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Cite as: AIP Conference Proceedings **2213**, 020042 (2020); https://doi.org/10.1063/5.0000190
Published Online: 25 March 2020

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Spatial and temporal Variation of Water Quality Index of Euphrates River in Anbar Governorate, Iraq

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Abstract. This study aims to investigate the spatio-temporal variation of water quality index (WQI) of Euphrates River in Anbar Governorate. The water samples were collected from nine stations in 2018.Fifteen water quality parameters namely, pH , temperature (T), turbidity (TUR) dissolved oxygen(DO) ,electrical conductivity (EC) , total dissolved salts (TDS) , sulfate ion (SO_4^{2-}), Chloride ion(Cl) ,nitrate ion (NO_3^-),Phosphate ion (PO_4), total hardness (T.H), Alkalinity (Alk),calcium (Ca^{2+}), magnesium (Mg^{2+}), and total bacteria (TB) were measured for calculation of the WQI using the methodology of Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI) . The WQI level of Euphrates River in the study area during 2018 ranges from 43.33 to 64.8 with mean of 55.10. According to the mean value of WQI, the water quality is mostly classified as "marginal" for overall drinking water utilities in the period of research. In general, the result of temporal variation analysis of WQI shows ″ marginal ″ water quality in most months, except of January and September, the water quality is fair and poor, respectively. The result of the spatial variation analysis exhibits marginal water quality in all sampling stations and the WQI value decreases in the downstream stations. Compared to the result of a previous study, the water quality of the Euphrates River in the research region retained its marginal status. The deterioration of Euphrates River water can be ascribed to anthropogenic activities.

INTRODUCTION

The deterioration of quality of the surface water has become a global serious concern due to increased pollution and climate change (1, 2). Water quality of any water body (river, lake, … etc.) can be evaluated using physical, chemical and biological parameters. These parameters are described as pollutants when their levels exceed the local, regional and international guidelines. To assess water quality, various methods have suggested, such as, multivariate statistics, modeling and multi-metric indices (3, 4,5). The WQI is one of the most effective methods to assess the quality of water. WQI is used to evaluate suitability of water for different uses. The first WQI was developed by Horton (1965) (6). The most WQI was suggested by the American Public Health Association (7). The various water quality indices have been reviewed by (8). A WQI is individual unitless number describing the state of water quality of a water body. It is acquired by aggregating the reading and measurement values of the selected water quality parameters. The benefits of using WQI were reported by (9). WQI method has been applied in many countries to evaluate the state of water bodies (11,9,10). The WQI of Euphrates River and its branches in Iraq was assessed by several researchers (12,13,14 ,15 ,16, 17). The WQI is very helpful to propagate the water quality information to the general audience and

2nd International Conference on Materials Engineering & Science (IConMEAS 2019)
AIP Conf. Proc. 2213, 020042-1–020042-8; https://doi.org/10.1063/5.0000190
Published by AIP Publishing. 978-0-7354-1964-3/$30.00

decision-makers, giving a good idea of the spatio-temporal change in the water body's health. Many previous studies lack a water quality coefficient calculation (18,19).

The goal of this study is to investigate the temporal and spatial variation of WQI of Euphrates River in Al Anbar Governorate, Iraq.

MATERIALS AND METHODOLOGY

Water sampling

The samples of water were collected monthly from January to December 2018 from nine stations: Haditha (S_1), Baghdadi (S_2), Hit (S_3), North of Ramadi (S_4), South of Rammadi(S_9), Figure 1. The water samples (250ml) were collected in sterile bottles, transported to the laboratories of Directorate of Environment of Al-Anbar Governorate, University of Anbar for chemical analysis. (S_5), Fallujah(S_6), Alwarar (S_7),Alwarar (S_8) and Alhabanih

