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Water quality index along the Euphrates between the cities of Al-Qaim and Falluja: A comparative study

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Abstract. Water Quality Index (WQI) is a useful and unique method of measuring water quality. It is often used to determine the status of water quality in simple terms (e.g. good or bad, usable or unusable) to assess water quality and evaluate its suitability for different purposes. The research objectives are to assess the spatial variability of the water quality index (WQI) and make comparisons among monitors sites on the Euphrates River in Anbar Governorate. The monitoring and assessment were carried out on eleven sampling sites along the Euphrates River between the cities of Al-Qaim and Fallujah, spatially and temporally, over a period of 4 years from 2010 to 2013. To calculate the WQI, several Physico-chemical parameters, namely, pH, electrical conductivity (EC), total dissolved solids (TDS), total hardness (T.H), turbidity (TUR), dissolved oxygen (DO), alkalinity (Alk.), calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), potassium (K^{+}), chloride ion (Cl^{-}), sulphate ion ($SO4^{2-}$) and nitrate ion (NO^{3-}) were analysed in line with the Canadian Council of Ministers of the Environment Water Quality Index methodology (CCME WQI). The water quality index values in these stations on the Euphrates River in the study area ranged from fair to a marginal category in the study period. The current results concluded that the alterations existed in the concentration of the Physico-chemical parameters in most months, except January and September, along the Euphrates between the cities of Al-Qaim and Fallujah, as a result of harmful practices. The present study revealed that the Euphrates River water is polluted due to human activities, agricultural run-off, the release of inadequately treated wastewater, making it unsuitable for human consumption unless treated properly.

Keywords: Euphrates River, Physicochemical analysis, Spatial variation, water quality index (WQI), water pollution.

1. Introduction

Water is a prime natural resource and one of the most abundant commodities with nature. But it is also a highly misused one. Water sources are naturally found in different forms in the environment [1]. Today, surface water is easily polluted due to farm waste and wastewater. Both anthropogenic factors and natural processes can affect/influence the quality of worldwide surface water [2]. Water quality in any given area or source can be assessed using various physical-chemical and biological parameters. Public health is at risk when the values of the parameters are not within safe limits. Hence, the Water Quality Index (WQI), established by the Canadian Council of Ministries of the Environment (CCME) and also known as CCME [3], has been accredited to evaluate the appropriateness of water quality for human consumption. The WQI is calculated using mathematical equations that classify the nature of water bodies with numbers that have been formulated by various environmental monitoring agencies to determine their suitability for human consumption [4]. The quality of water in the Euphrates River is a major concern due to the population growth and related industrial developments in addition to the poor sewerage system [5]. Large dams built close to urban areas have resulted in increased potential risks to downstream life and property [6]. A large proportion of the used water may return to the water source heavily loaded with contaminants [7]. The WQI aims to provide a single value, ranging from 0 to 100, for easy interpretation of water quality monitoring data easily [8]. Among the parameters most commonly affecting water quality are total dissolved solids, total hardness, pH, dissolved oxygen, biological oxygen demand, nitrate and phosphate [9]. Urban waste and anthropogenic activities have led to poor water quality in the downstream region (in Ramadi city), while the water quality was marginal in the upstream region [10]. In the region of the middle Euphrates River, Index values were ranked as fair to poor, according to the CCME WQI, from May 2013 to April 2014 [11]–[13].

2. Sampling and Study Area

The Euphrates River is one of the perennial river basins in Iraq. Crossing the Syrian border, the river provides most of the water supplies to two major cities (Ramadi and Fallujah) as well as in small towns and several villages in Anbar governorate. The river then flows through Fallujah. The Euphrates River system has been surveyed intensively to select different sites for sample collection. Several water samples were collected from 11 regions in the river at 12-month intervals over a period of four years. The sampling sites were chosen to represent river sites receiving land drainage and other waste as the river receives large amounts of domestic, industrial as well as agricultural waste throughout the year, especially during heavy rains in winter (Sept.-Dec.).

This study was part of our research on “The status of the Euphrates River in Anbar governorate.” The current study, on the assessment of drinking water quality, used a cross-sectional study design and was conducted in 11 selected regions throughout the governorate: Alqaam (R_1) Haditha (R_2), Baghdadi (R_3), Hit (R_4), North of Ramadi (R_5), South of Ramadi (R_6), Fallujah (R_7), Alwarar (R_8), Alwarar (R_9), Alhabanih (R_{10}) and Altherthar (R_{11}) (see Figure 1).

