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EVALUATION THE WATER QUALITY OF SOME WATER TREATMENT IN BAGHDAD CITY/ AL-KARKH SIDE USING SEVERAL WATER QUALITY INDICES

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Abstract
The present study was conducted on the drinking water treatment plants located in three districts which are (Al-Qadisiyah, Al-Dora, Al-Kadhimiya) in Baghdad city. The study aims to assess the water quality produced from the above three plants using various water quality indices. Twelve physical and chemical parameters have been tested which are pH, turbidity, electrical conductivity, calcium, magnesium, chloride, total hardness, alkalinity, sulfate, sodium and total dissolved solids. Five different approaches and methodologies of water quality indices were applied to get the level of pollution during a period of nine months, starting from November 2021 until July 2022.The values WAV WQI for all water treatment pants indicate that the water quality was good. Also, the results of the MNE WQI showed that all water treatment plants produced clean water, but Al-Qadisiyah treatment plant in April, the water was very clean. The values of (weighted method) indicated that the water quality for all water treatment plants was good, but Al- Kadhimiya water treatment gives excellent water quality, and it was moderately polluted of Al-Qadisiyah plant in months of May and July .It was found that all water treatment plant studied gives excellent quality using based on values of CCME and BCWQI indices. It is found that the values of all chemical and physical parameters are within Iraqi standards. Finally, in the present study, many statistical equations were found for the purpose of calculating the water quality index for each water treatment plant studied with a proper coefficient of determinations.
Key words: Water Quality Indices, WAV WQI, water treatment plants, CCME, BCWQI.

Introduction

Water is a valuable natural resource that we utilize for drinking and a variety of other reasons in our daily lives. [1]. Safe drinking water is essential for human health around the world; as a universal solvent, water is a primary source of protection against contamination and illness, according to the World Health Organization (WHO) Water-borne diseases account for 80% of all diseases, and drinking water in many countries does not satisfy WHO criteria [2], with 3.1 percent of deaths attributed to the unclean and poor quality of water. [3]. Water pollution occurs when unwanted contaminants enter water, altering its quality and posing a threat to the environment and human health. [4]. Some drinking water supplies have been contaminated with germs, viruses, heavy metals, and salts as a result of insufficient treatment and management of waste industrial outputs. [5] Diseases such as cholera, dysentery, and typhoid are caused by a lack of safe drinking water and proper sanitation measures, and millions of lives are lost each year in impoverished countries [6]. Water is required not only for metabolic systems in the human body, but also for

other activities related with human life, such as distilled water for laboratories, medical factories, minerals in drinking water, industries, agricultural, aquatic cultures, and other similar activities [7]. The WQI can be defined as a mathematical tool transforming large quantities of data obtained from physical and chemical properties of water into a single number representing the level of water quality [14]. Water quality is determined by its physical, chemical, and biological characteristics. Before using water for different intended uses, such as potable, agricultural, recreational, and industrial water utilizations, it is vital to determine the water's quality. It's critical to establish water quality metrics in order to assess the condition, quality, and level of contamination of surface water. Processing related data is necessary, and professionals should be shown the outcomes. Using water quality indicators is one of the simplest ways to evaluate current water quality conditions [10]. a need for all living things as a result, "no water, no life" is correct [9]. As a result, the goal of water treatment is to deliver water that is as close to pure as possible. Depending on the source of water, the degree of contamination, and the desired water quality, this treatment may be traditional or advanced. All water treatment plants in Iraq are conventional, and they strive to remove suspended and pathogenic contaminants. Sedimentation and filtering with coagulant assistance are employed to remove suspended and colloidal particles in these traditional plants, and chlorine is used to kill pathogens. After the water had went through the treatment process, multiple tests were carried out to measure its parameters and compare them to standards in order to assess its quality and determine whether it fulfilled the requisite criteria. Physical, chemical, and biological factors are all tested in this water.

The Tigris river is Baghdad's primary source of drinking water; yet, in recent years, there has been a rise in wastewater and direct Tigris river discharge. Furthermore, the presence of antibiotics in drinking water, in addition to other contaminants, was discovered [8], As a result, one of the most important resources is water.

