DETERMINATION OF WATER QUALITY INDEX AND SUITABILITY OF SHATT AL ARAB RIVER AND TREATED WATER FOR SOME WATER TREATED PLANTS IN BASRAH

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Abstract: Shatt Al-Arab River is the main water source for all water treatment plants in Basrah governorate. In order to assess its suitability as a source for domestic water supply and the performance of some of main water treatment plants, water quality index (WQI) is obtained for both raw and treated water for 10 water treatment plants. Physic-chemical parameters were monitored for the calculation of WQI for Winter, Spring, Summer, and Autumn seasons from March-2011 to March- 2012.The parameter which were taken into account for the present work are pH, turbidity, electric conductivity, total alkalinity, total hardness, Ca, Mg, Cl, SO4, TDS, Na, and K. The results indicate that Shatt Al Arab is very poor for domestic, industrial, and irrigation purposes during Winter, Spring, Summer, and Autumn seasons, while seven of ten of consider of water treatment plants produce water of poor quality.

Keywords; Water Quality Index (WQI), Physico- Chemical parameter, water treatment plants, Shatt Al Arab river.

حساب مؤشر نوعية المياه (WQI) لبيان صلاحية مياه نهر شط العرب والمياه المعالجة لبعض محطات التصفية في البصرة

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الخلاصة

يعد نهر شط العرب المصدر الرئيس للمياه لمعظم محطات التصفية في محافظة البصرة. ولغرض تقييم ملائمة مياه النهر كمصدر للاستهلاك البشري إضافة لبيان صلاحية بعض محطات التصفية الرئيسية في البصرة تم استخدام مؤشر نوعية المياه (WQI) لتقييم 10 محطات لتصفية المياه الخام والمياه المعالجة. تم استخدام WQI للفصول الشتاء ،الربيع ,الصيف، والخريف للفترة من اذار ٢٠١١ ولغاية اذار ٢٠١٢ . المؤشرات المستخدمة هي ph ، العكارة ، التوصيلية الكهربائية، القلوية، العسرة الكلية، الكالسيوم، المغنيسيوم، الكلور، الكبريتات، المواد الذائبة الكلية، الصوديوم، والبوتاسيوم. أشارت نتائج الدراسة إلى إن المياه الماخوذه من نهر شط العرب خلال الفصول المشار إليها أعلاه كانت رديئة وغير ملائمة للشرب والاستخدامات المختلفة كالإغراض الصناعية والزراعية بينما كانت المياه المعالجة لسبع محطات من عشرة اخذت بنظر الاعتبار تنتج مياه ذات نوعية رديئة.

1-Introduction

Shatt Al Arab river is the main source for all water treatment plants in Basrah governorate including the large and package treatment units. It is a tidal water body receives fresh water from Tigris and Euphrates rivers at its upstream boundary and effected by tide from the North–East of Arabian Gulf at its downstream boundary. Also, Shatt Al Arab River is used as disposal site for a portion of untreated sanitary sewage which is discharged to it through the highly polluted lateral creeks. Therefore, the water of this river is of variable quality due to natural and man-made reasons and, subsequently, needs to be assessed as a source of domestic water supply.

The quality of water is the degree of its portability and is determined by the amount and level of physico-chemical, and microbial parameters and metals (which included suspended and dissolved substances in the water). The problem of drinking water contamination, water conservation and water quality management become very important in the recent years. [1]. In this study, the water quality of Shatt Al -Arab River has been assessed using water quality index (WQI). WQI is regarded as one of the most effective way of monitoring of water quality [2]. It is a mathematical equation used to transform large number of water quality data into single number [3]. Therefore, it represents simple and easy way for decision makers to study the possible uses of any water body [4]

2- The Study Area

Shatt Al -Arab River forms the outlet of the two main rivers of Iraq, the Tigris and Euphrates. It is located between 30°59′ to 30°27′N latitude and 47°26′to 48°4′ E longitude. It flows along a wide channel in a south-easterly direction and downstream of Al Fao and discharges into the Arabian Gulf, as shown in Fig.(1). The river is characterized by arid to semi arid climate with dry hot Summers and cold Winters. The 1۰ considered water treatment plants(WTPs are; 1- Baradia, 2- ShattAl- Arab, 3- Al- Rabat, 4- Al Jubiala, 5- Garma 1, 6- Garma 2, 7- Twenty Five Millon, 8- Basrah Mohad, 9- Al Diar, and 10-Al Qurna. Shatt Al-Arab WTP is located on the east side of Shatt Al- Arab River, while the remaining treatment plants are located on the west bank of Shatt Al-Arab. The details of these water treatment plants including their capacity and flowsheet were given in [Albadran. F.A.J "Evaluation of Water Treatment Plants in Basrah Governorate"][5].

