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Evaluation the quality of raw and treated water for number of water treatment plants in Baghdad, using a water quality Index

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Abstract

Laboratory tests were conducted to evaluate the quality of drinking water on some water treatment plants in Baghdad (AlKarkh, Shark Dijla, AlWathba, and Alkramh), the samples taken from raw (Tigris River) and treated water. The measurements of some physical and chemical properties 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 $CaCO_3$), magnesium, calcium, sulfate, iron, fluoride, Nitrate, chloride, color and conductivity. The samples were taken from the treated water that outside from the plant from 2005 to 2013. The study showed that the range of water quality index for raw water is (51-57) and can be classified as a bad water and needs advanced treatment, while the water quality index of treated water was (86, 81,80,80) for (AlKarkh, Shark Dijla, AlWathba and Alkramh) respectively. The water quality index of treated water of (AlKarkh, Shark Dijla, AlWathba and Alkramh) can be classified as Category II (good).

Key words: Canadian water quality index, raw water, treated water

تقييم نوعية المياه الخام و المعالجة لعدد من محطات معالجة المياه في بغداد ، باستخدام مؤشر جودة المياه

الخلاصة

أجريت الفحوصات المختبرية لتقييم نوعية مياه الشرب في بعض محطات معالجة المياه في بغداد (الكرخ، شرق دجلة، الوثبة، الكرامة)، وتم سحب عينات أخذت من الخام (نهر دجلة) والمياه المعالجة. قياسات بعض الخصائص الفيزيائية والكيميائية اخذت كل شهر ولمدة ثماني سنوات من أجل تقييم نوعية مياه الشرب وكفاءة هذه المحطات. تم حساب نوعية مياه الشرب باستخدام مؤشر النموذج الكندي (المجلس الكندي لوزراء البيئة) في تقييم نوعية المياه، كما ساهمت ثلاثة عشر متغير في حساب المؤشر: درجة حرارة مئوية الماء، العكارة ، ودرجة الحموضة، والصلابة الكلية (كما كربونات الكالسيوم $CaCO_3$)، المغنيسيوم ، الكالسيوم ، كبريتات الحديد ، الفلوريد ، نترات ، كلوريد ، اللون و الموصلية. تم أخذ عينات من المياه المعالجة الخارجة من المحطات من عام 2005 إلى عام 2013. وأظهرت الدراسة أن نطاق مؤشر جودة المياه للمياه الخام هو (51-57)، ويمكن

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أن تصنف على أنها مياه سيئة وانها بحاجة معالجة متقدمة، في حين كان مؤشر جودة المياه من المياه المعالجة (86، 80،80،81) ل (الكرخ، شرق دجلة، الوثبة والكرخ) على التوالي. ويمكن تصنيف مؤشر جودة المياه من المياه المعالجة من (الكرخ، شرق دجلة، الوثبة والكرخ) من الفئة الثانية (جيد).

الكلمات المرشدة : مؤشر جودة المياه، المياه الخام، المياه المعالجة

INTRODUCTION

Different water sources are suffering at the present time a contamination as a result of the large increase in population and industrial, agricultural expansion, and the lack of proper planning in building cities, which led to a doubling of the amount of industrial, agricultural and human waste entering these sources of water. Water quality monitoring program has become necessary to re-locate 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 (2).

The water quality index was used for the first time by Horton, 1965[(3)] and developed by Deininger and Maciunas, 1971[(4)] and Shihab and Al - Rawi, 1994[(5)] and Avvannavar and Shrihari, 2007[(6)] and Mojahedi and Attari, 2009[(7)] and Abdul-Razak et al., 2009[(8)] and Alobaidy et al., 2010[(9)] and Eassa and Mahmood, 2012[(10)]. The present study aims to find a water quality index value for raw and treated water 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 as shown in Figure (1). These plants are the most important drinking water plants because the study area was dense with numbers of population along the banks of the river, as well as the presence of some industrial activities, and wastewater treatment units, which casus biological, chemical and physical pollutants, that effect on the quality of the water.

