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RESEARCH ARTICLE - ENGINEERING

Evaluation of Water Quality at the Confluence Region of Diyala and Tigris Rivers Based on the Weighted Arithmetic Method

Khadeeja G. Sabeeh [1*], Mustafa T. Mustafa [1], Alhassan H. Ismail [2], Corina Boncescu [3]

[1] Engineering Technical College - Baghdad, Middle Technical University, Baghdad, Iraq

[2] Institute of Technology / Baghdad, Middle Technical University, Baghdad, Iraq

[3] S.l. Dr. ing., Faculty of Energy Engineering, University POLITEHNICA of Bucharest, Romania

[*] Corresponding author E-mail: kkatsbyh@gmail.com

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Abstract

This study is conducted to assess the water quality index (WQI) of the Diyala and Tigris River confluence region south of Baghdad (Al-Tuwaitha), based on the Weighted Arithmetic method. Sixteen samples of water were collected from different location in the region through two periods 5/11/2021 and 13/3/2022. Water quality parameters such as (PH, EC, TDS, TH, Ca, Mg, Cl, Turbidity, ALK, SO4, HCO3, Na, and K) were used to evaluate WQI in the study area.
The final results showed that the water was not suitable for drinking due to the high concentration of water quality parameters. In the 5 November 2021, the water quality in the study area was classified into (good, poor, very poor, and polluted) where the percentages of the above classes were 4%, 6%, 39%, and 51% respectively, while the percentages for the season 13thMarch 2022 were 1%, 41%, and 58% with very poor, polluted, and very polluted class, respectively.
The water was not suitable for drinking due to the high concentration of water quality parameters in most locations in the study area. There are many sources of pollution in the region that dump their harmful waste into the river, which led to increase the concentrations of water quality parameters in most locations of study area.

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Keywords: Baghdad; Drinking; Diyala; Tigris; WQI.

1. Introduction

Freshwater resources are extremely limited around the world, so preserving freshwater quality is critical for both public health and aquatic life. Water quality issues have become a major concern in recent years as a result of population growth, urban expansion, and technological advancement. Water can be contaminated in a variety of ways due to unregulated or regulated but poorly designed and monitored disposal practices. These factors have an impact on the quality of water resources, particularly surface waters, resulting in water contamination [1,2].

World Health Organization (WHO) reported that in developing countries over three million people (90 % of children under 5) die every year because of waterborne diseases [3,4]. Thus, proper assessment and reporting of surface water quality is an important task.

In Iraq, there are internal and external factors affecting the water quality of rivers; some controlled and others uncontrolled factors[5]. Climate change and its consequences, such as decreased precipitation and rising temperatures, are uncontrollable factors[6]. The total water resources inside the Arabian Peninsula decreased between 0 and 250 mm through the period 2002 and 2015[7]. The controlled factors have a significantly negative effect on water resources, but their effects include more specific regions. The controlled factors are primarily represented by dam construction and irrigation projects in the upper catchment[8]. Dam construction in the upper parts of the Tigris and Euphrates catchments (Turkey, Syria, and Iran) has a significant impact on surface water in Iraq because Turkey supplies approximately 80% of the water supply to the Euphrates and Tigris Rivers [9].

Water pollution affects not only water quality but also human health, economic development, and social prosperity [10]. As a result of the increasing human activities due to the population density in the city, which disposes of wastewater in the river without treatment, often leads to severe water pollution in this region. Therefore, water quality variations for the confluence region of the Diyala and Tigris rivers need to be continuously monitored for specified water parameters. The water quality is specified in terms of its biological, chemical, and physical parameters, and checking its quality is significant prior to use for purposes of drinking, irrigation, industrial, and recreational water usage. Any water sample could have varying levels of contamination in terms of many tested parameters [11].

