Water Quality Index for Basrah Water Supply

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ABSTRACT

The water quality index (WQI) is a very effective method that allows to compare the quality of various water samples based on the indicator values of each sample. In this study, water quality index for Basrah water supply was determined by choosing nineteen water treatment plant (WTP) in Basrah city. Twelve chemical and physical parameters of each WTP were analyzed for one year during 2011. The results show that the WQI values of water supply in Basrah city are ranged from 83 to 275. About 10% of water supply can be classified as a good water, 74% can be classified as a poor water and the remaining 16% are very poor water. The prime cause of deterioration in Basrah water quality is the poor quality of the raw source water represented by Shatt al-Arab river, due to the large amount of contaminants are discharged in it. In addition, it is affected by the tide phenomenon of Arab Gulf which causes increase of salts concentrations. Also, the WTPs in Basrah city are conventional type that do not deal with soluble elements. These plants need upgrading by adding filter membranes or ion exchange units, to produce safe water for human consumption.

Keywords: Water quality index, Water treatment plants, Basrah, relative weight, Iraqi standard.

مؤشر جودة المياه المجهزة للبصرة

الخلاصة

مؤشر نوعية المياه (WQI) هو وسيلة فعالة جدا تسمح لمقارنة نوعية عينات مياه مختلفة على أساس قيم المؤشرات لكل منها . تهدف هذه الدراسة إلى إيجاد مؤشر جودة المياه في مدينة البصرة. لغرض تحقيق هذا الهدف تم اختيار تسع عشرة محطة لمعالجة المياه (WTP) في المدينة. أخذت ثلاثة عينات مياه معالجه من كل محطة للفترة من كانون الثاني ٢٠١١ لغاية كانون الأول ٢٠١١, تم تحليل كل عينه لغرض أيجاد بعض الخواص الكيميائية والفيزيائية. أظهرت النتائج أن قيم مؤشر جودة المياه لمدينة البصرة تراوحت من ٨٣الى ٢٧٥. ويمكن تصنيف ١٠٪ من المياه المجهزة للمدينة بأنها مياه الصالحة للشرب، في حين تصنف ٧٤٪ منها باعتبارها مياه رديئة، بينما كانت ١٦% منها مياه سيئة للغاية. يعزى السبب الأول لتدهور نوعية المياه في البصرة هو كمية الملوثات الكبيرة التي تطرح في شط العرب الذي يمثل المصدر الرئيسي للمياه الخام في البصرة إضافة إلى تأثره بظاهرة مد الخليج العربي التي تسبب ارتفاع تركيز الأملاح فيه. إضافة إلى أن محطات معالجة المياه في البصرة هي من النوع التقليدي التي لا تتعامل مع الأملاح الذائبة. هذه المحطات

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تحتاج أن تزود بوحدات التبادل الأيوني او وحدات التناضح العكسي (RO) لجعل المياه آمنه للاستهلاك البشري.

INTRODUCTION

Good drinking water quality is essential for the well being of all people. Unfortunately in many countries around the world some drinking water supplies have become contaminated, which has impacted on the health and economic status of the populations [1].

Water pollution is a serious problem for human health and the environment. The extent of the problem has been confirmed by many reports from UN organizations and related statistics. For example the Global Environment Outlook report (2000) produced by the United Nations Environment Programme (UNEP) included the following statistics [2]:

- Already one person in five has no access to safe drinking water.
- Polluted water affects the health of 1.2 billion people every year, and contributes to the death of 15 million children less than 5 years of age every year.
- Three million people die every year from diarrhoeal diseases (such as cholera and

dysentery) caused by contaminated water.

- Vector-borne diseases, such as malaria, kill another 1.5–2.7 million people per year, with inadequate water management a key cause of such diseases.

Drinking water should be aesthetically pleasant, ideally looking clear, colorless and well aerated with no unpalatable taste and odor. However, suitability in terms of public health is determined by microbiological, physical, chemical and radiological characteristics. Also a number of chemical contaminants (both organic and inorganic) are found in water. These cause health problems in the long run and, therefore, detailed analyses are warranted [3].

WATER QUALITY INDEX

Water quality index is defined as a rating reflecting the composite influence of different water quality parameters on the overall quality of water [4,5,6] The concept of indices to represent gradation in water quality was first proposed by Horton (1965) [7].

