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Evaluating the Water of the Tigris River Between the Cities of Al-Mosul and Al-Badoush Dams in Northern Iraq

Mariam Adnan Ibrahim[1], Ahmed Mohamed Taher [2], Ibrahim Omar Saeed[3*]
[1]Department of Biology, College of Pure Science, University of Tikrit, Iraq
[2]Ministry of Education, Open College of Education / Nineveh Center, Iraq
[3]Department of Biology, College of Science, University of Tikrit, Iraq

***Corresponding author:** dr.ibrahim1977@tu.edu.iq

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ABSTRACT

During this study, the physical and chemical parameters of the Tigris River water were measured at four sites along the Tigris River extending between Mosul and Badoush Dams for the period from September 2023 to February 2024 to evaluate the Tigris River water and its suitability for human use at the sites (1, 2, 3 & 4). The physical, chemical and biological parameters were studied, such as pH, air and water temperature, electrical conductivity (EC), total dissolved solids (TDS), total alkalinity, active phosphate (PO_4), nitrite (NO_2), chloride (Cl^-), active silica (SiO_2), and total plate count (TPC). Some of them were conducted in the field and others in the laboratory. It was found that most of the parameters that were studied are consistent with the international and Iraqi specifications for drinking water, except for the total platelet count (TPC), especially at station No. (4), which was noticeably high, reaching $12.9*10^2$ cells/ ml. The pH values ranged from 6.5-7.37, water temperature from 7-24 degrees Celsius, while the electrical conductivity (EC) was at a rate of 251µS/ cm. The average value of total dissolved solids (TDS) was 166.35mg/ L, and the percentage of dissolved oxygen (DO) was at a rate of 8.94mg/ L. Silica levels ranged from 1.00-2.23µg/ L, while the rate of effective phosphate was 0.04µg/ L, and the nitrite values were at a rate of 0.254µg/ L.

INTRODUCTION

Rivers and lakes are important sources of fresh water and constitute the vast majority of water suitable for drinking and human consumption. Iraq has the Tigris and Euphrates rivers and their tributaries and estuaries, which provide Iraq with an abundance of fresh water. Since Iraq is one of the countries that depend on crude oil for its energy sources, it is vulnerable to oil pollution, which contaminates water bodies burdening them with petroleum carbohydrates, which are considered among the most dangerous pollutants. Additionally, rivers and seas are polluted with oil, household and factory waste, and sewage water, which has become one of the problems of the era in the field of pollution of surface water and even groundwater **(Shambara, 2021)**. Fertilizers and pesticides used in agriculture pose a danger no less

than other pollutants since Iraq is one of the countries that depend on agriculture for its economic sources. This pollution causes a change in the natural balance of the aquatic environment and pushes it toward an environment devoid of quality, harmful to marine organisms and unfit for human use. This has prompted researchers to study water quality assessment and to follow it up continuously throughout the year in order to observe the changes occurring in water bodies and in the characteristics of their water quality **(Al-Mandeel *et al*., 2024)**. The most relied upon characteristics in assessing water quality are the physical, chemical and biological characteristics of water, as well as the Canadian model for assessing water quality, which is considered an important index that researchers can rely on to make a decision as to whether the water under study is suitable for drinking and human consumption or not **(Al-Safawi, 2018)**. Recent research has shown a scarcity of water and poor management, which has caused drought in many parts of Iraq, especially in the central and southern regions, which has prompted many researchers to study the environmental reality of surface water and ways to control pollutants, methods of guiding water, building dams and other solutions that would reduce the problems of water scarcity and poor quality **(Bream *et al*., 2019; Al-Shanona *et al.,* 2020)**.

MATERIALS AND METHODS

Study area

Mosul Dam is located north of Mosul city, about 50km on the Tigris River. The study was conducted on the eastern side of the river within coordinates of 36.6214839 North, 42.8411453 East and along the river starting from Mosul Dam and ending at Badoush Dam. The study area is characterized by abundant agriculture and reliance on the river course for irrigation and watering animals. It is characterized by few villages and the absence of factories and pollutants, except for the waste of some villages and districts such as Wana district (Fig. 1).