Nomenclature & Symbols			
AW-WQI	Arithmetic Weighted Water Quality Index	GPS	Global Positioning System
IQS	Iraq Quality Standard	GAP	Southeastern Anatolia Project
GIS	Geographic Information System	PH	Hydrogen Ion
EC	Electric Conductivity (µs/cm)	TDS	Total Dissolved Solids (mg/L)
TH	Total Hardness (mg/L)	Ca	Calcium (mg/L)
Mg	Magnesium (mg/L)	Cl	Chloride (mg/L)
SO_4	Sulfate (mg/L)	ALK	Alkalinity (mg/L)
HCO_3	Bicarbonate (mg/L)	Na	Sodium (mg/L)
K	Potassium (mg/L)	Wi	Weight of parameter
$V_{standard}$	Standard limit value for water quality parameter	V_{actual}	Measured value
V_{ideal}	Ideal Value	Qi	Sub index of ith parameter

In water quality standards, different parameters, their limit values, and water samples that exceed these limit values are anticipated to have health implications. The majority of studies have concentrated on this topic by emphasizing how to express water quality in a way that is practical, understandable, and comparable [12]. The Water Quality Index (WQI) is a single number that can be easily calculated and used to describe the overall quality of water bodies. It provides a quick and simple methodology for determining water quality by only looking at a single aggregate value and the corresponding scale. WQI collects a large number of water quality parameters and expresses them in understandable terms such as excellent, good, poor etc., to make it understandable and simple to use by users [13]. The concentration of parameters in the water has a significant impact on the WQI assessment. As a result, studying these parameters individually does not provide the full vision for the WQI [14]. There are many previous studies that dealt with the issue of water quality such as [15] assessed the WQI in the Misan River of Iraq using the Arithmetic Weighted method and Overall Index of Pollution during the period 2017-2018. They analyzed nine physical and chemical variables such as PH, Turbidity, Total Suspended Solids (TSS), Total Hardness (TH), Total Dissolved Solids (TDS), Chloride (Cl), Nitrate (NO3), Sulphate (SO4), and Phosphate (PO4). They showed that all stations were very poor and were classified as undrinkable due to the increase in the concentration of TDS, TSS, SO4, and TH for all stations [16] assessed the WQI in the Karaikal and nearby regions in India based on Arithmetic Weighted method for two different seasons from January 2011 to October 2011. They analyzed some of physical and chemical properties of water such as PH, Electrical Conductivity (EC), TDS, TH, Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), Dissolved Oxygen (DO), SO4, Cl and NO3. They found that groundwater in a few areas was not suitable for domestic and agricultural purposes. [17] discovered the fluctuation of WQI of the Tigris River within Baghdad city using the Arithmetic Weighted method. They analyzed thirteen parameters for drinking water samples of River such as pH, Alkalinity, Turbidity, Dissolved Solid, Hardness, Calcium, Magnesium, Cl, SO4, Ammonia, Fluoride, Iron, and Aluminum. They showed that WQI of the Tigris River did not reach excellent levels nor fall to unsuitable conditions, except for occasional untreated water samples. This study aims to evaluate the water quality of Diyala and the Tigris River confluence region south of Baghdad for drinking purposes by Weighted Arithmetic Method.

2. Materials and Methods

2.1. Study Area

The Diyala River is generally regarded as the third-largest Tigris River tributary in Iraq. The river flows eastward into Iraq from its source in Iran's Zagros Mountains. The study area is situated between latitudes (33° 11'00" N and 33° 15'00" N) and longitudes (44° 29'00" E and 44° 32'00" E) southeast of Baghdad in the Al-Tuwaitha region as shown in Fig. 1 [18]. The Tigris and Diyala rivers have experienced low flow in recent decades as a result of the South-eastern Anatolia Project (GAP) in Turkey and irrigation projects in Iran [19]. This increased the salinity of the river's water [20].