Fig. (1): Location of sampling sites at the study area on the Shatt Al Arab river.

3- Application of WQI

WQI indicates the quality of water in terms of index number, which represents overall quality of water for any intended use. It is defined as a rating reflecting the composite influence of different water quality parameters [6]. WQI of Shatt Al- Arab and the treated water of 10 WTPs were calculated considering twelve important physic-chemical parameters using WHO [7] and IQS standards [8] . The water samples were collected from 1۰ different locations during a period of 12 months extended from March-2011 to March-2012. The physic-chemical analysis of water comprised of following parameters; temperature, pH, turbidity, total dissolved solid (TDS), electric conductivity (EC), total alkalinity, total hardness, chloride, phosphate, calcium, magnesium, sodium and potassium.

The calculation of WQI was made using the weighed Arithmetic index method in the following steps [9];

1- Calculation of unit weight of parameter,
2- Calculation of sub index of quality rating (q_n) for each of the water quality parameters, and

3- Calculation of water quality index (WQI).

3-1 Calculation of Unit Weight (Wn)

The unit weight (Wn) for each water quality parameter is inversely proportional to the recommended standard of the corresponding parameters [10];

$$Wn = K/ Vs \quad \ldots\ldots (1)$$

where

Wn = unit weight for n^{th} parameters

K = proportionality constant

Vs = standard permissible value for n^{th} parameter.

3-2 Calculation of Sub Index of Quality Rating (q_n)

The quality rating or sub index (q_n) corresponding to the n^{th} parameter is a number reflecting the relative value of this parameter in the polluted water with respect to its standard permissible value. The value of q_n is calculated using the following expressions [11] ;

$$q_n = 100 (Vn-Vi) /(Vs-Vi) \quad \ldots (2)$$

where

q_n = quality rating for the n^{th} water quality parameter.

Vn = observed value of the n^{th} parameter at a given sampling station..

Vs = standard value for nth parameters

Vi = ideal value of n^{th} parameter in pure water.

In Eq. (2) the values of Vi for all parameters are taken to be zero except, that of pH which is equal to 7.0. For pH the ideal value is 7.0 (for natural water) and a permissible value is 8.5 (for polluted water). Therefore, the quality rating for pH is calculated using the following relation:

$$\mathbf{q_{pH} = 100 [(V_{pH} -7.0) / (8.5 – 7.0)]} \quad \ldots(3)$$

where

V_{pH} = observed value of pH during the study period.

3-3 Calculation of WQI

WQI is calculated from the following equation [12].

$$WQI = \sum qn\ Wn\ /\ \sum Wn \quad \ldots\ldots (4)$$

4-Results and Discussion

4-1 Results and Discussion of physical-Chemical Parameters

Table (1) presents the results of the statistics of physico-Cemical parameters of raw water quality in Shatt Al- Arab river. The results showed that the mean values of pH, Ca, and K for samples examined are within the maximum permissible limit of WHO and IQS standards while the mean values of turbidity, TDS, electric conductivity, total alkalinity, total hardness, SO_4, Mg, Na are not with the permissible limit of standard. The statistical results showed that the coefficient of variance (CV %) in all the examined water samples of Shatt Al-Arab river variables are not homogeneous.

Table (2) presents the results of the statistics of physico-Chemical parameters of water quality for treated water. It shows that the mean values of pH, turbidity, Ca, and K for samples examined are within the maximum permissible limit of WHO standard except mean turbidity it is not within the permissible limits of IQS standard while the mean value of TDS, electric conductivity, total hardness, SO4, Mg, Na, are not within the permissible limit of WHO and IQS standards. The people prone to health hazards due to polluted drinking water therefore, some effective measures are required to enhance the drinking water quality by delineating an effective water quality management plan and internal a new technological for water treatment like reverse osmosis. The results of the coefficient of variation (CV%) showed that all the examined treated water variables are not homogenous.