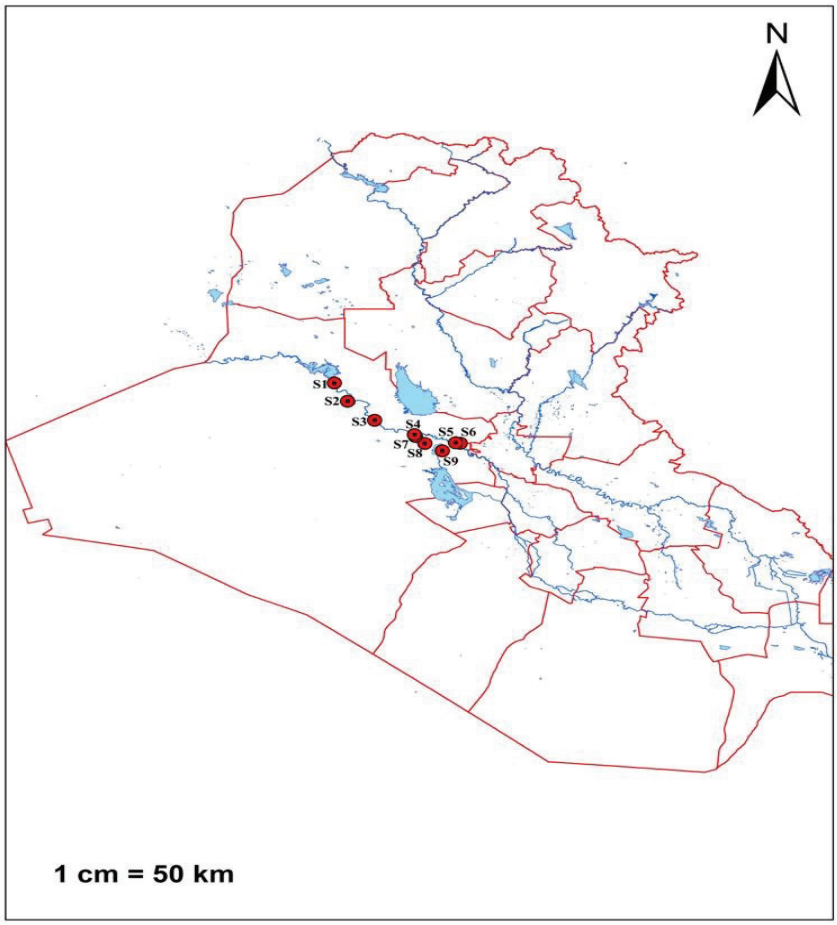

FIGURE 1. Location map of Anbar governorate, sampling stations.

Physico-chemical parameters analysis

To assess the WQI, we measured and analyzed 15 physicochemical parameters (pH, temperature (T), turbidity (TUR) dissolved oxygen(DO), electrical conductivity (EC), total dissolved salts (TDS), sulfate ion (SO_4^{2-}), Chloride ion(Cl), nitrate ion (NO_3^-), Phosphate ion (PO_4), total hardness (T.H), alkalinity (Alk), calcium (Ca^{2+}), and magnesium (Mg^{2+}). The values of EC, pH and T were measured in the field while the levels of TDS were performed in the laboratory. Total hardness (T.H), alkalinity (Alk) and chloride were measured by titration. The concentrations of Ca^2 were measured by AES while concentration of Mg^{2+} assessed by using AAS. The standard solution1000 mg / L was

prepared by dissolving the required weight in a liter of distilled water and kept in a bottle made of polyethylene and then a series of diluted standard solutions was prepared at different concentrations. Concentrations of NO_3^-, $PO_4^{-3}$and SO_4^{2-} were estimated by using UV-VIS spectrophotometric analysis.

The WQI has been calculated using 15 physicochemical parameters (pH, T, DO, Ca^{2+}, Mg^{2+} Cl^-, NO_3^-, PO_4^{3-}, ALK, SO_4^{2-}, EC, TDS, TH, and TUR) and the WHO guidelines (objectives) of drinking water quality (Tables 1). The WQI of Euphrates River was calculated using CCMEWQI method. For more details about CCMEWQI were documented in CCME (20). After the CCMEWQI is calculated, water quality is classified as one of the categories mentioned in Table 2 (20).