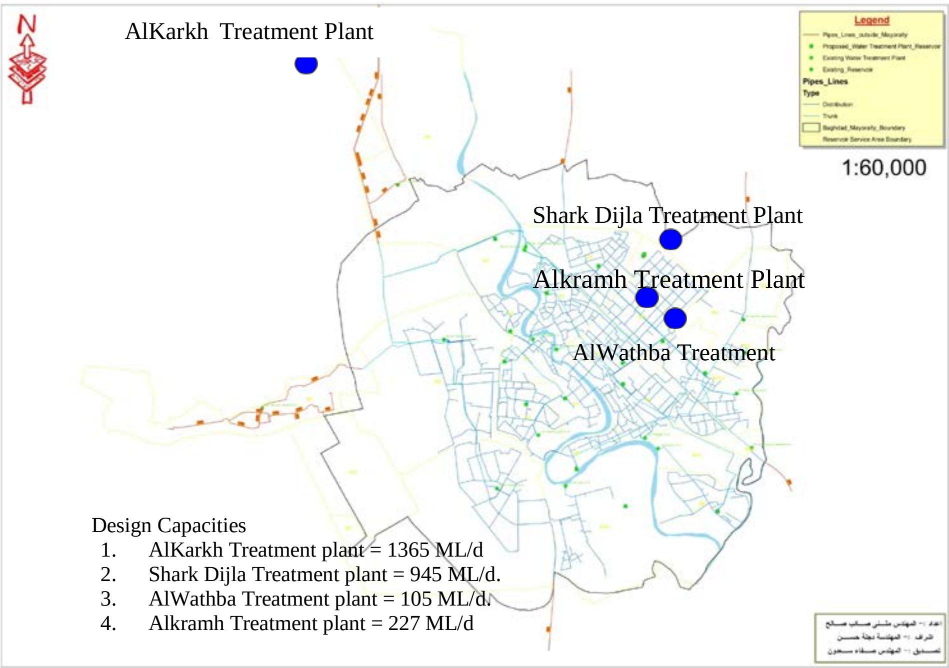

Figure (1): Study area with the water treatment plant (Mayoralty of Baghdad)

Field work

Samples were taken to assess of the raw and treated water by using plastic bottles of 0.5 liter after the water washed the outside of the processing unit three or more times before bottling sample as described in the standard methods for examination water and wastewater [11]. The Data represented eight years, starting from 2005 to 2013.

Laboratory work

Some physical and chemical tests carried out on samples taken from the site, a (temperature of the water ˚C, turbidity NTU, pH, total hardness mg/l (as $CaCO_3$), magnesium mg/l, calcium mg/l, sulfate mg/l, iron mg/l, fluoride mg/l, Nitrate mg /l, chloride mg /l, color, conductivity µs/cm), in accordance to standard methods for the examination of water and wastewater [11]. The tests of temperature, turbidity, TDS and pH were measured on site at the position of sampling and the other tests were done in the laboratory.

Application of water quality index for drinking purposes

After collecting the results and classified according to the time and place in the matrix was used water quality index of the Canadian model (CCME-WQI) and described by Canadian Council of Ministers of the Environment, 2001[12]. The Canadian water quality index, allows researchers to free choice of entering variables in the model and the freedom of standard border situation and then the water specifications acceptable [2]. 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:

1.The first factor F1 (Scope): 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 and is calculated from the equation (1) below :

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

2.The second factor F2 (frequency): 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. Calculated from the equation(2) below :

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

3.The third factor (F3) (Amplitude) : Represents the failed tests and which do not correspond with the objectives and values of the tests are calculated according to the following steps: -

i) The number of times by 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 as follows in eq. (3). When the test value must not exceed the objective:

$$excursion_i = \frac{\text{Failed Test Value}}{\text{Objective}_\text{i}} - 1 \qquad \ldots.(3)$$

For the cases in which the test value must not fall below the objective, can be expressed as in eq. (4):

$$excursion_i = \frac{\text{Objective}_\text{i}}{\text{Failed Test Value}} - 1 \qquad \ldots.(4)$$

ii) 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, is calculated as in eq. (5):

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

iii) F3 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 the equation(6) below :

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

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:

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

The values of water quality index that products must be ranging from (0 – 100), and these values are express about water quality according to table (1)

Table (1) : Classification water quality index with respect to (CCME, 2001)

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:

1-Temperature :

The results showed that the variation in the temperature of raw and treated water for all treatment plants was a very little, and observed that the temperature of raw and treated water is identical to Iraqi specifications (IQS 417, 2001)[13] for drinking water.