Table (1): Statistics of constituents in Shatt Al Arab raw water

Parameter+ Standard values	Statistical Indices	Statistical results of the indicated station number									
		No.1	**No.2**	**No.3**	**No.4**	**No.5**	**No.6**	**No.7**	**No.8**	**No.9**	**No.10**
pH WHO=6.5-8.5 IQS=6.5-8.5	mean	7.3	7. 8	8.16	7.69	7.83	7.8	8.1	7.9	7.97	7.8
	SD	0.04	0.17	0.59	0.22	0.22	0.1	0.15	0.13	0.26	0.22
	CV(%)	1.0	2.20	7.20	2.00	2.00	1.7	2.0	1.70	3.30	2.80
Tur. WHO=10NTU IQS=10NTU	mean	15.6	14	1726	23.20	25.35	34.5	29.8	23.8	24.9	47.1
	SD	2.9	3.44	5.19	9.74	15.34	17.7	20.26	5.32	11.3	30.5
	CV(%)	18	24	29.00	40.00	60	5.20	67.80	22.2	46.6	64.8
TDS WHO=1000mg/l IQS=1000 mg/l	mean	1946	1821	1648	2331	1435	1770	1061	982.8	1284	990
	SD	163.2	55.2	180.9	199.2	505.7	508.5	59.1	412.4	348.5	59.9
	CV(%)	8	3	10.9	47	35	28	5.6	41.2	27.1	6.11
EC WHO=1000 µ mho/cm IQS=1000 µ mho/cm	mean	3502	2990	2666	2289	2361	2925	1889.	1918	2134	1830
	SD	342.3	113.1	264.4	795.3	827.1	846.3	231.1	258.1	574.6	126.5
	CV(%)	9.7	3.7	49.9	35.00	35	29	12.2	13.5	26.9	7.70
Alk WHO=120 mg/l IQS= 120 mg/	mean	159.8	158.8	157	169.5	149.3	157.7	154.8	141.8	169.5	168.6
	SD	3.84	5.89	10.22	5.55	29.03	17.3	6.54	14.5	7.12	13.33
	C.V(%)	2.4	3	6.5	3.20	19	12	4.22	10.2	4.20	7.90
TH WHO=300 mg/l IQS= 500 mg/l	mean	715.3	713	634	682	640	683.3	502.4	522	562	450
	SD	57.9	75.27	62.32	71.92	164.9	133.5	58.5	56.7	149.7	37.3
	CV(%)	8.2	1	9.8	10.5	26	19.5	11.6	10.1	26.6	8.30
Cl WHO=250 mg/l IQS= 250 mg/l	mean	649.5	580	521.3	520.5	416.3	577.3	326.3	351	389.8	282.5
	SD	90.4	39.32	63.16	64.73	150.7	214.3	42.03	45.8	95.1	12.1
	CV(%)	13.9	6.7	12.10	12.40	356	37	12.8	13.1	23.4	4.20
So_4 WHO=250mg/l IQS=400mg/l	mean	528.1	528.5	463.3	623.8	447.8	497.8	320.5	337	381.0	259
	SD	54.2	70.34	74.09	237.7	101.1	131.3	54.1	53.8	135.7	35.74
	CV(%)	10.3	13.3	15.90	38.00	40.4	26	16.8	15.9	35.6	13.7
Ca WHO=200 mg/l IQS= 125 mg/l	mean	139	142.3	127.3	157.8	120	120.8	99.5	104.3	115	97.5
	SD	10.93	14.97	12.39	45.8	29.3	23.3	9.55	8.5	31.6	1.5
	CV(%)	7.8	10.5	9.700	29.0	24.0	19	9.6	8.1	27.6	1.5
Mg WHO=50 mg/l IQS= 50 mg/l	mean	76.17	87.5	77	121.2	80.5	93	61.5	75.3	67.3	58.0
	SD	29.1	10.28	7.81	28.6	26.3	22.2	8.8	12.9	17.4	8.53
	CV(%)	38	11	10.00	23.7	33.0	23	14.3	17.2	25.8	16.8
Na WQI=200 mg/l IQS= 200 mg/l	mean	41.2	170.3	338.3	495.0	254.0	367.3	203.5	216.3	231	172.8
	SD	59.2	98.07	37.59	325.1	113.2	138.4	34.7	38.7	63.1	13.3
	CV(%)	14.4	57.60	11.12	65.00	44.0	37	17.08	17.0	27.3	7.70
K WHO=12 mg/l IQS=12 mg/l	mean	11.7	7.65	10.2	12.0	10.25	7.9	7.3	7.71	8.15	5.65
	SD	2.2	1.94	4.87	3.23	4.43	0.9	2.74	2.51	2.36	0.77
	CV(%)	18.9	25	47	24.00	43.00	11.0	37.8	32.6	29	13.6