It is necessary to continually studying the water quality, because it is greatly affects human health. For the purpose of evaluating the level of drinking water quality in the city of Baghdad , more than one water quality index has been used and for several selected plants on the Karkh side, which are as follows : Al-Qadisiyah, Al-Dora and Al-Kadhimiya.

Study area and methods:

The present study was conducted to evaluate the treatment efficiency of three water treatment plants in the city of Baghdad on the Karkh side which are :(Al-Qadisiyah, Al-Dora and Al-Kadhimiya) using five indices of water quality. The source of raw water of these plant is the Tigris river.

Samples of drinking water were collected from plants studied for the period from November 2021 to July 2022. Twelve parameters were used for calculating the water quality index. These parameters are : pH, turbidity, electrical conductivity, calcium, magnesium, chloride, total hardness, alkalinity, sulfate, sodium and total dissolved solids. The Iraqi recommended Guidelines for drinking water specifications are presented in Table 1.

1.Measurement of water quality Index:

The most general characteristic of the present study is the use of several water quality indices in order to ascertain the level of pollution in sone water treatment plant in the Baghdad city Al-Karkh side .The water quality indices used in the present study are as follows:

1.1 Weigh Average Method WAV (WQI)

The WQI index can be determined by the following steps [11]:

1- In this method each parameter has been given a relative weight (Wi).

2- Computing the quality rating scale (qi) for each parameter by using the following equation:

$qi=(Ci/Si)100$ ….(1)

Where:

qi= quality rating scale

Ci= concentration of each parameter in each water sample in (mg/L).

Si=Iraqi drinking water standards for each chemical parameter.

3- Computing the sub index of each parameter by using the following equation:

$SIi=Wi\times qi$ …..(2)

Where

SIi= is the sub index of each parameter

$WQI = \sum SIi$ …. (3)

1.2 The Ministry and Environment Method MNE WQI

The second water quality index is the method which is adopted by Ministry of Nature and Environment (MNE) of Mongolia [12]. In this method the number of parameters has been taken into account and all the parameters have the same weight. The selected parameters included (Ca+2, Mg+2, TH, Cl-, Na+, SO4-2, Alk, Fe+3 and TDS).

$WQI = \sum(Ci/Si)/n$ …...(4)

Where:

n= is the number of parameters

1.3 Water Quality Index

In order to calculate the Water Quality Index, the following steps were used:

Weighting: The word weighting implies relative significance of each of the factor in the overall water quality and it depends on the permissible level in drinking water as suggested by Iraqi standard. Factors which have higher permissible limits are less harmful and have low weightings [13].

$Wi = K/Sn$ (1)

Wi - Unit weight of chemical factor, K - constant of proportionality and is given as:

$K=1/(1/Vs1+1/Vs2+\ldots\ldots+1/Vsn)$ (2)

Vsi - standard value of ith parameter

Rating scale: Each chemical factor has been assigned a water quality rating to calculate WQI.

Qi = 100 [(Va-Vi)/ (Vs-Vi)] (3)
Where,
Qi = Water quality for each parameter (i)
Va - average of measured values in the water sample for three months at one place
Vs - Standard value of ith parameter
Vi - ideal value for pure water (0 for all parameters except pH)
The above equation becomes:
Qi=100(Va/Vs) (4)
For pH: The ideal value = 7.0; Max. Permissible value = 8.5,
QpH = 100 [(Va-7.0)/ (8.5-7.0)]
WQIi=Qi*Wi (5)
Water Quality Index (WQI) = [Σ QiWi)/ΣWi] (6)
ΣWi = total unit weight of all chemical factors.

