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Water quality assessment of Sawyer river using some environmental indices

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ABSTRACT— The assessment of water quality is very important for knowing its suitability for various purposes. Water quality index (WQI) indicates the quality of water in terms of index number for any intended use. It is defined as a rating reflecting the composite influence of different water quality parameters were taken for calculation of water quality index. The water quality of the Al-Sawyer River, which is the main branch of the Euphrates River in the Al-Muthanna Governorate in southern Iraq, was assessed. These study evaluated the water quality using four models of water indices, which are weighted Arithmetic (WA-WQI), Canadian Council of Environment Ministers for the Water Quality Index (CCME), Heavy Metals Index (HPI). as well as Minimum operator index (min). Monthly water samples were collected from three stations on the river from November 2020 to October 2021 and were analyzed, The results of the study showed used the CCME Index to assess the quality of water for drinking, irrigation and living aquatic purposes. And the results were (41.52,Poor) for drinking, ccme for irrigation water value ranged (60.5-93.91, Fair to Good),as well as for aquatic living ranged (Poor –Fair), The results indicated that the river water quality is unsuitable for drinking, but it is suitable for irrigation and aquatic life. WA-WQI Indicator Results showed (237.5, 184.6, 228.6) in three stations respectively, The results of this indices also revealed that the river water is unfit for human consumption. The results indicated that the values of HPI of the three stations were (238.8, 185.5, 230.2) High Polluted in the all stations. The Results WQImin ranged between (Bad to Good water).

KEYWORDS: Water quality, Environmental indices, Al-Sawyer river, Pollution

1. INTRODUCTION

Water is used for a variety of purposes in the ecosystem, including drinking, agriculture, industrial activities, and hydropower generation, and its quality and availability are influenced by population growth, urbanization, and various human activities [1- 3].

Water quality is determined by the chemical, physical and biological parameters of water. It is a measure of the state of the water with respect to the necessities of human needs or purposes [4]. Water quality is usually calculated by evaluating a water sample's chemical and physical properties to water quality objectives or guidelines [5]. The Water Quality Index (WQI) is the simplest methods for assessing water quality [6].

Horton [7] suggested the primary WQI, and additional concepts were proposed as improvements to the initial approach. Many WQIs have been created and certified around the world [8- 11], with the statistical inclusion and translation of parameter values being the main variations [4], [12], [13]. The values of several physicochemical and biological properties in a water sample are used to create indices. It's a tool for exchanging data on water quality [14]. The Oregon Water Quality Index (OWQI), the National Sanitation

Foundation's Water Quality Index (NSF-WQI), the Heavy Metals Pollution Index (HPI), and the Canadian Water Quality Guideline-Water Quality Index (CCME-WQI) are just a few examples of indexes [15].

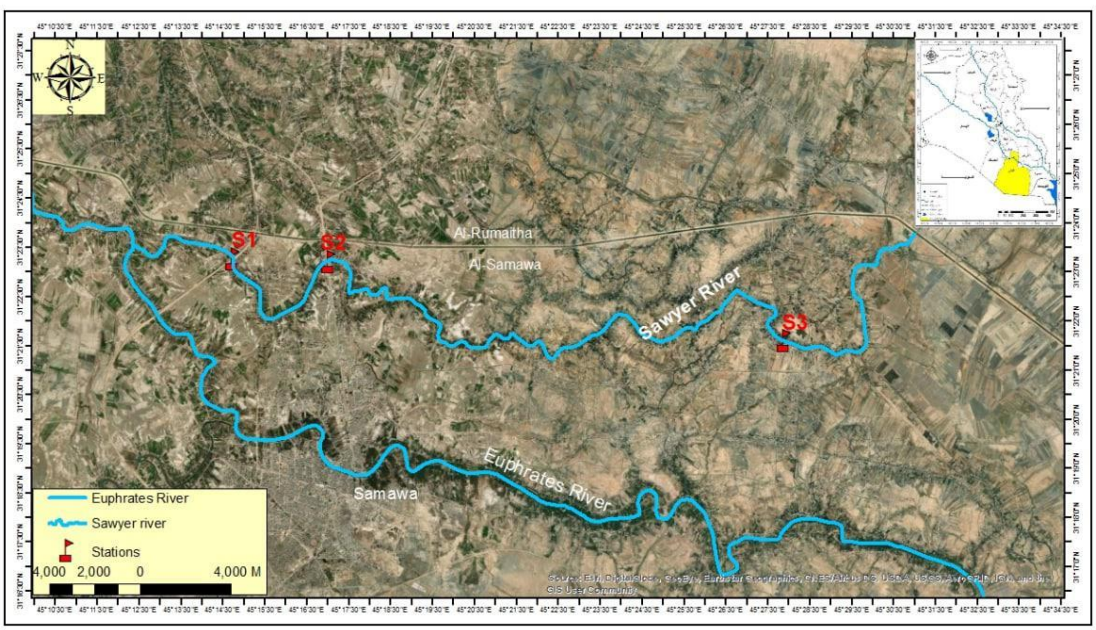
The CCME-WQI is considered as a flexible tool. WQI employed a variety of parameters to assess water quality for various purposes and provide a broad assessment of water's health and fitness for human consumption [15]. A weighted arithmetic water quality index is used in the calculation. In contrast to previous techniques, the WAWQI method incorporates various water quality criteria into a mathematical equation that scores the health of a water body using a number called the water quality index and describes the acceptability of water sources for human use [16]. Due to heavy metals' hazardous and non-biodegradable character in aquatic biological systems [17], river contamination with heavy metals is becoming a big issue. Heavy metals are likely to be transported to humans, animals, and plants as a result of ingesting and utilizing this contaminated water, causing major health and life difficulties [18]. Due to a lack of studies on the Al-Sawyer River and the dependence of communities on it for their agricultural fields and in order for animals to drink. The paper idea was chosen to evaluate its waters in terms of use.