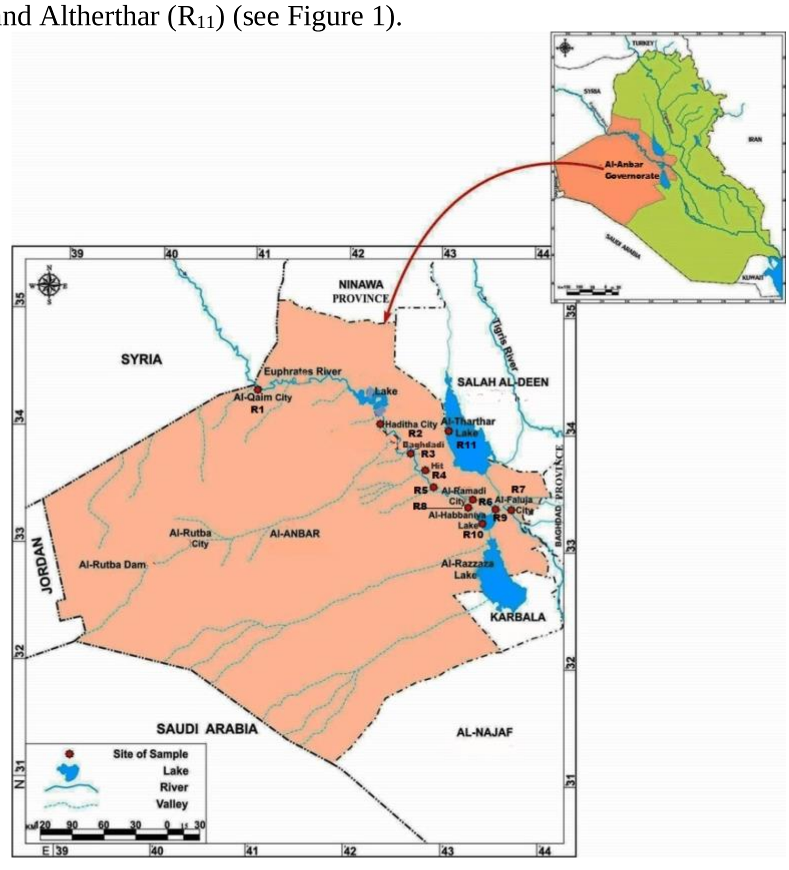

Figure 1: Location map showing sampling regions in Al-Anbar governorate

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3. Material and Method

To characterize water quality throughout the main basin of the river, eleven regions for monthly sampling were selected and marked, from Alqaam (R_1) to Altherthar (R_{11}). Regularly collected surface samples were collected in sterile plastic polyethylene bottles from January 2010 to December 2013 to undergo various physicochemical analyses.

Over four continuous years, various physical and chemical estimates were made. The test methods included in this research are listed in Table 1. The analyses of water quality parameters were done for all water samples to calculate the WQI using the standard analytical procedures as recommended by the CCMEWQI method.

Table 1: Analytical methods, samples were recorded in triplicate at 25°C

Parameters No.	Characteristics	Analytical method	Unit
1	Potassium (K^+)	Flame photometric	PPm
2	Sodium (Na^+)	Flame photometric	PPm
3	Calcium (Ca^{2+})	Ethylene diamine tetraacetic acid titrimetric	PPm
4	Magnesium (Mg^{2+})	Ethylene diamine tetraacetic acid titrimetric	PPm
5	Chlorides (Cl^-)	Tintometer	PPm
6	Nitrates (NO_3^-)	Tintometer	PPm
7	Sulphates (SO_4^{2-})	Tintometer	PPm
8	Turbidity (TUR)	Nephelometric Turbidity Units	-
9	pH	Electrode	-
10	Dissolved Oxygen (DO_2)	Electrode	PPm
11	Alkalinity (Alk)	Tintometer	PPm
12	Total hardness (TH)	Ethylene diamine tetraacetic acid titrimetric	PPm
13	Electrical conductivity (EC)	Conductivity meter	µS/cm
14	Total dissolved solids (TDS)	Conductivity-TDS meter	PPm

4. The classification system

4.1. The CCME Water Quality Index model

This index is combined of three factors (14):

F_1 represents the percentage of parameters, whose objectives are not achieved during the time period of interest.

$$F_1 = (\text{Number of Failed Variables/ Total Number of Variables}) * 100$$

F_2 the percentage of individual tests which do not achieve their objectives (“failed tests”)

$$F_2 = (\text{Number of Failed Tests/ Total Number of Tests}) * 100$$

F_3 represents the amount by which failed test values do not achieve their objectives and is calculated in three steps.

F_3 is then computed to give a value between 0 and 100

$$F_3 = \{nes/ (0.01\, nes+0.01)\}$$

Classification based on the CCME WQI of water quality was used to classify the Euphrates River water supplies examined in this study, as follows (14):

Category 1: Excellent 95–100: This is ideal water quality protected with an actual absence of threat to the user’s health.

