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RESEARCH ARTICLE

Using the Water Quality Index as a Powerful Tool to Assess the Water Quality for Drinking Purposes in Al-Salam, Western Region of Baghdad City, Iraq

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Abstract

Background: Tap waters play an important role in fulfilling the people needs for drinking and domestic purposes. Contaminate the tap water with different pollutants has become an issue of great concern for 90% of people who are depended on the tap water as the main source of drinking. Pollutants can make their way easily into the delivering pipes which suffer from the leaking resulting in decreasing the quality of water. Objective: Therefore, assess the water quality for drinking purpose by calculating the water quality index is an important tool to ascertain whether the water is suitable for human consumption or not. Methods: In the present work, the water quality of the Al-Salam, western region of Baghdad city, Iraq was investigated for 7 months (Jan-July 2017). 63 tap water and 7 water station samples were collected and analyzed using standard methods. The index proposed measuring nine parameters which are: TDSs, pH, TH, DO, phosphates, nitrates, temp, BOD_5, fecal coliform, turbidity and conductivity. The calculated values of parameters were normalized into the scale (0-100) and converted to the quality rating statements (Excellent, good, medium, bad and very bad). Results: The results show that WQI values of the tap water samples have ranged from 64- 83% while it ranged from 88-94 for the water station samples. Also, it can notice that none of the water samples is recorded WQI=100 during the entire period of the study. The proposed NFS index was able to determine the water quality and it presents an accurate, rapid and modern way to evaluate and monitor the water quality.

Keywords: *Water quality index, Drinking water, Pollution.*

Introduction

Generally, the fresh water is one of the important spheres and effective tool which can affect the human life and economic development [1, 2]. Also, it plays an essential role in the well-being and prosperity of all people [3, 4]. However, in many countries, including Iraq, drinking water pipelines which transport the water from the water stations to the consumers have become contaminated. Contamination of water from the diffuse sources with various types of pollutants has serious negative effects on the human health, economy, and environment [4]. Many factors such as anthropogenic [5-8], hydrological conditions, climate, precipitation inputs, weathering, and environment can influence on the water quality by changing the physical and chemical characteristic of the water [9, 10].The quality of drinking water which acceptable for human consumption is dependent on the composition of that water. Characterization the quality of water is determined by chemical, physical and microbiological parameters. Exceeding the values of these parameters above of acceptable limits will put the human health at serious risk [11, 12]. The current perception of many people is that any uncolored waters always indicate to the purity, clean and suitability of that water for the drink, which is totally wrong and unacceptable perception. Because people are ignoring the possibility of contaminating that waters with pollutants or the presence some

of the water compositions at high concentrations which may affect directly on the human health if they continue to drink that water [12]. Therefore, many of organizations such as Centers for Disease Control and world health have set a safe limit for each of chemical contaminants which presence in drinking water [11, 12].

Quality of water can be measured by calculating the water quality index which is the most effective method for determining the water quality. The method consists of a mathematical equation where all of the water parameters are included [13]. In 1965, Horton was the first person who developed the index which was used to measuring the water quality by using different water parameters.

Each parameter has two factors: it assigned weight and respective standard. These factors indicate the impact and significance of that parameter on the index. The general procedure for measuring the WQI is conducted by following three steps: first, selecting the parameters, second, calculating the parameters function for each one, finally, gathering data through the mathematical equation [14]. By applying the previous steps, a single number will be obtained, which is the quality index. This number represents the overall quality of water for a specific time and location under using some of the water parameters.

Therefore, the importance of the index can be illustrated in the following points: the index converts a complex data to the simple understandable term (e.g. excellent, good, medium, bad and very bad) [15, 16], makes comparing the water quality for the studied sites easy, denotes the suitability of water for drinking [17] and transmitting the information which concerns water quality to the people in simple, planners, policymakers and managers [18-20]. Several number of indices have been used for evaluation of water quality such as Weight Arithmetic Water Quality Index (WA-WQI) [17, 21], Canadian Council of the Environment Water Quality Index (CCM-WQI) [20, 22], and Oregon Water Quality Index (O-WQI) [23, 24].

These indices have applied by many international organizations and countries for determination of water quality in particular location. However, the most universal acceptable model of the index for determining the water quality is the National Sanitation Foundation Water Quality Index (NFS-WQI) [14,17, 25, 31].

This model proposed in 1974 by Brown and Forsythe [32] and compares the observations data with the standards or the background concentration of the specific site [33]. This point has given the index an advantage in applying in many countries with minor modification [16]. The sources of fresh water in Iraq come from the rivers (Tigris and the Euphrates), lakes and underground water.

The main source of water which is used for drinking purposes comes from the rivers. The quality of water at drinking water supply stations is good and suitable for human consumption. However, Iraq has problems in the national distribution networks.

