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Evaluation the Quality of Raw and Treated Water for Number of Water Treatment Plants in Baghdad, by Using Canadian Model for a Water Quality Index

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Abstract

Laboratory tests on some physical and chemical properties were conducted to evaluate the quality of drinking water on some water treatment plants in Baghdad (Al-Qadisiya, Al-Dora, Al-Wahda and Al-Rasheed), these samples were taken from raw and treated water. The measurements of taken every month and for eight years in order to evaluate the drinking water quality and efficiency of these plants. The quality of drinking water was calculated by using Canadian model index (Canadian Council of Ministers of the Environment) in water quality evaluation, as contributed thirteen variables in the index calculation: the temperature of the water, turbidity, pH, total hardness (as CaCO3), magnesium, calcium, sulfate, iron mg/L, fluoride, Nitrate, chloride, color, conductivity. The samples were taken from the treated water effluent from 2005 to 2013. The study showed that the range of water quality index for the raw water is (49-54) and can be classified as a bad water and it's needing advanced treatment, while the water quality index of treated water was (77,78, 70, 67) for (Al-Qadisiya, Al-Dora, Al-Wahda and Al-Rasheed) respectively. Therefore, the water quality index of treated water of (Al-Qadisiya, Al-Dora, Al-Wahda and Al-Rasheed) can be classified within the third category (moderate).

***Keywords*: **Canadian water quality index, raw water, treated water.

تقييم نوعية المياه الخام والمياه المعالجة لعدد من محطات المعالجة في مدينة بغداد، باستخدام مؤشر نوعية المياه الكندي

الخلاصة

اجريت العديد من التجارب لتقييم نوعية مياه الشرب في بعض محطات الاسالة وهي (القادسية، الدورة، الوحدة و الرشيد) في مدينة بغداد، هذه النماذج تم اخذها من الماء الخام والماء المعالج وأجريت بعض الفحوصات الفيزيائية والكيميائية المأخوذة شهريا ولمدة ثمان سنوات لغرض تقييم نوعية مياه الشرب وكفاءة اداء هذه المحطات. تم حساب نوعية مياه الشرب باستخدام مؤشر نوعية المياه الكندي وذلك باستعمال ثلاثة عشر متغير في حساب هذا الدليل وهذه المتغيرات هي : درجة الحرارة مْ ، الكدرة NTU، الدالة الحامضية، العسرة الكلية، المغنيسيوم، الكالسيوم، الكبريتات ، الحديد، الفلورايد، النترات، الكلورايد، اللون، والتوصيلية الكهربائية. أخذت هذه النماذج للفترة من 2005 الى 2013، وقد بينت هذه الدراسة ان مدى مؤشر نوعية المياه للماء الخام (نهر دجلة) يتراوح بين (49 - 54) والذي يمكن تصنيفه على انه ماء رديء ويحتاج الى معالجة متقدمة، في حين كان مؤشر نوعية المياه للماء المعالج (77، 78، 67،70) للمحطات (القادسية والدورة والوحدة والرشيد) على التوالي، لذا يمكن تصنيف هذه المياه ضمن الصنف الثالث (معتدل) من التصنيف المعلن من قبل وزارة البيئة الكندية.

***الكلمات الدالة*:** مؤشر نوعية المياه الكندي، المياه الخام، المياه المعالجة.

Introduction

Different water sources are suffering at the present time to a large contaminated as a result of the large increase in population and industrial and agricultural expansion and the lack of proper planning in building cities, which led to doubling the amount of wastes entering these sources of water. So water

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quality monitoring program has become necessary to re-located the correct functioning of the water treatment plants because of the continuous qualitative alteration that gets in the water body water [1]. Scientists and experts in water quality development index efficient water quality (water quality index), where counting this indicator favorite scientific method for being many water quality and formulation variables used in digital expression descriptive includes the integrated effect of these variables on water quality, and have an active role in operations control of water quality strategy and its management, so that they can from which water classification qualitatively for various activities within specific categories and scientific manner is simple and useful. The water quality index was used for the first time by Horton [2], and developed after him many of the water quality index models such as that done by Alobaidy et al. [3] and Eassa and Mahmood [4]. The present study aims to find a water quality index value for raw and treated water in the Baghdad city, based on a number of physical and chemical variables.