Category 2: Good 80-94: Water quality is safe for lifetime use, rarely departing from natural or desirable levels and with only a minor degree of potential adverse health effects.
Category 3: Fair 65-79: Water quality is usually protected, but sometimes harmful health effects may become more common, especially with long-term use.
Category 4: Marginal 45–64: Water quality is often suitable for short-term or emergency use only, but it is unsafe for continuous use over a longer period.
Category 5: Poor 0-44: Water quality can pose a major human health risk even over with short-term use; water should be adequately treated to be used for drinking purposes.

5. Results and discussion

5.1. Physicochemical analyses

Drinking water quality assessment is a timely requirement among the emerging public health issues in this situation where the availability of safe water is at risk due to both natural and anthropogenic activities. This study conducted throughout the study area (Euphrates River) aimed at assessing drinking water quality by measuring multiple physico-chemical properties. Figures 2, 3, 4 and 5 show the physicochemical analysis of the water samples used to calculate the WQI from January to December over a four-year period, 2010-2013. The pH of the water may be affected by the mixture of CO_2 with HCO_3 [15]. PH values of water samples throughout the study area were in agreement with the standard values over a period of three years - 2010, 2012 and 2013. The obtained pH values ranged from 7.4-8.7 and thus it was found to be safe as drinking water. Nitrate concentrations in the river water was found to be from 1.5 to 7.8 ppm (Figure 2). Therefore, nitrate concentration (NO_3^-) in all of the samples was below WHO guidelines. High levels of nitrate and nitrite in drinking water may be associated with an adverse effect on health [16]. However, nitrate levels in all the collected samples did not pose a major problem of water quality [17].

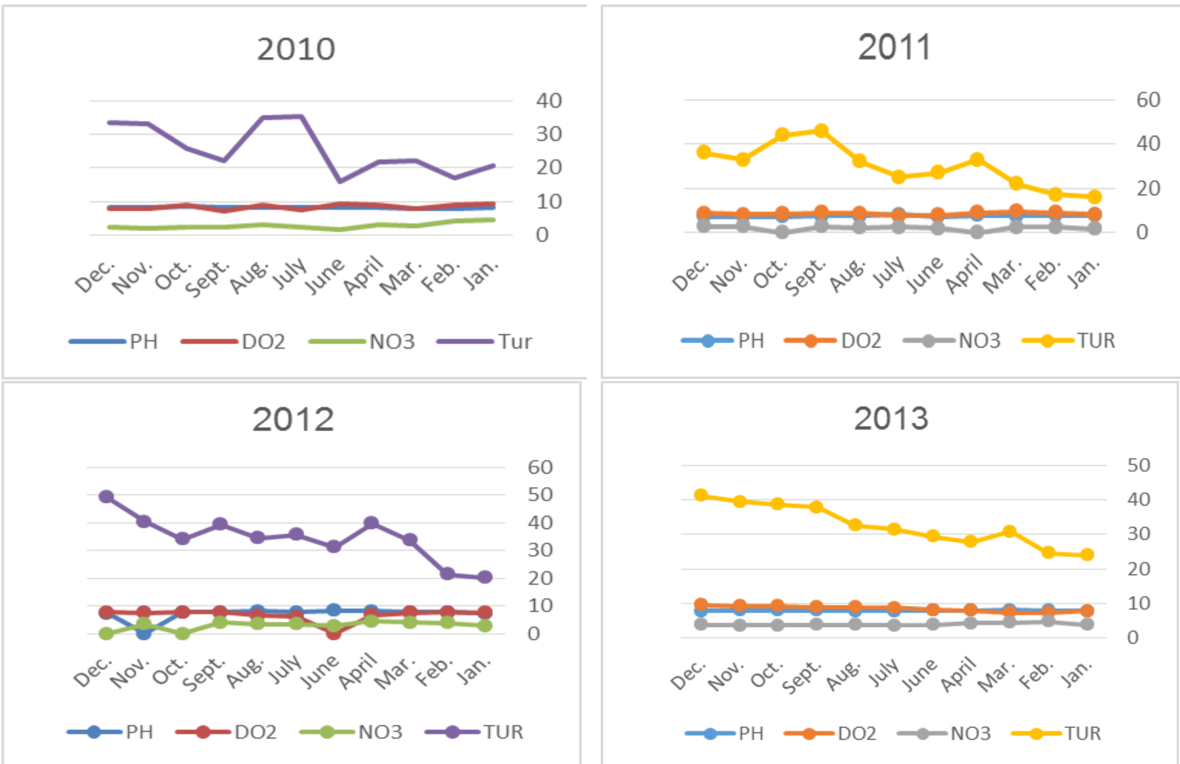

Figure 2: pH, DO_2, NO_3 and Tur of water sample collected during the study period
*DO_2 (Dissolved Oxygen)

