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An Assessment of the treated water quality for some drinking water supplies at Basrah

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Abstract:

In the present study, treated water samples are gathered from four drinking water supplies (Garma I, Al-Muwahad, Twenty five and Jubila) at Basrah during March, April, May and October / 2011, then ten chemical parameters are analyzed. Anova test of variance shows no spatial variations for all studied chemical parameters except for Sulphate (<0.05), free chlorine (<0.05) and total chlorine (<0.01) which reflect raw water quality in addition to treatment efficiency for each drinking water supply. The difference in dosage of both chlorine and alum [$AlK (SO4)_{2}. 12H_2O$] added at each water supply leading to existence of significant spatial differences in free chlorine, total chlorine and sulphate .The whole study period assessment of treated water quality at each water supply is achieved by the application of the CCME WQI model on all of the studied chemical parameters except total chlorine according to guideline values set by Iraqi standards (2001), World Health Standards WHO (1984) and WHO (1993), the results indicate that water quality can be rated as poor at both Garma I and Al-Muwahad water supplies respectively and as Marginal at both Twenty five and Jubaila water supplies respectively. This deterioration in water quality for the studied water supplies reflects poor raw water quality that is supplied to them.

Keywords: Treated water-Water supplies-Water quality-CCME WQI.

1. Introduction:

Pollution of water resources have been an essential issue in the world because of the increasing in pollution resources such as industrial, agricultural, and domestic. Thus, there is a globally increased interest in providing safe water for different uses like drinking, irrigation and industrial uses. The quality of water is defined in terms of its physical, chemical and biological parameters. It is assessed with help of various parameters to indicate the pollution level. So, the use of indices to condense and summarize large volumes of water quality data has increasingly gained acceptance to reflect the composite influence of those parameters [1].

Water quality index (WQI) is an arithmetical tool used to transform large quantities of water quality data into a single cumulatively derived number which resembles the degree of pollution or in other words the water quality classification as excellent, good, medium, bad, and very bad [2],[3],[4]. The WQI was first developed by Horton in early 1970s based on weighted arithmetical calculation, a number of researchers all over the world developed WQI models based on weighing and rating of different water quality parameters [5],[6],[7].

The CCME Water Quality Index is based on a formula developed by British Colombia Ministry of Environment recommended that at minimum, four variables sampled at least four times be used in the calculation of the index values, it does not give any weighted numbers but treats the values of parameters in mathematical ways to ensure that all parameters contribute adequately in the final numbers of the index and standardizes parameters according to the specific objectives [8],[5]. The application of CCME WQI requires water quality guideline (objectives), some times there is need to derive site-specific guidelines (mean, median, standard deviation, mean± standard deviation and percentile value) for those parameters that are naturally higher (or lower) the objectives [2],[9].

The objective of the present study is to provide an assessment of treated water quality supplied to residents at Basrah by using CCME WQI model. In Iraq, the first application of CCME WQI was done for Hawizah marsh using Nature Iraq (an Iraqi environmental, non governmental organization registered in Iraq) data survery in 2008 [10], [11],[12] , then it was applied to Hammar marsh based on 2005 and 2006 data after restoration [12]. Later several researchers had been applied this model for studying water quality like Ibd [13], Moyel [4]. Also, another water quality indices model had been applied by several researchers [3],[7],[10],[1].

2. Experimental:

There are many drinking water supplies at Basrah governorate which have supplied water for residents after treated it by several stages they are: coagulation and flocculation, rapid sand filtration and chlorination. In the present study, water samples ,after these treatments, are gathered from four drinking supplies (Garma I, Al-Muwahad, Twenty five and Jubila) at Basrah governorate during March, April, May and October / 2011 as shown in figure 1 for analyzing ten chemical parameters (variables) they are: pH, Total dissolved solids, Total hardness, Alkalinity, Calcium , Magnisium, Chloride, Sulphate, Free chlorine and Total chlorine, then the results of these variables are used in the calculation of CCME WQI model in order to assessment of treated waters for human consumption.