SD=Standard Deviation CV=Coefficient of Variation

No. 1= Baradia No. 2=Shatt Al Arab No.3=Al Rabat No.4=Al Jubiala No.5 = Garma 1
No.6 = Garma 2 No. 7=25 Millon No.8= Basrah Mohhad No.9=Al Diar No.10 =Al Qurna

Table (2): Statistics of constituents in treated water

Parameter+ Standard Values	Statistical Indices	Statistical results of the indicated station number									
		No.1	No.2	No.3	No.4	No.5	No.6	No.7	No.8	No.9	No.10
pH WHO=6.5-8.5 IQS=6.5-8.5	mean	7.65	7.56	7.59	7.55	7.53	7.65	7.88	7.51	7.54	7.71
	SD	0.11	0.12	0.23	0.303	0.91	0.05	0.13	0.22	0.26	0.14
	CV(%)	1.50	1.50	3.10	4.10	1.21	0.70	1.68	3.00	3.50	1.90
Tur. WHO=10NTU IQS=10NTU	mean	4.04	6.3	6.32	6.63	4.45	7.5	6.5	4.27	5.20	12.25
	SD	0.91	1.20	1.39	2.52	0.77	2.45	3	1.42	1.23	6.38
	CV(%)	22.8	19.0	22.00	37.9	17.50	32.00	46.00	33.00	23.70	52.00
TDS WHO=1000mg/l IQS=1000 mg/l	mean	1406	1216	1212	1428	1312	1656	1115	956.3	1274	964.3
	SD	624	340	620.8	179.1	533.5	755.5	231.6	515.7	396.4	50.36
	CV(%)	44.3	27.3	51.22	12.50	40.6	45.60	21.00	54.00	32.00	5.20
EC WHO=1000 µ mho/cm IQS=1000 µ mho/cm	mean	1389	1380	1986	2419	2182	2238	1837	1857	2134	1605
	SD	543.9	544	952.8	124.4	891.9	430.1	427.2	982	657.4	108.6
	CV(%)	38.36	39.4	47.90	5.10	40.80	19.20	23.20	26.00	31.00	6.70
Alk WHO=120 mg/l IQS= 120 mg/l	mean	145.1	143	149	156.7	135	150	149	142.5	160	160.7
	SD	9.07	5.90	13.32	4.99	23.46	16.75	6.06	10.75	5.88	11.23
	CV(%)	6.25	3.40	8.90	3.22	17.40	11.10	4.10	7.50	3.60	6.90
TH WHO=300 mg/l IQS= 500 mg/l	mean	461.7	468	510	758	592	634	480.7	501.2	564	440
	SD	56.46	76.9	192.4	297.3	192.2	192.3	45.75	106.4	173.6	33.31
	CV(%)	18.8	16. 5	37.70	39.22	32.5	30	9.60	21.00	31.00	7.50
Cl WHO=250 mg/l IQS= 250 mg/l	mean	271.5	256	241.3	446	373.8	547.7	315.5	333.3	364.8	272.5
	SD	94.7	87.3	95	96.1	163	319.2	76.77	99.38	112.3	8.81
	CV(%)	34.80	34.1	39.37	21.55	43.4	58.30	23.9	28.00	31.00	3.30
So_4 WHO=250mg/l IQS=400mg/l	mean	277	310	362.7	574.8	411	458	325.7	334	383.3	253.5
	SD	100.2	89	182.4	296.4	191.8	179.9	84.35	87.21	158.5	35.74
	CV(%)	36	28.7	51	51.5	46.6	39.4	25.80	26.00	41.00	14.00
Ca WHO=200 mg/l IQS= 125 mg/l	mean	91.8	98	101.8	144.5	113.5	116.5	100.2	101.7	115.3	95.50
	SD	19.36	20. 7	38.82	59.71	33.75	32.43	15.98	18.83	34.36	1
	CV(%)	21	21.1	38	41	29.7	27.8	15.90	18.50	29.00	1.04
Mg WHO=50 mg/l IQS= 50 mg/l	mean	62.1	73.2	62.5	96.75	75.22	85.25	62.50	59.00	67.25	49.25
	SD	13.3	15.8	23.3	36.3	26.6	29.8	12.28	20.87	21.60	8.26
	CV(%)	22	21.7	37.2	37.7	35.3	35	19.60	36	32.00	16.7
Na WQI=200 mg/l IQS= 200 mg/l	mean	156	149.8	225.5	463.3	221.8	346	194	203	228.2	160.5
	SD	62.7	90.9	146.	195.9	115.9	203.4	51.19	64.28	70.62	12.47
	CV(%)	40.22	60.6	64.99	42.29	52.22	58.6	26.30	32	31.00	7.5
K WHO=12 mg/l IQS=12 mg/l	mean	6.5	6.7	6.3	8.1	8.7	7.9	6.4	6.43	7.60	5.18
	SD	1.5	3.2	2.5	4.3	4. 6	1. 6	2.42	2.44	1.97	0.86
	CV(%)	23.4	47.8	39	53.3	53	29.6	27.40	38.00	26	16.00