2-Color :

The results showed that the variation in the color of raw and treated water for all treatment plants was a very little, and observed that the color of raw and treated water is identical to Iraqi specifications (IQS 417, 2001) [13] (less than 5 unit) for drinking water.

3-Turbidity:

Figures (2) shows the values of turbidity in treated water during the study period, the turbidity of raw water between (23-243) NTU, from figure (2) the turbidity values in treated water for all treatment plants were ranging between (1-4) NTU and identical to Iraqi Specifications (IQS 417, 2001) [13] (less than 5 NTU).

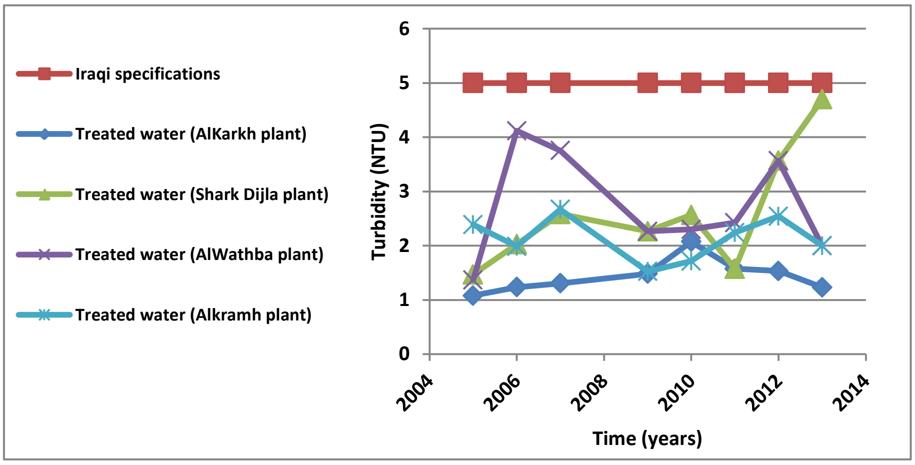

Figure (2): shows the turbidity values in treated water during the study period

4-PH :

Figure (3) shows pH values during the study period, the results show that the pH values in the raw water (river water) tended to be alkalinity and ranging from (7.8 to 8.2) and the reason for this was the type of soil in the study area which limestone ($CaCO_3$), which is one of the main sources in increasing of pH values [14], this result agree with results of Al-Jeboory, 2005[15] that the surface water in Iraq is alkalinity water, either with regard to treated water figure (3) shows the pH was identical to Iraqi specification limits (IQS 417, 2001) [13] (7- 8.5) as ranged from (7.4 to 7.8), also notes the pH values was deceasing in the treated water compared to the raw water due to materials were added to the water entering the plant, such as alum, chlorine, which will lead to reduced pH values after Addition [16].

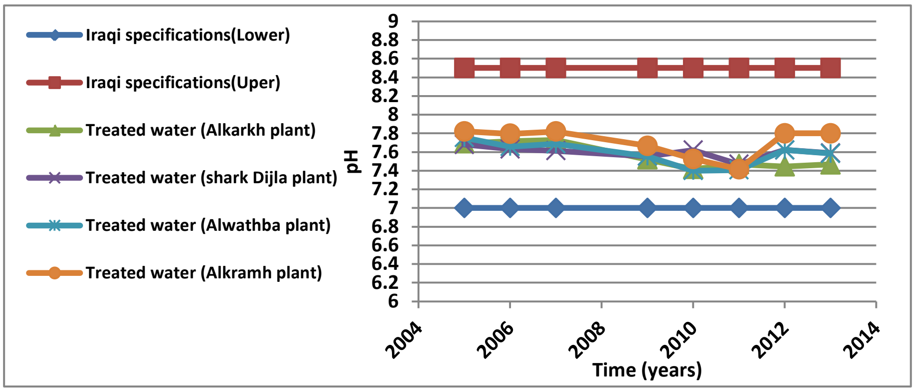

Figure (3): shows pH values during the study period

5-Electrical conductivity:

Figure (4) shows the electrical conductivity values during the study period, this values of electrical conductivity of raw water ranging between (604-946)µs/cm, while treated water were conductivity values ranging between (601 -998)µs/cm as shown in figure (4), and so these values are acceptable within Iraqi specification limits.

