Water quality deterioration of the Euphrates River before entering Iraqi lands

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Abstract

Euphrates River passes through Turkey and Syria before Iraq. The aim of this research is to investigate whether the water quality of the river deteriorated before entering Iraq or not. The water quality of the river was represented by measuring nine parameters including: total dissolved solids, total hardness, sulfates, chlorides, calcium, magnesium, hydrogen power, electrical conductivity, and sodium adsorption ratio.

The change in water quality was determined by comparing measurements of 1998 and 2010. Paired *t*-tests were used to compare water quality parameters for the two years of measurements. These tests were repeated nine times for the nine water quality parameters of Euphrates River in Qaim Station (near the Iraqi–Syrian Border). The statistical decisions for these tests indicated that the deterioration of the quality of the river occurred when comparing the two years at a significant level of 0.01.

The classification and appropriate beneficial use of Euphrates River was determined using Bhargava water quality index. Water quality indices were calculated for irrigation, drinking and industrial uses for the two years. The classification of the river for irrigation use was reduced from *excellent* to *good* for 1998 and 2010 respectively. The classification of the river for drinking use was reduced from *good* to *polluted* for 1998 and 2010 respectively. For industrial use, the quality degraded from *acceptable* to *severely polluted* for 1998 and 2010 respectively. These results indicate that the waters of Euphrates River were polluted in Turkey and Syria before entering Iraq.
Keywords: Euphrates River, water quality index, paired t-test, Bhargava.

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1 Introduction

Euphrates River has its springs in the highlands of Eastern Turkey and its mouth at the Arabian Gulf (as shown in Figure 1). It has four tributaries which spring all from Turkey (El-Fadel *et al*. [1]).

The length of Euphrates River from its beginning in Turkey to its end in Iraq is about 3000 kilometers, of which 41% is in Turkey, 24% is in Syria, and 35% is in Iraq (Frenken [2]). The first station in Iraq, where the river passes, is Qaim Station, which is 0.713 km downstream from borders with Syria (Al-Bahrani [3]).

2 Euphrates water quality parameters

Nine water quality parameters were measured monthly in the Euphrates River at Qaim Station during the period of 1998 and 2010 (NCWRM [4]). These parameters were total dissolved solids (TDS), sulfates (SO_4^{-2}), total hardness as carbonates (TH), calcium (Ca^{+2}), magnesium (Mg^{+2}), chlorides (Cl^{-1}), hydrogen power (pH), electrical conductivity (EC), and sodium adsorption ratio (SAR).

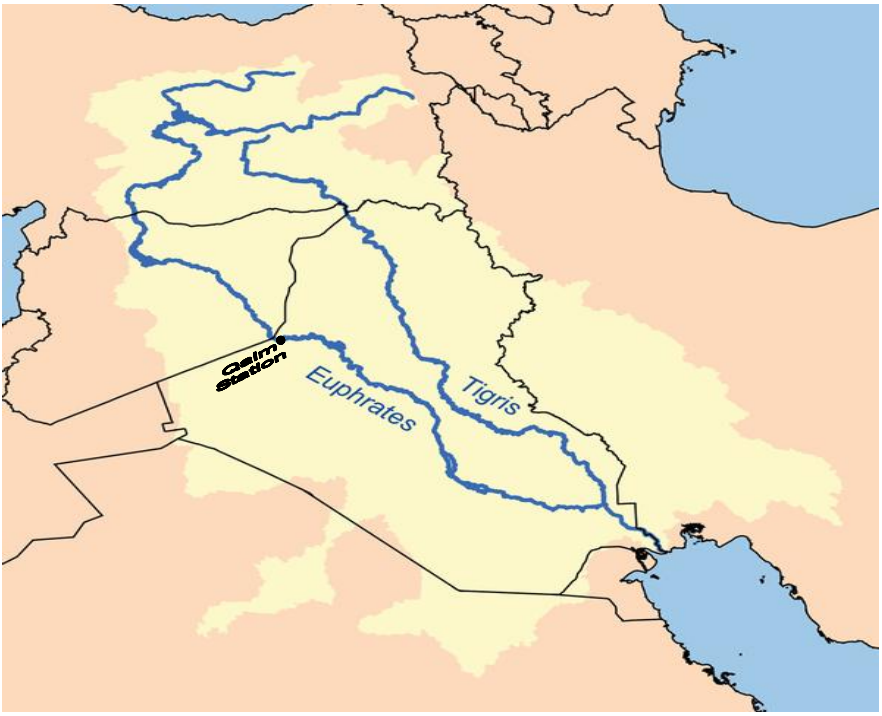

Figure 1: Path of Euphrates River.