1.4 The CCME WQI index:

In the present study CCME WQI was used to calculate the water quality. This index can be determined as follows:
The F1 is called Scope which represents the percentage of variables that do not meet their objectives at least once during the interval under consideration
("failed variables"), relative to the total number of variables measured:

$$F1 = \left[\frac{\text{Number of failed variables}}{\text{Total number of variables}}\right] * 100$$

F2 is called Frequency which represents the percentage of failed tests :

$$F2 = \left[\frac{\text{Number of failed tests}}{\text{Total number of tests}}\right] * 100$$

F3 is called Amplitude, which represents the deviations of the failed tests from their objectives. It is determined as follows:
The term "Excursion" represents the number of times that certain concentration is different from the objective. When the value of the test is less than the objective, Excursion is given by:

$$\text{Excursion} = \left[\frac{\text{Failed Test value}}{\text{Objective}}\right] - 1$$

When test value is greater than the objective, Excursion is given by:

$$\text{Excursion} = \left[\frac{\text{Objective}}{\text{Failed Test value}}\right] - 1$$

The sum of exertions of individual tests divided by the total number of tests is called normalized sum of excursions (nse) and is computed as follows:

$$nse = \left[\frac{\sum_{i=1}^{n} \text{Excursion}}{\text{Failed Test value}}\right] - 1$$

F3 is a function of nse and is given by:

$$F3 = \left[\frac{\text{nse}}{0.01 + 0.01\text{nse}}\right] - 1$$

Finally CCME WQI is calculated as follows:

$$CCMEWQI = 100 - \left[\frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1.732}\right]$$

The water quality is ranked according to CCME WQI as stated in Table [14].

1.5 British Columbia water quality index (BCWQI):

This index was developed by the Canadian Ministry of Environ-ment as an increasing index. For water quality evaluation, where water quality parameters are measured and their violation is determined by comparison with a predefined limit. The BCWQI makes possible the classification on the basis of all existing measurement parameters [15]. The formula is expressed as:

$$\text{BCWQI} = \left[\frac{F_1^2 + F_2^2}{1.453}\right]^{0.5}$$

Where: F1 (scope) = number of the non-succeeded varia-bles to the total number of the variables; F2 (frequency) = number of the unsuccessful tests to the total number of tests.

$$F1 = \frac{NF}{TNV} * 100$$

$$F2 = \frac{NFT}{TNT} * 100$$

Where: NF = number of the failed variables, TNV = total number of variables, NFT = number of the failed test; TNT = total number of the tests.In the BCWQI formula 1.453 is the constant used to give confidence to the scale index number from 0 to 100. The degree of the confidence in the BCWQI depends on the repeated sampling procedure [15].In order to calculate the WQI, the Iraqi drinking water standard values corresponding to the measured parameters were used, as shown in Table 1.

Table1. Iraqi drinking water standards [19] [20] [21] [22] [23] [24] [25].

Iraqi standard	unit	parameter
6.5-8.5	-	pH
125-200	mg/L	Alkalinity
500	mg/L	Total Hardness as CaCO3
100	mg/L	Magnesium (Mg^{+2})
150	mg/L	Calcium (Ca^{+2})
200	mg/L	Sodium (Na^{+})
350	mg/L	Chloride (Cl-)
400	mg/L	Sulphate $SO4^{-2}$

5	NTU	Turbidity
2000	µs/cm	Conductivity
1000	mg/L	TDS

Table(2)Water quality classification based on WAV method

WQI value	Water Quality
0-25	Excellent
26-50	Good water
51-75	Poor water
76-100	Very poor water
>100	Water unsuitable for drinking

Table (3) Water quality classification based on MNE method

WQI value	Water Quality
≤0.3	Very clean
0.31-0.89	clean
0.9-2.49	Slightly polluted
2.5-3.99	Moderately polluted
4-5.99	Heavily polluted
≥6.0	Dirty water

Table(4), Water quality index scale

WQI	Description
0-25	Excellent
26-50	Good
51-75	Moderately polluted
76-100	severely polluted
>100	unfit for human consumption

Table(5), The water quality is ranked according to CCME and BCWQI WQI as stated.