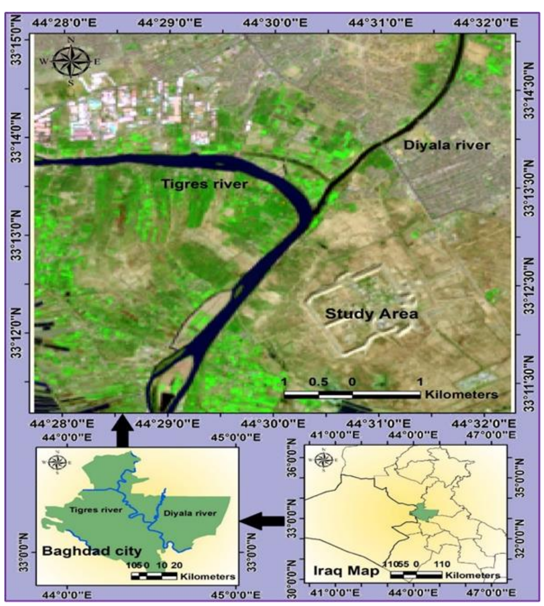

Fig. 1. Location of the study area ((Prepared by author depend on Iraq administrative map, scale1:1000000; State Commission of Survey 2010 and Landsat 8 images 13/3/2022)

2.2. Data Collection and Water Quality Tests

In this study, Weighted Arithmetic Method (AW-WQI) was utilized to evaluate water quality and the impact of selected water quality parameters for this study caused by human and industrial activities in the Diyala and Tigris River confluence region. Samples were collected in two periods 5/11/2021 and 13/3/2022 for sixteen locations in the studied area using plastic bottles of (1000) ml at a depth of between (20-30) cm. These samples were tested and analyzed in the laboratory to determine their chemical, physical, and biological properties. The (PH, EC, and TDS) parameters were tested in laboratory of Institute of technology –Baghdad using devices such as (PH-meter and Oakton pcs tester 35). While (TH, Ca, Mg, Turbidity, SO4, Cl, ALK, Na, HCO3, and K) parameters were tested in the laboratories of Iraqi Ministry of Science and Technology and Mayoralty of Baghdad. Weather conditions were suitable on the day of sample collection from the site to determine the coordinates of each station using a GPS navigation device and boat. Fig. 2 shows the sample locations in the study area. Tables 1 and 2 show the final statistical analysis of these parameters.

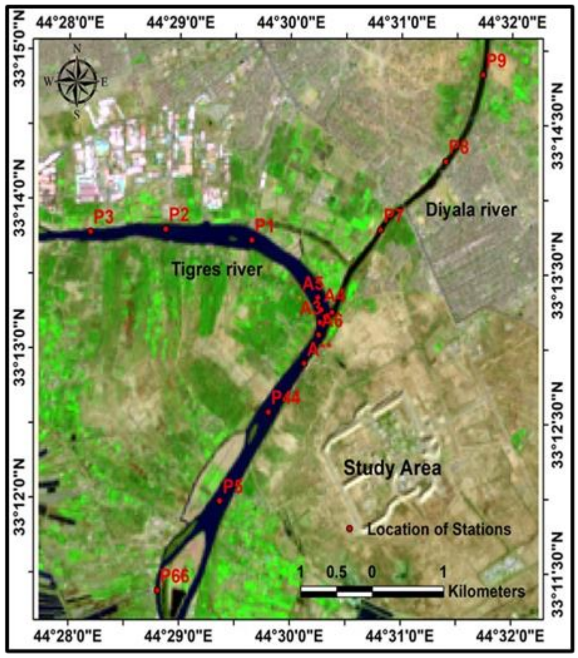

Fig. 2. The sampling stations in the study area

Table 1. The Statistical Analysis of Water Quality Parameters for the period 5th November 2021

parameter	Min. value	Max. value	Average value
PH	7.4	7.9	7.62
TDS (mg/L)	489	1077	636.31
EC (µs/cm)	971	1950	1226.19
TH(mg/L)	400	920	545
Ca (mg/L)	100	270	153.13
Mg (mg/L)	23	67	41.63
Turbidity (NTU)	3.9	37.9	20.68
Cl (mg/L)	64.98	229.92	112.15
ALK (mg/L)	134	976	490.13
SO4 (mg/L)	53	135	93.44
HCO3 (mg/L)	183.7	560	324.36
Na (mg/L)	62	178	87.62
K (mg/L)	1.8	12.8	5.46