Table 1 The information used during the study period to calculate the temporal variation of the Euphrates River WQI.

Month	Parameter													
	pH	T	DO	Ca^{2+}	Mg^{2+}	Cl^-	NO_3^-	PO_4^{3-}	ALK	SO_4^{2-}	EC	TDS	TH	TUR
January	7.85	17	8.92	128.16	48.22	149.61	3.40	0.040	140.38	**303.94**	**1047.83**	**943.05**	**1040.5**	**12.49**
February	7.78	14.78	7.75	81.88	42.72	108.83	2.96	0.044	122.66	**258.61**	**871.61**	**783.96**	**1042.16**	**11.37**
March	7.91	22.2	9.16	82.94	34.5	143.88	3.08	0.042	179.94	172.94	**758.69**	682.82	**960.16**	**13.48**
April	7.38	27	9.24	79	39.72	148.5	2.85	0.035	186.94	**251.08**	**755.7**	506.31	**868.16**	**9.69**
May	7.48	26.88	9.3	78.44	40.88	147.88	2.92	0.04	194.11	242.31	**757.77**	**833.55**	**872.33**	**12.31**
June	7.41	30.11	9.51	75.44	46.66	172.27	**12.79**	0.038	198.22	233.68	**1167.23**	**782.05**	**865.5**	**74.5**
July	7.49	31.72	9.63	77.27	35.38	161.05	**12.81**	0.040	**205.22**	**362.53**	**1169.6**	**783.63**	**871.16**	**35.80**
August	7.71	33.05	9.18	82.14	**50.33**	141.95	**10.58**	0.040	**213.47**	**273.77**	**1036.38**	**932.75**	**1001.59**	**28.86**
September	7.54	27.71	9.27	79.93	47.05	148.88	2.86	0.035	**207.03**	**252.83**	**1346.30**	**902.02**	**867.5**	**29.7**
October	7.78	23.33	8.15	187.33	**61.94**	149.88	2.69	0.038	128.62	**269.61**	**1171.13**	**784.65**	**1010**	**20.4**
November	7.83	18.77	8.41	126.72	**55.55**	148.72	3.00	0.040	177.33	**300.83**	**1346.29**	**902.01**	**1029.83**	**21.80**
December	7.85	17	8.92	128.16	**57.27**	149.61	3.40	0.040	140.38	**303.94**	**1257.4**	**955.62**	**1039.5**	**24.98**
Objectives	6.5-8.5		>2	200	50	200	10	3	200	250	750	750	750	5

*Bolded values do not fulfill the goal.

TABLE 2. CCME WQI and status of water quality (20).

CCME WQI Categories	Status of water quality
Excellent (CCME WQI Value 95 – 100)	With virtual lack of danger or impairment, water quality is protected ; conditions that are very near to natural or pristine.
Good (CCME WQI Value 80 – 94)	With only a small degree of risk or deficiency, water quality is protected; circumstances rarely deviate from natural or desirable concentrations.
Fair (CCME WQI Value 65 – 79)	Water quality is generally protected but sometimes endangered or impaired; sometimes circumstances are different from natural or desirable concentrations.
Marginal (CCME WQI Value 45 – 64)	The quality of water is often endangered or impaired; circumstances often deviate from natural or desirable concentrations.
Poor (CCME WQI Value 0 – 44)	The quality of water is almost always threatened or impaired ; circumstances generally deviate from the desirable natural concentrations.

