Journal homepage
www.ajas.uoanbar.edu.iq
Anbar Journal of Agricultural Sciences
(University of Anbar – College of Agriculture)

A STUDY ON THE IMPACT OF CLIMATE CHANGE ON THE WATERS OF LAKE HABBANIYAH, 2019-2023

Y. H. Mahmood [1]*   A. Sh. Jasim [2]

[1] Biology Department, College of Education, University of Samarra, Iraq.
[2] Biology Department, Open Educational College, Ministry of Education, Iraq.

***Correspondence to:** Yawooz Hameed Mahmood, Biology Department, College of Education, University of Samarra, Iraq.
Email: yavuz.h86@uosmarra.edu.iq

Article info

Received: 2025-01-28
Accepted: 2025-03-15
Published: 2025-06-30

DOI-Crossref:
10.32649/ajas.2025.187544

Cite as:
Mahmood, Y. H., and Jasim, A. Sh. (2025). A study on the impact of climate change on the waters of lake habbaniyah, 2019-2023. ibrahimi. Anbar Journal of Agricultural Sciences, 23(1): 614-626.

Abstract

This research covering the period 2019-2023 involved a limnological study to assess the impact of climate change on the waters of Lake Habbaniyah. The study found that the mean air temperatures ranged from 29.9-31 °C, water temperatures from 24.9-26 °C, pH of 7.6-8, EC of 954.5-2054.3 µS/cm. Meanwhile, alkalinity hardness for Ca, Mg, Cl, SO_4, NO_3, PO_4, and DO were 109.7-170.1, 336.1-583.6, 74.4-136, 41.5-65.1, 139.9-287.4, 214.1-569.8, 1.6-3.7, 0.05-0.7 and 5.6-8 mg/L, respectively. The largest capacity, highest water levels, and areas for the lake occurred in 2019 at 2930 million m^3, 50.64 m, and 416 km^2, respectively while the lowest were 650 million m^3, 42.61 m, and 200 km^2, respectively in 2023. This indicates that climate changes has affected the characteristics of the lake.

Keywords: Climate changes, Limnology, Lake Habbaniyah.

التغيرات المناخية وأثرها على مياه بحيرة الحبانية للفترة 2019-2023

ياوز حميد محمود [1]* علي شكر جاسم [2]

[1] قسم علوم الحياة، كلية التربية، جامعة سامراء، العراق.

[2] قسم علوم الحياة، كلية التربية المفتوحة، وزارة التربية، العراق.

***المراسلة الى:** ياوز حميد محمود، قسم علوم الحياة، كلية التربية، جامعة سامراء، العراق.

البريد الالكتروني: yavuz.h86@uosmarra.edu.iq

الخلاصة

هدفت الدراسة الحالية إلى دراسة البيئة المائية لبحيرة الحبانية للفترة 2019–2023 لتقييم مخاطر تغيرات المناخية على بحيرة الحبانية. وأظهرت الدراسة أن متوسط التغيرات تراوحت في درجة حرارة الهواء 29.9 – 31 درجة مئوية ودرجة حرارة الماء 24.9– 26 درجة مئوية ودرجة الحموضة 7.6– 8 والتوصيل الكهربائي 954.5–2054.3 ميكروسيمنز/سم بينما سجلت نتائج القاعدية والعسرة والكالسيوم والمغنيسيوم والكلور وSO_4 وNO_3 وPO_4 والأوكسجين المذاب (109.7 – 170.1) و(336.1 – 583.6) و(74.4 – 136) و(41.5 – 65.1) و(139.9 – 287.4) و(214.1 – 569.8) و(1.6 – 3.7) و(0.05 – 0.7) و(5.6 – 8) ملغم/لتر على التوالي خلال فترة الدراسة، وسجلت أكبر سعة وأعلى منسوب مائي ومساحة لبحيرة الحبانية في عام 2019 بواقع (2930 مليون م^3) و(50.64 م) و(416 كم^2) على التوالي، في حين سجلت عام 2023 اقل سعة وأعلى منسوب مائي ومساحة (650 مليون م^3) و(42.61 م) و(200 كم^2) على التوالي، وهذا يشير هذا إلى أن التغيرات المناخية أثرت على خصائص مياه البحيرة.

