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Evaluation of Water Quality in the Northern Region of the Shatt al-Arab River, Southern Iraq

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ABSTRACT

This study investigated the water quality in the northern section of the Shatt al-Arab River in southern Iraq using the Canadian water quality index (CCME-WQI) at three monitoring stations: Qurna, Al-Deir, and Al-Hartha. The study was conducted from December 2022 to November 2023. Monthly water samples were collected and analyzed for various environmental parameters, including water temperature, salinity, pH, total dissolved solids, light penetration, water velocity, reactive nitrate, ammonium ions, total phosphate, chlorophyll A, biological oxygen demand, and total suspended solids. The calculated water quality indices for the three stations were 57.8, 60.6, and 55.2, respectively, categorizing the water quality as "marginal," indicating susceptibility to pollution and deviation from ideal conditions.

INTRODUCTION

Water quality scientists and experts have developed an efficient water quality index (WQI). This method is widely preferred today because it combines multiple variables into a single numerical expression, allowing water to be classified into specific categories in a simple and practical manner. This makes the results easily interpretable by decision-makers, administrators, and the general public. The water quality index (CCME WQI) was developed by the Canadian Council of Ministers of the Environment in 2001 **(CCME, 2001a, b)** and has since been implemented by many water agencies in different countries **(Boyacioglu, 2010)**.

Mohammed's study **(1965)** was one of the first environmental studies conducted on the Shatt al-Arab, and it was followed by numerous other studies on the river. Among these were several international studies, including the study of **Khan *et al.* (2003)**, which evaluated the water quality of three rivers in Canada to assess their suitability for drinking, irrigation, and aquatic life using the Canadian water quality index (WQI).

Moyle (2010) used the Canadian WQI to evaluate the water quality of the northern part of the Shatt al-Arab, assessing its suitability for general use, irrigation, and drinking. The study results showed that the general water quality index values were classified into the moderate and poor categories. The water quality index for drinking water was classified into the poor category, while the irrigation water quality index (IWQI) values were classified into the good and weak categories. **Al-Saboonchi *et al.* (2011)** used the WQI to assess the water quality of the eastern Al-Hammar Marsh. The study found that the water in the marsh was classified into the fifth (poor) category.

This study aimed to evaluate the water quality of the northern part of the Shatt al-Arab in southern Iraq.

MATERIALS AND METHODS

Study area

The study was conducted on the Shatt al-Arab. Three sites were selected (Qurna, Al-Deir and Al-Hartha), within the coordinates N:47.440523 E:31.005447; N:47.5795 E:30.804273; N:30.77801 E:47.6081, respectively. The width of the river varies in these locations ranging from 130 to 133m. Water depth in three stations ranged between 6-12m, 5-13m and 7-10m, respectively (Image 1). Agricultural activities and fishing boats are increasing in the study area. Several aquatic plants were recorded, including *Phragmites australis*, *Ceratophyllum demersum*, and *Typha domingensis*, which were classified according to **Al-Abbawy and Al-Mayah (2010)**. The presence of animals such as buffalo is also noted, with local inhabitants engaging in various activities, including agriculture. Palm groves and animal husbandry are widespread in the area.