2. Materials and methods

2.1 Description of the study area

Al- Sawyer River is the principle branch of the Euphrates River in Al-Muthanna Governorate The beginning of its branch is at Al-Majd region in Al-Rumaitha district, north of Al-Samawa city, where the length of the Al-Sawyer River is (32 km) and the rate of drainage is 16 m3 /s [19].

Three stations have been chosen to river. In the Al-Dahara region, the first station (31 2316.25"N - 45 1443.46"E) is about 3 kilometers from the river's source. The second station (31 2313.01"N- 45 17.00.75"E) is about 7 km from the river's source and is located in the center of Samawa city (Al Jarukhi Bridge). The third station (31 2135.92 "N- 45 2752.94" E) is in the Al-Ghanim area, some 25 kilometers from the riv er's source



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(Fig. 1). Fig: Map showing sampling sites in Sawyer River during the study period

2.2 Field sampling and Analytical Method

Water samples were collected monthly from November 2020 to October 2021 at each sampling station. Samples were preserved and analyzed according to [20].

Water temperature(WT), air temperature(AT), Biological oxygen demand(BOD), total dissolved solids (TDS), total suspended solid (TSS), electrical conductivity (EC), salinity, hydrogen ion concentration (pH), dissolved oxygen (DO), turbidity (Tur.), total hardness (TH), Calcium(Ca^{+2}) and Magnesium (Mg^{+2}), alkalinity, phosphates ($PO4^{-}$), nitrates ($NO3^{-}$), Nitrite($NO2^{-}$), heavy metals(Cd,Zn,Pb). It was measured according to the methods shown in the table below

Table 1.

NO	Parameters	Acronyms	Unit	Methods
1	Air Temperature	AT	C°	Mercury Thermometer (0-100C°);[21]
2	Water Temperature	WT	C°	[21]Mercury Thermometer (0-100C
3	Hydrogen ion concentration	pH	-	multi-meter Sm801; [22]
4	Electrical conductivity	EC	S/cmµ	multi-meter Sm801; [22]
5	Salinity	-	‰	By the Conductivity Equation Salinity‰ =EC x 640 x 10^{-6}; [23]
6	Total dissolved solids	TDS	mg/l	gravimetrically according to [20]
7	Total suspended solid	TSS	mg/l	gravimetrically according to [20]
8	Biological oxygen demand	BOD	mg/l	incubation for 5 days at 20 ° C; [24]
9	Dissolved oxygen	DO	mg/l	Azide modification(Winkler method); [20]
10	Total hardness	TH	$mgCaco_3$ /l	Titration with EDTA-2Na and EBT as an indicator;[20]
11	Calcium	Ca^{+2}	$mgCaco_3$ /l	Titration with EDTA-2Na and Meroxide as an indicator; [20]
12	Magnesium	Mg^{+2}	mg/l	mg Mg/L [total hardness (as mg CaCO3/L)-calcium hardness(as mg $CaCO_3$/L)]*0.243;[20]
13	Total Alkalinity	TA	mg/l	As CaCO3 by titration method; [20]
14	Phosphates	PO_4^{-}	g/lµ	Molybdate ascorbic acid method; [25]
15	Nitrates	NO_3^{-}	g/lµ	Cadmium reduction method; [26]
16	Nitrite	NO_2^{-}	g/lµ	Colorimetric methods; [26]

17	Turbidity	Tur	NTU	using the Lovibond Turbidity meter;[27]
18	Cadmium	Cd	g/lμ	by flame atomic absorption spectrophotometer; [20]
19	Lead	Pb	g/lμ	by flame atomic absorption spectrophotometer; [20]
20	Zinc	Zn	g/lμ	by flame atomic absorption spectrophotometer; [20]

Calculation of the WQI:-

1-Weighted Arithmetic Water Quality Index Method (WA WQI):

calculated the Water Quality Index (WQI) by using the Weighted Arithmetic Index method by using Thirteen parameters (pH, DO, total hardness, Ca^{+2}, Mg^{+2},NO3, NO_2,PO_4, Cd, Zn, Pb, TDS, turbidity(using these expressions [28]

$$\boldsymbol{WQI} = \frac{\sum Q_i W_i}{\Sigma W i} \ \textbf{(1)}$$

Qi: quality rating scale for each parameter

$$\boldsymbol{Qi} = 100 \left[\frac{Vi - Vo}{Si - Vo}\right] \ \textbf{(2)}$$

Vi: estimated concentration of ith parameter in the analyzed water

Vo: the ideal value of this parameter in the pure water

Vo=0 (except PH=7 and DO=14.6 mg/l), *Si*: recommended standard value of ith parameter

$$\boldsymbol{Wi} = \frac{K}{S_i} \ \textbf{(3)}$$

Where *K*: proportionality constant and can also be calculated by using the following equation

$$\mathbf{K} = \frac{1}{\sum 1/S_i} \textbf{(4)}$$

Table 2. Water Quality Rating as per (WA-WQI,CCME-WQI,HPI-WQI, $WQI_{\min}$)