كلمات مفتاحية: التغيرات المناخية، دراسة لمنولوجية، بحيرة الحبانية.

Introduction

The expanding global population and sprawl of industries has led to increased water pollution and contamination that pose significant health risks for humanity (11). Following the current climate and environmental changes, the Middle East, and particularly Iraq, has been affected by a serious water crisis. Almost all of Iraq's drinking water, irrigation, and electricity generation is sourced from two rivers, the Tigris and Euphrates. However, Iraq does not control the flow of the rivers. Both begin in Turkey, and additional dams built there and Syria have reduced downstream flows to Iraq (3). Lake Habbaniyah is one of the largest surface water and important freshwater resources in Anbar governorate and the surrounding regions. It has helped mitigate the impact of droughts and floods by storing large amounts of water and using it for drinking, and for industrial and agricultural water supply systems (5).

The presence of various elements, including organic matter of plant and animal origin, nutrients, and toxic chemicals, has caused the lake to progressively become more contaminated. These pollutants are mostly produced by industrial, agricultural, and urban activity (16). Climate change has a major effect on how rainfall and evaporation relate to each other, causing fluctuations in water content and affecting its quality (4). This study assessed the suitability of Lake Habbaniyah water for irrigation and consumption based on Iraqi standards.

Materials and Methods

Study Area: Lake Habbaniyah (Fig. 1) is located in Anbar governorate, 60 km west of Baghdad between 39°18´03 N and 34°23´12 E at an elevation of between 35-90 m above sea level. The lake is 9-13 m deep, 35 km long, 25 km at its widest, and a storage capacity of $3.26x10^9$ m^3 (8). It is mainly fed by the Euphrates River. The Habbaniyah project was considered for a period as the main means of protection against floods on the Euphrates River until the Haditha dam was built. It was based on the recommendations of Willcox in 1911, but implementation was delayed due to the First World War (1). The project was finally completed in 1956 (16).

Samples Collection: Three water samples were randomly collected monthly from 2019 to 2023 in polyethylene bottles at 30 cm depths based on a preliminary field study of various sites in Lake Habbaniyah. The samples were tested for air temperature, water temperature, pH, electrical conductivity, turbidity, alkalinity, total hardness, calcium, magnesium, chloride, sulfate, phosphate and nitrate ions to evaluate their suitability for irrigation and consumption baased on Iraqi standards.

Air temperature was determined with a thermometer, while water temperature and pH and EC was evaluated with pH and conductivity meters. Turbidity (NTU) was determined by turbidimeter, and total hardness and alkalinity calculated using a titrimetric meter in the laboratory. The methods described by (17) were used to determine nitrates and phosphates. The determination of sulfate, chloride, calcium, and magnesium followed the methods described in (9).

