How to Cite:
Al-Ali, I. A., & Al-Dabbas, M. A. (2022). Assessment of some organic and inorganic pollution Indices / Euphrates River/ Iraq. *International Journal of Health Sciences*, *6*(S3), 12395–12417. https://doi.org/10.53730/ijhs.v6nS3.9484

Assessment of some organic and inorganic pollution Indices / Euphrates River/ Iraq

Iman A. Al-Ali
Department of Geology, College of sciences, University of Baghdad, Baghdad, Iraq
*Corresponding author email: Mohammedrahman842004@gmail.com

Moutaz A. Al-Dabbas
Department of Geology, College of sciences, University of Baghdad, Baghdad, Iraq
Email: profaldabbas@yahoo.com

***Abstract*--**In this study, four sites were selected,extended from Haditha reservoir to Al- Hindiya Barrage included Al- Ramadi and Al-Falluja sites, on Euphrates River stretch to conduct an environmental study about the effect of deceasing discharge on the water quality for the period extended from 2005 to 2020. Shedding light on the climate parameters as one of the most effective parameters on the discharge rate. As a novel aspect of this study, the discharge records, as well as the organic and inorganic pollutants were assessed, which includes;major ions (cations and anions), trace elements and the most important biological analysis such; (BOD5, COD, E. coli, fecal coliform bacteria and total bacteria count (TBC) MPN/100 ml). For this purpose, the statistical package for social sciences (SPSS), asmulti variant analysishas been applied to evaluate variables sources groups. The results revels two groups of pollutant sources; (F1) which represented 71.27%of total variance, having Eigen value 4.9, includes the pollutants resulting from anthropogenic sources as; total dissolved solids, E. coli, total bacteria count, Fecal coliform bacteria (FCB), BOD5 and COD.While(F2) represents 18.76% of the total variance, having Eigen value 3.3, includes the ions produced by physical weathering of gypsum and calcareous rocks which distributed in study arealike: Ca2+, Mg+, Na+, K+, Cl- and SO42−. The inverse distance weighing (IDW) technique, as atoolinArcGISprogra has been applied to find the general trend of ions concentration in the studied sites. The result insurance the increasing ions concentration and the biological pollution indicators downstream,whereas, the dissolved oxygen (DO) shows a visible decrease downstream. Investigating the water type indicatedcontiniousechanges in water quality with time, water type in Haditha and Al- Ramadi was MgSO4, while it altered in

Manuscript submitted: 18 Feb 2022, Manuscript revised: 27 April 2022, Accepted for publication: 9 June 2022

to $NaSO_4$ atAl- Falluja and Al- Hindiya. Therefore; it should be mention, that regular check- ups and follow- ups are required to undertake seasonal surveys on pollution levels and water quality of Euphrates River.

***Keywords*---**euphrates river, SPSS, inverse distance weighting (IDW), water type, biological pollution.

Introduction

Euphrates River is the longest river in western Asia, it originates from the mountains of eastern Turkey, its length is 2786 km, flows about 1200 km in Turkey, 700 km in Syria and 1000 km in Iraq, having catchment area of around 440000 km^2 shared by five countries; Iraq, which shared by 47 percent, Turkey share by 28 percent, Syria shared by 22 percent, Saudi Arabia shared by 2.97 percent and Jordan shared by only 0.03 percent (Al- Ansari et. al., 2019). Iraq is located downstream the river course, so the water quantities is decreased and the river salinity is raised until it reaches to unfavorable levels as a result of numerous natural and human threats (Al- Ansari et.al., 2019). Many researchers have been studied the negative effect of climate change and dams' construction on the discharge quantities and the water quality of the river (Kolars and Mitchell, 1991; Al- Bomula, 2012; Al- Al- Ansari et. al., 2018; Al- Ansari et. al., 2019; Khaleefa& Kamel, 2021; Al- Ali& Al- Dabbas, 2021).

Water contamination has been linked to the spread of diseases caused by bacteria, including acute infectious diarrhea caused by E. coli (Stark et al., 2000).The organic and inorganic compounds have been detected in drinking water sources. More organic matters led to increase the biological oxygen demand ($BOD_{5)}$ and the chemical oxygen demand (COD), which leading consequently to deplete the concentration of dissolved oxygen (DO) inwater body(Montgomery,2006). Water body that polluted with BOD_5 and COD has a major perturbation in the aquatic ecosystems, reduced species diversity and rise the harmful microbe's numbers (Labbate et.al., 2016&Zeglin, 2015). Therefore; organic and inorganic parameters are considered a suitable sensor for measuring the pollution levels in surface water (Montagemry, 2006).

In term of the climatic changes, Iraq is highly affected by the global climatic changes due to its position in the arid area (Salman et al, 2017). Extensive variance in precipitation, temperature which in turn affected on the water discharge rates and increase the salinity (IPCC, 2007; Feleke et al., 2016). As a result, the water discharge entering the Iraqi territories showed a visible decrease over the years,and the obtainable water cannot justify the requirements of the increased population in term of quality and quantity (Al- Ansari et al., 2018). Due to the direct effect of the geologic formation on the river water quality, the study of the geology is required. The main formations that Euphrates River flow through are: Ana Formation (Upper Oligocene), which consists of hard limestone, Euphrates Formation (Lower Miocene), which consist mainly of limestone, dolostone and marl, Al- Fatha Formation (Middle Miocene) consists of green marl, claystone, limestone and gypsum. Al- Nfayil Formation (Middle Miocene), which consisting of an alternation of green marl and limestone (Jassim&Goff, 2006).

Euphrates River, which is continuous dynamic system, therefore; its quality is constantly changing (Abdulhadi, 2015). This research aims to evaluate the variation of discharge rates of Euphrates River, and investigate its effect on the hydrochemical analysis of major ions, trace elements, and the main biological pollution indicators such as: BOD_5, COD, E. coli bacteria, total Bacteria count and fecal coliform bacteria (MPN/100 ml) and determine its source.The study area is extended between latitude is 42°07′35″E to 44°11′37″E, and longitude between 36°11′34″N to 32°31′59″N (Figure 1).

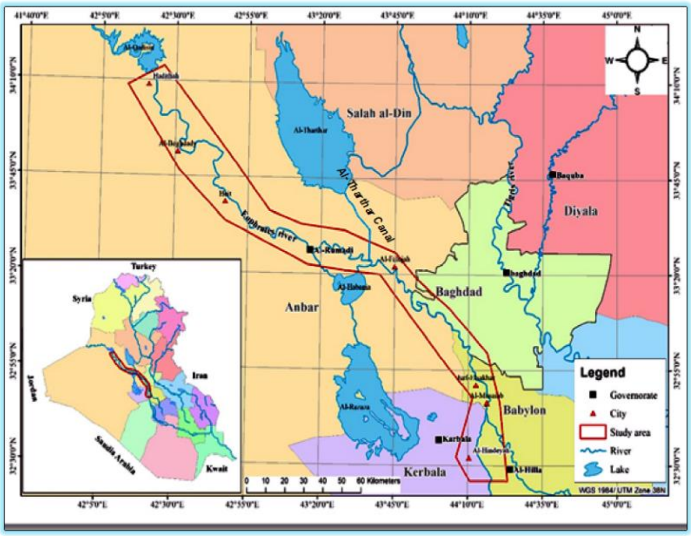


Figure 1. Gauging sites within Euphrates River (Al- Ali& Al- Dabbas, 2021)

Material and Methods

Fourgauging siteswere selectedto condute a hydrochemical study and determined the water type under the constrain of water sacrisity, theseare: Haditha, Al-Ramadi, Al- Falluja and Al- Hindiyafor the period (2005- 2020). For this purpose, the records of mean annual discharge rates, as well as the mean annual climate parameters were determined(IMO, 2020). The most important climatic parameters that have the greatest impact on discharge rates and wate quality are; Rainfall and Temperature.The mean monthly climate parameter were correlated with time. Then, the mean monthly discharge rates were correlated with the climatic parameters to show the effect of climate parameters on the discharge rate and consequently on the water quality for the period (2005- 2020). Physical parameters include;electrical conductivity (EC), total dissolved solids (TDS), hydrogen number (PH) and the water temperature (Tw). Major cations include; Calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), potassium (K^{+}),while major anions include; sulfate (SO_4^{-2}), chloride (Cl^{-}) and bicarbonate (HCO_3^{-}). Trace elements include;(Zn, Pb, Cd, Cr, and Fe).