2.1. Apparatus:

1. Multimeter.
2. Lovibond kit.
3. Hote plate.

2.2. Reagents:

a- Standard sulphuric acid, 0.025 M.
b- Phenolphthalein indicator.
c- Methyl orange indicator.
d- Standard Na_2 EDTA solution, 0.01 M.
e- Standard calcium carbonate solution, 0.01 M.
f- Erichrome black T indicator.
g- Buffer solution of pH=10 (Ammonium chloride & Ammonium hydroxide).
h- Murexide indicator.
i- Buffer solution of pH=13 (1 N NaOH).
j- Silver nitrate standard solution, 0.0141 N.
k- Potassium chromate indicator.

l- Standard Barium chloride solution, 0.01 M.

m- Hydrochloric acid, 1N.

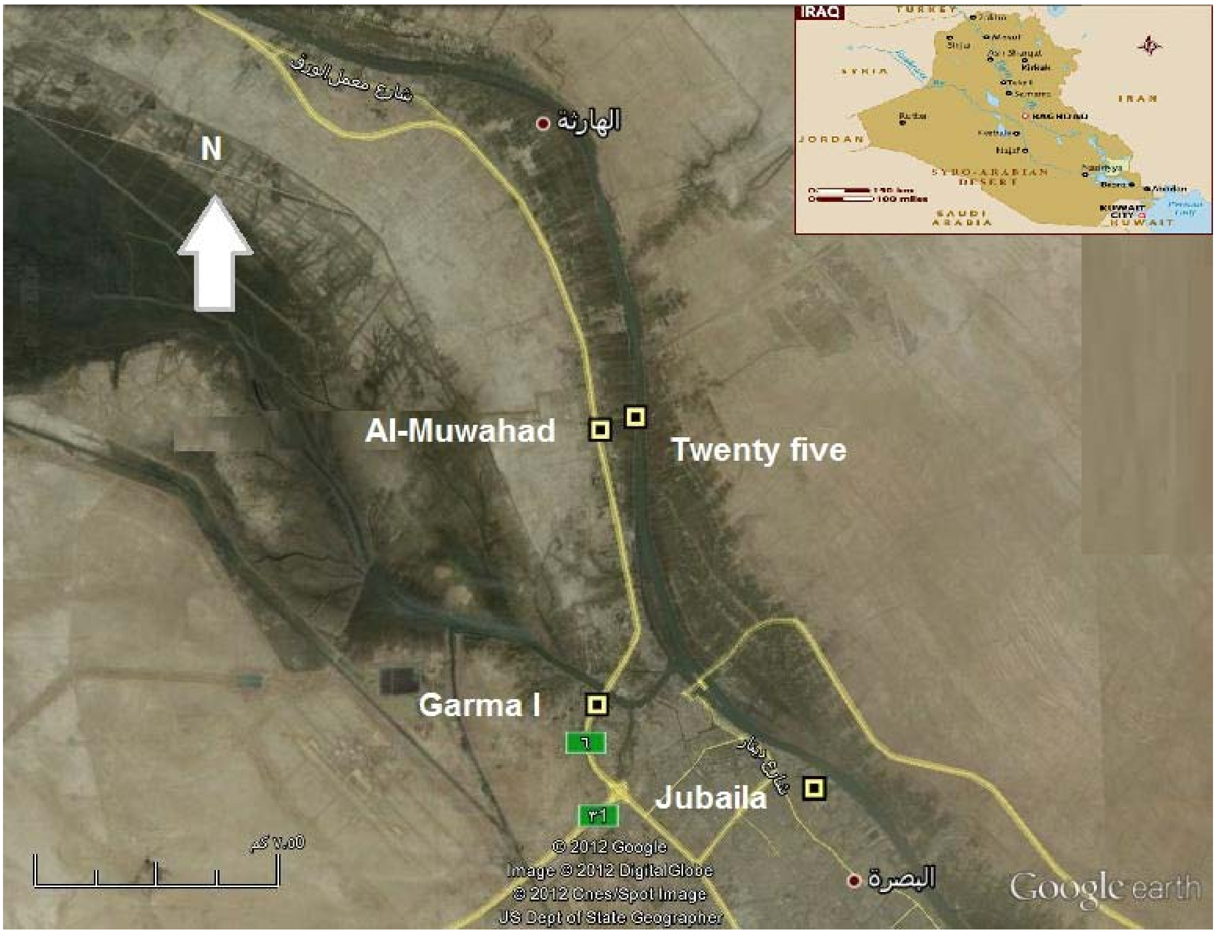

Figure 1: map of the southern part of Iraq (Basrah governorate) showing the studied stations.

