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ASSESSMENT THE WATER QUALITY INDEX OF AL-HINDIYA DRINKING PROJECTS.

تقييم مؤشر نوعية المياه لمشاريع ماء الهندية

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ABSTRACT

The assessment process of drinking water quality are considered the most important issue that must be studied and consideration because of its significant effect on human health. In this study, two drinking projects within Al-Hindiya province in Karbala city were evaluated based on weighted arithmetic and CCME water quality indexes during years 2014 to 2016. The physicochemical parameters which were used in developed these indexes involve: Turbidity (Turb.), pH, Electrical Conductivity (EC), Alkalinity (Alk.), Calcium (Ca^{+2}), Magnesium (Mg^{+2}), Chloride (Cl^-), Total Hardness (TH), Sulfate (SO_4^{-2}), Total Dissolved Solids (TDS) and Sodium (Na^+). The Iraqi standard for drinking water (IQS- 417, 2001) was adopted. The results of the weighted arithmetic WQI showed that the raw water was unsuitable for drinking while the treated water had a good quality and the improvement ratio in water quality were between (75-90)%, while the CCME-WQI results indicate that the raw water quality was fair and the treated water good for drinking except in dry period of year 2015 where the quality of treated water was fair for drinking, knowledge that the raw water index was also the lowest in this time, the improvement ratio in water quality index based on this index were between (11-20)%. Also, it can be concluded that the improvement in water quality for both index were greater in dry season than wet season.

KEY WORDS: Raw, Treated, Water quality, Weighted arithmetic, CCME, Improvement ratio.

الخلاصة:

ان عملية تقييم نوعية مياه الشرب من المواضيع المهمة التي يجب دراستها واخذها بنظر الاعتبار بسبب تأثيرها الهام على صحة الإنسان. في هذه الدراسة تم تقييم مشروعين للشرب في قضاء الهندية ضمن مدينة كربلاء باستخدام مؤشر نوعية الماء الحسابي الموزون والمؤشر الكندي خلال الفترة من 2014 إلى 2016. العوامل الفيزيائية الكيميائية التي استخدمت في تطوير هذه المؤشرات تشمل: العكورة، الأس الهايدروجيني، التوصيل الكهربائي، القلوية، الكالسيوم، المغنيسيوم، الكلوريد، العسرة الكلية، الكبريتات، المواد الصلبة الذائبة الكلية والصوديوم. تم اعتماد المواصفة العراقية لمياه الشرب رقم 417 لسنة 2001. بينت نتائج المؤشر الحسابي الموزون أن المياه الخام غير صالحة للشرب في حين أن المياه المعالجة كانت ذات نوعية جيدة وكانت نسبة التحسن في نوعية المياه بعد المعالجة تتراوح بين (75- 90)٪ بينما بينت نتائج مؤشر نوعية الماء الكندي أن نوعية المياه الخام كانت معتدلة في حين أن المياه المعالجة جيدة للشرب باستثناء الفترة الجافة من عام 2015 حيث كانت نوعية المياه المعالجة معتدلة للشرب، علما بأن مؤشر المياه الخام كان أيضا في أدنى مستوى في هذا الوقت وتراوحت نسبة التحسن بقيمة المؤشر اعتمادا على هذه الطريقة بين (11-20)% . اشارت النتائج ايضا أن نسبة التحسن في نوعية المياه المعالجة لكل من المؤشرين كانت أكبر في الموسم الجاف من الموسم الرطب.

1. INTRODUCTIO

Water is the most important necessities for survival and it considered natural wealth in the world. In the past, many great civilizations were constructed along or near water sources, so the improvement in the water resources has often led to development in social, economic and health fields of many countries in the world. However, pollution of waters often effects on the benefits obtained from these developments.

At the present time, various surface water sources suffer from high pollution due to increase in population growth, industrial development, bad disposal of the different sewage, absence of the proper planning for using water, and change in climate [1]. So, the re-evaluate the efficiency of water treatment stations becomes very necessary in order to control on the water quality due to the continuous qualitative change that occurs in the chemical and physical properties of the water molecule.

The standards or guidelines which use to determine the water quality are varying depending on their type and the purpose of using water, i.e. the guidelines of irrigation water differ from those for drinking or industrial use and so on. For drinking water, there are numerous guidelines to determine the suitability of water for this purpose and provide clean and safe water to protect human health from different diseases, such as world health organization (WHO), Canadian Drinking Water Quality (CDW), Iraqi drinking water standards (IQS) and etc.

The assessment of the water quality using traditional methods which are based on a comparison of experimentally measured parameter values with standard guidelines, does not give a clear indication of the water quality trends across geographic regions and over time. So, scientists and researchers developed an efficient indicator of water quality (WQI) which is considered the most preferred scientific method using different parameters and formulating them into descriptive dimensionless single term that explain the whole status of the water system [2].

The water quality index was first suggested by Horton 1965, then it was developed by Brown et al.1970 [3][4]. After that, scientific research and experiments have been continued over years to develop and improve the water quality index, for example: Sullivan et al. 2003 using projects in Tanzania, Sri Lanka and South Africa, to develop the water poverty index (WPI) which measures the water stress at the community levels and household, this index is a single number combines a range of data that related directly and indirectly to water stress such as quantity, variability, quality, the purpose of the use of water, environmental fields and management capacity for water [5].

Meireles et al. 2010, developed the irrigation water quality index in the Acarau Basin, North of the Ceara state, Brazil [6], many researchers used this index such as Khalaf and Hassan who used this index to study the groundwater quality of 30 wells in the Dammam confined aquifer in area of Karbala desert during March 2012 [7].

