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Assessing Water Quality in the Northern Part of Shatt Al-Arab River Using the River Pollution Index

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Abstract

This study assessed water quality in the northern part of the Shatt Al-Arab River from Qurna to Al-Jazeera Al-Mohammadiyah using the River Pollution Index (RPI).Water samples were collected monthly from the six stations between October 2017 and September 2018.The RPI, calculated from the dissolved oxygen (DO), biochemical oxygen demand (BOD_5), total suspended solids (TSS), and ammonia-nitrogen (NH_3-N), ranged from 2.25 to 5.75. The lowest RPI value was recorded at Al-Shafee station in December (2.25), indicating lower pollution levels, while the highest RPI was observed at Al-Jazeera Mohammedia station in April (5.75), indicating moderate pollution. The overall average RPI for the study area was 3.55, categorizing the region as moderately polluted. Significant spatial and temporal variations in pollution levels were observed, and industrial and agricultural activities were identified as the major contributors to the pollution load.This study confirms the efficacy of RPI in monitoring river water quality and highlights the urgent need for targeted management strategies to address pollution in the Shatt Al-Arab River.

Keywords: Shatt Al-Arab River, water quality, river pollution index, Iraq, water pollution assessment

Introduction:

Rivers are a crucial freshwater resource that sustains various human activities and ecological processes.However, these vital waterbodies are increasingly polluted by anthropogenic sources such as urban runoff, industrial effluents, and agricultural discharges (Sevda et al., 2018; Everard, 2019).In Iraq, water resources have experienced significant degradation due to rapid population growth, industrialization, and agricultural expansion along the banks of the Tigris and Euphrates Rivers, which has led to the discharge of pollutants into these water bodies (Gatea, 2018).

The Shatt Al-Arab River, formed by the confluence of the Tigris and Euphrates rivers, is a vital watercourse in southern Iraq and possesses immense economic and social importance as the primary surface water source for the Basra Governorate.Water is used for a multitude of purposes, including drinking water supply, irrigation, fisheries, navigation, and industrial applications (Moyel, 2014).Furthermore, Shatt Al-Arab serves as a critical link for freshwater flow from Iraq to the Arabian Gulf, making it an essential component of the hydrological cycle of the region.

Regrettably, the Shatt Al-Arab River has been subjected to various pollution sources, primarily the discharge of untreated domestic sewage, industrial effluents, and agricultural runoff laden with fertilizers, pesticides, and other contaminants (Adlan and Al-Abbawy, 2022).These pollutants not only pose severe health risks to humans and aquatic life but also adversely impact the beneficial uses of rivers, such as water supply, recreation, and ecosystem services.

Monitoring and controlling surface water quality are imperative to ensure water suitability for human consumption, agricultural practices, and industrial operations.River water quality assessment is the primary step in the implementation of effective surface water quality management strategies (Khalili et al. 2020; Larijani 2023). The River Pollution Index (RPI) is a reliable and user-friendly tool that integrates multiple water quality parameters to provide a comprehensive assessment of river pollution levels (Bhuyan and Bakar, 2017). This study aimed to evaluate the water quality in the northern part of the Shatt Al-Arab River using the RPI, thereby providing crucial information for decision makers and stakeholders to develop appropriate management strategies and safeguard this vital water resource.

By focusing particularly on the northern part of the Shatt Al-Arab River, an area that has not received sufficient attention in prior studies, this study contributes to the body of the current material.This study evaluates water quality as it is now, but it also finds important sources of contamination and trends over time using the RPI.This information is essential for stakeholders and decision-makers to create focused management plans.This study also advances the field of water quality evaluation and management by offering a methodological framework that may be used in other areas with comparable problems.

2.Materials and Methods

Study Area:

The study area is located within the boundaries of Basra Province and encompasses the northern part of the Shatt Al-Arab River, which originates from the confluence of the Tigris and Euphrates rivers in the northern region of Basra.The river then flows southward for approximately 200 km before being discharged into the Arabian Gulf.The northern part of the Shatt Al-Arab River is characterized by rural agricultural areas and is less affected by salinity intrusion from the Arabian Gulf than the southern part, which exhibits a higher population density and agricultural activities.

Sampling Locations:

Six sampling stations were selected along the northern part of the Shatt Al-Arab River considering the different anthropogenic activities in the vicinity (Table 1, Figure 1).These stations were chosen to represent various potential pollution sources, including boating activities, oil fields, power plants, and human settlements.