2.3. Analytical methods:

Both pH and Total dissolved solids (TDS) were measured at sampling sites by using Horiba model W-2030 MFG. NO.812003. Also, Both total chlorine and free chlorine were analyzed according to DPD method at sampling sites by using Lovibond kit.

Total hardness was determined by titration with Na_2 EDTA as standard solution after the addition of Buffer solution (PH=10) and Erichrome black T indicator according to [14], as expressed in the following equation:

Total hardness (mg/l as $CaCO_3$) = $\frac{A \times B \times 1000}{V}$

Where:

A: volume of standard Na_2 EDTA solution used in titration.

B: milligram per liter calcium carbonate which equivalents to one milliliter of Na_2 EDTA standard solution used in titration.

V: volume of sample used in titration.

Alkalinity was determined by titration with 0.025 N standard sulphuric acid and both Phenolphthalein and Methyl orange indicators according to [14], as expressed in the following equation:

Alkalinity (mg/l as $CaCO_3$) = $\frac{A \times N \times 50000}{V}$

Where:

A: volume of standard sulphuric acid solution used in titration.

N: normality of standard sulphuric acid solution.

V: volume of sample used in titration.

Calcium was determined by titration with Na_2EDTA as standard solution after addition of Buffer solution (PH=13) and Murexide indicator according to [14], as expressed in the following equation:

Calcium (mg/l as $CaCO_3$) = $\frac{A \times B \times 400.8}{V}$

Where:

A: volume of standard Na_2 EDTA solution used in titration.

B: milligram per liter calcium carbonate which equivalents to one milliliter of Na_2 EDTA standard solution used in titration.

V: volume of sample used in titration.

Magnesium was determined by calculation as the difference between total hardness and calcium hardness according to [14] by applying the following equation:

Magnesium (mg/l as $CaCO_3$) = (total hardness - calcium hardness) × 0.243.

Chloride were also analyzed by titration with standard silver nitrate and potassium chromate as indicator according to [14], as expressed in the following equation:

Chloride (mg/l) = $\frac{(A-B) \times N \times 35450}{V}$

Where:

A: volume of standard silver nitrate standard solution used in titration for sample.

B: volume of standard silver nitrate standard solution used in titration for blank.

N: normality of standard silver nitrate solution.

N: volume of sample used in titration.

While sulphate was determined indirectly as hardness by titration according to [15]. Firstly: total hardness was determined as mentioned formerly, secondly: the sulphate was precipitated as barium sulphate, under heating in acidic medium with 1 N hydrochloric acid, after the addition of axcess amount of 0.01 M standard barium chloride, finally, the remained barium ions in solution were determined as total hardness [total hardness + $BaCl_2$]) and the calculation of sulphate in milligram per liter was obtained according to the following equation:

Sulphate (mg/l) = (total hardness + 1000 - [total hardness + $BaCl_2$]) × 0.96.

2.4. WQI calculation:

The whole study period assessment of treated water quality at each water supply (the over all water quality) was achieved by application of the CCME WQI model on all of the studied chemical parameters except total chlorine. Its calculation comprised three factors as follows [8]:

F_1 (Scope) represents the percentage of variables that do not meet their objectives at least once during the time period under consideration (failed variables), relative to the total number of variable measured:

F_1 = [Number of failed variable/ Total number of variable] ×100 (1)

F_2 (Frequency) represents the percentage of individual tests that do not meet objectives (failed tests):

F_2 = [Number of failed tests / Total number of tests] ×100 (2)

F_3 (Amplitude) represents the amount by which failed test values do not meet their objective. F_3 is calculated in three 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. When the test value must not exceed the objective:

Excursion= [Failed test $value_i$ / $objective_i$]-1 (3a)

For the cases in which the test value must not fall below the objective:

Excursion= [$objective_i$ / Failed test $value_i$]-1 (3b)

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 divided by the total number of tests (both those meeting the objectives and those not meeting objectives). This variable, which is referred to as the normalized sum of excursions, or nse, is calculated as:

$Nse = \sum_{i=1}^{n} excursion$ / total number of tests (4)

iii) F_3 is then calculated by asymptotic function that scales the normalized sum of excursions from objectives (nse) to yield a range between 0 and 100.