Al-Shujairi 2013 formed Iraqi water quality index for Tigris and Euphrates rivers (IRWQI) depending on seven measure parameters to evaluate the water quality for difference uses, the results indicated that the quality of water ranged from very good to very poor [8]. Al-Awadi evaluated the efficiency of four treatment plant on Euphrates river and al-Hussainyah branch canal in Karbala city by using weighted arithmetic index for both raw and treated water during year 2014 [9]. Sim et al. 2015, developed a multiple variables computer-aided water quality index (PLS-WQI) which is based on partial least squares regression (PLS) and the training set were computationally created based on the guideline of Malaysia National Water Quality Standards (NWQS) to predict the water quality. This algorithm was efficient tool for temporal and spatial routine monitoring of water quality and can be easily used with other guidelines [10].

Sun et al. 2016 produced a modified WQI named (WQI min) which based on Principal Component Analysis (PCA) and correlations analyses of the water parameters in both dry and wet seasons during the period 2011-2012 for Dongjiang River in southern China, the results showed (WQI min) was reflect adequately the seasonal changes in water quality that was lightly worse in dry season compared with wet season [11].

The current study aimed to assessment the drinking water quality of the two purification projects in the province of AL-Hindiya, Karbala city, using both the weighted arithmetic and Canadian water quality indexes during the wet and dry periods of years 2014 to 2016.

2. MATERIALS AND METHODOLOGY.

2.1 Study Area

Euphrates River is the main source of surface water in Al-Hindiya district within Karbala governorate. The largest water projects in this region are AL-Hindiya and Al-Moahhad drinking water purification plants fig.(1), which have a design capacity of 2000 m^3/hr. for two projects. Monthly parameters for raw and treated water states during the period 2014-2016 were obtained from the directorate of Karbala water and then organized as wet and dry seasons. These parameters are involved: Turbidity (Turb.), pH, Electrical Conductivity (EC), Alkalinity (Alk.), Calcium (Ca^{+2}), Magnesium (Mg^{+2}), Chloride (Cl^-), Total Hardness (T.H), Sulfate (SO_4^{-2}), Total Dissolved Solids (TDS) and Sodium (Na^+). The Iraqi Standard for drinking water (IQS- 417, 2001) which illustrate in table (1) was adopted to developed the required indexes [12]. The average of the main physical and chemical properties of raw and treated water samples for AL-Hindiya and Al-Moahhad drinking projects are given in table (2) and (3) respectively, note that the bold values in these tables indicate that they exceeded the permissible values within the Iraqi standard.