The Water Quality Index aims at assessing the quality of water from a source through a single numerical value, calculated on the basis of one system which translates all the constituents and their concentrations present in a sample into a single value. This is a very effective method that allows to compare the quality of various water samples based on the indicator values of each sample. To calculate the water quality indices the methodology presented by Rajendra was performed[8].

STUDY PURPOSE

The purpose of this study is to determine the water quality index (WQI) for Basrah water supply by considering the physical and chemical properties from nineteen water treatment plants (WTP) in Basrah city .

METHODOLOGY

To determine the WQI for water supply in Basrah city, nineteen water treatment plants were chosen, as shown in the Figure (1) . Three samples were taken monthly from each WTP during one year (from January 2011 to December 2011). Each sample was analyzed to determined twelve parameters including pH, total dissolved solids (TDS), total hardness(T.H.), turbidity, calcium (Ca^{++}), magnesium (Mg^{++}), sodium (Na^{+}), potassium (K), alkalinity, electrical conductivity (EC) , chloride (Cl^{-}) and sulphate (SO_4^{--}) by using standard procedures recommended by APHA and Eaton et al. [9,10].

For computing the WQI, three steps are followed. In the first step, each of the twelve parameters has been assigned a weight (wi) according to its relative importance in the overall quality of water for drinking purposes as shown in Table (1).

The maximum weight of 4 has been assigned to each parameter which major importance in water quality assessment [8].

In the second step, the relative weight (Wi) is computed from the following equation [6,7,8,11] :

$$W_i = \frac{w_i}{\sum_{i=1}^{n} w_i} \quad \text{... (1)}$$

Where, Wi is the relative weight, wi is the weight of each parameter and n is the number of parameters. The calculated relative weight (Wi) values of each parameter are also given in Table (1).

In the third step, a quality rating scale (Qi) for each parameter is assigned by dividing its concentration in each water sample by its respective standard according to the guidelines laid down in the Iraqi standards [12] illustrate in Table (1) and the result is multiplied by 100:

$$\boldsymbol{Q_i = (\frac{C_i}{S_i}) \times 100} \quad \text{... (2)}$$

Where Q_i is the quality rating, C_i is the concentration of each parameter in each water sample, and S_i is the Iraqi drinking water standards for each parameter.

For computing the WQI, the SI_i is firstly determined for each chemical parameter, which is then used to determine the WQI as in the following equation

$$SI_i = W_i \cdot Q_i \quad \text{… (3)}$$

$$WQI = \sum_{i=1}^{n} SI_i \quad \text{… (4)}$$

SI_i is the sub index of ith parameter; Q_i is the rating based on concentration of ith parameter and *n* is the number of parameters.

The computed WQI values are usually classified into five categories (Table 2): excellent, good, poor, very poor and unfit water for drinking purposes [9,13] .

RESULTS AND DISCUSSION

In order to determine the water quality index (WQI) for Basrah water supply , physical and chemical properties of nineteen WTPs are analyzed, including pH, electrical conductivity (EC), turbidity, alkalinity , total hardness , total dissolved solid (TDS), sulphate (SO_4^{--}), chloride (Cl^-), calcium (Ca^{++}), magnesium (Mg^{++}), sodium (Na^+) and potassium (K^+), as shown in Table (3).

The cationic concentrations in the water samples from the water treatment plants are presented in Figure (2). The respective ranges for Na^+, K^+, Ca^{++}, and Mg^{++} concentration in mg/l varied from 65 to 733, 2.3 to 8.8 , 88 to 183 and 46 to 97, respectively. It can be seen that the 95% of Mg^{++} and 90% of Na^+ water samples have concentrations that exceeded the permissible limits for safe drinking water, while the K^+, Ca^{++} concentrations were within the permissible limits. The anionic concentration of Cl^-, SO_4^{--} in mg/l ranged between 133 to 1157 and 226 to 707 respectively, see figure (3). Approximately 100% of Cl^- and 60% of SO_4^{--} water samples have concentrations that exceeded the permissible limits for safe drinking water.