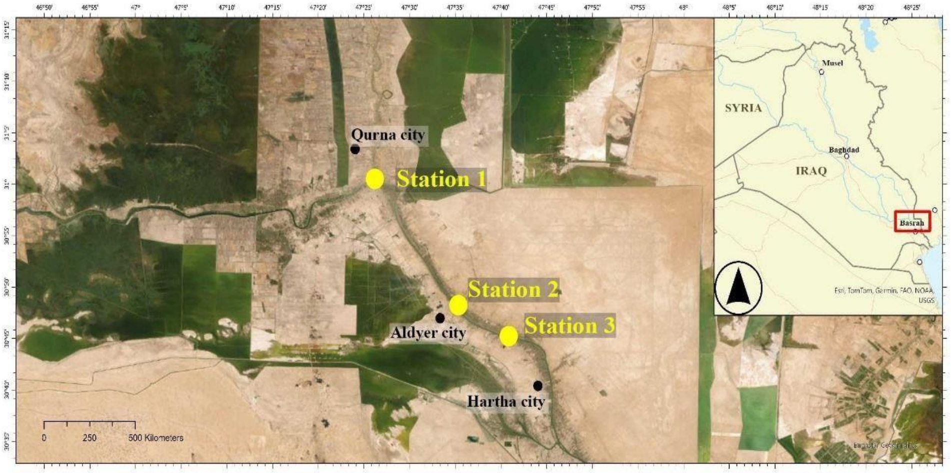


Image 1. Location of study stations

Field work

Water samples were monthly collected from all study stations, from December 2022 until the end of November 2023. The samples were collected using polyethylene bottles, from under the water surface at a depth ranging from 15-25cm. Some factors were measured in the field, others in the laboratory; factors measured in the field (water temperature, salinity, and pH) were assessed using the Combo water Quality Meter. Light transmittance was measured using a Secchi disk as well as current water.

Laboratory work

Dissolved oxygen was measured using the azide modification of the winkler method, as described by **Lind (1979)**. Total suspended solids (TSS) and biological oxygen demand (BOD_5) were determined according to the American Public Health Association **(APHA, 2005)**. Nutrient concentrations, including reactive nitrate (NO_3), ammonium ion (NH_4), total phosphate (PO4), and total nitrogen, were measured following **APHA (2017)**. Chlorophyll A was analyzed using the method of **Aminot and Rey (2000)**. Water quality index (WQI) was calculated based on the Canadian Council of Ministers of the Environment **(CCME, 2001)** protocol, which combines three key factors calculated as:

F1= (Number of failed Variables /Total number of Variables) X100

F2 = (Number of failed tests /Total number of tests) X100

$$F3 = \frac{nse}{0.01\,nse+0.01}$$

The water quality index is calculated from the following equation

$$WQI=100- (\frac{\sqrt{f^{2}1+f^{2}2+f^{2}3}}{1.732}$$

The resulting index value ranges from 0-100, then it expresses the condition of the water body. Table (1) shows the water quality categories.

Table 1. Water quality index scale

Categories classification	**Index**	**Description**
Excellent	**95-100**	Water is well protected and free from pollution sources (close to ideal)
Good	**80-94**	Water is well protected and meets specifications (far from ideal)
Fair	**65-79**	Water is often protected but polluted (sometimes far from ideal)
Marginal	**45-64**	Water is polluted (most often far from ideal)
Poor	**0-44**	Water is always polluted (far from ideal)

Statistical analysis

The data were analyzed statistically, using the Principal Components Analysis (PCA) method, for the studied factors, their impact on the environment, and their relationship with each other.

RESULTS

Fig. (1) shows the monthly and locational variations in water temperature at the study stations. The minimum temperatures recorded were 18.5, 16.0, and 15.0°C in December 2022 at the first, second, and third stations, respectively. The temperatures gradually rose, reaching maximum values of 37.0, 38.0, and 38.5°C in August 2023 at the three stations, respectively.

Fig. (2) shows the monthly variations in salinity concentrations during the study period, which fluctuated across the stations. The minimum salinity values were recorded in December 2022: 0.90, 0.99, and 1.60g/ L at the three stations, respectively. The maximum salinity values were recorded in August 2023: 1.50, 2.10, and 3.20g/ L at the first, second, and third stations, respectively.