Electrical conductivity is a measure of how readily a material transports electricity. In water, electrical conductivity is defined as the ability of water to conduct electricity. It is agreed that the maximum required for electrical conductivity in the water of the river is about 750 µS/cm. The range for total dissolved solids is 500 to 852 ppm (see Figures 3, 4, and 5). 500 ppm is the limit of total dissolved solids in drinking water set by the WHO [18]. Figure 3 shows that the calcium level was high, extending from 70 to114 ppm, while magnesium concentration in the river water was in the 23 - 59 ppm range. A certain level of magnesium and calcium in water sources are necessary to judge suitability for drinking and domestic purposes. Generally, water hardness is the amount of calcium, magnesium and other alkali earth metals dissolved in the water; the hardness value of water varies from 326 to 436 ppm (see Figure 4). Surface water is considered to be very hard if the hardness value is higher than 1000 ppm. Earth's alkalinity is due to the presence of magnesium and calcium as carbonate (CO_3^{2-}) forms. While the sodium concentration in the samples showed a range of 79 to 133 ppm, the average potassium concentration was 4.8 ppm (Figure 5).

The sulphate concentration can interact with different human organs when the sulphate level in drinking-water exceeds the acceptable limit of 200 ppm [18].

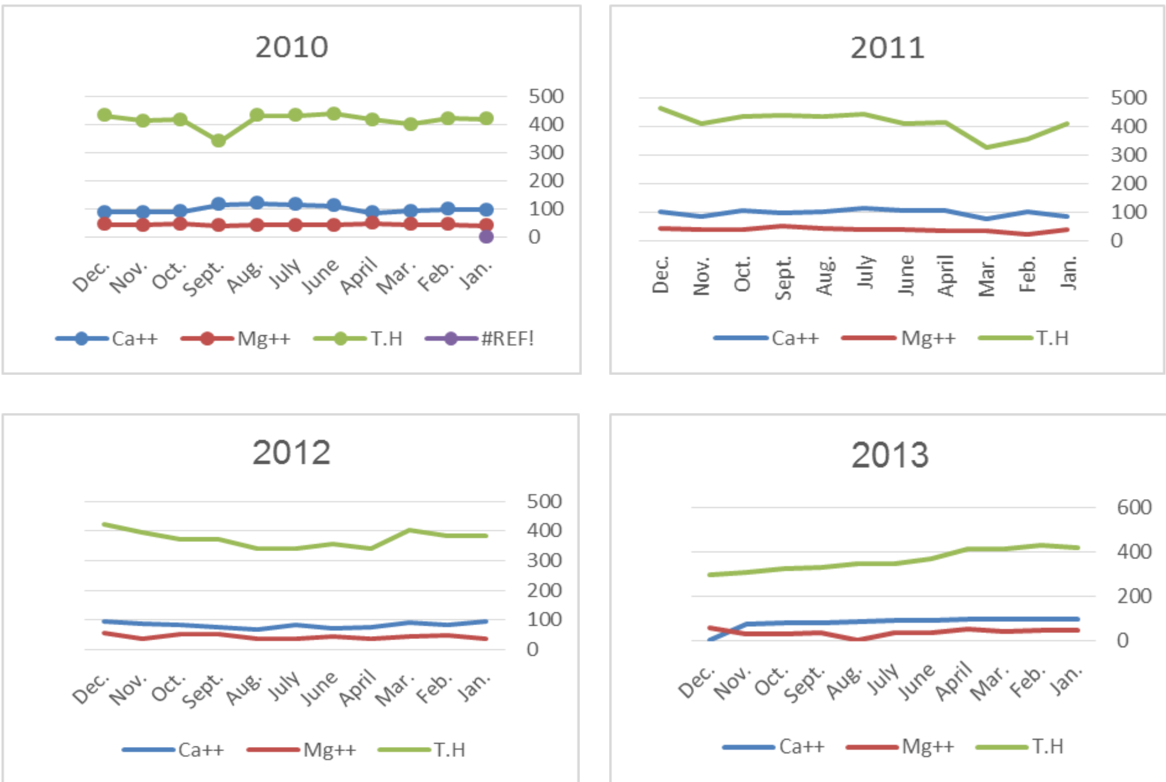

Figure 3: Ca, Mg and T.H values of water samples collected during the study period