It is indicated in Figure 2 that the monthly concentrations of these three water quality parameters (TDS, sulfates, and TH) are higher in 2010 than in 1998 for all months. In Figure 3, it is shown that the same thing happened for chlorides and magnesium, but for calcium the concentration in August 1998 was greater. In Figure 4, the monthly values of electrical conductivity (EC) and sodium adsorption ratio (SAR) were greater in 2010 than in 1998, but the behavior of hydrogen power (pH) is different where its monthly values began to reduce in 2010 to be close to 7 (neutral).

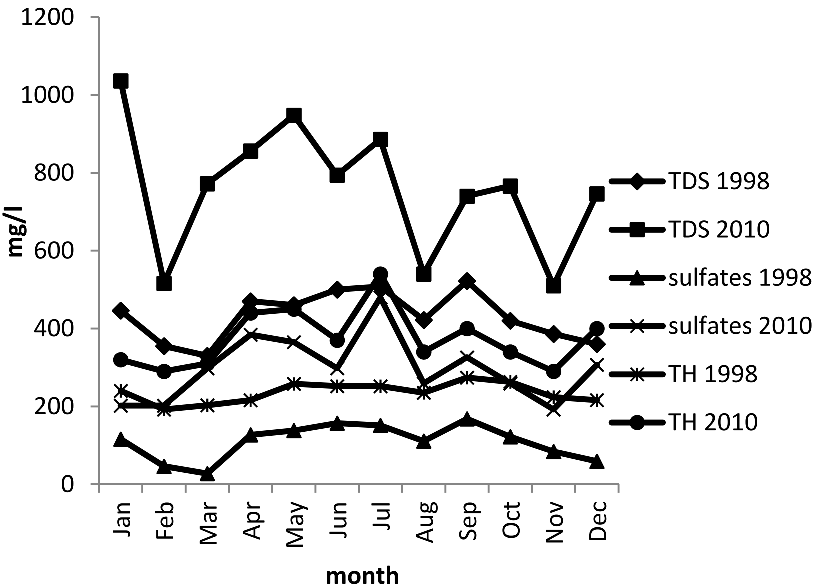

Figure 2: Monthly concentrations of total dissolved solids, sulfates, and total hardness for Euphrates River in Qaim Station for 1998 and 2010.

3 Paired *t*-test

This test supposes that the observations are ordered as pairs (X_i , Y_i) having the same length (n), which cannot be treated as independent variables. The four steps below illustrate this test (Abu-Salih and Awad [5] and Hogg and Craig [6]):

1) Determining the null hypothesis (H_0:μ_x=μ_y) corresponding to the alternative hypotheses (H_1: $\mu_x \neq \mu_y$), (H_1: $\mu_x > \mu_y$) or (H_1: $\mu_x < \mu_y$), where μ_x and μ_y are the arithmetic means of observations x_i and y_i subsequently.
2) Finding the test function:

$$T = \frac{\bar{D}}{S_D/\sqrt{n}} \tag{1}$$

where
$\bar{D}$ represents the arithmetic mean of difference $D_i = x_i - y_i$, S_D represents the standard deviation of the difference D_i, and n represents the length of the paired.