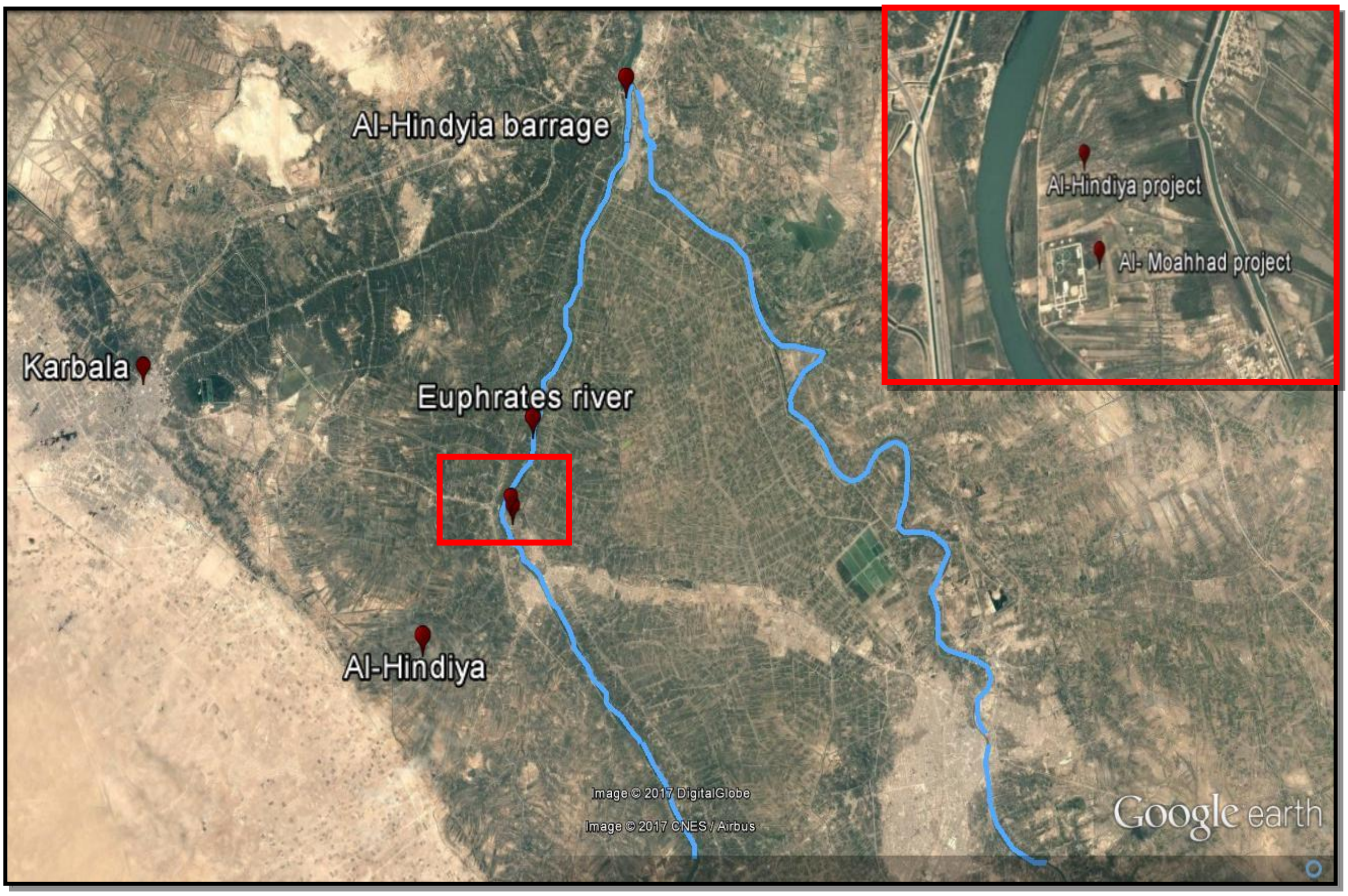

Fig.1: Location of the study purification plants.

Table 1: The Iraqi standard for drinking water (IQS-417, 2001)

Parameter	Tur. NTU	pH	E.C μS/cm	Alk. mg/ L	T.H mg/L	Ca mg /L	Mg mg/L	Cl mg/L	SO_4 mg/L	TDS mg/L	Na mg/L
Standard value	5	8.5	2000	125	500	75	50	250	250	1000	200

Table 2: The physicochemical parameters of Al- Hindiya project.

Parameter	2014				2015				2016			
	Wet		Dry		Wet		Dry		Wet		Dry	
	Ra.	Tr.	Ra.	Tr.	Ra.	Tr.	Ra.	Tr.	Ra.	Tr.	Ra.	Tr.
Tur.	14	1	25	1	15	1	11	0.2	15	1	27	0.5
PH	8.2	8	8	7.8	8.1	7.9	7.8	7.8	8.4	7.7	7.8	7.7
EC	1213	1227	994	998	1307	1310	1362	1356	1202	1202	1160	1159
Alk.	139	138	117	112	127	125	106	101	119	115	104	100
T.H	394	377	339	330	421	412	521	513	409	412	409	404
Ca	99	92	78	78	100	96	154	152	108	108	115	113
Mg	36	36	35	33	42	42	33	32	34	35	30	29
Cl	136	136	106	108	154	155	154	157	127	119	102	104
SO_4	281	284	236	240	296	300	413	416	314	323	320	325
TDS	783	776	667	663	844	840	880	875	765	767	725	725
Na	107	104	81	81	107	105	107	105	96	96	76	75

Table 3: The physicochemical parameters of Al-Moahhad project

Parameter	2014				2015				2016			
	Wet		Dry		Wet		Dry		Wet		Dry	
	Ra.	Tr.	Ra.	Tr.	Ra.	Tr.	Ra.	Tr.	Ra.	Tr.	Ra.	Tr.
Tur.	15	1	28	1	15	2	12	0.1	13	1	20	1
PH	8.2	8	8	7.8	8.1	8	7.8	7.8	7.9	7.8	7.8	7.6
EC	1248	990	1003	1012	1303	1314	1361	1368	1207	1209	1163	1167
Alk.	138	137	117	115	128	127	107	103	115	114	106	103
T.H	388	374	340	334	421	415	520	513	413	409	413	407
Ca	91	86	80	77	100	99	153	151	110	109	113	111
Mg	39	39	34	34	42	41	33	33	34	33	32	31
Cl	129	131	106	107	154	155	153	151	125	123	103	105
SO_4	294	299	240	244	296	299	412	416	311	315	324	325
TDS	801	789	631	666	844	848	880	884	763	757	728	731
Na	108	106	82	81	107	106	108	106	93	92	77	76

* Ra. : Raw water
* Tr. : Treated water

2.2 Water Quality Index (WQI)

The water quality index is a very efficient and useful process that gives a simple indicator about the quality of water for different use depending on some measured parameters. In this study, Water Quality Index (WQI) was calculated by using the Weighted Arithmetic Index and Canadian Council of Ministers of the Environment Water Quality Index (CCMEWQI), methods to evaluate the drinking water of Al-Hindiya water projects in karbala city.

a. Weighted Arithmetic Index

In order to calculate the quality of water based on the Weighted Arithmetic Index the flowing steps are adopted [13][14]:

1- The quality rating of i^{th} parameter ($Q_{i)}$:

$$Q_i = \left\{\left[\frac{(V_{act.} - V_{ide.})}{(V_{st.} - V_{ide.})}\right] * 100\right\} \quad \dots\dots\dots\dots (1)$$

Where:

$V_{act.}$ = the actual concentration of the parameter which is achieved from the analysis of water.

$V_{ide.}$ = the ideal value of that parameter (for pH parameter $V_{ide.}$ =7 and for other =0).

$V_{st.}$ = the recommended standard parameter of the water quality i.e. the (IQS- 417, 2001).

2- The relative unit weight of the parameter $W_{i\,:}$

$$W_i = \frac{K}{V_{st.}} \quad \dots\dots\dots\dots .(2)$$

Where K is the constant of the Proportionality, which is equal to: $K = \frac{1}{\sum\left(\frac{1}{V_{st.}}\right)}$ ………..(3)

3- The Arithmetic Water Quality Index WQI :

$$WQI = \frac{\sum Q_i * W_i}{\sum W_i} \quad \dots\dots\dots\dots.(4)$$

Table (4) illustrated the type of water quality For the method of weighted arithmetic index.