CWQI Categories	Ranks
95-100	Excellent
80-94	Good

65-79	Fair
45-64	Marginal

Results and Discussion:

The values of WAV WQI index of all water treatment pants are between (29.51-47.46) for treated water, and those results showed that all indicators of treated water of all water treatment plants studied were good, while the highest value was (47.46) in November at Al-Qadisiyah water treatment due to the high concentration of calcium,TH and sulphate. Also, the results showed that the values of the MNE WQI of all water treatment plants studied are between (0.28-0.45) for the treated water and all the values indicated that the treated water is clean , but Al-Qadisiyah treatment plant gives very clean according to MNE method classification in April month, while the highest value was (0.45) in November at Al-Qadisiyah water treatment due to the high concentration of calcium, TH and sulphate,. The values of index of (weighted method) ranged between (52.05-12.95) for the treated water. The results showed that all index values of treated water of all water treatment plants studied were good, but Al- Kadhimiya treatment plant produces excellent water quality throughout the study period. The another exception was happened in Al-Qadisiyah plant in May and July moths, where pollution was moderate polluted according to WQI method classification. The highest value found was(52.05) at Al-Qadisiyah water treatment plant in Jul , due to the high concentration of turbidity and alkalinity. The obtained value of the Canadian index was (99.99) for the treated water for all months studied, and the such value indicates that the treated water is excellent according to CCME method classification. Also, the value of the British index was (100) for the treated water for all months studied, and such value indicates that the treated water is excellent according to BCWQI method classification.The statistical program which is called STATISTICA,version (25) was used concluding statistical equations of water quality index in terms of time for all plant studied. The coefficient of determination (R2) is calculated to find the degree of credibility of the equations obtained, which is as follows of Al-Qadisiyah Water Treatment Plant as show in the figer.

In which, WAV is ,and t is in(month).The cofficent of determination R2 is equal to 0.761.

WAV=59.68-13.56t +2.22 (t) 2 -0.1 (t)3…(1)

In which, MNE is ,and t is in(month).The cofficent of determination R2 is equal to 0.78.

MNE=56.89-13.14*t+2.18*(t) 2-0.1*(t)3 ..(2)

In which, WQI is ,and t is in(month).The cofficent of determination R2 is equal to 0.917.

WQI=49.95-4.19*t +1.25*(t) 2 -0.09*(t)3 ..(3)

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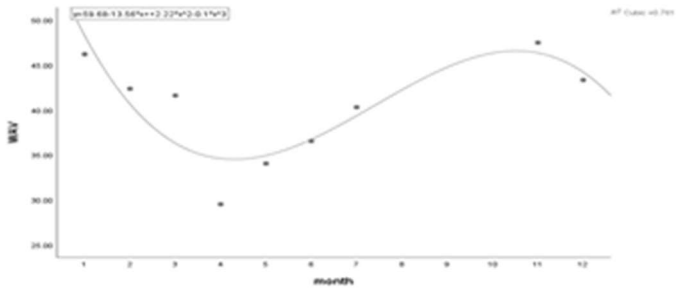

Fig. (1) Statistical Relationship of WAV Index and Time for Al-Qadisiyah Water Treatment Plant

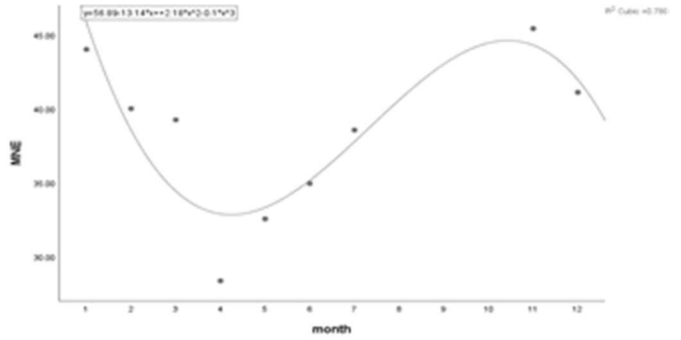

Fig. (2) Statistical Relationship of MNE Index and Time for Al-Qadisiyah Water Treatment Plant.

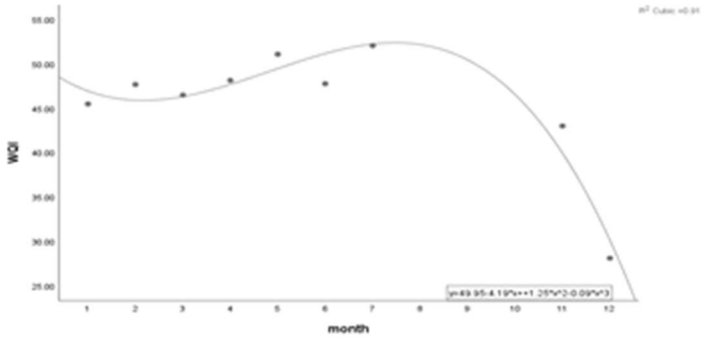

Fig. (3) Statisticeal Relationship of WQI Index and Time for Al-Qadisiyah Water Treatment Plant.