The infrastructure of these networks is in the critical situations. This study presents the important of water quality index for assessment and monitoring the quality of water for various purposes. Also, in this paper, the National Sanitation Foundation Water Quality Index (NFS-WQI) was applied in all results.

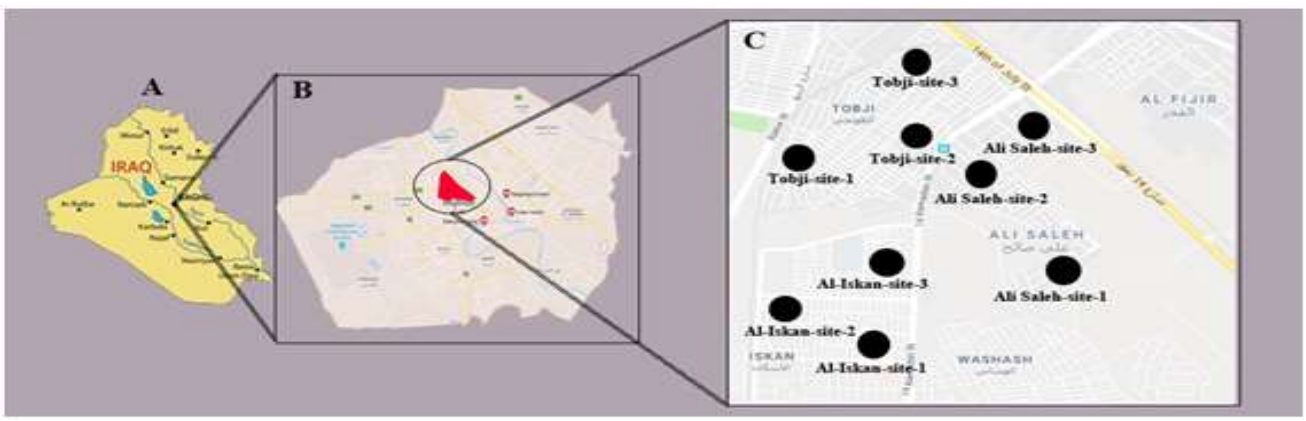

Figure 1: The map of studied area. A= Iraqi map, B= Baghdad city map and C= the studied sites. The circulated area in B shows the Al-Salam area in Baghdad city while the black points in C show the sampling points

Materials and Methods

Study Area and Sampling

The study area is Al-Salam neighborhood which located on the west of Al-Karkh in Baghdad city. The studied area has covered three locations at that neighborhood which are: Tobji, Al-Iskan, and Ali-Al Saleh, each location has three sampling sites as shown in Fig 1. 63 of tap water and 7 water station samples were collected from houses, three samples per month for each location for 7 months from January-July 2017. Glass bottles were used to collect the water samples which were then labeled based on their collection time and location. The bottles are treated with 2% nitric acid and rinsed five times with a distilled water prior collection of the samples.

Analytical Methods

All samples were monthly collected over 7 months, determined for the field parameters and then transported to the chemical laboratory for other parameters. The field parameters (pH, temperature in C°, total hardness (TH), total dissolved solids (TDS) and electrical conductivity (EC)) were measured using Hanna pH-EC meter (Model HI-9812). While the dissolved oxygen (DO) and the biochemical dissolved oxygen (BOD_5) measurements were conducted based on the standard method for examination of wastewater and water (APHA, Washington, 1998) [34]. The BOD_5 method depends on calculating the difference in concentrations between the initial and after 5 days after incubating the samples at 20 C°. The calibration process was made for all instruments according to their manuals prior to the measurements. All the parameters measurements were made in triplet and the mean was taken for further calculations. The laboratory analysis (Nitrates, and Total phosphorus) for all samples were carried out in triplicate. The total nitrate and total phosphorus measurements were made using the spectrophotometric method (UV-VIS spectrophotometer (Shimadzu).

The water samples were digested with hydrochloric acid, reacted with sodium nitroprusside and measured for the total nitrate analysis, while the digested samples were reacted with antimony potassium tartrate and measured for the total phosphorus [33]. The microbial tests, the fecal coliform (FC) was measured according to the method which mentioned by Garrity and Forbes respectively [35, 36]. The turbidity values were measured using a Turbidity type benchtop meter (HANNA, LP2000, and Italy).