SD=Standard Deviation CV=Coefficient of Variation

No. 1= Baradia No. 2=Shatt Al Arab No.3=Al Rabat No.4=Al Jubiala No.5 = Garma 1 No.6 = Garma 2 No. 7=25 Millon No.8= Basrah Mohhad No.9=Al Diar No.10 =Al Qurna

4-2 Results and Discussion of WQI Analysis

The physico-chemical parameters with their WHO and IQS standards, ideal value (Vi) and assigned unit weights factor (Wn) are listed in Table (3). The water quality rating for drinking purposes of any water system is given in Table (4)

Table (3): Water quality parameters

Water quality parameters	Standard value IQS	Standard value WHO	Ideal value(Vi)	Unit weights (Wn_i)
pH	6.5-8.5	7-8.5	7	0.3336112
Turbidity (NTU)	10	10	0	0.2835696
TDS (mg/l)	1000	1000	0	0.0028356
E.C (µ mho/cm)	1000	1000	0	0.0028356
Alkalinity (mg/l)	120	120	0	0.0236308
Total Hardness (mg/l)	500	300	0	0.0094523
Chlorides (mg/l)	250	250	0	0.0113428
Sulphate (mg/l)	400	250	0	0.0113427
Calcium (mg/l)	125	200	0	0.0141784
Magnesium (mg/l)	50	50	0	0.0567139
Sodium (mg/l)	200	200	0	0.0141784
Potassium(mg/l)	12	12	0	0.2363080

Table (4): Water quality classification based on WQI values

WQI value	Water quality
0-25	Excellent (water is clear and not in contact with domestic wastes. Ideal for all different purposes. No treated required).
26-50	Good (initiation of serious changes in water quality due to environmental deterioration. Useful for domestic and industrial purposes, suitable to secured wildlife and waterfowl).
51-75	Poor (drastic changes in water quality begin to occur the water can be used for domestic and industrial purposes after intensive treatment).
76-100	Very poor (dangerous changes may occur in the ecosystem. Constant disturbing smell. Conventional treatment costs are augmented).
>100	Unfit for drinking (highly dangerous pollution. Danger in any form of water consumption).

The water quality indices that were found for raw and treated water for four different season have been represented graphically in Fig. (2) and treated water in Fig. (3). The results showed that for raw water none of the samples are coming neither under good nor poor (the highest value is 145.68 in Gurma 1 during Summer while ,the lowest value 72.39 occurs for Al Diar during winter). The high value of WQI at Shatt Al- Arab in raw water has been found to be mainly due to the higher value of turbidity, TDS, E.C, alkalinity, total hardness, chlorine, sulfate, magnesium, sodium, and potassium. The values of WQI showed

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the higher percent of unsuitable category was found in Summer season as compared with the other seasons. The reasons for the high WQI values were continuous discharge of agricultural runoff malpractice, industrial effluents and sewage effluents flowing into the river. Fig. (3) shows that none of the treated samples are classified as excellent(the highest value is 74.53 in Al Jubila during Winter while ,the lowest value 34.3 occurs for Al Diar during Autumn). The results showed that 30% are good quality while 70% are poor quality in WTPs..

