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Research Article

Assessment of Technogenic Effects on the Water Quality of Major Iraqi Rivers

Ibraheem M. Alias [1], Ayham T. Al-Rawi [2,*]

[1]Northern Technical University, Technical Institute of Mosul, Iraq (ORCID: https://orcid.org/0009-0006-6781-2021)
[2]Northern Technical University, Technical Institute of Mosul, Iraq (ORCID: https://orcid.org/0000-0002-8417-5507)

[*](atalrawi@gmail.com) Email of the corresponding author

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Abstract – Iraq's major rivers Tigris, Euphrates, Diyala, and Shatt Al-Arab are experiencing significant water quality degradation due to industrial discharge, agricultural runoff, and urban wastewater. This study assesses the water quality of these rivers using the Water Quality Index (WQI) and laboratory analyses of physical, chemical, and biological parameters. Water samples were collected from upstream, midstream, and downstream locations to evaluate spatial variations in pollution levels.
Findings reveal that while most river sections are classified as "fair," water quality deteriorates to "poor" in the Shatt Al-Arab due to high levels of total dissolved solids (TDS) and heavy metals. Urban and industrial zones exhibit higher contamination, with heavy metals surpassing permissible limits, posing risks to public health and aquatic ecosystems. Nutrient-rich agricultural runoff has also contributed to eutrophication and reduced dissolved oxygen levels. Additionally, inefficient wastewater treatment systems and weak environmental regulations exacerbate pollution.
The study underscores the urgent need for integrated water resource management strategies, including stricter pollution controls, improved wastewater treatment infrastructure, and sustainable agricultural practices. Drawing from international case studies, it recommends policy interventions and technological advancements to enhance water quality. This comprehensive assessment of technogenic pollution's impact on Iraqi rivers provides valuable insights for decision-makers, aiming to promote sustainable water management and long-term environmental conservation.

Keywords – Iraqi rivers, Pollution, Sustainable development, Technogenic factors, Water quality index (WQI)

I. INTRODUCTION

The degradation of water quality in Iraqi rivers has become a critical environmental challenge, exacerbated by urbanization, industrial discharge, agricultural runoff, and upstream water controls. These factors increase pollutant concentrations, negatively affecting water usability and public health. Although several studies have examined water pollution in Iraq, limited research has focused on the combined effects of technogenic factors and sustainable development strategies.

This study addresses this gap by evaluating the water quality of the Tigris, Euphrates, Diyala, and Shatt Al-Arab rivers, employing the Water Quality Index (WQI) alongside comprehensive laboratory analyses.

The specific objectives of this research are to assess spatial and seasonal variations in water quality, to identify key pollutants and their sources, and to propose sustainable management strategies based on international best practices.

By providing an updated assessment of Iraq's river water quality, this study aims to inform policy decisions and promote sustainable water resource management.

Water is an essential resource that plays a fundamental role in sustaining life and supporting economic development. The availability of clean and safe water is crucial for drinking, agriculture, industry, and ecosystem balance [1]. However, the increasing impact of anthropogenic activities on water quality has raised significant environmental concerns, particularly in regions where water scarcity and pollution are prevalent [2]. In Iraq, the Tigris, Euphrates, Diyala, and Shatt Al-Arab rivers serve as primary water sources for millions of people, yet these rivers are under significant threat due to pollution from industrial, agricultural, and domestic sources [3].

Water quality is commonly assessed through various physicochemical and biological parameters, including pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), total dissolved solids (TDS), total suspended solids (TSS), and heavy metal concentrations [4]. The deterioration of these indicators due to increasing pollution levels has direct consequences on human health and aquatic ecosystems [5]. Moreover, studies have shown that water pollution contributes to the spread of waterborne diseases, affecting over 80% of illnesses worldwide [6].

A significant concern in Iraq is the discharge of untreated industrial wastewater, which contains hazardous pollutants such as heavy metals, organic compounds, and toxic chemicals. These pollutants have been linked to severe health effects, including cancer and neurological disorders [7]. Furthermore, agricultural runoff containing excessive amounts of fertilizers, pesticides, and herbicides has led to nutrient pollution, resulting in eutrophication and algal blooms [8]. Additionally, rapid urbanization and inadequate waste management have contributed to the increase in solid waste and sewage discharge into rivers, further degrading water quality [9].