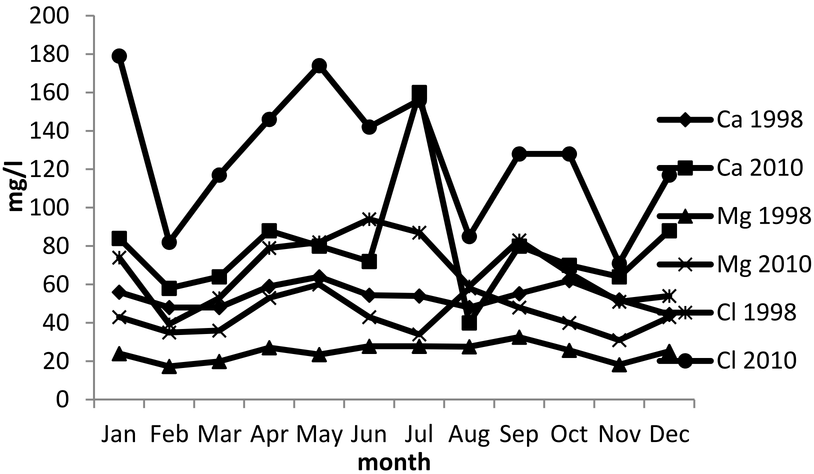

Figure 3: Monthly concentrations of calcium, magnesium, and chlorides for Euphrates River in Qaim Station for 1998 and 2010.

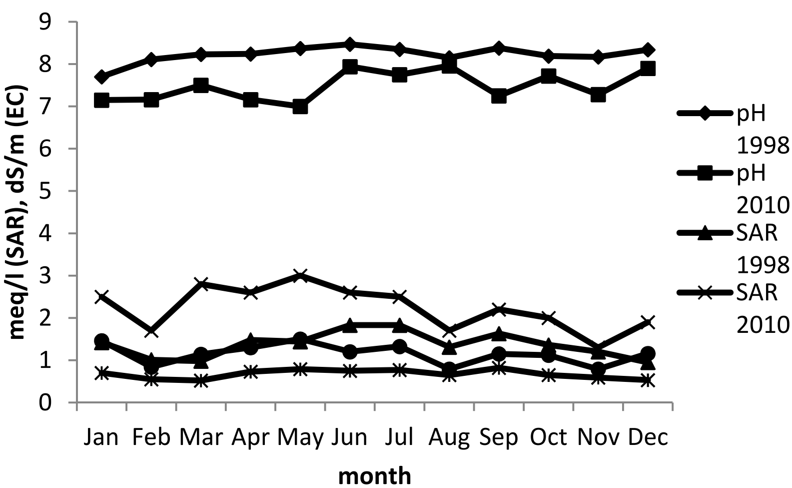

Figure 4: Monthly values of hydrogen power, sodium adsorption ratio, and electrical conductivity for Euphrates River in Qaim Station for 1998 and 2010.

$$S_D = \sqrt{\frac{\sum_{i=1}^{n}(D_i-\bar{D})^2}{n-1}} \quad (2)$$

3) Determining the tabulated value from *t*-distribution table at (n-1) degree of freedom, where the test function (T) submits to this distribution.
4) Adopting the statistical decision, either accepts the null hypothesis (H_0) or refuses it. The decision will accept the null hypothesis if the test function is located in a region of acceptance and will reject the null hypothesis if the test function is not located in a region of acceptance (as shown in Figure 5).

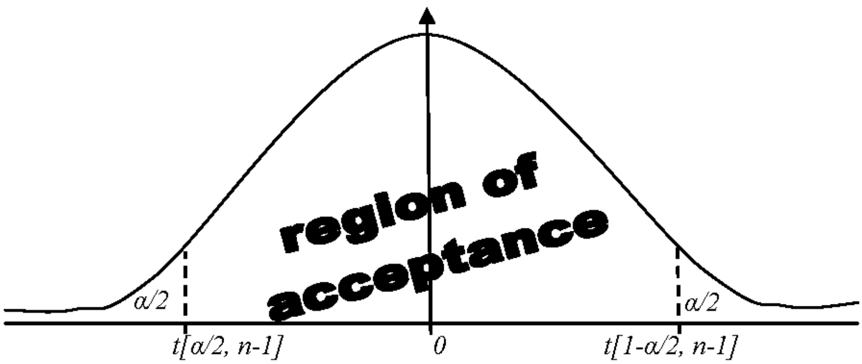

Figure 5: Region of acceptance in paired t-test.

This test was used nine times in this research so as to test the equality of water quality parameters of Euphrates River in Qaim Station between months of 1998 and 2010. Two hypotheses were proposed, null hypothesis (H_0:μ_{1998} = μ_{2010}) and alternative hypothesis (H_1: $\mu_{1998} \neq \mu_{2010}$), test functions were calculated for the nine water quality parameters and their absolute values were compared with tabulated value at (11) degree of freedom and (0.01) significant which is (3.106). The statistical decisions for these nine tests are illustrated in Table 1.