The TDS and EC are ranged from (655 to 2984) mg/l and (1104 to 4632) µs/cm respectively, (Fig.4). pH and turbidity values ranged from (7.4 to 7.9) and (3.3 to 4.7) NTU respectively. These values fall within the permissible limits for drinking water Figure (5), Figure (6). While total hardness and the alkalinity concentrations in mg/l ranged from 128 to 161 and 407 to 885. Figurers (7) and (8) show that the values of total hardness and alkalinity exceeded the permissible limits for drinking water.

To calculate the water quality index (WQI) based on the analyzed data , the quality rating for each parameter (Q_i) is calculated according to Eq.(3) and the results are illustrated in Table (4). Then the sub index (SI_i) is calculated for each water parameter Table (5). WQI are determined by using Eq.(4) as shown in the Table (6) and Figure (9). The results show that the WQI values for water supply to Basrah city ranged from 83-275. About 10% of water supply can be classified as good water, while 74% of water supply are classified as poor water, the remaining 16% can be classified as very poor water.

In order to give a clear view about the deterioration of Basrah water supply quality, two focal points should be considered . First is the quality of the raw water feeding Basrah water treatment plants and second is the type of treatment processes in these plants. Regarding to the first point, most of WTPs in Basrah receive 70%-100% of its raw water from Shatt al-Arab river and up to 30% from R-Zero canal. So, Shatt al-Arab river can be considered as the main source of raw water supplied to most WTPs in Basrah city. As been known, the concentrations of dissolved salts are very high in Shatt al-Arab river. This is due to the large amount of contaminants which are discharged in it. Also, it is affected by the tide phenomenon of Arab

Gulf, that causes water quality deterioration. Subsequently, it badly affects Basrah WTPs raw water, as shown in Table (7). Secondly, under this poor raw water quality, and because most of WTPs in Basrah city are conventional type that do not deal with soluble elements in water. As a result, the water quality of treated water supply by most of WTPs in Basrah is unsafe for human consumption. To decrease high concentrations of dissolved salts, these plants are to be upgraded with filter membranes or ion exchange units.

CONCLUSIONS

WQI values for water supply of Basrah city ranged from 83 to 275. About 10% of water supply can be classified as good water, 74% of water supply can be classified as poor water and 16% are classified as very poor water. The prime causes of deterioration of Basrah water quality is the poor quality of the raw source water which is represented by Shatt al-Arab river because large amount of the contaminants discharged in it. In addition, it is affected by the tide phenomenon of Arab Gulf which causes the increase in salts concentrations. The second reason is the WTPs in Basrah city are conventional type that do not deal with soluble elements in water. These plants must be upgraded with units as filter membranes or ion exchange to decrease high dissolve salts and make Basrah water supply safe for human consumption.

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Table (1) Iraqi Standards, weight (wi) and calculated relative weight (Wi) for each parameter[8,12].

Parametr	**Iraqi Standards Max. Limit**	**Weights (wi)**	**Relative weight (Wi)**
pH	6.5-8.5	4	0.114
Turbidity(NUT)	10	3	0.086
EC(μs/cm)	500	4	0.114
Cl^- (mg/l)	250	3	0.086
SO_4^{--} (mg/l)	400	4	0.114
Ca^{++} (mg/l)	200	2	0.057
Mg^{++} (mg/l)	50	2	0.057
Na^+ (mg/l)	200	2	0.057
K^+ (mg/l)	12	2	0.057
Alkalinity (mg/l)	120	3	0.086
Hardness (mg/l)	500	2	0.057
TDS (mg/l)	1000	4	0.114

Table (2) Classification of computed WQI values for human Consumption[9,13].

WQI range	**Type of water**
< 50	Excellent water
50.1 – 100	Good water
100.1 – 200	Poor water
200.1– 300	Very poor water
>300.1	Unfit for drinking

Table (3) The mean values of finished water quality measurement in Basrah WTP during 2011.