The biological pollution indicators include; biological oxygen demand (BOD_5), chemical oxygen demand (COD), Escherichia coli (E- Coli), Fecal coliform bacteria (FCB) and total bacteria count (TBC). The measurement of dissolved oxygen (DO) concentration in water is also required as it is a basis for aquatic life. All these analysis were obtained from (NCWRM, 2020). The water type has investigated according to Ivanov, 1968 and scholar, 1972. The Aq. QA software was applied to plot Schaller diagram to show the major ions variation within the four sites. The SPSS statistical program was applied to determine the possible sources of water pollutants and their associated research parameters (Hernández-Mena, 2021). The data set of 13 parameters was subjected to factor analysis (FA), and plot factor loadings. The varimax rotated factor matrix, the percentage of variance, the eigenvalues, and the cumulative percent of the rotated were determined. Using ArcGIS tool as an application to build a distribution map along the course of Euphrates River by using the interpolation technique of inverse distances weighting (IDW). The results of the current study are compared with the those of previous researchs to determine the spatial and temporal variation in water quality deterioration over the time under the constrain of the current condition of drought and construction of dams by the riparian countries.

Results

Hydrological condition of Euphrates River
Discharge m^3/s

Discharge rates are decreased gradually toward downstream; it is also decreased over the time with negative relationship with years (2005- 2020). Decreasing the discharge rates caused in water quality deterioration as indicated by the following discharge annual means 502, 383, 366 and 211.8 m^3/sec in Haditha, Al- Ramadi, Al Fallujah and Al- Hindiyarespectively (Figure 2).

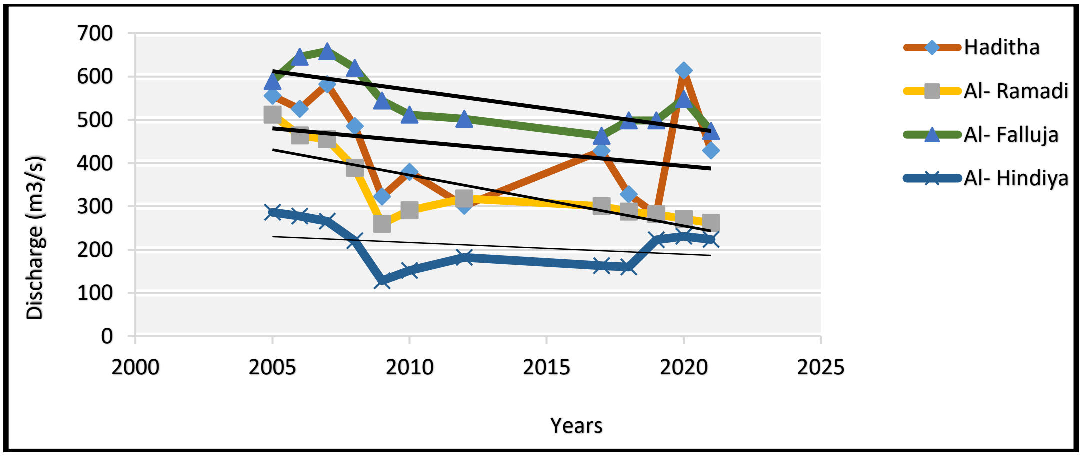


Figure 2. Mean annual discharge (m^3/S) in the studied sitess (2005- 2020).

Rainfall (mm)

Mean annual records of rainfall were decreased over the time, the results showeda visible decrease towarddownstream as the followingmeans;115.33, 112, 101.5and 89.66 mm in Haditha, Al- Ramadi, A- Falluja and Al- Hindiya respectively.

Air Temperature (°C)

An increase in air temperature leads to increase the ions concentration due to high rates of evaporation. Air temperature increased towards downstream from Haditha to Al- Hindiya for the period (1970- 2019). The means annual temperature were; 22.8, 24.1, 27.1 and 33.2 °C in Haditha, Al-Ramadi, Al- Falluja and Al- Hindiyasites respectively.

Inorganic Analysis and Relations
Physical Parameters Analysis

Range and average values of physical parameters includes; TDS, EC, pH and Tw. Water temperature is a good indicator for water pollution because of its impact on water quality (Vliet, et.al., 2011). Mean monthly water temperature showed an increase toward downstream, as the following;(22.2, 24.3, 25.2 and 28.8) °C, TDS concentration is a vital indicator for evaluating the quality of water,it shows an increase downstream as the following means 698.8. 764, 858 and 862.8 ppm. Mean monthlyECμs/cm also increased downstream, as the following means (844, 930, 1455 and 1380) μs/cm, mean monthly hydrogen number (pH) is also increased toward downstream as the following means (7.3, 7.44, 7.5 and 7.7) in Haditha, Al-Ramadi, Al- Falluja and Al- Hindiya respectively (Table 1). (Figure 3 Aand B).

Table 1
Ranges and average physical analysis for the period (2005- 2020)

Parameter	Physical Analysis of the Present study 2005- 2020									WHO, 2018
	U	*Haditha.*		*Al- Ramadi*		*Al- Falluja*		*Al-Hindiya.*		
Range Average		Range	Average	Range	Average	Range	Average	Range	Average	Range
TDS ppm		400-709	698.8	500-810	764	728-1250	858	475-1220	862.8	1000
*EC*μS/cm		685-1350	844	750-1100	930	880-1850	1 380	703-1780	1 415	1500
pH	-	7.0- 7.4	7.3	7.2- 7.7	7.44	7.1-7.8	7.5	7.1-8.2	7.7	6.5-8.5
Tw°C		20- 25	22.2	21- 27	24.3	22- 30	25.2	22- 33	28.8	<35