Which is as follows of Al-Dora Water Treatment Plant.
In which, WAV is ,and t is in(month).The cofficent of determination R2 is equal to 0.672.

WAV=56.85-9.9t +1.61 (t) 2 -0.07 (t)3…(4)
In which, MNE is ,and t is in(month).The cofficent of determination R2 is equal to 0.582.

MEN=53.62-8.82t +1.5 (t) 2 -0.07 (t)3……(5)
In which, WQI is ,and t is in(month).The cofficent of determination R2 is equal to 0.03.

WQI=32.7+1.54t -0.25 (t) 2 +0.01 (t)3……(6)

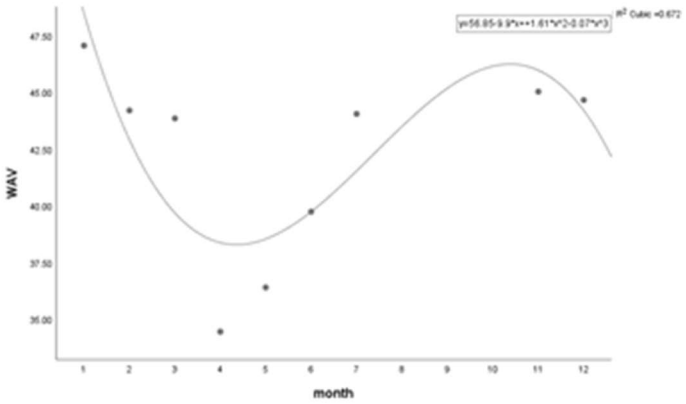

Fig. (4) Statistical Relationship of WAV Index and for Al-Dora Water Treatment Plant.

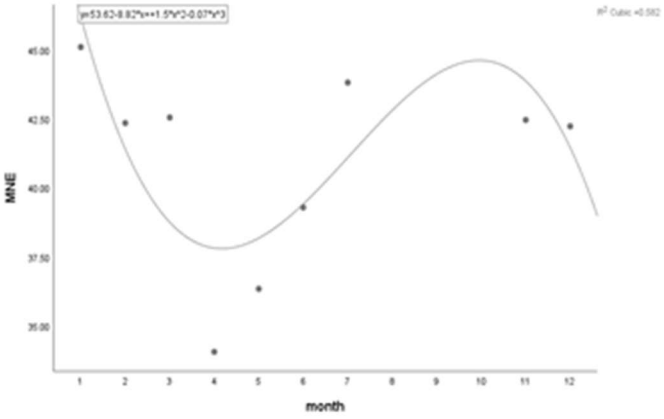

Fig. (5) Statistical Relationship of MNE Time Index and Time for Al-Dora Water Treatment Plant.

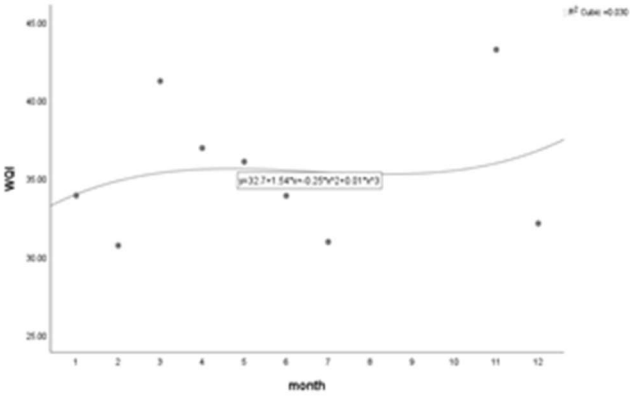

Fig. (6) Statistical Relationship of WQI Index and Time for Al-Dora Water Treatment Plant.

Which is as follows of Al-kadhimiya Water Treatment Plant. In which, WAV is ,and t is in(month).The cofficent of determination R2 is equal to 0.688.