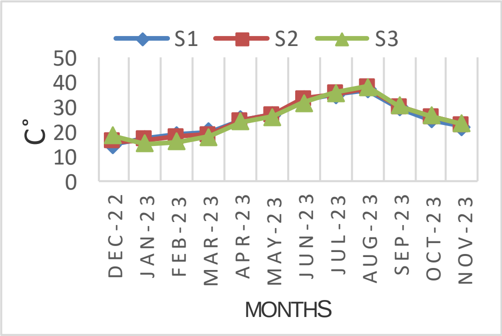


Fig. 1. Monthly changes in water temperature

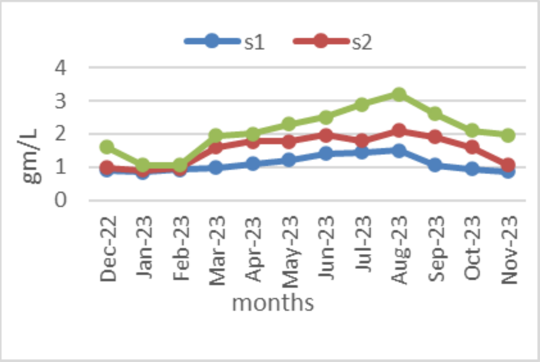


Fig. 2. Monthly changes in salinity concentrations

Fig. (3) shows the monthly and site-specific changes in pH values. The values tended toward slight alkalinity during the study period at all stations. The minimum values were 7.30, 7.10 and 7.00 in February 2023, while the maximum values were 7.40, 7.80 and 8.20 in August 2023 for the first, second and third stations, respectively.

Fig. (4) shows the monthly changes in dissolved oxygen (DO)values for the study stations. The minimum values were 6.10, 6.40 and 7.20mg/ L in August 2023, and the maximum values were 10.90, 10.50 and 10.60mg/ L in January at the three study stations, respectively.

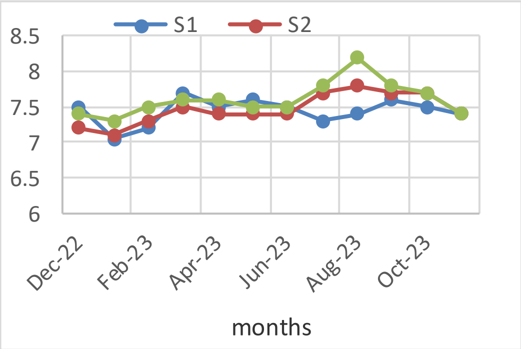
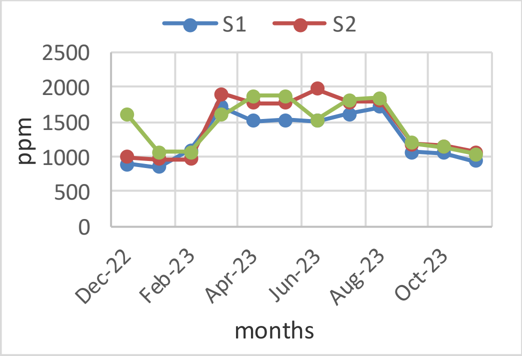


Fig. 3. Monthly changes in pH values

Fig. 4. Monthly changes in DO values

Fig. (5) shows the monthly variations in the values of total dissolved solids at the studied stations. The minimum values were 854, 1060, and 960ppm in January 2023, while the maximum values were 1720, 1840, and 1800ppm in August 2023 at the first, second, and third stations, respectively.

Fig. (6) shows the monthly changes in light penetration values through the water column at the study stations. The minimum values were recorded in August, which were 30.00, 29.50 and 36.00 cm, while the maximum values were 97.50 cm in December for the first, second, and third stations, respectively.



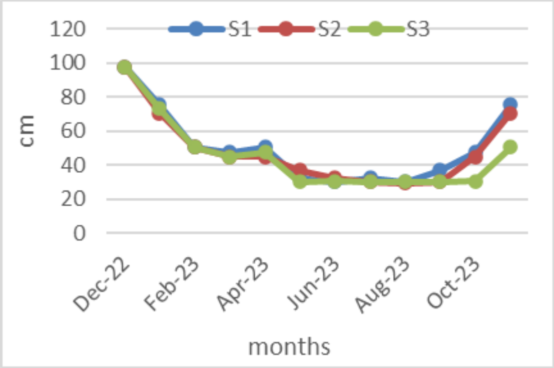


Fig. 5. Monthly changes in the values of TDS

Fig. 6. Monthly changes in light transmittance

Fig. (7) shows the monthly changes in current water values at the study stations. The minimum values were recorded as 0.10m/ s in February for the third station, 0.20m/ s for the second station in March and June, and 0.30m/ s for the first station in January, April and June. The maximum values were 0.60, 0.80 and 0.50m/ s in October for the first and second stations, and in November for the third station.