WTP	Turb. (NTU)	pH	EC 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	K^{+} mg/l
Albradiah(1)	4.7	7.6	2644	153	656	131	80	516	476	1636	324	7.1
Albradiah(2)	4.6	7.6	2255	146	538	122	71	409	418	1378	253	6.2
Alribat	4.3	7.6	2036	143	527	107	64	383	346	1242	233	5.6
R-Zero	3.7	7.9	1104	130	407	88	46	133	226	655	65	3.2
Garmma(1)	3.4	7.5	2471	146	639	128	78	464	454	1520	277	6.6
Garmma(2)	4.2	7.6	2476	146	662	128	77	472	453	1528	284	7.0
Almouhammed	4.0	7.7	2027	151	552	113	66	353	373	1226	217	5.3
25 million	4.1	7.8	1890	149	514	106	61	330	338	1148	204	4.9
Alarsifa	4.1	7.6	1241	132	433	90	51	170	247	736	90	3.7
Aljubila	4.5	7.6	2654	142	502	103	60	293	321	1052	175	4.8
Almdeina	3.8	7.5	2778	129	709	130	94	532	531	1715	327	7.7
Aldeir	3.4	7.8	1854	134	524	106	63	312	356	1119	183	4.9
Alnashua	3.3	7.6	1828	134	533	109	64	307	348	1109	180	4.6
Shatt AlArab	3.8	7.6	2599	154	641	131	77	459	456	1600	314	7.1
Hammdan jisser	4.5	7.5	3143	161	800	160	97	693	614	2129	442	8.8
Mhiela	4.7	7.5	2857	149	676	139	80	588	488	1772	370	8.0
Allibani	4.5	7.5	2442	152	710	146	84	668	533	1976	426	7.6
Syhan	4.4	7.4	3528	128	705	147	82	813	520	2186	516	7.8
Alfao	4.6	7.6	4632	136	885	183	96	1157	707	2984	733	8.2

Table (4) Quality rating (Qi), of each parameter of WTP samples for Basrah City.

WTP	Turb. (NUT)	pH	EC 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	K^{+} mg/l
Albradiah(1)	89.4	47	529	128	131	66	80	516	119	162	59	164
Albradiah(2)	89.4	46	451	122	108	61	71	409	105	127	52	138
Alribat	89.4	43	407	119	105	54	64	383	87	117	47	124
R-Zero	92.9	37	221	108	81	44	46	133	57	33	27	66
Garmma(1)	88.2	34	494	122	128	64	78	464	114	139	55	152
Garmma(2)	89.4	42	495	122	132	64	77	472	113	142	58	153
Almouhammed	90.6	40	405	126	110	57	66	353	93	109	44	123
25 million	91.8	41	378	124	103	53	61	330	85	102	41	115
Alarsifa	89.4	41	248	110	87	45	51	170	62	45	31	74
Aljubila	89.4	45	531	118	100	52	60	293	80	88	40	105
Almdeina	88.2	38	556	108	142	65	94	532	133	164	64	172
Aldeir	91.8	34	371	112	105	53	63	312	89	92	41	112
Alnashua	89.4	33	366	112	107	55	64	307	87	90	38	111
Shatt AlArab	89.4	38	520	128	128	66	77	459	114	157	59	160

hammdan jisser	88.2	45	629	134	160	80	97	693	154	221	73	213
Mhiela	88.2	47	571	124	135	70	80	588	122	185	67	177
Allibani	88.2	45	488	127	142	73	84	668	133	213	63	198
Syhan	87.1	44	706	107	141	74	82	813	130	258	65	219
Alfao	89.4	46	926	113	177	92	96	1157	177	367	68	298

Table (5) Sub index values (SIi) of each parameter.

WTP	pH	Tur.	EC	Alk.	T.H.	Ca	Mg	Cl	SO_4	TDS	Na	K
Albradiah(1)	10	4	60	11	7	4	9	18	14	19	9	3
Albradiah(2)	10	4	52	10	6	3	8	14	12	16	7	3
Alribat	10	4	47	10	6	3	7	13	10	14	7	3
R-Zero	11	3	25	9	5	3	5	5	6	7	2	2
Garmma(1)	10	3	56	10	7	4	9	16	13	17	8	3
Garmma(2)	10	4	57	10	8	4	9	16	13	17	8	3
Almouhammed	10	3	46	11	6	3	8	12	11	14	6	3
25 million	10	4	43	11	6	3	7	11	10	13	6	2
Alarsifa	10	4	28	9	5	3	6	6	7	8	3	2
Aljubila	10	4	61	10	6	3	7	10	9	12	5	2
Almdeina	10	3	63	9	8	4	11	18	15	20	9	4
Aldeir	10	3	42	10	6	3	7	11	10	13	5	2
Alnashua	10	3	42	10	6	3	7	11	10	13	5	2
Shatt AlArab	10	3	59	11	7	4	9	16	13	18	9	3
Hammdan jisser	10	4	72	11	9	5	11	24	18	24	13	4
Mhiela	10	4	65	11	8	4	9	20	14	20	11	4
Allibani	10	4	56	11	8	4	10	23	15	23	12	4
Syhan	10	4	81	9	8	4	9	28	15	25	15	4
Alfao	10	4	106	10	10	5	11	40	20	34	21	4