WQI=55.35-9.37t +1.41 (t) ^{2} -0.06 (t)^3 ...(7)

In which, MNE is ,and t is in(month).The cofficent of determination R^2 is equal to 0.633.

MNE=52.31-8.4t +1.31 (t) ^{2} -0.06 (t)^3..(8)

In which, WQI is ,and t is in(month).The cofficent of determination R^2 is equal to 0.877.

WQI=21.25+2.45t -0.75 (t) ^{2} +0.04 (t)^3 ..(9)

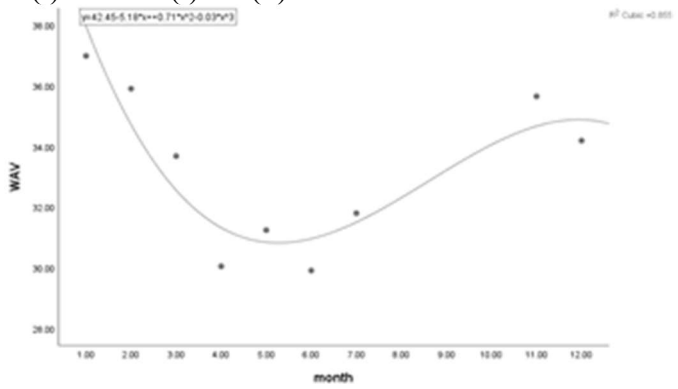

Fig. (7) Statistical Relationship of WAV Index and for Al-kadhimiya Water Treatment Plant.

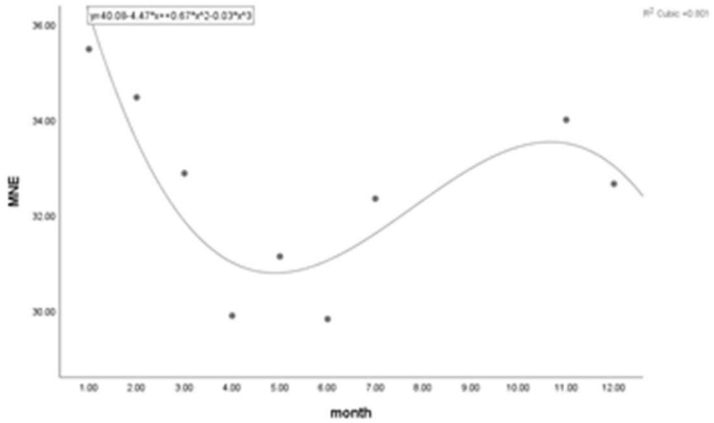

Fig. (8) Statistical Relationship of Time MNE Index and Time for Al-kadhimiya Water Treatment Plant.

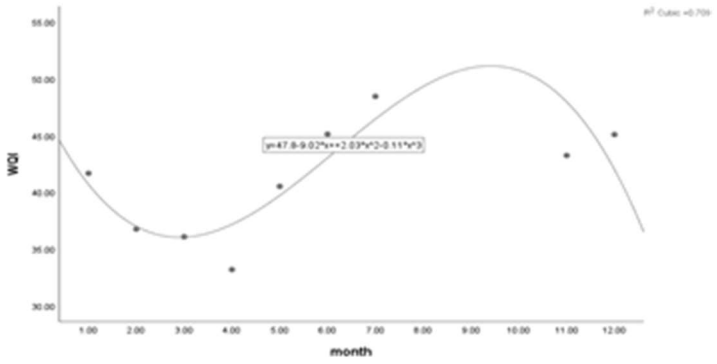

Fig. (9) S tatistical Relationship of WQI Index and Time for Al-kadhimiya Water Treatment Plant.