Effective nitrate (NO_3)

Fig. (8) shows the changes in nitrate values during the study period for the studied stations. The minimum values were recorded as 0.99, 0.79 and 0.72µg in June for the first, second and third stations, respectively, while the highest values were 1.85, 1.97 and 2.02µg in November for the first station and October for the second and third statios respectively.

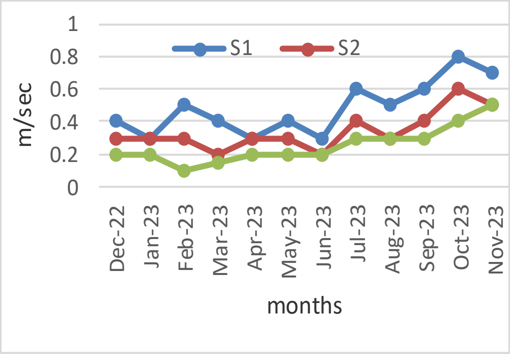


Fig. 7. Monthly changes in current water values

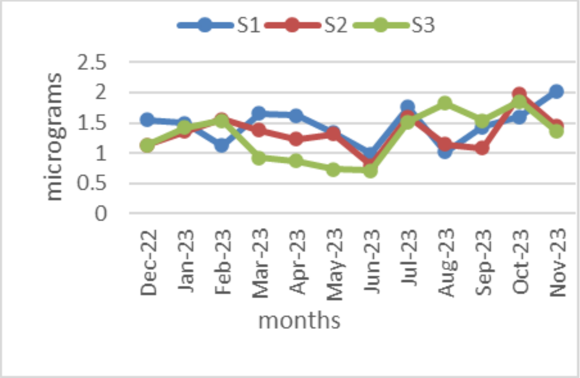


Fig. 8. The changes in nitrate values during the study period

Total nitrogen (TN)

Fig. (9) shows the monthly and site changes in the measured total nitrogen values at the study stations. The minimum values were 1.05, 1.02 and 1.52mg/ L in August for the stations, respectively. The maximum values were 2.81, 2.98mg/ L in June for the first and third stations and 2.62mg/ L in December for the second station.

Ammonium ion NH_4^+

Fig. (10) shows the monthly changes in the measured ammonium values during the study period. The minimum values were 0.14, 0.18 and 0.26ppm in March, April and May for the first, second and third stations respectively. Th maximum values were 0.87ppm in October for the first station and 1.56 and 1.12ppm in September for the second and third stations.