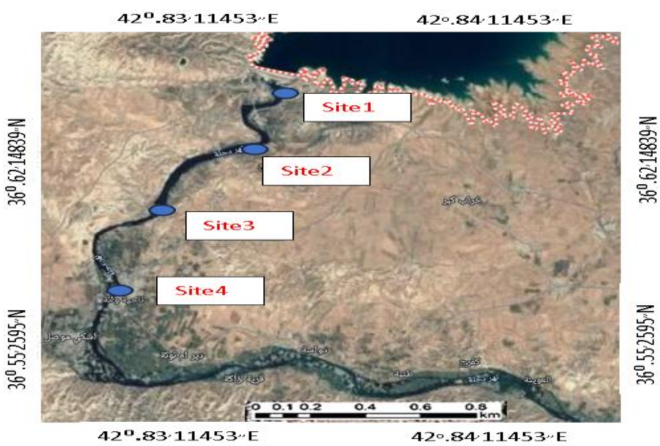

Fig. 1. Map of the studied area showing sites along the Tigris River

The study started from September 2023 to the end of February 2024, covering six months during which the physical and chemical properties of the water under study were measured once a month. Water samples were collected early in the morning from the four study sites that were selected along the Tigris River from Mosul Dam Lake to the beginning of Badoush Dam about 5km between each location (Fig. 1). This was done by taking special plastic bottles and directly filling them from the river water, taking into account not to leave air bubbles. The bottles were marked with the site numbers and the date of taking the sample and were transported in special boxes to the laboratory to conduct tests. Some of them were conducted in the field and different sources were adopted according to the tests **(Taher & Saeed, 2022)**.

Table 1. Methods of analysis

No	Examination	Unit	Name of the tool or device	Reference
1	pH	--	(pH Meter) Romanian origin	**(APHA, 2017)**
2	Temperature	Celsius	Mercury thermometer	--
3	Total dissolved solids	mg/L	Multi meter	**(APHA, 2017)**
4	Electrical conductivity	µS/cm	Electrical conductivity meter	**(APHA, 2017)**

Total alkalinity

The total alkalinity was measured following the method shown by **APHA (2017)**. 50ml of the water sample was taken, and 3 drops of the methyl orange indicator were added. The sample was then titrated using 0.02N sulfuric acid until the color changed to reddish orange, and the concentration of CaCO3 was expressed in mg/L. Total alkalinity was calculated using the following equation:

Total Alkalinity = (V H_2SO_4 × N H_2SO_4 × 1000 × Eq.wt of Ca CO3) / (V Sample).

Chloride

50ml of water was taken and placed in a 250ml beaker, and potassium dichromate (K_2CrO_4) reagent was added following the method of **ASTM (1984)**. After mixing the mixture well, 0.025N silver nitrate solution was added until the color of the mixture changed to the distinctive pale red color. The chloride results were expressed in mg/L according to the following equation: Cl^- = (V $AgNO_3$) × N $AgNO_3$ × 1000 × Atomic Wt. of Cl / (V sample).

Dissolved oxygen (DO)

According to **Mackerath (1963)**, dissolved oxygen was measured. Glass bottles were filled with water samples from the study sites, gently to prevent air bubbles. 2ml of manganese sulphate were added, followed by 2ml of potassium iodide to stabilize the oxygen. The bottle was turned upside down several times, gently, and the sample was kept away from sunlight. Then 2ml of concentrated sulfuric acid was added and shaken well. In the laboratory, 100ml of the sample was taken, and the yellow solution, amounting to 203ml, was tittered with sodium thiosulphate ($Na_2S_2O_3$), and expressed in mg/L.

Chemical oxygen demand (COD)

Chemical oxygen demand (COD) is an important test as an indicator of oxygen consumption resulting from chemical oxidation of organic materials. Using the Wagtech COD device, the chemical oxygen demand was measured at the four sites over a period of six months. Every two months, the water sample was placed in a special glass bottle, shaken vigorously, then 2ml of the sample was added to remove the cover of the Wagtech COD device. Using the heating, cooling and digestion method for two hours at a temperature of 150 degrees Celsius, the samples were examined using a spectrophotometer at a wavelength of 490 nanometers **(APHA, 1998; APHA, 2017)**.

