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Application of Water Quality Index to Assessment of Tigris River

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A B S T R A C T

This study aimed at using the application of Water Quality Index (WQI) in evaluating the quality of Tigris River in Misan province, Iraq for public usage. Fourteen water quality parameters were considered (pH, Electrical conductivity, Total dissolved solids, Total hardness, Total alkalinity, Turbidity, Calcium, Magnesium, Sodium, Potassium, Chloride, Nitrate, Sulphate, Phosphate). WQI values ranged from 93.78 and 264.29 for winter and summer season respectively, and its ranged for all sites between 65.581 to 160.461 and 173.589 to 446.478 for both season respectively. The high value of WQI had been found mainly from the higher values of pH, total hardness, total alkalinity, turbidity, potassium, nitrate and phosphate. The analysis reveals that the WQI of Tigris river its poor and unsuitable for human consumption and other purposes, and its need some treatments before consumption and its also needs to be protect from pollution.

Introduction

Water is the most essential and prime necessity of life. It is an essential requirement for the life supporting activities. Surface water generally available in rivers, lakes, ponds and dams is used for drinking, irrigation and power supply etc. Tigris river consider the main source of surface water in Misan province. Water is polluted artificially by naturally or human activities. In newly reclaimed lands, agricultural and industrial activities may create different sources of pollution (Barbooti *et al.*, 2010).

In Iraq, the municipalities are responsible for the production and delivery of drinking water, because of the war operations in this country, these led to an increase in environmental problems, including water contamination (Euphrates and Tigris), air pollution and ecosystem degradation (Hassan *et al.*, 2010).

The availability of water in Iraq shows a great deal with spatial and temporal variability. The increase in population and expansion of economic activities undoubtedly leads to increasing demand of water use for various purposes. Water resources in Iraq, especially in the last two decades have also suffered of remarkable stress in terms of water quantity due to different reasons such as the dams built on Tigris and Euphrates in the riparian countries, the global climatic changes and the local severe decrease of the annual precipitation rates and improper planning of water uses inside Iraq (Rahi and Halihan, 2010).

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 (Asadi *et al*., 2007; Buchanan and Triantafilis, 2009). WQI may be defined as 'a rating that reveals the composite influence of a number of water quality parameters on the overall water quality' (Shankar and Sanjeev, 2008).

WQI reflects the composite influence of different water quality parameters and is calculated from the point of view of the suitability of (both surface and groundwater) for human consumption.

It is the aim of the present study to make a comprehensive evaluation of the physicochemical parameters of the drinking water supplied to the homes in Amara city from the many water sites along the Tigris river in Misan Province.

Materials and Methods

In this study, ten sites were selected along the Tigris River (Ali El-Gharbi, Kumait, Amara dam, Alwihda, Al-Misharh, Al-Kahla'a, Qalat Saleh, Al- Azir, Al-Majar and Al-Maymonah) Figure 1. Water samples were collected from the surface water during the months of November 2014 to August 2015. These samples were analyzed for14 physicochemical parameters by following the established procedures. The parameters pH, electrical conductivity were monitored at the sampling site and other parameters like total dissolved solids, total alkalinity, total hardness, turbidity, calcium, magnesium, sodium, potassium, chloride, nitrate, Sulphate and phosphate were analyzed in the laboratory as per the standard procedures of APHA (1995).

Calculation of WQI

The Water Quality Index (WQI) was calculated using the standards of drinking water quality recommended by the World Health Organization (WHO, 2006). The weighted arithmetic index method (Brown *et al*., 1970) was used for the calculation of WQI of the surface water. The quality rating scale for each parameter qn was calculated by using the following expression.

$$qn= 100 [Vn - Vio] / [Sn - Vn] ....(1)$$

(Let there be n water quality parameters and quality rating or sub index (qn) corresponding to nth parameter is a number reflecting the relative value of this parameter in the polluted water with respect to its standard, maximum permissible value).

qn = Quality rating for the nth water quality parameter

Vn = Estimated value of the nth parameter at a given sampling point.

