



Evaluating Raw and treated water quality of Greater Zab River within Erbil city by index analysis

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Abstract: *The present study is aimed at assessing the water quality index (WQI) for water samples from Greater-Zab river and the three water treatment plants (WTPs) on Greater Zab River, a tributary of Tigris River within Erbil city, Kurdistan region of Iraq, at Ifraz village. A water quality index provides a single number that expresses overall water quality at a certain location and time based on several water quality parameters. The objective of an index is to turn complex water quality data into information that is understandable and useable by the public. Thirteen most important parameters such as turbidity, pH, electrical conductivity, total dissolved solids, alkalinity, total hardness, calcium, magnesium, sodium, potassium, chloride, nitrate and sulfate were taken for calculation of WQI for a period of four years during 2009 to 2012. The WQI values for raw water sample of greater Zab River was 126.56 in 2009 and 264.10 in 2012; this means is poor and very poor for drinking purposes respectively. The result indicated that water quality index of three WTPs is good in 2009 and is excellent in 2012 in respect to drinking uses. The efficiency of WTPs for drinking purposes showed that Ifraz three is more efficient than Ifraz two and Ifraz two more efficient than Ifraz one. Most of the parameters analyzed in this study were within the guideline given by World Health Organization for drinking purposes while few others were not.*

Keyword: raw water, treated water, greater zab, river, erbil, city

I. Introduction

Water is super abundant on the planet as a whole, but fresh potable water is not always available at the right time or the right place for human or ecosystem use. The importance of water is underscored by the fact that many great civilizations in the past sprang up along or near water bodies. The development of water resources has often been used as a yardstick for socioeconomic and health status of many nations worldwide. However, pollution of waters often negates the benefits obtained from the development of these water resources [1]. It is well known that clean water is absolutely essential for several purposes for healthy living [2]. According to WHO organization, about 80% of all the diseases in human beings are caused by water [2]. Rivers are large natural stream of water emptying into an ocean, lake, or other bodies of water and usually fed along its course by converging tributaries. Although they contain only about 0.0001% of the total amount of water in the world at any given time, rivers are vital carriers of water and nutrients to areas all around the earth [3]. Rivers are the most important natural resource for human development but it is being polluted by indiscriminate disposal of sewage, industrial waste and plethora of human activities, which affects its physicochemical and microbiological quality. Increasing problem of deterioration of river water quality, it is necessary to monitoring of water quality to evaluate the production capacity [2]. [4] Suggested that the various water quality data could be aggregated into an overall index. Water quality index is well-known method as well as one of the most effective tools to expressing water quality that offers a simple, stable, reproducible unit of measure and communicate information of water quality to the concerned citizens and policy makers. It, thus, becomes an important parameter for the assessment and management of surface water. WQI is defined as a rating reflecting the composite influence of different water quality parameters. WQI is calculated from the point of view of the suitability of surface water for human consumption [5]. The objective of the present work is to apply the WQI tool to evaluate the historical changes in the water quality of Greater Zab River (Raw water & three Water Treatment Plants) during the period from 2009 to 2012. It must be mentioned that The Greater-Zab River (Bahdinan River) is the only source of surface water in Erbil city for drinking and other purposes. Three WTPs were constructed on this river at Ifraz village and to qualify the efficiency of their units.

II. Materials and Methods

A. Experimental Sites

Erbil province is the capital of Iraqi Kurdistan with about two million populations and situated in the northeast of Iraq. Its boundaries extended from longitude $43^{\circ} 15' E$ to $45^{\circ} 14' E$ and from latitude $35^{\circ} 27' N$ to $37^{\circ} 24' N$. [6]. The climate most closely to Irano-Turanian type. The annual rain fall may exceed 1000 mm. The average rain fall in Erbil city is 440 mm. Erbil city is currently served by two types of water resources[7].

The Greater-Zab River (Bahdinan River) is the only source of surface water in Erbil city for drinking and other purposes [8]. Three WTPs were constructed on this river at Ifraz village (figure 1).

The upper or grater Zab River together with Rawanduz river are the only source of surface water available for supplying water for drinking and other purposes. The Greater Zab originates in Turkish Kurdistan and is partly regulated by the Bekhma dam. Its length is 392 Km from the source to Almakhlut village in south of Mosul [9]. Three Water treatment plants (WTP) have been constructed with intake of raw water from this river at Ifraz village [9]:

Ifraz 1 (conventional WTP) constructed in 1968 with design capacity of 38400 m³/day. This is an old WTP and most treatment units in this plant are in poor condition which requires repair and good maintenance (9).