Table 1: Paired *t*-test for water quality parameters of Euphrates River in Qaim Station for 1998 and 2010.

Parameters	**Unit**	**|T|**	**t[0.995;11]**	**Decision**
TDS	mg/l	7.625	3.106	Refuse H_0
TH	mg/l	7.032	3.106	Refuse H_0
Sulfates	mg/l	8.730	3.106	Refuse H_0
Calcium	mg/l	3.072	3.106	Accept H_0
Magnesium	mg/l	7.962	3.106	Refuse H_0
Chlorides	mg/l	8.287	3.106	Refuse H_0
pH	unitless	7.509	3.106	Refuse H_0
EC	dS/m	6.224	3.106	Refuse H_0
SAR	meq/l	8. 257	3.106	Refuse H_0

4 Water quality index

The definition of the water quality index may be summarized as a unitless number on a scale from 0 to 100. The better the water quality, the higher the value of the index. Very clean water has an index of 100, and very polluted water has an index of 0 (Dojlido *et al.* [7]).

There are two main approaches for water quality index quantification – one based on *absolute sub-indices*, which are defined as the water quality formulas that their solution is independent of the water quality standard, and another water quality index is called *relative sub-indices*, which are formulas that their solution depends on the water quality standard (Khan *et al*. [8]).

The geometric mean formula was suggested by Bhargava as an absolute sub-index which expressed as:

$$WQI = \left[\pi_{i=1}^{n} \ fi\left(P_i\right)\right]^{1/n} \times 100 \quad (3)$$

where f_i (P_i) is the sensitivity function for each parameter including the effect of the parameter weight which is related to a certain activity and varies from (0–1), and n is the number of parameter (Bhargava [9]).

The geometric mean formula can easily deal with relative parameters for different uses by using sensitivity functions curves which take the value between zero to one. The nature of the sensitivity functions is determined by the impact of a change in the value of the parameter on water quality for irrigation, drinking, and industrial uses (as shown in figures 6–8). These curves are used to evaluate the quality of waters and give the importance of any parameter for a specific use; it also gives weight to every parameter. WQI according to Bhargava method is also used to classify waters into five groups (as shown in Table 2) and to determine the WQI for each use of different water activities depending on the parameters which affect water activity (Al-Bahrani *et al*. [10] and Mahdi [11]).

Water quality indices of Euphrates River in Qaim Station were calculated according to Bhargava method for irrigation, drinking, and industrial uses for 1998 and 2010. The water quality classification was found also for these three uses (as shown in Table 3).

It is noticed from Table 3 that there is deterioration in the water quality of Euphrates River in Qaim Station especially for drinking and industrial uses. The waters of the river degraded for drinking use from *good* to *polluted*, while it degraded for industrial use from *acceptable* to *severely polluted* for 1998 and 2010 respectively. The water quality of the river reduced for irrigation use from *excellent* to *good* for 1998 and 2010 respectively. This means that there is deterioration for the quality of Euphrates River before arriving in Iraq during the period from 1998 to 2010.