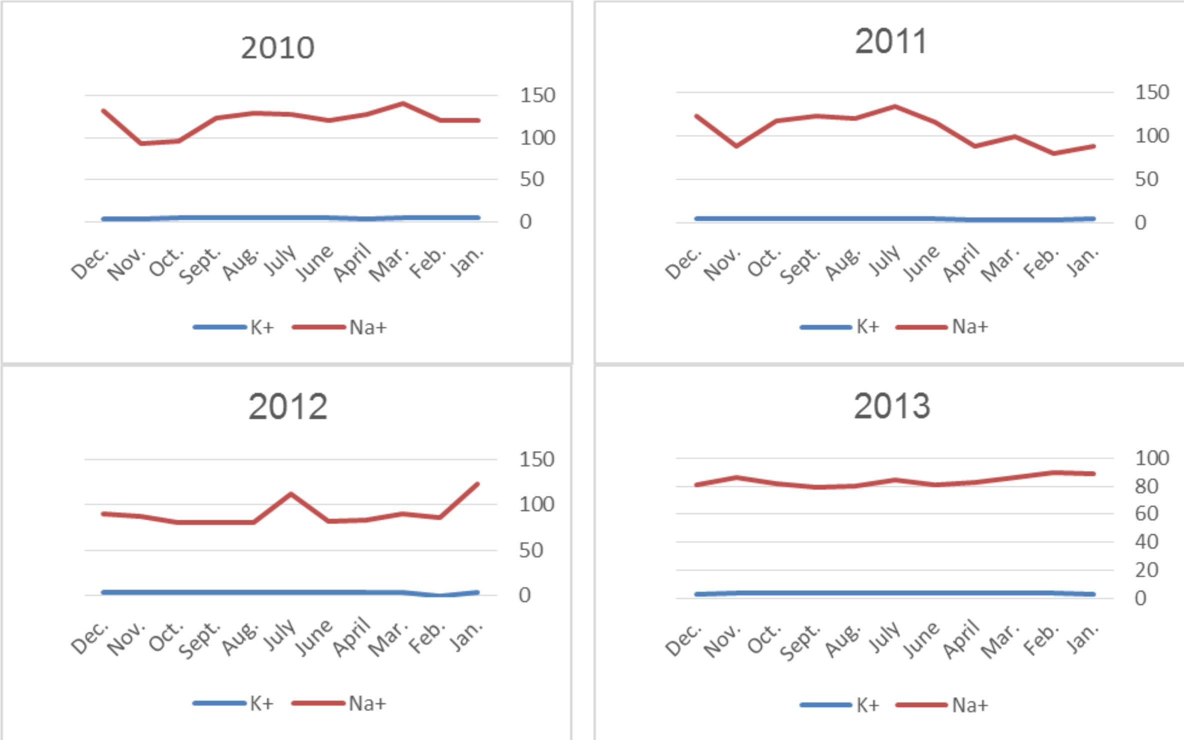

Figure 4: Na and K concentrations of water samples collected during the study period