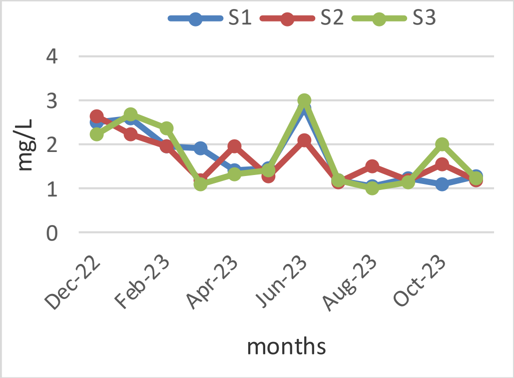


Fig. 9. Monthly measured total nitrogen values

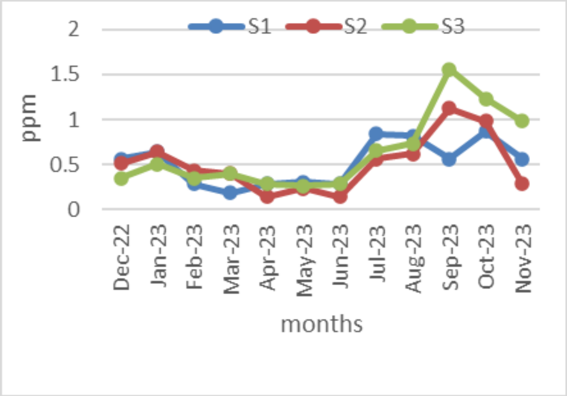


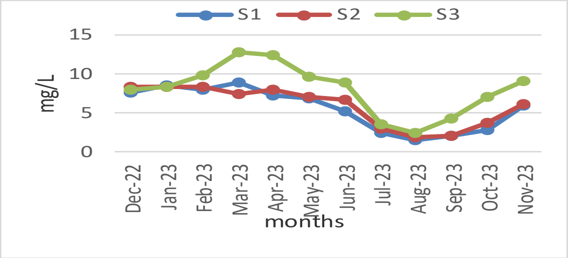
Fig. 10. Monthly changes in the measured ammonium values

Total phosphate

Fig. (11) shows the monthly and site changes in the values of total phosphate concentrations in the study stations. The minimum value was 0.15, 0.03 and 0.07mg/ L in April for the first, second and third stations respectively. The maximum value recorded was 1.41, 1.08 and 1.03mg/ L in January for the first, second and third stations respectively.

Chlorophyll a

Fig. (12) shows the monthly changes in the measured chlorophyll a value at the study stations during the study period. The minimum values were 1.50, 2.30 and 1.80mg/ L for the first, second, and third stations, respectively, in August. Additionally, the measured maximum values were 8.80mg/ L during April for the first station, 8.23mg/ L in January for the second station, and 12.80mg/ L in March for the third station.



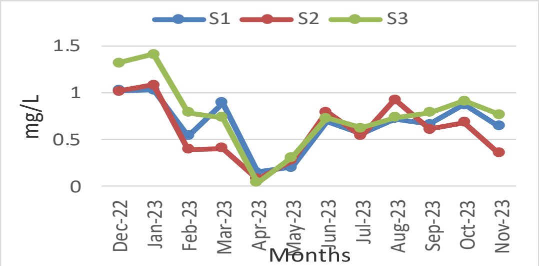


Fig. 11. Monthly and site changes in the values of total phosphate

Fig. 12. Monthly changes in the measured chlorophyll a values

Biological oxygen demand (BOD5):

Fig. (13) shows the monthly and site changes of BOD5 values for the study stations. The minimum values were 1.5.10mg/ L in January for the first and third stations and 1.40mg/ L in December for the second station. The maximum value was 3.40mg/ L in August for the third station and 2.83mg/ L in April for the first and second stations, respectively.

Total suspended solids (TSS)

Fig. (14) shows the monthly changes in the values of suspended solids in water. The minimum values were in January, which were 6.60g/ L at the first station, 5.30g/ L at the second station, and 5.30g/ L in February at the third station. The maximum values were 19.50, 15.60, 28.20g/ L in August at the first, second, and third stations, respectively.