Table 1: Classification of water quality based on weighted arithmetic index value [15]

The value of Water Quality Index	Category of Water quality	Grading
0-25	Excellent	A
26-50	Good	B
51-75	Poor	C
76-100	Very poor	D
>100	Unsuitable for drinking	E

b. The CCME WQI

The CCME WQI model is developed based on three calculated factors (scope, frequency and amplitude), These three factors combine to produce a single value range between 0 and 100 which represents the whole quality of water.

The following steps illustrate the procedure used to calculate CCME WQI [16]:

1- Scope (F_1) : includes the ratio between the number of variables which their values do not identical with the objectives set (standard values) and the total number of variables as in equation (5)

$$F_1 = \frac{\text{No. of failed variables}}{\text{Total No. of variables}} \times 100 \quad \dots\dots\dots..(5)$$

2- Frequency (F_2): it is the relation between the number of failed tests which do not match the model objectives group and the values of all tests. It is calculate as follows:

$$F_2 = \frac{\text{No. of failed tests}}{\text{Total No. of tests}} \times 100 \quad \dots\dots\dots\dots..(6)$$

3- Amplitude (F_3) : explain the amount that failed tests do not meet their objectives. It is calculated in three steps:

a- Excursion: it is the number of times in which a singular parameter concentration is more than the objective (or less than, in case of min. objective) and is calculate as follows:

$$\text{excursion}_i = \left[\frac{\text{Failed test value}_i}{\text{objective}_i}\right] - 1 \quad \dots\dots\dots\dots(7)$$

b- Normalized sum of excursions (nse): it is the ratio between the summation of the excursions and the total number of tests (i.e. both the failed and success tests), and is calculate as follows

$$\text{nse} = \frac{\sum_{i=1}^{n} \text{excursion}_i}{\text{Total No.of tests}} \quad \dots\dots\dots\dots\dots(8)$$

c- F_3 is calculated as in equation (9):

$$F_3 = \left[\frac{\text{nse}}{0.01\ \text{nse} + 0.01}\right] \quad \dots\dots\dots\dots (9).$$

4- Finally, the Index value is found as in eq (10):

$$\text{CCME WQI} = 100 - \frac{\sqrt{F1^2 + F2^2 + F3^2}}{1.732} \quad \dots\dots\dots\dots\dots(10)$$

The CCME WQI values range between (0- 100), where the value of 100 indicates the best index score while the value of 0 is the poorest index as shown in table (5).

Table 2: Classification of water quality based on CCME- WQI

CCME WQI range	Type of water quality
95-100	Excellent
80 -94	Good
79 – 65	Fair
64 – 45	Marginal
44 – 0	Poor

c. Improvement ratio in WQI

In order to evaluate the effectiveness of the treatment projects, the improvement ratio in the quality of raw water after passing through the purification processes have been calculated according to the following equation:

$$\text{Improvement ratio \%} = \frac{\Delta\ \text{WQI}}{\text{WQI of raw water}} * 100 \dots\dots(11)$$

Where : ΔWQI is the difference in WQI between raw and treated water.

3. RESULTS AND DISCUSSION:

a. The analysis of raw and treated water parameters

The test results of raw water for the two treatment plants indicated that the most parameters that exceeded the permissible level of Iraqi standard for drinking use during the study period were turbidity, calcium and sulfate as shown in tables 1&2. Turbidity is considered the most significant parameter for drinking water [17], however the average turbidity value for the rainy season of year 2015 was more the than the dry season, whereas for the years 2014 and 2016 the value of the dry season was higher. Turbidity is formed in raw water as a result of phytoplankton growth, human activities such as agriculture, building and mining which can increase the sediment levels entering water, also, during the rainy season due to the soil erosion belongs to a high runoff. The results of treated water tests show that the study treatment plants were very efficient in removing the turbidity, especially in the dry season.

The main source of calcium ions in natural water is the sedimentary and carbonate rocks such as dolomites, limestone and gypsum when the stream flows over them. For sulfate, approximately all surface waters are contained sulfate ions, and their existence is limited with presence of calcium ions to form together a slightly dissoluble $CaSO_4$, the source of sulfate in raw water is the different sedimentary rocks which include anhydride and gypsum.

The concentration of calcium ion in the treated water is less than the raw water, but the improvement rate is very small and it is also outside the Iraqi specifications because the plants are reducing the time of the hydraulic retention in the sedimentation and filtration basins so as to satisfy the increasing demand for water also, the delay in the wash filters lead to reduce the plants efficiency to removing calcium carbonate or salts. From the results and for all the cases there were increasing in concentration of ion sulfate in treated water than the raw water due to the addition of aluminum sulfate $Al_2\,(SO4)_3$ in the purification of drinking water, and after that, the sulfate ion enters in the composition of this compound and thus, after its solubility in the water during the purification process, the sulfate ion will be released and thus increase its concentration in the treated water.

In general, It can conclude that for both stations the water purification process was largely concentrated on the removal of water turbidity while the other parameters had very little improvement with the knowledge that there were some ions whose their concentration were increased in treated water than raw water as explained above.

b. Results of weighted arithmetic water quality index

For Al- Hindiya drinking project and as shown in figs.(2) and (3) the values of weighted arithmetic index for raw water during wet and dry seasons were more than100 thus, according to table (4) the quality of water is unsuitable for drinking purpose. In the other hand, the treated water for both seasons was fall under good quality category as their index values range between (32 to 49).