WA-WQI according[29]	Grading	Classify of Water quality	WQI Value	CCME-WQI according [31,32]	WQI Value	Rating of Water quality
	A	Excellent Water quality	0-25		95-100	Excellent Water quality
	B	Good Water quality	26-50		80-94	Good Water quality
	C	Poor water quality	51-75		60-79	Fair Water quality
	D	Very Poor water quality	76-100		45-59	Marginal Water quality
	E	Unsuitable	Above 100		0-44	Poor Water quality
HPI-WQI according	HPI	Pollution index		criteria standard based on	NSF-WQI	Descriptor
	< 15	Low pollution			91-100	Excellent
	15-30	Medium Pollution			71-90	Good water

	> 30	High pollution			51-70	Medium water
					26-50	Bad water
					0-25	Very bad water

2- Canadian Council of Ministers of Environment Water Quality Index Method (CCME WQI)
This index is combined of three factors according [31], [32]

F_1 (Scope) represents the percentage of parameters that do not meet their guidelines at least once during the time period under consideration ("failed parameters"), relative to the total number of parameters measured

$$F_1 = \left[\frac{\text{Number of failed parameters}}{\text{Total number of parameters}}\right]*100 \qquad (1)$$

F2 (Frequency) represents the percentage of individual tests that do not meet guidelines ("failed tests"):

$$F2 = \left[\frac{\text{Number of failed tests}}{\text{Total number of tests}}\right]*100 \qquad (2)$$

F3 (Amplitude) represents the amount by which failed test values do not meet their guidelines. F3 is calculated in three steps.

i) The number of times by which an individual concentration is greater than (or less than, when the guideline is a minimum) the guideline is termed an "excursion" and is expressed as follows. When the test value must not exceed the guideline:

$$\text{3a) excursion}_i = \left[\frac{\text{Failed test value}_i}{\text{Objective}_j}\right]-1$$

For the cases in which the test value must not fall below the guideline

$$\text{3b) excursion}_i = \left[\frac{\text{Objective}_j}{\text{Failed test value}_i}\right]-1($$

ii) The collective amount by which individual tests are out of compliance is calculated by summing the excursions of individual tests from their guidelines and dividing by the total number of tests (both those meeting guidelines and those not meeting guidelines). This parameter, referred to as the normalized sum of excursions, or *nse*, is calculated as

$$nse = \frac{\sum_{i=1}^{n} excursion_i}{\text{Number of tests}} \qquad (4)$$

iii) F_3 is then calculated by an asymptotic function that scales the normalized sum of the excursions from guidelines (*nse*) to yield a range between 0 and 100.

$$F3 = \left[\frac{nse}{0.01nse+0.01}\right] \qquad (5)$$

Once the factors have been obtained, the index itself can be calculated by summing the three factors as if they were vectors. and using the Pythagoras theorem. The sum of the squares of each factor is therefore equal to the square of the CCME WQI. This approach treats the index as a three-dimensional space defined by each factor along one axis. With this model, the index changes in direct proportion to changes in all three factors.

CCMEWQI =100-[$\frac{\sqrt{F_1^2+F_2^2+F_3^2}}{1.732}$]

The divisor 1.732 normalizes the resultant values to a range between 0 and 100, where 0 represents the "worst" water quality and 100 represents the "best" water quality. classify CCME-WQI method is shown in the Table 2.

3-Heavy metal pollution index (HPI)
This index explains and assesses heavy metals content and the contamination degree in water, with a critical value of 100. These coefficients are calculated in three steps:
first calculate the (Wi), which represents the relative weight of each element i as in equation (1).
Secondly calculate the quality sub index (Qi) for each element as in equation (2),
thirdly, summing the subsidiary-coefficients Qi for all elements i. Then HPI calculated using equation (3) and as suggested by [30], [34].

$$W_i = \frac{1}{S_i} \text{ ……………(1)}$$

$$Q_i = \sum_{i=1}^{n} = \left(\frac{M_i - l_i}{S_i - l_i} \right) *100 \text{………(2)}$$

$$HPI = \frac{\sum_{i=1}^{n} W_i Q_i}{\sum_{i=1}^{n} W_i} \text{……..(3)}$$

Wi = the relative weight of the element coefficient i and is between (0-1), Si = the maximum allowable i element that is used by the world health organization [35] scale unit in (µg/L), n the number of elements used, Qi = sub index for elements i, M = the monitored value (the analyzed value) of the studied elements as shown in Table (3). li refers to the ideal value of the elements and is equal to zero for the studied elements. The (-) sign indicates the numerical difference between two values. HPI was applied to the elements studied in mg/l and their classified as shown in Table (2).