Globally, various nations have implemented strategies to mitigate water pollution and enhance water management. In China, advanced wastewater treatment technologies and stringent environmental policies have significantly improved the water quality of major rivers such as the Yangtze and Yellow Rivers [10]. Similarly, the European Union's Water Framework Directive has led to the successful restoration of the Rhine River by enforcing strict regulations on industrial discharge and agricultural runoff [11]. In contrast, the Mississippi River in the United States continues to face water pollution challenges due to agricultural runoff, prompting efforts to promote sustainable farming practices and precision irrigation methods [12].

The objective of this study is to assess the impact of technogenic factors on the water quality of major Iraqi rivers, identify key pollutants, and evaluate their implications for sustainable development. By utilizing the Water Quality Index (WQI) and comparing findings with national and international water quality standards, this research aims to provide a scientific basis for effective water resource management in Iraq [13]. Additionally, the study explores potential mitigation strategies, including wastewater treatment advancements, policy interventions, and sustainable agricultural practices, to ensure long-term environmental and public health benefits [14].

II. Materials and Method

This study was conducted at the Northern Technical University, Technical Institute of Mosul, in collaboration with the Iraqi Ministry of Environment, Water Quality Monitoring and Evaluation Department. The research focused on four major Iraqi rivers; the Tigris, Euphrates, Diyala, and Shatt Al-Arab which serve as primary sources for drinking water, agriculture, and industrial use. Water samples were collected from multiple sites along each river, covering upstream, midstream, and downstream sections to assess spatial variations in water quality.

The assessment was based on the Water Quality Index (WQI) and verified through laboratory analysis of chemical properties (electrical conductivity, pH, and concentrations of calcium, magnesium, sodium, sulphates, chlorides, nitrates, phosphates, heavy metal concentrations, pH), biological properties (BOD and

COD), and physical properties (TDS, TSS, and TH) [4]. Equation (1) provides the index technique used to create the WQI [13]:

$$WQI=\sum_{i=1}^{n} Q_i W_i \ldots\ldots\ldots\ldots\ldots(1)$$

Where: "Q_i" is the sub-index for water quality parameter; "W_i" is the weight associated with water quality parameter, and "n" is the number of water quality parameters. This method ranges from 0 to 100, where 100 represents perfect water quality conditions, while zero indicates water that is not suitable for the use and needs further treatment. The quality rating "Q_i" can be obtained using equation (2):

$$Q_i = \frac{100(V_i - V_0)}{S_i - V_0} \ldots\ldots\ldots\ldots (2)$$

Where: "V_i" is the actual amount of the parameter; "V_0" represents the ideal value of the parameter. (V_0=0), except for pH (V_0 = 7) and DO (V_0 = 14.6 mg/l), and "S_i" is the standard allowable value for parameter. The unit weight "W_i" is calculated using equation (3):

$$W_i=\frac{K}{S_i} \; ; K=\frac{1}{\sum\left(\frac{1}{s_i}\right)} \ldots\ldots\ldots\ldots\ldots\ldots(3)$$

III. RESULTS

The study looked at the water quality in the Tigris, Euphrates, Diyala, and Shatt al-Arab Rivers in 2022 to keep an eye on, maintain, and minimize pollution in surface water. This was done by looking at river water testing and the water quality index (WQI) as factors. The Water Quality Guide was used to check the water quality, and the examination system was compared to the standard specifications for drinking water. This is because treatment plants get their drinking water from rivers, which they filter, sterilize, and then give to people for drinking and other uses. The water supply was looked at. We took water samples from Iraq's Tigris, Euphrates, Diyala, and Shatt Al-Arab rivers. These rivers are the main supplies of water for homes, farms, businesses, and other uses, mostly as raw water for purifiers that purify drinking water. We did the following tests to find out how good the water was in the four rivers [15]:

1. pH: This measures how acidic a liquid is. The ranges for alkalinity are 7 to 14 and for acidity are 1 to 7.
2. Total Dissolved Solids (TDS): When sodium and potassium salts like chlorides, sulphates, nitrates, and phosphates are mixed, they make total dissolved salts.
3. Phosphates (PO_4) and nitrates (NO_3).
4. The amount of dissolved oxygen (DO).