Table 2. The Statistical Analysis of Water Quality Parameters for the period 13thMarch 2022

parameter	Min. value	Max. value	Average value
PH	7.88	8.58	8.25
TDS (mg/L)	574	1487	803.75
EC (µs/cm)	857	2220	1186.56
TH(mg/L)	316	744	436.94
Ca (mg/L)	81	160	103.31
Mg (mg/L)	26	85	43.63
Turbidity (NTU)	28	81	46.44
Cl (mg/L)	62	214	98.31
ALK (mg/L)	140	338	189.81
SO4 (mg/L)	165	496	247.69
HCO3 (mg/L)	40	400	196.25
Na (mg/L)	36.2	50	42.49
K (mg/L)	1.98	2.96	2.32

2.3. Arithmetic Weighted Water Quality Index (Aw-WQI)

The following procedures can be used to compute water quality for drinking purposes based on (AW-WQI):

1) Calculation of the weight (Wi) for each quality parameter by the following formula [21]:

$$Wi = \frac{K}{\mathrm{V(standard)}} \quad (1)$$

Where:

K: is the proportionality constant

V (standard): the Iraqi water quality parameter standard recommended (IQS/417/2001) is shown in Table 3.

2) Calculation of the sub index the ith parameter Qi by the following formula [21]:

$$Qi = \left\{\frac{(Vactual-Videal)}{(Vstandard-Videal)}\right\} *100 \quad (2)$$

Where:

Qi: is the quality rating of the parameter for a total of water quality parameters.

$Vactual$: is the measured value of the quality parameter.

$Videal$: is the ideal value (Ph and Dissolved Oxygen are assumed to be equal to (7 and 14.6 mg/L, respectively), while the remaining parameters are zero).

3) Calculation of the water quality index by the following formula [21]:

$$WQI=\{\sum WiQi/\sum Wi\} \quad (3)$$

The water quality classes based on (AW-WQI) are displayed in Table 4 [7].

Table 3. Recommended Iraq standard of the water quality parameter for drinking water

Parameters	Unit	V standard for water drinking (IQS 417)
PH	***	8.5
Sulfate (SO4)	mg/L	250
Calcium	mg/L	50
Magnesium	mg/L	50
Total _dissolved_solids (T.D.S)	mg /L	1000
Chloride (Cl)	mg/L	250
Alkalinity (ALK)	mg/L	200
Turbidity	NTU	5
Total hardness (TH)	mg/L	500
Electrical construction (EC)	(µs/cm)	1000
Bicarbonate (HCO3)	mg/L	120
Sodium (Na)	mg/L	200
Potassium (K)	mg/L	12

Table 4. Classification of water quality values

Value of WQI	Water quality rating
< 50	Excellent
50 – 100	Good
100 – 200	Poor
200 – 300	Very poor
300 – 400	Polluted
> 400	Very polluted

3. Result and Discussion

This study was carried out to evaluate the water quality of the confluence of the Diyala and Tigris rivers, southeast of Baghdad, based on the AW-WQI, method. Various physio-chemical parameters of sixteen locations in the studied area were collected to analyze water quality for drinking purposes. To analyze the suitability of water for drinking purposes in the study area, each sample was compared to water quality guidelines based on Iraqi Standards (417), which give the minimum and maximum allowable limits for water quality parameters in the river.

The final results illustrated that, the rating water quality index values for the locations ranged between (66-385) classified between (good to polluted) for the period 5th November 2021 and (296-743) classified between (very poor to very polluted) for the period 13th March 2022 as shown in Tables 5 and 6. Also, final maps of water quality which were produced by ArcGIS 10.8 program illustrated that the study area was classified for the period 5th November 2021 into four classes according to the water quality index. These classes included good, poor, very poor, and polluted. The percentages for above classes were 4%, 6%, 39%, and 51% respectively. while in season 13thMarch 2022, the water quality was classified into 1% as very poor,41% as polluted, and 58% as very polluted as shown in Figs. 3 to 6. The reason for this variance is due to the different concentrations of water quality parameters of the locations in the study area that exceed the permissible limit of Iraqi standards for water quality which made them unfit for drinking as shown in the Tables 1 and 2.