Figs. (4) and (5) illustrate the index values at Al- Moahhad drinking project, the quality of raw water for both dry and wet seasons was, also classified as unsuitable for drinking purpose while the treated water was within good class. The results indicate that there were significant improvement in drinking water quality after passing through the purification plants, to find the percentage values of this improvement, equation (11) had been applied according to the weighted arithmetic index. Regarding to Al- Hindiya new project, as shown in fig.(6), the highest improvement ratio was in the year 2016 which was about 90% during dry period, while the plant efficiency was equal for two seasons during the year 2015, in addition to that the min. value was in year 2014 in wet period which was about 74%.

Fig.(7) explains the improvement ratio in WQI for Al- Moahhad drinking project, it can clearly concluded from the chart, the best effectiveness treatment for this plant was in year 2014, in which the increases ratio in WQI were about 78% and 88% for wet and dry season respectively, while the min. ratio was in year 2016 through wet season 72%.

In general it can be said that the effectiveness of two treatment plants based on weighted arithmetic WQI was better in the dry season compared with wet season during the period of study.

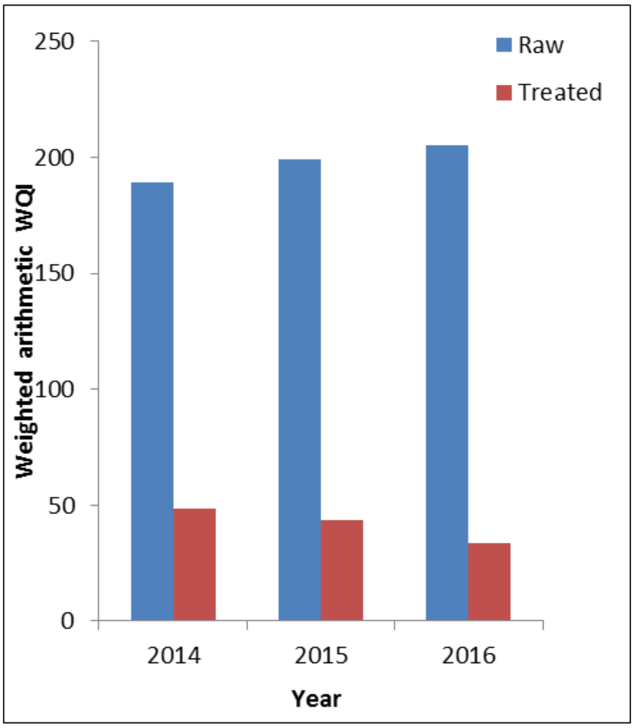

Fig.2: Weighted arithmetic WQI for raw and treated water at Al- Hindiya drinking project (wet season)

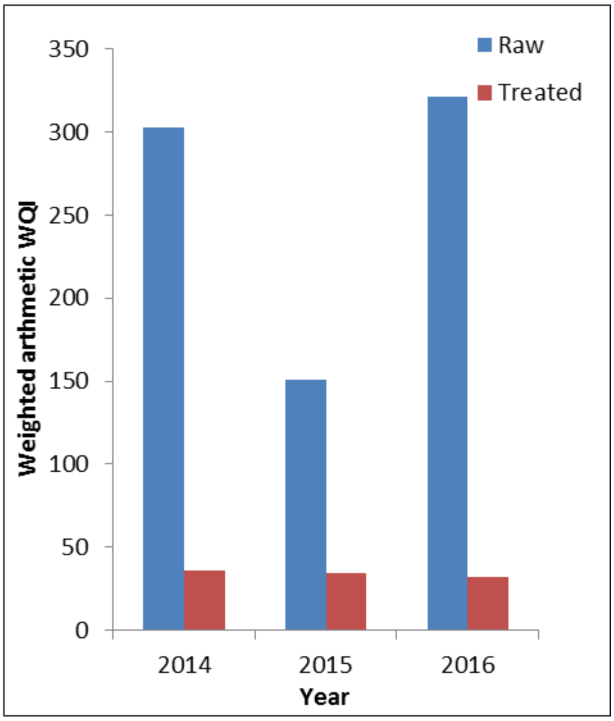

Fig.3: Weighted arithmetic WQI for raw and treated water at Al- Hindiya drinking project (dry season)

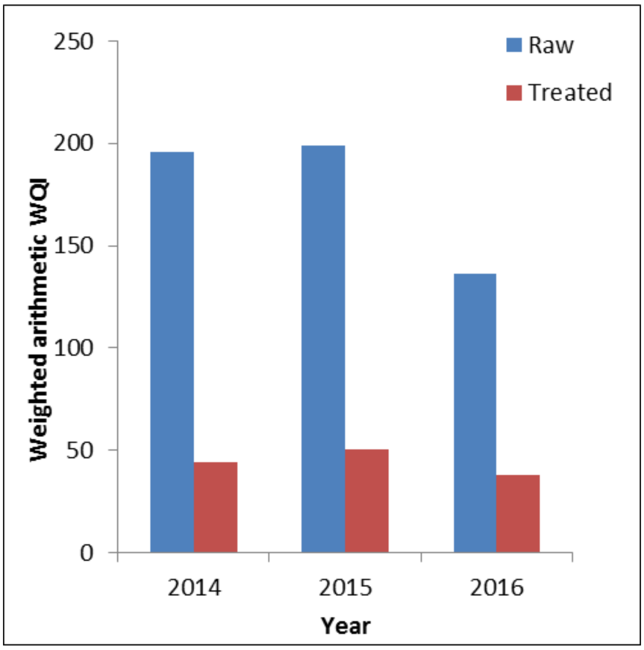

Fig.4: Weighted arithmetic WQI for raw and treated water at Al- Moahhad drinking project (wet season).