Reactive silicate

Silica was measured using molybdenum silicate according to the method of **APHA (2017)**. A CE 1011 CECIL spectrophotometer was used at a wavelength of 410nm, and the results were expressed in mg/ L.

Reactive phosphorus

Freshwater is usually rich in phosphorus. To monitor phosphorus dynamics in ecosystems and to ensure water quality, reactive phosphorus was measured using the ascorbic acid reduction method **(APHA, 2017)** and spectrophotometrically at a wavelength of 880nm. The reactive phosphorus ratio was measured and expressed in mg/L.

Nitrite

Nitrite was measured by CE 1011 CECIL spectrophotometer at a wavelength of 543nm, and the result was expressed in µg/ L, using the method of **Strickland and Parsons (1972)**.

Total plate count (TPC)

The total number of plates indicates the number of living organisms and includes all types of bacteria, molds and yeasts in aerobic conditions and moderate temperature. This was done by making a series of dilutions (10^{-1}, 10^{-3}, and 10^{-5}) of three replicates for each dilution and by pouring the plates and incubating them at a moderate temperature of 37 degrees Celsius for 48 hours. The number of colonies was calculated and multiplied, and the result was multiplied by the inverse of the dilution, and the outcome was indicated in cells/ml **(Sneath *et al*., 1986)**.

RESULTS AND DISCUSSION

Physical properties

The results shown in both Fig. (2) and Table (2) show that the pH of the Tigris River water ranged from 6.5 to 7.37 during the study period. The highest value was at site (4) in February and the lowest value was at site (1) in September. The reason for the decrease in the pH may be due to the increase in the solubility of carbon dioxide gas, which is inversely related to temperature, the presence of aquatic plants, and climate change **(Abdullah *et al*., 2018)**. It is worth noting that the pH ranged within the **WHO (2011)** standards, which is within the range of 6.5 to 8.5. Among the physical characteristics, it is also noted from data in Fig. (2) and Table (2) that the air temperature ranged between 10 to 35ºC during the study period, where the highest temperature was recorded in the September at site (4) and the lowest temperature was recorded in February at sites (2) and (3). This finding align with the study of **Younis and Saeed (2023)**. With respect to the water temperature, it ranged between 7 to 24 ºC, where the highest value was recorded at site (4) for September and the lowest temperature at sites (2) and (3) in the months of January and February. It is noted that the temperatures are consistent with the standards of **WHO (2011)**.

The results also showed that the electrical conductivity was between 200 to 297µS/ cm, as shown in Fig. (2) and Table (2). Moreover, the electrical conductivity rate was 251µS/ cm for all sites throughout the study period. This is consistent with what was reached by **Shihab and Kannah (2023)**, who conducted a study on the waters of Tigris River at Wana. **Oleiwi and Al-Dabbas (2024)** noted that the result of the electrical conductivity was low and the reason for this may be that the river course passes far from cities and city waste and heavy metals and chemicals, especially industrial ones.

Table (2) and Fig. (2) show that the total dissolved solids ranged between 130.41 to 188.02mg/ L, where the highest value was at site (4) in September and the lowest value was at site (3) in February. As it is clear, the speed of water flow in the river course and the nature of the geochemical composition of the sediments and the presence or absence of tributaries and other characteristics related to the Tigris River have an effect **(Rasheed & Saeed, 2024)**. The amount of total dissolved solids, and the more industrial, domestic and agricultural waste, the higher the value of total dissolved solids. The proportionality between the value of total dissolved salt and electrical conductivity must not be unseen, as they have an inverse proportion. An increase in total dissolved solids affects the increase in the electrical conductivity of water **(Zhu *et al*., 2018)**.