Description of Study Area

The study area consists of four water treatment plants were selected in Baghdad city. These plants are the most important drinking water plants because the study area was dense with numbers of the pollutants along the banks of the river, as well as the presence of some industrial activities, in addition to a number of wastewater outfall, which are distributed on both sides of the river. Therefore, the existence of dangers of various biological, chemical and physical pollution, which will effect on the quality of the Tigris river. The water of this river is a main source of treatment plants in the study area as shown in Fig. (1). Physical and chemical tests were carried out by Baghdad Government, according to standard methods [5], on samples taken from the site, like (turbidity NTU, pH, total hardness (as CaCO3), magnesium, calcium, sulphate, iron, fluoride, Nitrate, chloride, TDS, conductivity). Tests of turbidity, TDS and pH were carried out at the site and the other tests were done in the laboratory. The data collection of this study continued for eight years, starting from 2005 until 2013.

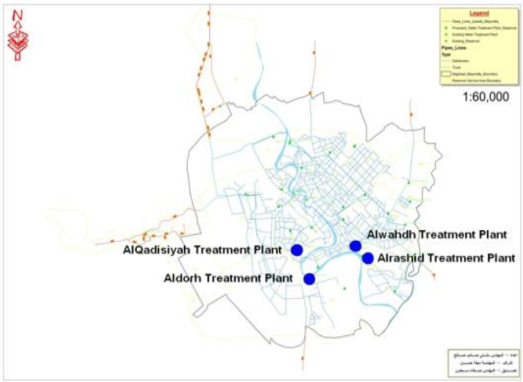


Fig. 1. The study area with the water treatment plant

Application of Water Quality Index for Drinking Purposes

The collecting data was classified according to the time and placed in the matrix. The water quality will be computed by using Canadian model (CCME-WQI) [6]. This model is based on confusion between the three mathematical factors in calculating the final Figure crossing on the status of water quality is the scope, frequency and amplitude, where these factors are calculated from the specific to each variable equations, where the final Figure of acquired reflect on the state of water quality, as follows:

The First Factor F1 (Scope)

This factor represents the ratio between the number of variables that do not match their values with the objectives set for the model (Objective) and the total number of variables, this factor is calculated from the following equation:

$$F1 = \frac{\text{Number of failed variables}}{\text{Total number of variables}} \times 100 \qquad (1)$$

The Second Factor F2 (Frequency)

This factor represents the ratio between the number of tests that did not meet the objectives set for the model and the total number of tests values. This factor is calculated from Eq. (2) below:

$$F2 = \frac{\text{Number of failed tests}}{\text{Total number of tests}} \times 100 \qquad (2)$$

The Third Factor (F3) (Amplitude)

This factor represents the failed tests and which do not correspond with the objectives and values of the tests are calculated according to the following steps: -

The number of times which an individual concentration is greater than (or less than, when the objective is a minimum) the objective is termed an “excursion” and is expressed in Eq. (3). When the test value must not exceed the objective:

$$\text{excursion}_i = \frac{\text{Failed Test Value}}{\text{Objective}_i} - 1 \qquad (3)$$

Equation (4) is expressed for the cases in which the test value must not fall below the objective:

$$\text{excursion}_i = \frac{\text{Objective}_i}{\text{Failed Test Value}} - 1 \qquad (4)$$

The collective amount by which individual tests are out of compliance is calculated by summing the excursions of individual tests from their objectives and dividing by the total number of tests (both those meeting objectives and those not meeting objectives). This variable, referred to as the normalized sum of excursions, or *nse*, which is calculated as in Eq. (5):

$$\text{nse} = \frac{\sum_{i=1}^{n} \text{excursion}_i}{\text{No. of tests}} \qquad (5)$$

*F*3 is then calculated by an asymptotic function that scales the normalized sum of the excursions from objectives (nse) to yield a range between 0 and 100, and can be Calculated from Eq. (6) as shown below:

$$F3 = \frac{\text{nse}}{0.01\, nse + 0.01} \qquad (6)$$

Once the factors have been obtained, the index itself can be calculated by summing the three factors as if they were vectors. The sum of the squares of each factor is therefore equal to the square of the index. This approach treats the index as a three-dimensional space defined by each factor along one axis. With this model, the index changes in direct proportion to changes in all three factors, then the WQI can be calculated by Eq. (7) below:

$$CCME\ WQI = 100 - \frac{\sqrt{F1^2 + F2^2 + F3^2}}{1.732} \qquad (7)$$

The values of water quality index that products must be ranging from (0–100) and these values are classified as shown in Table (1).