Sn = Standard permissible value of the nth parameter.

Vio = Ideal value of nth parameter in pure water (i.e. 0 for all other parameters except the parameter pH and Dissolved Oxygen (7.0 and 14.6 mg/l respectively).

Unit weight was calculated by a value inversely proportional to the recommended standard value Sn of the corresponding parameter.

$$Wn = K/Sn \text{ ....(2)}$$

Wn = unit weight for the nth parameters.

Sn = standard value for the nth parameters.

K = constant for proportionality.

The overall WQI was calculated by aggregating the quality rating with the unit weight linearly and then compared with the WQI categories (Table1).

$$WQI = \sum qn\, Wn / \sum Wn$$

During the study period showed that the mean of pH values were ranged from 7.53 in winter season (Table 2) to 7.69 in summer season (Table 3), these values of pH within allowable limits for surface water (WHO, 2006). pH is an important parameter which determines the suitability of water for various purposes (Yogendra and Puttaiah, 2008).

Mean values of EC, Total hardness, TDS and Total alkalinity ranged from 2053.10 – 2352.64 dS/m, 618.00 – 642.93 mg $CaCO_3$/L, 1275.90 – 1348.46 mg/L and 194.50 – 220.60 mg/L respectively, these values increased in winter season and decreased in summer season, the high values of EC, TDS, T.H and T.A parameters in winter season may be attributed to the high precipitation in this season which due to dissolution and leaching the salts from soil to the Tigris river (Al-Sabah *et al*., 2011). All mean values of these parameters were above the permissible limits (WHO, 2006), and the high concentration especially total dissolved solids in the surface water is a pointer to the fact that there are intense anthropogenic activities along the river and run off with high suspended matter content (Chapman, 1996).

Values of Turbidity decreased in winter and ranged between 10.64 – 41.70 NTU. Mean concentrations of calcium, magnesium, sodium, chloride, Sulphate and phosphate increased during winter season compared with the summer season (Table 2&3), this may be attributed to the high rain fall in this season which dissolve the salts from soil to the river (Hassan *et al*., 2010).

High concentrations of some ions such as chloride indicate higher degree of organic pollution (Munawar, 1970). Magnesium in water may be attributed to the chemistry of the geological composition of the river bed-rock. Excess in Mg in drinking water might impair human health and lead to heart and kidney diseases (Ayeni *et al*., 2011; Ojosipe, 2007).

Table.1 Water Quality Index (WQI) Categories (Chatterji and Raziuddin, 2002).

Water Quality Index Level	Water Quality Status
0 -25	**Excellent water quality**
26 – 50	**Good water quality**
51 - 75	**Poor water quality**
76 – 100	**Very poor water quality**
> 100	**Unsuitable for drinking**

Table.2 Physiochemical parameter values for all sampling sites of Tigris river (winter season)

