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Assessments of Water Quality index (WQI) For Tigris River in Mosul City/North of Iraq

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Abstract: The study of surface water of Tigris river reach in Mosul city is of particular importance due to the discharge of several effluents from municipal sewage, industries, hospitals, agricultural and urban run-off into the reach which contribute in the pollution of river water. The aim of this study was to analyze some physicochemical water quality parameters such as (pH, Dissolved oxygen, Temperature, Turbidity, Total dissolved solid, Nitrate, Phosphate, BOD_5) as well as E.coli bacteria for (17) sites of Tigris river reach in Mosul city, between Rasheedia in the north of the city and Qiara in the south of the city and present the complex water quality data of the river in a form that can easily be understood by the technical and non-technical personnel. To achieve this aim, the National Sanitation Foundation Water Quality Index (NSF WQI) has been applied on the analytical results of the parameters to obtain a single value that was used to rank the river at each of the sampling station. This index was computed for a period of three months between (Dec. 2013- March 2014) and it specifies the appropriate usage category, but it can also reveal the changes occurred at the level of the aquatic ecosystem. The novelty brought to the flowing water quality management consists in the underlining of the value of this index as potential indicator of the ecological state of the rivers. The results of the Water Quality Index showed that river water for all of the stations investigated can be ranked as medium. For public water supply system, this water requires necessary treatment.

Introduction

Rivers are indispensible freshwater systems that are necessary for the continuation of life. They are resources of great importance across the globe. The benefits of these systems to all living organism cannot be over emphasized as they remain one of the most essential human needs (Mousazadeh, 2013).

The quality of anybody of surface water is a function of either or both natural influences and human activities (Manahan, 2005). Ajibade (2004) enumerated a list of man's daily activities that require water application and that those roles played by river probably provide a basis for the adverse effect of its deficiency in either quality or quantity. Of all the human activities, industrial waste is the most common source of water pollution in recent times. The quantum of these pollutants is such that rivers receiving these effluents cannot give dilution needed for their continued existence as good quality water sources (Mousazadeh, 2013) .

The situation has aroused global concern over the public health impacts attributed to the deterioration of rivers as a result of pollution.

Research has shown that eighty percent of all the diseases which claim lives in the third world countries are directly related to poor drinking water quality. More than six million children die yearly (about 20,000 children per day) as a result of waterborne diseases linked to shortage of safe drinking water or sanitation (WHO, 2006).

The deterioration of water in the physical and chemical properties is often slow and not readily noticeable as the water system adapt to the changes until an apparent alteration of the water occurs. It becomes imperative to monitor the quality of the river in order to prevent it from further deterioration and ensure availability of quality water for domestic and agricultural purposes (Zahraa et al., 2012)

Tigris river is of strategic importance to the people of Mosul city and surroundings. The river is dammed just outside the city for water supply to the community and it is also used for irrigation along its course (Al-Sanjri, 2001). The objective of the study was to assess the variation of some physicochemical properties of Tigris river and evaluate its water quality status using water quality index (WQI). The concept of water quality index (WQI) was first proposed by Horton (1965). A water quality index (WQI) is defined as a rating reflecting the composite influence of different water quality parameters on the overall quality of water (Harkins, 1974). The current method of determining water quality index which is in practice utilizes the national sanitation foundation (NSF) which is one of the most effective ways to communicate information on environmental trends and river water quality (Abbasi & Abbasi, 2012).

Material and Methods:

Study area

This study was conducted on Tigris river reach passing through Mosul city and across recent sediments, Fig. (1). The climate of Mosul city is dry and hot in summer and cold in winter while, it looks moderate in both spring and autumn seasons and cloudy and rainy during rainy season. Tigris river is a major river of economic, agricultural, and environmental significance in the city as it supplies the bulk of water used by the people of Mosul and its environs for different activities depending on its point of contact (Al-Hamdani, 2007).