Data Analysis

Calculation the Water Quality Index (WQI_{NFS})

National Sanitation Foundation Water Quality Index (NSF-WQI) was applied to calculate the water quality. The index is used to convert a large data of water into the single number which summarizes the quality of the parameters. The WQI_{NFS} depends on nine parameters which are: pH, Biochemical dissolved oxygen (BOD_5), temperature, total phosphorus, total nitrates, dissolved oxygen (DO), turbidity, total solids and fecal coliforms [32]. The weightings and normalizations of each parameter are different and depend on the water usages [37], as shown in Tables 1 and 2. The following equations were used to calculate the WQI_{NFS} which is:

$$WQI = \sum_{i=1}^{n} q_i^{wi} \quad (1)$$

$$\sum_{1=1}^{n} w_i = 1 \quad (2)$$

Where the WQI_{NFS} is the is a single number and ranges from 0 to 100 (Table 1), q_i is the quality rating of each parameter (i) which is obtained from the curve of quality, n is the number of parameters (n = 1,2,3,.....9), and w_i is the weighting factor of parameter i (Table 2).

Table 1: The description of WQINFS numbers

Numerical ranges	The interpretation of WQI
100-91	Excellent
90-71	Good
70-51	Medium
50-26	Bad
25-0	Very Bad

Table 2: The weights of each parameters based on WQI_{NFS} [32]

Parameter	WQI weight
Total Solids	0.08
Turbidity	0.08
Temperature in C°	0.10
Total Phosphates	0.10
Nitrates	0.10
BOD_5	0.10
pH	0.12
Fecal Coliform Density	0.15
Dissolved Oxygen	0.17

Table 3: The total hardness classification according to Sawyer and McCarty [38]

The concentration of Total hardness (TH) in (mg/L)	Category
> 300	Very hard water
150-300	Hard water
150	Soft water

The total hardness of water samples was measured and classified based on Sawyer and McCarty (1967) [38]. This classification gives valuable information about whether the water (soft water, hard water, and very hard water) (Table 3).

Results and Discussion

During the period of the study (7 months), the quality of water samples were explored by measuring all the recommended parameters by the National Sanitation Foundation (NSF) to calculate the water quality index. All the parameters were measured to the collection sites as shown in Fig 1. The results of microbiological, physicals and chemicals parameters which were obtained from the water samples tabulated in Tables 4 to 11.

The obtained results in the Tables 4, 5 and 6 show that all the studied sites have presented pH values ranged from (6.5-8.5) which are within the recommended limits according to Iraqi specifications number (26) [39] and international standard limits number (24)[40, 41] for a drinking water.

The BOD_5 levels of Al-iskan location have shown high values when compared with the recommended values (2 ppm) by Iraqi specifications number (26). The explanation of this behavior is that normally untreated sewage water has very high levels of BOD_5, therefore, mix the sewage water with the fresh water due to the leaks in the pipelines lead to an increase in the BOD_5 levels. While the remaining locations have recorded normal BOD_5 levels.

Table 4: The measurements of chemical, physical and microbiological parameters for sampling points

Sample Location	Parameter	The allowable limits*	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17
(Al-Iskan) Site-1-	TDSs (ppm)	**1000**	285	283	387	414	373	370	332
	Turbidity (NTU)	**5**	0	2	5	3	2	0	0
	Temp C°	**-**	20	20	21	22	22	22	23
	Total Phosphates (ppm)	**0.1**	0.56	0.61	0.66	0.49	0.71	0.65	0.75
	Nitrates (ppm)	**45**	4.1	3.5	5.6	5.21	6.79	7.35	4.12
	BOD_5 (ppm)	**2**	2.2	2.1	2.3	3.2	2.5	2.4	2.6
	pH	**6.5-8.5**	6.56	6.96	6.99	7.06	7.11	7.27	7.39
	Fecal Coliform (100ml)	**200**	210	222	205	195	225	230	247
	Dissolved Oxygen (%sat)	**100**	65	66	75	44	75	66	63
	Conductivity $\mu S.cm^{-1}$	**-**	41	40	41	42	41	40	42
	Total Hardness (ppm)	**150**	100	99	98	89	84	83	80

*** The allowable limits according to Iraqi [39] and International specifications [40, 41].**

Table 5: The measurements of chemical, physical and microbiological parameters for sampling points

Sample Location	Parameter	The allowable limits*	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17
(Al-Iskan) Site-1-	TDSs (ppm)	**1000**	279	280	287	295	250	270	312
	Turbidity (NTU)	**5**	0	0	3	3	1	0	0
	Temp C°	-	20	20	20	20	20	20	20
	Total Phosphates (ppm)	**0.1**	0.04	0.04	0.05	0.05	0.02	0.07	0.05
	Nitrates (ppm)	**45**	3.21	3.24	4.46	4.42	6.42	8.02	3.89
	BOD_5 (ppm)	**2**	1.1	2.2	2.1	3.41	1.42	1.22	1.31
	pH	**6.5-8.5**	6.52	7.06	7	7.02	7.1	7.47	7.35
	Fecal Coliform (100ml)	**200**	19	22	21	21	25	19	24
	Dissolved Oxygen (%sat)	**100**	75	56	55	56	65	69	70
	Conductivity $\mu S.cm^{-1}$	-	44	43	41	41	45	39	42
	Total Hardness (ppm)	**150**	111	105	98	99	87	84	84
*** The allowable limits according to Iraqi [39] and International specifications [40, 41].**									