$F_3 =[nse/ 0.01 nse+ 0.01]$ (5)

After the factors have been obtained, the index itself can be calculated as follows:

$CCME\ WQI = 100-[\sqrt{F_1^2+F_2^2+F_3^2} / 1.732]$ (6)

The divisor 1.732 normalises the resultant values to a range between 0 and 100, where 0 represents the “worst” water quality and 100 represents “best” water quality.

Once the CCME WQI value has been determined, water quality is ranked by relating it to one of the following categories:

Excellent: (95-100)-water quality is protected with a virtual absence of threat or impairment; conditions very close to natural levels.

Good: (80-94)- water quality is protected with only a minor degree of threat or impairment; conditions rarely depart from natural or desirable levels.

Fair: (65-79)- water quality is usually protected but occasionally threatened or impaired; conditions sometimes depart from natural or desirable levels.

Marginal: (45—64)- water quality is frequently threatened or impaired; conditions often depart from natural or desirable levels.

Poor: (0-44)- water quality is almost always threatened or impaired; conditions usually depart from natural or desirable levels.

3. Results and Discussion:

In the present study, the chemical analysis results of treated water taken from four drinking supplies at Basrah governorate are summarized in table 1 and the percentage of parameters exceeding the guideline values (objectives), recommended by Iraqi standards [16], WHO [17], WHO [18], are illustrated in figures 2,3,4 and 5 for Garma I, Al-Muwahad, Twenty five, and Jubaila stations respectively. .

The pH of treated water is an important factor for chlorination efficiency [19]. It is used as indicator for acidity and alkalinity of water [14]. The results show that pH values (minimum, maximum, and mean) vary from slightly acidic to highly alkaline waters at all drinking water supplies during the study period, the minimum ones are within the permissible limits according to Iraqi standards [16]. While the maximum ones exceeded them (except at Jubaila water supply) which constituent of 25%, 25%, 25% and 0 % at Garma I, Al-Muwahad, and Twenty five stations respectively may be because of elevating concentrations of bicarbonate and carbonate salts for alkaline-earth metal (i.e. calcium and magnesium) [3] as shown in table 1.

Water containing high dissolved solids may cause laxative or constipation effects [20]. The results of total dissolved solids have exceeded the permissible limits of 1000 mg/l and recommended by Iraqi standards [16] for all drinking water supplies during the study period. In general, total dissolved solids Values < 1000 are considered fresh water and values > 1000 mg/l are considered brackish water [21].

Hardness is the property of water which prevents the lather formation with soap and increases the boiling point of water leading to the danger of over heating of boilers in addition to clogging troubles of pipelines [22],[23]. The hardness of water depends mainly on the presence of calcium and magnesium salts. The minimum values of total hardness are within the permissible limits of Iraqi standards [16]. While the maximum ones exceed them and constituent 75%, 25%, 25% and 50% at Garma I, Al-Muwahad, Twenty five, and Jubaila stations respectively .

Table 1: Summary results of the present study chemical analyses (all parameters are measured in mg/l except pH).