Table 3 The standards values of (Si), weight of metals (Wi) used in calculation of (HPI)

Metals	Si	W_i=1/S_i
Cd	0.003	333.33
Pb	0.01	100
Zn	3	0.333

4- Minimum Operator Index WQI_{min}
Minimum Operator Index this indicator of water quality was calculated using only three variables, (WQI min) [36] using (DO, EC, and Turb.) After normalization
$WQI_{min=}$ $(C_{DO}+C_{EC}+C_{Turbid})$/3
Where:
C DO : is the value due to dissolved oxygen after normalization
C E C : is the value due to Electrical condictivity after normalization
C Turbid : is the value due to turbidity after normalization

Table. 4. Normalization factors for WQI_{min} calculation ,as proposed by [36]

Parameters	Normalization factor										
	100	90	80	70	60	50	40	30	20	10	0
Dissolved oxygen(mg/l)	≥7.5	≥7.0	≥6.5	≥6.0	≥5.0	≥ 4.0	≥ 3.5	≥ 3.0	≥2.0	≥ 1.0	<1.0
Conductivity μS cm) (	<750	<1000	<1250	<1500	<2000	<2500	<3000	<5000	<8000	≤12000	>12000
Turbidity (NTU)	<5	<10	<15	<20	< 25	<30	<40	<60	<80	≤100	>100

Classification WQI_{min}criteria standard based on NSF-WQI; [33] in the table.**2**.

3. Results and Discussion

3.1 Physical and chemical parameters

Physicochemical results were, for air and water temperature (14-44°C, 11.66–31.00°C) respectively. These variations in AT,WT between stations and months are well known in Iraqi climate that it's characterized by the hot desert climate [37], [38], Water temperature is essential in aquatic systems because it impacts a variety of physical, chemical, and biological characteristics of a river, such as the concentration of DO that can be dissolved in water, plant photosynthesis, aquatic organism metabolic rates, and sensitivity to toxic wastes [39].

Electrical conductivity ranges from 2220 to 5632 µS/cm. Climate, soil, geological origin, and ionic salt content are all factors that affect these variations [40], High conductivity content levels can be created by natural weathering of specific types of rocks or human causes such as industrial waste and sewage, and higher EC values are associated to higher Ca^{+2} Mg^{+2} values [41]. The results of the statistical analysis indicated that there were significant differences ($P \leq 0.05$) between the stations and the months, was a significant increase in the August, May recorded as (4604.4 mg/l, 4397.2 mg/l) respectively, compared to the rest months. While spatial significant differences ($p \leq 0.05$) showed that the EC at St.1 was (3415.5 mg/l) lowest compared to the mean that recorded of St.2 and St.3 during the study period were (3545.7 mg/l), and (4192.6 mg/l). These results are consistent with the study of [42] on the Euphrates River where range observed was EC 3000-9000µS/cm.

The salinity results 1.42-3.6 ppt. The increase in salinity of the Euphrates between Al Samawa and Al Nassiriah may be caused by saline groundwater intrusion from the Iraqi Western Desert [43] due to heavy rainfall, which causes large amounts of salts to drain from agricultural land on both sides of the river [42].

As for Turbidity results ranged 1.26–83.25 NTU. Turbidity in water is caused by suspended particles such as clay, silt, finely divided organic materials, plankton, and other microscopic organisms [44].

The total dissolved solids results ranged 931.6–3132 mg/L. Agricultural and residential runoff, leaching of soil contamination, and point source water pollution discharge from industrial or sewage treatment plants are the primary causes of TDS in receiving waters [45].

The total suspended solid results between 13.33-766.66 mg/l. This could be due to the river collecting large amounts of contaminated water from human activities such as washing [46]. Clay, silt, sand, decomposition materials, and microbes make up the suspended material. Because they obscure sunlight, increased suspended solids limit biodiversity in water [47].

pH ranged from 7.26 to 8.83. As in many previous studies on Iraqi rivers, it has a slightly alkaline average value [48], [49]. Indicate the value of increased pH in an aquatic ecosystem due to alkaline runoff and precipitation during precipitation events [50]. So the results of this study showed a negative correlation was found between pH and AT, WT ($r=^{-}0.746$, $r=^{-}0.755$).

The mean values for dissolved oxygen ranged from 4.8 to 17.73 mg/L. The most important parameter for evaluating water quality is DO, which has an impact on aquatic life and organism distribution[51].Many factors contribute to increased DO in water, including photosynthetic activity in the system, low temperature, low salinity, and atmospheric oxygen mixing with water by wind and stream current action [52],this due to that the concentration of dissolved oxygen of water is influenced by water temperature, and it has been proven that dissolved oxygen solubility decreases as temperature rises [53].

The results biological oxygen demand ranged 3.33–14 mg/L. The high value of BOD was explained by [54], as a result of the decrease in river water level and the high decomposition processes by microbial organisms due to the higher temperature. These results are consistent with the study of [55] on the Euphrates River where range observed was BOD (1-15) mg/l.

As for Total alkalinity ranged 135-250.66 mg/l. The carbonate and bicarbonate content of water is measured using TA [56], [57]. The high TA levels in the winter could be due to the rain, which scrapes and removes basal ions from the river banks [58]. It has been confirmed statistically that showed a positive correlation between total alkalinity and total hardness, calcium and magnesium ($r= 0.434$, $r=0.337$, $r=0.298$) respectively.

