Education and Scientific Research, University of Mosul, 296 pp.

Abdul Majeed, M.K.M. (2022). Evaluation of some physicochemical and biological properties of liquid waste from the Medical City compound / Baghdad and treatment

with nanotechnology.MSc. Thesis.College of Education for Pure Sciences, Tikrit University, 132 pp.

Al-Ani, R.R; Al-Obaidy, A.M. and Hassan, F.M. (2019).Multivariate analysis for evaluation the water quality of Tigris River within Baghdad City in Iraq. Iraqi J. Agric. Sci., 50(1): 331-342.

Al-Asadi, S. (2015).Environmental study of the algae community and some environmental pollutants in Al-Husseiniya-Holy Karbala, Iraq. In: PhD Thesis.

Al-Fatlawi, H.J.J. (2011). Environmental study and the quality and quantity of algae in the Euphrates River between the districts of Al-Hindiya and Al-Manathira.PhD thesis, Department of Life Sciences, College of Science, University of Babylon, 179pp.

Al-Ghurairi, W.A.S. (2014). Environmental study of algae in the Yusufiyah River, Baghdad, Iraq.messageMaster's degree, College of Science for Girls, University of Baghdad, 91 pp.

Al-Hassany, J.S. and Al-Bayati, H.A. (2017).Screening of epiphytic algae on the aquatic plant *Phragmitesaustralis* inhabiting Tigris river in Al-Jadria site,Baghdad, Iraq. Baghdad Sci. J., 14: 85-98.

Al-Husseini, K.H. and Al-Salman, A.J.P.A. (2020).Quarterly variation and their impact on phytoplankton dynamics in the Gharraf River environment in southern Iraq. Plant Arch., 20(1): 1354-1360.

Al-Janabi, Z. (2011). Applications of water quality indicators in the Tigris River within the city of Baghdad-Iraq.MSc. Thesis, College of Science for women/University of Baghdad.

Al-Lami, A.(2004). A comparative environmental study of zooplankton in water bodies of varying salinity in central Iraq,.Ibn al-HaithamJ. Pure Appl. Scie., 17(1): 11-16.

Al-Magdamy, B.A.H and Al-Salman, I.M.A. (2021).Variation of non-diatomic algae in a martyr monument lake under different climate factors. IOP Conf. Series: Earth Environ. Sci., 779: 012084

Al-Saeedi, H.M.S.(2022). Acomparative Ecological Study of the Phytoplankton Community in Lotic and Lentic in Aquatic Ecosystem within Baghdad City A thesis Submitted to the council of College of Education for Pure Sciences - Ibn Al-Haitham, University of Baghdad, 164pp

Al-Tamimi, A.A.M. and Al-Mersomy, S.M.S.,(2018).Using diatoms as biological indicators to determine water quality of AlHabbaniyah Lake–Iraq.Association of genetic and environmental resources conservation (AGERC). In Proceeding of the 5th International conference of genetic and environment, Baghdad, Iraq, pp. 159-169.

Antoine, S.E. (1977). Seasonal Variation of Environmental Characteristics and Phytoplankton Blooms of the River Tigris. Iraq. M.Sc. Thesis, University of Basrah, 150 pp.

APHA. (2017). American Public Health Association Standard Methods For Examination of Water and Waste Water. 23rded Edition Washington. 1325.

Azani, N.; Ghaffar, M.A.; Suhaimi, H.; Azra, M.N.; Hassan, M.M.; Jung, L.H.; Rasdi, N.W.(2021). The impacts of climate change on plankton as live food: A review. IOP Conf. Series: Earth Environ. Sci., 869: 012005

Basu, S. and Mackey K.R. (2018). Review Phytoplankton as Key Mediators of the Biological Carbon Pump: Their Responses to a Changing Climate. Sustainability, 10(3): 869.

Chen, D.(2021). Impact of climate change on sensitive marine and extreme terrestrial ecosystems: Recent progresses and future challenges. This article belongs to Ambio's 50th Anniversary Collection. Theme: Climate change impact. Ambio, 50:1141–1144

Desikachary, T.V. (1959). Indian Council of Agricultural Research. New Delhi., 686, 1959.

Dudgeon, D.; Arthington, A.H.; Gessner, M.O.; Kawabata, Z.; Knowler, D.J.; Leveque, C.; Naiman, R.J.; Prieur-Richard, A.H.; Soto, D.; Stiassny M.L. and Sullivan, C.A. (2006). Freshwater biodiversity: importance, threats, status and conservation challenges. Biol. Rev., 81: 163-182.