No. of site	Sites	pH	EC µS/cm	TDS mg/l	T.H mg/l	T.A mg/l	Turb. NTU	Ca	Mg	Na	K	Cl	NO_3	SO_4	PO_4
								mg/l							
1	**Ali El-Gharbi**	7.55	2441.5	1355.5	675.0	225.0	6.5	167.5	37.5	146.0	4.25	417.5	6.86	425.0	**0.083**
2	**Kumait**	7.45	2331.3	1371.6	646.5	225.0	6.4	161.0	39.5	141.4	4.35	390.5	5.27	415.0	**0.089**
3	**Amara dam**	7.80	2328.5	1329.0	636.3	234.0	8.5	150.0	46.0	134.0	3.94	400.0	5.35	424.0	**0.184**
4	**Al-Wihda**	7.70	2384.5	1298.0	624.0	215.0	5.5	155.0	43.5	148.5	3.80	364.0	5.25	371.5	**0.176**
5	**Al-Misharah**	7.50	2205.0	1295.5	635.0	200.0	8.5	153.5	44.5	130.0	3.65	139.4	5.39	419.0	**0.105**
6	**Al-Kahla'a**	7.40	2427.0	1391.0	625.0	222.0	20.5	147.5	48.0	139.0	3.55	430.5	5.10	437.5	**0.101**
7	**Qalat Saleh**	7.35	2285.0	1335.5	646.0	215.0	9.0	150.0	42.5	129.0	3.40	424.0	6.20	425.0	**0.067**
8	**Al-Azir**	7.65	2393.6	1397.5	625.0	232.5	9.5	157.5	39	137.5	4.10	386.0	5.27	416.0	**0.091**
9	**Al-Majar**	7.60	2430.5	1346.0	660.0	232.5	9.0	164.0	39.5	144.5	4.40	402.5	5.52	395.0	**0.112**
10	**Al-Maymonah**	7.30	2299.5	1365.0	656.5	205.0	23.0	146.5	47.5	129.5	3.40	415.0	6.14	441.0	**0.128**
Min.		7.3	2205	1295.5	624	200	5.5	146.5	37.5	129	3.4	364	5.10	371.5	**0.067**
Max.		7.8	2441.5	1397.5	675	234	23	167.5	48	148.5	4.4	430.5	6.86	441	**0.184**
Mean		**7.53**	**2352.64**	**1348.46**	**642.93**	**220.60**	**10.64**	**155.25**	**42.75**	**137.94**	**3.88**	**402.4**	**5.64**	**416.9**	**0.114**

Table.3 Physiochemical parameter values for all sampling sites of Tigris river (summer season)

No of site	Sites	pH	EC µS/cm	TDS mg/l	T.H mg/l	T.A mg/l	Turb. NTU	Ca	Mg	Na	K	Cl	NO_3	SO_4	PO_4
								mg/l							
1	**Ali El-Gharbi**	7.8	2027	1066	630	180	68	153	33	135	5.2	330	8.3	300	**0.028**
2	**Kumait**	7.5	2003	1278	620	190	75	160	38	145	5.3	318	8.1	298	**0.031**
3	**Amara dam**	7.7	2060	1312	610	200	38	162	33	148	5.8	300	6.28	258	**0.045**
4	**Al-Wihda**	7.8	2055	1272	635	200	45	149	28	130	4.8	300	6.81	278	**0.051**
5	**Al-Misharah**	8.1	2142	1285	618	185	41	162	38	143	5.0	381	7.5	345	**0.037**
6	**Al-Kahla'a**	8.0	2048	1332	610	200	25	165	40	142	4.6	338	6.5	320	**0.048**
7	**Qalat Saleh**	7.6	2044	1276	640	200	30	145	30	128	4.7	352	5.85	285	**0.061**
8	**Al-Azir**	7.3	2047	1310	600	200	28	150	31	127	4.5	340	5.47	308	**0.073**
9	**Al-Majar**	7.2	2072	1365	600	190	27	147	45	130	4.7	348	6.8	310	**0.045**
10	**Al-Maymonah**	7.9	2033	1263	617	200	40	155	37	139	5.2	340	7.3	295	**0.028**
Min.	**Min.**	7.2	2003	1066	600	180	25	145	28	127	4.5	300	5.47	258	**0.028**
Max.	**Max.**	8.1	2142	1365	640	200	75	165	45	148	5.8	381	8.3	345	**0.073**
Mean	**Mean**	**7.69**	**2.53.1**	**1275.9**	**618**	**194.5**	**41.7**	**154.8**	**35.3**	**136.7**	**4.98**	**334.7**	**6.89**	**299.4**	0.045