A. Contrasting test findings with 1967's strategy for preventing contamination of public waterways and rivers No. (25) [3]:

Table 1. River maintenance System of 1967.

Test type	**pH**	**TDS**	**NO_3**	**PO_4**	**DO**
		mg/l	**mg/l**	**mg/l**	**mg/l**
Permissible limit	6.5 – 8.5	Depending on the river's characteristics	< 15	< 0.4	> 5

Table 2. Standard Specifications No. (471) of 2009 (Second Update).

Test type	**pH**	**TDS**	**NO_3**	**PO_4**	**DO**
		mg/l	**mg/l**	**mg/l**	**mg/l**
Permissible limit	6.5 – 8.5	< 1000	< 50	No limit	No limit

Table 3. Classification of water quality according (WQI) values.

No.	River water condition	What dose each score mean?	Colour	Range
1	Excellent	Mostly well and superb		95-100
2	Good	Pollution's effects but still resilient		80-94
3	Fair	Significantly pollution's effects		65-79
4	Bad	Severely pollution's effects		45-64
5	Very bad	Danger to indigenous species and human health		0-44

Results of the water quality analysis of the rivers (under study):

Table 4. Classification of Tigris River water quality according to (WQI) values.

Governorate	WQI	Classification
Nineveh	74	Fair
Salah Al-Din	74	Fair
Baghdad	75	Fair
Wasit	73	Fair
Maysan	75	Fair
Basra	66	Fair
Sahtt Al-Arab	63	Bad

Table 5. Classification of Euphrates River water quality according to (WQI) values.

Governorate	WQI	Classification
Anbar	77	Fair
Babil	75	Fair
Najaf	88	Good
Al-Qadisiyah	65	Fair
Al-Muthanna	56	Bad
Basra	67	Fair
Dhi Qar	68	Fair

Table 6. Classification of Diyala River water quality according to (WQI) values.

Governorate	WQI	Classification
Diyala	62	Bad

Table 7. Classification of Shatt Al-Arab River water quality according to (WQI) values.

Governorate	WQI	Classification
Basra	55	Bad

B. Contrasting test findings with 2009's Drinking Water Standard Specification No. (471) (second update) [3]:

Table 8. Classification of Tigris River water quality according to (WQI) values.

Governorate	pH	TDS mg/l	NO_3 mg/l	PO_4 mg/l	DO mg/l
Nineveh	7.7	241.5	3.54	0.035	5.49
Salah Al-Dain	7.51	343.5	3.60	0.4	9.17
Baghdad	7.205	520	4.18	0.37	9.685
Wasit	7.7	663	6	0.36	9.235
Maysan	7.65	930	7.57	0.0405	6.77
Basra	8.50	1200	0.88	0.39	7.41

Table 9. Classification of Euphrates River water quality according to (WQI) values.

Governorate	pH	TDS	NO_3	PO_4	DO
		mg/l	mg/l	mg/l	mg/l
Anbar	7.2	673	2	0.115	6
Babil	7.45	753	4.27	0.245	6.7
Karbala	7.45	962	1.495	0.009	No data
Najaf	7.06	1054.5	3.425	0.075	11.75
Al-Qadisiyah	7.8	962	3.257	0.187	5.1
Al-Muthanna	7.93	2410	7.09	0.37	7
Dhi Qar	8	2370	1.265	0.0705	14.5
Basra	8.4	1200	0.79	0.03	6.80

Table 10. Classification of Diyala River water quality according to (WQI) values.

Governorate	pH	TDS	NO_3	PO_4	DO
		mg/l	mg/l	mg/l	mg/l
Diyala	7.4	1373	2.35	0.085	4.8

Table 11. Classification of Shatt Al-Arab River water quality according to (WQI) values.