RESULTS AND DISCUSSION

The results of calculation of CCME -WQI of Euphrates River in Al-Anbar governorate in 2018 show that the mean of WQI level is 57.4. This level reports the Euphrates River water quality in the study region as marginal category. This category describes the water quality as" The quality of water is often endangered or impaired; circumstances often deviate from natural or desirable concentrations" (20). The WQI of Euphrates River for the period from November 2008 to June 2009 was estimates in part of the study area using the National Sanitation Foundation (NSFWQI) method (21). The WQI value was observed to be 68 and the water quality was categorized as medium class. The CCMEWQI) of Euphrates between Heet and Rammadi Cities (S3, S4, S5, S6, S7 and S8 in the current study) for the period between November 2008 and June 2009 was calculated by (12). They described the water quality status as marginal category. The results of our study confirm that Euphrates River water quality in the research region remains marginal and exposes to deterioration and the main contribution of human activities reflects this deterioration. Depending on CCMEWQI values, the quality of Euphrates River water in Qadisiyah province was categorized as poor to marginal for the period from September 2015 to June 2016 (16). Euphrates River in region of Middle Euphrates has the fair to poor quality from May 2013 to April 2014) according to CCME WQI values (22). The water quality of Euphrates River in Al-Kifil, Al-Kufa, Al-Shamiya, Al-Manathera, and Al-Shannafiya for the years 2015 and 2016 is good to poor according CCMEWQI (15).

Temporal variation of WQI

The results of temporal variation of WQI of Euphrates in Al-Anbar Governorate are illustrated in Figure 2. The WQI categories range from poor (in September) to marginal (in Feb., March, Apr., May, June, July, Aug., Oct., Nov. and Dec.) to fair (in Jan.). The poor water quality in September is attributed to increasing of ALK level, Figure 3. The fair water quality in January results from decreasing of ALK and NO3- levels, Figure 3. The summer months (June, July and August) show low marginal water quality resulting from high levels of TDS, NO3-, and Cl^-, Figure 3

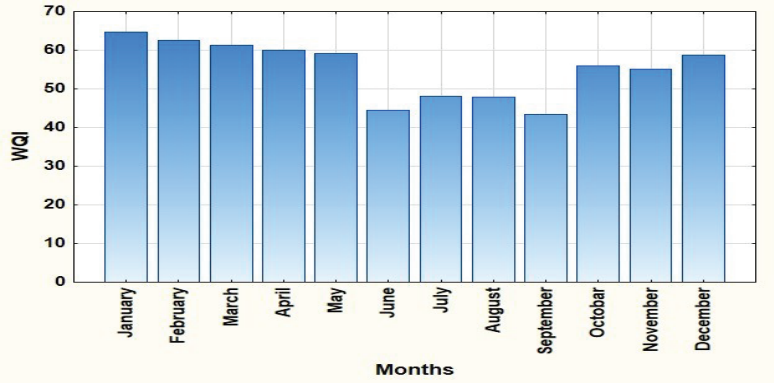

FIGURE 2. Temporal variation of WQI of Euphrates River in Al-Anbar Governorate.