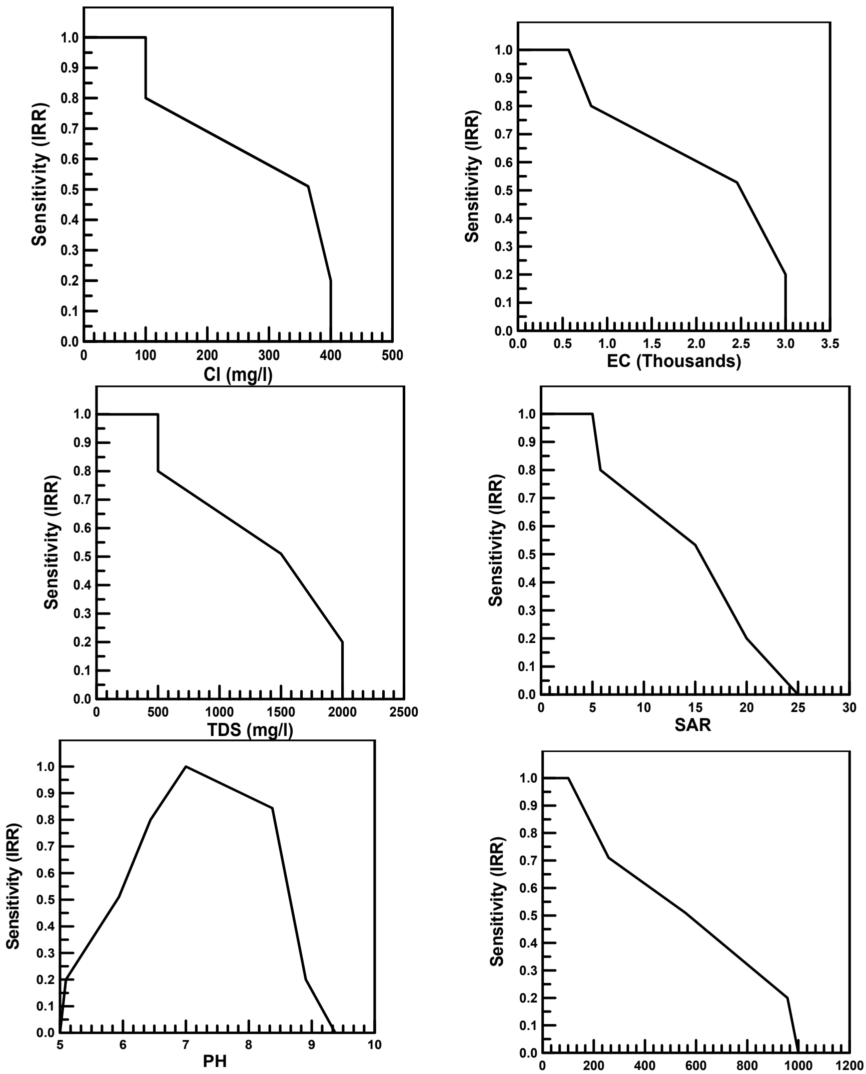

Figure 6: Sensitivity functions curves according to Bhargava for irrigation use (Bhargava [9]).