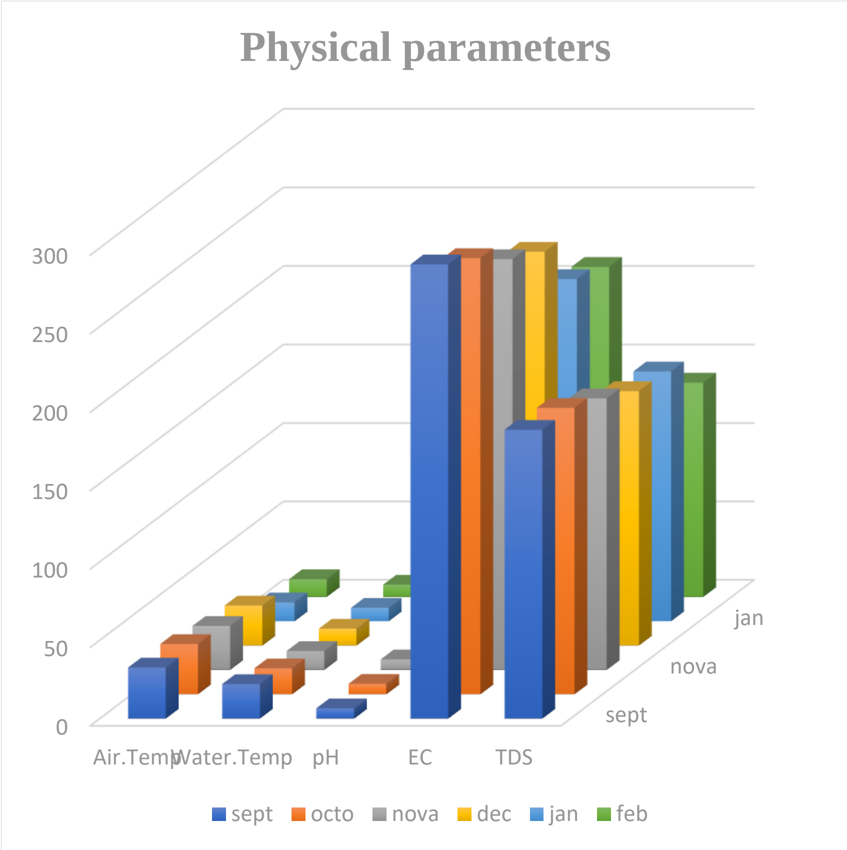

Fig. 2. Monthly changes in the studied physical parameters during the study period

Chemical properties

Table (2) and Fig. (3) show that total alkalinity reached its highest value at site (4) in September, where it recorded 128.12mg/ L, and the lowest value was recorded at site (3) in February, where it reached 90.62mg/ L. This is related to the temperature and the dissolution of carbon dioxide gas, which produces carbonic acid. This affects total basicity (temporary hardness) or calcium and magnesium bicarbonate, which are free of alkaline substances in the water. These substances are released by microorganisms that decompose organic materials in the presence of oxygen **(Keraga *et al.*, 2017)**.

$$CO_2 + H_2O \rightarrow H_2CO_3$$

$$CaCO_3 + H_2CO_3 \rightarrow Ca^{+2} + 2HCO_3^-$$

$$Ca\text{-}Mg\ (CO_3)_2 + 2H_2CO_3 \rightarrow Ca\ (HCO_3)_2 + Mg\ (HCO_3)_2$$

The decrease in total alkalinity may be due to the fact that aquatic plants perform photosynthesis and exhaust carbon dioxide, which reduces the production of carbonic acid **(Lateef *et al*., 2020)**. Fig. (3) and Table (2) show that the chloride values ranged between 16.72 - 25.34mg/ L. This result is due to the nature of sedimentary rocks and the leakage of some agricultural and household waste, especially at site (4), which causes an increase in chloride values, which remain in a dissolved ion state permanently if the conditions are normal **(Aljaburi *et al*., 2024)**. On the other hand, the results showed that the percentage of dissolved oxygen (DO) in the study area was somewhat high, ranging between 6.00 - 12.30mg/ L, where the highest value was at station 4 in February, while the lowest value was at station 3 in September among previous studies **(Hmoshi *et al*., 2024)**. The inverse correlation between temperature and the value of dissolved oxygen in water may be due to an increase in the value of dissolved oxygen maybe attributed to the lack of organic matter and the difference in the numbers and types of living organisms living in the river. These organisms contribute to the consumption of dissolved oxygen in the water. Additionally, the lack of depletion of dissolved oxygen by microorganisms, as well as the speed of the water current, which may increase the solubility of oxygen, as well as the lack of waste in the vast majority of the areas under study through which the Tigris River passes, all contribute to this relationship **(Alwan & Saeed, 2024)**.