6-Total hardness:

Figure (5) shows the total hardness values during the study period, the total hardness of raw water ranging between (242-362) mg/l, and the treated water was (243-359) mg/l as shown in figure (5), and these values are within the limits of the Iraqi specifications (500 mg/l).

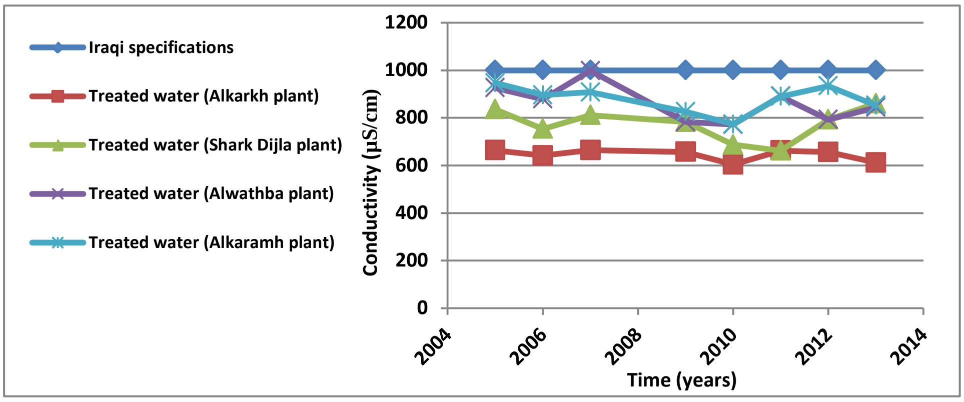

Figure (4): shows the electrical conductivity values during the study period

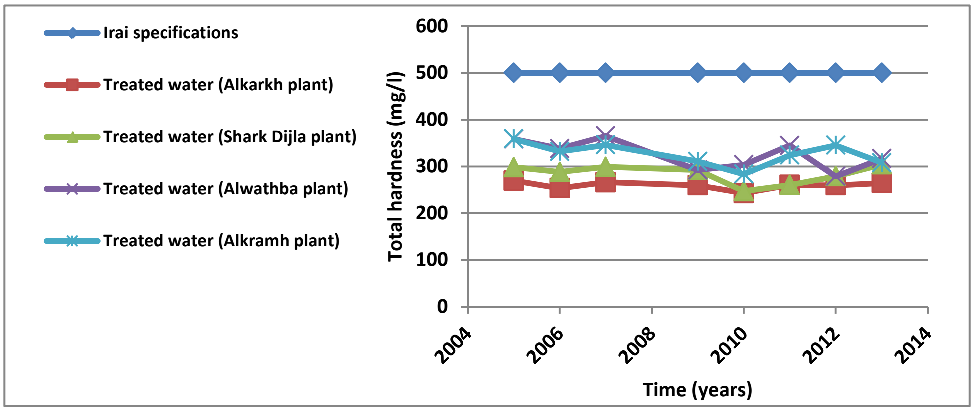

Figure (5): shows the total hardness values during the study period

6-Calcium:

Figure (6) shows the variation calcium concentration during the study period, the concentration of calcium in the raw water ranging from (60-96)mg/l, and the results showed a variation in calcium ion concentration in treated water (60-100)mg/l, also the obtained results and for the most cases the calcium ion concentration in the treated water was great than it is in the raw water, and attributed the reason for this to that these plants are reducing the time the hydraulic retention time in the basins of sedimentation and filtration in order to satisfy the increasing need for demand for water by consumers, whether for domestic purposes or for industrial purposes in addition to the delay in the wash filters and thus would lead to reduce the efficiency of the work units plants in removing turbidity containing a carbonate or bicarbonate or calcium salts of the city's water supplier. The results also indicated that most of the calcium ion concentration in the treated water samples was not identical to Iraqi specification (IQS 417, 2001) [13], which states does not exceed calcium ion in drinking water values (75 mg / l).