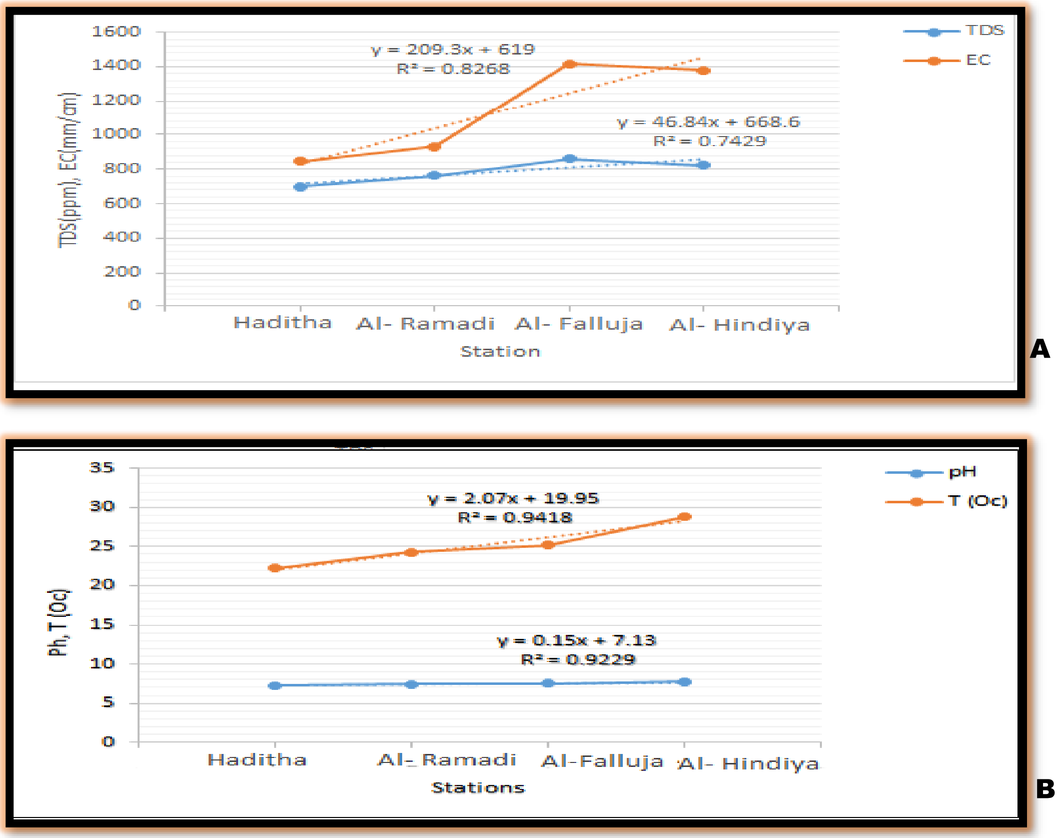


Figure 3. Mean annual physical analysis, A: TDS ppm and EC µs/cm. B: pH, and Tw°C of Euphrates River (2005-2020) (NCWRM, 2020)

Chemical Analysis

Mean annual major ions concentrations(Ca^{2+}, Mg^{2+}, Na^{+}, K, SO_4^{-2}, $Cl^{-}$and HCO_3^{-})showed a notable increase toward downstream over the years(Table 2).This is attributed to the series natural and anthropogenic conditions. Mean monthly Ca^{2+} concentrationswere as the follow;65.4, 70.8, 74.4 and 78.2ppm. Mg^{2+} concentration is highly varied between the studied sites, showing the isible increase towareddownstream as the following; 41.9, 42.3, 55.1 and 55.3 ppm, Na^{+} concentrationhaving the following means;(76.5, 84, 106 and 103.8), mean monthly K^{+}concentration was (5.79, 5.8, 8.2, 8.33)ppm.Mean monthly major anions also showed a visible increase towareddownstream, mean monthly $SO_4^{=}$comcentratin were as the follow; 267.8, 271.2, 368.2, 387.4 ppm, Cl^{-}99.4, 140, 162, 176.2 ppm. HCO_3^{-}139, 135, 139.4, 138 ppmin Haditha, Al- Ramadi, Al- Falluja and Al- Hindiya respectively (Table 2).

Table 2
Range, average and standard deviation of chemical analysis (2005-2020)

Sites Name	Parameters	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Cl^{-}	$SO4^{2-}$	HCO_3^-
ppm								
Haditha	Range	29- 112	20-95	30-127	3.2-7.9	42- 208	138-589	60-193
	Mean	65.4	41.9	76.5	5.79	99.4	267.8	139
	ST.DV	16.7	13.8	19	1.05	33.33	68.3	60
Al-Ramadi	Range	12-112	23- 110	62-200	3–7.9	82-245	144-599	79-171
	Mean	70.8	42.3	84	5.8	140	271.2	135
	ST.DV	23.4	13.8	28.3	1.3	40	67	22
Al-Falluja	Range	14-148	12- 98	48- 197	4.6-12.5	36- 231	200-549	95-189
	Mean	74.4	55.1	116	8.2	162	368.2	139.4
	ST.DV	23	7.2	30	5.9	26.6	33.7	20
Al-Hindiya	Range	30-119	22- 82	39- 178	3.5–8.8	12–764	177–587	92-201
	Mean	78.2	55.3	123.8	8.33	176.2	387.4	138
	ST.DV	20.2	15	26.2	0.7	22.8	60.4	28
WHO,2018	ppm	200	150	100	12	250	250	-
IQS,2009	ppm	200	150	100	12	350	400	200

Elements Analysis

Trace elements can be defined as the elements which have concentration with less than 1 ppm. Five trace elements were analyzed in the Euphrates River water, these are; (Zn, Pb, Cd, Cr, and Fe). (Table 3). Trace elements analysis results indicate an increasing toward downstream. Mean monthly Zn concentrationwas (0.33, 0.8, 0.87. 1.024) ppm, Pb (0.0011, 0.0022, 0.007, 0.0081), Fe was (0.14, 0.17, 0.19, 0.22) ppm, Cd was (0.012, 0.012, 0.046, 0.048) ppm, and Cr was (0.028, 0.03, 0.036, 0.033) ppm in Haditha, Al- Ramadi, Al- Falluja and Al-Hindiya respectively. Noted that all the traces were within the permissible limits of (IQS, 2009), and (WHO, 2018)(Table 3).

Table 3
Mean monthly and standard deviation (ST.DV.) values of trace elements (ppm) in the studied sites

Traces	Haditha.		Al- Ramadi		Al- Falluja		Al- Hindiya		WHO, 2018	IQS, 2009
(ppm)	Mean	ST.DV.	Mean	ST.DV.	Mean	ST.DV	Mean	ST.DV.		
Zn	0.33	0.037	0.8	0.033	0.87	0.021	1.024	0.014	3	3
Pb	0.0011	0.0031	0.004	0.0022	0.007	0.003	0.0081	0.0014	0.01	0.01

Cd	0.0012	0.003	0.00122	0.002	0.0046	0.001	0.0048	0.001	0.005	0.005
Fe	0.14	0.003	0.17	0.0015	0.19	0.0021	0.22	0.0023	0.3	0.3
Cr	0.028	0.031	0.031	0.030	0.036	0.033	0.003	0.05	0.05	0.05

Biological pollution indicators

The biological analysis includes; dissolved oxygen (DO), chemical oxygen demand (COD), biological oxygen demand (BOD_5), Escherichia coli (E- Coli), Fecal coliform bacteria (FCB) and total bacteria count (TBC). These analyses indicate the extent of the biological pollutant indices in the river water and gives evidence of the organic pollutant existing (Table 4).

Dissolved Oxygen (DO)

Dissolved oxygen defines as the measurement of water quality, it is typically expressed with ppm or mg/l. DO concentration in water is affected by ambient temperature, atmospheric pressure, and ion activity (Michael, 2006). The main sources of DO in water isphotosynthetic activities of aquatic plants. It necessary for aquatic systems to survival and growth of many aquatic organisms and is used as an indicator of the health of surface-water bodies (Michael, 2006). The concentration of DO at Haditha station ranged between (3.2- 10.8) mg/l, with average of 7.3 mg/l, in Al- Ramadi ranged between (2.4- 7.2) mg/l, with average value 6.8 mg/l, while it ranged between (2.4- 6.8) mg/l with average value of 6.3 mg/ l, and between (2.1-6.3) mg/l with average value of 5.5 mg/l in Al- Falluja and Al- Hindiya respectively (Table 4). The DO in Haditha is very suitable for most aquatic life, whereas the rest sites are critical (USEPA, 2005).

