Assessment of Water Quality for Drinking Water Supplies Plants at Basrah, Iraq.

تقييم نوعية مياه محطات تجهيز مياه الشرب في محافظة البصرة، العراق

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Abstract

Water Quality Index (WQI), a simplified way of representing water quality information, was used for assessment of the water quality for water treatment plants in Basrah Governorate. The study conducted for forty water treatment plants streaches from northern sectors, Qurnah and Mudainah towards the southern sectors Umm Qasser and Safwan, in which eight variables as chemical parameters for each sample were analyzed for a period of three years 2012-2014. Parameters studied were, total hardness, sulphate, chloride, sodium, calcium, magnesium, turbidity, and Electric conductivity. Average values for all measured chemical parameters were exceeded the permissible limits for safe drinking water. The results show that the WQI values of water treatment plants in Basrah Governorate ranged between 26 and 89. For the three years of study 2012-2014 most of water treatment plants within Basrah Governorate were either poor or marginal, few were fair and good. Al-Abass and Shuaibah water treatment plants which represent only 5% among the 40 studied plants were classified as good, while others were classified as marginal or poor, that was during the years 2012 and 2013 then it was deteriorate afterwards, moreover, WQI showed that drinking water released from water treatment plants within Basrah Governorate were never reach excellent levels.

Key Words: Water quality index, treatment plants, Shatt Al-Arab River, Chemical parameters, Basrah city.

الخلاصة

استخدم مؤشر جودة المياه ،وهو طريقة مبسطة لتمثيل معلومات نوعية المياه،لتقييم نوعية مياه محطات الاسالة ضمن الرقعة الجغرافية لمحافظة البصرة حيث شملت الدراسة 40 محطة اسالة ممتدة من القرنة والمدينة شمالاً وام قصر وسفوان جنوبا. اعتمدت الدراسة على ثمانية متغيرات كيمياوية لكل عينة مياه وهي العسرة الكلية والكبريتات والكلوريد والصوديوم والكالسيوم والمغنيسيوم والعكارة والتوصيلية الكهربائية خلال ثلاث سنوات 2012 و 2013 و 2014 كان معدل القياسات للمتغيرات الكيمياوية اكبر من الحدود المسموح بها دوليا لمياه الشرب وكان مؤشر جودة المياه في محافظة البصرة بحدو 26 - 89 . وخلال سنوات الدراسة الثلاثة 2012 و 2013 و 2014 كانت معظم محطات الاسالة في البصرة اما رديئة او على الحدود غير المرضية وعدد قليل كان مقبولاً او ملائم. محطتين فقط هما العباس والشعيبة كانتا جيدتين واللتان مثلتا نسبة 5% من بين المحطات الاربعين المدروسة والبقية صنفت على انها رديئة او عند الحدود الرديئة، حيث كانت هذه المواصفات خلال عامي 2012 و 2013 , وبعد ذلك حصل تدهور بحيث توضح ان مؤشر جودة المياه في محطات اسالة محافظة البصرة لم ترتقي الى درجة الجودة العالية .

كلمات مفتاحية: مؤشر جودة المياه، محطات الاسالة، نهر شط العرب، متغيرات كيمياوية، مدينة البصرة.

Introduction

Due to Shortage of water discharge through Tigris and Euphraties Rivers towards the Shatt Al-Arab River, as well as the intrusion of saline water from Arabian Gulf, The quality of Shatt Al-Arab waters deteriorate and became unacceptable. Data for the Shatt Al-Arab and for the raw water collected since 1998 by the Department of Irrigation represented the exact problem related to the salinity. For the Shatt Al Arab, salinity expressed as the electrical conductivity (E.C. in micro Siemens/cm at 25 ^oC) is increased from 2,500 US/cm in 1998 to 4,500 US/cm in October 2002, and a turbidity laying close to the mean values of 30-40 NTU [1].

Drinking water is considered the most basic needs for ongoing daily consumption to human. The CCME WQI is based on formula developed by British Colombia Ministry of Environmental 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 to the specific objectives [2 , 3] . The application of CCME WQI requires water quality guideline (objectives), some times there is a need to derive site-specific guidelines (mean, median, standard deviation, mean±standard deviation and percentile value) for those parameters which are naturally higher (or lower) the objectives [4 , 5].