The results in the Fig. (3) and Table (2) show that the concentration of effective phosphate ranged between 0.002-0. 10µg/ L, so that the highest value was in September at site 4, while the lowest value was in February at site 3. According to **Taher and Saeed (2023)**, the decrease in effective phosphate in rivers is due to the abundance of rain, climate change, and the depletion of phosphorus or the scarcity of its sources such as rocks and bird droppings that reach water sources, as phosphorus is considered one of the most important sources of effective phosphate **(Al-Saedi *et al*., 2024)**. On the other hand, the nitrite values ranged in the water samples under study between 0.12-0.50µg/ L, where nitrite reached its highest value in September and its lowest value was in February. The reason for the high nitrite, especially at station 4, is attributed to the proximity of agricultural areas and the abundance of rain that washes nitrogen-rich fertilizers into the river **(Al-Sarraj *et al*., 2014)**. The results in Table (2) and Fig. (3) also showed the silica concentration, which ranged between 1.00-2.23µg/ L. The reason for the low silica concentration in the river water in the stations that were studied is attributed to the presence of algae in large and dense forms. Algae, especially the *bacilli*, use silica in building their walls, in addition to some diatoms that consume silica, as well as to the nature of the structure and texture of the soil in the study area **(Almoula *et al*., 2021)**.

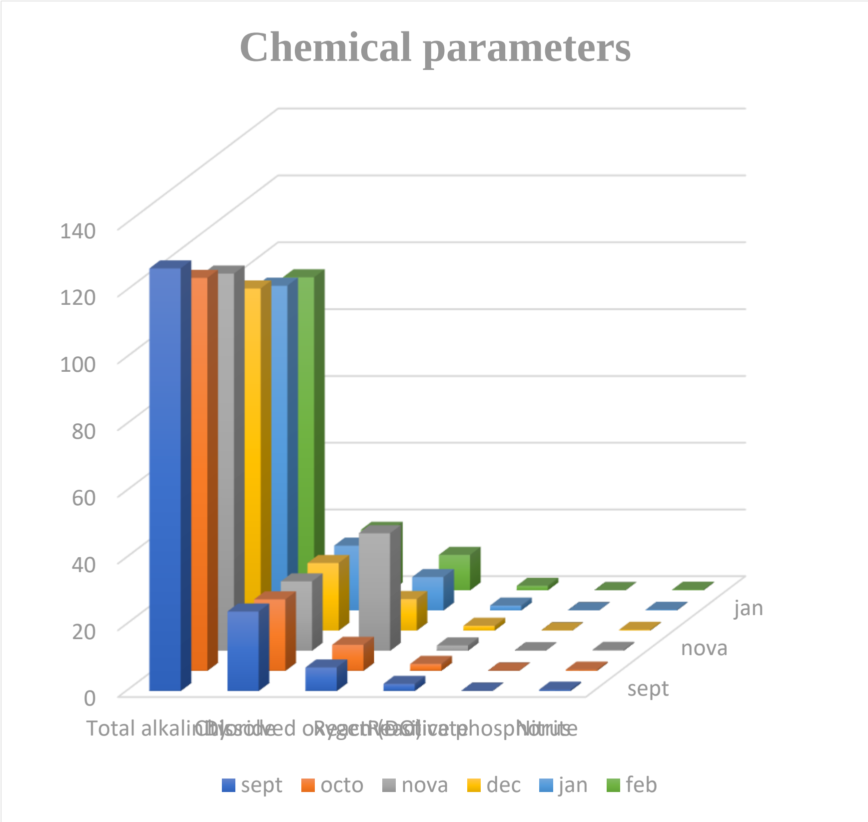

Fig. 3. Monthly changes in the studied chemical parameters during the study period