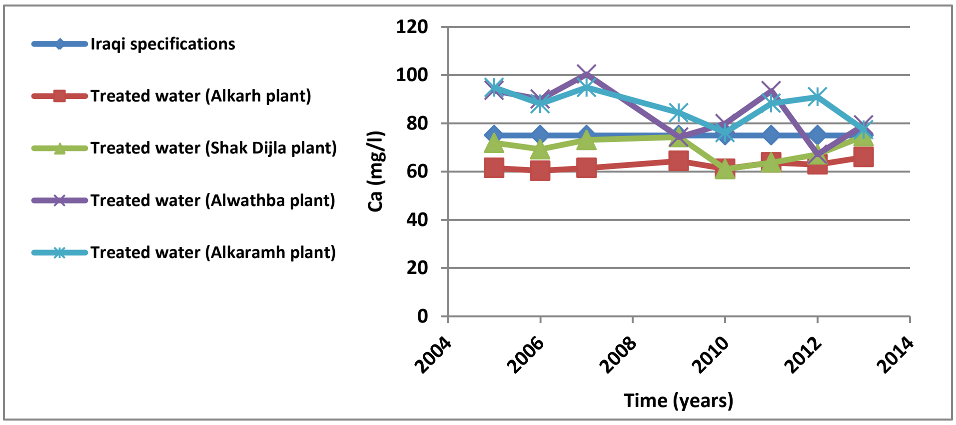

Figure (6): shows the variation calcium concentration during the study period

7-Magnesium:

Figure (7) shows magnesium concentrations during the study period, the magnesium concentration in raw water ranging from (21-33)mg/l, the Figure (7) showed that the magnesium ion concentration in the treated water ranged from (21-33)mg/l, and the results showed that there is a disparity in the magnesium ion concentration in the treated water and this corresponds to the study conducted by the [17] on the water Hussein liquidation plant in city of Karbala, indicated that these results were obtained that the magnesium ion concentration in the treated water was identical to Iraqi specifications (IQS 417, 2001) [13], which states that do not exceed the magnesium ion concentration in drinking water, the values of (50) mg / l.

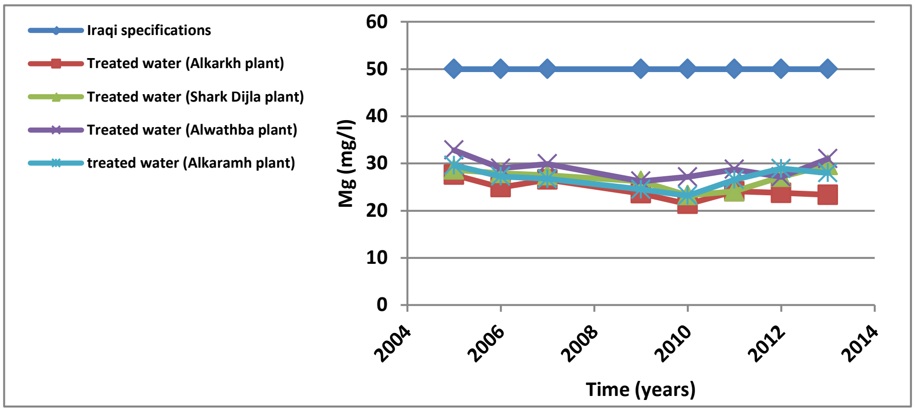

Figure (7): shows magnesium concentrations during the study period

8-Chloride:

Figure (8) shows the chloride concentration during the study period, the concentration of chloride in raw water ranging from (31-70)mg/l, and in the treated water was range between (34-76), the results show in some cases concentration of chloride ion in the treated water was greater compared to the raw water, the main reason for this is to add chlorine to the water, and the secondary causes are washing filters process delay and reduce the hydraulic retention time in sedimentation tanks and filtration, which will lead to make the units not taking the enough time to filter the raw water. This is within the limits of the Iraqi specifications.