Ifraz 2 constructed in 1985 with a design capacity of 69000m³/day. Currently it supplies about 44000 m³/day [9].

Efraz 3 constructed in 2006 with a design capacity of 144000 m³/day.

The treatment processes in these plants includes four main steps; screens, sedimentation (coagulation and flocculation) filtration and chlorination [9].

B. Sample Collection and Analysis

Historical Drinking water from three WTPs is continuously analyzed in monthly in General Directorate of Water & Sewerage Quality Assurance – Drinking Water Quality Control dep. Laboratory division/ Erbil in the years 2009, 2010, 2011 and 2012. Also, seasonally water samples were collected from the Greater Zab River (Raw water) during January 2009 to August 2012 and analyzed following methods outlined in the Standard Method for Examination of Water and Wastewater [10]. The following water quality parameters were determined which were chosen as the major indicators namely turbidity, pH, electrical conductivity, total dissolved solids, alkalinity, total hardness, calcium, magnesium, sodium, potassium, chloride, nitrate and sulfate

C. Water Quality Index

For computing water quality index three steps are followed as.

In the first step, each of the 13 parameters has been turbidity, pH, electrical conductivity, total dissolved solids; alkalinity, total hardness, calcium, magnesium, sodium, potassium, chloride, nitrate and sulfate assigned a weight (wi) according to its relative importance in the overall quality of water for drinking purposes. The maximum weight of 5 has been assigned to parameters like pH, sulfate and nitrate due to their major importance in water quality assessment. The parameters like turbidity, pH, electrical conductivity, total dissolved solids, alkalinity, total hardness, calcium, magnesium, sodium, potassium, chloride, nitrate and sulfate were assigned a weight between 1 and 5 (table 1) depending on their importance in the overall quality of water for drinking purposes [11].

In the second step, the relative weight (Wi) is computed using a weighted arithmetic index method given below in the following steps [4]:

$$RW = \frac{\sum_{i=1}^n w_i}{\sum w_i} \text{-----} 1$$

Where, Wi is the relative weight, wi is the weight of each parameter, n is the number of parameters.

In the third step, a quality rating scale (qi) for each parameter except pH was assigned by dividing its concentration in each water sample by its respective standard according to the drinking water guideline recommended by the [12] and the result is multiplied by 100:

