Journal of Techniques, ISSN: 2708-8383, Vol. 4, No. 4, December 31, 2022, Pages 1-11

JOURNAL OF TECHNIQUES

Journal homepage: http://journal.mtu.edu.iq

RESEARCH ARTICLE - ENGINEERING

Effects of Industrial Wastewater on Water Quality Tigris River at Baghdad Using (GIS) Technique

Sahar Isam Wadeea[1*], Rana Mozahim Hamdoon[1], Mudhaffar Sadiq Al-Zuhairy[2]

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

[2]Alfurat_ Alawsat Technical University, Iraq

* Corresponding author E-mail: saharisam70@gmail.com

Article Info.

Article history:

Received
05 June 2022

Accepted
15 July 2022

Publishing
31 December 2022

Abstract

Tigris River has been affected by industrial wastewater pollution in Iraq. One water sampling point was taken for each of the five sites of industrial wastewater plants, which are located south of Baghdad along the length of the river about 9 Km within the study area from (33°15'52.63"N, 44°22'13.98"E) to (33°16'54.94"N, 44°27'15.86"E) navigated by GPS (GARMIN 72), coordinates system WGS_1984_UTM_Zone_38N. The Analysis of water quality Includes several parameters; WQI was used to assess the water quality of the river according to a mathematical equation. Five water quality parameters were considered, those are Hydrogen Ion Concentration (pH), Biochemical Oxygen Demand (BOD5), Chemical Oxygen Demand (COD), Sulfate (SO4), Phosphate (PO4), and Total Suspended Solids (TSS) for the period (2020 to 2021). Water Quality Index (WQI) analysis technique according to an arithmetic weighted formula and using geographic information system (GIS) technique - Symbology method was used to display the results and analyzes as accurate and up-to-date colourful maps to describe water quality. Indicate the water sampling results were classified from poor to very poor for the period 2020 to 2021. The research aims, to use (GIS) to show that industrial wastewater runoff must be treated properly and completely before being discharged into the water stream.

Publisher : Middle Technical University

Keywords: Tigris River; GPS; Industrial Wastewater; GIS Technique; WQI.

1. Introduction

One of two main rivers in Iraq is "Tigris" which flows through many governorates from the north to the south, and it is considered the main source of drinking water for all living creatures in the country, in addition to being one of the largest one in the Middle East [1, 2]. The length of the Tigris River basin is about 1,800 Km and covers a total of. Area of 473,103 Km^2, which is about 58 % located in Iraq. The total population living in the Tigris River basin is about 23.4 million (ESCWA, 2013), of whom 18 million live in Iraq. The Tigris River, the watershed area of Iraq has an area of about 235,000 Km^2, and the length of the river runs about 1,415 Km through Iraq [3]. Water, for the ecosystem, is the main component and a valuable national treasure. Surface water is the most important form of water for human activities, the surface water is the most important, such as industry, agriculture, drinking water, hydropower generation, and various other economic sectors. The population of Iraq is approximately 40,194,216 in (2018) with a growth rate is approximately 2.5% (2018). Most of the population lives live in the northern, central, and eastern regions of the country along the banks of the Tigris River. Large portions of the western and southern regions are sparsely populated and sometimes uninhabited due to the difficult environment and shortage of life facilities for being desert areas (Central Intelligence Agency 2019);[4]. The increasing deterioration of water quality resulting from climate change and the high rates of pollution whose water is used for industrial uses, irrigation, water supply, and other uses is one of the most important global trends in environmental issues [5]. Direct wastewater discharge in urban and industrial areas has led to a deterioration in the quality of river water, especially in recent years [6-8]. WQI is a numerical mechanism derived from cumulative exposure that determines a certain degree of water quality [9, 10]. In other words, the WQI summarizes huge amounts of water quality data in easy terms (e.g., excellent, good, bad, etc.) Because reports on management and community traditions are among the approved criteria [9]. With the development of scientific techniques, water quality assessment using precise techniques It is a water quality index (WQI) to assess the condition of water displayed on maps (GIS) to represent the spatial distribution of parameters became a practical approach used in recent times is ideal as a useful tool for finding solutions to water resource problems at the local or regional level. From geospatial information systems distribution maps can be made for all types of pollutants specified by the party requesting the examination, so the resulting information is a very useful database and a basis for assessing the type and quantity of polluting elements for decision makers to take decisions that address the problem and remedial measures [11-13], see Fig. 1.

Nomenclature			
BOD5	Biochemical Oxygen Demand	SO4	Sulfate
COD	Chemical Oxygen Demand	TSS	Total Suspended Solids
GIS	Geographic Information System	UTM	Universal Transverse Mercator
GPS	Global Positioning System	WGS	World Geodetic System
PH	Hydrogen Ion Concentration	WQI	Water Quality Index
PO4	Phosphate		

The study aims to

- Evaluate the effect of industrial wastewater pumping plants on Tigris River on the water quality that showed in spatial distribution colourful maps by using Arc GIS software by created WQI colourful map; the classified resulted of the weighted arithmetic water quality index values into five levels (Excellent, Good, Poor, Very Poor and Unsuitable water) for surface water.
- Discuss the suitability of the Tigris River in the study sites at consumption for human consumption based on the calculated WQI values, comparing water quality with Iraqi water quality standards.