The values of (TDS, EC, TH, and Mg) exceeded the permissible limit of the Iraqi specification 417 in the upper part of the confluence with the Diyala River. While the values of (Turbidity, HCO3, and Ca) exceeded the permissible limit for the two seasons in most locations in the study area. SO4 values were within the permissible limit for season 5th November 2021, while it exceeded the permissible limit in season 13thMarch 2022 and K values in this season were within the permissible limit.

Values of (Cl, Na, and PH) for the two seasons were within the permissible limit of the specification in all stations of the study area. Where the water classification was poor and mostly incompatible with the Iraqi standards for water quality in most of the locations with the upper part of the confluence with the Diyala River.

There are many sources of pollution in the region that dump their harmful waste into the river, which led to increase the concentrations of water quality parameters in most locations of study area as shown in Fig. 7.

Table 5. Results of AW-WQI drinking water (date: 5th November 202

Station	Σwi	ΣQiWi	WQI	Rating
A1	1	385.81	385.81	Polluted
P7	1	337.15	337.15	Polluted
P8	1	249.2	249.2	Very poor
P9	1	216.86	216.86	very poor
P1	1	170.87	170.87	Poor
P2	1	117.03	117.03	Poor
P3	1	66.21	66.21	Good
A5	1	194.6	194.6	Poor
A3	1	202.15	202.15	Very poor
A4	1	286.38	286.38	Very poor
A2	1	123.09	123.09	Poor
A6	1	168.78	168.78	Poor
A**	1	275.11	275.11	Very poor
P44	1	325.05	325.05	Polluted
P5	1	225.28	225.28	Very poor
P66	1	154.77	154.77	Poor

Table 6. Results of AW-WQI drinking water (date: 13thMarch 2022)

Station	Σwi	ΣQiWi	WQI	Rating
A1	1	743.30	743.30	very polluted
P7	1	571.71	571.71	very polluted
P8	1	577.15	577.15	very polluted
P9	1	296.12	296.12	very poor
P1	1	364.95	364.95	polluted
P2	1	332.12	332.12	polluted
P3	1	374.41	374.41	polluted
A5	1	451.42	451.42	very polluted
A3	1	401.58	401.58	very polluted
A4	1	398.75	398.75	polluted
A2	1	425.30	425.30	very polluted
A6	1	391.13	391.13	polluted
A**	1	415.88	415.88	very polluted
P44	1	421.92	421.92	very polluted
P5	1	375.92	375.92	polluted
P66	1	447.51	447.51	very polluted