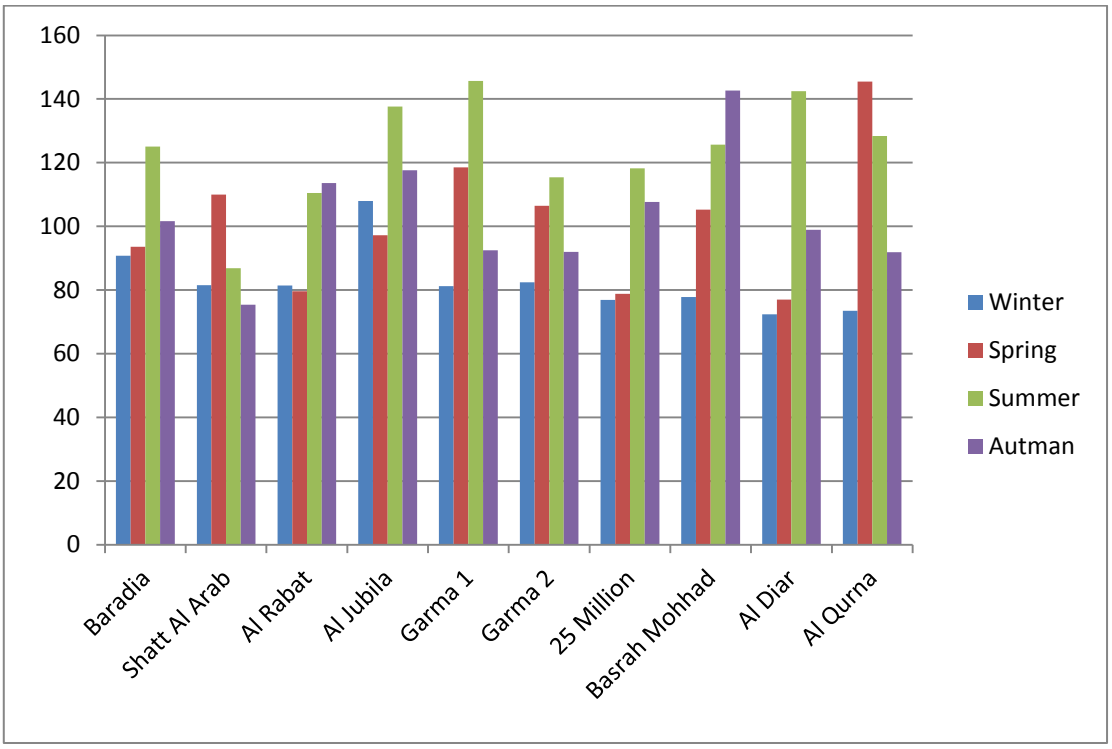


Fig. (2): Graphical Representation of WQI. (Raw Water)