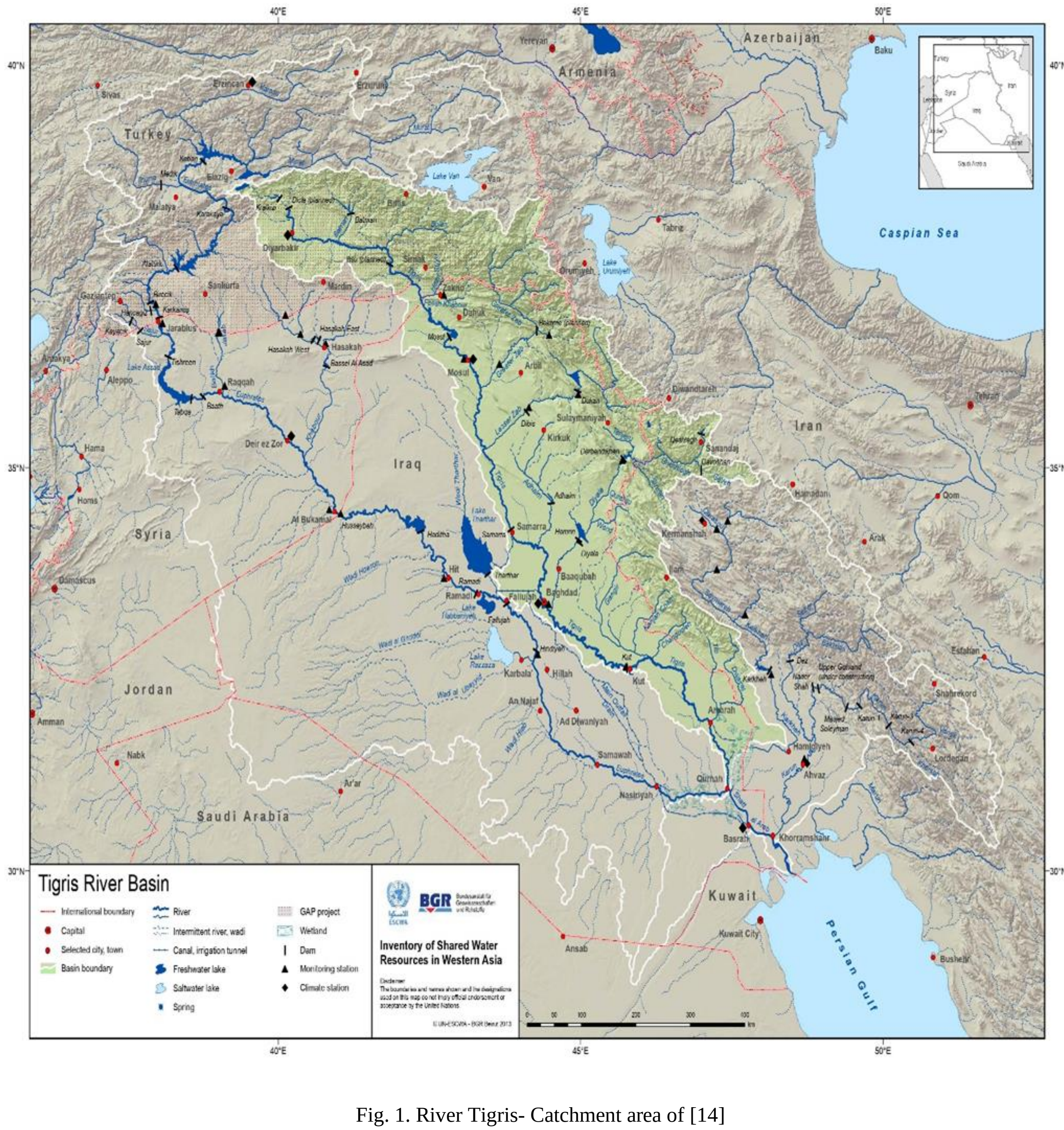

Fig. 1. River Tigris- Catchment area of [14]

2. Materials and Method

2.1. Area Study

Baghdad is the capital, with sites in the central zone of Iraq between (33° 10' N, 44 09' E) and (33° 29' N, 44° 33' E)[15]. The coordinates at which Tigris River enters (44˚24'E, 33˚36'N), with a length of approximately 110 Km along Baghdad [16, 17]. Tigris divided Baghdad into two parts: the first part named Al-Karkh lies southwest while the second part named Al-Rusafa lies northeast of it [15], see Fig. 4. Due to the high population density, the population in 2016 reached more than 8,765,000 million. Therefore, it is considered the largest governorate in terms of population density in the country[18]. The area of Baghdad is close to 800 Km^2, where more than 65% of its total area is used in the establishment, the establishment of industrial institutions, and factories in it. This massive industrial use has led to the generation of various environmental problems that threaten the health and effectiveness of the population, in addition to the deterioration of the healthy ecosystem of the city due to the discharge of water sanitation represented by domestic and industrial effluents and their by-products for all service, industrial and health institutions directly to Tigris River, which is the main and almost the only source in Baghdad utilizing its water for agricultural irrigation and water supplies, industries, etc.; Therefore, Tigris River suffers from the impact of pollution [19], see Figs. 2, 3 and 4.

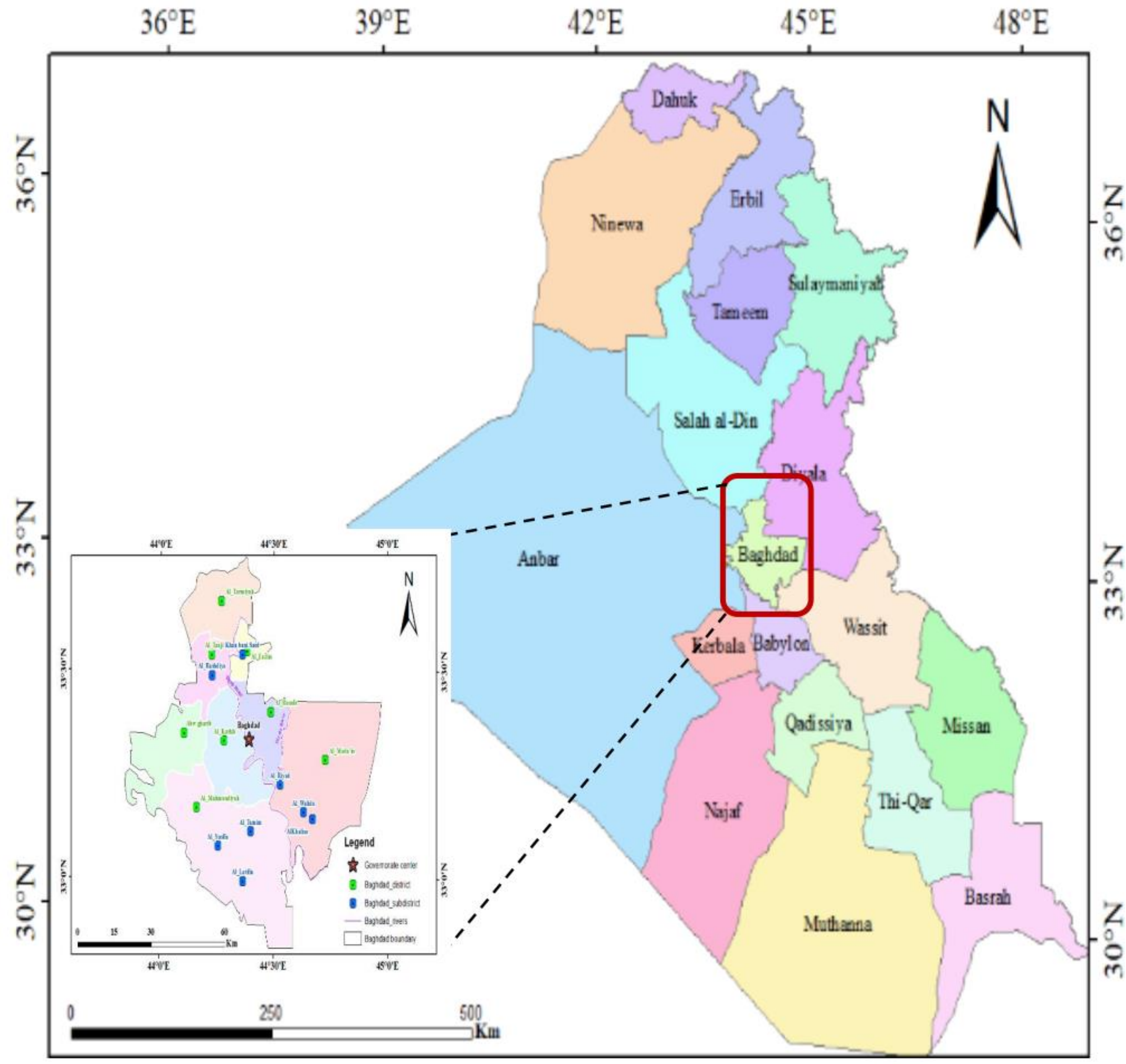

Fig. 2. Location map of the study area [20]