Table1. Position of Shatt Al-Arab River stations during the study period

Station name	Station number	GPS positions	Activities
Qurna	1	N: 31° 00' 2.1" E: 47° 27' 17.5"	Boats
Shafee	2	N: 30° 51' 13.1 " E: 47° 32' 28.8"	Boats
Deir	3	N: 30° 48' 14.8" E: 47° 34' 52.5"	Boats

Nahran omar	4	N: 30° 45' 28.4" E: 47° 39' 29.6"	Oilfields
Hartha	5	N: 30° 40' 40.14 " E : 47° 45' 30.9"	Powerplant
Mohammedia Island(Jazeera)	6	N : 30° 36' 32.55 " E : 47° 45' 45.2"	Powerplant and Human activity region

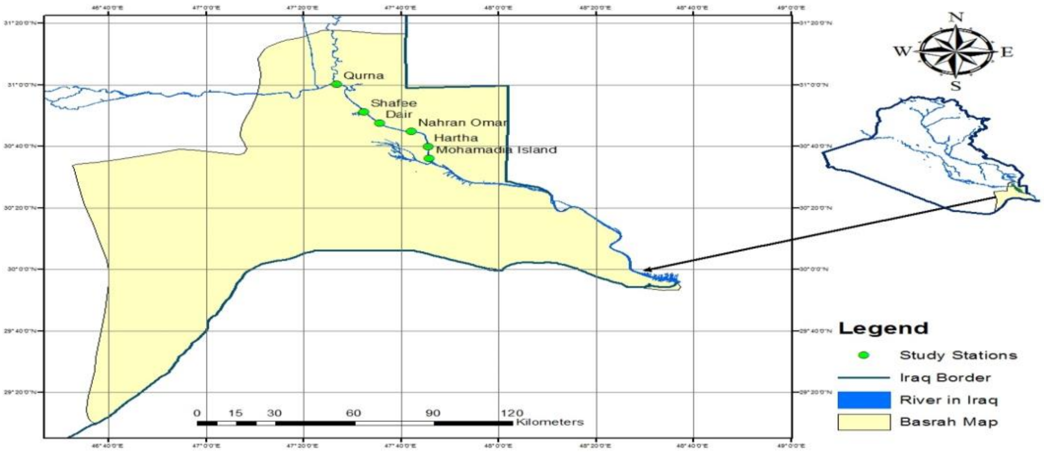

Figure 1. Map of the Study area

Sample Collection and Analysis

Water samples were collected monthly during the reflux period, from October 2017 to September 2018, at six designated sampling stations along the northern part of the Shatt al-Arab River.Sampling stations were strategically selected to represent various potential pollution sources, including areas affected by boating activities, oil fields, power plants, and human settlements.

Standard methods outlined in the American Public Health Association guidelines (APHA, 2005) strictly adhere to sample collection, transportation, and preservation to ensure data reliability and consistency.Water samples were collected in pre-cleaned 1-liter polyethylene bottles, which were rinsed three times with river water before sample collection.Samples were collected 30 cm below the water surface to avoid surface contamination.Field measurements of the temperature and pH were conducted on-site using calibrated portable meters.

The collected samples were immediately stored in a refrigerated box maintained at 4°C to preserve the integrity of the samples and to minimize biological and chemical changes during transportation to the laboratory.A chain of custody forms was used to track sample handling and transfer.

In the laboratory, the following physical and chemical parameters were analyzed within 24 h of sample collection.

1. Dissolved Oxygen (DO) was measured using a US-made EXTECH apparatus (Model DO700) with a precision of ±0.2 mg/L.The probe was calibrated before each use following the manufacturer's instructions.
2. Biochemical Oxygen Demand (BOD_5): Determined using the 5-day BOD test, as described by APHA (2005).The samples were incubated at 20°C for 5 days, and the difference in the dissolved oxygen concentration was measured.

3. Total Suspended Solids (TSS): Analyzed following the APHA (2005) guidelines using the gravimetric method.The samples were filtered through pre-weighed glass fiber filters, dried at 103-105°C, and weighed to determine the TSS concentration.
4. Ammonia-Nitrogen (NH_3-N) was quantified according to the method outlined by APHA (2005), using the Nessler method.A spectrophotometer was used to measure the intensity of the yellow color that developed after the addition of Nessler reagent.

Quality control measures were implemented during the sampling and analysis process.These included the use of field blanks, laboratory blanks, and duplicate samples to assess the potential contamination and analytical precision.All laboratory equipment was calibrated regularly, and standard solutions were freshly prepared for each analysis.