Governorate	pH	TDS	NO_3	PO_4	DO
		mg/l	mg/l	mg/l	mg/l
Basra	8.5	2340	0.70	0.24	10.64

IV. DISCUSSION

The findings of laboratory analyses of the acid function (pH), total dissolved solid salts (TDS), dissolved oxygen (DO), phosphate (PO_4), and nitrates (NO_3) are used to assess the quality of water. When water samples are compared and utilized for drinking, they must meet the standard requirements listed in (Table 1) for 1967, besides Standard Specifications No. (471) of 2009 (Second update) as shown in (Table 2):

1. Acidity function (pH): The health of humans is adversely affected by any shift in acidity. Nevertheless, it will give the body a positive charge if the acidity function is within the allowable limit (neutral). If not, it can lead to symptoms in humans such as weariness, exhaustion, and bodily fluid retention. Instead, it improves human health by promoting activity and vitality.
2. Total Dissolved Solid (TDS): These salts cause economic losses because they cause drinking water distribution pipes to corrode, and their presence in concentrations above allowable limits affects both aquatic life and humans by causing them to lose fluids from their tissues through osmotic pressure, in addition of alteration in hue and flavor, so the appropriate amount for drinking water must be less than 1000 mg/l.
3. Phosphates (PO_4) and nitrates (NO_3): Its concentrations have increased because of wastewater and cleaning fluid consumption, as well as the application of chemical fertilizers in agriculture. Its constituents are regarded as some of the fundamental components in algal growth. Because there is less dissolved oxygen in the water because of their increase, algae's growth and reproduction are impacted, which in turn affects the overall homogeneity of aquatic species.
4. Dissolved oxygen (DO): The standards in the water indicate that the amount of dissolved oxygen in the water body helps to maintain the survival of aquatic organisms. On the other hand, pollution from sewage and industrial and agricultural pollutants causes a drop in dissolved oxygen, which in turn causes a decline in aquatic life.

The (WQI-Water Quality Index) guide is used to provide a thorough assessment and summary of the tests using a standard number range from (0-100). The level of water quality is expressed by the guide's resulting value. A lower water quality indicates poor water quality, and a greater water quality indicates poor water quality. To good water quality, as demonstrated by (Table 3), which lists the water quality index-based classification of water quality.

In (Table 4) for Tigris River, shows an (fair) level of classification of the water quality of the Tigris River in Nineveh Governorate, with a value of (74). The continued classification of the river's water quality throughout its course in Salah Al-Din Governorate, with a degree of (fair) and a value of (74). The river's water quality continues to be rated as "fair" throughout its course in (Baghdad) Governorate, with a value of (75). The river's water quality continues to be rated as "fair" during its course in Wasit Governorate, with a value of (73). The stability of the river's water quality classification at a degree of (fair) with a value of (75) throughout its course in (Maysan) Governorate. The continued classification of the river's water quality at a degree of (fair) in the Basra Governorate in the north before the confluence with the Euphrates River and the formation of the Shatt al-Arab, with a value of (66).Tigris River: (Table 4) shows the increase in the concentration of total dissolved solid salts (TDS) above the specified value (1200 l/mg), as well as a relative increase in the concentration of phosphate (PO_4). The classification decreased to a degree of (poor) in the waters of the Shatt Al-Arab and a value of (63) due to the concentration of total dissolved solid salts (TDS) is higher than the specified concentration (2340 mg/l).

(Table 5) shows the Euphrates River's water quality classification in the Anbar Governorate is acceptable (with a value of 77), in the Babil Governorate, it is acceptable (with a value of 75), in the Najaf Governorate, it is good (with a value of 88), in the Al-Qadisiyah Governorate, it is acceptable (with a value of 65), and in the Al-Muthanna Governorate, it is good (with a value of 75), with an acceptable degree, with a value of (68), despite the high concentration of total dissolved solid salts (TDS) being higher than the permissible level of (2370 mg/l) in Basra Governorate in the north before its confluence with the Tigris River and the formation of the Shatt al-Arab, and with a poor degree, with a value of (56), due to the high concentration of total dissolved solid salts, crossing the permissible limit, with a value of (2410 mg/l), in Dhi Qar Governorate. With a value of (67), the categorization was deemed acceptable due to the total dissolved solid salts (TDS) concentration being higher than the allowable limit of (1200 mg/l).

(Table 6) shows that the water quality of the Diyala River in Diyala Governorate is classified as bad with a value of (62) because of the high concentration of total dissolved solid salts (TDS) in the results of tests with the standard specification above the permissible concentration of (1373 mg/l).