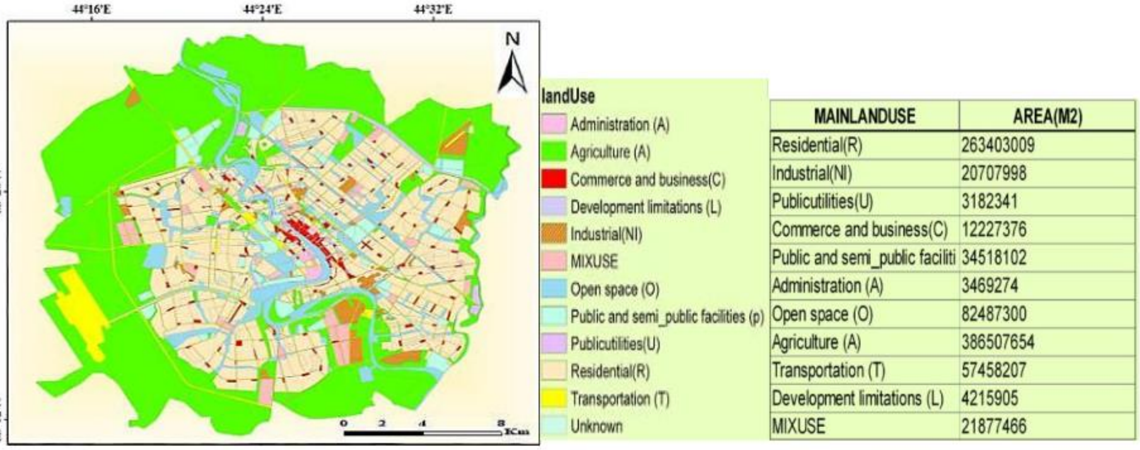

Fig. 3. Baghdad – land use map [20]

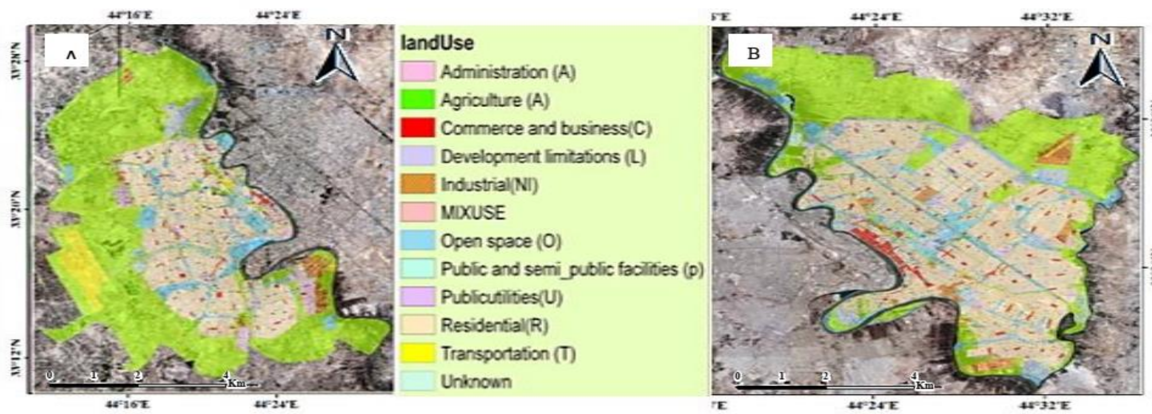

Fig. 4. A) Al- Karkh and B) Al-Rusafa – land use map [20]

The study area (Tigris River with Baghdad City) is located between (33°15'52.63"N, 44°22'13.98"E) to (33°16'54.94"N, 44°27'15.86"E) observed by GPS (GARMIN 72) coordinates system WGS_1984_UTM_Zone_38N. The length and area of the search area were calculated using the program ArcGIS 10.4.2 (Esri, Redlands, CA, USA); it was approximately 9 Km in length and 2.3 Km^2 area. These sites represent the industrial wastewater stations for five industrial facilities, which are: site 1 (Dora Thermal Power Plant) by observed coordinates (44°22'34"E, 33°15'44"N), site 2 (Midland Refineries Company \ Dora Refineries) by observed coordinates (44°25'50"E, 33°16'50"N), site 3 (Southern Baghdad Thermal Power Plant) by observed coordinates (44°27'09"E, 33°17'23"N), site 4 (Baghdad South Gas Power Plant-1) by observed coordinates (44°27'23"E, 33°17'24"N) and site 5 (Baghdad South Gas Power Plant-2) by observed coordinates (44°27'35"E, 33°17'09"N), see Fig. 5, see Table 1.

Fig. 5 Map of Study Area with Sampling Sites (Google Earth & ArcGIS 10.4.2)

Table 1. Industrial sampling location

Site	Name	Coordinate (WGS_1984_UTM_Zone_38N)	
		E(longitude)	N(latitude)
1	Dora Thermal Power Plant	44°22'34"E	33°15'44"N
2	Midland Refineries Company \ Dora Refineries	44°25'50"E	33°16'50"N
3	Southern Baghdad Thermal Power Plant	44°27'09"E	33°17'23"N
4	Baghdad South Gas Power Plant-1	44°27'23"E	33°17'24"N
5	Baghdad South Gas Power Plant-2	44°27'35"E	33°17'09"N

2.2. GPS

A Global Positioning System (GPS) is a navigation system using satellites, a receiver, and algorithms to synchronize location, velocity, and time data for air, sea, and land. [18]. In this search, the coordinates of the water sampling test points for the industrial wastewater stations of the five industrial facilities located in the search area were observed by GPS (GARMIN 72) with an accuracy of up to ±3m, coordinates system WGS_1984_UTM_Zone_38N, see Fig. 6.