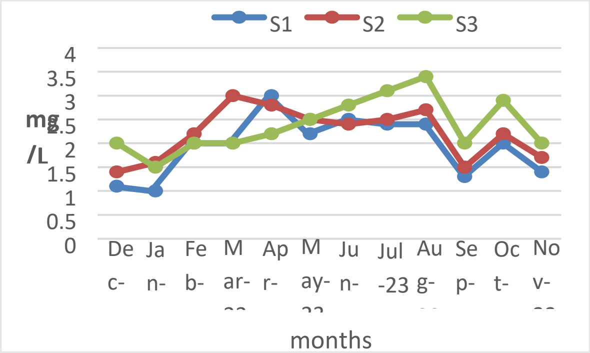


Fig. 13. Monthly and site changes of BOD_5 values

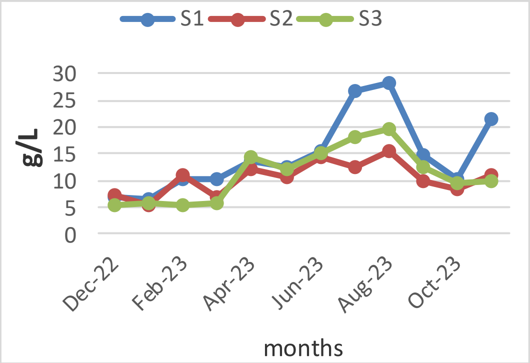


Fig. 14. Monthly changes in the values of TSS

Water quality index (Canadian model) (CCME-WQI)

The current study showed that the values of the Canadian index for Shatt al-Arab water are shown in Table (2). The maximum value was recorded at the first station (Qurna) which was 77.00 in May. The minimum value was recorded which was 40.10 at the second station in September.

Table 2. The values of the Canadian index for Shatt al-Arab water

Month	St1	St2	St3
Jan	**52.8**	**52.8**	**56.4**
Feb	**52.4**	**52.3**	**55.2**
Mar	**58.3**	**52.8**	**71.2**
Apr	**48.5**	**74.0**	**69.0**
May	**77.0**	**76.9**	**70.0**
Jun	**76.4**	**68.8**	**60.9**
JUL	**61.3**	**61.0**	**54.7**
Aug	**48.7**	**51.1**	**42.8**
Sep	**46.6**	**40.1**	**41.2**
Oct	**49.0**	**61.1**	**47.3**
Nov	**41.3**	**61.5**	**58.5**
Dec 2022	**49.8**	**74.9**	**66.7**
Average	**55.2**	**60.6**	**57.8**

The principal components analysis (PCA) was used for the studied factors and their impact on the environment and their relationship with each other. The results are presented in Figs. (15, 16, 17), which display two-dimensional biplots representing the relationships between different factors and their effects on the environment at the three stations. It is evident from the figures that these relationships are shown along the F1 and F2 axes in the dataset, highlighting the relative importance and correlations between the variables. The variables, including total phosphate, transparency, nitrate concentration, ammonium, chlorophyll a, and other studied factors, are represented by arrows. The x-axis (F1) represents the first dimension, which explains 51.16% of the total variance, while the y-axis (F2) represents the second dimension, explaining 23.53% of the total variance.

The relative positions of the variables on the chart indicate the degree of their correlation. Variables that are close to each other are positively correlated, meaning they change together, while variables in diametrically opposite directions are negatively correlated, meaning they change in opposite directions. The length of the vectors (arrows) representing the variables indicates the strength of the correlation.

Fig. (15) shows the correlations between factors at the first station. Temperature and pH have a direct relationship, indicating that an increase in temperature leads to a rise in pH, possibly due to increased biodegradation of organic matter and chemical reactions associated with higher temperatures. Salinity and total dissolved solids also show a direct relationship, suggesting that an increase in salinity is accompanied by a rise in dissolved solids, potentially due to increased mineral inputs or evaporation processes in the area. Additionally, nitrogen and phosphorus are directly related, meaning an increase in either of these factors is associated with an increase in the other, possibly due to shared sources or chemical processes. Dissolved oxygen (DO) and biological oxygen demand (BOD5) show an inverse correlation, indicating that higher BOD5 (biodegradable organic matter) leads to decreased DO levels, as oxygen is consumed during biodegradation.

Fig. (16) shows the relationships at the second station, where several groups are distinguished, including the physical-chemical factors group. This group displays direct relationships among its elements, such as pH, temperature, salinity, and total and dissolved solids. For example, an increase in temperature leads to higher salinity and dissolved solids, likely due to increased evaporation and dissolution.