Tigris river supplies the entire city with water for different applications and purposes. Untreated wastewater such as municipal sewage, industries and hospitals is discharged in it (plate 1 and 2) and these wastewater discharges will certainly affect the places located downward Mosul city. One of the most harmful wastewater sources drained into the river from the left bank side, is Al-Khosar tributary see plates (3,4,and 5). This tributary runs through a big part of the city which allows it to gather a huge quantity of civilian wastewater as well as whatever small industries waste along the way. This pollution source and the one that preceded it, which runs through the old part of the city, are considered the most damaging pollution sources to the river in Mosul city (Al-Sanjri, 2001)

Sampling Procedure and Sample Analysis

Surface water samples were collected from (17) monitoring stations along Tigris river reach in Mosul city between the period (Dec. 2013- March 2014) . The samples were all collected with the help of the river safety police by cruising the river across the sample stations . The choice of the locations is to reflect virtually all the activities done on the river. Plastic bottles cleaned as recommended by Hanson (1973) were used for the collection of the samples. The water samples were then analyzed for the following physical and chemical properties: The pH, Total dissolved solid, temperature and turbidity were measured with their respective meters.
Dissolved oxygen, BOD_5, Nitrate, Phosphate and E.coli bacteria were determined using standard methods recommended by the American Public Health Association, APHA (1998) as shown in table (1).

Table (1) Physicochemical parameters of all sites of Tigris river reach in Mosul city.

parameter→ location ↓	pH	TDS	DO %	BOD_5	NO_3	PO_4	E. Coli	Temp.	Turbidity
Site 1	7.8	283	48.42	1	0.044	0.35	245	12.1	10.3
Site 2	7.8	305	46.85	2.1	0.066	0.36	240	12.2	5.5
Site 3	7.8	299	51.45	1.5	0.073	0.37	300	12.3	4.4
Site 4	7.8	309	48.9	2.6	0.071	0.37	325	11.7	4.7
Site 5	7.9	290	48.44	2.4	0.07	0.36	280	11.3	6.7
Site 6	8	316	51.21	1.4	0.069	0.36	420	12.1	6
Site 7	7.8	323	51.78	1.6	0.093	0.35	380	11.8	3.6
Site 8	7.8	318	49.24	1.7	0.072	0.38	281	11.2	7.3
Site 9	7.9	321	46.34	2	0.09	0.37	600	11.9	6.7
Site 10	7.9	325	54.5	1.4	0.056	0.44	500	12.5	6.4
Site 11	7.7	373	47.97	4	0.082	0.35	797	11.7	9.1
Site 12	7.6	308	52.34	2.2	0.076	0.38	290	11.5	11.3
Site 13	7.8	375	47.97	2.9	0.09	0.4	320	11.7	12.4
Site 14	7.8	331	66.53	1.2	0.063	0.35	180	13	6.5
Site 15	7.3	329	70.48	5	0.087	0.38	190	17	4.1
Site 16	8.5	356	67.63	3.3	0.132	0.37	220	13.1	5.2
Site 17	7.8	360	64.33	7.4	0.176	0.42	205	12.8	13.5