Chemical Oxygen Demand (COD)

COD is a measure of O2 required to oxidize the organic and non-organic maters exist in water. High COD values is indicator of water pollution. In this study the COD concentration values range between 1to4.2 mg/l, with average of 2.1 mg/l for Haditha site, and between 0.4 to 4.4 mg/l, with average value of 3 mg/l in Al-Ramadi site, while it increased in Al- Falluja, ranged between 1.1 to 7.4 mg/l, with average value 4.6 mg/l, it ranged between 1.7 to 14.2mg/l with average of 8.2 mg/l at Al- Hindiya site (Table 4).

Biochemical Oxygen Demand (BOD)

BOD is the measure of oxygen required to break down the organic matter aerobically. BOD in Haditha site ranged between (0.2- 3) mg/l, average 1.66 mg/l, whereas it ranged between 0.2 to 3.21 mg/l, with average value1.73 mg/l in Al-Ramadias this value represent a clean water. BOD increased moreover downstream, it ranged between 0.4 to 4.8 mg/l, with average value of 2.2 mg/l at Al- Falluja station and between (0.3-4.8) mg/l with average value of 2.8 mg/l at Al- Hindiya site, as this value is within the permissible limit of (IQS, 1996).(Table 4).

Escherichia Coli (E- Coli bacteria)

The most crucial tests fecal coliform and Escherichia coli (E. coli) as awater pollution indicators found in animal and human feces. It has the ability of growth and fermentation properties at higher than 44C°. If Escherichia coli dedication in water, it may be a good evidence of fecal contamination, therefore; surface water should be examined regularly to detect water pollution (Brandt et al, 2000). E-Coli in Haditha site ranged between (0- 4140) MPN/100 ml, average is 2340MPN/100ml, whereas it ranged between (0–5810)MPN/100ml, with average value 3510 MPN/ 100 ml in Al-Ramadi, the pollution in E- Coli is raiseddownstream to range between (100-11537)MPN/100ml with average value of 8341MPN/100ml, and between (100-12420) MPN/100ml, with average of 8540 MPN/100ml in Al- Falluja and Al- Hindiya respectively (Table 4).

Fecal coliform bacteriaMPN/100ml

The Fecal coliform bacteria includes aquatic bacteria entering the water through sewage water and excreta of living organisms.It must be eliminated during the treatment of water, due to its negative effect on drinking water. High range of differences between the values of coliform bacteria, high values indicate different sources of pollution in organic matter (Al- Bassam et. al.,2014). The coliform bacteria values in Haditha ranged between (440- 23640), average value of11344 MPN/100 ml, it ranged between (633- 24260), with average of 12521 for Al-Ramadi sites. The fecal coliform increased at Al- Falluja, ranged between (560-28440), average value (13820)MPN/100ml, andit ranged between (600- 42580) MPN/100ml withaverage value of 15540 MPN/100 ml at Al- Hindiya site. Fecal coliform bacteria were exceeding the limits of (WHO, 2018) in Euphrates River water(Table 4).

Total Bacteria Count TBC/ 1ml

The presence of these microbes implies that there has been fecal contamination. The TBC performed by calculating the components of the plate for each 1 ml of aquatic bacteria entering the water through sewage and excreta of living organisms. The whole river is considered contaminated with Total bacteria count in various locations and in different months, as its number exceeds the permissible limits. In Haditha site TBC ranged between 32 to 433/1ml, with average value 224/1ml. In Al- Ramadi site, TBC ranged between 38 to 487/ 1ml, with average vale 254/1ml, TBC increased in Al- Falluja, it ranged between 40- to 517/1ml, average value is 277, in Al- Hindiya site ranged between 50- 623/1ml, with average value of 318/1ml. The highest number of TBC appears in Al-Hindiya site, as a result of the nutrients from wastes water. High rates of TBC in water body affected the survival of aquatic microflora (Hader et al, 1998). It was normal result to raise the count of bacteria count downstream due to increase human wastes and increase the temperature which lead to increase a microbial activity through its effect on enzymatic activities of these microbes; temperature is an important controlling factor influenced the bacterial growth (WHO, 2003, Abdo et al, 2010) (Table 4).

Table 4
Mean monthly biological and bacteriological pollutaion indices (2005- 2020)

Sites	Biologic analysis	DO mg/l	BOD mg/l	COD mg/l	E. Coli MPN/100ml	TBC/ 1 ml	FCB MPN/100 ml
Haditha	Range	3.2- 10.8	0.2- 3	1- 4.2	0- 4140	32- 433	440- 23640
	Average	7.3	1.66	2.1	2340	224	11344
	ST.DV	0.21	0.053	0.43	212	123	119
Al- Ramadi	Range	2.4- 7.2	0.2- 3.21	1.1- 4.4	0- 5810	38- 487	633- 24260
	Average	6.8	1.73	3	3510	254	12521
	ST,DV	0.16	0.23	0.87	322	129	158
Al- Falluja	Range	2.4- 6.8	0.4- 4.8	1.1- 7.4	100- 115371	40- 517	560- 28440
	Average	6.3	2.2	4.6	8341	277	13820
	ST.DV	0.12	0.41	1.3	324	137	166
Al- Hindiya	Range	2.1- 6.3	0.3- 4.87	1.7- 14.2	100- 12420	50- 623	600- 24580
	Average	5.5	2.8	8.2	8540	318	15540
	ST.DV	0.082	0.33	1.55	265	142	171
IQS,1996		7-11*	<5 mg/l	<5 mg/l	5 cells/50 ml	50CFU/ml	4cells/100ml

*US EPA, 2005

Water Type Investigation
Ivanov Formula

This formula depends on the ratio of the main ions (cations and anions) expressed by epm % which have percentage more than 15% of availability arranged in descending order. The Mean annual water types were investigated based on the values of mean monthly analysis for the period 2005- 2020 in the studied sites(Table 3). By applying Ivanov, 1968; the water type was $MgSO_4$ at Haditha and Al- Ramadi sites, while it altered into $NaSO_4$atAl- Fallujaand Al- Hindiyasites, (equation 1,2,3 and 4) respectively. According to the water type analysis for the period (2005- 2020), it was foud that the prevalent water type at Haditha and Al- Ramadi sites was $MgSO_4$, with a percentage of 63.6% and 58.2% respectively, while the prevalent water type at Al- Falluja and Al- Hindiya sites is $NaSO_4$which comprises the percentage of 64% and 45.4 % respectively.

SO_4^{-2}52.1 Cl^-26.5 HCO_3^-21.3
TDS 698 mg/l————————————pH 7.3 .... ($MgSO_4$) 1
Mg^{+2}34.1Na^+ 32.47 Ca^{+2} 32

SO_4^{-2}47.6 Cl^- 33.7 HCO_3^- 18.6
TDS 764 mg/l————————————pH 7.44 .... ($MgSO_4$)..... 2
Mg^{+2}34.6 Ca^{+2} 32.2 Na^+31.7

SO_4^{-2}48.6 Cl^-35.3 HCO_3^- 16

TDS 858 mg/l————————————pH 7.5 ……. ($NaSO_4$) ……3
Na^+ 34.5 Mg^{+2} 34.4Ca^+29.4

SO_4^{-2}50.01 Cl^-33.5 HCO_3^-16.4
TDS 822.8 mg/l————————————pH 7.7 ……. ($NaSO_4$) … 4
Na^+ 34.7Mg^{2+} 34.02 Ca^{2+} 28.7

Schoeller diagram, 1972

This diagram used to show the relative concentrations of Hydrochemical ions typically expressed in meq/l (Schoeller, 1972). According to the mean monthly values of Euphrates River. As it clear, Haditha and Al- Ramadi Sitessprevalent cations are followed this arrange; Mg^{2+}> Ca^{2+}> Na^+ + K^+ while the prevalent anions were followed this arrange; SO_4^{2-}> Cl^-> HCO_3^-. At Al- Falluja and Al-Hindiyasitess, the prevalent cations become follow this order; Na^++K >Mg^{2+}> Ca^{2+}while the more prevalent anions are; SO_4^{2-}> Cl^-> HCO_3^-(Figure 4).