$$Q_i = (C_i/S_i) \times 100 \text{ -----2}$$

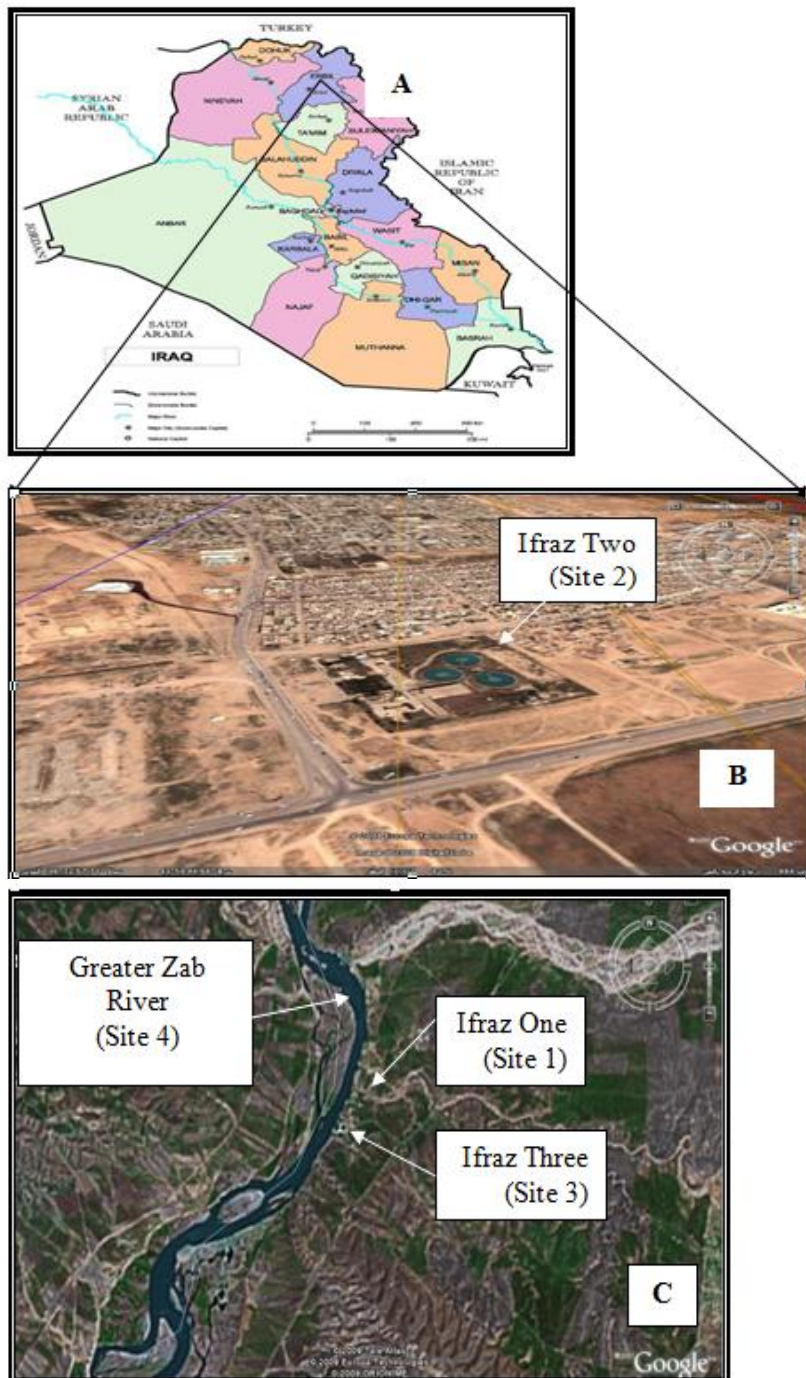


Figure (1): A-Shows map of Iraq within Erbil city.
 B-Shows Ifraz Two (WTP)
 C-Shows Ifraz One & Ifraz Three (WTPs) and raw water (Greater Zab River)

$$Q_{pH} = [C_i \times V_i / S_i \times V_i] \times 100 \text{ -----3}$$

Where, Q_i = the quality rating, C_i = value of the water quality parameter obtained from the laboratory analysis, S_i = value of the water quality parameter obtained from recommended WHO or Iraqi standard of corresponding parameter, V_i = the ideal value which is considered as 7.0 for pH.

Equations 2 and 3 ensures that $Q_i = 0$ when a pollutant is totally absent in the water sample and $Q_i = 100$ when the value of this parameter is just equal to its permissible value. Thus the higher the value of Q_i is, the more polluted is the water [13].

Finally, for computing the WQI, the sub indices (SI_i) were first calculated for each parameter, and then used to compute the WQI as in the following equations:

$$SI_i = W_i \times Q_i \text{ -----4}$$

$$WQI = \sum SI_i \text{ -----5}$$

The computed WQI values could be classified as <50 = Excellent; $50.1-100$ = Good;

$100.1-200$ = Poor; $200.1-300$ = Very poor; >300 = Unsuitable described in [14].

Table I WHO standards weight (w_i) and calculated relative weight (Wi) for each parameter.

Parameters	Unit	Water quality standard	Weight (w_i)	Relative Weight (Wi)
Turbidity	NTU	5	3	0.090909
pH		6.5-8.5	4	0.121212
EC	$\mu\text{S}/\text{cm}$	1000	3	0.090909
TDS	mg/L	500	3	0.090909
Alkalinity	mgCaCO_3/L	200	1	0.030303
T. Hardness	mgCaCO_3/L	200	2	0.060606
Calcium	mg/L	100	2	0.060606
Magnesium	mg/L	30	2	0.060606
Sodium	mg/L	200	1	0.030303
Potassium	mg/L	10	1	0.030303
Chloride	mg/L	250	2	0.060606
Nitrate	mg/L	50	5	0.151515
Sulfate	mg/L	250	4	0.121212
			$\sum w_i = 33$	$\sum Wi = 1$

III. RESULTS AND DISCUSSION

The average of the main physical and chemical properties (turbidity, pH, electrical conductivity, total dissolved solids; alkalinity, total hardness, calcium, magnesium, sodium, potassium, chloride, nitrate and sulfate) of water samples from Greater-Zab river and the three WTPs were given in Tables (II, III, IV and V).

Turbidity of water samples after treatment at the three WTPs were ranged from (1.7-6.2), were lower value recorded in Ifraz three during 2011 and higher values calculated in Ifraz one during 2009, this may be related to the efficiency of the treatment units and the raw materials that used in each treatment plant.

Values of pH of Greater Zab River water (7.4-7.8) and in WTPs (7.1-7.5) samples were within WHO acceptable limit [12], making it marginal for irrigation and drinking purposes.