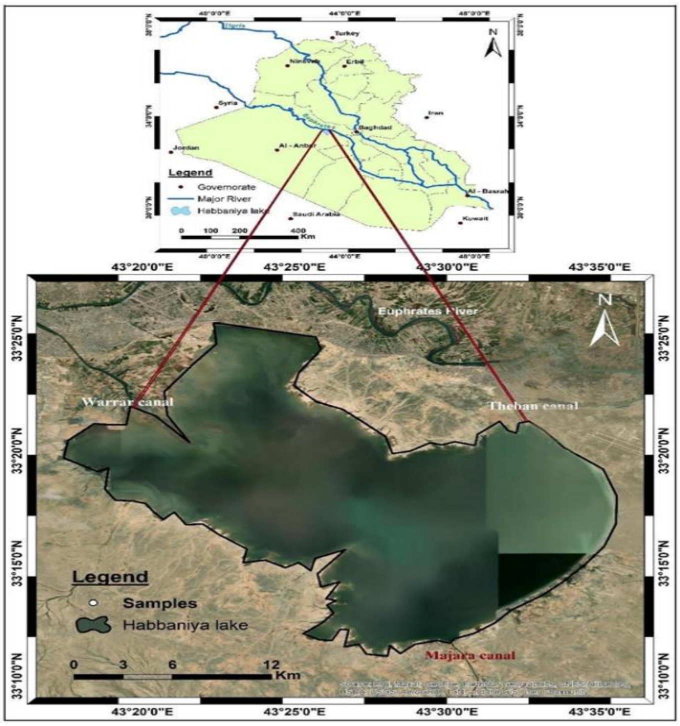

Fig. 1: Lake Habbaniyah.

Statistical Analysis: The ANOVA and the Duncan tests ($P \leq 0.05$) were used on all data sets to compare means on the presence or absence of differences between them in the groups to assess water quality. SPSS (Statistical Package for the Social Sciences) 21 version statistical software was used for analysis.

Results and Discussion

Tables 1 and 2 show an increase in the mean temperatures of the air and water in the lake from 29.9 °C to 31°C and 24.9 °C to 26 °C in 2019 and 2023, respectively. This is evidence of the climate changes that is affecting the world in general including Iraq.

Table 1: Air temperatures at Lake Habbaniyah (° C).

Years / Months	2019	2020	2021	2022	2023
January	16.4	16	17.7	15	16
February	19	19.2	19	19.5	20
March	23	23.4	23.5	23	24
April	29	29.1	29.3	29.6	30
May	33	34	33.5	34.2	35
June	40	41	41	41.5	42
July	42	42.3	43	43	44
August	43	43	43.5	44.1	44.5
September	38	39	38	39	40
October	31	31.5	32	32	33
November	27	24	23	23	24
December	18.5	19	19.5	20	20.5
Mean	29.9a	30.1a	30.2a	30.3a	31a

Numbers with different letters indicate significant differences at the $P \leq 0.05$ significance level while those with similar letters indicate no significant differences.

The higher mean temperature of the water led to increased water loss through evaporation and a reduction in lake water volume due to rising temperatures (20).

Table 2: Water temperatures of Lake Habbaniyah (° C).

Years / Months	2019	2020	2021	2022	2023
January	15.2	15.6	17.1	13	14
February	17	15.2	20	18	17.8
March	21	20.1	19.6	20.2	20
April	28	30	25.5	23	23.1
May	30	29	27.8	28	26.8
June	28	33	28.9	32.3	35.9
July	30	35	35.7	36	37.6
August	32	36	37	38	38.5
September	29	29	30.2	32	32.7
October	28	24	27.8	26	28.1
November	25	18	26	25.1	21.4
December	16.2	18	16.3	16	17
Mean	24.9a	25.2a	25.9a	25.6a	26a

Numbers with different letters indicate significant differences at the $P \leq 0.05$ significance level while those with similar letters indicate no significant differences.

The mean pH values of 7.8 in 2019 and 8 in 2023 (Table 3) show that the waters in Habbaniyah Lake tending to be weakly alkaline (5). The growth of algae in the water leads to an increase in total alkalinity (15).

Table 3: Water pH values for Lake Habbaniyah.

Years / Months	2019	2020	2021	2022	2023
January	7.4	7.7	8.1	8.1	8.3
February	7.9	7.7	7.7	8.1	8.1
March	7.1	7.4	8.1	8.2	8
April	8.2	7.9	8.2	8.2	8.4
May	8.2	7.2	8.4	8.2	8.2
June	8	7.3	8.4	8	8.9
July	7.9	7.2	8.1	7.9	7.6
August	7.9	7.9	8.1	7.6	8
September	8	7.8	7.3	8.1	7.5
October	8	7.9	7.2	8.3	7.9
November	7.9	8.2	7.3	8.1	7.9
December	7.9	7.9	7.9	8.1	7.8
Mean	7.8b	7.6a	7.9b	8.0b	8.0b

Numbers with different letters indicate significant differences at the P ≤ 0.05 significance Level while those with similar letters indicate no significant differences.