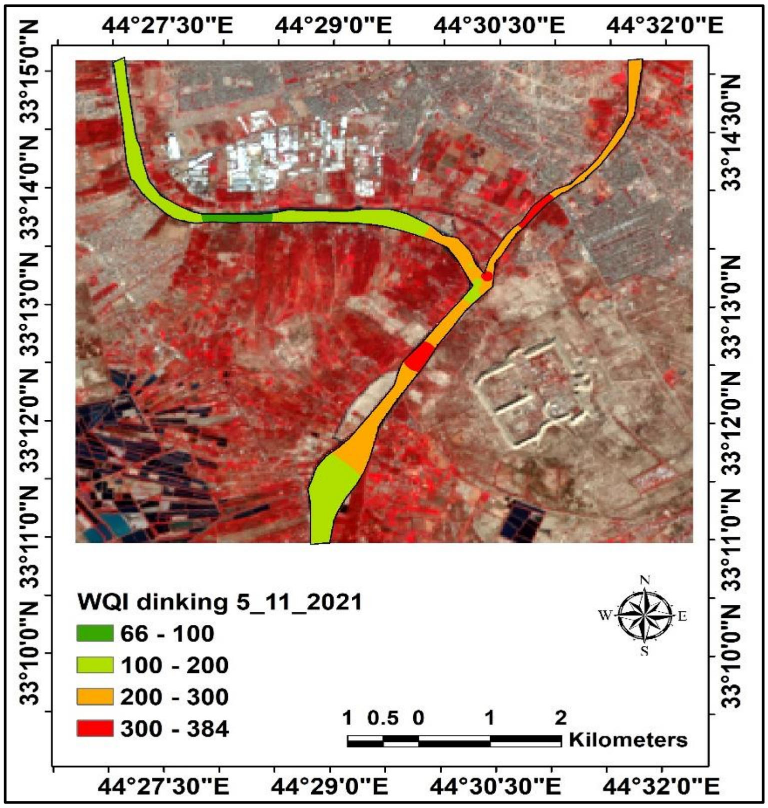

Fig. 3. water quality for drinking in the study area 5th November 2021(prepared by author depend on Arc GIS 10.8 program)

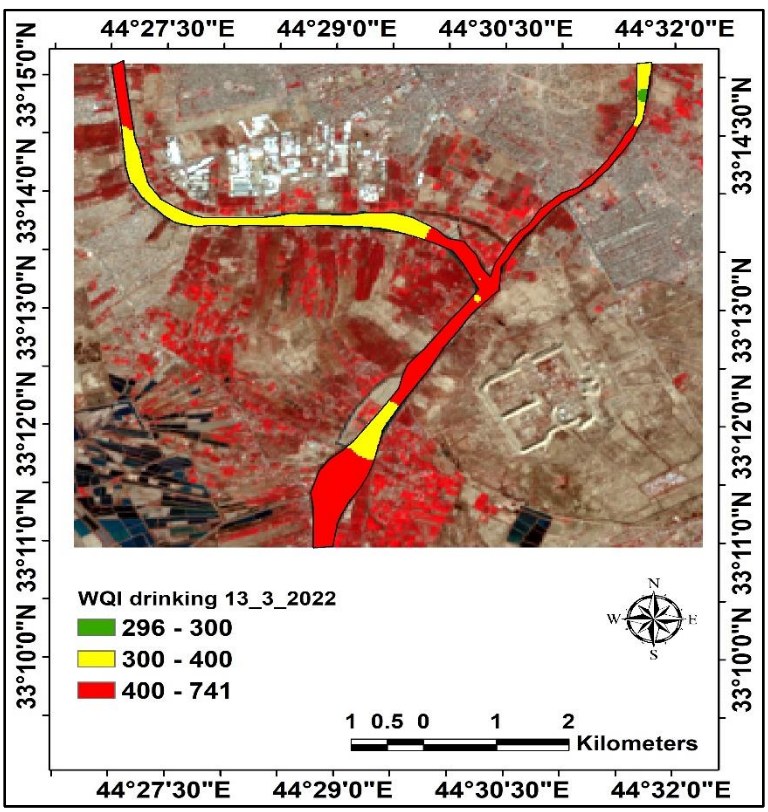

Fig. 4. water quality for drinking in the study area 13thMarch 2022 (prepared by author depend on Arc GIS 10.8 program)

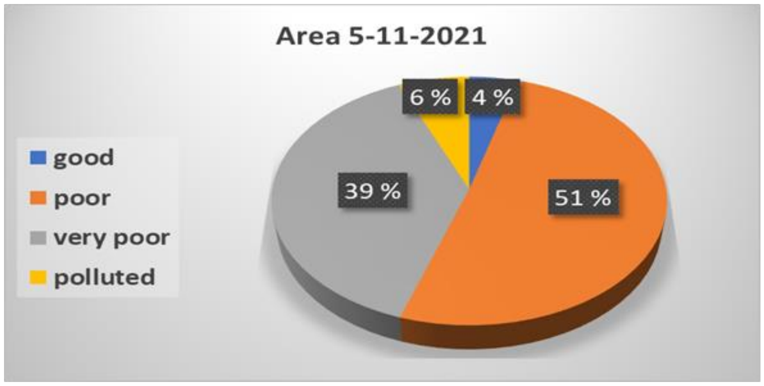

Fig. 5. Percentages of Water Quality Classes for 5th November 2021 in the Study Area