Table.4 Calculation of Water Quality Index of Tigris River (winter season)

parameter	mean value	Standard permissible value (Si) WHO (2006)	Unit weight (Wi)	Quality rating (qi)	Wiqi
pH	7.53	8.5	0.117	88.58	**10.36**
E.C	2352.64	1000	0.001	235.26	**0.23**
TDS	1348.46	500	0.002	269.69	**0.54**
T.H	642.93	200	0.005	321.46	**1.60**
T.A	220.60	120	0.009	183.83	**1.65**
Turbidity	10.64	5	0.2	212.8	**42.56**
Ca	155.25	200	0.005	77.62	**0.38**
Mg	42.75	200	0.005	21.37	**0.10**
Na	137.94	250	0.004	55.17	**0.22**
K	3.88	10	0.1	38.8	**3.88**
Cl	402.4	250	0.004	160.96	**0.64**
NO_3	5.64	10	0.1	56.4	**5.64**
SO_4	416.9	200	0.005	208.45	**1.04**
PO_4	0.114	5.5	0.181	2.07	**0.37**
WQI=∑Wiqi/∑Wi= 93.78			∑Wi = 0.738		**∑Wiqi = 69.21**

parameter	mean value	Standard permissible value (Si) WHO (2006)	Unit weight (Wi)	Quality rating (qi)	Wiqi
pH	7.53	8.5	0.117	88.58	**10.36**
E.C	2352.64	1000	0.001	235.26	**0.23**
TDS	1348.46	500	0.002	269.69	**0.54**
T.H	642.93	200	0.005	321.46	**1.60**
T.A	220.60	120	0.009	183.83	**1.65**
Turbidity	10.64	5	0.2	212.8	**42.56**
Ca	155.25	200	0.005	77.62	**0.38**
Mg	42.75	200	0.005	21.37	**0.10**
Na	137.94	250	0.004	55.17	**0.22**
K	3.88	10	0.1	38.8	**3.88**
Cl	402.4	250	0.004	160.96	**0.64**
NO_3	5.64	10	0.1	56.4	**5.64**
SO_4	416.9	200	0.005	208.45	**1.04**
PO_4	0.114	5.5	0.181	2.07	**0.37**
WQI=∑Wiqi/∑Wi= 93.78			**∑Wi = 0.738**		**∑Wiqi = 69.21**

All values in mg/l except pH , EC(µS/cm) and turbidity (NTU)

Table.5 Calculation of Water Quality Index of Tigris River (Summer season)

parameter	mean value	Standard permissible value (Si) WHO (2006)	Unit weight (Wi)	Quality rating (qi)	Wiqi
pH	7.69	8.5	0.117	90.47	**10.58**
E.C	2053.1	1000	0.001	205.31	**0.20**
TDS	1275.9	500	0.002	255.18	**0.51**
T.H	618	200	0.005	309	**1.54**
T.A	194.5	120	0.009	162.08	**1.45**
Turbidity	41.7	5	0.2	834	**166.8**
Ca	154.8	200	0.005	77.4	**0.38**
Mg	35.3	200	0.005	17.65	**0.09**
Na	136.7	250	0.004	54.68	**0.22**
K	4.98	10	0.1	49.8	**4.98**
Cl	334.7	250	0.004	133.88	**0.53**
NO_3	6.89	10	0.1	68.9	**6.89**
SO_4	299.4	200	0.005	149.7	**0.74**
PO_4	0.045	5.5	0.181	0.82	**0.14**
WQI=∑Wiqi/∑Wi= 264.29			**∑Wi = 0.738**		**∑Wiqi= 195.05**