In Iraq, the first application of CCME WQI was done for Hawizah marsh using Nature Iraq data survey during 2008 [6 - 8], later on it is applied to Hammar marsh based on data of 2005 and 2006 after restoration[8]. Then work has extended by other researchers for studying water quality [9], and moreover other researchers were applied another water quality indices [4 , 6 , 10].

At Al-Hillah Governorate , CCME WQI has been used for the assessment of raw and treated water in the water treatment plants which supplied from Shatt Al-Hillah depending upon certain chemical parameters and revealed that water quality was good according to all parameters studied except that for turbidity [11].

WQI of the CCME has been used to assess the drinking water quality in the city of Pogradec, Poland, and indicated good except the problem influenced by turbidity[12] .

Water quality index CCME WQI has been used to assess the quality of Tigris river waters and the results indicated that water of Tigris river gas the worst quality for WQI between 37 and 42 [13]. Moreover, WQI has been applied for Agricultural purposes [14].

Water quality is difficult to evaluate from a large number of samples, each containing concentrations for many parameters [15]. On the other hand, Water Quality Index (WQI) is a very useful and efficient method for assessing the suitability of water quality. It is also a very useful tool for communicating the information on overall quality of water [16 ، 17] to the concerned citizens and policy makers. upon the designated water uses and local preferences. Water quality indices (WQIs) have been developed to integrate water quality variables [13 18 ،19] . A WQI summarizes large amounts of water quality

Water quality index was first formulated by Horton [20] and later on used by several workers for the quality assessment of different water resources. It is one of the aggregate indices that have been accepted as a rating that reflects the composite influence on the overall quality of numbers of precise water quality characteristics [21] . Water quality index provide information on a rating scale from zero to hundred. Higher value of WQI indicates better quality of water and lower value shows poor water quality. WQI is a dimensionless number that combines multiple water-quality factors into a single number by normalizing values to subjective rating curves [22] , therefore, a numerical index is used as a management tool in water quality assessment [23] . Hence WQI is classified as follows : Poor for 0 - 45, Marginal for 45 – 64, Fair for 65 – 79, Good for 80 – 94 , Excellent for 95 - 100.

Practically, WQI could be conducted in four steps: 1- Selection of parameters, only effective parameters are important on a certain basis, 2- Transformation of parameters into dimensionless scale and rating curve, 3- Weighting of parameters, some are more important than other, and 4- Aggregation.

Experimental

This study considered the WQI developed by the Canadian Council of Ministers of the Environment based on the formulation introduced by British Columbia Ministry of Environment CCME WQI [25 , 26].

Water samples were collected from 40 water treatment plants spread over all Basrah Governorate which stretches from Northern part , Qurnah and Mudianah, through out its central part representing Harthah, Garmatt Ali, Al-Jubailah, Al-Bradaieah , Shatt Al-Arab, down to the Southern sector represented by Abu Al-Khaseeb, Faw, Khor Al-Zubair, Abu Floose, Muhailah, Safwan and Umm Qasser through the years 2012, 2013, and 2014, Figure 1 shows most of the studied plants which located along Shatt Al-Arab River. The water samples were collected in 1 liter polyethylene bottles for each sampling site, stored in cool box, and transferred to the laboratory for analysis.

Required chemical parameters were analyzed immediately after sample collection, according to the following table No. 1 :

Table 1. Procedures used for detection of studied parameters, Referance [25].