Fernandes, V., Sabu, E.A., Shivaramu, M.S., Gonsalves, M.J.B.D. and Sreepada, R.A. (2019).Dynamics and Succession of Plankton Communities with Changing Nutrient Levels in Tropical Culture Ponds of Whiteleg Shrimp.Aquac. Environ. Interact., 11: 639-655.

Furet JE, Benson-Evans K. (1982). An evaluation of the time required to obtain complete sedimentation of fixed algal particles prior to enumeration. Br. Phycol. J., 17(3):253-258.

Gobler, C.J. (2020) Climate Change and Harmful Algal Blooms: Insights and perspective. Harmful Algae, 91: 10173.

Griffith, A.W. andGobler, C.J. (2020). Harmful algal blooms: a climate change co-stressor in marine and freshwater ecosystems. Harmful Algae, 91: 101590.

Hassan, B.A.; Ibrahim, T. M.; AL-Salman, I.M. and Ismael, A.M.(2018). Impact of water mixing areas in qualitative variationsof phytoplankton algae and some physiochemical characteristics of water on a section of tigris river. Plant Arch.,18(2): 2477-2484.

Hassan, F.M.; El-Sheekh, M.M. and Wahhab, T.A. (2023). Environmental factors drive phytoplankton primary productivity in a shallow Lake. Egypt. J. Aquat. Biol. Fish., 27(2).

Kasim, M. (2011).Correlation of environmental factors and Diatom assemblages in Akkeshi-Ko estuary system. J. Coastal Devel., 14(3): 242-254.

Langmuir, D. (1997). Aqueous Environmental Geochemistry. Prentice Hall, USA, 600pp.

Lind, O.T. (1979). Hand book of Common Methods in Limnology. C.V Mosby, St. Louis, 199 pp.

Luo, S.; Wu, B.; Xiong, X. and Wang J.(2016).Effects of Total Hardness and Calcium:Magnesium Ratio of Water during Early Stages of Rare Minnows (*Gobiocyprisrarus*). Am. Assoc.Lab. Anim. Sci., 66(3): 181-187.

Manseaua, F. ;Bhirya , N.; Molsonb , J. and Cloutierc D.(2022). Factors affecting river turbidity in a degrading permafrost environment: the Tasiapik River, Umiujaq (Nunavik). Can. Sci. Publ. Arctic Sci., 8(4): 1202-1216.

Moura, A.N.; Bittencourt-Oliveira, M.C. and Nascimento, E.C. (2007).Benthic Bacillariophyta of the Paripe River estuary in Pernambuco state, Brazil. Braz. J. Biol., 67(3): 393-401.

Moussa, Z.F. and Al-Magdamy, B.A.H.(2023). Study of the quality of attach algae to the concrete supports of some bridges within Baghdad city. History Med., 9(1): 1182–1186.

Nural-Islam, A.K.M.; Zaman, K.M. (1975).Limnological studies of the River Buriganga III. Biological aspect.J.Asiatic.Soc.Bangladesh Sci., 1(1): 45-65.

Pan, Y.; Stevenson, R. J.; Hill, B. H.; Herlihy, A.T. and Collins, G.B. (1996). Using diatoms as indicators of ecological conditions in lotic systems: A regional assessment. J. North Am. Bethol. Soc., 15(4): 481-495.

Prescott, G.W. (1969). The algae: A review. Nelson and Sons, Inc: 436 pp.

Rasheed, K.A., Flayyh, K.A. and Dawood, A.T. (2017). The biological indicators studies of zooplankton in the Tigris River at the city of Baghdad. Int.J. Environ. Agri. Biotechnol. (IJEAB), 2(1).

Reynolds, C.S. (1984). The ecology of freshwater phytoplankton. Cambridge Univ, Press, Cambr.UK..

Sabri, A.W.; Maulood, B.K. and Sulaiman, N.I. (1989).Limnological studies, on river Tigris: some physical and chemical characters.J. Biol. So., 20 (3): 565–579.

Sieed, S.M.; Nadim, H. and Khorshid K.M. (2021). The effect of climate changes on the externalenvironment of a project social housing andprotection methods to achieve quality of life. J.Art Archit. Res. Stud., 2(3):37-51.

Singh, S.P. and Singh, P. (2015). Effect of temperature and light on the growth of algae species, A review. Renew.Sust. Ener. Revi.,50:431-444

Smith, R. (2004).Current methods in aquatic science .University of Waterloo. Canada.

Wahhab, T.A. and Hassan, F.M. (2023). Environmental parameters drive the phytoplankton community structure: a case study in Baghdad Tourist Island Lake, Iraq. Ibn Al-HaithamJ. Pure Appl. Sci., 36(1): 74-87.

Wetzel, R.G. (2001). Limnology. 3rdEdition. AcademicPress, California, 431 pp.