Fig.1 Mapping of study area with the location of sampling points

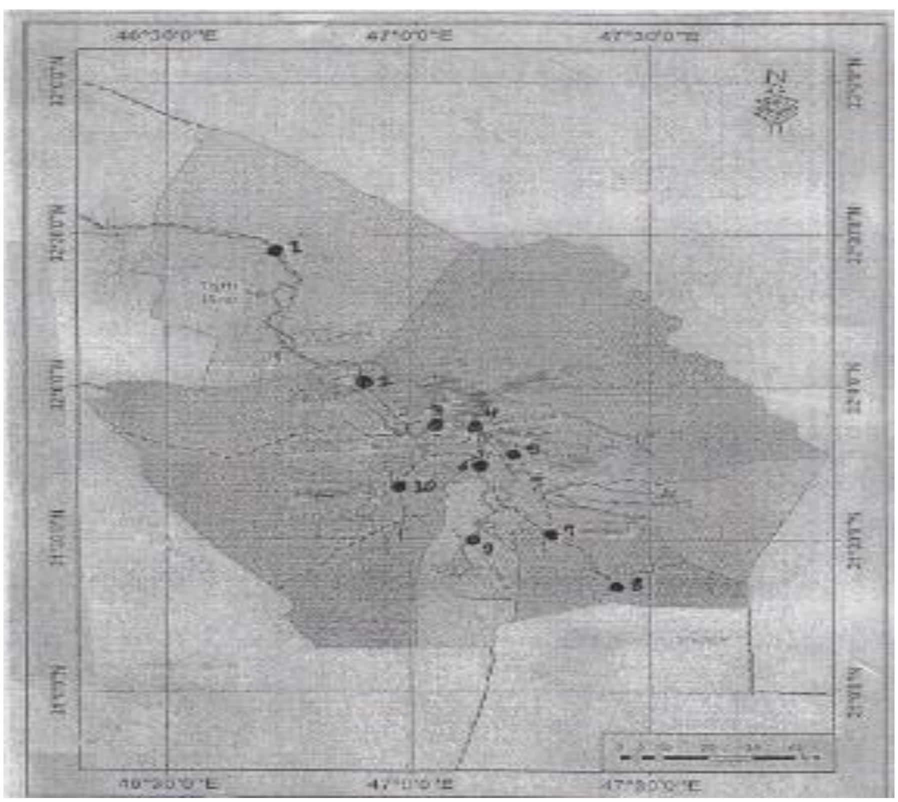

Table.6 Calculation of sub – indices and WQI for the water samples (winter season)

No. of site	pH qiwi	EC qiwi	TDS qiwi	TH qiwi	TA qiwi	Turb. qiwi	Ca qiwi	Mg qiwi	Na qiwi	K qiwi	Cl qiwi	NO3 qiwi	SO4 qiwi	PO4 qiwi	∑qiwi	WQI
1	10.392	0.2442	0.542	1.787	1.687	26.0	0.418	0.093	0.233	4.25	0.668	6.86	1.062	0.273	54.509	**73.860**
2	10.255	0.2331	0.598	1.616	1.687	25.6	0.402	0.098	0.226	4.35	0.624	5.27	1.037	0.293	52.239	**70.784**
3	10.735	0.2329	0.532	1.591	1.755	34.0	0.375	0.115	0.214	3.94	0.640	5.35	1.060	0.605	61.145	**82.852**
4	10.599	0.2385	0.519	1.560	1.612	22.0	0.387	0.108	0.237	3.80	0.582	5.25	0.928	0.579	48.399	**65.581**
5	10.324	0.2205	0.518	1.587	1.500	34.0	0.383	0.111	0.208	3.65	0.630	5.39	1.047	0.345	59.913	**81.183**
6	10.186	0.2427	0.556	1.562	1.665	82.0	0.368	0.120	0.222	3.55	0.688	5.10	1.093	0.332	107.684	**145.913**
7	10.117	0.2285	0.534	1.615	1.612	36.0	0.375	0.106	0.206	3.40	0.678	6.20	1.062	0.220	62.353	**84.489**
8	10.530	0.2394	0.559	1.562	1.744	38.0	0.394	0.097	0.220	4.10	0.617	5.27	1.040	0.299	64.671	**87.630**
9	10.461	0.2431	0.538	1.650	1.744	36.0	0.410	0.098	0.231	4.40	0.644	5.52	0.987	0.368	63.294	**85.764**
10	**10.048**	**0.2300**	**0.546**	**1.641**	**1.537**	**92.0**	**0.366**	**0.118**	**0.207**	**3.40**	**0.664**	**6.14**	**1.102**	**0.421**	**118.420**	**160.461**

Table.7 Calculation of sub – indices and WQI for the water samples (summer season)