No.	Parameter	Procedures [25]
1	pH	pH meter
2	EC	Portable multimeter
3	Ca^{2+},Mg^{2+} & Total hardness	Titration with Na_2EDTA
4	Chloride	Titration with $AgNO_3$
5	Sodium	Flame photometer
6	Sulphate	Colorimetry
7	Turbidity	Turbidity meter

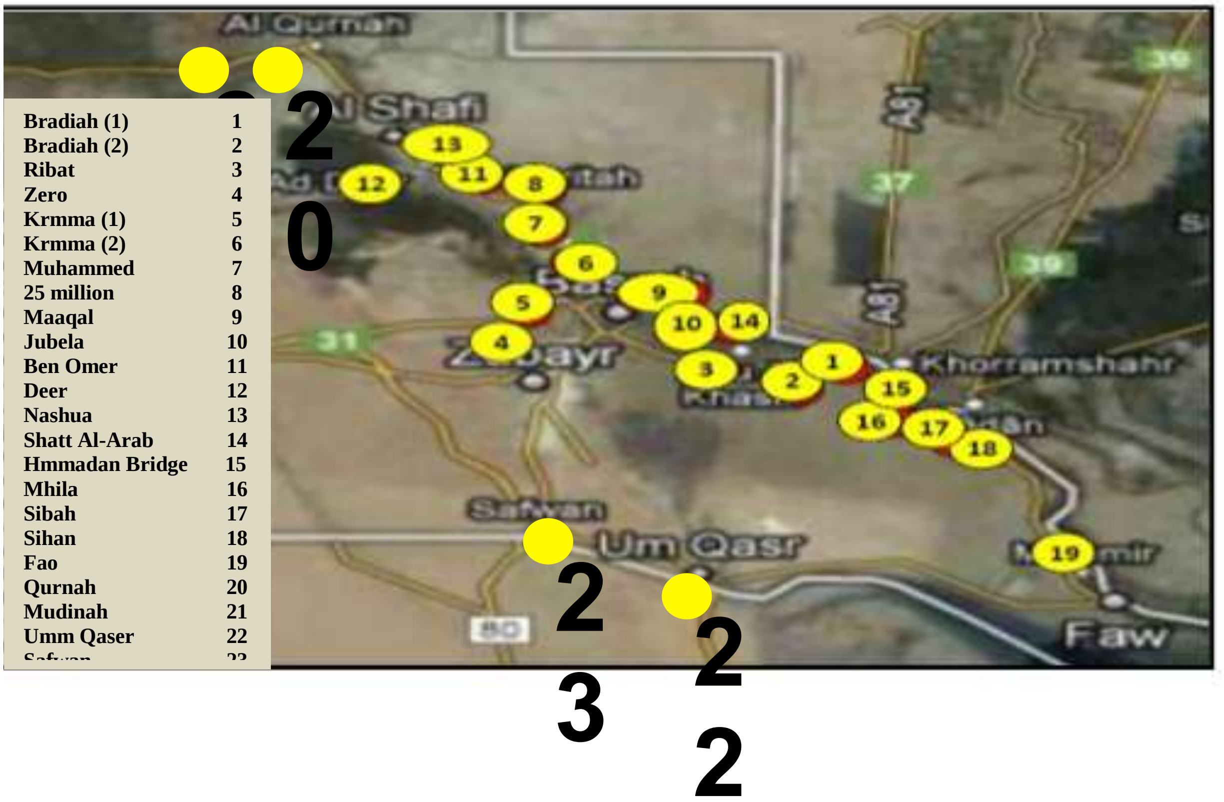

Figure 1: Location map for Basrah Governorate, Southern Iraq, Showing Shatt Al-Arab River and sites of most studied water treatment plants

pH and electrical conductivities were measured by means of portable multimeters. Major cations, Ca^{2+} , and Mg^{2+}, and total hardness were determined by titration methods with Na_2EDTA, Cl^- ions by titration against silver nitrate; Na^+ was determined by Flame Photometry, SO_4^{2-} was determined by Colorimetric Method, while turbidity was measured by turbidity meter [25, 26] .

Calculation of Water Quality Index (WQI)

In current study, calculation of water quality index was based on 8 important physico-chemical parameters. WQI was calculated by using the Canadian Water Quality Guidelines, [24], in which Weighted Arithmetic Index model was used [16]. In this model, different water quality components were multiplied by a weighting factor and are then aggregated using simple arithmetic mean.