Table 6: The measurements of chemical, physical and microbiological parameters for sampling points

Sample Location	Parameter	The allowable limits*	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17
(Al-Iskan) Site-3-	TDSs (ppm)	**1000**	282	271	266	389	422	289	267
	Turbidity (NTU)	**5**	0	3	3	3	3	0	0
	Temp C°	-	20	21	20	21	21	21	21
	Total Phosphates (ppm)	**0.1**	0.03	0.03	0.03	0.07	0.05	0.06	0.03
	Nitrates (ppm)	**45**	3.1	2.5	4.7	6.32	5.68	6.45	5.33
	BOD_5 (ppm)	**2**	1.9	2.1	1.8	2.2	1.5	2.4	1.9
	pH	**6.5-8.5**	7.06	6.86	6.79	7.01	6.99	7.02	7.4
	Fecal Coliform (100ml)	**200**	22	22	23	24	25	20	21
	Dissolved Oxygen (%sat)	**100**	55	56	68	78	66	68	78
	Conductivity $\mu S.cm^{-1}$	-	40	39	33	42	40	40	40
	Total Hardness (ppm)	**150**	115	114	102	93	85	86	85
*** The allowable limits according to Iraqi [39] and International specifications [40, 41].**									

Table 7: The measurements of chemical, physical and microbiological parameters for sampling points

Sample Location	Parameter	The allowable limits*	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17
(Al-Iskan) Site-3-	TDSs (ppm)	**1000**	263	265	255	298	311	312	299
	Turbidity (NTU)	**5**	0	1	1	0	0	0	0
	Temp C°	-	21	21	21	21	21	22	21
	Total Phosphates (ppm)	**0.1**	0.03	0.03	0.04	0.03	0.04	0.04	0.04
	Nitrates (ppm)	**45**	3.9	3.5	4.99	6.01	6.52	6.88	3.98
	BOD_5 (ppm)	**2**	1.1	1.9	2.1	1.9	2.1	1.3	1.4
	pH	**6.5-8.5**	6.5	6.55	6.65	6.95	6.85	7.01	7.11
	Fecal Coliform (100ml)	**200**	22	24	39	20	21	19	20
	Dissolved Oxygen (%sat)	**100**	55	67	69	52	76	56	59
	Conductivity $\mu S.cm^{-1}$	-	41	42	43	40	45	45	47
	Total Hardness (ppm)	**150**	100	101	91	90	89	87	89
*** The allowable limits according to Iraqi [39] and International specifications [40, 41].**									

Table 8: The measurements of chemical, physical and microbiological parameters for sampling points

Sample Location	Parameter	The allowable limits*	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17
(Tobji) Site-2-	TDSs (ppm)	**1000**	280	280	299	275	298	244	285
	Turbidity (NTU)	**5**	0	0	0	0	0	0	0
	Temp C°	-	20	20	20	20	20	20	20
	Total Phosphates (ppm)	**0.1**	0.04	0.05	0.04	0.06	0.08	0.07	0.04
	Nitrates (ppm)	**45**	3.31	4.24	3.44	3.52	3.33	3.38	4.39
	BOD_5 (ppm)	**2**	1.13	1.22	1.35	1.95	1.05	1.26	1.02
	pH	**6.5-8.5**	6.32	6.66	7.01	7.02	7.01	7.45	7.25
	Fecal Coliform (100ml)	**200**	19	20	20	20	20	21	25
	Dissolved Oxygen (%sat)	**100**	69	66	59	55	58	69	79
	Conductivity $\mu S.cm^{-1}$	-	44	45	32	41	42	49	37
	Total Hardness (ppm)	**150**	120	123	115	98	84	85	80
*** The allowable limits according to Iraqi [39] and International specifications [40, 41].**									

Table 9: The measurements of chemical, physical and microbiological parameters for sampling points