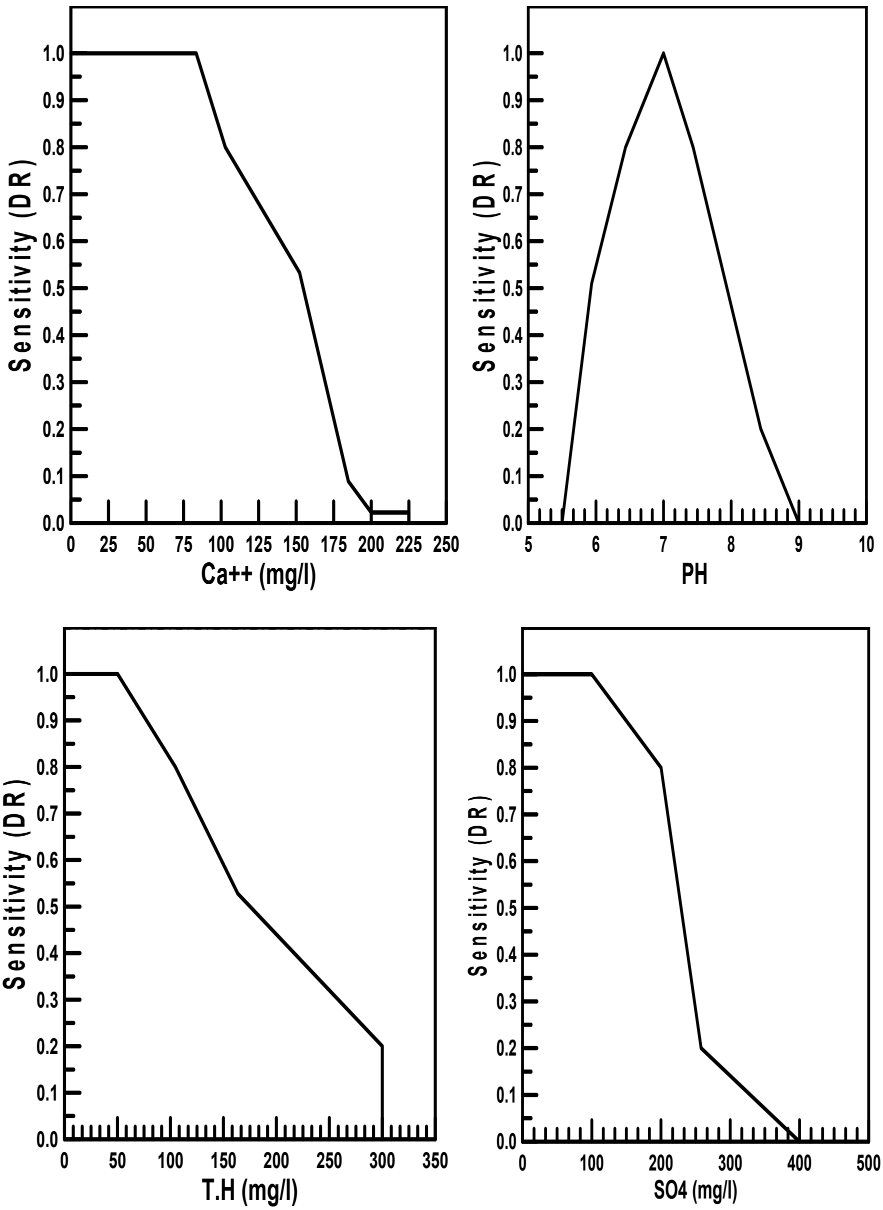

Figure 7: Sensitivity functions curves according to Bhargava for drinking use (Bhargava [9]).

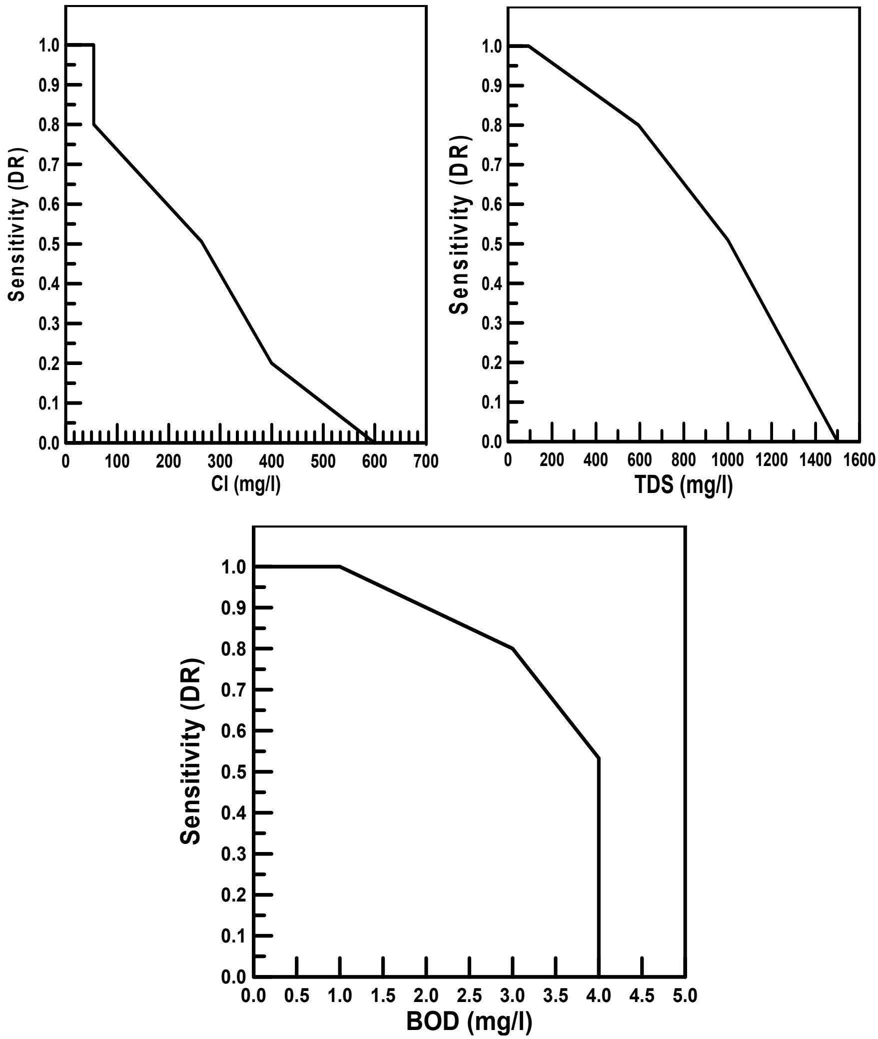

Figure 7: Continued.