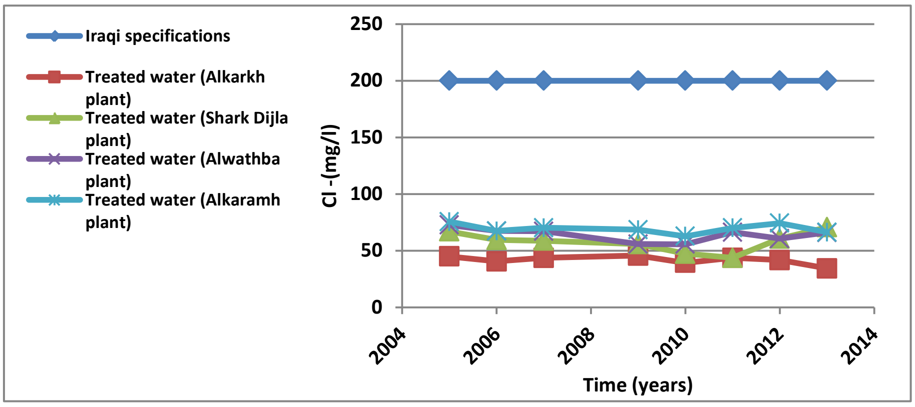

Figure (8): shows the chloride concentration during the study period

9-Sulfates:

Figure (9) shows the sulfate concentration during the study period, the concentration of sulfate in raw water between(103-251)mg/l, and in treated water was ranging between (112-251)mg/l, the results showed the increasing in ion sulfate concentration in treated water compared to the raw water, the main reason for this was the addition of alum (Al_2 (SO_4) $_3$) to the water, this compound enters in its composition the ion sulfates where after the dissolution of this compound will be free of sulfate in the form of ions thus increasing its concentration in the water than it is in the raw water, and the results showed exceed the sulfate ion concentration the limits of the Iraqi specifications and for all treatment plants except AlKarkh, and Shark Dijla, were within the permissible limits, which did not exceed 200 mg /l.

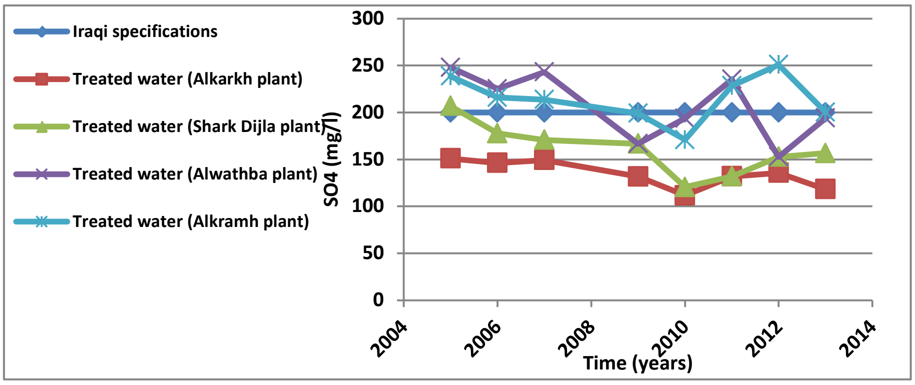

Figure (9): shows the sulfate concentration during the study period

10-Iron (Fe) :

Figure (10) shows the iron concentration during the study period, the concentration of iron in raw water between (0.33-12) mg/l, and in treated water was ranging between (0.03-0.14) mg/l, It can be concluded from the figure that the ion iron concentration in water is not exceeded the permissible limits (0.3 mg /l) by the Iraqi specification and this means that the iron concentration in the treated water is considered normal. The presence of iron, with concentrations of more than one (0.3) mg /l, cause taste and remove clothing color, solid cortices in the main water pipe [18].

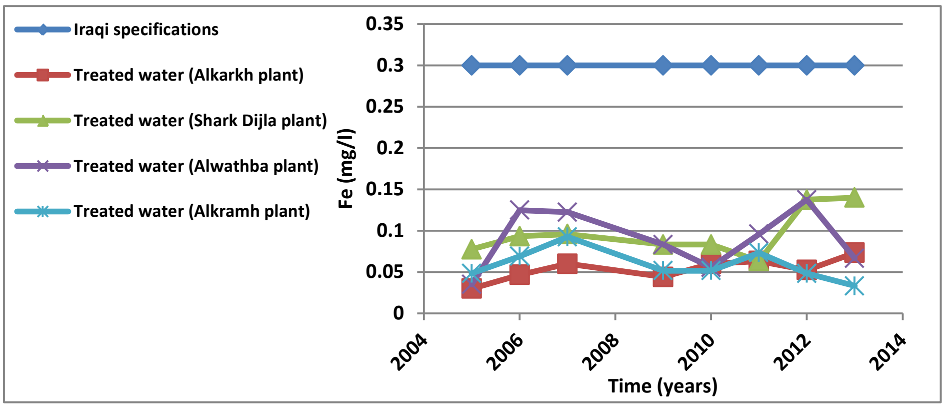

Figure (10): shows the iron concentration during the study period

11-Fluoride(F):