Sample Location	Parameter	The allowable limits*	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17
(Tobji) Site-3-	TDSs (ppm)	**1000**	272	271	286	375	399	345	245
	Turbidity (NTU)	**5**	0	0	0	0	0	0	0
	Temp C°	**-**	20	20	20	20	20	20	21
	Total Phosphates (ppm)	**0.1**	0.03	0.04	0.04	0.06	0.07	0.05	0.06
	Nitrates (ppm)	**45**	2.1	2.4	3.6	5.42	5.77	7.02	5.78
	BOD_5 (ppm)	**2**	1.2	2.11	1.85	1.91	2.1	2.2	2.2
	pH	**6.5-8.5**	7.01	7.01	7.02	7.05	7.08	7.02	7.09
	Fecal Coliform (100ml)	**200**	22	22	23	22	22	22	22
	Dissolved Oxygen (%sat)	**100**	76	55	67	74	65	66	69
	Conductivity µS.cm^{-1}	**-**	41	40	39	42	46	41	41
	Total Hardness (ppm)	**150**	135	112	95	80	85	84	86
*** The allowable limits according to Iraqi [39] and International specifications [40, 41].**									

Table 10: The measurements of chemical, physical and microbiological parameters for sampling points

Sample Location	Parameter	The allowable limits*	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17
(Ali-Al Saleh) Site-1-	TDSs (ppm)	**1000**	310	311	309	418	363	374	299
	Turbidity (NTU)	**5**	1	1	0	0	0	0	0
	Temp C°	**-**	21	21	21	21	21	21	21
	Total Phosphates (ppm)	**0.1**	0.04	0.03	0.03	0.04	0.05	0.04	0.04
	Nitrates (ppm)	**45**	3.8	3.8	4.7	4.6	5.9	5.8	3.2
	BOD_5 (ppm)	**2**	1.2	1.3	2	2.4	1.9	1.5	1.6
	pH	**6.5-8.5**	6.78	6.95	6.85	6.8	6.98	7.02	7.03
	Fecal Coliform (100ml)	**200**	25	31	32	30	34	11	22
	Dissolved Oxygen (%sat)	**100**	69	69	70	74	66	65	55
	Conductivity µS.cm^{-1}	**-**	41	59	55	52	41	40	39
	Total Hardness (ppm)	**150**	105	101	100	98	89	85	87
*** The allowable limits according to Iraqi [39] and International specifications [40, 41].**									

Table 11: The measurements of chemical, physical and microbiological parameters for sampling points

Sample Location	Parameter	The allowable limits*	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17
(Ali-Al Saleh) Site-2-	TDSs (ppm)	**1000**	300	309	305	325	363	388	300
	Turbidity (NTU)	**5**	0	1	1	0	0	0	0
	Temp C°	**-**	21	21	21	21	21	21	21
	Total Phosphates (ppm)	**0.1**	0.04	0.04	0.04	0.04	0.05	0.05	0.04
	Nitrates (ppm)	**45**	3.7	3.7	3.9	4.51	5.65	5.44	4.21
	BOD_5 (ppm)	**2**	1.2	1.1	2	2.01	2.05	2.09	2.08
	pH	**6.5-8.5**	7.02	7.02	7.04	7.21	7.31	7.41	7.09
	Fecal Coliform (100ml)	**200**	26	25	26	32	33	13	21
	Dissolved Oxygen (%sat)	**100**	65	69	72	73	65	65	70
	Conductivity µS.cm^{-1}	**-**	40	40	55	53	49	42	39
	Total Hardness (ppm)	**150**	103	100	100	99	86	91	85
*** The allowable limits according to Iraqi [39] and International specifications [40, 41].**									

Table 11: The measurements of chemical, physical and microbiological parameters for sampling points

Sample Location	Parameter	The allowable limits*	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17
(Ali-Al Saleh) Site-3-	TDSs (ppm)	**1000**	302	301	304	326	377	379	298
	Turbidity (NTU)	**5**	1	1	1	1	0	0	0
	Temp C°	**-**	21	21	21	21	21	21	21
	Total Phosphates (ppm)	**0.1**	0.03	0.03	0.03	0.03	0.03	0.04	0.04
	Nitrates (ppm)	**45**	2.9	3.1	3.6	4.32	4.98	5.44	3.95
	BOD_5 (ppm)	**2**	1.1	1.1	1.2	1.9	1.95	1.93	1.96
	pH	**6.5-8.5**	6.92	6.96	6.97	6.59	6.69	6.91	7.01
	Fecal Coliform (100ml)	**200**	23	23	26	31	32	32	32
	Dissolved Oxygen (%sat)	**100**	69	69	74	75	71	72	60
	Conductivity µS.cm^{-1}	**-**	40	49	56	57	49	43	40
	Total Hardness (ppm)	**150**	120	105	103	99	95	95	110
*** The allowable limits according to Iraqi [39] and International specifications [40, 41].**									

The drinking water temperature values of the studied locations have ranged from 20-23 °C with 21.5 °C as an average which generally refers to cold to warm waters and prefers for the consumers also, the high temperature has a negative impact on the water quality since, the high temperature enhances the growth of microorganisms which may affect directly on the odor, taste, and color of water. Electrical conductivity values of the drinking water samples are shown in Tables 4, 5 and 6. Measuring the amount of the total dissolved ionic components in the water gives the value of electrical conductivity of that water.