Values of EC of water samples from selected sites were (347-580 $\mu\text{S}/\text{cm}$) lower than the acceptable level recommended by [12]. The level of TDS was from 187 to 289 mg/L and was all lower than the acceptable level (500 mg/L). TDS is a measure of all the chemical constituents dissolved in water, it is mostly influenced by the concentration of major ions; calcium, bicarbonate, magnesium, sulfate and chloride and it is closely linked to the EC [15]. The results obtained by water surveys conducted in this investigation showed that total hardness values were often higher than the minimal permissible level recommended by the WHO for drinking water. The observed values of alkalinity were slightly within the permissible level recommended by the WHO for drinking water.

Concentration of Ca^{+2} , Mg^{+2} , Na^{+} , K^{+} and Cl^{-} in water samples for water samples from Greater-Zab river and the three water treatment plants (WTPs) which ranged between 44-69, 6.6-40.5, 2.6-8.0, 0.7-1.7 and 6.6-12.8 respectively. The concentration of the ions mentioned above was all lower than MCL suggested by [12].

Maximum contaminant level (MCL) of NO_3^{-} according to [12] is 50 mg/L. The maximum value of NO_3^{-} in drinking water samples after treatment in Ifraz 1, Ifraz 2 and Ifraz 3 were 9.6, 15 and 10 mg/L respectively were lower than the acceptable level for drinking purposes according [12]. Source of NO_3^{-} in surface water is runoff from fertilized use, leaching from septic tanks, sewage and erosion of natural deposits [15].

The concentrations of sulfate of this survey varied from (33.7-111mg/L) were within the acceptable level for drinking purposes according to [12].

The values of WQI very much depend upon the value of turbidity & pH in water. The lower value of turbidity in water, the clearer the water. The value of turbidity at the sampling site of WTPs is lower than 6.2 NTU except water sample in Greater Zab River is reach to 130NTU. On the basis of the WQI, the quality of the water is categorized from very bad to excellent [14].

Applying the former equations on the results of water analysis data of Greater Zab River, annual WQI (Raw and Treated) have been described in (table 6). Spatial profiles of the results showed that, for raw water, none of the samples are coming neither under "Excellent" (< 50) nor "Good" (range 50.1-100) water quality, indicating that the Greater Zab River water is generally "Poor" (range 100.1-200) or "Very poor" (range 200.1-300) during this study. This may reflect the effect of pollution from urban wastes and anthropogenic activities. On temporal basis, the WQI values for raw water were highly increased in the two years (2010-2011). The effect of dryness in the area in the last four years might be behind the clearly observed depletion of WQI throughout this period

Nevertheless, for spatial profiles of treated water, none of the samples are classified as "poor" or "very poor". The results showed "Good" to "Excellent" quality in all WTPs. As for temporal trend, water quality was generally "Good to excellent in Ifraz one and excellent in Ifraz two and three (Table Vi), is obvious from this classification that on the basis of the WQI, three WTPs from the study area is of acceptable quality for human consumption.

Comparing the level of turbidity before and after treatment (tables 2, 3, 4 and 5) at each WTP, we found that the efficiency of treatment units at the three WTP were in the order; Ifraz 3 > Ifraz 2 > Ifraz 1. It means that treatment units in Ifraz 1 are inefficient and more turbid when it compare with Ifraz 2 & 3. Because Ifraz 1 is an old project (constructed at 1969), it needs repairing and reconstruction. Although Turbidity has no health effect but it can interfere with disinfection and provide a medium for microbial growth it may indicate the presence of microbes.

For both raw and treated water, the phenomenon of water quality degradation along Greater Zab River was generally evident throughout the four years results. Therefore, the authorities should practice more efforts in controlling various activities along the river bank. The urgent water management rules should be applied, enforcing waste-water treatment systems among the factories and other activities.

In this paper the application of water quality index approach to for water samples from Greater-Zab river and the three water treatment plants (WTPs) on Greater Zab River, a tributary of Tigris River within Erbil city, Kurdistan region of Iraq, at Ifraz village. Had the purpose of providing a simple, valid method for expressing the results of several parameters in order to assess the water quality.

Assembling different parameters into one single number leads an easy interpretation of index, thus providing an important tool for management purposes [16].

Efficiency (E%) of the Water Treatment Plants situated at Greater Zab River was calculated by determining the WQI of the raw water and treated water supplied by using the formula given below:

$$E\% = \frac{\text{WQI of raw water} - \text{WQI of treated water}}{\text{WQI of raw water}}$$

Table (VII) represents the efficiency of the water treatment plant situated at Erbil City, it has been concluded that the raw water is poor and very poor in quality throughout the period of study, as the efficiency of WTPs range from 57.39.07 to 84.29 in the whole period of study. This means the efficiency of WTPs in Erbil city are fair in 2009 and very good in 2012.