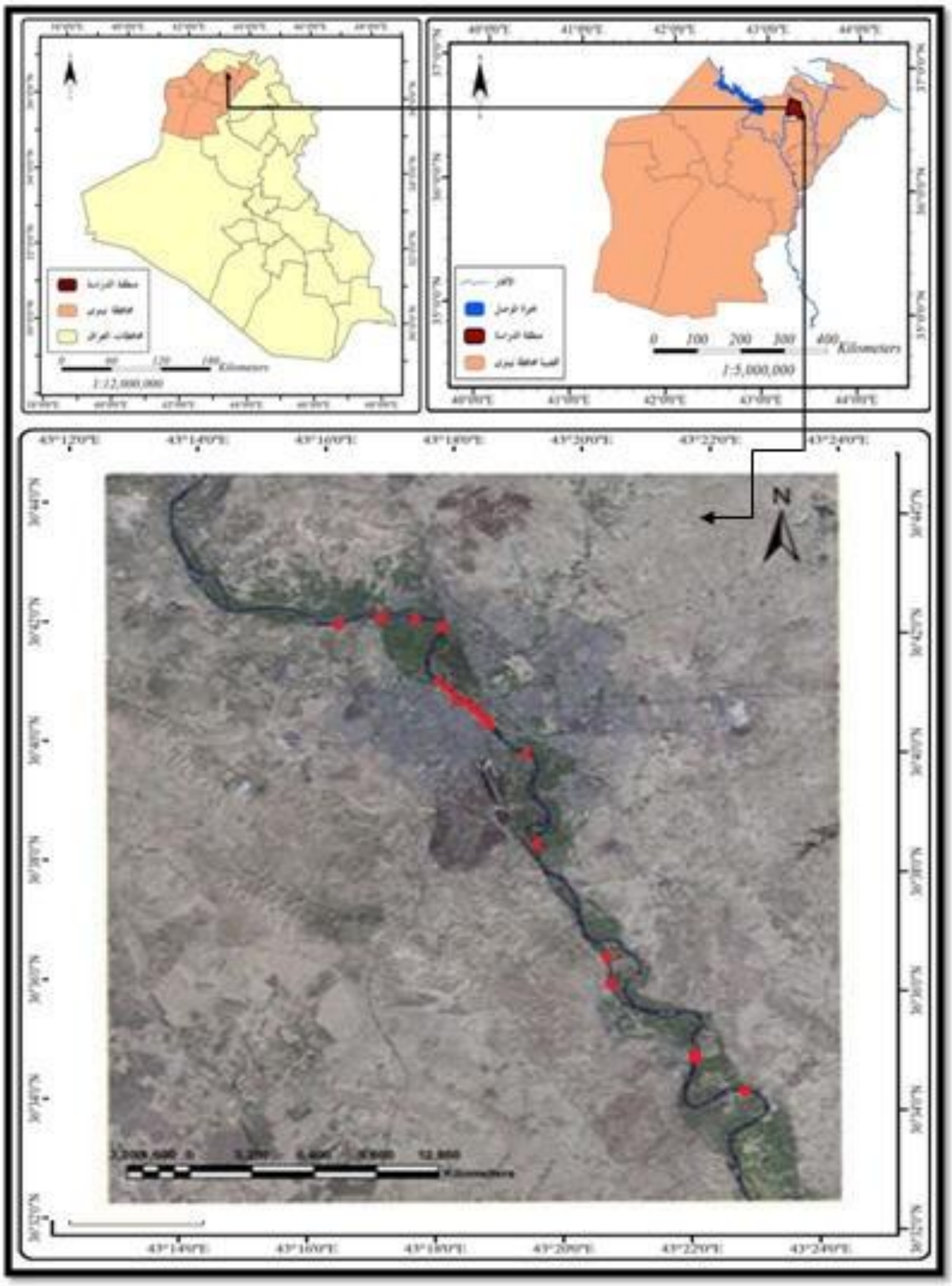

Fig.(1) Location of study area

Plate (1) Hospital Discharge

Plate (2) Municipal Sewage

Plate (3)

Plate (4)

Plate (5)

Plate (3,4,and 5) Al-Khoaser Tributary.

Water Quality Index Calculation

Water Quality Indices make use of a 'single value' for the expression of overall water quality of a particular source at a certain time on the basis of some water quality variables. The Indices aim at bridging the gap between technical personnel and general public by simplifying the complex way of presenting result so that it could be understood by all. Selection of some significant water quality parameters is paramount to having good representation of all and to providing a simple indicator of water quality. Though, a lot of water quality indices are being used for water assessment, some (if not all) seem to have a common similarity as they have their basis of comparing water quality parameters with their respective regulatory standards with interpretation of the results as good or bad (Venkatesharaju et al., 2010).

In general water quality indices incorporate data from multiple water quality parameters into a mathematical equation that rates the health of water body with a single number. That number is placed on a relative scale to justify the water quality in categories ranging from very bad to excellent. One of these indices is the NSF Water Quality Index, a standardized method for comparing the water quality of various water bodies, developed in 1970 by the National Sanitation Foundation (Brown R.M. et al., 1970) (Adewoye, 2013) . Nine water quality parameters were selected based on Delphi method to include in the index. These parameters are dissolved oxygen, fecal coliforms, pH, biochemical oxygen demand, temperature changes, total phosphates, nitrates, turbidity and total dissolved solids. Some parameters were judged more important than others, so a weighted mean was used to combine the values (Table 2).