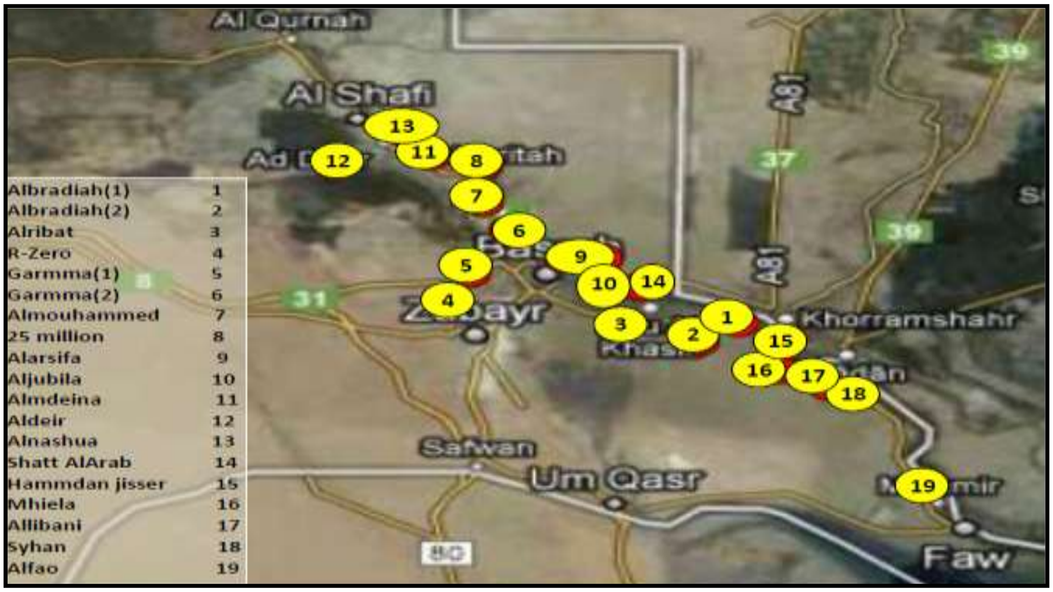

Figure (1) Water Treatment Plants Location.

Table (6) WQI and water classification of each for each WTP in Basrah city.

WTP	WQI	Water classification	WTP	WQI	Water classification
Albradiah(1)	169	Poor water	Almdeina	175	Poor water
Albradiah(2)	146	Poor water	Aldeir	123	Poor water
Alribat	134	Poor water	Alnashua	121	Poor water
R-Zero	83	Good water	Shatt AlArab	163	Poor water
Garmma(1)	157	Poor water	Hammdan jisser	205	Very poor water
Garmma(2)	159	Poor water	Mhiela	180	Poor water
Almouhammed	133	Poor water	Allibani	179	Poor water
25 million	126	Poor water	Syhan	211	Very poor water
Alarsifa	91	Good water	Alfao	275	Very poor water
Aljubila	139	Poor water			