Fig. 6. GPS (GARMIN 72)

2.3. GIS Software

Geographic Information System (GIS) is a type of useful software to produce and evaluate database that contains the geographic-spatial distribution of data and other types of information which descriptions of phenomena for each site along with software tools for managing, analyzing, and visualizing that data in different types of maps, graphs, charts, and statistical tables according to mathematical equations [19]. The application of this technique allows users to cover the overlay, determine and analyze the percentages of the parameters concentrations which contained five water quality parameters: Hydrogen Ion Concentration (pH), Biochemical Oxygen Demand (BOD5), Chemical Oxygen Demand (COD), Sulfate (SO4), Phosphate (PO4) and Total Suspended Solids (TSS) For the period (2020 to 2021), then analyze the pollution rates for the sampling water of the test samples pollution path has been designed for the wastewater discharge plants of the five industrial facilities located on the Tigris River, with a length of more than 9 Km between Dora Thermal Power Plant and Baghdad South Gas Power Plant-2 , using GIS- ArcView 10.4.2 program (Esri, Redlands, CA USA) by providing the required input data for the Physico-Chemical parameters approved in the stations described above site data and the results of laboratory chemical tests represented by calculating the concentration ratios for each element referred to above, to run GIS model integration of sampling sites with conducted water data to produce spatial distribution maps spatial tool analysis was used symbology technique are applied to the quality of water feature values in industrial wastewater plants using colourful thematic maps, see Figs. 5 and 7, see Table 1.

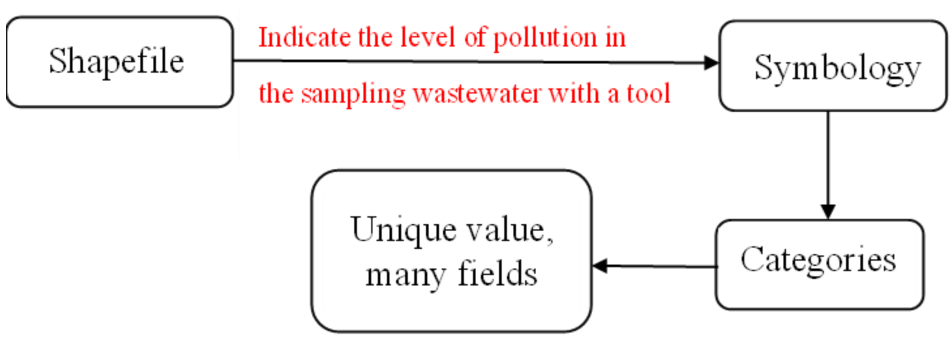

Fig. 7. Workflow-Steps of creating a coloured digital map indicating the level of pollution at the industrial water sampling sites

2.4. Application of the WQI

Mathematical equations are used in the Water Quality Index (WQI) to evaluate water quality as both easy-to-use and useful mathematical laws. Reduces a large number of tests of many parameters of water quality standards to a single number and simple terms (Excellent, Good, Poor, Very poor, etc.), then it can be entered into multiple programs [11, 19, 22]. It will use the arithmetic the weighted formula in this research [20], Due to the presence of a large number of equations, so we have relied in this research on the Ministry of Environment - Technical Department, in which WQI values are calculated according to the following equations [21],

$$qi = [\frac{Ci}{Si}] * 100 \quad (1)$$

Where
qi: - quality rating scale.
Ci: - valued concentration of ith parameter.
Si: - the standard value of the ith parameter.
The quality rating scale qi was calculated for each parameter by dividing its observed focus value in each water sample by its standard value, then multiplying the outcome by 100. Eq. (2) which was used to find the relative weight (*Wi*) to a conformable parameter as a value inversely proportional to the standard value Si.

$$Wi = \frac{1}{Si} \quad (2)$$

Then, Eq. (3) the Water Quality Index (WQI) was used to calculate by aggregating quality rating scale qi with unit weight *wi*:

$$WQI = \sum_{i=1}^{n} qi * wi \quad (3)$$

Where,
wi: - the unit weight of the ith parameter
n: - number of the parameters considered
Generally, WQI is deliberated for any specific and fixed use of river water.
At last, Eq. (4) using for overall WQI was computed:

$$WQI = \frac{\sum_{i=1}^{n} qi * wi}{\sum_{i=1}^{n} wi} \quad (4)$$

2.5 Data Analysis and Discussion

In this study, the weighted arithmetic method was used to calculate the water quality index (WQI). Six parameters (PH, COD, PO4, SO4, BOD5, and TSS) were used to determine the overall WQI to water sampling of the five selected wastewater discharge plants to industrial sites along the Tigris River, see Fig. 5, Table 1, for the period 2020-2021. These parameters are also important for calculating Water Quality Index for different purposes. The arithmetic weighted WQI formula for each selected sampling water in the five industrial sites in Baghdad capital from wastewater discharge along the Tigris River in the search area was calculated using Equation 4 and was formulated utilizing Excel 2016 software, see Fig. 7, comparing the results of the overall Water Quality Index (WQI) equations with the Water Quality Index (WQI) classification approved by the Ministry environment to be classified according to the values of the results into the colourful (Blue, Green, Yellow, Orange, and Red) which are represented (Excellent, Good, Poor, Very poor and Unsuitable) respectively, see Tables 2, 3, 4, 5 and 6, see Fig. 9 and 10.

Table 2. Iraqi standards for water quality [26]

No.	Parameters	Code	Si (mg/l)
1	Hydrogen Ion Concentration	PH	6.5-8.5 (Average=7.5)
2	Biochemical Oxygen Demand	BOD5	40
3	Chemical Oxygen Demand	COD	100
4	Sulfate	SO4	400
5	Phosphate	PO4	3
6	Total Suspended Solids	TSS	60

Table 3. Water Quality Index category by Weighted Arithmetic method [26]

Class	WQI-Category	Rang
A	Excellent	0-25
B	Good	25-50
C	Poor	50-75
D	Very poor	75-100
E	Unsuitable	> 100

Table 4. Colors classified indicator for WQIs in Excel [26]

WQI-Category	Rang	Colour
Excellent	0-25	
Good	25-50	
Poor	50-75	
Very poor	75-100	
Unsuitable	> 100	

Table 5. Physico-Chemical parameter values for water sampling sites [25]

Site	Year	NAME	PH (mg/l)	BOD5 (mg/l)	TSS (mg/l)	PO4 (mg/l)	SO4 (mg/l)	COD (mg/l)
1	2021	Dora Thermal Power Plant	8	51	48	1.45	155	151
2	2021	Midland Refineries Company \ Dora Refineries	7.5	58	215	1.24	266	114
3	2021	Southern Baghdad Thermal Power Plant	8.04	42	55	1.18	150	189
4	2021	Baghdad South Gas Power Plant-1	7.5	62	96	1.98	200	221
5	2021	Baghdad South Gas Power Plant-2	7	90	273	1.67	330	180
1	2020	Dora Thermal Power Plant	7	62	60	1.24	120	187
2	2020	Midland Refineries Company \ Dora Refineries	7	95	30	1.27	100	114
3	2020	Southern Baghdad Thermal Power Plant	7.2	50	35	1.55	400	106
4	2020	Baghdad South Gas Power Plant-1	7.5	120	65	1.98	380	342
5	2020	Baghdad South Gas Power Plant-2	7.81	120	234	1.2	240	231