(Table 7) shows that Shatt Al-Arab River which is formed by the confluence of the Tigris and Euphrates rivers in the Basra Governorate in southern Iraq, the high concentration of (TDS) in test results using the standard specification exceeds the permissible concentration, reaching (2340 mg/l), classifying the water quality of the Shatt al-Arab River in Basra Governorate as (bad).

The findings of laboratory analyses of the acid function (pH), total dissolved solid salts (TDS), dissolved oxygen (DO), phosphate (PO_4), and nitrates (NO_3) are used to assess the quality of water. When water samples are compared and utilized for drinking, they must meet the standard requirements listed in (Table 2) for 2009. This classification is based on an assessment of the hydrological resource water by comparison with the following standard specifications, shown in green (Fair) and red (Unfair).

In (Table 8) shows that the water quality analysis of the Tigris River yielded positive results, the concentrations of nitrates (NO_3) and salts (TDS) within the permissible limits were found in all governorates, indicated in green, except Basra Governorate, which achieved a higher value of (1200 mg/l). The accumulation of salts from the source to the estuary was the cause of the increase in total dissolved solid salts (TDS) in the Tigris River, as this measure was exceeded in the governorates overlooking the Tigris River, both Maysan and Basra.

(Table 9) shows that the Euphrates River in the coastal governorates, all of the values for the (pH), (TDS), and nitrates (NO3) are within the allowable limits; these governorates are shown in green, except the governorates of Najaf, Al- Al-Muthanna, Dhi Qar, and Basra, which had higher values. Except for Al-Qadisiyah Governorate, which was below acceptable, all of the acceptable levels are shown in red.

For Diyala River (Table 10) shows that the readings for nitrate and acidity are within the allowed limits, which are shown in green. Total dissolved solid salt (TDS) concentrations were higher than allowable limits in the Diyala Governorate, with readings over (1373 mg/l) (shown in red) and overlooking the Diyala River.

(Table 11) shows that the values in Shatt Al-Arab River, (PO4) and (TDS) values were higher than unallowable limits by red colour, but values of (pH), (NO_3), and (DO) were within allowable limits, in the Basra Governorate, shown in green colour.

It can be said that for the years 2020/2021–2022, the results show both improvement and degradation in the water quality index (WQI) values of the river water (under study), moving through the governorates that overlook the river valley and concluding with the Shatt al-Arab River.

To compare the findings of the current study with international research on river water quality, (Table 12) highlights common pollution sources, trends, and regulatory measures, offering valuable insights for policy development in Iraq.

Table 12. Comparative analysis of water quality studies in different river systems.

Study Reference	Location	Key Findings	Similarities/Differences with Current Study
[10]	Yangtze & Yellow Rivers, China	High industrial waste and chemical fertilizer pollution, increasing heavy metals	Similar heavy metal contamination trends, but Yangtze has larger-scale industrial pollution
[5]	Ganges River, India	Industrial discharge and untreated sewage causing severe pollution	Similar contamination sources, but Ganges shows higher bacterial contamination due to poor sanitation
[7]	Mississippi River, USA	Agricultural runoff contributing to dead zones	Similar eutrophication issues, but Mississippi has more advanced nutrient management measures
[11]	Rhine River, Germany	Strict regulatory measures improved water quality	Suggests policy-driven improvements could be effective in Iraq

V. CONCLUSION AND RECOMMENDATIONS

This study has provided a comprehensive assessment of the water quality in four major Iraqi rivers; the Tigris, Euphrates, Diyala, and Shatt Al-Arab using the Water Quality Index (WQI) as a primary tool for evaluation. The findings reveal significant spatial variations in water quality across different governorates, with the Tigris and Euphrates rivers generally exhibiting "fair" to "good" water quality, while the Diyala and Shatt Al-Arab rivers are classified as "bad" due to elevated levels of total dissolved solids (TDS) and other pollutants. The results underscore the critical impact of technogenic factors, such as industrial discharge, agricultural runoff, and untreated sewage, on the degradation of water quality in these rivers. Furthermore, the study highlights the urgent need for integrated water resource management (IWRM) strategies, enhanced pollution control measures, and transboundary cooperation to address the growing challenges of water scarcity and contamination in Iraq. By implementing the recommended actions such as advanced wastewater treatment, sustainable agricultural practices, and public awareness campaigns Iraq can mitigate the adverse effects of water pollution, protect public health, and ensure the long-term sustainability of its water resources. This research contributes to the broader understanding of water quality dynamics in arid and semi-arid regions and provides a foundation for future studies aimed at improving water management practices in Iraq and beyond.