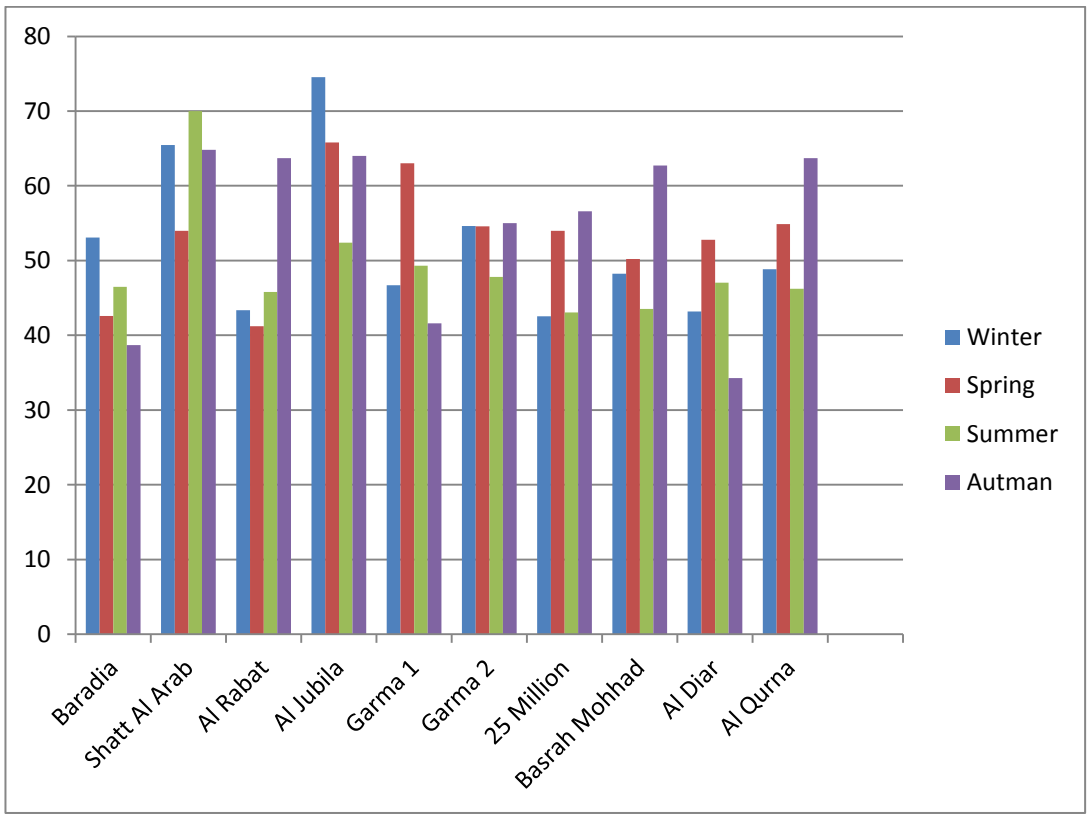
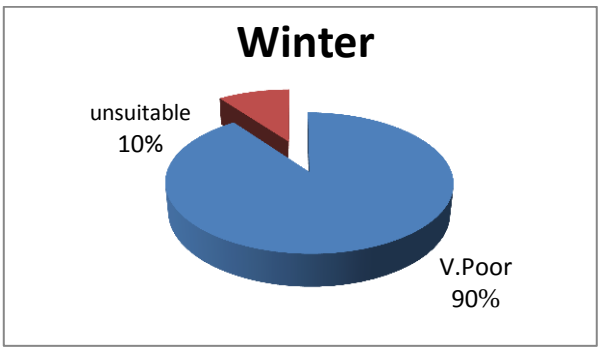
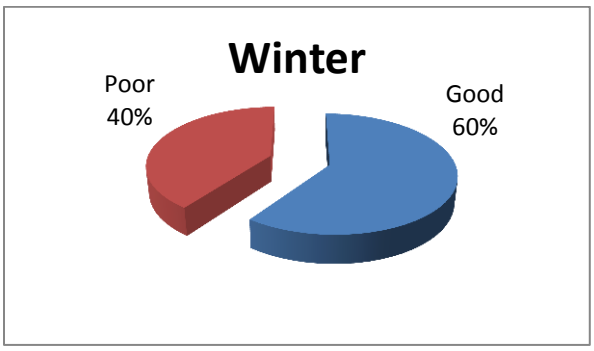


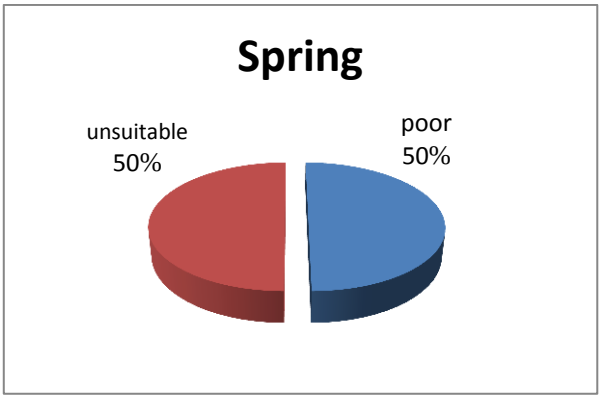
Fig. (3): Graphical Representation of WQI. (Treated Water)

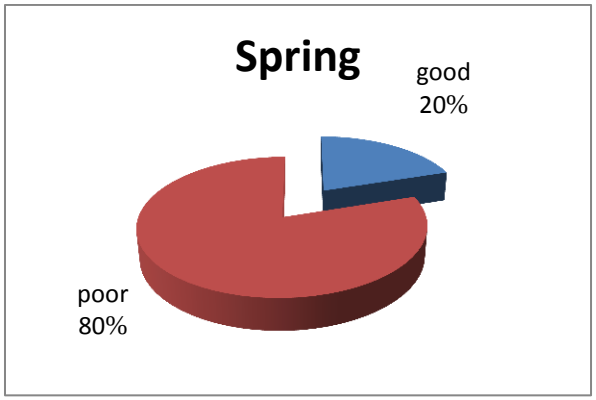
Fig. (4) shows WQI categories of samples (percentage) in various seasons. The values of WQI in raw water showed the higher percent of unsuitable category was found in Summer season as compared with other seasons. In Fig. (5) for treated water, the water quality rating analysis reveals that 65% of samples were found as good in winter and Summer while in Spring and Autumn it was only 25% samples were good and 75% poor samples.