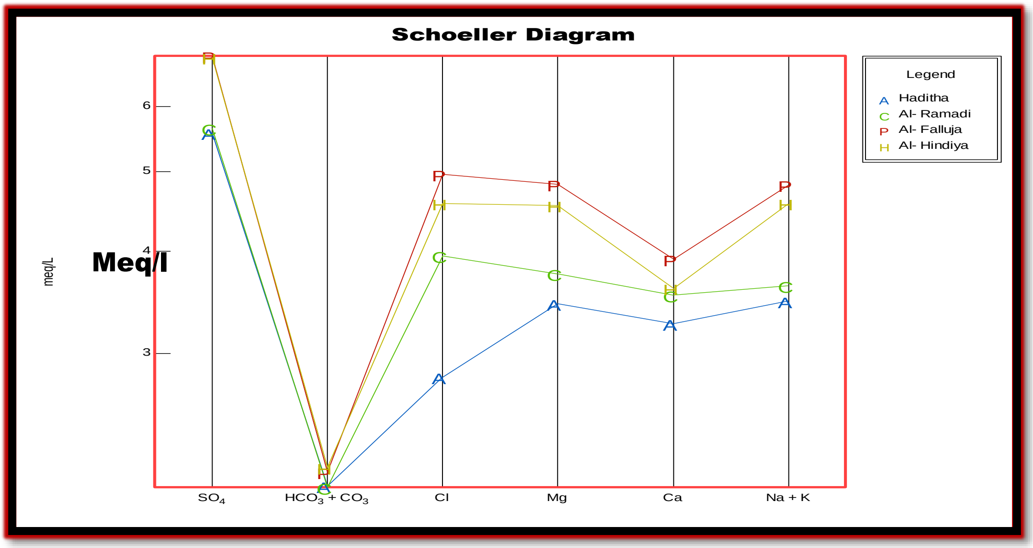


Figure 4. Schallerdiagram showing the ions distribution within the studied sites

SPSS Correlation Analysis

Factor analysis' overall goal is to summarize data so that linkages and patterns may be easily evaluated and understood. It's usually used to organize variables into a small number of clusters based on their shared variance. As a result, it aids in the separation of constructs and concepts (Yong and Pearce, 2013). Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA) are the two most common factor analysis methodologies (CFA). EFA aims to identify complicated patterns by studying the dataset and testing predictions, whereas CFA strives to confirm hypotheses and uses route analysis diagrams to describe variables and factors (Child, 2006). The criteria used to evaluate the number and significance of factors are enormous.The factor analysis is mathematically difficult,because it involves uncorrelated elements, therefore;the orthogonal rotation (Varimax) was used to estimate the primary parameters sources in the water of the Euphrates River. Rotated factor loadings, rotated Eigen values, and the scree plot are used to interpret factor analysis (Yong and Pearce, 2013).

By applying the dimension reduction of Factor analysis parameters for the selected studied sitess over the years (2005- 2020).The data of organic and inorganic parameters were entered into the SPSS program as Variable data, in order todetermine the factor analysis for data and find the most important factors affecting on Euphrates River water quantity. The results reveals two factors, the most influential variables on the water quality. The first factor (F1) represents 78.82% of the accumulative variances, with an Eigen value of about 4.9, while the second factor which represents 18.76%, having an Eigen value 3.3 (Table 5). The default value of Eigen value was used, which is 1, as a basis to determine the influential factor which providing a greater impact of significance (Figure 5).

Table 5
Rotated Component Matrix of variables with Eigen value, the variance % and accumulative%for factors analysis result

Rotated Component Matrix[a] Component	F1	F2
Cl	.847	
K	.810	
Na	.801	
SO4	.798	
Ca	.792	
HCO3	.692	.520
BOD	.610	.302
Tw	-.397	-.339
TDS		
Mg	.867	
Total coli form	-.357	.831
E.COLI	-.357	.831
pH	-.324	-.763
COD		.547
Eigen value	4.9	3.3
Variance %	32.27	26.08
Accumulative %	32.27	58.36

The plot resulting from the rotated component matrix indicated two main factors affecting the water qualityconstituents. The first group of variables(F1) have a positive loading including variables with anthropogenicpollution sources resultingfrom the agriculture and municipal wastes includes;BOD, COD, pH and Tw, while the second group factors (F2); include elements which resulting from the basic components of natural component of soil composition comprises of calcareous,gypsum and the evaporates rocks which scattered in the study area like:Ca^{+2}, Mg^{+2}, SO_4^{-2},Na^+, Cl^-, $HCO_3^-$and K^+(Kim &mueller., 1978).

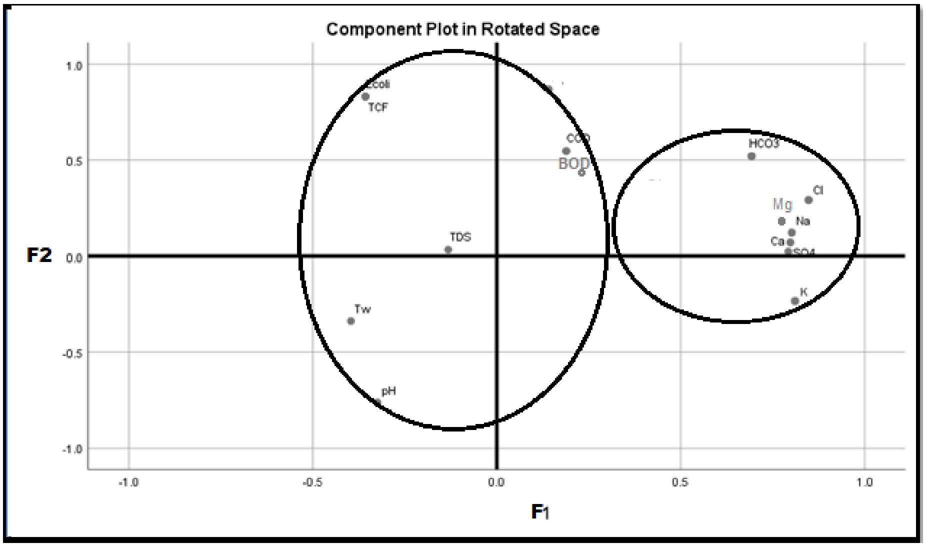


Figure 5. Component plot in space for all the studied sites (2005- 2020).

Water- Rock Interaction

The definition of the relationship between rock and water which reflects on the hydrochemical functions of river characteristics.The difference in the chemical composition of water is due to the evaporation and dilution processes that affect the concentrations of total dissolved salts, in addition to the interaction between water and rock(Subramani et.al., 2010).Studying the hydrochemical properties of the water in different sites and times is to understand and accurate interpret of evaluate trends of distribution especially in the surface water system. In this work, several functions were used to distinguish the effects of distinct weathering processes on the water hydrochemistry for the studied sites (Table 6). By applying the function of rCa/rMg, the results show that the ratio of rCa^{2+}/rMg^{2+} has an average value of 0.81, that reflect the influence of Meteoric fresh water more than the effect of groundwater sources(El-Sayed et.al., 2012). Also the results reflect the effect of the dissolving carbonate and gypsum rocks.