Table 6. Industrial water sampling sites category using the weighted Arithmetic method

Site	Year	NAME	Overall (WQI)	Category
1	2021	Dora Thermal Power Plant	70	Poor
2	2021	Midland Refineries Company \ Dora Refineries	73	Poor
3	2021	Southern Baghdad Thermal Power Plant	64	Poor
4	2021	Baghdad South Gas Power Plant-1	85	Very Poor
5	2021	Baghdad South Gas Power Plant-2	89	Very Poor
1	2020	Dora Thermal Power Plant	65	Poor
2	2020	Midland Refineries Company \ Dora Refineries	66	Poor
3	2020	Southern Baghdad Thermal Power Plant	68	Poor
4	2020	Baghdad South Gas Power Plant-1	93	Very Poor
5	2020	Baghdad South Gas Power Plant-2	84	Very Poor

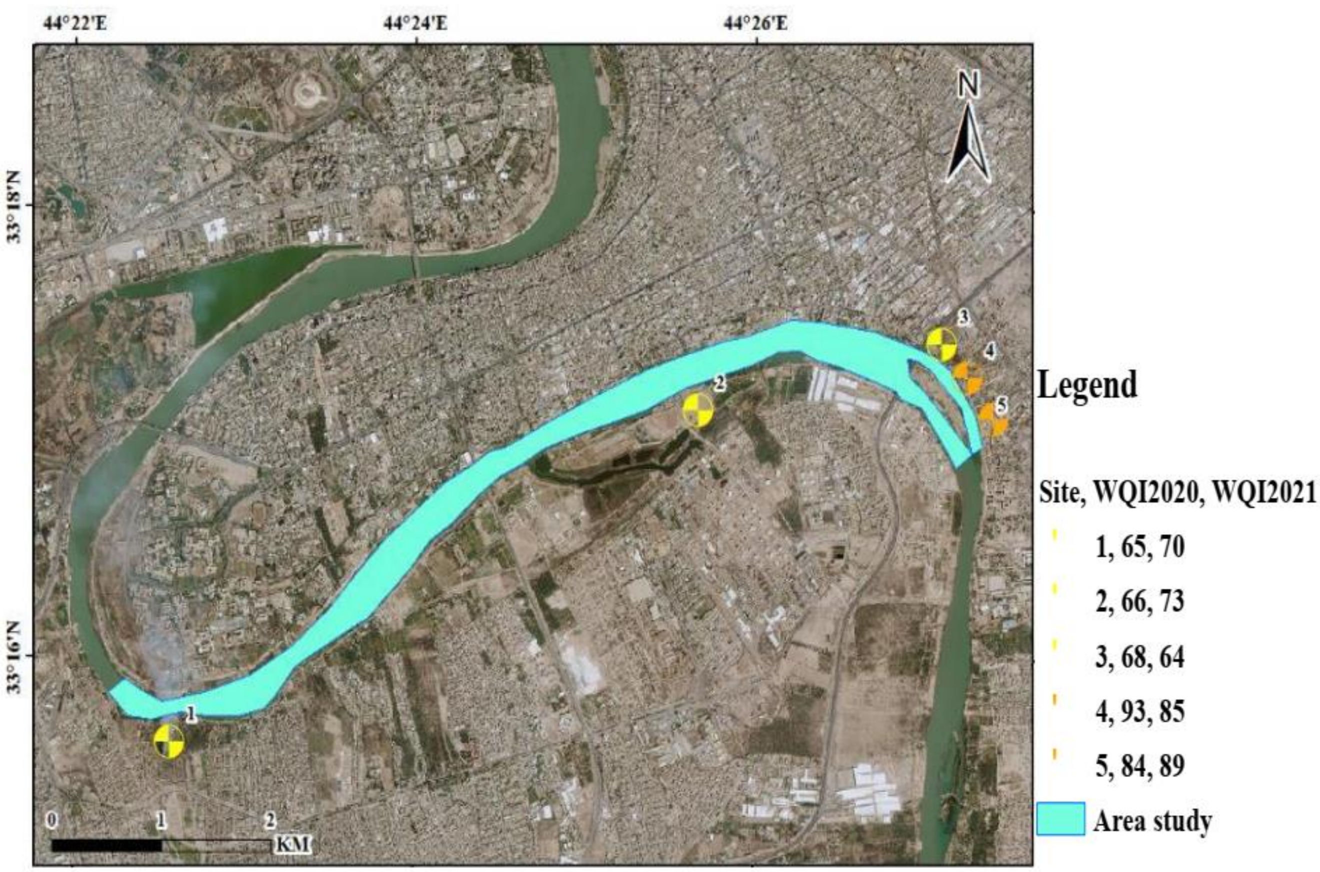

Fig. 8. Map of WQI 2020- 2021 by GIS technique – Symbology

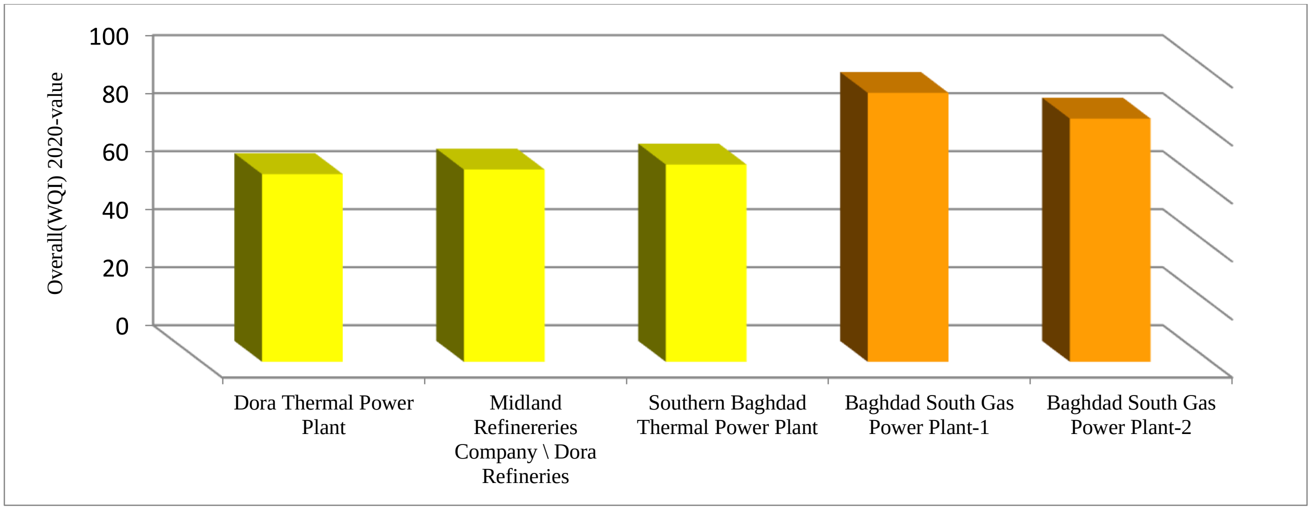

Fig. 9. Water quality Index within Tigris River (2020) using Weighted Arithmetic method in Excel-Chart Tools