Table 4 shows a rise in the mean electrical conductivity (EC) values in Habbaniyah Lake from 979.4 µS/cm in 2019 to 2054.3 µS/cm in 2023. The high levels of acidity or alkalinity have a negative impact on human and environmental health as they affect the growth of microorganisms through their effect on the enzymes involved in the process of growth and biosynthesis (20).

Table 4: Electrical conductivity values in Lake Habbaniyah (µS/cm).

Years / Months	2019	2020	2021	2022	2023
January	1530	788	1345	1170	1790
February	885	834	1476	1128	1816
March	712	942	1677	1150	1862
April	700	910	1115	1340	1862
May	700	982	1440	1314	2092
June	698	898	1221	1402	2182
July	700	930	1440	1590	2116
August	1245	970	1331	1574	2300
September	678	1080	1270	1530	2216
October	990	1024	1115	1596	1998
November	1460	1042	1195	1546	2872
December	1455	1054	1080	1560	1546
Mean	979.4a	954.5a	1308.7b	1408.3b	2054.3c

Numbers with different letters indicate significant differences at the P ≤ 0.05 significance level while those with similar letters indicate no significant differences.

Table 5 shows the mean alkalinity values in Habbaniyah Lake ranging from the lowest at 109.7 mg/mL in 2019 to the highest of 170.1 mg/L in 2021. Higher levels of algae increases the total alkalinity of the water as they deplete the carbon dioxide in the water during the day (15).

Table 5: Water alkalinity levels in Lake Habbaniyah (mg/L).

Months \ Years	2019	2020	2021	2022	2023
January	116.4	108.6	181.3	120	150.3
February	110.7	110.4	120.2	124	155.2
March	104.76	124.1	227.8	188	135.8
April	116.4	151.9	127.5	198	155.2
May	130.5	104.6	194	198	124.1
June	98	124.1	287.3	192	121.4
July	100.8	174.6	194	195	125.2
August	93.1	124.1	116.4	126	138.6
September	85.3	128.04	116.4	192	149.7
October	131.9	135.8	127.5	142	155.5
November	116.4	125.3	116.4	160	182.3
December	112.5	135.8	232.8	164	125.3
Mean	109.7a	128.9b	170.1c	166.5c	143.2b

Numbers with different letters indicate significant differences at the P ≤ 0.05 significance level while those with similar letters indicate no significant differences.

The study shows mean total water hardness was highest at 583.6 mg/L in 2023 while the lowest was 336.1 mg/L in 2019 (Table 6). This is due to the industrial and human waste discharged into the lake, as well as the lack of adequate drainage from the lake (18).

Table 6: Total water hardness values for Lake Habbaniyah (mg/L).

Months \ Years	2019	2020	2021	2022	2023
January	441	444.3	364.3	452.6	551.4
February	365	478.5	309.1	452	501
March	288	575.1	353.28	437.9	544
April	304	393.7	294.4	382.7	480.2
May	304	456	320	463.6	588.9
June	295	490	290.7	441.6	581.4
July	300	456	327.5	482.3	783.8
August	395	349	309.1	463.6	581.7
September	296	397.4	312.8	496.8	610.4
October	352	393.7	315.4	460	585.1
November	342	452.6	408.5	460	736
December	352	379	511.5	507.8	460
Mean	336.1a	438.7b	343.0a	458.4b	583.6c

Numbers with different letters indicate significant differences at the P ≤ 0.05 significance level while those with similar letters indicate no significant differences.

The highest mean calcium values in the lake water was 136 mg/L (2023) while the lowest was 74.4 mg/L (2021), as seen in (Table 7). The use of chemical compost and pesticides by farmers, which mixes with lake water, as well as the nature of the lake's bed and edges, which contain limestone and gypsum rocks that are susceptible to chemical dissolution processes, increases such calcium concentrations (6). The increase in calcium in the lake's waters in January 2020 (141.2 mg/L) may be due to decomposition processes of alumino silicates and magnesium (7).