The current results (Fig. 4) show that the chemical oxygen demand (COD), which was measured over a period of six months and once every two months, ranged between 0.85 - 1.59mg/ L. This indicates that the water in the river under study is in good condition and that the water flow is good and sufficient and there is a lack of pollutants. Since COD is an indicator of the chemical oxidation of organic materials and since its value is low, this indicates a lack of organic materials and an increase in the percentage of dissolved oxygen according to **Tsunatu *et al.* (2016)**.

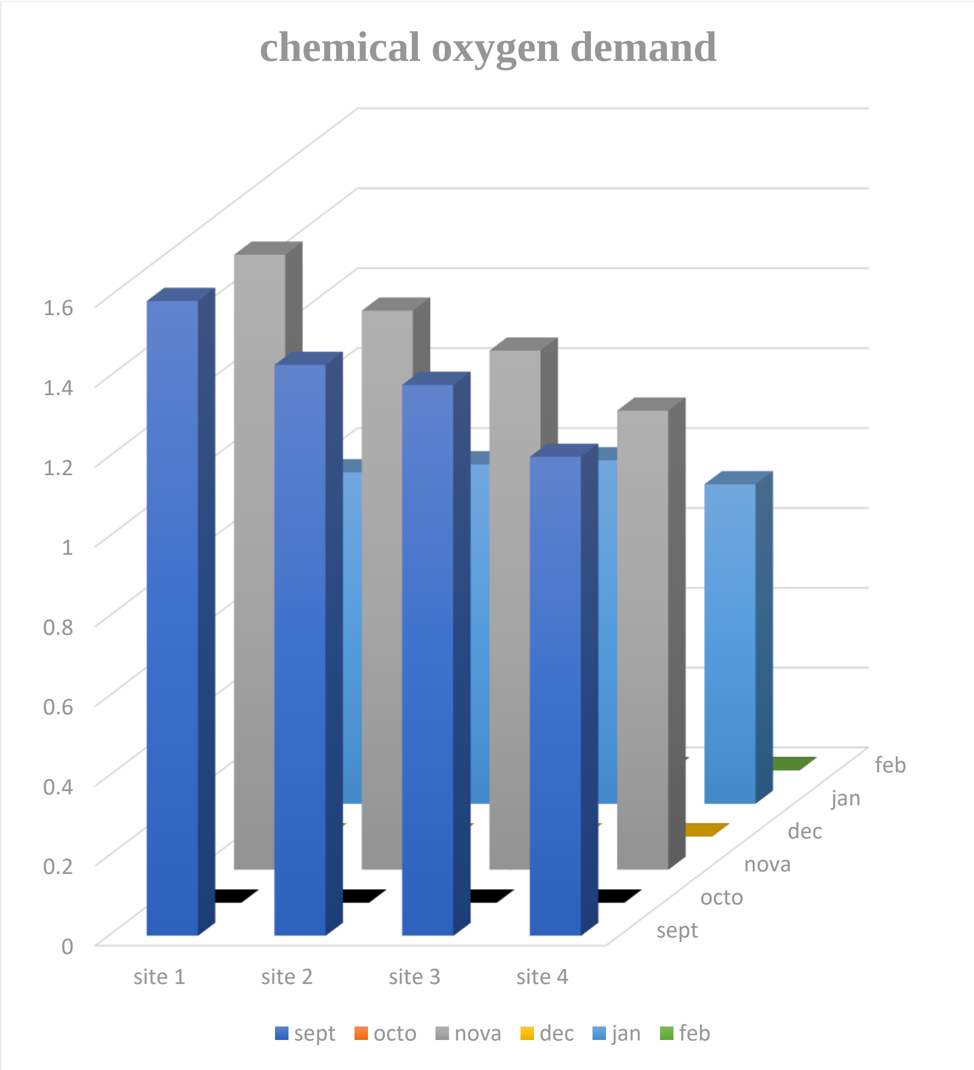

Fig. 4. Monthly changes in chemical oxygen demand studied during the study period

Fig. (5) shows the numbers and growth of bacteria, from which we can read the total plate count (TPC) in the river, where the highest value was recorded in February, at 12.9 * 10^2 cells/ml, and in September the lowest value was recorded, at 2.7 * 10^2 cells/ml.