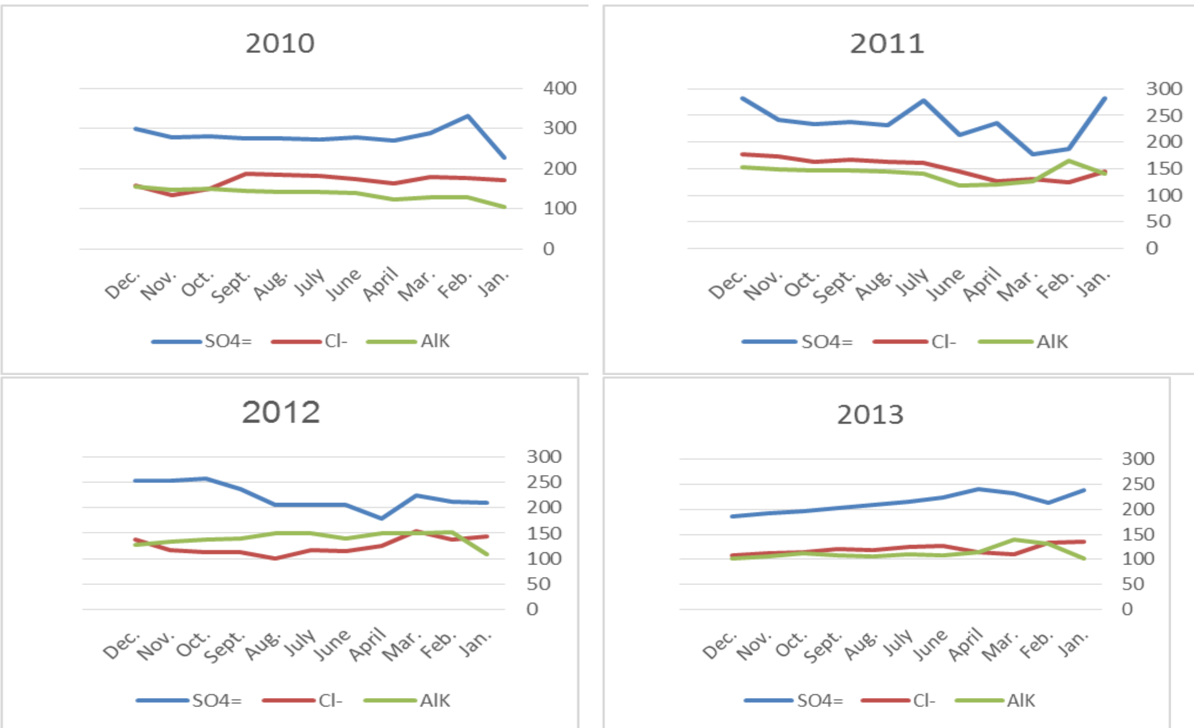

Figure 5: SO_4, Cl and Alk values of water samples collected during the study period

5.2. Temporal variation of WQI

Figure 6 presents the average water quality index in different seasons from water samples of the Euphrates in Al-Anbar Governorate from 2010 to 2013. Based on the WQI results, the quality varied from marginal during May and August to the fair during January, February, April, June, July, October and November. However, in September the results indicated that the quality was falling under the good category (see Figure 7). The WQI for all the sampling stations was rated as fair throughout the study period, while for March 2013 it was marginal. Almost all the WQI values fell within the fair category for the year 2011 due to an increase in electrical conductivity and total dissolved solids (TDS) level. During the study, it was observed that the quality of water was classified under category 3 in January, possibly as a result of decreasing alkalinity and nitrate ion levels. The high concentration of turbidity, electrical conductivity, total dissolved solids and sulphate ion during the summer season (June, July and August) usually causes low marginal water quality.