Table (2) Water Quality Parameters and Their Weight.
(Source: http://www.water-research.net/watrqualindex.htm)

Parameter	Weight
Dissolved oxygen	0.17
Fecal coliform	0.16
pH	0.11
Biochemical Oxygen Demand	0.11
Temperature Change	0.10
Total Phosphate	0.10
Nitrate	0.10
Turbidity	0.08
Total Solids	0.07

In other words, NSFWQI summarizes large amounts of water quality data into simple terms for reporting to management and the public in a consistent manner.

$$WQI = \sum_{i=1}^{n} wiqi$$

Where:
WQI = aggregative Water Quality Index a number between 0 to 100
wi = the weight of i^{th} parameter, a number between 0 to 1
qi = the quality of i^{th} paramer, a number between 0 to 100
n = total number of parameters

The advantages of using such index is to assess the quality of surface waters are (Damo & Icka, 2013):
● its ability to represent measurements of many water quality parameters in a single number;
● its ability to combine numerous parameters with different measurement units;
● its effectiveness as a communication tool.

Table (3) classification of Water Quality Index (WQI)

Range	Quality
90-100	Excellent
70-90	Good
50-70	Medium
25-50	Bad
0-25	Very bad

Since 2000 there are two online calculators for calculating the index:
WQHYDRO (Aroner, 2002) and Monitoring the Quality of Surface waters, Brian Oram, according to Field Manual for Water Quality Monitoring (http://www.water-research.net/watrqualindex/index.htm).

The water quality Index (WQI) of the parameters analyzed shown in table (1) of the (17) sites along the Tigris river reach in Mosul city has been calculated in this study as shown in tables (4-20) and it is found to be ranged between (57.57- 68.43).

Table (4) Calculation of WQI for site (1) up of Al-Rasheedia

Parameters	Observed value	Unit weight W_n	Quality rating q_n	W_nq_n
D.O%	48.42	0.17	42	**7.14**
E.coli	245	0.16	35	**5.6**
BOD_5	1	0.11	95	**10.45**
pH	7.8	0.11	90	**9.9**
Temperature	12.1	0.10	36	**3.6**
Nitrate	0.044	0.10	90	**9**
Phosphate	0.35	0.10	76	**7.6**
Turbidity	10.3	0.08	75	**6**
TDS	283	0.07	62	**4.34**
				WQI= 63.63

Table (5) Calculation of WQI for site (2) Down of Al-Rasheedia

Parameter	Observed value	Unit weight W_n	Quality rating q_n	W_nq_n
D.O%	46.85	0.17	39	**6.63**
E.coli	240	0.16	36	**5.76**
BOD_5	2.1	0.11	78	**8.58**
pH	7.8	0.11	90	**9.9**
Temperature	12.2	0.10	36	**3.6**
Nitrate	0.066	0.10	90	**9**
Phosphate	0.36	0.10	75	**7.5**
Turbidity	5.5	0.08	85	**6.8**
TDS	305	0.07	59	**4.13**
				WQI= 61.9

Table (6) Calculation of WQI for site (3) Before factory

Parameter	Observed value	Unit weight W_n	Quality rating q_n	W_nq_n
D.O%	51.45	0.17	46	**7.82**
E.coli	300	0.16	34	**5.44**
BOD_5	1.5	0.11	90	**9.9**
pH	7.8	0.11	90	**9.9**
Temperature	12.3	0.10	36	**3.6**
Nitrate	0.073	0.10	90	**9**
Phosphate	0.37	0.10	74	**7.4**
Turbidity	4.4	0.08	87	**6.96**
TDS	299	0.07	60	**4.2**
				WQI= 64.22

Table (7) Calculation of WQI for site (4) After factory

Parameter	Observed value	Unit weight W_n	Quality rating q_n	W_nq_n
D.O%	48.9	0.17	42	**7.14**
E.coli	325	0.16	33	**5.28**
BOD_5	2.6	0.11	69	**7.59**
pH	7.8	0.11	90	**9.9**
Temperature	11.7	0.10	37	**3.7**
Nitrate	0.071	0.10	90	**9**
Phosphate	0.37	0.10	74	**7.4**

Parameter	Observed value	Unit weight W_n	Quality rating q_n	$W_n q_n$
Turbidity	4.7	0.08	87	**6.96**
TDS	309	0.07	58	**4.06**
				WQI= 61.03