Parameters \ Stations		Garma I	Al-Muwahad	Twenty five	Jubaila
PH	**Minimum**	**7.2**	**7.7**	**6.8**	**7.3**
	Maximum	**9**	**9.3**	**9.4**	**8.5**
	Mean	**7.9**	**8.1**	**7.8**	**7.7**
	Standard value	**6.5-8.5**			
TDS	**Minimum**	**1237.5**	**1110**	**1095**	**1185**
	Maximum	**2025**	**1950**	**2017.5**	**1725**
	Mean	**1647.2**	**1521.6**	**1411.9**	**1348.1**
	Standard value	**1000**			
Total hardness	**Minimum**	**390**	**370**	**320**	**390**
	Maximum	**715**	**610**	**770**	**720**
	Mean	**556.9**	**446.3**	**466.3**	**533.8**
	Standard value	**500**			
Alkalinity	**Minimum**	**52**	**36**	**32**	**40**
	Maximum	**96**	**90**	**90**	**102**
	Mean	**70.5**	**66.5**	**50**	**66.3**
	Standard value	**120**			
Calcium	**Minimum**	**64.1**	**72.1**	**76.2**	**88.2**
	Maximum	**140.3**	**120.2**	**144.3**	**136.3**
	Mean	**104.5**	**99.7**	**106.2**	**112.7**
	Standard value	**50**			
Magnisium	**Minimum**	**41.3**	**36.5**	**19.4**	**38.9**
	Maximum	**111.8**	**85.0**	**99.6**	**94.8**
	Mean	**71.9**	**51.6**	**48.9**	**61.4**
	Standard value	**50**			
Chloride	**Minimum**	**239.9**	**189.9**	**179.9**	**239.9**
	Maximum	**589.8**	**489.8**	**569.8**	**459.9**
	Mean	**444.9**	**303.7**	**319.9**	**382.4**
	Standard value	**250**			
Sulphate	**Minimum**	**979.2**	**758.4**	**729.6**	**998.4**
	Maximum	**1180.8**	**1046.4**	**1056**	**1084.8**
	Mean	**1050.8**	**925.2**	**919.2**	**1023.6**
	Standard value	**250**			
Free chlorine	**Minimum**	**0.1**	**0**	**0**	**0**
	Maximum	**1**	**0.3**	**0.3**	**0.3**
	Mean	**0.5**	**0.2**	**0.1**	**0.1**
	Standard value	**5**			
Total chlorine	**Minimum**	**1.5**	**1**	**0.2**	**0**
	Maximum	**3**	**4**	**3**	**2**
	Mean	**2.4**	**1.9**	**1.4**	**0.5**
	Standard value	**No guideline value**			

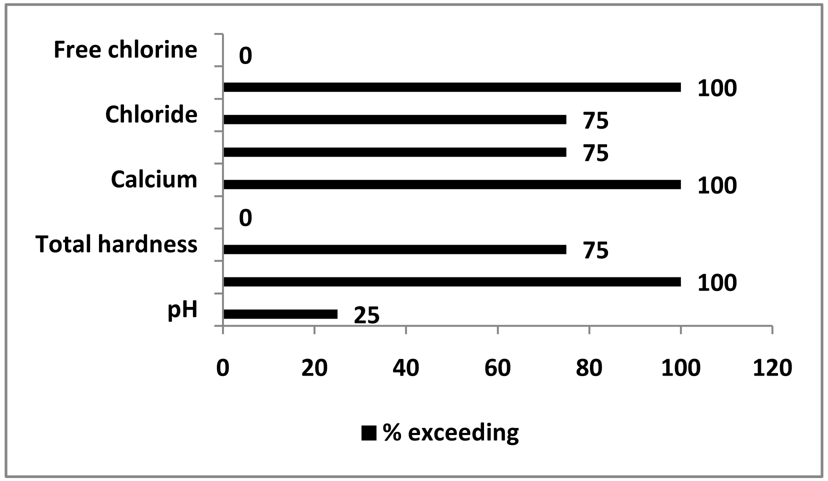

Figure 2: percentage of parameters exceeding guideline values at Garma I water supply.

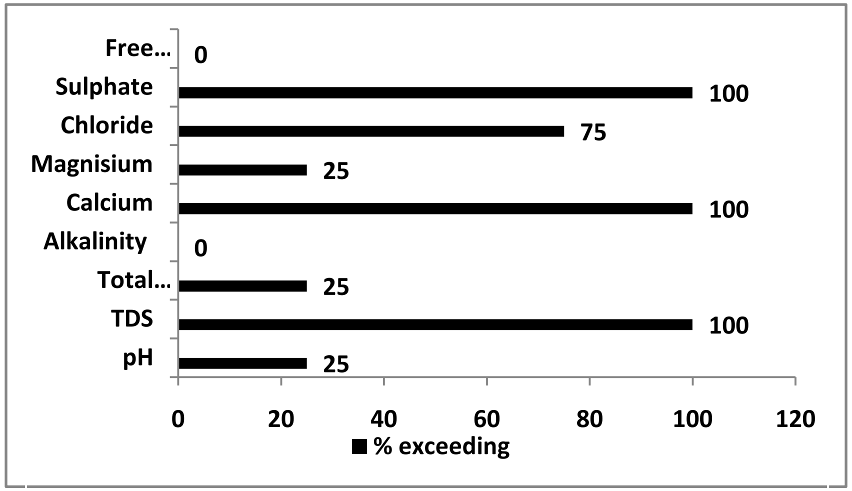

Figure 3: percentage of parameters exceeding guideline values at Al-Muwahad water supply.