The function of rNa+/rCl- is one of the best functions used to determine the origin of water. If the value is greater than 1, it is of atmospheric originas in Haditha site(1.18) indicated the Meteoric fresh water sources, whereas the value is less than 1; having the values of (0.90, 0.99 and 0.89) in Al- Ramadi, Al- Falluja and Al- Hindiya respectively, indicated thatNa^+ concentration is less than Cl^-,as an evidence of the interaction of sediment dissolution of the geological formations within he study areawhich acts as points of contact with the sedimentary cover and allowed of groundwater to mix with surface water (Al-Bassam 1985). The dissolution of Calcium, gypsum and anhydrite in the water are indicated by the ratio between rSO_4^{2-}/rCl^- which is 0.96in Haditha, (1.41) in Al- Ramadi, (1.66) in Al- Falluja and (1.60) in Al-Hindiyasites (Figure 8). The graphic relation of Ca^{2+} + Mg^{2+} versus SO_4^{2-}+ HCO_3^- is close to the 1:1 line as a normal case if the dissolutions of calcite and gypsum rocks which are the dominant reactions in the water (Fisher, 1997). If there is an excess concentrations of Ca^{+2} and Mg^{+2}, hence the points are shifted in to the left, as a result of increasing the values of them relative to SO_4^{-2}, and HCO_3^- concentrations. Vice versa, when the ion concentrations exchange tends to shift points towards the right, this mean that there is excess saturation of SO_4^{2-} andHCO_3^- in water. As it clear from the graph, all the studied sites are tend to settled near the basic line, with little shift toward the right, indicated water saturation with SO_4^{-2} and HCO_3^-relative to $Ca^{+2}$and Mg^{+2}(Figure 6).

Table 6
Concentration of Hydrochemical function (epm) of Euphrates River sites (2005–2020)

Sites	*rCa2+/rMg²⁺*	*rSO_4^{2-}/rCl^-*	*Ca^{2+} + Mg2+*	*SO_4^{2-} + HCO_3^-*	*rCl^-*	*rNa+/rCl –*	*rNa+*
Haditha	0.81	0.96	6.67	7.84	2.8	1.185	3.32
Al-Ramadi	1.00	1.41	7.06	7.86	4	0.90	3.63
Al-Falluja	0.81	1.66	8.31	9.951	4.62	0.99	4.6
Al-Hindiya	0.85	1.60	8.51	10.33	5.03	0.89	4.51

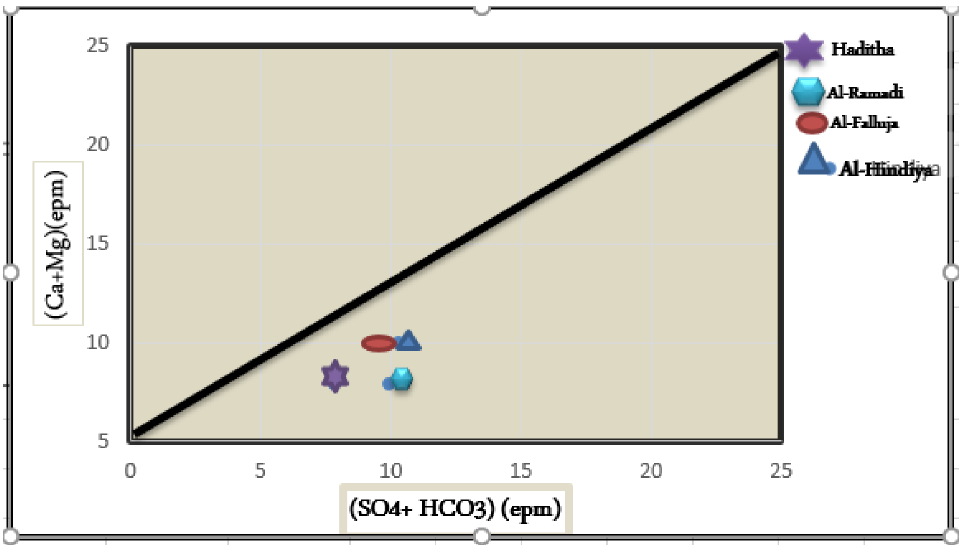


Figure 6. SO_4^{2-} + HCO_3^-versus Ca^{2+} + Mg^{2+}relation in Euphrates River sites

Total Ionic Salinity (TIS)

The plot of total ionic salinity (TIS) has been performed according to(Apollaro, 2022). Geochemical properties of Euphrates River sites were studied to facilitate the explanations of the evolutionary trends of surface water systems, the interpretation was supported with maps of hydrochemical divisions of Total Ionic Salinity (TIS) diagram which explain their distribution and locations (Figure 7). In general, most of surface water samples, presents the TIS value between 10 to 30 meq/l , as in the studied sites (Apollaro, et al., 2022).

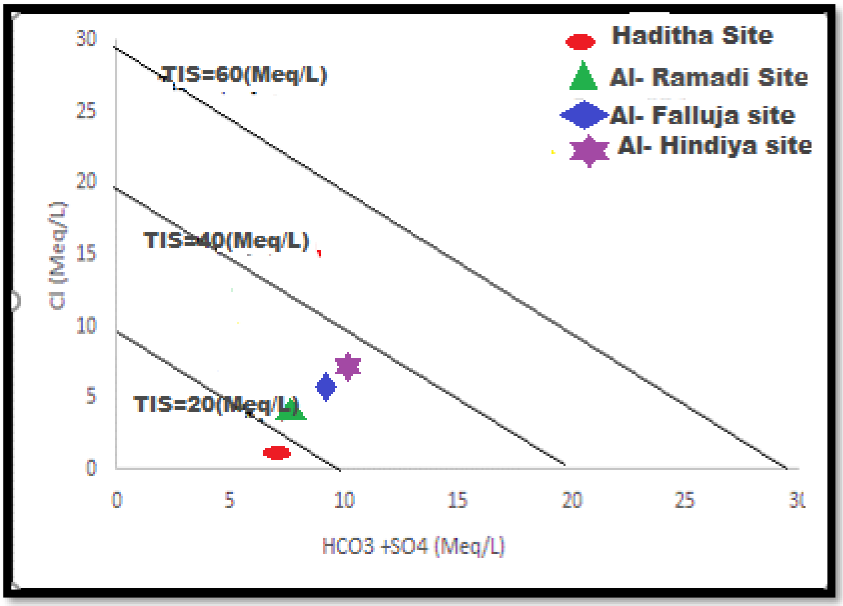
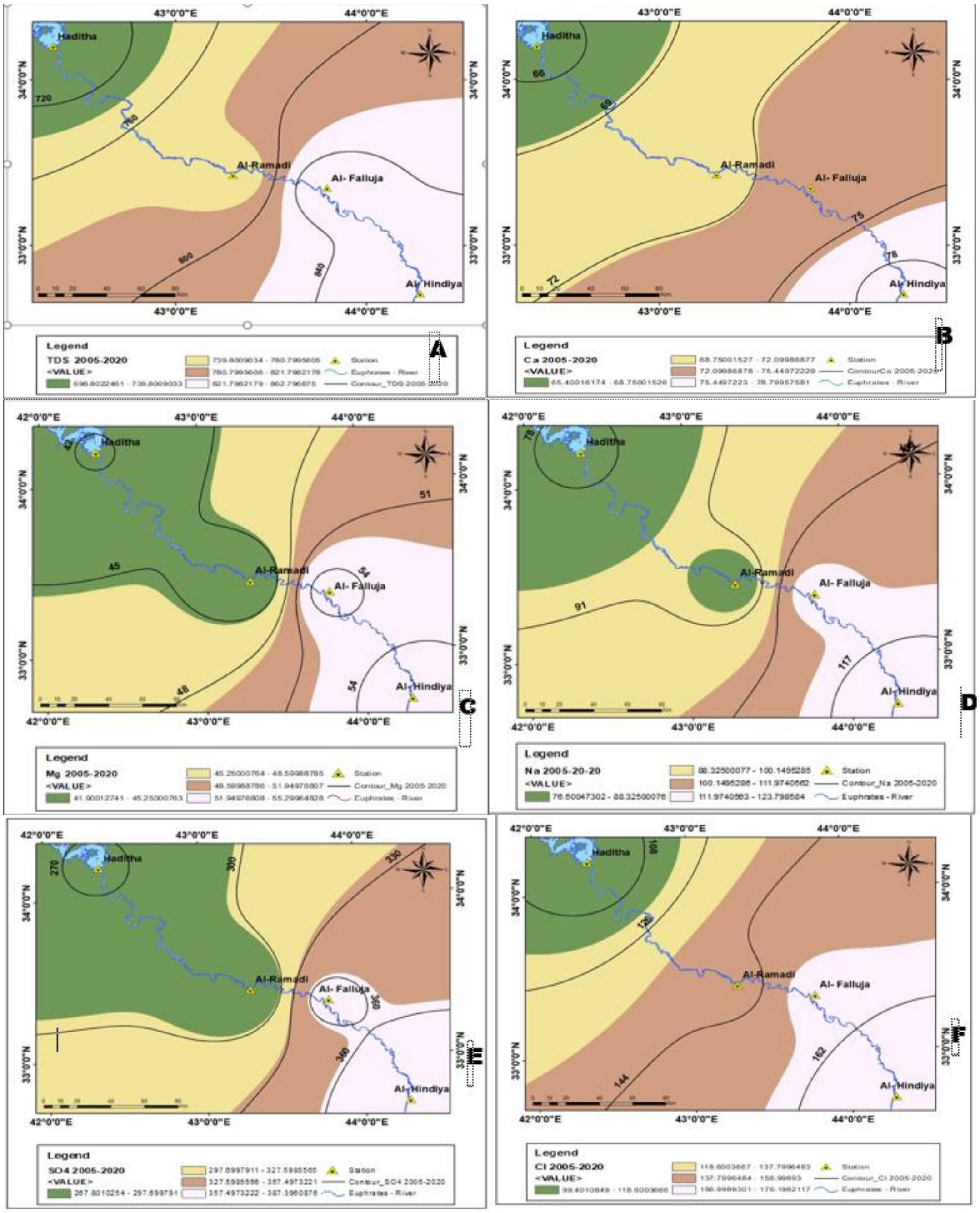