Table (8) Calculation of WQI for site (5) Before Hospitals recycling station

Parameter	Observed value	Unit weight W_n	Quality rating q_n	$W_n q_n$
D.O%	48.44	0.17	42	**7.14**
E.coli	280	0.16	34	**5.44**
BOD_5	2.4	0.11	72	**7.92**
pH	7.9	0.11	87	**9.57**
Temperature	11.3	0.10	39	**3.9**
Nitrate	0.07	0.10	90	**9**
Phosphate	0.36	0.10	75	**7.5**
Turbidity	6.7	0.08	83	**6.64**
TDS	290	0.07	61	**4.27**
				WQI= 61.38

Table (9) Calculation of WQI for site (6) After Hospitals recycling station

Parameter	Observed value	Unit weight W_n	Quality rating q_n	$W_n q_n$
D.O%	51.21	0.17	45	**7.65**
E.coli	420	0.16	30	**4.8**
BOD_5	1.4	0.11	91	**10.01**
pH	8	0.11	84	**9.24**
Temperature	12.1	0.10	36	**3.6**
Nitrate	0.069	0.10	90	**9**
Phosphate	0.36	0.10	75	**7.5**
Turbidity	6	0.08	84	**6.72**
TDS	316	0.07	57	**3.99**
				WQI= 62.51

Table (10) Calculation of WQI for site (7) After Sulphur Spring

Parameter	Observed value	Unit weight W_n	Quality rating q_n	$W_n q_n$
D.O%	51.78	0.17	46	**7.82**
E.coli	380	0.16	31	**4.96**
BOD_5	1.6	0.11	88	**9.68**
pH	7.8	0.11	90	**9.9**
Temperature	11.8	0.10	37	**3.7**
Nitrate	0.093	0.10	90	**9**
Phosphate	0.35	0.10	76	**7.6**
Turbidity	3.6	0.08	89	**7.12**
TDS	323	0.07	57	**3.99**
				WQI= 63.77

Table (11) Calculation of WQI for site (8) Before Al-Meedan Discharge

Parameter	Observed value	Unit weight W_n	Quality rating q_n	W_nq_n
D.O%	49.24	0.17	43	**7.31**
E.coli	281	0.16	34	**5.44**
BOD_5	1.7	0.11	86	**9.46**
pH	7.8	0.11	90	**9.9**
Temperature	11.2	0.10	40	**4**
Nitrate	0.072	0.10	90	**9**
Phosphate	0.38	0.10	73	**7.3**
Turbidity	7.3	0.08	81	**6.48**
TDS	318	0.07	57	**3.99**
				WQI= 62.88

Table (12) Calculation of WQI for site (9) After Al-Meedan Discharge

Parameter	Observed value	Unit weight W_n	Quality rating q_n	W_nq_n
D.O%	46.34	0.17	39	**6.63**
E.coli	600	0.16	27	**4.32**
BOD_5	2	0.11	80	**8.8**
pH	7.9	0.11	87	**9.57**
Temperature	11.9	0.10	36	**3.6**
Nitrate	0.09	0.10	90	**9**
Phosphate	0.37	0.10	74	**7.4**
Turbidity	6.7	0.08	83	**6.64**
TDS	321	0.07	57	**3.99**
				WQI= 59.95

Table (13) Calculation of WQI for site (10) Before Al-Khoaser Discharge

Parameter	Observed value	Unit weight W_n	Quality rating q_n	W_nq_n
D.O%	54.5	0.17	50	**8.5**
E.coli	500	0.16	29	**4.64**
BOD_5	1.4	0.11	91	**10.01**
pH	7.9	0.11	87	**9.57**
Temperature	12.5	0.10	35	**3.5**
Nitrate	0.056	0.10	90	**9**
Phosphate	0.44	0.10	66	**6.6**
Turbidity	6.4	0.08	83	**6.64**
TDS	325	0.07	56	**3.92**
				WQI= 62.38

Table (14) Calculation of WQI for site (11) After Al-Khoaser Discharge

Parameter	Observed value	Unit weight W_n	Quality rating q_n	W_nq_n
D.O%	47.97	0.17	41	**6.97**
E.coli	797	0.16	24	**3.84**
BOD_5	4	0.11	61	**6.71**
pH	7.7	0.11	91	**10.01**
Temperature	11.7	0.10	37	**3.7**
Nitrate	0.082	0.10	90	**9**
Phosphate	0.35	0.10	76	**7.6**
Turbidity	9.1	0.08	78	**6.24**