The recorded values have ranged from 33-59 µS cm^{-1} which are within the recommended values by Iraqi specifications. From the total dissolved solids values (TDS) in the Tables 4, 5 and 6, all the studied sites have reported TDS values very far below the recommended Iraqi values of 1000 mg L^{-1}. The water that contains TDS values less than 1000 mg L^{-1} can consider as a freshwater and suitable for drinking purpose. The turbidity values in the drinking water of all studied sites have ranged from 0-5 NTU which are within the range of recommended Iraqi values where the highest turbidity value presented at Al-iskan location which recorded turbidity value up to 5 NTU. However, the international organizations like world health and European standards established that the turbidity of drinking water must not be higher than 5 NTU and ideally if it was less than 1 NTU. In the drinking water, high turbidity values lead to developing gastrointestinal diseases [42] because of contaminants such as bacteria and viruses can easily be attached to the suspended solids in water, therefore, decreasing the turbidity levels in the drinking water less than 1 NTU will make it ideal for drinking purpose.

The primary indicator of suitability and pot ability of drinking water for human consumption is the total fecal coliform test. This test calculates the concentration of total coliform bacteria which are associated with other diseases that cause by organisms [43]. However, contaminate the water with faecal may not always refer to the presence of coliform organisms. Therefore, the water that contains coliforms may suggest to the presence of pathogenic enteric microorganisms like *Shigella spp*, *Vibrio cholera* and *Salmonella spp*.

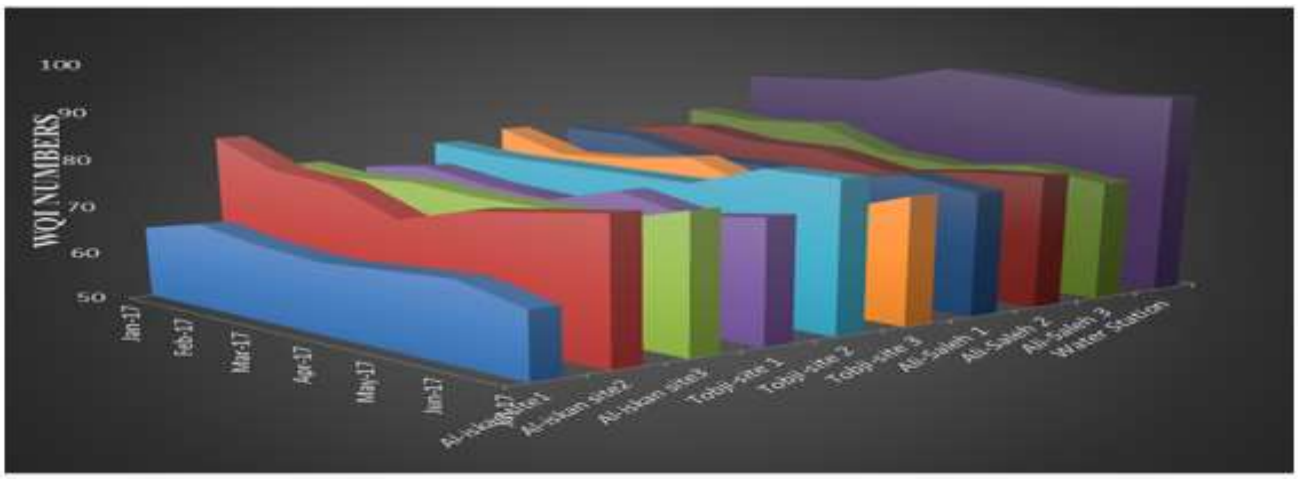

Figure 2: The calculated indexes of the all sites and water station

The all studied sites have recorded numbers of fecal coliforms less than 200/100ml which are within the recommended limits except the Al-iskan location (site 1), this site recorded fecal coliform numbers (205-247) higher than the recommended limits (200/100 ml) and the remaining sites. Usually, a higher number of the fecal coliform number in water comes from sanitary effluent which is lead to the following perception there is a leak in the water pipelines at site 1. This leak leads to mixing the fresh water which comes from the water station with the sewage water and causing in increasing the numbers of fecal coliform in the water. The values of total nitrogen for all studied sites ranged from (2.1-7.35 ppm) and were of below recommended permissible limits (45 ppm). There are no significant differences between the studied sites. Usually, nitrate considers as an indicator of the seasonal variation which is come from the human waste or animals. In the present study, the phosphorus levels in all studied sites were to

be below the permissible levels based on Iraqi specification number (26) (0.1 ppm) except Al-iskan location site (1). This site reported very high phosphorus levels which it ranged from (0.49 - 0.75 ppm). This site has recorded significant differences in the phosphorus levels within the period of study. Based on the literature [44], increasing the concentration of phosphate content in the water usually due to present of sewage contamination.