Global experiences in water pollution management, we observe that countries facing comparable challenges have implemented various strategies to mitigate water contamination.

In China, for instance, industrial and agricultural activities have significantly deteriorated the water quality of the Yangtze and Yellow Rivers. Studies indicate that the increasing use of industrial waste and chemical fertilizers has led to higher concentrations of hazardous substances such as lead and mercury, while also negatively affecting dissolved oxygen levels [10]. To address these issues, the Chinese government has adopted technology-driven approaches, including reverse osmosis and biofilm technologies, to enhance water quality.

Similarly, the Ganges River in India faces severe pollution due to the discharge of industrial waste and untreated sewage. In response, the Indian government has launched extensive initiatives, such as the

Namami Gange program, aimed at modernizing water treatment facilities and strengthening the monitoring of industrial pollution sources [5].

In the United States, agricultural runoff is a major contributor to water pollution in the Mississippi River, leading to the formation of dead zones in the Gulf of Mexico. To mitigate this issue, the U.S. has implemented water conservation measures, including promoting the use of organic fertilizers over chemical alternatives and adopting precision farming techniques [7].

A notable example of successful water quality restoration is the Rhine River in Germany, which suffered from decades of industrial contamination. The implementation of stringent regulations, such as the European Union Water Framework Directive, has significantly improved water quality by reducing pollutant levels to acceptable standards [11].

The following strategic recommendations are put forth in order to address the urgent issues of water pollution and guarantee the long-term management of Iraq's river systems:

1. Integrated Water Resource Management (IWRM):

Ensure that political entities, environmental agencies, and research institutes work together to create a national framework for sustainable water governance. Water allocation that is sustainable, wastewater treatment, and pollution control should be given top priority in this framework.

2. Enhanced Water Quality Monitoring and Pollution Control:

To quickly identify contaminants, important rivers should have real-time, continuous water quality monitoring systems in place. Reinforce industrial and agricultural discharge rules and impose harsher sanctions for noncompliance.

3. Transboundary Water Cooperation and Diplomacy:

To guarantee equitable water distribution and lessen the detrimental effects of water shortage on people downstream, negotiate international water-sharing agreements with upstream nations (Turkey, Iran, and Syria) under UN supervision.

4. Promotion of Renewable Energy in Water Management:

Encourage businesses and wastewater treatment facilities to switch to renewable energy sources like wind and solar to lessen thermal pollution and environmental damage brought on by the production of electricity from fossil fuels.

5. Advanced Wastewater Treatment and Recycling:

Invest in cutting-edge wastewater treatment technology, such as membrane filtration, bioremediation, and artificial wetlands, to enhance the quality of wastewater released into rivers and encourage the repurposing of treated wastewater in industry and agriculture.

6. Sustainable Agricultural Practices:

To reduce the use of pesticides and chemical fertilizers that increase nutrients, and to reduce pollution and water waste, organic farming, integrated pest management and efficient irrigation methods such as drip irrigation should be encouraged.

7. Rainwater Harvesting and Alternative Water Sources:

Develop large-scale rainwater harvesting and desalination projects to supplement freshwater resources, particularly in regions facing severe water shortages.

8. Public Awareness and Community Engagement:

Start national efforts to inform people about the dangers of tainted water to their health, pollution prevention, and water conservation. Encourage neighborhood-based projects to clean up riverbanks and lessen the amount of trash that is dumped into waterways.

9. Industrial Waste Management and Heavy Metal Reduction:

To reduce the amount of heavy metal pollution in waterways, enforce stronger rules for the disposal of industrial waste. Encourage industries to implement closed-loop water recycling systems and advance greener industrial methods.

10. Strengthening Environmental Laws and Enforcement Mechanisms:

Environmental regulations should be updated to conform to global water quality standards. Strict enforcement should be ensured by frequent inspections and open reporting procedures.

Iraq may address the technological effects on its river systems, protect public health, and promote long-term environmental sustainability by putting these suggestions into practice.

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