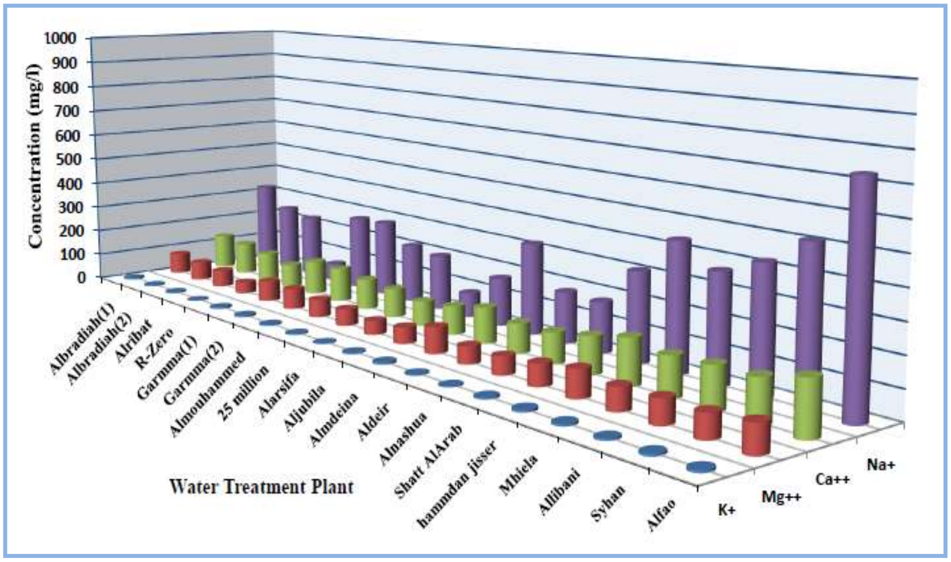

Figure (2) The values of cationic concentration for WTP samples during the study period (2011).

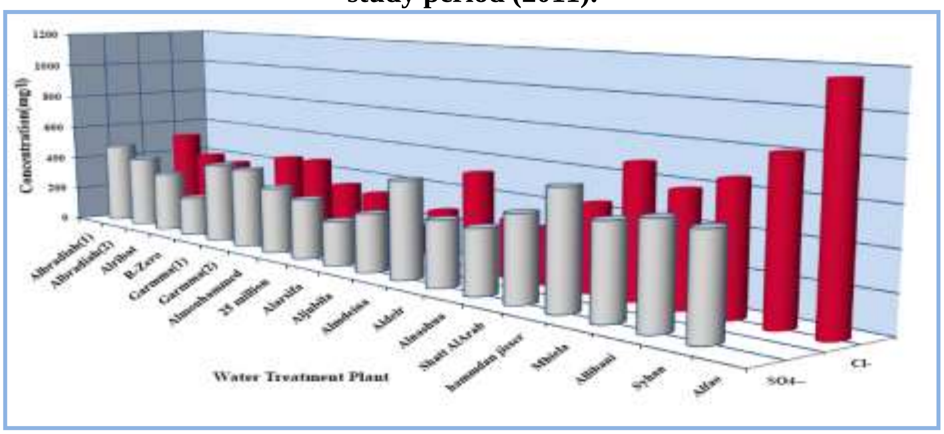

Figure (3) The values of anionic concentration for WTP samples during the study period (2011).

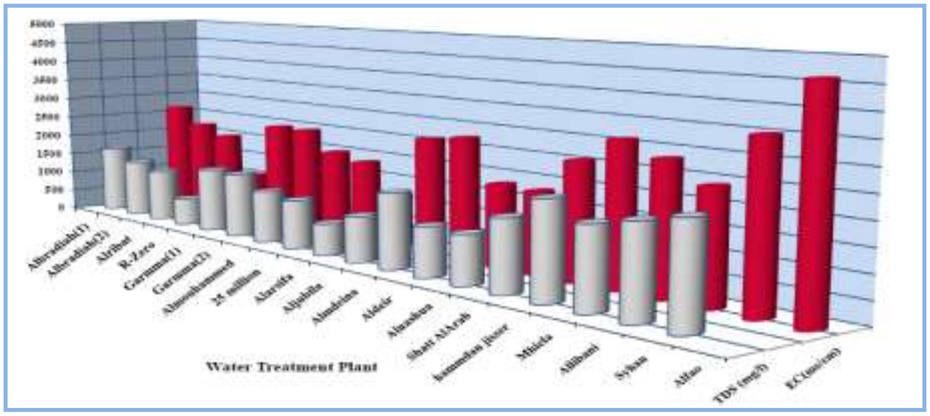

Figure (4) The values of TDS and EC for WTP samples during the study period (2011).