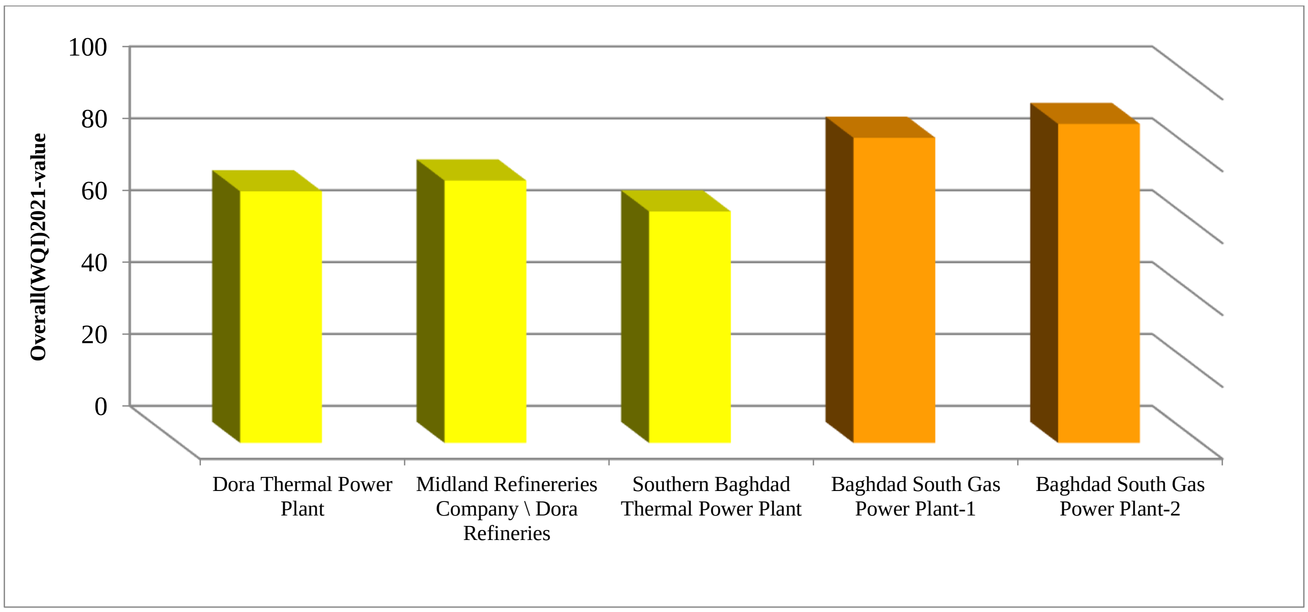

Fig. 10. Water quality Index within Tigris River in (2021) using Weighted Arithmetic method in Excel-Chart Tools

3. Results and Discussions

The GIS- Symbology_categories technique maps represent the arithmetic weighted (WQIs) of Tigris at Baghdad city due period 2020 to 2021 between Dora Thermal Power Plant and Baghdad South Gas Power Plant-2. Displays the colour indicator used within the GIS- [Symbology _categories] maps according to the "WQI" classification. Indicate the results from the arithmetic weighted (WQIs) analysis classified from poor to very poor, see Figs. 5, 7and 8, see Tables 1 and 3.

- From Dora Thermal Power Plant to Southern Baghdad, Thermal Power Plant have a grade poor in two years 2020 and 2021 while Baghdad South Gas Power Plant-1 to Baghdad South Gas Power Plant-2 at all times the quality of water is very poor during the same period above, poorly represented by a yellow colour, very poor representation by orange colour in Excel 2016 software chart, see Tables 4 and 6.
- The water pollution path was designed for the wastewater discharge plants of the five industrial facilities located and pumped directly along the river without treatment on the Tigris River, with a length of more than 9 Km between the Dora Thermal Power Plant and Baghdad South Gas Power Plant-2. The main water parameter causing these high WQI values is the high concentrations of Biochemical Oxygen Demand (BOD5), Chemical Oxygen Demand (COD), Hydrogen Ion Concentration (PH), and Total Suspended Solids (TSS) in the flowing water. The recorded data indicated BOD5 concentrations between (42 to 90) mg/l in 2021 while in 2020 were (62- 120) mg/l; in COD concentrations between (114 to 221) mg/l in 2021 while in 2020 were (114- 342) mg/l in the five plants in the search area; while PH concentrations reached in 2021 8 mg/l at Dora Thermal Power Plant, 8.04 mg/l at Southern Baghdad Thermal Power Plant; While in the year 2020 at Baghdad South Gas Power Plant-2 reached 7.81 mg/l.
- In the year 2021 TSS concentrations reached (and 96&273) mg/l at Baghdad South Gas Power Plant-1 & Baghdad South Gas Power Plant-2 respectively; while in 2020 (65&234) mg/l respectively.

These high values add to the remaining parameters taken into consideration when calculating WQI, see Fig. 8. Baghdad has an area of 800 Km^2, and the population is approximately 8 million in 2018 with a growth rate is approximately 2.5%. Tigris river enters Baghdad at Al-Mada'in District with coordinates (33°46'25"N, 44°22'51"E), The river flows outside Baghdad from the district Mada'in (33°03'04" N, 44°37'50" E), (MINISTRY OF WATER RESOURCES / STATE COMMISSION ON SURVEY), with Length 110 Km, river basin area 235000 Km^2; all the above values are approximate due to the influence of the continuous geological changes of the nature of the land and the course of the river's runoff. 65% of the industrial establishment and factories are located in Baghdad. This condition generates ecological problems threatening the ecosystem of Baghdad city, due to the discharge of wastewater from these institutions and factories directly to the body of the Tigris River. The river water is used for irrigation, medical, domestic water supply, industrial, and other uses, so the Tigris River suffered from the effect of conservative pollutants as it receives wastewater discharged from service and industrial effluents, see, Fig. 11.