Table 7: Water calcium values for Lake Habbaniyah (mg/L).

Years / Months	2019	2020	2021	2022	2023
January	79	141.2	78	83.7	120.3
February	77	97.6	66.2	103.4	122.1
March	82	132	80.9	100	113.3
April	86	78	96	97.1	135.4
May	88	101.5	61.8	114.8	136.8
June	84	132.4	64.7	103	135.4
July	84	101.5	63.3	107.4	191.3
August	98	88.3	86.8	97.1	125.5
September	90	88.3	67.7	110.4	142.7
October	133	78	69.1	120.7	135.8
November	132	88	75.1	104.5	169.2
December	133	116.2	83.9	120.7	104.5
Mean	97.1b	103.5b	74.4a	105.2b	136.0c

Numbers with different letters indicate significant differences at the P ≤ 0.05 significance level while those with similar letters indicate no significant differences.

The highest mean magnesium value in the lake was 65.1 mg/L in 2023 while the lowest was 41.5 mg/L in 2020 (Table 8). Cations (calcium and magnesium) are among the ions that participate widely in the formation of living mass, as the concentration of calcium ions is higher than of magnesium ions in natural aquatic systems, in general. The lower quantities of magnesium in dissolved form is due to its tendency to precipitate in large quantities, or it may be due to the interaction of CO_2 with calcium, which is greater and stronger than that with magnesium (2).

Table 8: Levels of magnesium in Lake Habbaniyah (mg/L).

Years / Months	2019	2020	2021	2022	2023
January	44	50	40	62	56
February	42	41	60	53	64
March	36	41	55	51	71
April	40	38	40	38	40
May	40	43	65	48	67
June	35	36	65	50	66
July	36	30	65	58	80
August	50	40	40	60	60
September	38	38	45	60	69
October	77	32	40	43	70
November	43	54	30	54	85
December	46	55	40	56	54
Mean	43.9b	41.5a	48.7b	52.7b	65.1c

Numbers with different letters indicate significant differences at the P ≤ 0.05 significance level while those with similar letters indicate no significant differences.

As seen in (Table 9), the highest mean value for chloride was 287.4 mg/L in 2023 while the lowest at 139.9 mg/L was in 2020. Industrial and agricultural activities, irrigation and drainage water, cleaning materials, and organic waste are major sources of these pollutants in the surface and ground waters of urban areas (13). Chloride salts are more available in water than other salts due to their ease of dissolution and the difficulty of chloride adsorption on the surface of natural minerals (12).

Table 9: Levels of chloride in Lake Habbaniyah (mg/L).

Years / Months	2019	2020	2021	2022	2023
January	121	197.8	245	156.1	224.5
February	114	73.6	155.3	150.4	216.2
March	155	112.8	235	141	263
April	158	94	191.76	167.3	244.4
May	158	127.8	115.4	157.2	295.1
June	154	99.64	291	165.4	319.6
July	158	107.1	115.4	197.3	338.4
August	130	135.3	225	182.3	290.8
September	160	154.6	185.8	150.4	305.4
October	160	150.4	191.7	197.4	253.8
November	188	280	235	199.5	498.2
December	180	146.6	195.4	188	199.5
Mean	153.0a	139.9a	198.4b	171.0b	287.4c

Numbers with different letters indicate significant differences at the $P \leq 0.05$ significance level while those with similar letters indicate no significant differences.

The highest mean value for sulphate (SO_4) in the lake waters was 569.8 mg/L in 2023 while the lowest at 214.1 mg/L was for 2020 (Table 10). The increase in SO_4 levels may be due to the higher water and air temperatures, which intensifies evaporation processes and the decomposition of organic materials, the use of agricultural fertilizers and animal waste, as well as the increase in industrial waste (14). Climate change has a significant impact on the relationship between rainfall and evaporation and contributes to increasing or decreasing water in the area, thus altering its quality (4).