This study showed that the number of microorganisms increased significantly in winter after being in lower numbers in autumn. This is due to the abundance of rain and floods that sweep away organic materials and dead plant remains. Additionally, the rivers witness a fluctuation in nutrients, which gives more opportunity for the growth of microorganisms **(Mallika *et al*., 2017)**. It is worth noting that station 4 witnessed a significant increase in the total plate count (TPC) due to the proximity of this area to the villages with population, which gives the opportunity for organic materials to reach the riverbed **(Edham *et al*., 2014)**.

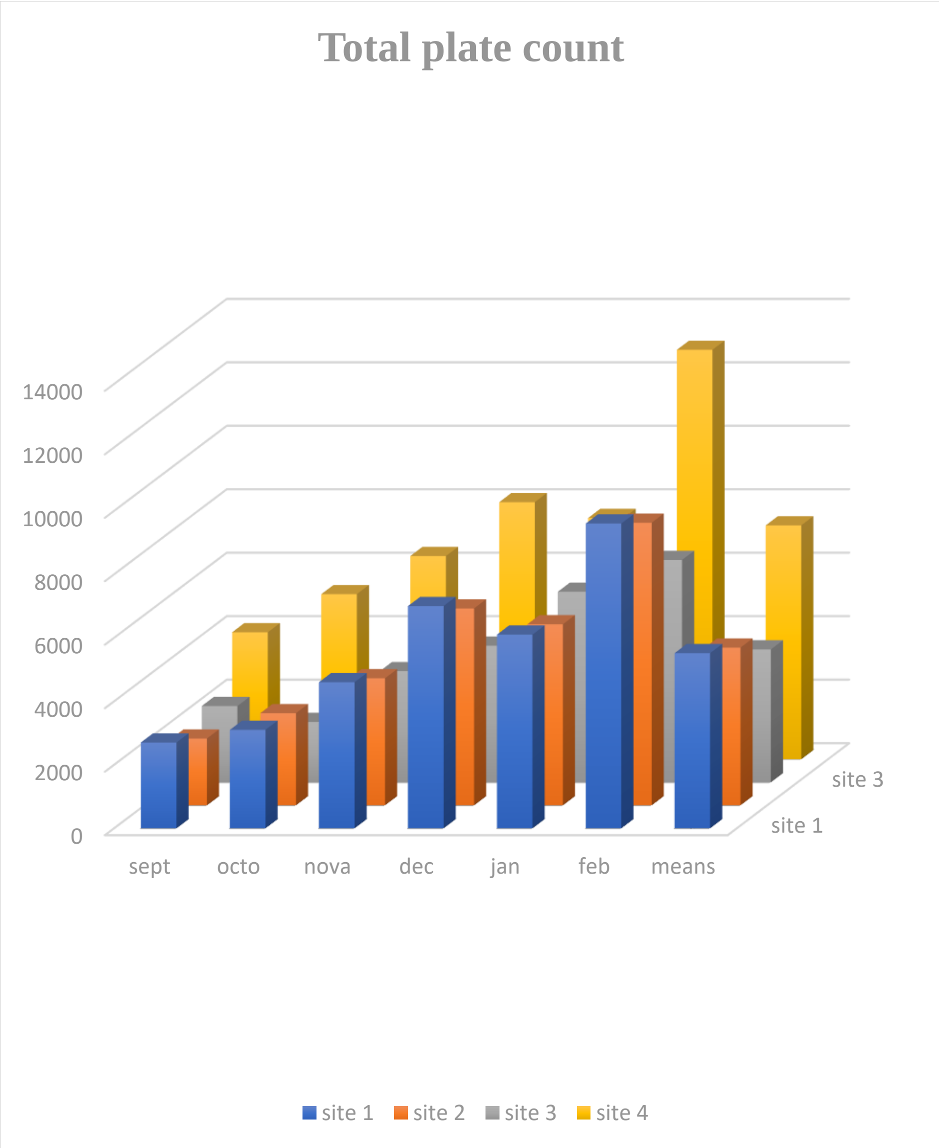

Fig. 5. Monthly changes in total plate count studied during the study period

Table 2. Monthly changes in chemical and physical parameters of the sites during the study period

	Months	pH	EC	TDS	Air Temperature	Water Temperature	Total alkalinity	Chloride	Dissolved oxygen (DO)	Reactive silicate	Reactive phosphorus
Site 1	**September**	6.5	291.00	187.00	34	23	127.02	24.11	7.22	2.19	0.08
	October	6.52	282.22	186.34	33	17	120.87	22.00	8	2.12	0.07
	November	6.58	278.01	172.00	29	12	113.00	21.87	8.98	1.85	0.06
	December	6.75	263.97	169.34	26	11	103.55	20.76	9.87	1.75	0.06
	January	7.23	220.00	165.21	13	9	97.08	20.00	10.22	1.69	0.03
	February	7.3	217.73	137.45	12	8	95.12	18.79	10.32	1.40	0.01
	Mean	**6.81**	**258.82**	**169.55**	**24.5**	**13.3**	**109.44**	**21.25**	**9.10**	**1.83**	**0.05**
Site 2	**September**	6.52	281.00	181.90	31	21	126.22	23.10	6.98	2.09	0.06