Figure (11) shows the fluoride concentration during the study period, the concentration of fluoride in raw water between (0.07-0.21)mg/l, and in treated water was ranging between (0.07-0.17)mg/l. It can be concluded from the figure (11) that the fluoride ion concentration in the water was less than the permissible limits (0.5 – 1.5) mg/l by the Iraqi specification. The presence of fluoride ion concentrations with more than the permissible limits cause tooth decay among consumers, therefore it must be within the range (0.5 – 1.5) mg / l.

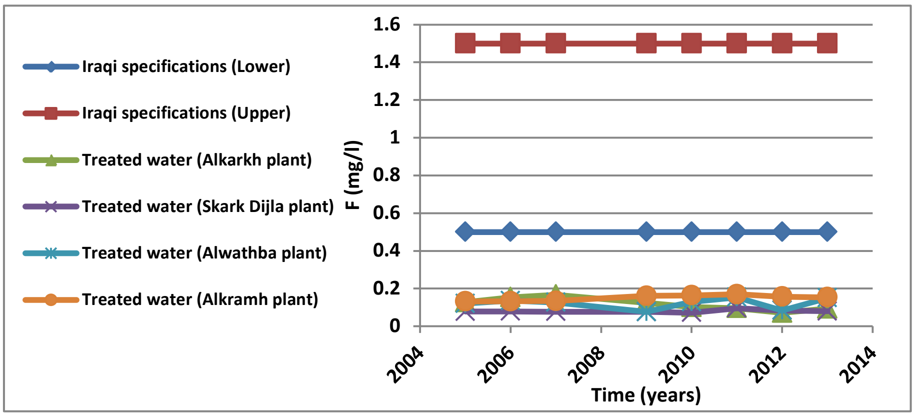

Figure (11): shows the fluoride concentration during the study period

12-Nitrate NO_3 :

Figure (12) shows the nitrate ion concentration during the study period, the concentration of nitrate ion in raw water between (0-1.4)mg/l, and in treated water was ranging between (0-1.44) mg /l, It can be concluded from the figure that the nitrate ion concentration in the treated water was within the permissible limits (40 mg / l) by the Iraqi specification. The presence of nitrate ion concentrations with more than the permissible limits causes cyanosis in children young age.

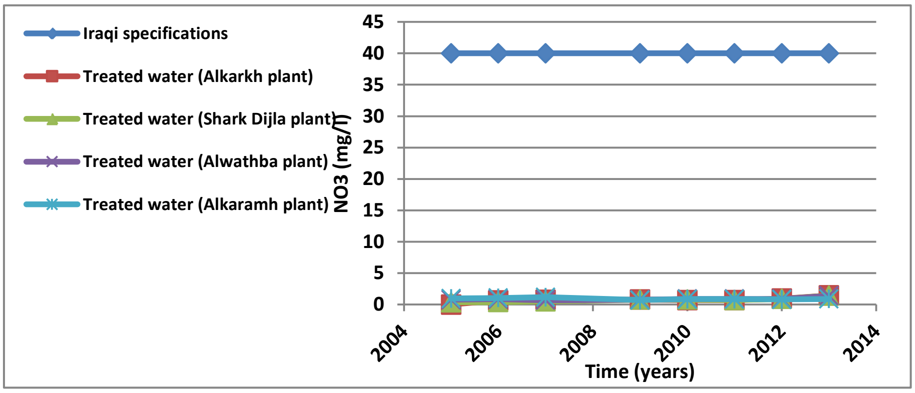

Figure (12): shows the nitrate ion concentration during the study period

Water quality index values:

After completing the first stage of water quality index calculations, which included the classification of variables, 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 including calculation water quality index values for drinking purposes. The water quality index values for raw water throughout the study period were ranging (51-57) (classified as Category IV – bad). The results of AlKarkh, and Shark Dijla treatment plants and as shown in Figure (13) show that the water quality index values of treated water were (86 and 81) respectively (category II-good), while the raw water quality index values of the two plants (57 and 55) respectively, we conclude from this that the quality of drinking water has been improved of the water quality index from fourth category (for raw water) to the second category (good) (for treated water) and this show that there is a relative commitment in the two treatment plants by applying the specification of drinking-water quality. Also the results showed that the water quality index of treated water from AlWathba and Alkramh was (80) for each of them (classified as Category II – good), while the raw water quality index value at the two plants (51 and 54) respectively and as shown in figure (13), it concluded that the quality of drinking water has been improved of the water quality index from fourth category (for raw water) to the second category (good) (for treated water) and this show that there is a relative commitment in the two treatment plants by applying the specification of drinking-water quality.