In Baghdad city, there are many water treatment plants (WTPs) located on the banks of the river. This situation generates environmental problems that threaten the ecosystem of Baghdad city , due to the discharge wastewater and products by water treatment plants (WTPs) located on the banks of the river of these institutions and factories pumping directly into a watercourse without accurate and good treatment compared to Iraqi and international standards to the Tigris River, with pumping rates up more than 64800 m^3/h in the amount of wastewater discharged with cumulative amount of wastewater discharge by domestic wastewater discharge reach to more than 135435 m^3/h, the total value cumulative amount of wastewater discharge plants industrial and domestic activities discharged to more than 249440 m^3/h which is total amount of pollution is approximately1299547752 m^3/y into the Tigris River, where the percentage of industrial pollution reached more than 65%,domestic more than 34% (Ministry of Environment – Department to Protect and Improvement in the Central Region), see Fig. 12. In general, the main wastewater discharge parameter causing deterioration in results of "water quality indices" for selected stations is the high concentrations of Biochemical Oxygen Demand (BOD5) and Chemical Oxygen Demand (COD). The results from the arithmetic weighted (WQIs) analysis consider Industrial wastewater running into the Tigris River unfit for water purposes. To produce potable water within Iraqi Water Standards different treatment processes are required.

Fig. 11. Industrial treatment plants outfall photos, (A) Dora Thermal Power Plant outfall and (B) Southern Baghdad Thermal Power Plant outfall [25]

Cumulative of wastewater discharged (m^3/h)	The amount of wastewater discharged (m^3/h)	Industrial	Site
233635.6	82000	Dora Thermal Power Plant	1
234385.6	750	Midland Refineries Company \ Dora Refineries Plant	2
249385.6	15000	Southern Baghdad Thermal Power Plant	3
249391.6	6	Baghdad South Gas Power Plant-1	4
249400.6	9	Baghdad South Gas Power Plant-2	5

Fig. 12 Discharge rates of domestic and industrial activities on the Tigris River in [25]

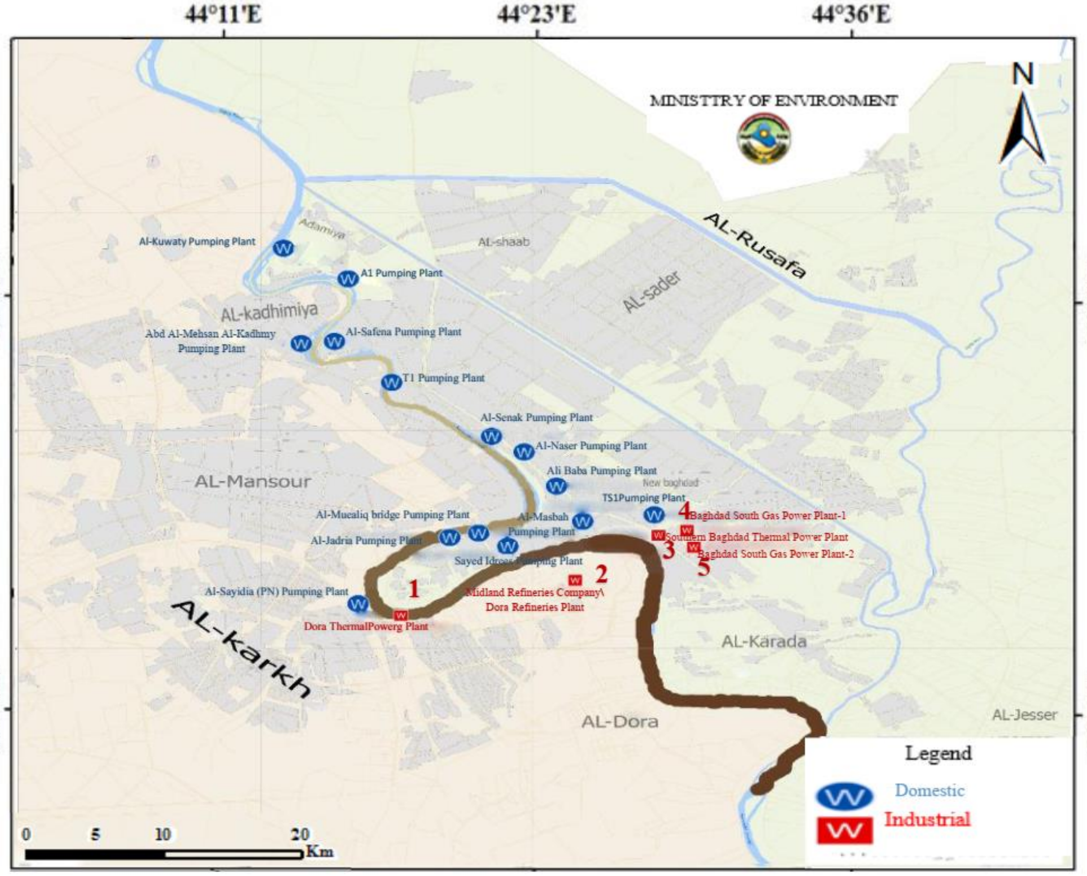

Fig. 13. Discharge rates of domestic and industrial activities on the Tigris River in [25]

4. Conclusion

Traditional analysis of Physico-Chemical characteristics could not provide the overall assessment of water quality in the river. Thus, we need a tool such as the WQI, to determine accurate levels of water quality. The Arithmetic weighted method was selected because of its flexibility in choosing input parameters (i.e., Physico-Chemical characteristics) and minimizing large amounts of data to the simplest form. The results from the Arithmetic weighted method WQI analysis classified the industrial wastewater discharge as very poor to pollute at Baghdad South Gas Power Plant-1& Baghdad South Gas Power Plant-2 for the period 2020-2021, while it was poor to pollute at Dora Thermal Power Plant, Midland Refineries Company\ Dora Refineries and Southern Baghdad Thermal Power for the same period. WQI reached a maximum value in 2021 of 89 at Baghdad South Gas Power Plant-2 with The amount of liquid wastewater discharged into the Tigris River (m^3/h) and the cumulative amount of liquid wastewater discharged into the Tigris River (m^3/h) were approximately equal 9 & 249400.6 respectively, while in 2020 reached a maximum value of 93 at Baghdad South Gas Power Plant-1 with The amount of liquid wastewater discharged into the Tigris River (m^3/h) and Cumulative amount of liquid wastewater discharged into the Tigris River (m^3/h) were approximately equal 6 & 2493916 respectively. WQI was integrated with GIS to extract water quality levels to be accessible to decision-makers, helped to join the collected data with the sampling locations were organized in a scientific method, and became easy to be presented spatial distribution maps (i.e., colourful maps) in a corrected geographical location collectively with its spatial analysis, calculation, graphs, and outcome, it became so editable and easy to reanalyzed and updated, see Fig. 11.