	October	6.59	272.22	179.06	32	16	114.12	20.90	7.84	2.02	0.05
	November	6.62	248.01	170.71	27	12	111.90	20.00	8.65	1.30	0.04
	December	6.67	237.97	159.87	24	10	101.45	19.36	9	1.12	0.02
	January	7.19	217.00	161.08	11	8	96.68	18.80	9.72	1.26	0.01
	February	7.22	204.73	132.71	10	7	92.82	17.72	10	1.19	0.01
	Mean	**6.80**	**241.15**	**164.22**	**22.5**	**12.3**	**107.19**	**19.98**	**8.69**	**1.49**	**0.03**
Site 3	**September**	6.51	289.00	179.94	30	20	124.99	22.70	6	2.00	0.05
	October	6.53	268.22	177.61	29	15	113.23	19.79	6.45	1.99	0.04
	November	6.6	241.01	173.90	26	11	110.00	19.00	7.99	1.09	0.03
	December	6.6	229.97	148.82	24	10	99.75	18.91	8.77	1.00	0.02
	January	7.14	215.00	140.93	10	7	95.28	18.21	9.05	1.07	0.01
	February	7.2	200.73	130.41	10	7	90.62	16.72	9.78	1.00	0.002
	Mean	**6.76**	**240.65**	**158.60**	**21.5**	**11.6**	**105.64**	**19.22**	**8.00**	**1.35**	**0.02**
Site 4	**September**	6.6	297.00	188.02	35	24	128.12	25.34	8	2.23	0.10
	October	6.72	289.22	187.56	34	18	122.67	23.04	8.9	2.19	0.09
	November	6.89	280.01	176.10	30	13	117.00	22.21	9.59	2.00	0.08
	December	7.13	271.97	170.94	28	12	105.15	21.96	10.12	1.90	0.07
	January	7.32	230.00	169.81	14	10	100.00	20.70	11	1.79	0.06
	February	7.37	221.73	145.75	13	9	96.42	19.27	12.3	1.73	0.04
	Mean	**7.00**	**264.98**	**173.03**	**25.6**	**14.3**	**111.56**	**22.08**	**9.98**	**1.97**	**0.07**
Sites Means		**6.84**	**251.40**	**166.35**	**23.5**	**12.9**	**108.46**	**20.63**	**8.94**	**1.66**	**0.04**

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