Figure 7. The diagram of the study sitesTotal Ionic Salinity (TIS) distribution

Spatial &Temporal Distribution of Organic & Inorganic elements

The spatio- temporal distribution of the physio-chemical and biological elements was represented by using the interpolation technique of Inverse Distances Weighting (IDW), within ArcGIS program to build a prediction mapsalong the studied sites on Euphrates River(Carré F, Girard MC, 2002).Data hasdistributedaccordingtoconcentration variation spatially and temporarily from the low to high concentration. The distribution maps revels thespatial and temporal increase of all major ions toward downstream whichincludes: (TDS, Ca^{+2}, Mg^{+2}, Na^{+}, Cl^{-}, SO_4^{-2}) and the and biological pollution indicators (BOD and E. Coli bacteria) (Figures 8 A, B, C, D, E, F, G and H). Except for theconcentration of the dissolved oxygen (DO)mg/l,which showed a visible decreasetoward downstream indicatesthe oxygen depletion due to consumption the available oxygen for decompositionthe organic mattersin a water body (Figure 8:I).


A
TDS 2005-2020
B
Ca 2005-2020
C
Mg 2005-2020
D
Na 2005-20-20
E
SO4 2005-2020
F
Cl 2005-2020
Legend
<VALUE>
Station
Euphrates - River
Haditha
Al-Ramadi
Al- Falluja
Al-Hindiya
42°0'0"E
43°0'0"E
44°0'0"E
33°0'0"N
34°0'0"N

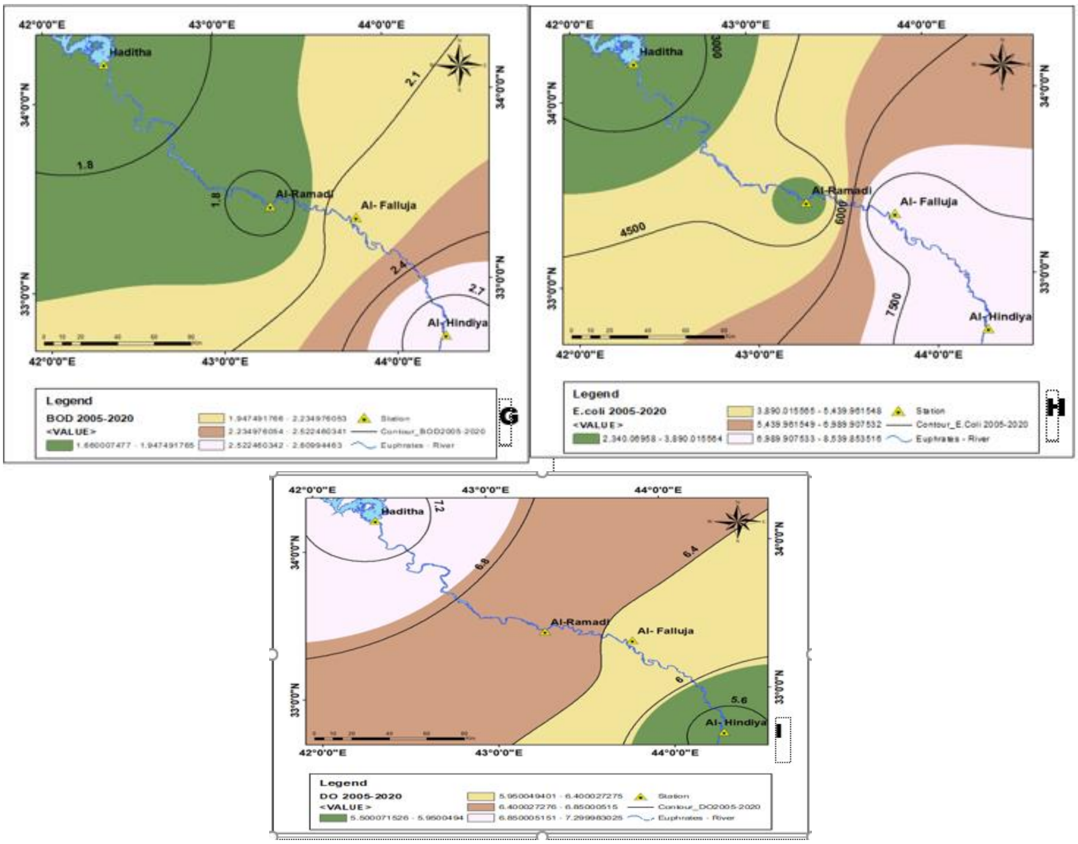


Figure 8. Spatio- temporal distribution maps of A: TDS (ppm), B: Ca+2 (ppm), C:Mg+2 (ppm), D: Na+ (ppm), E: SO4-2 (ppm), F: Cl-(ppm), G: BOD (ppm), H: E. coli (MPN/100ml) and I: DO (mg/l)for the period (2005- 2020)

Discussion

In recent years, The Euphrates River has sufferedfrom a notable decrease in the discharge rates, which negatively reflect on the water quality over time, especialy downstream due tomanyfactors, some of which is related with the human activities such as the dams construction and the corresponding increase in population, wich in turn ledsto increase the water demadfor potable water sources, added to the large amount of waste water returned from irrigation,the wasts thrown into the river. While the natural conditions is related withclimatic changes as rainfall rareness and the increase in the temperature rates. This study underlined the negative effects of decreasing discharge rates onthe water quality of Euphrates River in four sites, these are;Haditha, Al- Ramadi, Al- Falluja and Al- Hindiyaduring the period (2005- 2020). The study concluded that the discharge of Euphrates River is decreasing with time from from Haditha to Al- Hindiya sites.