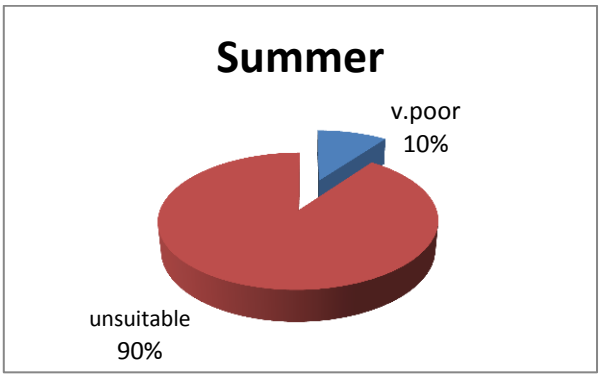
From the present observation, it can be calculated that raw water quality of Shatt Al- Arab is under stress (V. Poor to Unsuitable) of severe pollution due to high value of parameters in water and discharge of wastewater from various sources into the river. The water is not suitable for drinking, bathing and swimming. The calculated WQI (%) of treated water revealed that the water quality is poor for drinking purposes, except where the WQI exceeds to permissible limit 50 in some WTPs. The study reveals that the water treatment needs some degree of new and modern plants before consumption and also needs to be protected from the perils of the prevailing contamination.

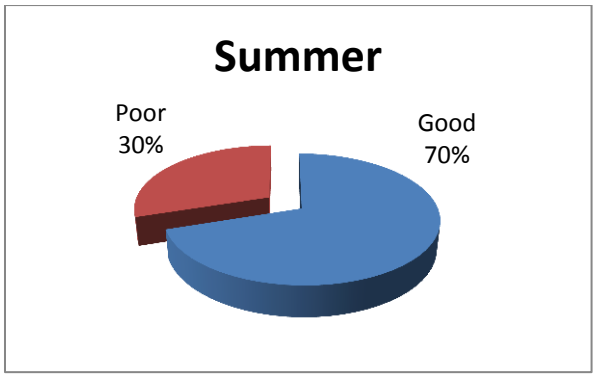


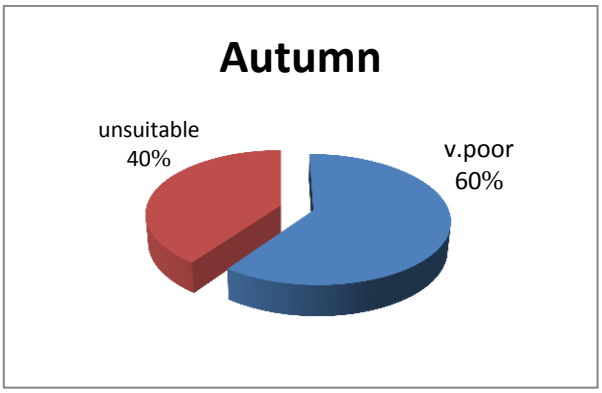












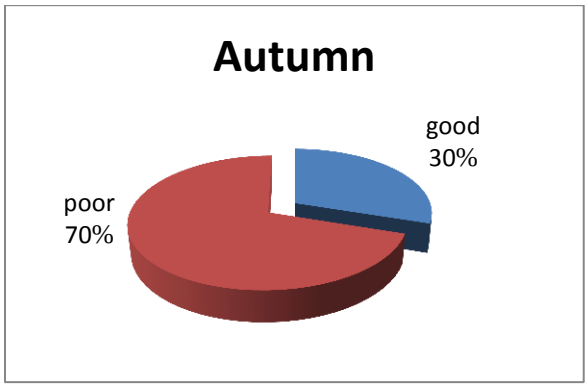


Fig. (4) WQI Categories of raw water samples (%) in various seasons

Fig.(5) WQI Categories of treated water samples (%) in various seasons

Conclusion

The study clearly indicates that the Shatt Al Arab water in four seasons Winter, Spring, Summer, and Autman can't be used for public, industrial,

irrigation and other consumption without treatment .

Further the calculated WQI for raw water of Shatt Al- Arab revealed that it is very poor to be used for the portable water uses. While, the WQI of treated water produced by seven of ten considered water treatment plants has poor quality.

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Notation

CV= coefficient of variation

K= proportionality constant

pH= hydrogen ion concentration

qn= quality rating of water quality parameters

SD=standard deviation

TDS=total dissolved solid

Vs= standard permissible value for parameters

Vn= observed value of parameter

Vi=idealvalue of parameter pure water

Wn= unit weight of parameters

WTP= water treatment plant

WHO= water health organization