Strict measures should be applied in order to control the levels of pollutants discharged into Greater Zab River from different kinds of point and nonpoint sources

IV. CONCLUSION

There are some limitations of WQI. For instance, WQI may not carry enough information about the real quality situation of the water. Also many uses of water quality data cannot be met with an index. But there are more advantages of WQI than disadvantages. An index is a useful tool for "communicating water quality information to the public and to legislative decision makers;" it is not "a complex predictive model for technical and scientific application" [17]. As WQI for four years were compared, it was found that the water was almost clear throughout the sampling time in WTPs. The WQI for the WTPs samples ranges from 43.409 in Ifraz three during 2011 to 54.084 in Ifraz one during 2009. All the water treatment plants samples estimated using the water quality index fall in the good water to excellent class and are all suitable for drinking purposes.

But was observed WQI for Greater Zab River ranged from 126.956 to 285,555 and therefore can be categorized into "poor water" and "very poor water, this means that the water is very much turbid and it is contain any impurities. The results from data analysis show that river water samples on Greater Zab River are certainly unsafe for drinking purposes without any form of treatment.

Table II Physical and chemical properties of water samples from Greater Zab River during study period

Year Parameters	2009	2010	2011	2012
Turbidity	39.2	130	125	122
pH	7.8	7.6	7.9	7.4
EC	424	480	467	552
TDS	212	240	234	277
Alkalinity	187	165	185	151
Hardness	258	215	236	201
Calcium	65.8	60	57	65
Magnesium	31.5	16	25	9
Sodium	5.3	7.1	8.0	7.5
Potassium	1.6	1.2	1.7	1.0
Chloride	9.5	7.8	12.8	6.6
Nitrate	7.9	8.1	6.3	9.9
Sulfate	73.2	71	78	68

Table III Physical and chemical properties of water samples from Ifraz one during study period

Year Parameters	2009	2010	2011	2012
Turbidity	6.2	2.5	2.2	2.2
pH	7.7	7.4	7.5	7.4
EC	392	416	426	543
TDS	196	213	213	274
Alkalinity	195	155	166	145
Hardness	200	227	230	209
Calcium	69	61	56	62
Magnesium	6.6	17.5	21.7	12.6
Sodium	5.6	7.5	5.7	4.9
Potassium	1.1	1.0	0.9	0.7
Chloride	9.0	11.3	9.0	7.4
Nitrate	9.5	4.8	6.1	9.6
Sulfate	33.7	52.8	52.6	70.9

Table IV Physical and chemical properties of water samples from Ifraz two during study period

Year Parameters	2009	2010	2011	2012
Turbidity	4.3	2.3	2.0	2.1
pH	7.4	7.5	7.5	7.4
EC	419	402	419	540
TDS	210	201	210	270
Alkalinity	191	166	164	147
Hardness	244	218	223	198
Calcium	67	60	49	60
Magnesium	18.4	16.9	23.9	11.8
Sodium	5.0	7.1	5.5	6.0
Potassium	1.0	0.9	0.9	0.8
Chloride	9.0	11.0	10.0	6.8
Nitrate	15.0	4.1	8.0	12.6
Sulfate	66.4	60.0	46.0	59.3

Table V Physical and chemical properties of water samples from Ifraz three during study period

Year Parameters	2009	2010	2011	2012
Turbidity	4	2.0	1.7	2.0
pH	7.2	7.6	7.3	7.2
EC	347	434	413	580
TDS	187	217	206.5	289
Alkalinity	138	171	167	149
Hardness	246	229	220	217
Calcium	44	54	52	61
Magnesium	40.5	21.9	21.5	15.6
Sodium	2.6	6.3	6.2	5.7
Potassium	1.4	1.4	0.9	0.7
Chloride	11.0	10.8	9.5	7.0
Nitrate	5.0	5.9	7.3	10.0
Sulfate	111.0	50.6	44.0	66.7

Table VI Water Quality Index for Greater Zab River and three WTPs during the studied period

Year Water sample	2009	2010	2011	2012
Greater Zab River	126.956 Poor	285.555 Very poor	280.007 Very poor	264.102 Very poor
Ifraz one	54.084 Good	51.249 Good	45.614 Excellent	45.707 Excellent
Ifraz two	49.828 Excellent	48.808 Excellent	43.983 Excellent	44.690 Excellent
Ifraz three	43.999 Excellent	47.558 Excellent	43.409 Excellent	43.544 Excellent

Table VII Efficiency of the water treatment plants

Years WTPs	2009	2010	2011	2012
Ifraz one	57.39	82.05	83.70	82.69
Ifraz two	60.75	82.90	84.29	83.07
Ifraz three	65.34	83.34	84.29	83.51

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