TDS	373	0.07	50	**3.5**
				WQI= 57.57

Table (15) Calculation of WQI for site (12) down of Al-Josseq district

Parameter	Observed value	Unit weight W_n	Quality rating q_n	W_nq_n
D.O%	52.34	0.17	47	**7.99**
E.coli	290	0.16	34	**5.44**
BOD_5	2.2	0.11	76	**8.36**
pH	7.6	0.11	92	**10.12**
Temperature	11.5	0.10	38	**3.8**
Nitrate	0.076	0.10	90	**9**
Phosphate	0.38	0.10	76	**7.3**
Turbidity	11.3	0.08	73	**5.84**
TDS	308	0.07	58	**4.06**
				WQI= 61.91

Table (16) Calculation of WQI for site (13) of Al-Bosaif area

Parameter	Observed value	Unit weight W_n	Quality rating q_n	W_nq_n
D.O%	47.97	0.17	41	**6.97**
E.coli	320	0.16	33	**5.28**
BOD_5	2.9	0.11	68	**7.48**
pH	7.8	0.11	90	**9.9**
Temperature	11.7	0.10	37	**3.7**
Nitrate	0.09	0.10	90	**9**
Phosphate	0.4	0.10	71	**7.1**
Turbidity	12.4	0.08	71	**5.68**
TDS	375	0.07	50	**3.5**
				WQI= 58.61

Table (17) Calculation of WQI for site (14) Before Hammam Al-Aleel area

Parameter	Observed value	Unit weight W_n	Quality rating q_n	W_nq_n
D.O%	66.53	0.17	69	**11.73**
E.coli	180	0.16	38	**6.08**
BOD_5	1.2	0.11	93	**10.23**
pH	7.8	0.11	90	**9.9**
Temperature	13	0.10	34	**3.4**
Nitrate	0.063	0.10	90	**9**
Phosphate	0.35	0.10	76	**7.6**
Turbidity	6.5	0.08	83	**6.64**
TDS	331	0.07	55	**3.85**
				WQI= 68.43

Table (18) Calculation of WQI for site (15) After Hammam Al-Aleel area

Parameter	Observed value	Unit weight W_n	Quality rating q_n	W_nq_n
D.O%	70.48	0.17	76	**12.92**
E.coli	190	0.16	38	**6.08**
BOD_5	5	0.11	56	**6.16**
pH	7.3	0.11	93	**10.23**
Temperature	17	0.10	27	**2.7**
Nitrate	0.087	0.10	90	**9**
Phosphate	0.38	0.10	73	**7.3**
Turbidity	4.1	0.08	88	**7.04**
TDS	329	0.07	56	**3.92**
				WQI= 65.35

Table (19) Calculation of WQI for site (16) Before Al-Qiara Oil Refinery

Parameter	Observed value	Unit weight W_n	Quality rating q_n	W_nq_n
D.O%	67.63	0.17	71	**12.07**
E.coli	220	0.16	36	**5.76**
BOD_5	3.3	0.11	65	**7.15**
pH	8.5	0.11	66	**7.26**
Temperature	13.1	0.10	34	**3.4**
Nitrate	0.132	0.10	90	**9**
Phosphate	0.37	0.10	74	**7.4**
Turbidity	5.2	0.08	86	**6.88**
TDS	356	0.07	52	**3.64**
				WQI= 62.56

Table (20) Calculation of WQI for site (17) After Al-Qiara Oil Refinery

Parameter	Observed value	Unit weight W_n	Quality rating q_n	W_nq_n
D.O%	64.33	0.17	65	**11.05**
E.coli	205	0.16	37	**5.92**
BOD_5	7.4	0.11	44	**4.84**
pH	7.8	0.11	90	**9.9**
Temperature	12.8	0.10	35	**3.5**
Nitrate	0.176	0.10	90	**9**
Phosphate	0.42	0.10	69	**6.9**
Turbidity	13.5	0.08	69	**5.52**
TDS	360	0.07	52	**3.64**
				WQI= 60.27