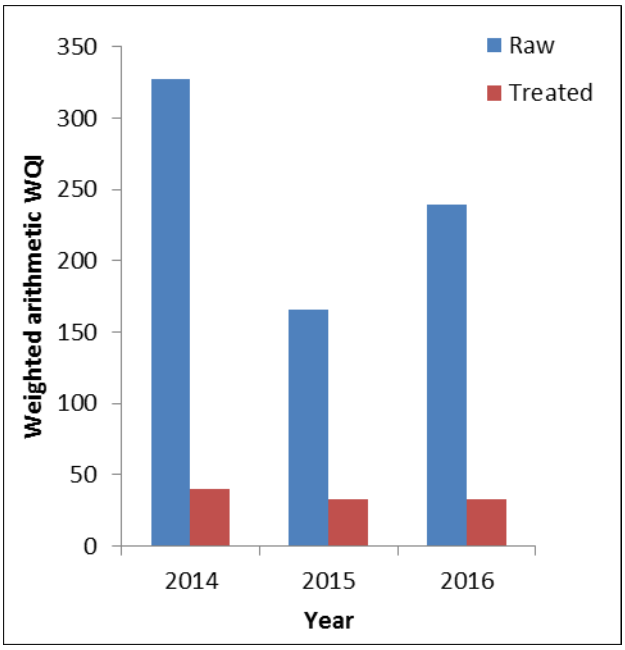

Fig.5: Weighted arithmetic WQI for raw and treated water at Al- Moahhad drinking project (dry season).

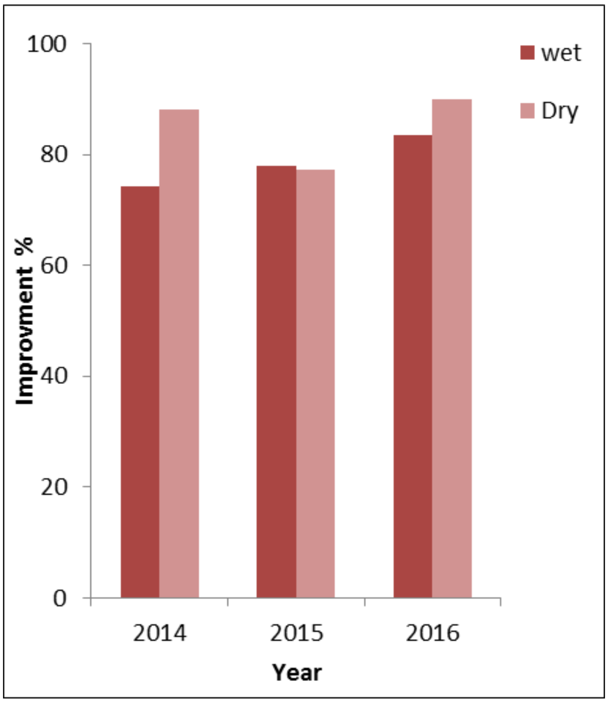

Fig.6: The improvement ratio in weighted arithmetic WQI of Al- Hindiya project .

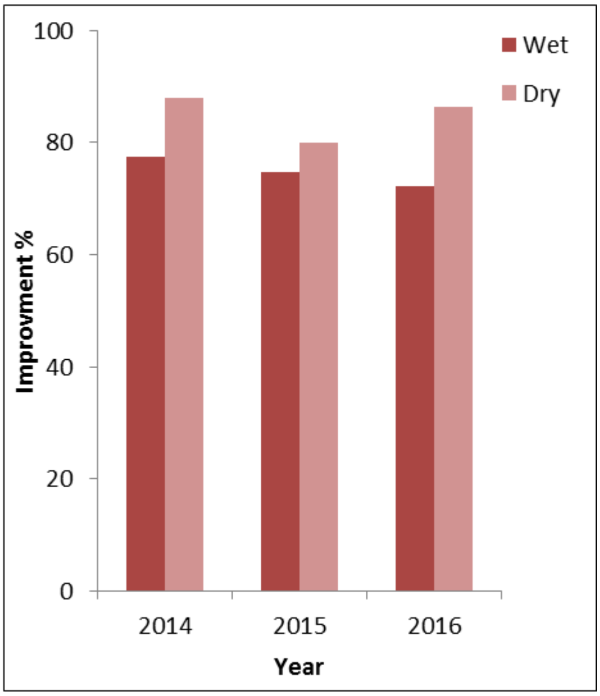

Fig.7: The improvement ratio in weighted arithmetic WQI of Al- moahhad project.

c. Results of CCME water quality index

The CCMEWQI was also applied for two drinking projects, for Al- Hindiya plant and as shown in Figures (8) and (9), the average values of calculated CCME-WQI in both seasons for raw water was fall within fair class according to table (5), while for treated water the average index values indicate that the quality of water for drinking uses can be ranked as good during study time expect in dry period of year 2015 which was the quality of treated water classified as fair drinking, knowledge that the raw water index was also the lowest in this time.

Figs. (10) and (11) illustrated the index values at Al- Moahhaed drinking project, as the index value of raw water for both dry and wet seasons ranged between (69-76), so the quality was also classified as fair drinking water while the treated water index were classified into good quality category, except in 2015 during the dry season where the value of the Canadian index was about 78, which means that the quality of treated water is fair to drink, noting that the value of the index of raw water in this period was also fewer as in Al- Hindiya project.