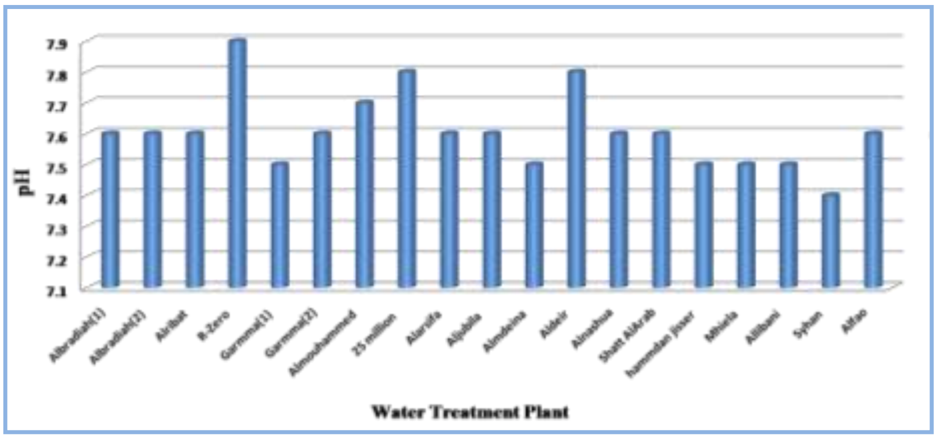

Figure (5) The values of pH for WTP samples during the study period (2011).

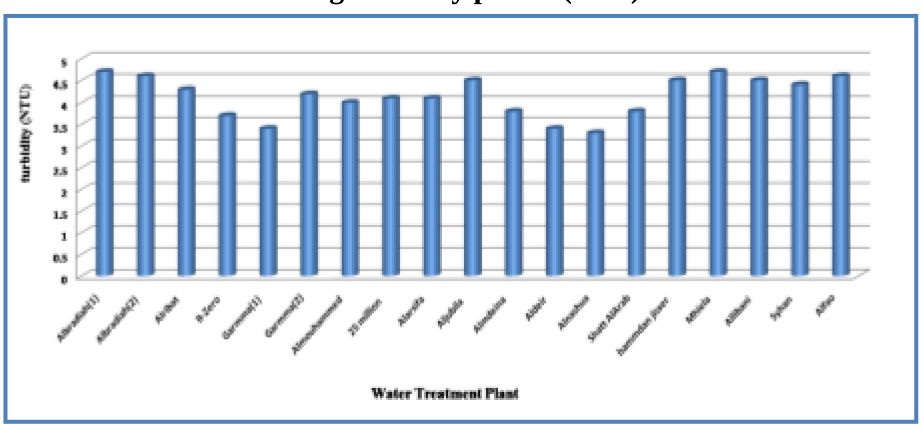

Figure (6) The values of turbidity for WTP samples during the study period (2011).

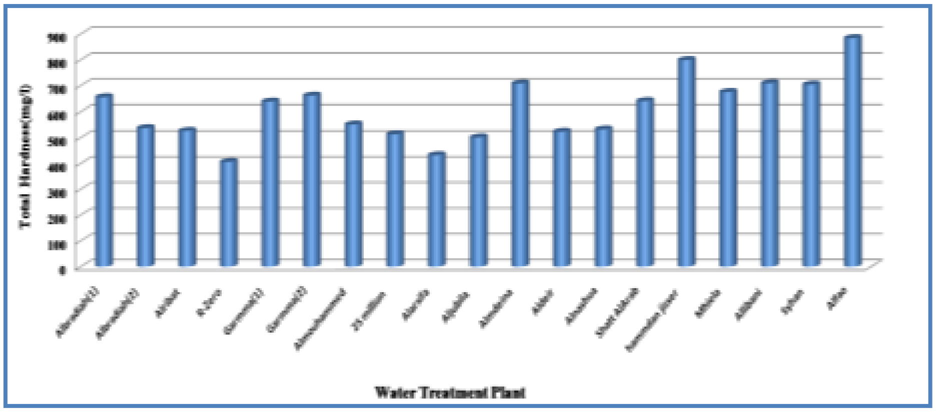

Figure (7) The values of total hardness for WTP samples during the study period (2011).