Table 10: Water sulphate values for Lake Habbaniyah (mg/L).

Years / Months	2019	2020	2021	2022	2023
January	240	195	395	260	490
February	256	160	315	230	500
March	194	230	488	210	475
April	180	175	260	285	475
May	180	260	320	350	700
June	180	185	317	450	523
July	175	145	320	415	510
August	301	235	350	430	680
September	180	265	285	475	550
October	260	230	260	475	510
November	375	210	260	475	950
December	360	280	185	480	475
Mean	240.0b	214.1a	312.9c	377.9c	569.8d

Numbers with different letters indicate significant differences at the $P \leq 0.05$ significance level while those with similar letters indicate no significant differences.

The highest mean value for nitrates (NO_3) in the lake was 3.7 mg/L in 2023 while the lowest was 1.6 mg/L in 2019 and 2021 (Table 11). This could be due to an increase in the rate of phytoplankton consumption of nitrogen sources during 2023, indicating higher algae growth and pollution of the lake's water for that year.

Table 11: Levels of nitrates in Lake Habbaniyah (mg/L).

Years / Months	2019	2020	2021	2022	2023
January	1.5	4.1	2.1	4.5	3.9
February	1.2	6.1	1.3	5.6	3.8
March	1.9	5.5	1.2	6.5	4
April	1.3	2.3	1.4	3.2	3.4
May	2.8	3.1	1.2	3.2	4
June	1.5	3.1	2.6	2.3	3.8
July	1.1	3.1	1.5	3.7	3.6
August	1.1	2.4	1.1	2.3	3
September	1.8	2.3	1.7	2.2	3.8
October	1.1	2.3	1.2	2.8	3.8
November	1.3	4.2	1.1	3.1	3.9
December	3.3	1.8	3.5	1.1	4.2
Mean	1.6a	3.3b	1.6a	3.3b	3.7b

Numbers with different letters indicate significant differences at the $P \leq 0.05$ significance level while those with similar letters indicate no significant differences.

The highest mean value for phosphates (PO_4) was recorded at 0.7 mg/L in the lake during 2023, while the lowest was 0.05 mg/L in 2019 (Table 12). This lower PO_4 value is due to its increased consumption by plants and phytoplankton, as it is an important element in their growth. Studies have confirmed the existence of a direct relationship between phosphate concentrations and phytoplankton density, as well as the flow of human and industrial waste and detergents into the water (10).

Table 12: Phosphate levels in Lake Habbaniyah (mg/L).

Years / Months	2019	2020	2021	2022	2023
January	0.09	0.03	0.009	0.2	0.4
February	0.07	0.05	0.008	0.1	0.4
March	0.07	0.08	0.04	0.17	0.21
April	0.05	0.09	0.029	0.09	0.45
May	0.06	0.07	0.08	0.4	0.22
June	0.04	0.03	0.01	0.2	0.25
July	0.04	0.05	0.02	0.4	0.12
August	0.04	0.06	0.02	0.2	0.42
September	0.04	0.04	0.17	0.1	0.7
October	0.06	0.07	0.34	0.3	0.27
November	0.06	0.09	0.13	0.13	5.6
December	0.06	0.07	0.009	0.13	0.13
Mean	0.05a	0.06a	0.07a	0.2b	0.7b

Numbers with different letters indicate significant differences at the $P \leq 0.05$ significance level while those with similar letters indicate no significant differences.

The highest mean value for dissolved oxygen in the lake was 8.0 mg/L in 2019 and the lowest at 5.6 mg/L in 2023 (Table 13). Dissolved oxygen is a key requirement of organisms that live in water the absence of which could lead to biological problems or even their death. It's levels were found to have decreased over the study period, and this negatively affected the quality of the lake's water (20).

Table 13: Levels of dissolved oxygen in Lake Habbaniyah (mg/L).