For carrying out the calculation of WQI in this study, first, the quality rating scale (Qi) for each parameter was calculated by using the following equation:

$$Qi = [Ci / Si] \times 100 \qquad ......(1)$$

Then second, the Relative (unit) weight (Wi) was calculated by a value inversely proportional to the recommended standard (Si) for the corresponding parameter using the following relation;

$$Wi = I / Si \qquad ......(2)$$

Where, Wi = Relative (unit) weight for nth parameter. Si = Recommended standard values for nth parameter (as described in Quality rating calculation equation). I = Proportionality constant.
Thus, the Relative (unit) weight (Wi) to various water Quality parameters are inversely proportional to the recommended standards for the corresponding parameters.

Finally, the overall WQI was calculated by aggregating the quality rating with the unit weight linearly by using the following equation:

$$WQI = QiWi / Wi \qquad .....(3)$$

Where, Qi = Quality rating and Wi = Relative weight

The application of the WQI requires water quality guidelines or standards. Therefore, an appropriate guideline or standard for each water use was selected. The Iraqi standard for the protection of general water resources was used to evaluate the Shatt al-Arab River for protection of aquatic life[27]. WHO[28] and Iraqi guidelines were used for potable water supply [29], and the Food and Agriculture Organization standards were applied within this study.

Results and Discussion

Physic-chemical parameters were monitored for the calculation of WQI for the period of study from 2012 to 2014.The parameter which were taken into account for the present work are: pH, total hardness, sulphate, chloride, sodium, calcium, magnesium, turbidity, and electric conductivity.

The levels of the chemical parameters adopted in this study for water samples from the studied water treatment plants in two stages as raw and treated, are listed in table 2, during three years of study 2012, 2013, and 2014.

The WQIs calculated during the study period for the forty studied stations are represented in Table 3.

The WQI values for water treatment plants as raw and treated stages which scored annually at the studied forty stations are listed in table 4 with their classification as poor, marginal, good... etc stated with each value. Certain water treatment plants did not listed in table 4 due to technical failure resulting in lack of results. The results for WQI listed in table 3 were represented graphically and shown in figure 2 (A, B, and C) for the years 2012, 2013, and 2014 respectively. Pearson correlation for all recorded chemical parameters as well as the calculated WQI are listed in tables 5, 6, and 7 for the years 2012, 2013, and 2014 respectively.

Table 2: Levels of chemical parameters for water treatment plants in Basrah Governorate, 2012, 2013, and 2014.

Year / Parameters		2012	2013	2014	Guideline value
		(min-max)± stdev	(min-max)± stdev	(min-max)± stdev	
Turbidity (NTU)	Raw	(3.3-72)±9.58	(0.9-97)±12.36	(2.7-72.1)±9.13	5
	Treated	(1.3-5)±0.94	(1-23)±1.46	(0.8-57.3)±2.40	
EC (µmhos/cm) 25 °C	Raw	(1256-29694)±3208.56	(927-19780)±2562.89	(1139-13391)±2137.15	2000
	Treated	(1207-22012)±2394.22	(900-13287)±2309.40	(1116-13380)±2106.13	
TH as $CaCO_3$ (mg/l)	Raw	(466-3220)±373.00	(328-3000)±468.04	(400-2440)±397.91	500
	Treated	(466-2734)±314.64	(320-2932)±437.28	(400-2428)±392.24	
Ca (mg/l)	Raw	(95-642)±75.37	(67-600)±94.08	(72-483)±80.58	150
	Treated	(93-554)±63.29	(66-586)±88.07	(72-480)±79.36	
Mg (mg/l)	Raw	(48-394)±45.36	(39-366)±56.74	(41-566)±51.21	100
	Treated	(47-329)±38.27	(35-358)±53.14	(40-457)±49.40	
Cl (mg/l)	Raw	(144-10088)±1051.12	(99-6259)±670.21	(124-3201)±518.70	350
	Treated	(140-7030)±715.76	(95-3248)±570.73	(122-3193)±509.77	
SO_4 (mg/l)	Raw	(280-3028)±373.47	(160-2817)±463.51	(237-2286)±397.70	400
	Treated	(277-2551)±313.97	(158-2740)±429.80	(234-2271)±392.23	
Na (mg/l)	Raw	(57-6560)±767.34	(66-2012)±217.35	(82-2143)±345.86	200
	Treated	(55-4789)±531.42	(62-1060)±197.26	(80-2136)±340.33	

Table 3: Designation of stations in period from 2012 to 2014 (displayed as a percentage of the total number of stations [n =170]*) and the contribution of each parameter to the CWQI. Units of parameters are listed in table 2.