The improvement ratio in water quality based on CCME WQI can be explained in figs. (12) and (13). It can be noted this ratio increased in dry season compared with wet season and regarding with Al- Hindiya plant, the max. increasing ratio in WQI was in dry time of year 2016 which was about 20% and for Al- Moahhaed plant was in dry period of year 2014 which was 18%. It can be concluded that the improvement rate is higher in Al- Hindiya project, as it is anew operating plant, where the work began in 2014, while the Al- Moahhaed project has been operating since 1986 and it needs to continuous maintenance.

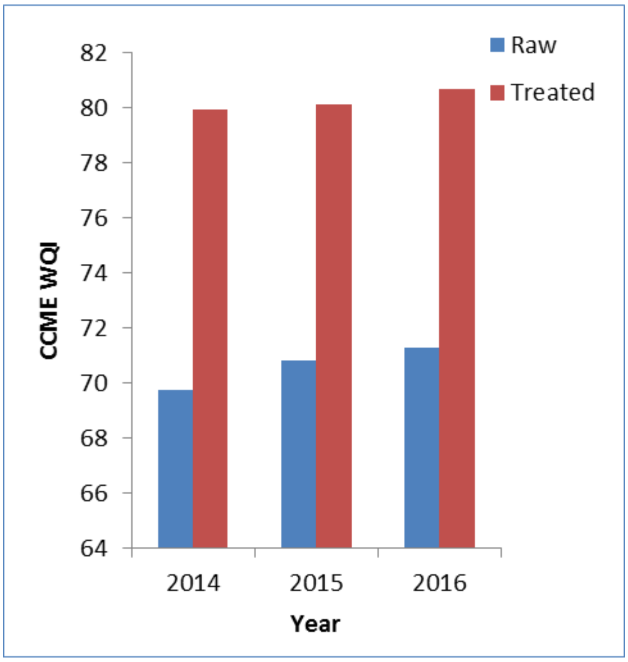

Fig.8: CCME- WQI for raw and treated water at Al-Hindiya drinking project (wet season).

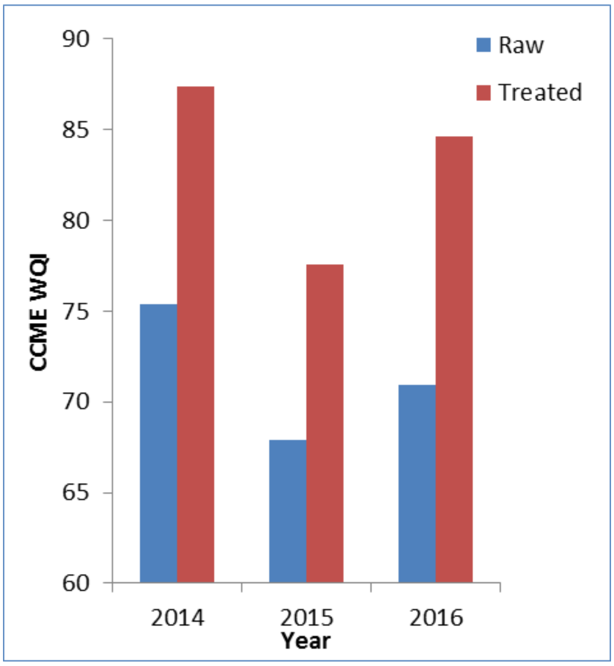

Fig.9: CCME-WQI for raw and treated water at Al-Hindiya drinking project (dry season).

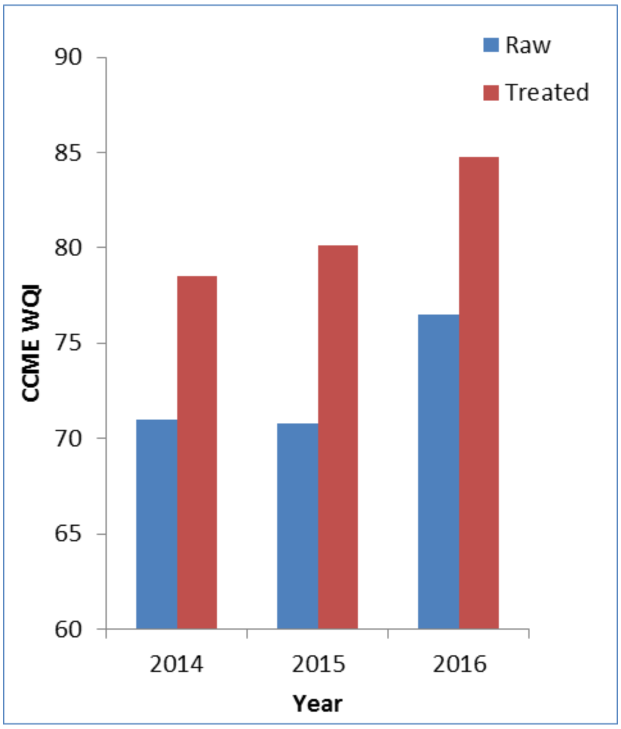

Fig.10: CCME-WQI for raw and treated water at Al- Moahhad drinking project (wet season).