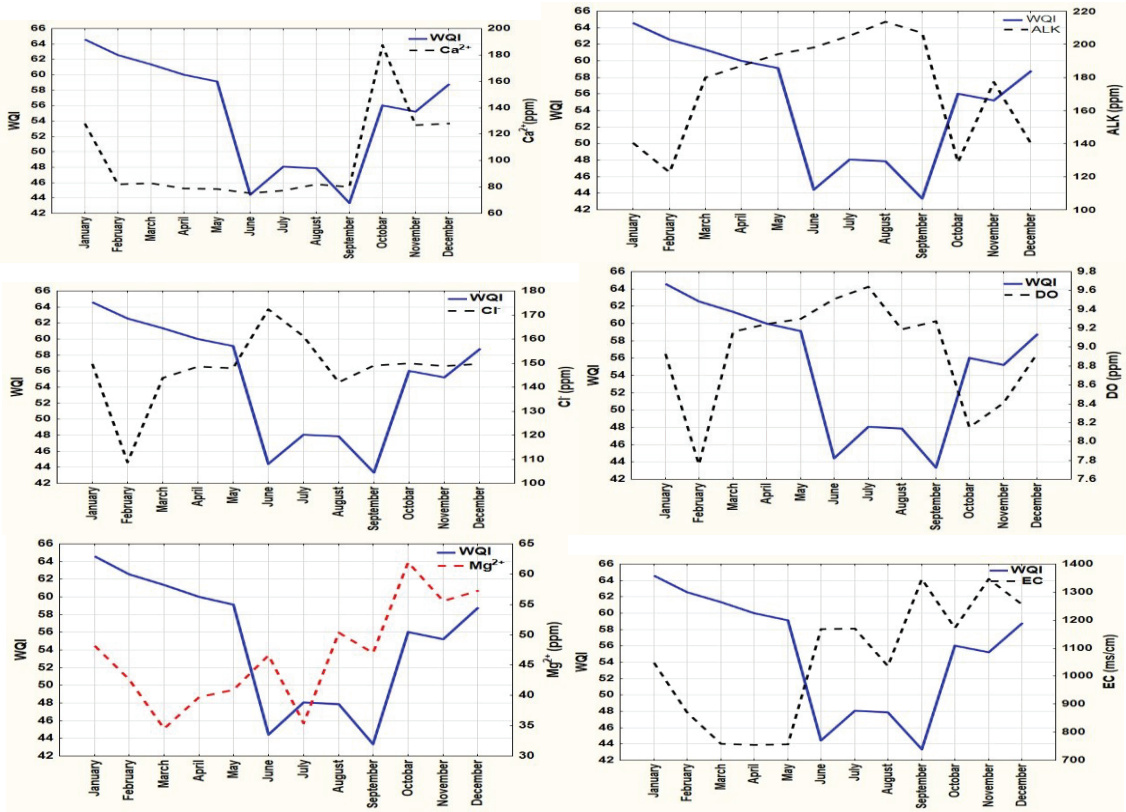

FIGURE 3. Temporal relation between the WQI and the physic-chemical parameters of Euphrates River water.