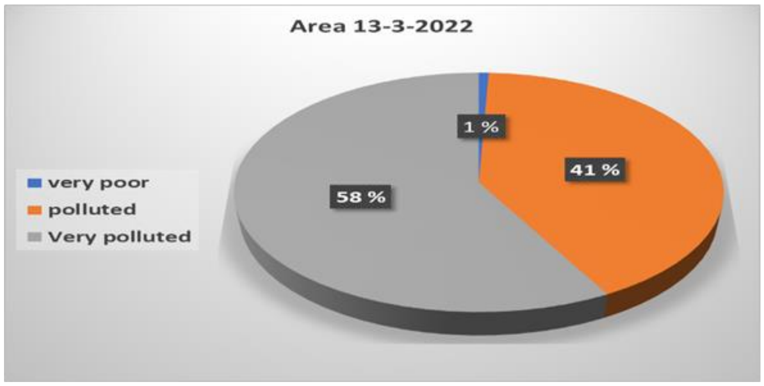

Fig. 6. Percentages of Water Quality Classes for 13thMarch 2022 in the Study Area

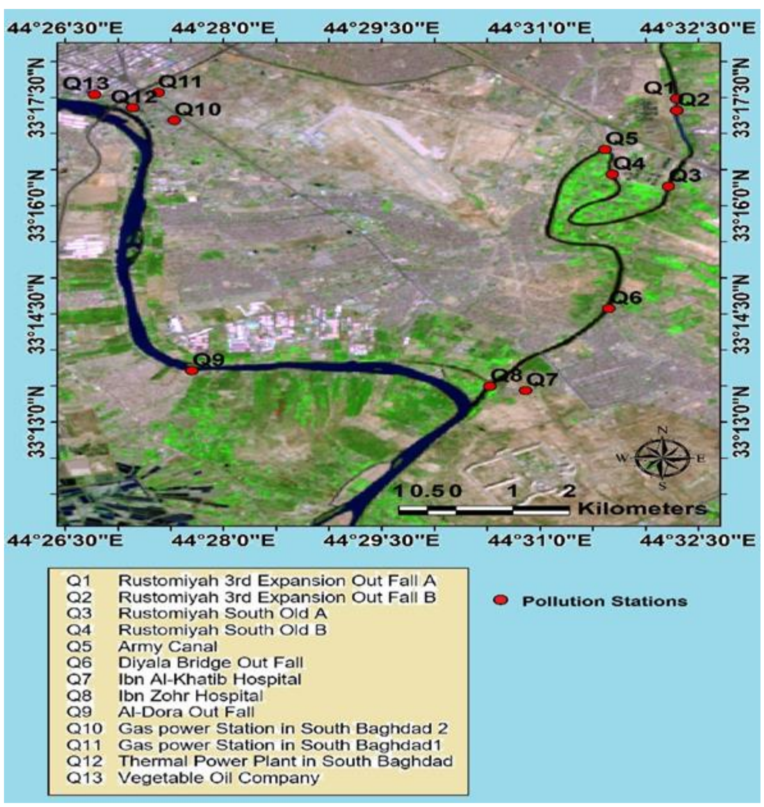

Fig. 7. Sources of pollution in the Study Area

4. Conclusions

The water quality index values for the locations in the study area classified into good, poor, very poor, and polluted for the period 5th November 2021. The percentages for above classes were 4%, 6%, 39%, and 51% respectively. while in season 13thMarch 2022, the water quality was classified into 1% as very poor,41% as polluted, and 58% as very polluted. The reason for this variance is due to the different concentrations of water quality parameters of the locations in the study area that exceed the permissible limit of Iraqi standards for water quality which made them unfit for drinking. The water was not suitable for drinking due to the high concentration of water quality parameters in most locations in the study area.

There are many sources of pollution in the region that dump their harmful waste into the river, which led to increase the concentrations of water quality parameters in most locations of study area.

5. Recommendations

Conducting a future study for same subject of this study using Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) parameters in addition to physical and chemical parameters of water which used in this study.

Acknowledgment

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