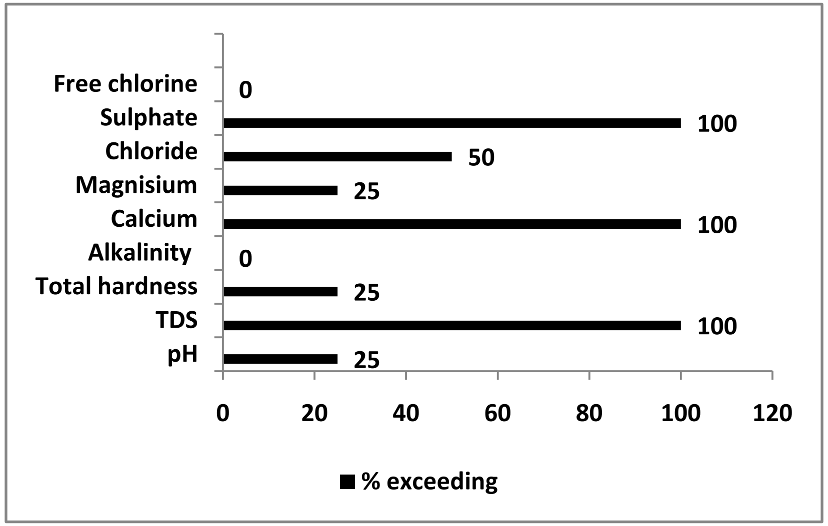

Figure 4: percentage of parameters exceeding guideline values at Twenty five water supply.

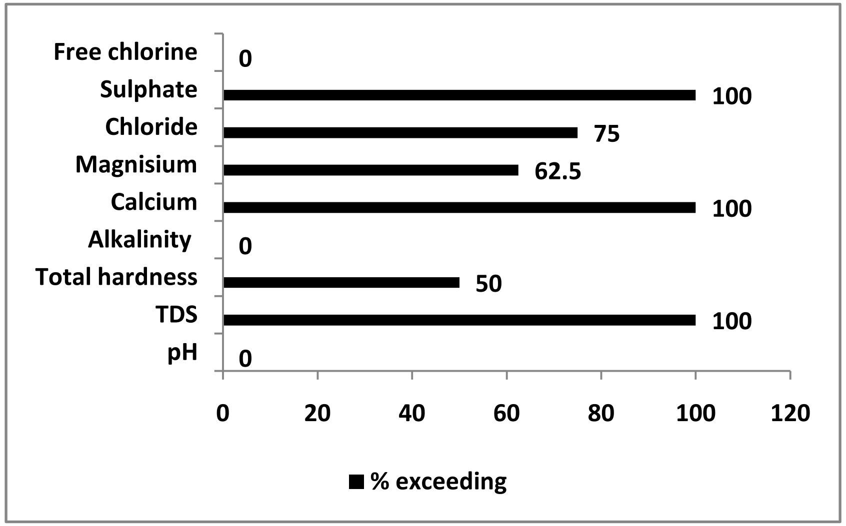

Figure 5: percentage of parameters exceeding guideline values at Jubaila water supply.

Total alkalinity is the measure of capacity of water to neutrized the strong acid. It is generally imparted by salts of carbonates, bicarbonates together with hydroxyl ions in free state [24]. The results of the present study shows that total alkalinity values do not exceed the objective of 120 mg/l which is recommended by WHO [17].

Higher levels of calcium can lead to the development of blood clots, kidney sclerosis and kidney problems with blood vessels [25]. In the present study, Calcium values exceed the permissible limits that are recommended by Iraqi standards [16] at all water supplies during the study period.