Rinfall decreases significantly downstream, while an increase in temperature observed. Therefore, the water type investigation indicates$MgSO_4$at Haditha and Al- Ramadi sites, while it altered into the $NaSO_4$ at Al- Falluja and A- Hindiya sites. The reason for water type diversity, is due to the dynamic system of water and the constantly moving, affecting by climatic conditions and so other anthropogenic factors like the irrigation water and other wastes dumped into the river, in addition to the dissolving of rocks which is in contact with water. Mean annual biological pollution indicatorsBOD, COD, E. Coli, TCFand TBCareshoweda visible increase downstream,whereas the dissolved oxygen (DO) showed a decrease contain downstream due to high consumption from the organisms in the water, it's within the acceptable limits in Haditha site, while its critical in the other sites. BOD5 values were within the clean water levels, whereas COD were within the clean water in Haditha, Al- Ramadi and Al- Falluja, while itexceeds the limits at Al- Hindiya site (IQS, 1996), thisis due to the return water from the agriculture and municipal activitieswhich dumped into the river as well as the accumulation of dissolved solids and microbial accumulated from all the upstream loads (Al- Ansari et.al., 2019). Noted that the dissolved oxygen (DO) was decreased downstream, indicated the water oxygen depleted and water quality deterioration.

The biological indicators of water pollution indicate that TBC, TCF and E. coli were exceeding the permissible limits in the studied sites. In order to investigate the results, the practical application of ArcGIS program (IDW) tool was applied to find the interpolation maps of general trend of TDS and other ions distribution within the study area, the results confirmed the spatial and temporal increase of TDS and other ions toward downstream. The biological pollution indicaors (BOD and COD)also increased downstream with time due to increase the pollutants of microbial assemblages and nutrients into the aquatic system, leading to increased heterotrophy, and increase the number of harmful microbes and consequently decrease the species diversity (Labbate et. al., 2016). There is a notable increase in major ions and the pathogenic bacteria over the time. By compaire the results of the current sudy with the other studies, it was noted the spatial and temporalincrease in major ions concentrationcompared to the previous studies (Table 7).

Statistical program (SPSS) has been applied to all parameters analyzed in the studied sitess, to put the results in the frame of multivariate monitoring the severity of environmental pollution, the results of factor analysis indicated two factors of water pollution sources; the first factor (F1) is having 73.8% of the total variance, it was in strong positive loading includes: Na^{+}, Cl^{-}, Ca^{+2}, Mg^{2+}, HCO_3^{-} ,and SO_4^{2-}, and Tw which its sources is from the natural inputs like the dissolution of carboniferous and Gypsum rocks which are scattered in the study area. while BOD, COD, BOD, E. Coli, TBCand FCB bacteria were grouped within (F2) as its source is anthropogenic and human wastes.

Parameters (ppm)	Present study 2005-2020		Al- Obeidi, 1983		Salman, 1987		Ryadh, 2004		Al Bomola, 2012		Al-Heety, 2011	Awadh& Ahmed, 2013		Hamad/ 2015	
											Hit- Al-Ramadi	Hit- Saqlawiya.			
	Haditha.	*Hindiya.*	*Haditha.*	*Hindiya*	*Haditha.*	*Hindiya.*	*Haditha*	*Hindiya*	*Haditha*	*Hindiya*		*High flow*	*Low flow*	*Haditha*	*Al-Hindiya*
TDS	698.8	822.8	694	796	543	940	590	887	866	982	1612	564	715	1000	1147
Ca^{+2}	65.4	72.2	26	68.5	46	168	80	165	80	123	96.37	63	119	98	100
Mg^{+2}	41.9	55.3	21	67	22.5	45	38	78	42.7	90	-	23	32	40	40
Na^{+}	76.5	103.8	31.5	24.5	48	136	70	120	82	131	154.09	101	122	100	125
K^{+}	5.79	6.3	4.32	4.22	4.18	4.60	4.0	4.24	-	-	6.01				
SO_4^{-2}	267	331	82	182	78	390	220	400	270	378	492.8	219	200	250	300
Cl^{-}	99.4	162	52	71.5	78	227	120	125	112	149	190.8	143	254	1 50	160
HCO_3	139.2	138	110	91.3	177	126	240	370	-	-	68.09			-	-
BOD	-	-	-	-	-	-	-	-	-	-	2.30	-	-	-	-
DO	-	-	-	-	-	-	-	-	-	-	9.21	-	-	-	-
Water Type	Mg-SO_4	Na-SO_4	Mg-HCO_3	Mg-SO_4	Mg-HCO_3	Mg-SO_4	Ca-SO_4	Ca-SO_4	Mg-SO_4	Ca-SO_4	Na-SO4	Na-SO_4	Na-Cl	Ca-SO_4	Na-SO_4

Conclusion

Climate change and the dam's construction by upstream countries led to decrease the discharge and Euphrates River flow entering in to Iraq.Water quality is highly affecting by discharge, in addition to the anthropogenic factors like agriculture activities, municipal and domestic wastes which thrown in to the river directly. Physical, chemical and biological analysis during the period (2005- 2020), for Euphrates River water indicated increase the concentration toward downstream except the dissolved oxygen (DO), which decrease gradually towered Al- Falluja and Al- Hindiya sites. High temperature rates led intern to accelerate the evaporation rates and increased salinity. Sharp increase values of ions concentration noticed in Al- Falluja and Al- Hindiyasites, this is attributed to the brackish water discharged from Al- Tharthar lake to the Euphrates River. TDS and ions concentration in Haditha and Al- Ramadi sites were within the permissible limits of IQS (2009), while it exceeds the standards in Al- Falluja and Al- Hindiya mostly.

Examined the trace elements of five traces; (Fe, Pb, Cu, Cr, and Cd) did not record any pollution mentioned, so they are within the permissible limits. Water type investigation, indicate the dominant water type in Haditha and Al- Ramadi is of (64%)Mg- SO_4, while the dominant water type in Al- Falluja and Al- Hindiya sites was Na- $SO_4$with (46.4%), as there is a clear decline in water quality toward downstream. By conducting a factor analysis, it was found two main factors affect the concentrations of the main variables, representing more than 87% of the variance. The most affecting factor (F1) represents 71.27% of the total variance percentage, including the elements caused by the anthropogenic pollutants like; COD, BOD, Total bacteria count (TBC), Fecal coliform (FCB), and E. Coli bacteria and TDS. While the second factor (F2) represents 16%, including the ions resulting from natural conditions like the dissolution of gypsum and calcareous rocks which distributed within the study area, including Na^+, Cl^-, Mg^{2+}, Ca^{2+} and SO_4^{2-}. The spatio- temporal distribution of TDS and ions concentration verification the water quality deterioration downstream over the years, and increase the dissolved oxygen consumption. due to decrease the discharge rates.

Recommendation

Controlling water quality is a crucial aspect of environmental preservation. Analyzing present water quality measures and the pattern of their change is helpful for making quantitative decisions, such as whether water quality is improving or deteriorating over time. These choices are crucial in the development of a water pollution control strategy.

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