Designation of water quality		Good	Fair	Marginal	Poor
2012	CWQI	3.6	3.5	25.0	67.9
2012	RTH	3.6	7.1	25.0	64.3
2012	RSO_4	3.6	7.1	25.0	64.3
2012	RCl	3.6	3.5	28.6	64.3
2012	RNa	3.6	3.5	28.6	64.3
2012	RCa	3.6	3.5	28.6	64.3
2012	RMg	3.6	3.5	25.0	67.9
2012	RTur.	7.1	0.0	7.2	85.7
2012	REC	3.6	7.1	25.0	64.3
2013	CWQI	2.8	6.9	52.8	37.5
2013	RTH	2.8	11.1	54.2	31.9
2013	RSO_4	2.8	11.1	51.4	34.7
2013	RCl	2.8	6.9	58.4	31.9
2013	RNa	2.8	9.7	54.2	33.3
2013	RCa	2.8	8.3	52.79	36.1
2013	RMg	2.8	6.9	52.8	37.5
2013	RTur.	5.6	8.3	48.6	37.5
2013	REC	2.8	11.1	51.4	34.7
014	CWQI	0.0	2.9	42.8	54.3
2014	RTH	0.0	2.9	25.7	71.4
2014	RSO_4	0.0	7.1	60.0	32.9
2014	RCl	0.0	2.9	55.7	41.4
2014	RNa	0.0	2.9	55.7	41.4
2014	RCa	0.0	2.9	28.5	68.6
2014	RMg	0.0	5.7	67.2	27.1
2014	RTur.	0.0	5.7	34.3	60.0
2014	REC	0.0	2.9	25.7	71.4

*** n: comprison between raw and treated water supply stations for three years.**

WQI: Water Quality Index, TH: Total Hardness, SO_4: Sulphates, Cl: Chlorides, Na: Sodium, Ca: Calcium, Mg: Magnesium, Tur: Turbidity, EC: Electric conductivity.

Table 4: Levels of WQI recorded within this study for raw and treated waters in water treatments plants at Basra Governorate for the years 2012, 2013, and 2014.

Water treatment Plant	2012		2013		2014	
	Raw	Treated	Raw	Treated	Raw	Treated
25 malyon	51 M	61 M	46 M	57 M	46 M	54 M
Abbas	75 F	88 G	76 F	89 G	59 M	69 F
Arebat	30 P	45 M	49 M	55 M	48 M	57 M
Basrah	37 P	46 M	47 M	57 M	45 M	53 M
Hamadan	26 P	34 P	31 P	40 P	35 P	42 P
Hay Hussein	38 P	46 M	39 P	49 M	39 P	46 M
Jobela 1	30 P	38 P	59 M	63 M	37 P	45 M
Jobela 2	30 P	38 P	39 P	49 M	38 P	46 M
Khor Zubair	39 P	46 M	41 P	52 M	40 P	43 P
Karmah 1	34 P	43 P	41 P	50 M	38 P	41 P
Labane	34 P	38 P	36 P	46 M	36 P	43 P
Mehelah	35 P	46 M	40 P	50 M	36 P	43 P
Mhegran	31 P	39 P	31 P	40 P	34 P	39 P
Shatt Al-Arab	29 P	38 P	42 P	47 M	34 P	44 P
Shuaibah	-	-	73 F	89 G	60 M	69 F
Al-Anfal	-	-	39 P	49 M	35 P	41P
Uasyan	-	-	36 P	46 M	37 P	43 P
El-Bajyah	-	-	36 P	72 F	49 M	57 M
Bradhyah 1	-	-	42 P	52 M	38 P	45 M
Bradhyah 2	-	-	36 P	35 P	38 P	44 P
Bradhyah 3	-	-	40 P	49 M	36 P	42 P
El- Deer	-	-	63 M	72 F	49 M	49 M
Al-Fayhaa	-	-	38 P	44 P	40 P	39 P
El-Hodah	-	-	41 P	46 M	45 M	53 M
Qurnah	-	-	54 M	62 M	50 M	60 M
4 Islands	-	-	53 M	59 M	41 P	44 P
Mutayhah	-	-	39 P	47 M	35 P	41 P
Nashwah	-	-	64 M	72 F	49 M	57 M
Abu Gharb	-	-	49 M	56 M	47 M	51 M
Seehan	-	-	42 P	54 M	37 P	45 M
Rayan	-	-	49 M	51 M	44 P	48 M

P: Poor 0-45, M: Marginal 46-64, F: Fair 65-79, G: Good 80-94.