Acknowledgement

The author gratefully acknowledges Eng. Zahraa Qadra Latif, Head of the Technical Department at the Ministry of Environment for her support and encouragement. Many thanks to Assistant chief chemicals Mr. Ahmed A. Hasan, director of the service activities division, Baghdad environment directorate, Ministry of Environment.

Reference

[1] N. O. Al-Musawi and F. M. Al-Rubaie, "Prediction And Assessment Of Water Quality Index Using Neural Network Model And Gis Case Study: Tigris River In Baghdad CitY," vol. 3, p. 12, 2017.
[2] V. K. Sissakian, M. F. A. Jab'bar, N. Al-Ansari, and S. Knutsson, "Meandering of Tributaries of the Tigris River Due to Mass Movements within Iraq," ENG, vol. 06, no. 11, pp. 712–730, 2014, doi: 10.4236/eng.2014.611070.
[3] S. Ali Abed, S. Hussein Ewaid, and N. Al-Ansari, "Evaluation of Water quality in the Tigris River within Baghdad, Iraq using Multivariate Statistical Techniques," J. Phys.: Conf. Ser., vol. 1294, no. 7, p. 072025, Sep. 2019, doi: 10.1088/1742-6596/1294/7/072025.

[4] A. Chabuk, Q. Al-Madhlom, A. Al-Maliki, N. Al-Ansari, H. M. Hussain, and J. Laue, "Water quality assessment along Tigris River (Iraq) using water quality index (WQI) and GIS software," Arab J Geosci, vol. 13, no. 14, p. 654, Jul. 2020, doi: 10.1007/s12517-020-05575-5.
[5] N. Nazhat Sabeeh, W. M. Sh. Alabdraba, G. Hasan Mohamed, and Z. B. Mohammed, "Water Quality Monitoring of Tigris River by Using (GIS)-Based Physicochemical Parameters in Baghdad, Iraq," IJET, vol. 7, no. 4.37, p. 57, Dec. 2018, doi: 10.14419/ijet.v7i4.37.23617.
[6] M. Kh. Mohammed, M. Sh. Naji, N. H. Ameen, and H. N. Karkosh, "Assessment of Water Quality for Tigris and Euphrates Water within Iraqi Borders," J. Phys.: Conf. Ser., vol. 1999, no. 1, p. 012152, Sep. 2021, doi: 10.1088/1742-6596/1999/1/012152.
[7] S. Ali Abed, S. Hussein Ewaid, and N. Al-Ansari, "Evaluation of Water quality in the Tigris River within Baghdad, Iraq using Multivariate Statistical Techniques," J. Phys.: Conf. Ser., vol. 1294, no. 7, p. 072025, Sep. 2019, doi: 10.1088/1742-6596/1294/7/072025.
[8] A. M. Rabee, B. M. Abdul-Kareem, and A. S. Al-Dhamin, "Seasonal Variations of Some Ecological Parameters in Tigris River Water at Baghdad Region, Iraq," JWARP, vol. 03, no. 04, pp. 262–267, 2011, doi: 10.4236/jwarp.2011.34033.
[9] A. K. Hussein, N. A. Kadhim, A. S. Jaber, and A. A. Abojassim, "Water Quality Index for Surface Water Assessment by Using Gis Techniques, Alnajaf, Kufa, Iraq," IOP Conf. Ser.: Mater. Sci. Eng., vol. 928, p. 072023, Nov. 2020, doi: 10.1088/1757-899X/928/7/072023.
[10] A. A. Bordalo, R. Teixeira, and W. J. Wiebe, "A Water Quality Index Applied to an International Shared River Basin: The Case of the Douro River," Environmental Management, vol. 38, no. 6, pp. 910–920, Dec. 2006, doi: 10.1007/s00267-004-0037-6.
[11] S. A. Abed et al., "Tigris River Water Quality Quantifying Using the Iraq Water Quality Index (IraqWQI) and Some Statistical Techniques," In Review, preprint, Apr. 2022. doi: 10.21203/rs.3.rs-1528749/v1.
[12] O. Khaleefa and A. H. Kamel, "On The Evaluation of Water Quality Index: Case Study of Euphrates River, Iraq," Kbes, vol. 2, no. 2, pp. 35–43, Aug. 2021, doi: 10.51526/kbes.2021.2.2.35-43.
[13] M. M. Noori, K. A. Abdulrazzaq, A. H. Mohammed, and A. I. Abbas, "Assessment Of Water Quality And Suitability Of Euphrates River In Iraq For Drinking Purpose By Applying Water Quality Indices (Wqis) And Geographical Information System (Gis) TechniqueS," p. 16.
[14] N. Al-Ansari, N. Adamo, and V. K. Sissakian, "Hydrological Characteristics of the Tigris and Euphrates Rivers," p. 26.
[15] M. S. Al-Hadithi, "Determination Of Groundwater And Surface Water Interaction In Baghdad City Using Isotopes Technique," p. 12, 2018.
[16] N. O. Al-Musawi and F. M. Al-Rubaie, "Prediction And Assessment Of Water Quality Index Using Neural Network Model And Gis Case Study: Tigris River In Baghdad CitY," vol. 3, p. 12, 2017.
[17] A. J. Kadhem, "Assessment of Water Quality in Tigris River-Iraq by Using GIS Mapping," NR, vol. 04, no. 06, pp. 441–448, 2013, doi: 10.4236/nr.2013.46054.
[18] N. Nazhat Sabeeh, W. M. Sh. Alabdraba, G. Hasan Mohamed, and Z. B. Mohammed, "Water Quality Monitoring of Tigris River by Using (GIS)-Based Physicochemical Parameters in Baghdad, Iraq," IJET, vol. 7, no. 4.37, p. 57, Dec. 2018, doi: 10.14419/ijet. v7i4.37.23617.
[19] A. S. Alsaqqar, A. Hashim, and A. M. Ali, "Water Quality Index Assessment using GIS Case study: Tigris River in Baghdad City," p. 7.
[20] Mayoralty of Baghdad
[21] L. Eldredge, "WAAS Performance Standard," p. 60, 2008.
[22] K.-T. Chang, Introduction to geographic information systems, vol. 4. McGraw-Hill Boston, 2008.
[23] N. O. Al-Musawi, S. K. Al-Obaidi, and F. M. Al-Rubaie, "Evaluating Water Quality Index Of Al Hammar Marsh, South Of Iraq With The Application Of Gis TechniquE," vol. 13, p. 13, 2018.
[24] M. K. AL-Taay, M. A. Abdulhafedh, and A. Y. T. Alsaffawi, "Assessment of Drinking Water Quality in Mosul University by Using WQI Model," KUJSS, vol. 13, no. 2, pp. 185–198, Jun. 2018, doi: 10.32894/kujss.2018.145758.
[25] Ministry of Environment – Department to Protect and Improvement in the Central Region.
[26] Ministry of Environment - Technical Department.