Calculation of the (RPI): The RPI was calculated based on four measured parameters (DO, BOD5, TSS, and NH3-N) using the following equation (Liou et al., 2004; Chen et al., 2012):

$RPI = (1/4) \Sigma Si$

Where Si represents the indicator category determined based on the criteria presented in Table 2. Si values were assigned based on the concentration ranges for each parameter, with higher values indicating higher pollution levels.

The RPI values were then classified into four categories to assess overall water quality in the study area.

- Good ($RPI < 2$)
- Less Polluted ($2 \leq RPI < 3$)
- Moderately Polluted ($3 \leq RPI < 6$)
- Highly Polluted ($RPI \geq 6$)

This classification system allows for a straightforward interpretation of the water quality status and facilitates comparisons between different sampling locations and time periods.

Data Analysis: In addition to the RPI calculation, statistical analyses were performed to identify the spatial and temporal trends in water quality parameters.These included descriptive statistics, analysis of variance (ANOVA) to test for significant differences between sampling stations and months, and correlation analysis to examine the relationships between different water quality parameters.

By conducting monthly sampling over a one-year period and analyzing key water quality parameters, this study provides a comprehensive assessment of pollution levels along the northern section of the Shatt al-Arab River. The use of the RPI allows for a standardized evaluation of water quality, enabling comparison with other studies and facilitating the development of targeted management strategies for this vital water resource.

Statistical Analysis

Statistical analysis included descriptive statistics for water quality parameters across all stations and months. Two-way ANOVAs was used to examine the effects of location and time on the parameters and RPI, with post-hoc Tukey's HSD tests for significant results.A time series analysis was conducted to identify trends and seasonal patterns in the water quality parameters and RPI over the study period.

3. Results and Discussion

3.1. Measured Physical and Chemical Properties of Water in the Northern Shatt al-Arab

Table 2 displays the average values and standard deviations of four water quality parameters (BOD, DO, NH_4, and TSS) measured at six different stations (Hartha, Mohammedia Island,

Nahran Omar, Deir, Qurna, and Shafee). In addition, it provides an average for each parameter across all stations.
Mohammedia Island had the highest average BOD (2.79 mg/L) and NH4 (75.92 mg/L), suggesting potential pollution. Nahran Omar has the highest average DO (7.78 mg/L), indicating good water quality. Qurna has a notably high average TSS (38.35 mg/L), raising concerns about suspended solids. Overall, the table provides a snapshot of the water quality at these stations, highlighting potential pollution concerns at Mohammedia Island and the high suspended solids at Qurna.Given that the data appear to be aggregated in the correct format, they can be used directly to create the markdown table.

Biochemical Oxygen Demand (BOD) measures the amount of dissolved oxygen consumed by microorganisms during the decomposition of organic matter in water, with higher values indicating more organic pollution. Dissolved Oxygen (DO) is the amount of Oxygen available in water for aquatic life, where higher values are generally better. Ammonium (NH_4) is a form of nitrogen that can be used as an indicator of pollution from sources, such as sewage or fertilizers.The Total Suspended Solids (TSS) measure the concentration of suspended particles in water and can affect water clarity and quality.

Table2:Annual mean of Physical and chemical parameters of Shatt Al-Arab River

Station	**BOD (mg/L)**	**DO (mg/L)**	**NH4 (mg/L)**	**TSS (mg/L)**
Hartha	1.45	6.77	64.29	2.24
MohammediaIsland (Jazeera)	2.79	7.12	75.92	1.6
Nahran Omar	1.63	7.78	56.73	1.27
Deir	2.37	7.43	61.42	1.79
Qurna	1.54	7.46	1.91	38.35
Shafee	1.54	7.76	38.35	1.91
Average	1.89	7.39	49.77	7.86

3.2. Monthly Changes in RPI Values

Figure 2 illustrates the monthly changes in the river pollution index (RPI) values at the study stations. The results demonstrated clear monthly and spatial variations in the RPI values throughout the study period.At Shafee station, the index values decreased from October to June, which was related to a reduction in the values of the contributing parameters.The period from January to March was characterized by a decrease in RPI values at the Qurna, Shafee, Nahr Omar, and Hartha stations due to an increase in dissolved oxygen levels, a decrease in biological oxygen demand values, and a reduction in total suspended solid concentrations during that period. These stations were classified as "Less Polluted" based on the RPI categories (Figure 2). Generally, higher dissolved oxygen levels in surface waters indicate better environmental quality (McKinsey & Chapman, 1998; Chiu et al., 2023).