Magnesium causes hardness in water. Also, higher levels affect human health leading to Encephalitis [21]. Results of Magnesium show that the maximum values exceed the permissible limits according to Iraqi standards [16], about 75%, 25%, 25% and 62.5% at Garma I, Al-Muwahad, Twenty five, and Jubaila stations respectively .

High concentrations of chloride can make water undesirable and therefore, not recommended for drinking [23]. The minimum values are within the permissible limits according to Iraqi standards [16]. While the maximum ones exceed them about 75%, 75%, 50 % and 75% at Garma I, Al-Muwahad, Twenty five, and Jubaila stations respectively .

High sulphate concentrations impart a bitter taste and may cause laxative effects in some individuals [21]. People who are drinking water with high level of sulphate may suffer from dehydration and diarrhea, children are often more sensitive to sulphate than adults [25]. The present study results exceed the permissible limits recommended by Iraqi Standards [16] for all water supplies.

Chlorine is mostly used in the disinfection of drinking water supplies. Values of total chlorine present the amount of chlorine added to drinking water which includes free chlorine and combined chlorine with dissolved chemicals and in the present study, its values vary from 0 at Jubaila to 4 mg/l at Al-Muwahad water supply. Free chlorine is defined as residual chlorine in water existed as dissolved gas (Cl_2), hypochlorous acid (HOCl), and /or hypochlorite ion (OCl^-). Its values are within the permissible limits of 5 mg/l which is recommended by WHO [18] at all water supplies along the study period. The excess amount of free chlorine above this value causes a risk of adverse health effects, in addition to the unpleasant water taste [26].

Anova test of variance shows no spatial variations for all studied chemical parameters except for Sulphate (<0.05), free chlorine(<0.05) and total chlorine(<0.01) which reflect raw water quality in addition to treatment efficiency for each drinking water supply. The difference in dosage of both chlorine and alum [$AlK(SO_4)_2$. 12 H_2O] that is added at each water supplies leads to existence of significant spatial differences in free chlorine, total chlorine and sulphate .

The results of Over all CCME WQI calculation for treated water stations have been listed with their corresponding water quality status in table 2. These results indicate that water quality can be rated as poor at both Garma I and Al-Muwahad water supplies respectively and as Marginal at both Twenty five and Jubaila water supplies respectively. This deterioration in water quality for the studied water supplies reflects raw water quality supplied to them which came from two resources, they are: Shatt Al-Arab and Al-Gharaf rivers, the second one characterized by decreasing both its salinity and hardness comparable with the first one. Sometimes, raw water entirely composed of Shatt Al-Arab river and sometimes, results from mixing of both Shatt Al-Arab and Al-Gharaf rivers.

In spite of using Al-Gharaf river as a resource of raw water for the studied drinking water supplies but their treated waters are depart from natural and desirable levels depending on the guideline set by Iraqi standards [16], WHO [17] and [18].

So, these water supplies need to further treatments in order to increase the efficiency of current treatments like: 1) Usage of coagulant aids in coagulation & flocculation stage 2) Usage of anthracite coal in filtration stage (27).

1. **Table 2: Results of over all CCME WQI calculation with corresponding water quality status.**

	WQI	F_1	F_2	F_3	Water quality status
Garma I	36	77.8	61.1	50.3	Poor
Al-Muwahad	44	77.8	50	27.3	Poor
Twenty five	45	77.8	47.2	30.2	Marginal
Jubaila	47	66.7	54.2	34.6	Marginal

As we mentioned formally, the index equation has included the calculation of scope (F1) and both extent (F2) and magnitude of parameter excursions (F3) from the guideline set by Iraqi standards [10], WHO [24] and [25]. So, in order to interpret the present results, we should demonstrate the role of each factor on deterioration of water quality statistically, a step wise multiple regression analysis is performed. The regression analysis shows that WQI are significantly related to both F_3 and F_1. We can be demonstrating these relationships in two model equations as below:

$WQI=57.235-0.404\times F_3$
($p<0.01$, $R^2=0.762$) [7]

$WQI=86.278-0.390\times F_3-0.394\times F_1$
($p<0.01$, $R^2=0.983$) [8]

These results lead us to conclude that both amplitude and scope have the greatest influence on the driven values of CCME WQI.

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