Total hardness, Calcium hardness and Magnesium results ranged (352-880 mgCaCO3/L, 160-453.33 mgCaCO3/L, 27.54-103.68mg/l)) respectively. The impact of human activities and sewage on the river and soil texture may be the cause of increased hardness, as evidenced by [59]. The two most prevalent minerals that make water "hard" are dissolved calcium and magnesium [60]. Throughout the study period, calcium concentrations were consistently greater than magnesium concentrations at all sites, which is likely due to calcium ion's better ability to react with carbon dioxide [61]. These results are consistent with the study of [42] on the Euphrates River where range observed was total hardness ranged from 600 to 1350. And Magnesium hardness ranged between 48.6 -219.91mgCaCO3/L.

Nitrite, nitrate and phosphate results ranged (1.03–10.85 µg/L, 2.3–156.4µg/L,0.12–30.59 µg/L) respectively. Increased absorption by phytoplankton and aquatic plants could be linked to nitrite [62]. Nitrate is an important nitrogen source for aquatic plants and creatures. Domestic sewage, agricultural waste, and soil erosion are the sources of this pollution [63]. Eutrophication can be increased by high phosphorus levels in water. Phosphorus is commonly found in sewage, detergent, and fertilizers [64].

Heavy metal concentrations (dissolved phase) cadmium, lead and zinc ranged (0.00-24.6 µg/L, 0.0-157.96 µg/L/l, 0.00-32.8 µg/L) respectively. Variations in dissolved heavy metal concentrations may be related to water drainage, household waste, and agricultural drifts down to river water, which vary from site to site and season to season, as well as the use of fertilizers to enrich neighboring lands and river drainage areas

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that pass by without prior treatment, resulting in significant differences in dissolved heavy metal concentrations [65]. There are not significant differences for cadmium and zinc.

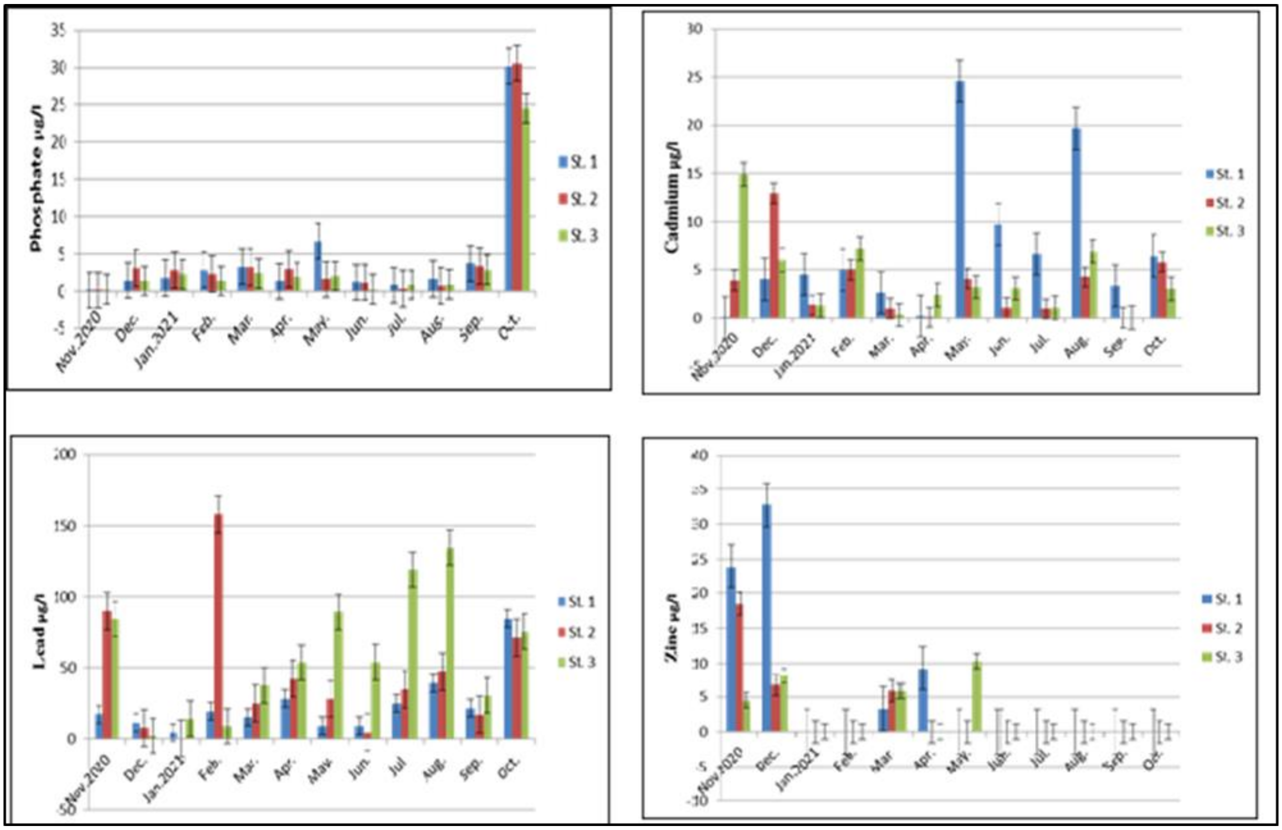

Fig.. Monthly variation in Phosphate_ Cadmium _Lead and Zinc mean value in Sawyer River during the study periods.