Months \ Years	2019	2020	2021	2022	2023
January	7.2	6.1	7.2	6.4	5.1
February	6.2	5.3	6.3	9.1	6.6
March	8.1	8.3	7.5	5.2	6.8
April	8.8	8.6	6.7	7.9	5.5
May	8.4	8.7	7.7	6.8	5.1
June	8.7	7.8	6.8	4.2	5.4
July	8.5	7.2	6.1	5.4	5.4
August	8.6	8.1	6.4	5.3	5.3
September	8.4	7.5	6.9	5.1	5.1
October	7.7	7.1	6.8	7.1	7.1
November	7.5	7.7	6.9	5	5
December	8	7.6	5.9	6.8	5
Mean	8.0d	7.5d	6.7c	6.1b	5.6a

Numbers with different letters indicate significant differences at the $P \leq 0.05$ significance level while those with similar letters indicate no significant differences.

Table 14: Capacity, highest water level, and area variables for Lake Habbaniyah.

Years	2019	2020	2021	2022	2023
Capacity (million m^3)	2930	3100	2880	1870	650
Highest water level (m)	50.64	50.42	50.12	47.31	42.61
Area (km^2)	416	416	405	335	200

The largest capacity, highest water level, and area for Habbaniyah Lake were recorded in 2020 at 3100 million m^3, 50.64 m, and 416 km^2, respectively while 2023 had the smallest at 650 million m^3, 42.61 m, and 200 km^2, respectively (Table 14). These negative changes indicate a serious degradation of the lake's vital characteristics that have contributed to greater pollution of its water (18).

Conclusions

The study showed that the waters of Lake Habbaniyah have been negatively affected by climatic changes to which Iraq is exposed due to the rise in air and water temperatures. The increase in the evaporation process has raised sulfate, chloride, nitrate, and phosphate levels and decreased the amount of dissolved oxygen. The study also showed that changes to the capacity, water levels, and area of the lake resulting from climate change has increased the level of pollution of the lake's water. There is a need to undertake mitigating strategies and programmes to address these issues in a way that ensures maximum benefit from this important resource.

Supplementary Materials:

No Supplementary Materials.

Author Contributions:

Y.H. Mahmood: methodology, analyses of data, writing—original draft preparation; A. Sh. Jasim: writing—review and editing. Both authors have read and agreed to the published version of the manuscript.

Funding:

This research received no external funding.

Institutional Review Board Statement:

The study was conducted following the protocol authorized by the University of Samarra, College of Education, Department of Biology.

Informed Consent Statement:

No Informed Consent Statement.

Data Availability Statement:

The study was based on primary data collected from random samples from the Iraqi Meteorological Organization and Seismology and Ministry of Water Resources, General Authority for Dams and Reservoirs, Ramadi Dam Project Management.

Conflicts of Interest:

The authors declare no conflict of interest.

Acknowledgments:

The authors are thankful for the help of the Iraqi Meteorological Organization and Seismology and the Ministry of Water Resources, General Authority for Dams and Reservoirs, Ramadi Dam Project Management, Iraq for their help and technical assistance in conducting this research.

References

1. Abdullah, M., Al-Ansari, N., and Laue, J. (2019). Water resources projects in Iraq: reservoirs in the natural depressions. Journal of Earth Sciences and Geotechnical Engineering, 9(4): 137-152.
2. Al-Rawi, Z. H., and Alkobaisy, J. S. (2024). Effect of glomus mosseae, azotobacter chroococcum and vermicompost tea on some rhizosphere characters and mycorrhizal dependency of cucumber plants. Anbar Journal of Agricultural Sciences, 22(2): 790-805. https://doi.org/10.32649/ajas.2024.184459.
3. Alkhafaji, H. (2018). Iraq's water crisis challenges and solutions. Al-Bayan Center for Planning and Studies, Baghdad, Iraq.
4. Al-Kubaisi, Q. Y., and Al-Kubaisi, M. H. (2018). Using water balance to assess the groundwater recharge in the area between Rutba and Dhabaa, western of Iraq. The Iraqi Geological Journal, 51(2): 135-148. https://doi.org/10.46717/igj.51.2.8Ms-2018-12-30.
5. Al-Kubaisi, M. H., Al-Kubaisi, Q. Y., Al-Saady, Y. I., and Jasim, A. A. (2022). Application of GIS Technique to Assess the Habbaniya Lake Water for Human

Consumption. Journal of University of Anbar for Pure Science, 16(1): 75. DOI: 10.37652/juaps.2022.174843.