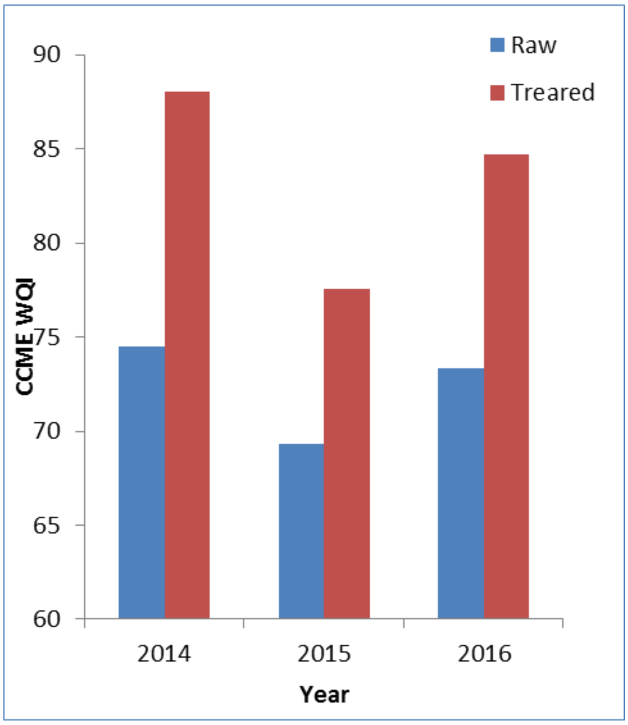

Fig.11: CCME WQI for raw and treated water at Al-Moahhad drinking project (dry season).

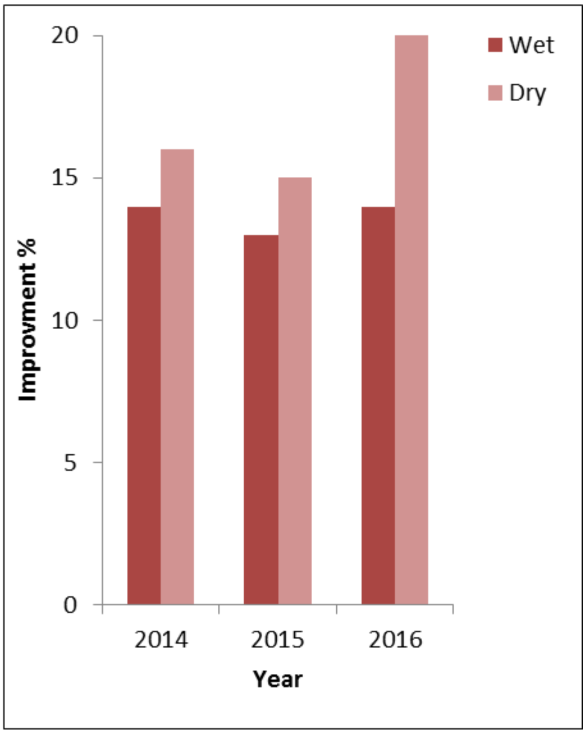

Fig.12: The improvement ratio in CCME-WQI of Al-Hindiya drinking project .

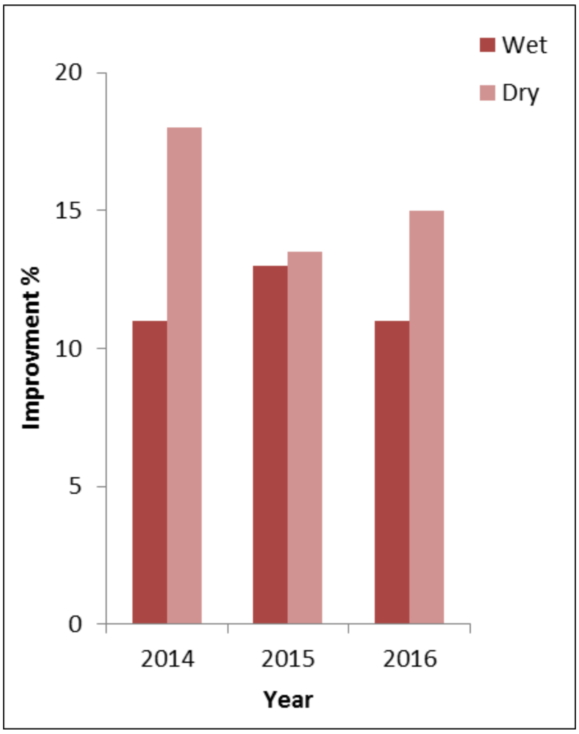

Fig.13: The improvement ratio in CCME-WQI of Al- Moahhad drinking project.

Clearly, the improvement ratio which depending on the weighted arithmetic index is much higher than that based on the Canadian index that is because, in the first case the quality of raw water after passing through the purification process is transferred from undrinkable to good water quality (grade E to B), while in the case of the Canadian indicator of quality water varies from moderate to raw drinking to good quality, i.e. there is little improvement in water quality.

4. CONCLUSION

The quality of raw and treated water were analysis for Al-Hindiya and Al-Moahhad drinking projects, based on weighted arithmetic and CCME WQI, the following results were obtained:

1- Turbidity, calcium ions and sulfate were the most parameters exceeded the permissible level of Iraqi standard for drinking use during the study period.

2- The work of the two stations were focused on purifying the water from turbidity primary compared to the other parameters.

2- According to weighted arithmetic WQI and for two projects raw water was unsuitable for drinking while the quality of treated water was good.

3- Depending on CCME-WQI, raw water was classified as a fair for drinking in both seasons and for two projects while for treated water the average index values indicate that the quality of water ranked as good during study time except in dry period of year 2015 where the quality of treated water was fair for drinking, knowledge that the raw water index was also the lowest. in this time.

4- Improvement ratio based on weighted arithmetic WQI ranged between (75-90)% while for CCME-WQI this ratio was between (11- 20)%.

5- Improvement ratio in water quality for both index were greater in dry season than wet season.

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