Therefore, it can explain that the high level of phosphorus in water means to higher levels of sewage contamination. The volume of oxygen that dissolves in water is called the dissolved oxygen. Generally, the source of oxygen in the water comes from transferring the oxygen from the air to the water by turbulence, waves and currents. Also, the following factors the lower temperature, fast-moving water and lower salinity lead to increase the level of dissolved oxygen [45]. The results showed that the dissolved oxygen concentrations in all sampling sites were below the permissible limits. However, the highest dissolved oxygen concentrations were observed in January, February and March, and that probably because of the low water temperature during these months. During the period of the study, the total hardness values ranged from 135 ppm in the winter to the 80 ppm in summers which are within the permissible limits (150 ppm).

There are no significant differences among all studied sites regards to the total hardness. Based on Sawyer and McCarty classification [38], all the sites have recorded a freshwater as shown in Table 7.

Table 7: The results of total hardness for all sampling points

The concentration of Total hardness (TH) in (mg/L)	Category
> 300	0%
150-300	0%
150	100 %

Table 8: The calculated quality rating and different indexes of the sampling points

	Parameter	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17
(Al-Iskan) Site-1-	TDSs (ppm)	61	62	48	45	50	50	55
	Turbidity (ppm)	99	93	86	90	93	99	99
	Temp C°	99	99	99	99	99	99	99
	Total Phosphates	57	55	52	61	50	53	48
	Nitrates (ppm)	70	80	62	64	58	57	69
	BOD_5 (ppm)	76	78	74	66	70	71	69
	pH	74	87	88	89	90	92	93
	F. Coliform	37	36	37	38	36	36	35
	D.O. (%sat)	66	68	81	36	81	68	62
	WQI_{NFS} number	65	68	66	65	66	67	64
Sample Location	**Parameter**	**Jan-17**	**Feb-17**	**Mar-17**	**Apr-17**	**May-17**	**Jun-17**	**Jul-17**
(Al-Iskan) Site-2-	TDSs (ppm)	64	64	65	64	58	58	60
	Turbidity (ppm)	99	99	90	90	96	99	99
	Temp C°	99	99	99	99	99	99	99
	Total Phosphates	98	98	98	99	99	97	98
	Nitrates (ppm)	86	85	68	68	59	55	72
	BOD_5 (ppm)	94	76	78	72	91	93	92
	pH	72	89	88	89	90	93	93
	F. Coliform	64	62	63	66	61	64	61
	D.O. (%sat)	81	52	51	51	66	73	75
	WQI_{NFS} number	83	78	77	72	76	78	80
Sample Location	**Parameter**	**Jan-17**	**Feb-17**	**Mar-17**	**Apr-17**	**May-17**	**Jun-17**	**Jul-17**
(Al-Iskan) Site-3-	TDSs (ppm)	62	63	64	48	44	61	64
	Turbidity (ppm)	99	90	90	90	90	99	99
	Temp C°	99	99	99	99	99	99	99
	Total Phosphates	99	99	99	97	98	98	99
	Nitrates (ppm)	88	93	67	54	62	59	63
	BOD_5 (ppm)	82	78	84	76	90	72	82
	pH	89	85	83	88	88	88	93
	F. Coliform	62	62	62	61	61	63	63
	D.O. (%sat)	51	52	72	85	68	72	85
	WQI_{NFS} number	76	75	76	75	75	75	79

Table 9: The calculated quality rating and different indexes of the sampling points

Sample Location	Parameter	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17
(Tobji) Site-1-	TDSs (ppm)	64	64	65	60	58	58	60
	Turbidity (ppm)	99	96	96	99	99	99	99
	Temp C°	99	99	99	99	99	99	99
	Total Phosphates	99	99	98	99	98	98	98
	Nitrates (ppm)	72	80	65	60	59	58	70
	BOD_5 (ppm)	94	82	78	82	78	92	91
	pH	72	73	77	87	84	88	90
	F. Coliform	62	61	55	63	63	64	63
	D.O. (%sat)	51	70	73	46	82	52	56
	WQI_{NFS} number	74	76	74	73	77	74	76
Sample Location	Parameter	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17
(Tobji) Site-2-	TDSs (ppm)	62	62	60	63	60	67	61
	Turbidity (ppm)	99	99	99	99	99	99	99
	Temp C°	99	99	99	99	99	99	99
	Total Phosphates	98	98	98	98	97	97	98
	Nitrates (ppm)	84	69	81	80	83	82	68
	BOD_5 (ppm)	94	93	93	82	95	93	95
	pH	65	78	88	88	88	93	92
	F. Coliform	64	63	63	63	63	63	61
	D.O. (%sat)	73	68	56	51	55	73	86
	WQI_{NFS} number	78	77	77	77	77	82	82
Sample Location	Parameter	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17
(Tobji) Site-3-	TDSs (ppm)	63	63	61	63	47	54	67
	Turbidity (ppm)	99	99	99	99	99	99	99
	Temp C°	99	99	99	99	99	99	99
	Total Phosphates	99	98	98	98	97	98	98
	Nitrates (ppm)	95	93	78	63	61	58	61
	BOD_5 (ppm)	93	78	83	82	78	76	76
	pH	88	88	88	89	90	88	90
	F. Coli form	62	62	62	62	62	62	62
	D.O. (%sat)	82	51	70	80	66	68	73
	WQI_{NFS} number	80	76	77	79	74	72	77