No. of site	pH qiwi	EC qiwi	TDS qiwi	TH qiwi	TA qiwi	Turb. qiwi	Ca qiwi	Mg qiwi	Na qiwi	K qiwi	Cl qiwi	NO3 qiwi	SO4 qiwi	PO4 qiwi	∑qiwi	WQI
1	10.736	0.2027	0.426	1.575	1.350	272.0	0.382	0.082	0.216	5.2	0.528	8.30	0.750	0.092	301.839	**408.996**
2	10.323	0.2003	0.511	1.550	1.425	300.0	0.400	0.095	0.232	5.3	0.508	8.10	0.745	0.112	329.501	**446.478**
3	10.598	0.2060	0.525	1.525	1.500	152.0	0.405	0.082	0.236	5.8	0.480	6.28	0.645	0.148	180.430	**244.485**
4	10.736	0.2055	0.509	1.587	1.500	180.0	0.372	0.070	0.208	4.8	0.480	6.81	0.695	0.167	208.139	**282.031**
5	11.149	0.2142	0.514	1.545	1.387	164.0	0.405	0.095	0.228	5.0	0.609	7.50	0.862	0.121	193.629	**262.369**
6	11.011	0.2048	0.532	1.525	1.500	100.0	0.412	0.100	0.227	4.6	0.540	6.50	0.800	0.158	128.109	**173.589**
7	10.461	0.2044	0.510	1.600	1.500	120.0	0.362	0.075	0.204	4.7	0.563	5.85	0.712	0.200	146.941	**199.107**
8	10.048	0.2047	0.524	1.500	1.500	112.0	0.375	0.077	0.203	4.5	0.544	5.47	0.770	0.240	137.955	**186.930**
9	9.910	0.2072	0.546	1.500	1.425	108.0	0.367	0.112	0.208	4.7	0.556	6.80	0.775	0.148	135.254	**183.271**
10	**10.874**	**0.2033**	**0.505**	**1.542**	**1.500**	**160.0**	**0.387**	**0.092**	**0.222**	**5.2**	**0.544**	**7.30**	**0.737**	**0.092**	**189.198**	**256.365**

Phosphate might be due to the leaching of agricultural wastes into the river or the use of phosphate additives in detergent formation which leached into water bodies through waste waters generated industrially, domestically or municipally (Olajire and Imeokparia, 2001).

Water quality index of the present water of Tigris river is established from important various physicochemical parameters in different seasons. The water quality index obtained for the river in different seasons of study period, winter and summer season (Table 4&5) were 93.78 and 264.29 in both season respectively, and its ranged for all sites between 65.581 to 160.461 and 173.589 to 446.478 (Table 6&7) for winter and summer season respectively, which indicate the poor quality of water and unsuitable for drinking (Chatterji and Raziuddin, 2002).

Water quality rating study clearly shows that the status of the water of Tigris river is unsuitable for the human uses and other purposes. Furthermore, the water samples were found to be more turbid especially during the summer season. This can be caused by reducing water body, more waste discharge, more urban domestic activities, algal growth and etc (Khwakaram *et al*., 2012). It is also showed that the pollution load is relatively high during summer season when compared to the winter season.

From Tables 6&7 water quality index of each site was ranged between 65.581 at site 4 to 160.461 at site 10 during winter season, while it is ranged between 173.589 at site 6 to 446.478 at site 2 during summer season. From all sampling sites had WQI greater than 100 except at site 4 (65.581) during winter season, this results can be considered as unsuitable for human consumption (Table 1), these waters must be treatment essential before using it for various purposes mainly drinking purposes (Das *et al*., 2012). The turbidity of the water samples is mainly responsible for the very high WQI values especially during summer season.

Average values of WQI indicate that water quality for drinking uses can be rated as poor and unsuitable in all study sites during two season, this may reflect the discharge of pollutants to the river from domestic sewers, storm water discharges, industrial wastes discharges, agricultural runoff and other sources (Alobaidy *et al*., 2010), all of which may be untreated, can have significant effects of both short term and long duration on the quality of a river system (Al-Janabi *et al*., 2012).

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