A

B

C

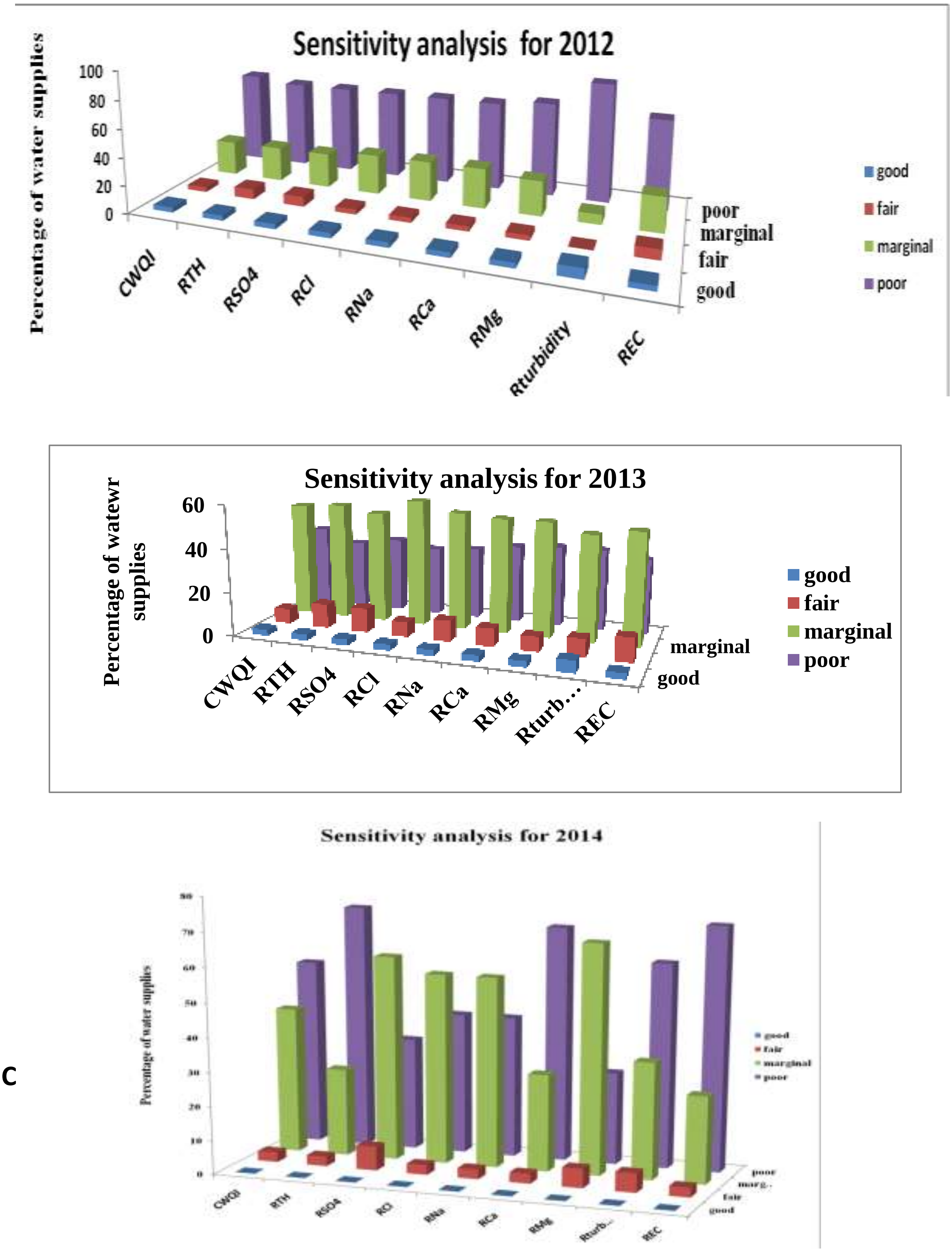

Figure 2: Graphical representation for WQI , A) for the year 2014, B) for the year 2013, and C) for the year 2014.