6. Al-Marawi, Q. A. R. (2012). Groundwater and the possibility of investing in it in Al-Jazeera region, Anbar Governorate using geographical information systems, p 114.
7. Al-Naimi, A. F. D., Diwan, M. H., and Kazim, W. M. (2010). Study of some physical and chemical properties of drinking water in Baladruz, Diyala Journal for Pure Science, 6(4): 122-135.
8. Al-Paruany, K. B., Al-Kubaisi, M. H., Al-Heety, S. O., and Jassaim, A. A. (2023). Assessment of water quality of Al-Habbaniya Lake by using statistical techniques (Cluster and factor analysis). In IOP Conference Series: Earth and Environmental Science, 1222(1): p. 012001. DOI: 10.1088/1755-1315/1222/1/012001.
9. APHA (American Public Health Association). (2005). Standard Methods for the Examination of Water and Waste Water. Washington, D.C., p 1193.
10. Fattah, O. A. (2024). The role of nitrogen and phosphorus biofertilizers in the uptake of some nutrients and growth of chickpeas (cicer arietinum l). Anbar Journal of Agricultural Sciences, 22(2): 942-961. https://doi.org/10.32649/ajas.2024.184463.
11. Hama Salih, N. Y., and Ahmad, A. B. (2024). The effect of domestic water filter types on the quality of drinking water. Anbar Journal of Agricultural Sciences, 22(1): 55-66. https://doi.org/10.32649/ajas.2024.183697.
12. Harrington, G. A., Cook, P. G., and Herczeg, A. L. (1999). Groundwater sustainability and water quality in the Ti-Tree Basin, Central Australia. CSIRO Land and Water.
13. Iscen, F. C., Emiroglu, Ö., Ilhan, S., Arslan, N., Yilmaz, V., and Ahiska, S. (2008). Application of multivariate statistical techniques in the assessment of surface water quality in Uluabat Lake, Turkey. Environmental Monitoring and Assessment, 44(1): 269-276. https://doi.org/10.1007/s10661-007-9989-3.
14. Mahmood, Y. H. (2023). Isolation and identification fungi from Khasah Su and the North Oil Company Channels / Kirkuk and testing their efficiency in greywater treatment. PhD thesis in Biology, College of Education, University of Samarra, Iraq.
15. Mustafa, M. H., and Jengiz, M. H. (2007). Quality difference between two location on Tigris River within Mosul City, Al-Rafidain Sciences Journal, 18(1): 111-124.
16. Mutar, Z. F. (2021). The environmental impacts consequences of the qualitative characteristics and the surface area change of water of Habbaniyah Lake. Al-Adab/Al-ādāb, (138).
17. Parsons, T. R., Matia, Y., and Lalli, C. M. (1984). A manual of chemical and biological methods for seawater analysis. Pergamon Press, Oxford, p 360. https://doi.org/10.1016/C2009-0-07774-5.
18. Saadallah, H. A. A., Bussat, S. F., and Al-Mukhtar, I. A. (2000). A study of the effect of the Hamrin reservoir on some water characteristics in the Diyala River, Diyala Journal, 2(7): 272-296.

19. Satam, A. T. M., Nahar, Z. J. M., and Khalaf, A. M. (2020). Building Digital Hydrological Models for the Habbaniyah Lake Reservoir to Calculate Area Variable. Multicultural Education, 6(4): 1-8. DOI: 10.5281/zenodo.4147322.
20. Yazan, J. Y., and Qassem, A. R. (2022). The qualitative characteristics of the water of Lake Habbaniyah, University of Anbar Journal for Humanities, 19(2).