In which, CCME is ,and t is in(month)of all Water Treatment Plant:

CCME=0*t +99.99 …..(10)

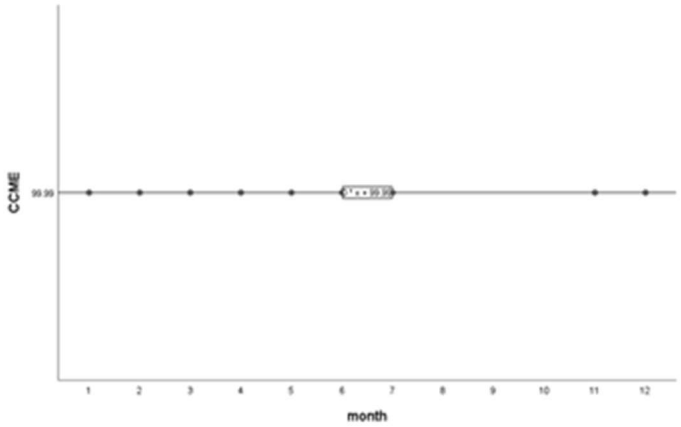

Fig. (10) Statistical Relationship of CCME Index and Time for AllWater Treatment Plant.

In which, BCWQI is ,and t is in(month)of all Water Treatment Plant:

BCWQI=0*t +100 ……(11)

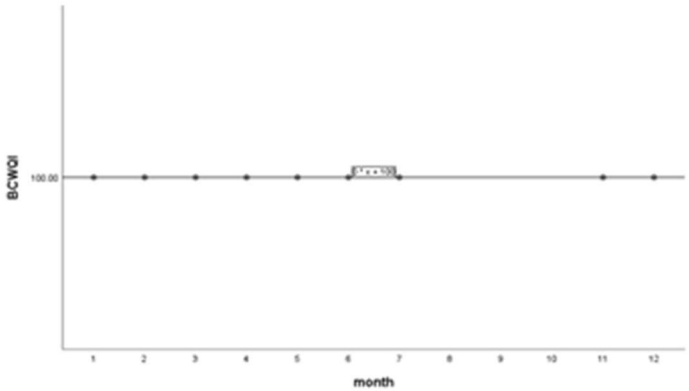

Fig. (11) Statistical Relationship of BCWQI Index and Time for All Water Treatment Plant.

CONCLUSIONS

The results showed that the treated water quality from the water treatment plants studies was good according to the WAV classification. All values of MNE index for treated water from all water treatment plants studied showed that the water is clean but for Al-Qadisiyah in April, the water quality was very clean according to MNE method classification. All values of WQI for treated water produced from all water treatment plants showed that treated water is good water but for Al-Kadhimiya WTP it was excellent in all months, the another exception was happed which Al-Qadisiyah in May and July month, which was moderately polluted according to WQI method classification. The results showed that the water quality for treated water was excellent according to the CCME classification. Finally the results showed excellent water quality can be obtained for treated water based on the BCWQI classification.

Table (6) Average monthly test results of treated water produced from Al-Qadisiyah water treatment plant [16].

Parameter	Measurement unit	Value in test								
		Nov 2021	Dec 2021	Jan 2022	Feb 2022	Mar 2022	Apr 2022	May 2022	Jun 2022	Jul2022
Turbidity	NTU	1.8	1.7	2.2	2.4	2.3	2.5	2.75	2.65	3
TH	mg·dm–3	415	388	403	383	404	292	300	322	360
PH	-	7.8	7.2	7.7	7.7	7.7	7.7	7.7	7.6	7.6
TDS	mg·dm–3	704	672	706	666	641	509	545	569	615
alk	mg·dm–3	125	133	147	154	147	150	143	137	140
Cl–	mg·dm–3	80	76	82	76	71	59	72	70	71
Mg2+	mg·dm–3	31	32	32	29	29	25	29	25	24
Calcium	mg/L	115	103	110	106	106	74	72	90	104
Sodium	mg/L	77.1	68.9	75.1	65.3	59.6	62.5	67.8	69.8	72.1
Sulfate	mg/L	345	273	315	253	234	178	188	213	255
EC	µs/cm	1067	1018	1070	1009	971	771	826	861	931

Table(7) Average monthly test results of treated water produced from AL-Dora water treatment plant [17].