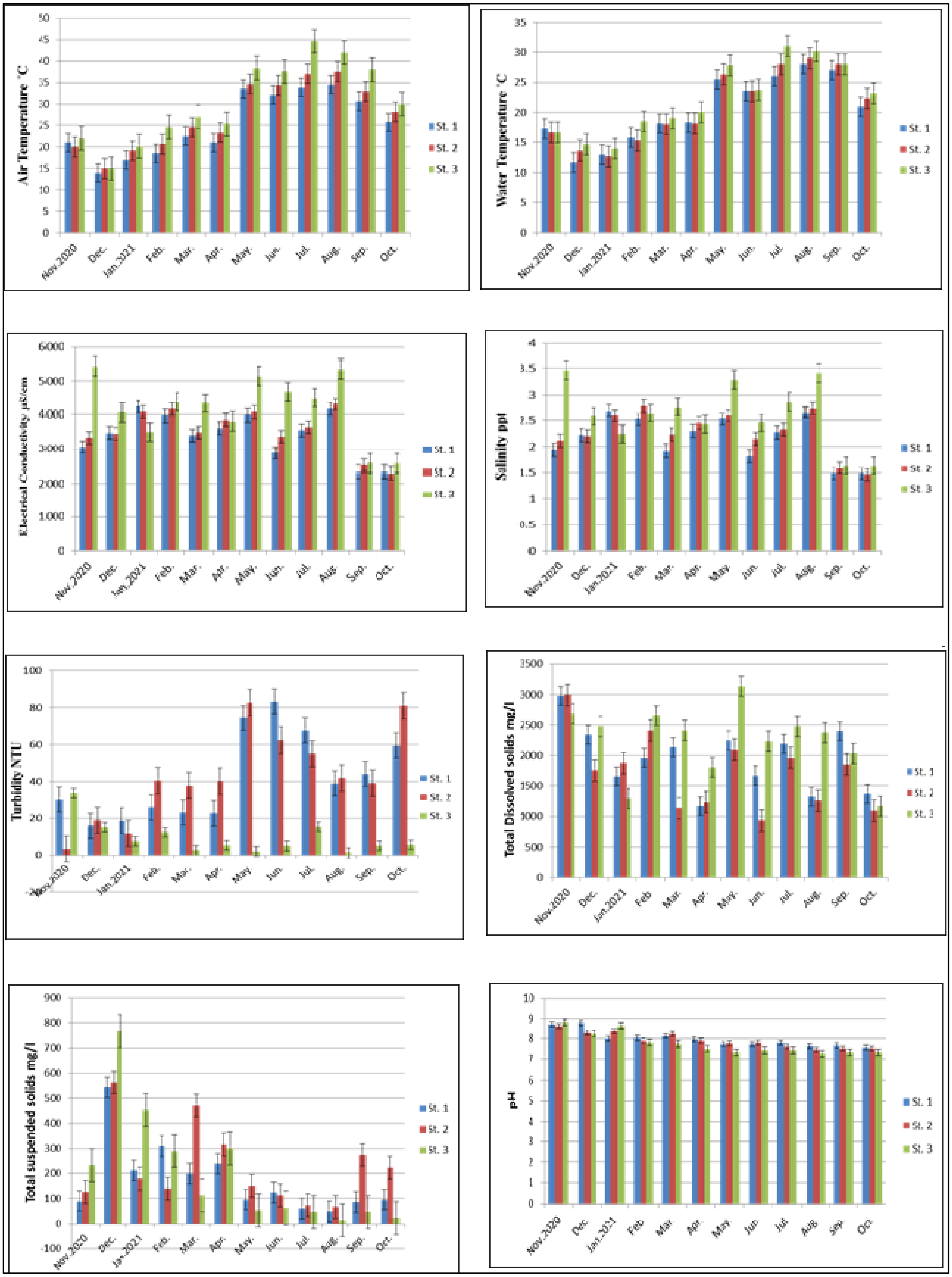

Fig.. Monthly variation in Air Temperature _Water temperature_ Electrical Conductivity, Salinity, Turbidity, TDS,TSS and pH mean value in Sawyer River during the study periods.