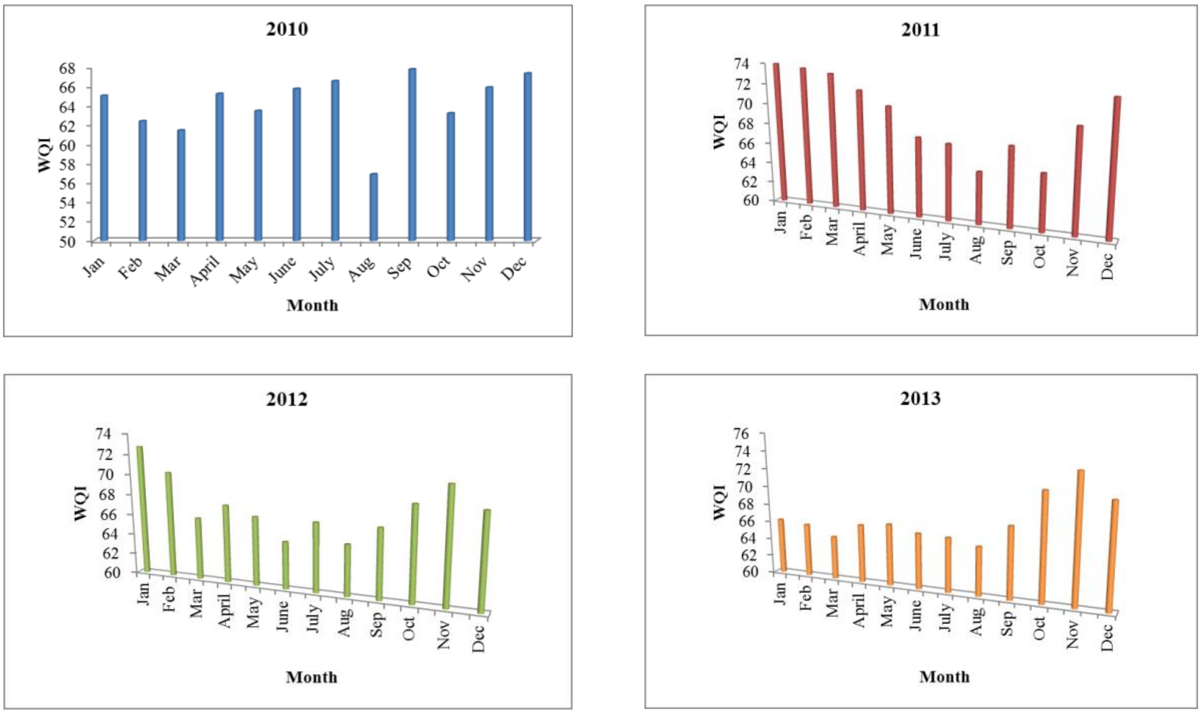

Figure 6: Temporal water quality variations of Euphrates River in the study area

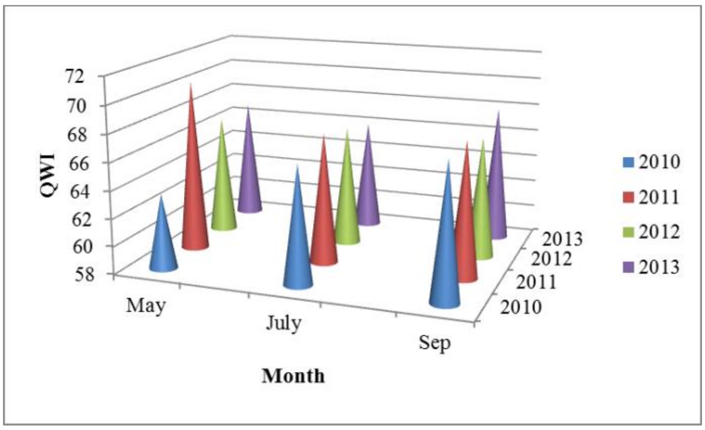

Figure 7: Temporal water quality variations of Euphrates River in the study area during May, July and Sept.

When the results from different seasons (winter, spring, summer and autumn) are compared, it is evident that there is a variation in the WQI (see Figure 8). This could be attributable to increasing electrical conductivity and total dissolved solids (TDS) level.

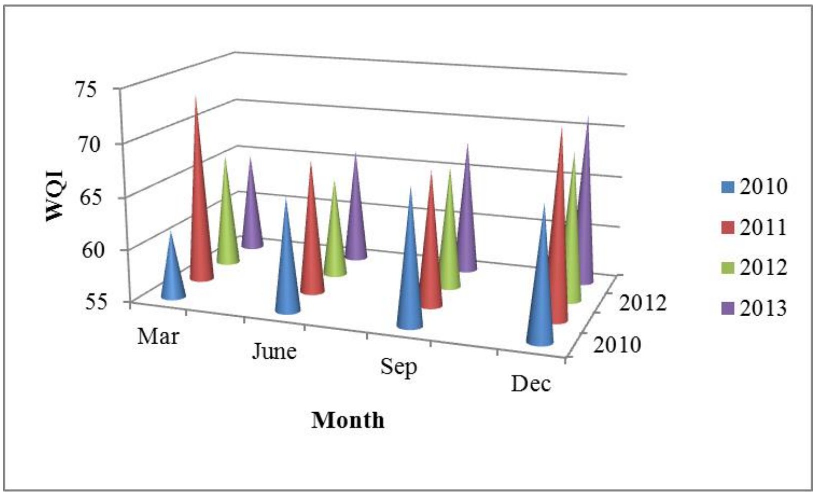

Figure 8: Temporal water quality variations of Euphrates River in the study area during different seasons

5.3. Spatial variation of WQI

The WQI and its spatial variation for all the sampling stations fluctuated between fair and marginal quality classes over the given study period (see Figure 9).