Table 1: Classification of water quality index according to [6].

Water Treatment Required	Quality	Rang	category
sterilization only	Excellent	95-100	I
Simple Treatment	Good	80-94	II
Conventional treatment	Moderate	65-79	III
Advanced treatment	Bad	45-64	IV
Unacceptable	Very bad	0-44	V

Results and Discussion

The Variables in Calculation of WQI

Temperature

The results showed that the variation in the temperature of raw and treated water for all treatment plants was very little, and observed that the temperature of raw and treated water is identical to the Iraqi specifications for drinking water [7].

Color

The results show that the variation in the color of raw and treated water for all treatment plants is very little, and observed that the color of raw and treated water is identical to the Iraqi specifications for drinking water [7], which is less than 5 unit.

Turbidity

Figure (2) shows the values of turbidity in treated water during the study period, the turbidity of raw water between (25-427) NTU. It can be seen from this Figure , the turbidity values in treated water for all treatment plants were identical to Iraqi Specifications (less than 5 NTU), except for the Al-Rasheed treatment plant during the years (2009-2012) and the Al-Wahda treatment plant during the year 2007 only, where it wasn't identical to

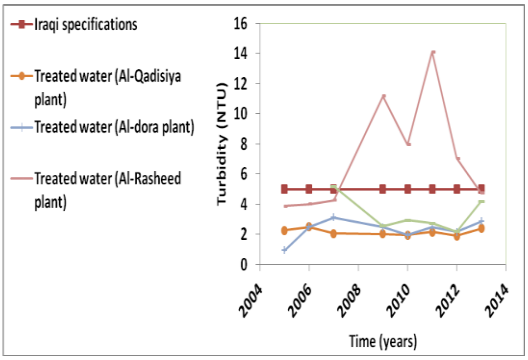


Fig. 2. Turbidity values in treated water during the study period.

Iraqi specifications because the hydraulic retention time in settling tanks and filtration was reduced in order to satisfy the increasing need of the demand water by consumers for the purposes of domestic or industrial, and thus would leads to reduce the efficiency of the work of units of these plants in the removal of turbidity from the treated water.

pH

Figure (3) shows pH values during the study period, the results show that pH values in the raw water (river water) tended to be alkalinity and ranging from (7.7 to 8.2). This is referring to the limestone soil (CaCO3) in the study area, which is one of the main source of increasing pH values [8]. This result agrees with results of previous study [9], which concluded that the surface water in Iraq is alkalinity water. The pH of treated water was identical to Iraqi specification limits, (7- 8.5), where it is ranged from (7.3 to 7.8). Also, it is noted that pH values decreased in the treated water as compared to the raw water, this is due to materials were added to the entering water to the plant, such as alum, chlorine, which will lead to reduce pH values [10].

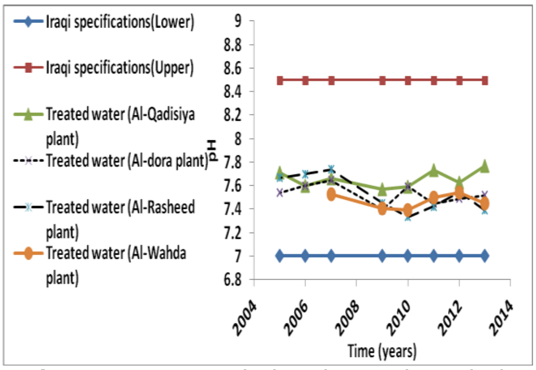


Fig. 3. pH values during the study period.

Electrical Conductivity (EC)

Figure (4) shows the electrical conductivity values of water exit from four treated plants during the study period, the values of electrical conductivity of raw water ranging between (513-932) µs/cm, while for treated water were ranged between (519-933) µs/cm. These values are acceptable within Iraqi specification limits.

Total Hardness

Figure (5) shows the total hardness values during the study period, the total hardness of raw water ranged between (294-368) mg/L, and for treated water was (295-370) mg/L. These values are within the limits of the Iraqi specifications which is equal to 500 mg/L.