The group of nutrients that interact with each other (phosphorus, nitrogen in its various forms) appear in a direct relationship, because they are part of the same life, geological and chemical cycles in the aquatic system. The increase in any of them leads to an increase in the other through chemical reactions and biological absorption. Some factors also show inverse relationships such as the biological requirement for BOD5 and DO. The increase in organic matter (BOD**5**) consumes dissolved oxygen in the aquatic medium through biodegradation processes, also chlorophyll a (Chlo a) is inversely related to nutrients, the growth of phytoplankton leads to greater consumption of nutrients.

Fig. (17) shows at the third station that total phosphorus, water transparency and total nitrogen are positively correlated and of high relative importance. Phosphorus and nitrogen are considered the main nutrients necessary for the growth of aquatic organisms, such as algae and aquatic plants. High levels of these nutrients lead to increased growth of these organisms, affecting water transparency. It was noted that the factors NO_3, NH_4 and pH were also positively correlated, but less important than the previous group. Temperature, BOD5, salinity and TSS are inversely correlated with other variables in general. The two-dimensional plot provides a visual representation of the relationships and relative importance of the variables in the data set, which helps understand the underlying structure and patterns.

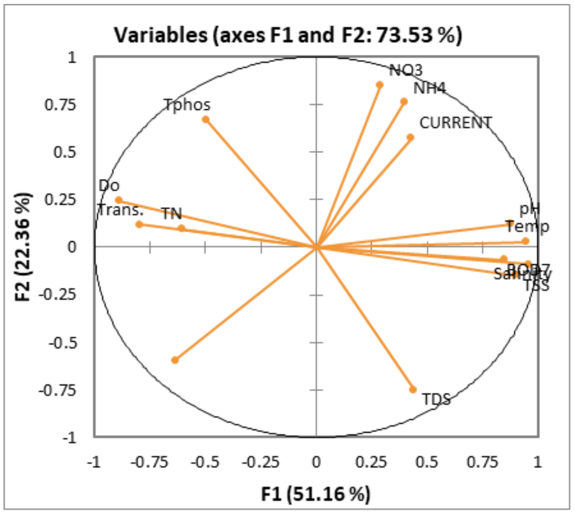


Fig. 15. Different correlations between factors in St1

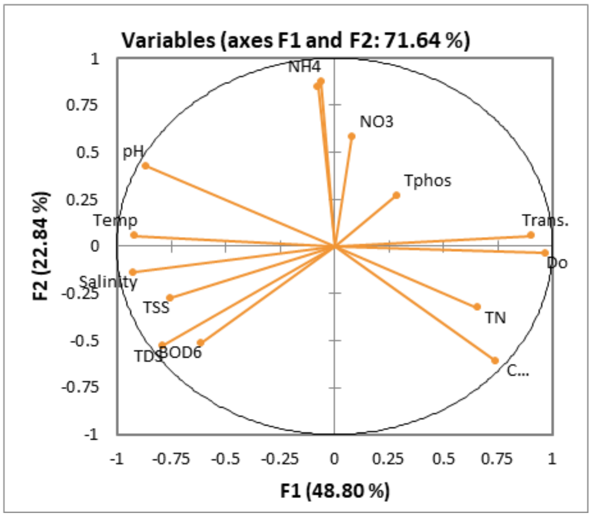


Fig. 16. Different correlations between factors in St2

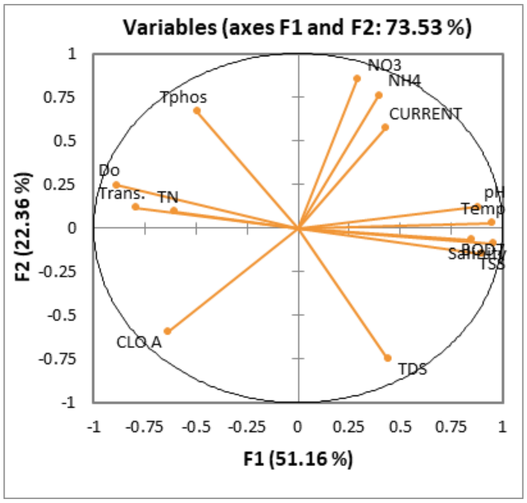


Fig. 17. Different correlations between factors in St3

DISCUSSION

The water temperature is directly proportional to the air temperature. The Shatt al-Arab is located in Basra, which is characterized by a hot, dry climate in the summer and a cold, humid climate in the winter, conditions that are reflected in the water temperature. The recorded water temperatures were higher than those in previous studies, with variations across different months. This result is consistent with those determined in several earlier studies such as that of **Rahi (2018)**.