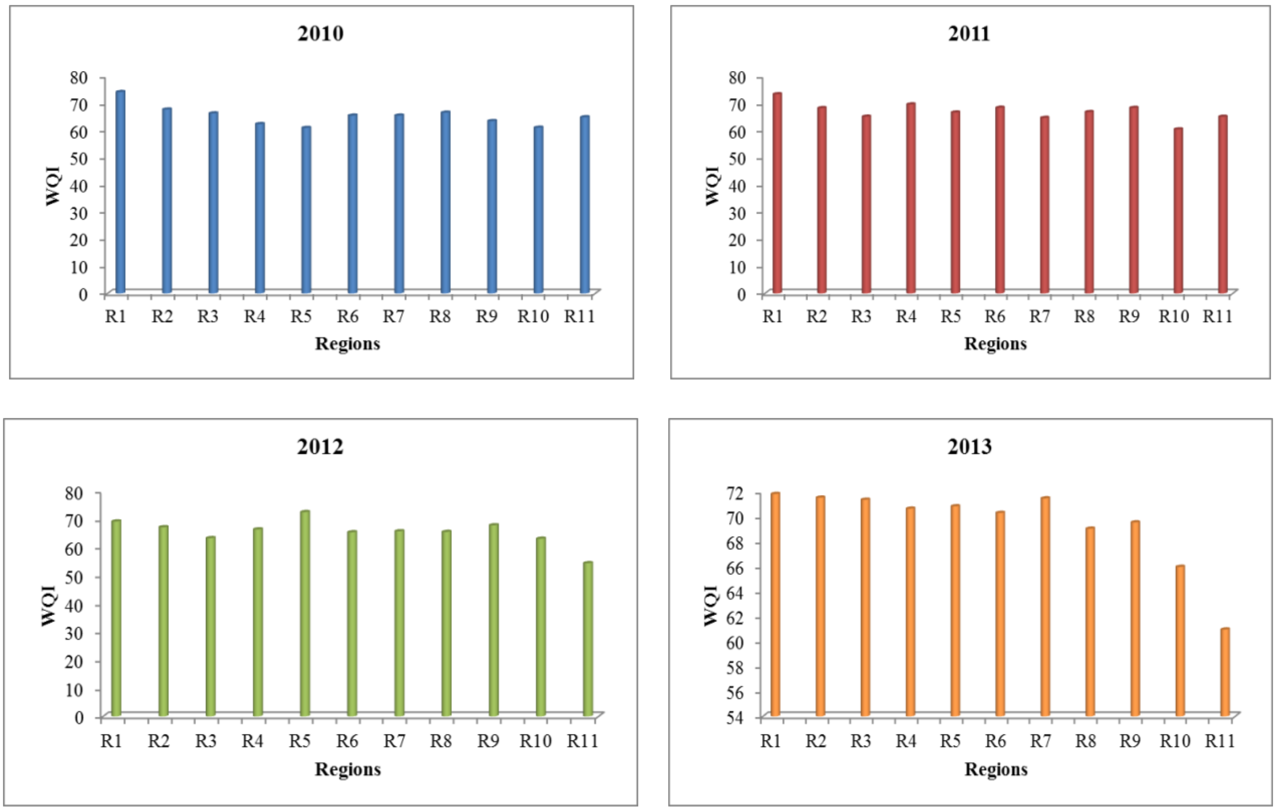

Figure 9: Spatial water quality variations of Euphrates River in the study area.

The WQI value decreases in downstream sampling regions compared with the upstream regions (Figure10). The minimum and upper values of the WQI were observed in R_1 and R_8 regions, respectively. The WQI values in R_8, located in Ramadi city, the largest urban centre of Al-Anbar Governorate, can be related to electrical conductivity, total dissolved solids, and magnesium and sulphate ion concentrations.

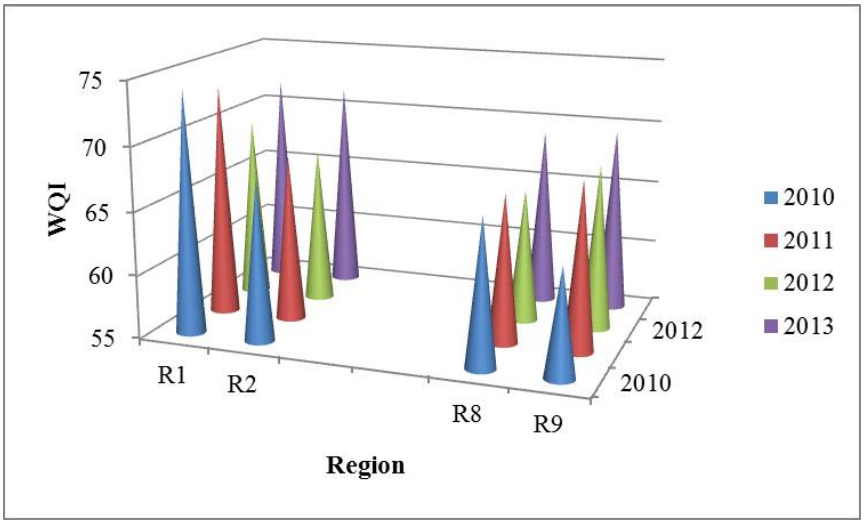

Figure 10: Spatial water quality variations of Euphrates River in the study area.

The classification of regions was fair to marginal in 2010 (Figure 10). Meanwhile, compared to the WQI for 2011, the data for all sampling stations were classified as fair, except R_{10}, which was marginal. The WQI was categorized as fair to marginal in 2012 (see Figure 10).

This work has aimed to assess, compare and judge the suitability of the study area in the Euphrates River for domestic water supply in urban and rural Anbar Governorate. According to the results, there was considerable disparity in the water quality data for the drinking water used to supply major urban and rural communities.

6. Conclusions

It is known that the water pollution level is increasing in the Euphrates River due to natural and man-made activities and is having an adverse effect on both aquatic life and public health. The main objective of this study, therefore, was to assess the status of drinking water quality in different areas of the Euphrates River throughout Al-Anbar Governorate. A total of 396 drinking water samples were collected from 11 regions. All the samples were analysed for 14 physicochemical parameters using standard procedures. The results show that the values of turbidity, total dissolved solids and electrical conductivity in some of the samples were higher than standard WHO values. This is evidence of pollution risks and poor drinking water. According to the CCME WQI, the WQI showed distinct upstream-downstream variation, the quality being 62 -74 and 63-69, respectively. Thus, for water from the Euphrates River to be consumed safely, it must receive sufficient treatment.

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