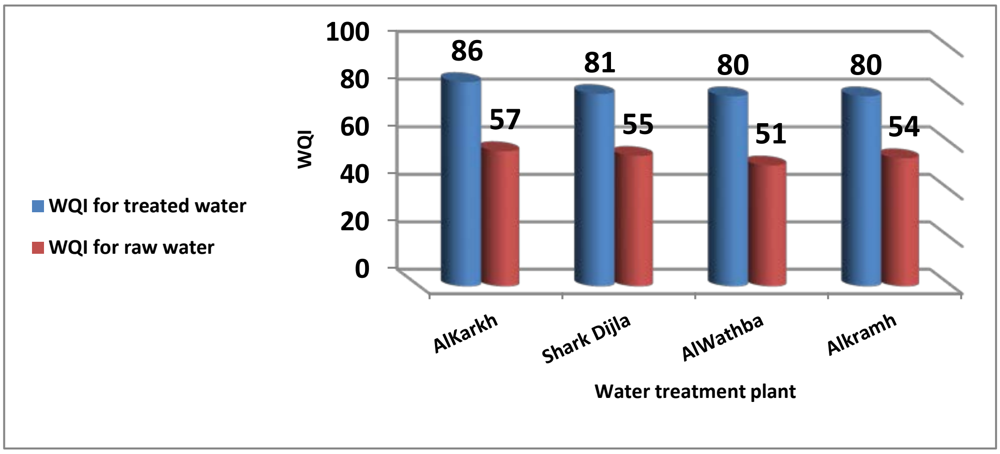

Figure (13): Shows the water quality index for all treatment plant

Conclusion:

It concluded the following points:

1. Temperature and color of raw and treated water is identical to Iraqi specifications (IQS 417, 2001) [(13)] for drinking water.
2. The turbidity of raw water between (23-243) NTU, and the turbidity values in treated water for all treatment plants were ranging between (1-4) NTU, pH values in the raw water (river water) tended to be alkalinity and ranging from (7.8 to 8.2), the pH in the treated water was identical to Iraqi specification limits (IQS 417, 2001) (7-8.5) as ranged from (7.4 to 7.8).
3. Electrical conductivity of raw water ranging between (604-946)µs/cm, while in the treated water the conductivity values ranging between (601 -998)µs/cm, the

total hardness of raw water ranging between (242-362)mg/l, and the treated water was (243-359) mg/l.

4. The concentration of calcium in the raw water ranging from (60-96)mg/l, and the results showed a variation in calcium ion concentration in treated water (60-100)mg/l, the magnesium concentration in raw water ranging from (21-33)mg/l, and the magnesium ion concentration in the treated water ranged from (21-33)mg/l.

5. The concentration of chloride in raw water ranging from (31-70) mg/l, and in the treated water ranges between (34-76) mg/l, the concentration of sulfate in raw water between (103-251) mg/l, and in treated water was ranging between (112-251) mg/l.

6. The concentration of iron in raw water between (0.33-12) mg/l, and in treated water was ranging between (0.03-0.14) mg/l, the concentration of fluoride in raw water between (0.07-0.21)mg/l, and in treated water was ranging between (0.07-0.17)mg/l, the concentration of nitrate ion in raw water between (0-1.4) mg/l, and in treated water was ranging between (0-1.44) mg /l.

7. The water quality index values for raw water throughout the study period were ranging (51-57) (classified as Category IV – bad), The results of AlKarkh, and Shark Dijla treatment plants , show that the water quality index values of treated water were (86 and 81) respectively (category II-good), while the raw water quality index values of the two plants (57 and 55) respectively, the water quality index of treated water from AlWathba and Alkramh was (80) for each of them (classified as Category II – good), while the raw water quality index value at the two plants (51 and 54) respectively.

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