Table 2: Water quality classification according to Bhargava method.

Class	WQI value	Water quality classification
I	100–90	Excellent
II	89–65	Good
III	64–35	Acceptable
IV	34–10	Polluted
V	Less than 10	Severely polluted

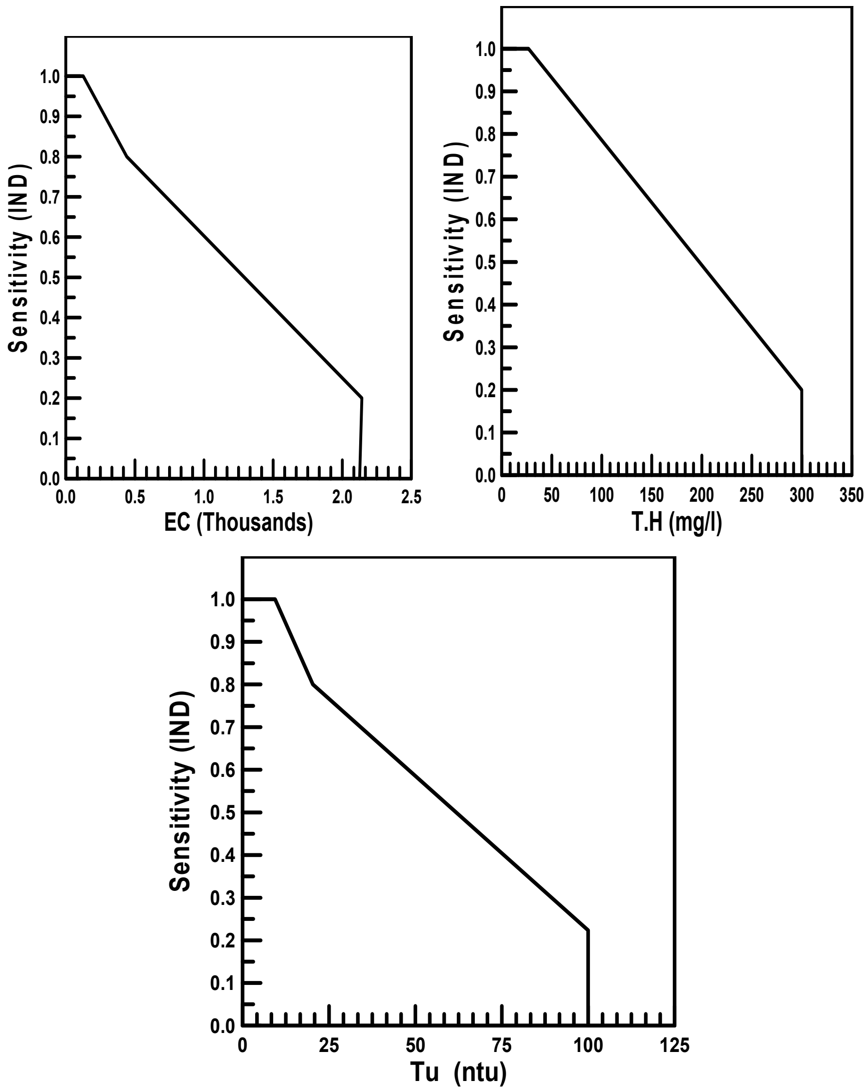

Figure 8: Sensitivity functions curves according to Bhargava for industrial use (Bhargava [9]).

Table 3: Bhargava water quality index for Euphrates River in Qaim Station.

Year	Irrigation use		Drinking use		Industrial use	
	WQI	classification	WQI	classification	WQI	classification
1998	94	excellent	69	good	53	acceptable
2010	81	good	30	polluted	8	severely polluted

5 Conclusions

It is noticed from this study that the waters of Euphrates River were polluted before arrival to Iraqi land. The comparison between measurement of water quality parameters of 1998 and 2010 indicated a real deterioration in water quality of Euphrates River. According to Bhargava water quality classification, the water appropriateness of Euphrates River for irrigation, drinking, and industrial uses were reduced and degraded in 2010 in comparison with 1998.

There are many reasons for this deterioration in the waters of the river during this period, such as dam construction along the river in Turkey and Syria, increasing municipal, industrial, and agricultural effluents in the river, and climate changes, which caused rainfalls reducing in Euphrates springs.

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