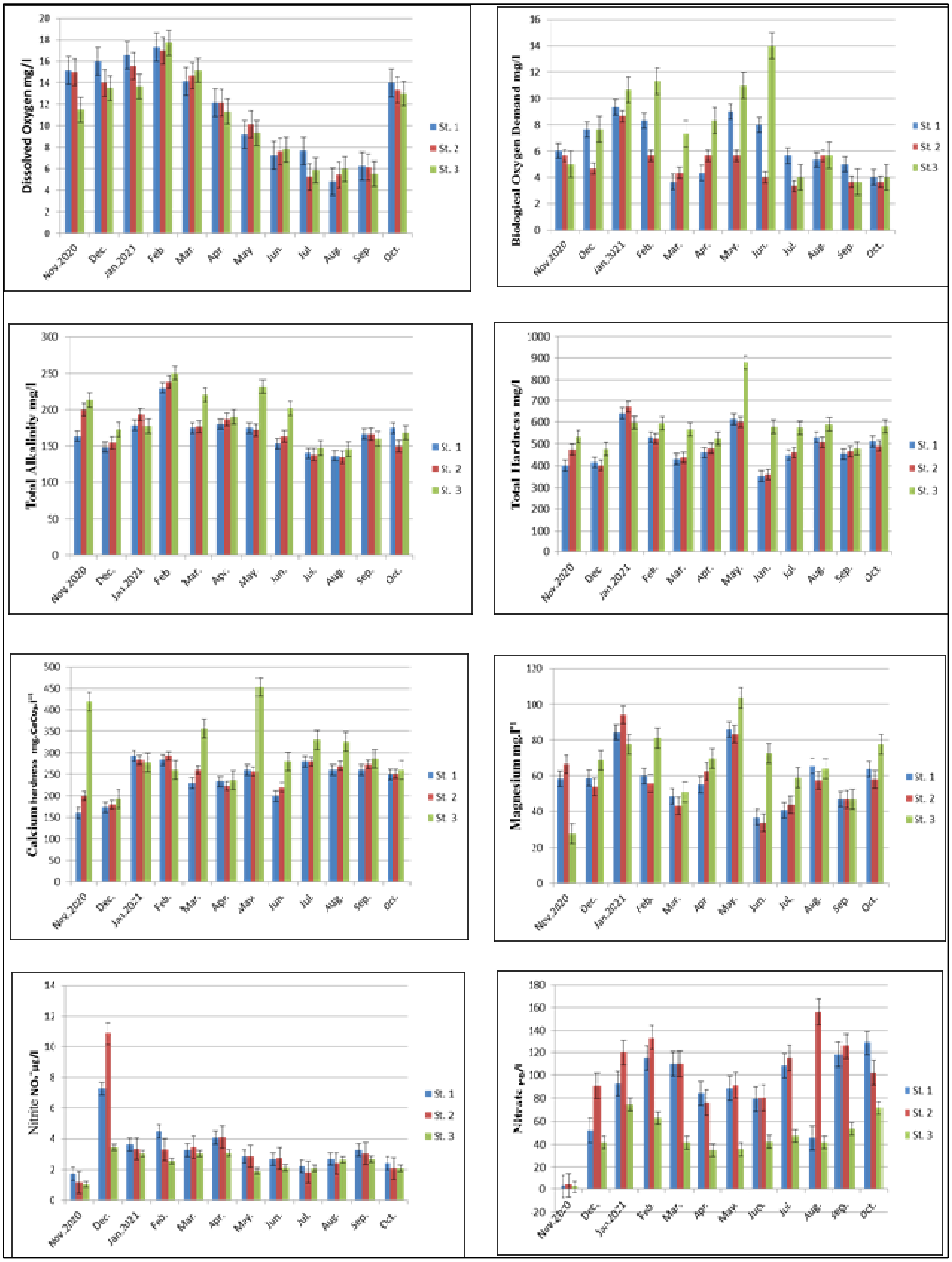

Fig. Monthly variation in DO_ BOD_ Total Alkalinity_ Total Hardness_ Calcium_ Magnesium_ Nitrite_ Nitrate mean value in Sawyer River during the study periods.

3.2 Water quality indices

Water quality index using method of WA-WQI for Al-Sawyer river, calculated and found ranged (17.96, Excellent) in the St.2 at January to (646.5, unsuitable) for drinking in the St.1 during May. As for results of the annual mean index for the three stations were 237.5, 184.6, 228.6, respectively. The results showed that the river water is unsuitable for drinking in all the stations. because of drainage of domestic wastewater, the discharge of rainwater, agricultural runoff, and other human activities on the river bank, PCA analysis showed the correlations between the WA-WQI and variables. From this study indicates that the overall WQI of Euphrates River water is not within the permissible limits for drinking water (100) can be attributed to the various human activities taking place at the river bank. This study was consistent with [66].

It showed the results of applying CCME for drinking purposes and was classified as ranging from (Poor to Fair) the highest values were (63.5 ,fair) in the St.2 during June. The lowest value recorded by the index was (38.64, poor) in the St.1 during August. An annual average was applied using CCME-WQI to drinking water and the results showed (41.52,Poor) that it is unsuitable for drinking Because most of the parameters used exceed the standard limits for water, PCA analysis showed the variables that most affect the value of the index.

It showed the results of applying the Canadian index for irrigation purposes and was classified as ranging from (Fair to Good), the highest values were (93.91 ,Good) in the St.3 during September. The lowest value recorded by the index was (60.5, Fair) in the St.3 at November. The results of the evaluation showed that the water of the Al-Sawyer river is suitable for use for irrigation purposes, PCA analysis showed the correlations between the CCME for irrigation and its variables.

for Aquatic Life indicated that it ranged between (Marginal - Fair), except for the St.2 and St.3 in November which were Poor. The highest values were (79.91 ,Fair) in the St.2 during June. The lowest value recorded by the index was (39.77, Poor) in the St.3 at November, PCA analysis showed the correlations between the CCME for aquatic living and its variables. According to similar studies in Iraq, the water quality of the Tigris and Euphrates Rivers fluctuates between poor and marginal categories [67,68]. This could be due to the inversion of pollutants from domestic sewers and industrial waste discharges into water resources, all of which could be untreated, resulting in significant actions on river quality [69].

The results of heavy metals pollution index (HPI) ranged from (17.93-650.8) Medium to High Polluted, the highest value of the index (650.8-High Polluted) in St.1 during May, as for the lowest value for the index (17.93-Medium) in St.2 during January. The results of the annual mean of the three stations St.1 ,St.2 ,St.3 indicated that (238.8,185.5, 230.2-High Polluted in the all site) respectively ,the river water is unsuitable for drinking. The levels of Zn, Cd and Pb are high in water because of industrial and agricultural discharge [70], PCA analysis showed the correlations between the HPI and its variables, it adds to sewage and water leaching into groundwater, as well as pesticides, increasing the concentration of heavy metals in the Euphrates River's waters [71], as a result the index values have increased above the permissible limits for drinking water.