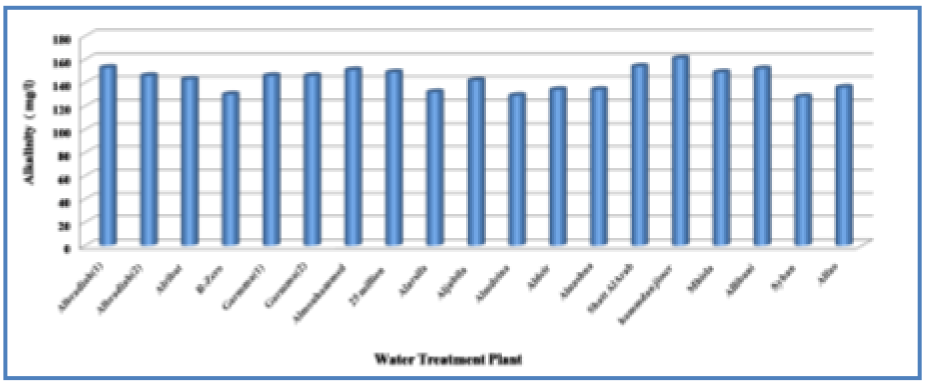

Figure (8) The values of alkalinity for WTP samples during the study period (2011).

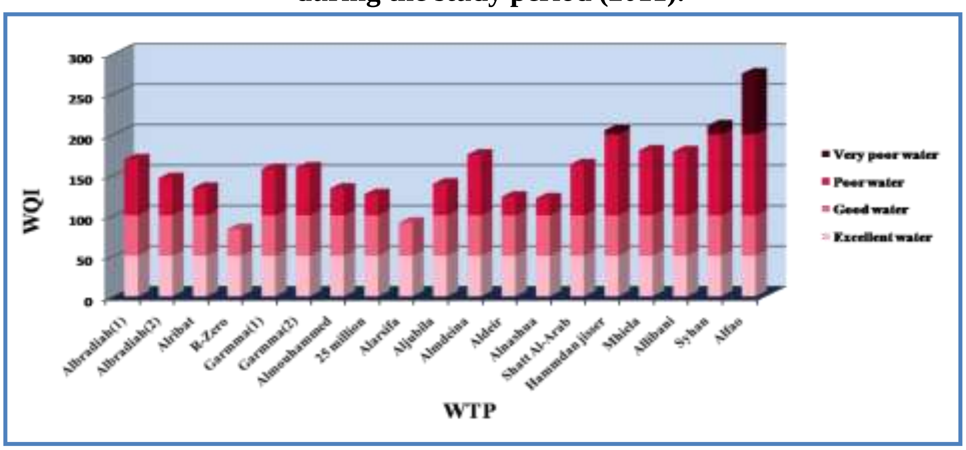

Figure (9) WQI for Basrah WTP during, 2011.

Table (7) The mean values of raw water quality measurement in Basrah WTP during 2011.

WTP	Turb. (NTU)	pH	EC 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	K^{+} mg/l
Albradiah(1)	21.2	7.75	2751	160	681	136	82	532	497	1707	395	7.7
Albradiah(2)	20	7.75	2870	166	680	125	76	470	450	1401	280	6.8
Alribat	18	7.85	2608	157	640	128	77	460	435	1302	285	6.3
R-Zero	19.5	8.1	1100	148	410	97	45	147	233	1210	147	3.4
Garmma(1)	21	7.63	2525	155	648	130	79	497	463	1555	287	7.1
Garmma(2)	21	7.6	2525	160	655	131	77	481	463	1530	287	7
Almouhammed	24	7.97	1995	151	565	115	68	383	378	1249	219	5.6
25 million	17	7.9	1910	159	540	120	61	350	377	1168	225	5.1
Alarsifa	35	7.95	1250	149	438	94	51	270	305	960	148	4.8
Aljubila	22	7.81	2680	162	630	131	76	396	390	1195	240	6.3
Almdeina	16.5	7.75	2890	138	712	136	96	560	539	1780	352	7.9
Aldeir	21.3	7.92	1950	150	548	111	67	333	368	1180	202	6.9
Alnashua	18.5	8.05	2010	150	550	118	68	376	389	1145	197	5.6
Shatt AlArab	16.8	7.68	2630	161	657	135	78	545	472	1641	342	7.9
Hammdan jisser	20.9	7.75	3467	175	838	161	99	701	642	2150	475	9.6
Mhiela	16.6	7.6	2891	166	687	139	80	630	496	1840	395	8.1
Allibani	18	7..67	2475	155	715	155	88	670	574	1988	475	7.9
Syhan	55	7.95	4112	152	808	160	97	885	608	2230	579	9.5
Alfao	92	7.8	12760	167	2020	245	276	3350	1600	5346	2300	12.3