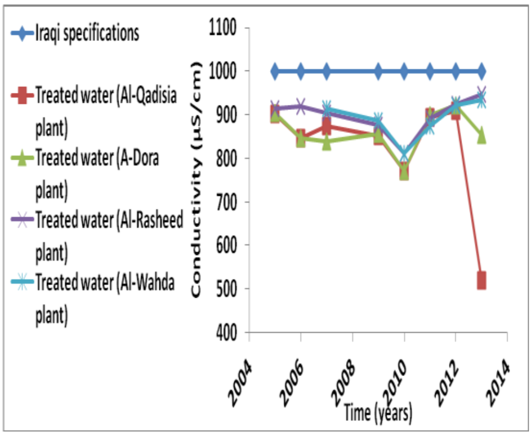


Fig. 4. Electrical conductivity values during the study period.

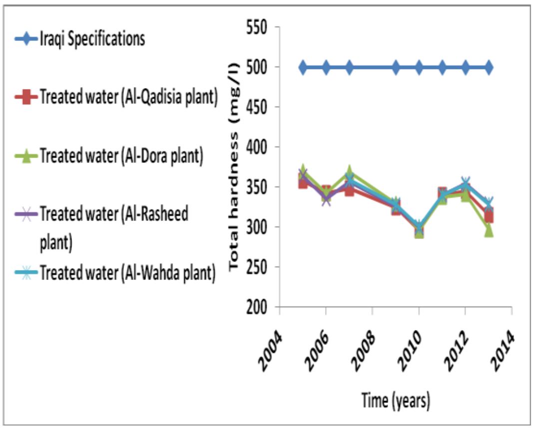


Fig. 5. Total hardness values during the study period.

Calcium (Ca)

Figure (6) shows the variation in calcium concentration during the study period, the concentration of calcium in the raw water ranging from (75-100) mg/L, and the results showed a variation in calcium ion concentration in treated water (76-100) mg/L, also the obtained results show, for the most cases, the calcium ion concentration in the treated water was greater than in the raw water. The results also indicated that most of the calcium ion concentration in the treated water samples was not identical to Iraqi specification, which states that the calcium ion in drinking water does not exceed 75 mg/L.

Magnesium (Mg)

Figure (7) shows magnesium concentrations during the study period, the magnesium concentration in raw water ranged from (26-34) mg/L, and in the treated water was ranged between (25-37) mg/L. Also, these results showed that there is a disparity in the magnesium ion concentration in the treated water, this corresponds to the study conducted by Al-Khafaji [11] on the water of Hussein liquidation plant in Karbala city, which indicates that the magnesium ion concentration in the treated water was identical to Iraqi specifications, which states that the magnesium ion concentration in drinking water not exceed 50mg/L.

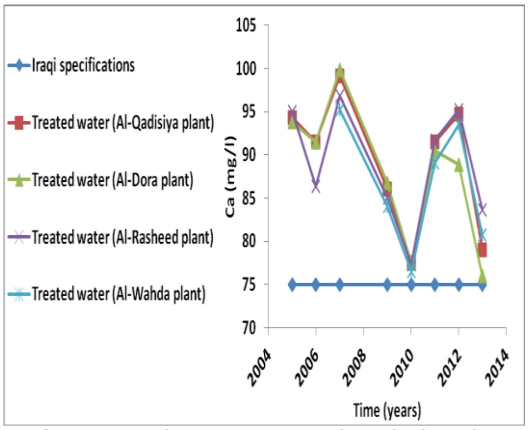


Fig. 6. Calcium concentration during the study period

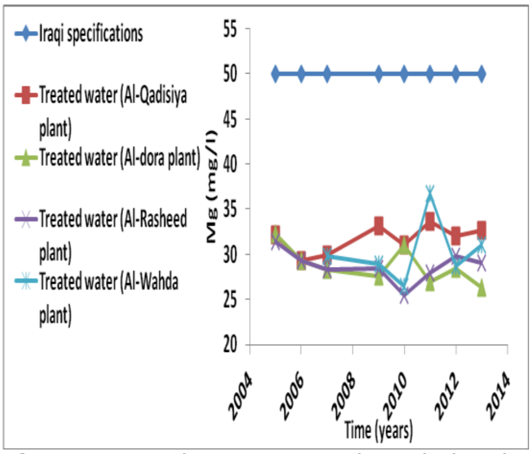


Fig. 7. Magnesium concentrations during the study period.