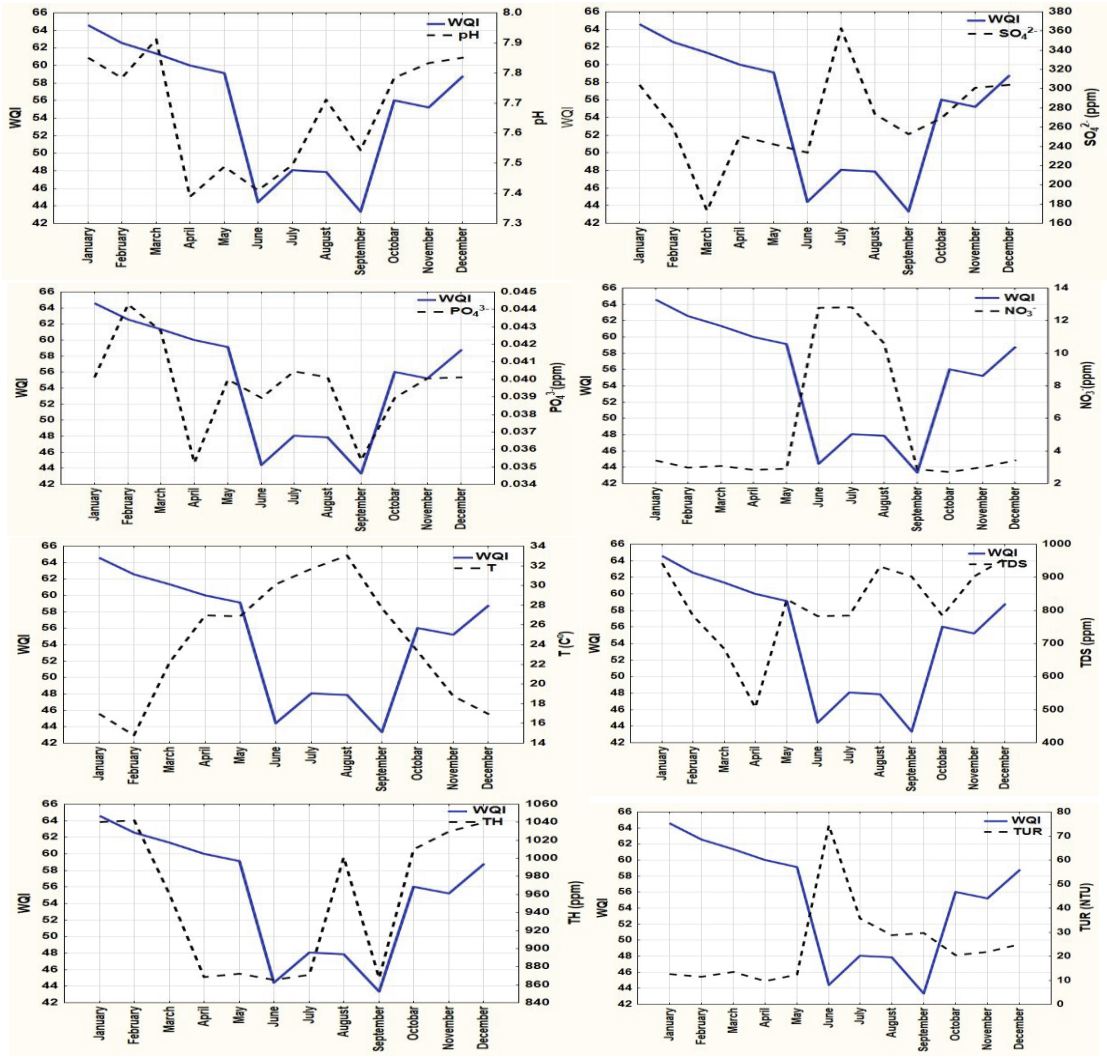

FIGURE 3. Continued. Temporal relation between the WQI and the physic-chemical parameters of Euphrates River water.

Spatial variation of WQI

The spatial variability of WQI shows marginal water quality in all sampling sites, Figure 4. The WQI value decreases in downstream sampling stations compared with the upstream stations. The highest and lowest values of WQI are in S1 and S8, respectively. The S8 locates in Rammadi City, capital of Al-Anbar Governorate and the largest urban center. The WQI value in S8 is interpreted in terms of increasing of concentrations of TDS, Cl-, Mg2+, PO43-, SO42-, and decreasing of DO

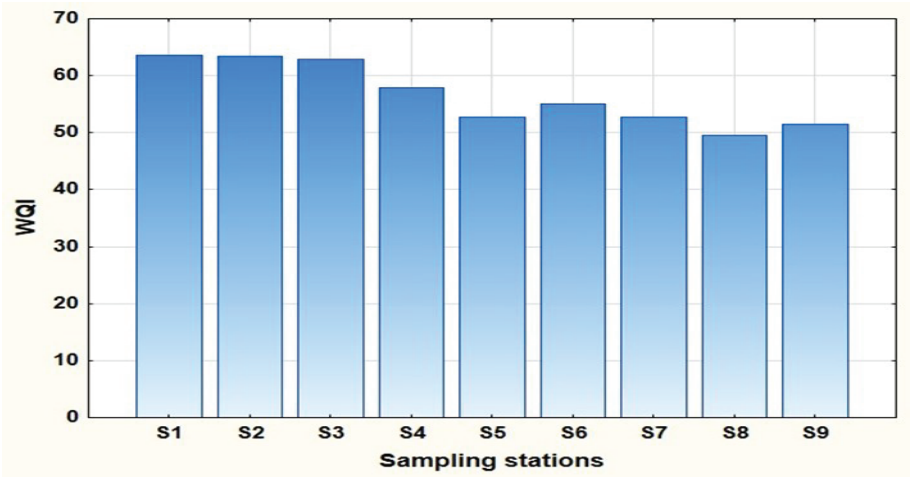

FIGURE 4. Euphrates River WQI spatial variation in Al-Anbar Governorate.

level, Figure 5. The low concentration of DO is ascribed to the sewage water, and the high concentrations of TDS, Cl-, Mg2+, PO43-, SO42 indicate the effects of municipal, agricultural, and industrial activities. Al-Heety et al. (12) found that the water quality in downstream region was poor. They attributed that to the urban wastes and anthropogenic activities in Rammadi City.