Table 10: The calculated quality rating and different indexes of the sampling points

Sample Location	Parameter	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17
(Ali-Al Saleh) Site-1-	TDSs (ppm)	64	64	65	60	58	58	60
	Turbidity (ppm)	96	96	99	99	99	99	99
	Temp C°	99	99	99	99	99	99	99
	Total Phosphates	98	99	99	98	98	98	98
	Nitrates (ppm)	74	74	67	67	61	61	86
	BOD_5 (ppm)	93	92	80	72	82	90	88
	pH	82	87	84	83	88	88	88
	F. Coliform	61	58	58	58	57	70	62
	D.O. (%sat)	73	73	75	80	68	66	51
	WQI_{NFS} number	79	79	76	76	75	78	76
Sample Location	Parameter	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17
(Ali-Al Saleh) Site-2-	TDSs (ppm)	62	62	60	63	60	67	61
	Turbidity (ppm)	99	96	96	99	99	99	99
	Temp C°	99	99	99	99	99	99	99
	Total Phosphates	98	98	98	98	98	98	98
	Nitrates (ppm)	76	76	72	67	62	63	69
	BOD_5 (ppm)	93	94	80	80	80	78	78
	pH	88	88	88	92	93	93	90
	F. Coliform	60	61	60	58	57	68	63
	D.O. (%sat)	66	73	78	79	66	66	75
	WQI_{NFS} number	78	80	78	78	75	77	78
Sample Location	Parameter	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17
(Ali-Al Saleh) Site-3-	TDSs (ppm)	63	63	61	50	47	54	67
	Turbidity (ppm)	96	96	96	96	99	99	99
	Temp C°	99	99	99	99	99	99	99
	Total Phosphates	99	99	99	99	99	98	98
	Nitrates (ppm)	91	88	78	68	65	63	71
	BOD_5 (ppm)	94	94	93	82	82	82	82
	pH	86	87	87	74	79	86	88
	F. Coliform	62	62	60	58	58	58	58
	D.O. (%sat)	73	73	80	81	76	78	57
	WQI_{NFS} number	81	80	81	76	75	77	75

Water Quality Index

It is a difficult task to evaluate the water quality, especially when different parameters for various uses are applied. In addition, the water quality has various definitions and depends on the water contents and parameters that are measured. Therefore, combining more than one parameter and converting into a single number will provide an easy explanation of water quality. As mentioned above, WQI_{NFS} has employed nine parameters to evaluate the water quality at sampling points and can be used to keep tracking the quality over time.

In this paper, the comparison of water quality was made among all the studied locations and also, between the studied locations and water station that responsible for the treatment of the water. In this study, from the WQI_{NFS} numbers, the Al-iskan location (site 1) reported the worst water quality in comparison with the other two locations Tobji and Ali al Saleh which recorded good quality and WQI_{NFS} numbers ranged from (72-83) during 7 months. This site (Al-iskan, site 1) has recorded WQI_{NFS} numbers ranged from (64-68) which is a medium quality, unsuitable for drinking and needs to be pretreatment before using it as shown in Table 8. The WQI_{NFS} numbers of water station have reported well to excellent quality during the study time and WQI numbers ranged from (88-94) as shown in Fig. 2. These qualities can lead to the following perception: a part of the quality of water may lose during transporting throughout the pipelines which link the water station with the houses. And this is usually happened due to the leaks in the pipelines. Therefore, monitoring the water quality by measuring the water quality index is very important to let people know when the maintenance of pipelines is necessarily required.

Conclusion

The NFS index proposed in this paper, using nine parameters was able to determine the water quality of Al-Salam area. This index presents an accurate, rapid and modern way to evaluate the water quality. The indexes numbers showed there is a critical situation in Al-iskan location site 1 and needs to fast response from the competent authorities to solve the problem. The WQI_{NFS} is an important tool and can be employed in monitoring the water quality and decrease the high cost when using other techniques.

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