RESULTS AND DISCUSSION

In the NSFWQI model, the water quality data for all the sampling stations are categorized as Medium, since all the data was between (57.57-68.43). It can be noted from the figure (1), that there is a slight deterioration in the river's water quality. But nonetheless, it gives a clear idea regarding the issue in the research. This deterioration began as soon as the river entered the heavy population area in the city. And it reached it's lower value after crossing Al-Khosar tributary, which travels across a big part of the city and gathers a large amount of sewage and wastewater. After surpassing Mosul city and dwelling areas, the river's water quality started to recover noticeably as the river's flow increased and almost no point source pollutants were found. This recovery was translated on the water quality data through the value (68.43) which represents the highest value of the (WQI) on the studied area. The water then started to decline due to the presence of the oil refinery in Al-Qiara District, which applies only simple treatment to the effluent that it does not suffice to the requirements of the discharge regulations. Dissolved oxygen (%), E.coli, Total dissolved solids and Temperature are the main parameters which lower the overall WQI value in all stations. When the calculated index values and water quality data are compared, the index values are rational at all monitoring stations. Based on water quality index, the water of Tigris river can be classified as class III and the water quality is medium. For public water supply system, this water requires necessary treatment.

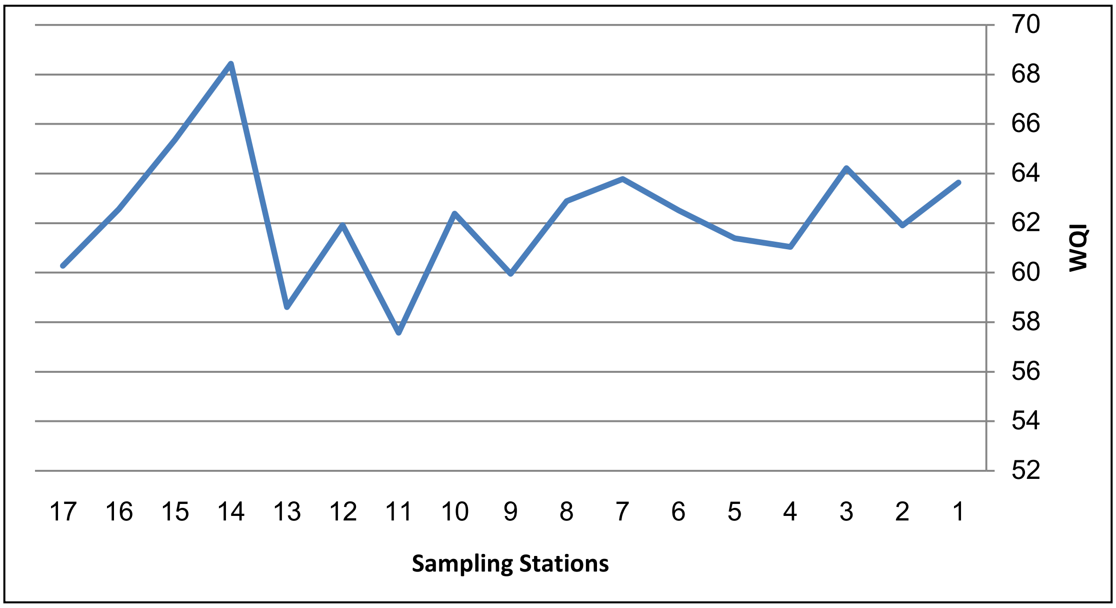

Figure (1) WQI values at sampling stations

CONCLUSIONS

Water Quality Index has become an important parameter for the assessment and management of surface water.

The NSFWQI was developed with the intent of providing a tool for simplifying the reporting of water quality data. It is a tool that provides meaningful summaries of water quality data that are useful to technical and policy individuals as well as the general public interested in water quality results. As a summary tool, it provides a broad overview of water quality data and is not intended to be a substitute for detailed analysis of water quality data.

According to the above WQI values at various sampling stations, there is a general progressive decline in WQI values along the downstream that indicated an increase in pollution. This is attributed to the effluent discharged from the factories, hospitals and mainly to the wastewater and sewage discharges which pours directly into the river.

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