The pH values in the current study were slightly alkaline throughout the seasons. This is attributed to several factors, including the activity of microorganisms that break down organic materials, producing carbon dioxide, which is consumed by plants and phytoplankton during photosynthesis. This finding is consistent with previous studies on the waters of the Shatt al-Arab **(AL-Shaheen, 2016; Gatea, 2018)**.

Light transmittance in the current study varied between 37.00 and 74.50cm, depending on the stations and seasons. These variations are due to the speed of water currents, which are influenced by climatic conditions and the movement of local boats. As a result, fine and suspended materials either move or settle in the water column **(Al-Hejuje, 2014)**. The highest dissolved oxygen values were recorded in January, and the lowest in August, indicating an inverse relationship with temperature **(Ali, 2014)**.

Fluctuations in total suspended solids were observed, with the highest values in August and July and the lowest in January. These changes are likely due to high temperatures, a decrease in the water level, and reduced microbial activity **(Salman & Nassar, 2014)**. The velocity of water currents varied according to temperature, rainfall, and changes in the water level throughout the year **(Bruno *et al*., 2013)**.

The maximum ammonium ion concentrations were recorded in September and October at the study stations. This could be due to reduced water volume and increased microbial activity during this period **(Woodworth *et al.*, 2019)**. Nitrate concentrations were at their highest in November at the first and second stations and in October at the third station, likely due to increased microbial activity associated with the decomposition of organic matter and rainfall on nitrogen-fertilized agricultural lands **(Abbas *et al.*, 2020)**.

Phosphate concentrations also varied during the study period, with the highest values recorded at the third station in January. This variation is likely linked to the activity of living organisms, including plankton and aquatic plants **(Abbas *et al.*, 2020)**.

Chlorophyll a, found in all green plants, algae, and phytoplankton, is distinct from other types of chlorophyll **(Degobbis *et al*., 2000)**. Its concentration in the environment serves as an indicator of photosynthetic efficiency and depends on the types of phytoplankton present in the water **(Yoder & Kennelly, 2003)**. The relationship between chlorophyll a and all nutrients is negative with temperature and salinity, but positive with light transmittance and dissolved oxygen **(AL-Shaheen, 2016; Abbas *et al.*, 2020)**.

The Water quality index (Canadian Model) showed a decrease in the index values at the study stations during the study period. The average values were 55.20, 60.60, and

57.80 for the stations, respectively, classifying the water quality as marginal. This indicates general deterioration in the river's water quality. The results are similar to those found by **Moyle (2010)**, who classified the water in the Shatt al-Arab as poor to marginal, with index values ranging between 3.00 and 65.00. The study of **Al-Hejuje (2017)** also classified the water as poor and marginal, with index values ranging from 32.00 to 55.00. Similarly, **Resen *et al.* (2014)** classified the Shatt al-Arab waters as marginal, with index values ranging from 47.00 to 67.00. These results indicate that the quality of the water is deteriorating and becoming increasingly polluted.

CONCLUSION

The results showed the analysis of the canonical correlation between living conditions during the study period. One of the key benefits of this program is its ability to display all environmental elements and bring them together in one cohesive form. The length and direction of the arrows indicate the strength of the correlation between environmental variables. A positive correlation is indicated when the arrows point in the same direction, while an opposite direction of the arrows suggests a negative or weak correlation between the living conditions. Living conditions affect aquatic ecosystems and their biological communities both directly and indirectly. Therefore, it was essential to employ specific techniques in analyzing environmental data to assess the impact of these factors on communities, including fish populations.

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