Parameter	Measurement unit	Value in test								
		Nov 2021	Dec 2021	Jan 2022	Feb 2022	Mar 2022	Apr2022	May 2022	Jun2022	Jul2022
Turbidity	NTU	2.7	1.6	1.7	1.3	2.2	1.9	1.9	1.8	1.7
TH	mg·dm–3	409	404	419	394	380	296	299	333	378

PH	-	7.35	7.42	7.44	7.51	7.52	7.51	7.47	7.42	7.33
TDS	mg·dm–3	711	683	715	676	644	514	550	580	624
alk	mg·dm–3	128	140	148	156	149	155	151	138	131
Cl–	mg·dm–3	68	83	87	81	74	62	71	69	73
Mg2+	mg·dm–3	32	36	38	32	31	27	29	29	32
Calcium	mg/L	113	103	106	106	102	74	73	86	98
Sodium	mg/L	67.6	65.3	92	86	97	104	122	113	136
Sulfate	mg/L	275	280	285	264	296	199	213	266	281
EC	µs/cm	1090	1046	1087	1036	986	785	847	896	964

Table (8) Average monthly test results of treated water produced from AL- Kadhimiya water treatment plant [18].

Parameter	Measurement unit	Value in test								
		Nov 2021	Dec 2021	Jan 2022	Feb 2202	Mar 2022	Apr2022	May 2022	Jun 2022	Jul 2022
Turbidity	NTU	0.6	0.7	1.5	1.3	1.1	1.3	1.2	0.9	0.8
TH	mg·dm–3	398	383	394	387	380	284	279	331	340
PH	-	7.1	7.2	7.1	7.2	7.2	7.2	7.2	7.1	7.2
TDS	mg·dm–3	702	664	695	665	632	504	543	572	618
alk	mg·dm–3	105	114	119	124	126	133	125	117	115
Cl–	mg·dm–3	81	79	85	80	75	61	67	67	66
Mg2+	mg·dm–3	33	33	33	34	32	25	25	23	23
Calcium	mg/L	105	99	104	99	100	72	71	86	99
Sodium	mg/L	62.2	67.2	87	80	94	101	116	105	132
Sulfate	mg/L	292	276	289	277	279	178	179	202	233
EC	µs/cm	1077	1020	1069	1023	972	774	837	881	951

Water quality indices for Al-Qadisiyah WTP Table (9)

WQI	11/2021	12/2021	1/2022	2/2022	3/2022	4/2022	5/2022	6/2022	7/2022
WAV	47.467	43.3168	46.1875	42.3488	41.6049	29.5198	34.0361	36.5440	40.2982
MNE	0.4541	0.411	0.4403	0.4005	0.3924	0.2836	0.3255	0.3494	0.3855
wqi	42.996	28.114	45.4477	47.675	46.482	48.129	51.088	47.763	52.054
CCME	99.9942	99.9942	99.9942	99.9942	99.9942	99.9942	99.9942	99.9942	99.9942
BCWQI	100	100	100	100	100	100	100	100	100

Table (10)Water quality indices for AL Dora WTP

WQI	11/2021	12/2021	1/2022	2/2022	3/2022	4/2022	5/2022	6/2022	7/2022
WAV	45.0375	44.6688	47.0690	44.2076	43.8543	34.4531	36.4069	39.7481	44.0574
MNE	0.4247	0.4224	0.4512	0.4236	0.4256	0.3404	0.3633	0.3929	0.4383
wqi	43.246	32.134	33.928	30.720	41.231	36.957	36.080	33.906	30.959
CCME	99.9942	99.9942	99.9942	99.9942	99.9942	99.9942	99.9942	99.9942	99.9942
BCWQI	100	100	100	100	100	100	100	100	100

Table (11)Water quality indices for ALkadhimiya WTP

WQI	11/2021	12/2021	1/2022	2/2022	3/2022	4/2022	5/2022	6/2022	7/2022
WAV	44.7203	42.9831	45.2252	43.6657	43.1512	32.9329	33.9710	36.7910	40.4307
MNE	0.4223	0.4080	0.4341	0.4178	0.4178	0.3251	0.3381	0.3621	0.4021
wqi	12.957	16.345	23.479	23.412	21.043	22.704	21.768	15.875	17.160
CCME	99.9942	99.9942	99.9942	99.9942	99.9942	99.9942	99.9942	99.9942	99.9942
BCWQI	100	100	100	100	100	100	100	100	100

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