Chloride (Cl)

Figure (8) shows the chloride concentration during the study period, the concentration of chloride in raw water ranged between (60-82) mg/L, and in the treated water ranged between (61-82) mg/L. The results show in some concentration cases of chloride ion in the treated water was greater than the raw water, this is due to adding the chlorine to the water. In spite of the increasing in concentration of chloride ion in the treated water was greater than its concentration in the raw water but was remain within the limits of the Iraqi specifications.

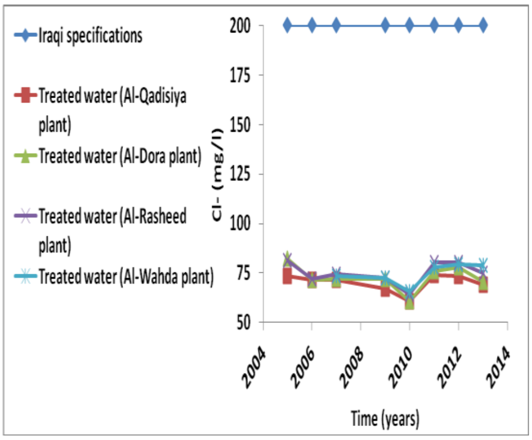


Fig. 8. Chloride concentration during the study period.

Sulfates

Figure (9) shows the sulfate concentration during the study period, the concentration of sulfate in raw water was (130-256) mg/L, and in treated water was ranged between (136-260) mg/L. These results showed an increasing in sulfate ion concentration in treated water as compared to the raw water. The main reason for this increasing is the addition of alum ($Al_2(SO_4)_3$) to the water, where the composition of this material includes the sulfate ion. Also, the results show that the sulfate ion concentration exceeds the limits of the Iraqi specifications through the study period for all plants except the year 2010, where this ion is within the permissible limit 200mg/L.

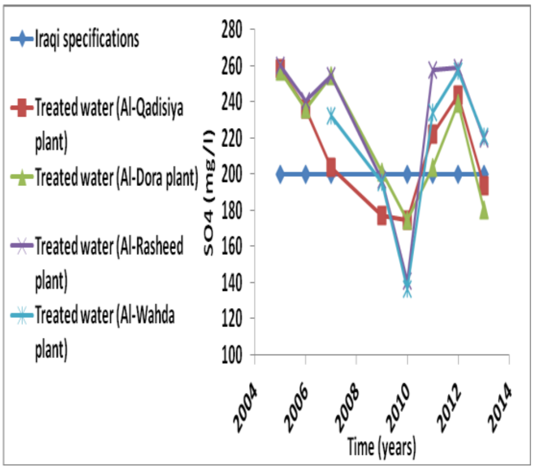


Fig. 9. Sulfate concentration during the study period.

Iron (Fe)

Figure (10) shows the iron concentration during the study period, the concentration of iron in raw water (0.5-5.8) mg/L, and in treated water was ranged between (0.027-0.33) mg/L. It can be concluded from this Fig. that the concentration of iron ion in water is not exceed the permissible limits 0.3mg/L, except one reading was in Al-Rasheed plant for the year 2010, this means that the iron concentration in the treated water was considered normal. The presence of iron, with concentrations of more than 0.3mg/L cause taste and remove clothing color, solid cortices in the main water pipe [12].

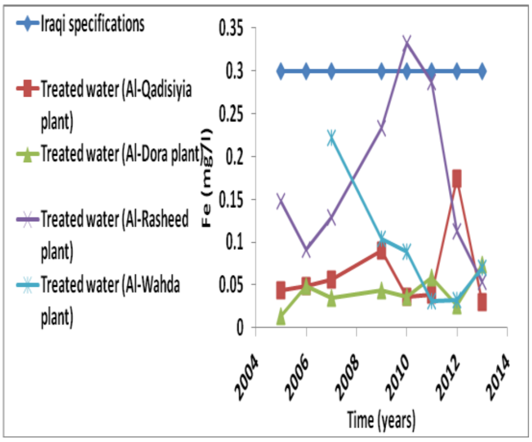


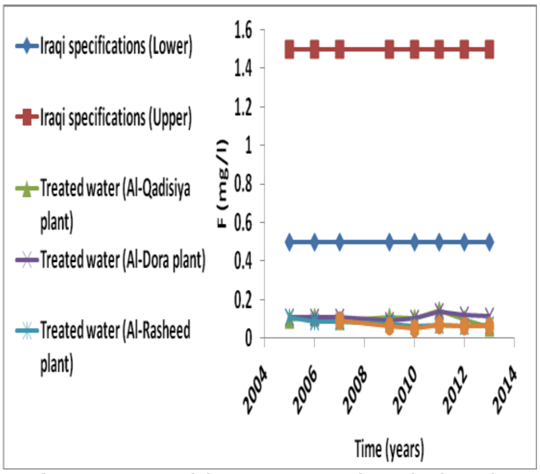
Fig. 10. Iron concentration during the study period.