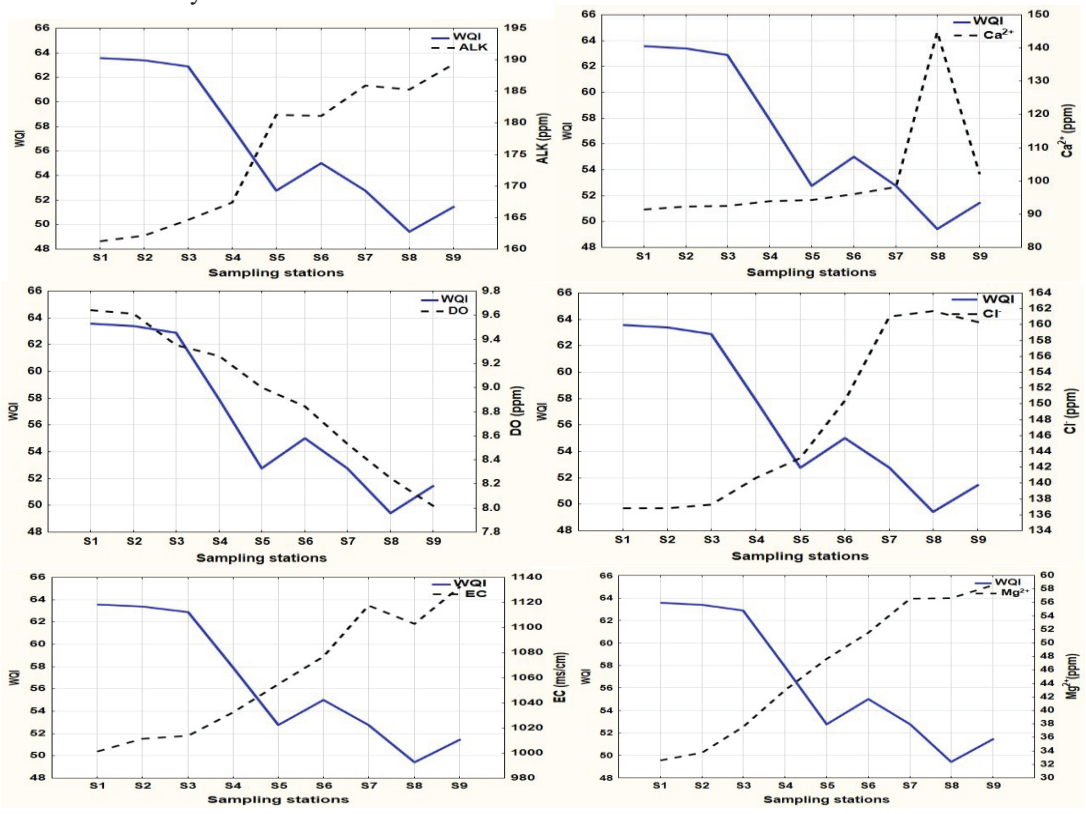

FIGURE 5. Spatial relation between the WQI and the physic-chemical parameters of Euphrates River water.