The reported values for the chemical parameters that were investigated for drinking water from water treatment plants within Basrah Governorate during the periods, 2012, 2013, and 2014 were exceeded the permissible limits set by WHO and Iraqi Criteria. Earlier study for water quality of Basrah water treatment plants during the year 2011 revealed that all studied parameters, Turbidity, Total hardness, Sulphate, Chloride, Sodium, Calcium, Magnesium and electric conductivity were exceeded the permissible limits for drinking water criteria [30] .

The results showed that water quality index (WQI) values for water supply to Basrah city ranged between 26 and 89, only 5% of water supply were good, the rest about 45% were marginal and about 50% were poor.

The designation of the studied water treatment plants in Basrah Governorate during the three years 2012, 2013, and 2014 and the contribution of each parameters to the CWQI revealed that good performance was reported during the year 2012 in a mean percent of 3.1 which decease to 2.8% during the year 2013 and then diminished to 0% during the year 2014. Other designations were fair as a mean values of 5%, 9,7%, and 0% during the years 2012, 2013, and 2014 respectively. The greater percent were designed as marginal 25%, 54%, and 55% as well as poor for the mean values 64%, 34%, and 41% during the years 2012, 2013, and 2014 respectively.

Few water treatment plants which are located to the northern part of Basrah governorate were ranked as good or fair such as Al-Anfal treatment plant. While the most of studied plants were ranked as marginal and poor for most of other plants which are located in the central or southern parts of Basrah Governorate. Plants located in the northern part of Shatt Al-Arab are effected by soft and fresh waters through Tigris River, Those who are located in the central part are effected by waste from heavy residential complexes located on the banks of Shatt Al-Arab River[31], while those in the Southern part of Shatt Al-Arab are affected by the saline wedge from Northern Arabian Gulf. More over due to continuous retardation of water discharge through Tigris River, the water quality for the drinking water released from water treatment plants at Baarah Governorate became even worst during the years 2013 and 2014. Several factors may have contributed to this situation. Freshwater inputs at upstream locations from the Tigris and Euphrates Rivers basin tend to decrease through the DS, especially in September and October months. This reduction of freshwater flow during this period combined with the intrusion of a marine salt wedge front from Arabian Gulf increases the concentration of these parameters especially with regards to salinity.

Pearson correlation for all recorded chemical parameters as well as the calculated WQI indicated that all parameters were correlated significantly at 0.01 level to each other as shown in tables 4,5, and 6 for the years 2012,2013, and 2014 respectively.

The decline in quality of water treatment plants of Basrah Governorate which depend upon waters of Shatt Al-Arab River, was due to reduction of fresh water discharge from Tigris and Euphrates revirs [32], low annual precipitation and the advance of salt wedge from The Arabian Gulf.

Conclusion

Several factors may have contributed to the deterioration of drinking water released from water treatment plants at Basrah Governorate. Freshwater inputs at upstream locations from the Tigris and Euphrates Rivers basin tend to decrease through the Northern part of Shatt Al-Arab River, and the intrusion of a marine salt wedge front into the Southern sector of Shatt Al-Arab River, in addition to increase discharge of waste water from the City and towns of Basrah Governorate which located on the Banks of Shatt Al-Arab River, all are combined to increase the concentration certain effected parameters such as salinity and turbidity. Both have a great effect upon the quality of drinking water for habitants in Basrah Governorate. Moreover, there is another quite effective factor which has a greate effect upon the quality of drinking water from water treatment plants, it is the types of treatment processes which reflects upon the efficiency of treatment plant, as the water of Shatt Al-Arab River is saline and turbid, more action need to taken as filtration, reverse osmosis ... etc .

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