The results of the minimum pollution index (min) used (DO,EC, Turbidity), highest value of the index (76.6- Good water) in St.2 during November and St.3 in March and October, as for the lowest value for the index (36.6-Bad water) in St.1 during August. Significant differences in water quality between good and poor water may be due to the increasing values of DO, and decreasing values of EC which increased the index value. While the low quality in some month may be due to decreased DO values, and increased Turbidity and EC values, PCA analysis showed the associations between min and its variants.

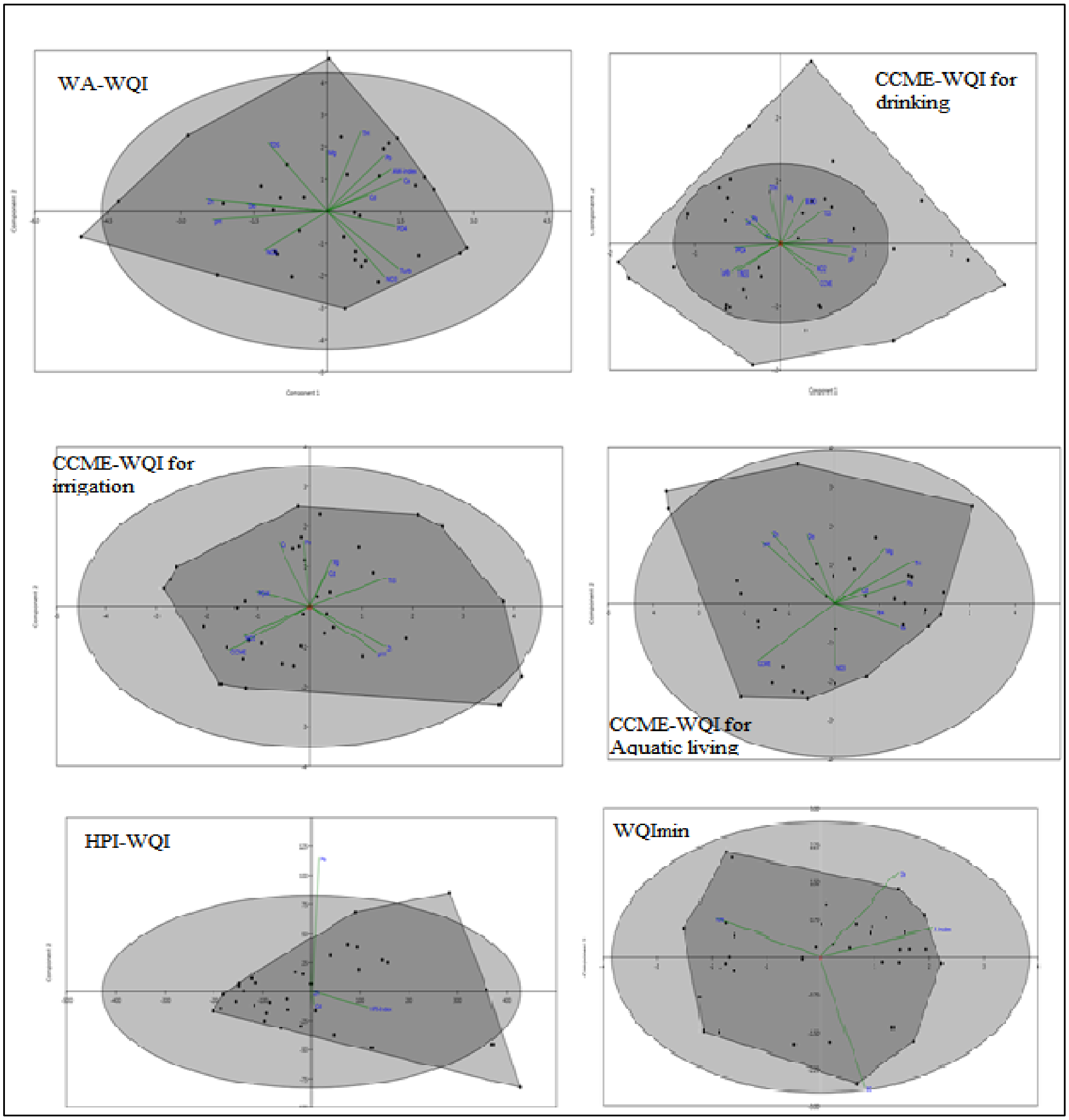

Fig. Water quality index variables responsible for changes in the values of WQI water according to Principal Component Analysis (PCA).

4. Conclusions

The results of the study revealed by use (WA-WQI,CCME-WQI,HPI-WQI, WQImin(that the river is unsuitable for use as drinking water, the WQI is fluctuated for irrigation between Fair to Good, as for aquatic life fluctuated between Marginal - Fair. It is known that the water pollution level is increasing in the Euphrates River due to runoff of the domestic sewage and the return water is from agricultural lands that are loaded with phosphate fertilizers and various human activities impacted negatively on the quality of water. Thus, is having an adverse effect on aquatic life and public health. The study showed that application of WQI is a useful tools in assessing the overall quality of river.

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