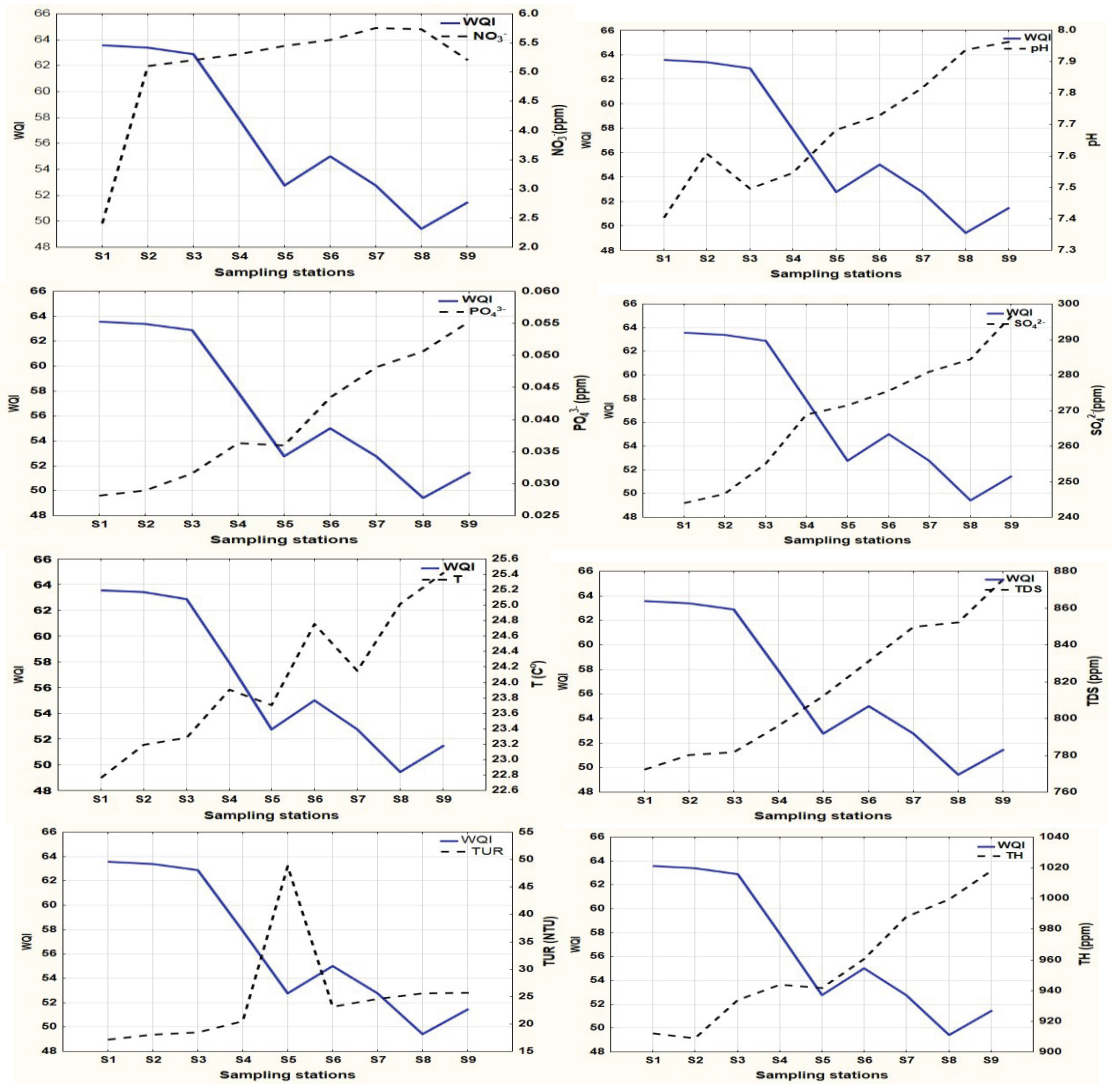

FIGURE 5. Continued. Spatial relation between the WQI and the physic-chemical parameters of Euphrates River water.

CONCLUSION

The quality of Euphrates River water in Al-Anbar Governorate is categorized as marginal in 2018. The water quality of Euphrates remains the marginal status from 2009 till 2018. Temporally, the water quality during most of the months of monitoring year is marginal except in January and September is fair and poor, respectively. The WQI level decreases from upstream to downstream of Euphrates River. The low WQI in downstream stations reflects effect of the anthropogenic sources.

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