Fluoride (F)

Figure (11) shows the fluoride ion concentration during the study period, the concentration of fluoride in raw water between was ranged (0.1-0.19) mg/L, while in treated water was between (0.05-0.14) mg/L. It can be concluded that the fluoride ion concentration in the water was less than the permissible limits of Iraqi specification (0.5–1.5) mg/L. The presence of fluoride ion concentrations with more than the permissible limits cause tooth decay among consumers.

Nitrate (NO_3)

Figure (12) shows the nitrate ion concentration during the study period, the concentration of nitrate ion in raw water between (0.22-1.44) mg/L, and in treated water was ranged between (0.26-1.48) mg/L. It can be concluded from the Fig. that the nitrate ion concentration in the treated water was within the permissible limits of Iraqi specification 40 mg/L. The presence of nitrate ion concentrations with more than the permissible limits causes cyanosis in children young age.



.**Fig. 11.** Fluoride concentration during the study period.

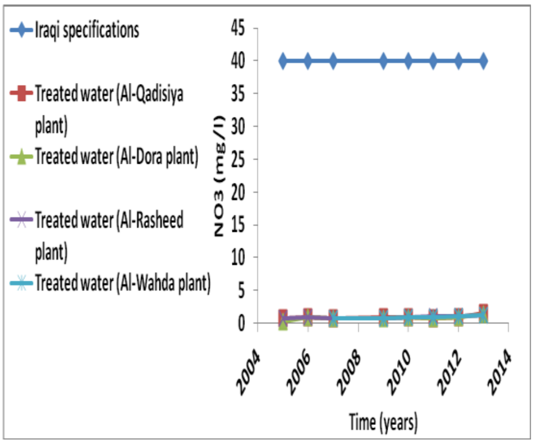


Fig. 12. Nitrate ion concentration during the study period.

Water Quality Index Values

After completing the first stage of water quality index calculation, which includes the obtaining the variables and tabulation values, then started the second stage, which includes calculation the values of the three factors: Scope (F1) and Frequency (F2) and Amplitude (F3) , then complete the last stage which is includes the calculation of water quality index values for drinking purposes. As shown in Fig. (13), the water quality index of treated water of (Al-Qadisiya, Al-Dora Al-Rasheed and Al-Wahda) plants is (77,78, 67 and 70) respectively, while the quality index value of raw water at the same plants was (53,54,50, 49) respectively. It can be concluding that the four water treatments plant have been improved of the water quality index from the fourth category (for raw water) to the third category (moderate) (treated water). Also, it can be seen from the results that smaller value of the water quality index for treated water was (67) in Al-Rasheed treatment plant.

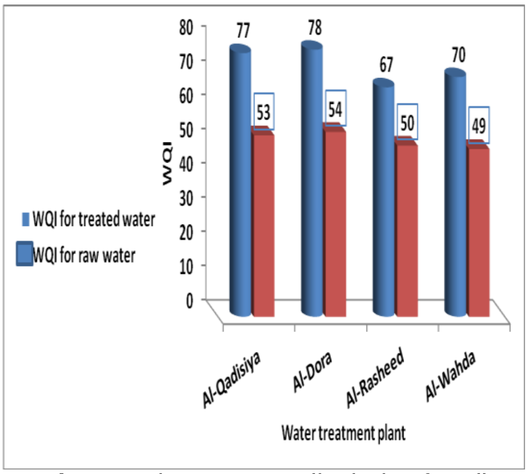


Fig. 13. The water quality index for all treatment plants.

Conclusions

1. The raw water of Tigris River through Baghdad City can be classified as a bad water and it's needing advanced treatment.
2. The treated water from four treatment plants in Baghdad city can be classified within the third category (moderate).

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