The high RPI values at the study stations from April to September were accompanied by elevated levels of index parameters.The highest RPI value was recorded in April at Al-Jazeera Al-Mohammadiya station, which can be attributed to the high percentage of total suspended matter due to dust storms coinciding with the time of sample collection and rainfall events that led to the resuspension of particulate matter (field observation).Lai and Kao (2013) demonstrated that suspended matter plays a crucial role in the calculation of the RPI, along with the current velocity, as the Shatt Al-Arab River flows from north to south (Lateef, 2020).The spatial variations in the RPI values during the seasons of the year showed the lowest values in the winter season at the Al-Shafee station because of the improved conditions of the variables contributing to the index, whereas the highest values were observed during the spring season at the Nahran Omar station.

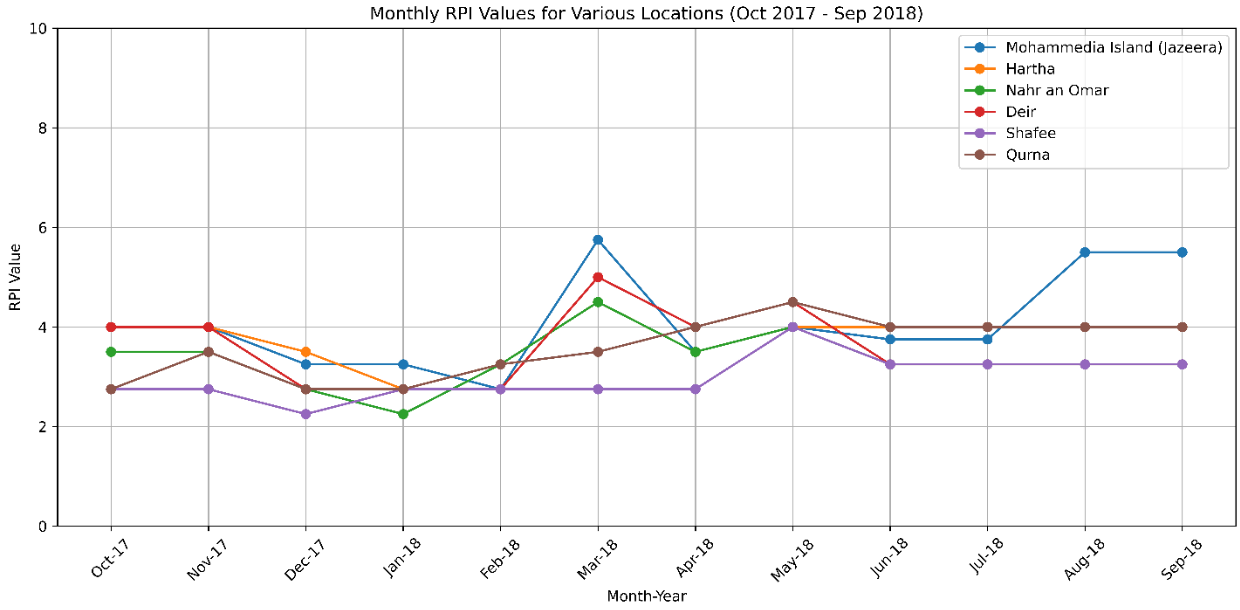

Figure 2 illustrates the monthly variations in river pollution index values at the study stations.

3.3. Annual Changes in RPI Values

Average annual RPI values varied across the study stations (Figure 3). The Qurna, Al-Deir, Nahran Omar, Al-Hartha, and Al-Jazeera Al-Mohammadiyah stations exhibited similarities in the classification category but with different RPI values. This variation can be attributed to the impact of the Qurna station on the observed changes and deterioration of water quality due to the decreased water levels received from its main tributaries and the complete closure of the Euphrates River with the Khamissiya Dam.Qurna station was affected by untreated sewage, agricultural waste containing fertilizers and pesticides, and a large number of human activities in the area, leading to its classification as "Moderately Polluted" according to the RPI categories.

The classification of the Deir and Nahran Omar stations as "Moderately Polluted" may be due to the influence of liquid waste from livestock herds near the river as well as boating activities and movements.The Shafee station exhibited lower RPI values compared to the other study stations and was classified as "Less Polluted" (Table 1) owing to the dilution effect of the Shafee stream, thereby reducing the impact of pollutants.

The RPI values increased at Al-Hartha station because of its proximity to a thermal power plant and the influence of discharges from this facility, which relies on water as a primary source for cooling.The highest RPI values were recorded at the Al-Jazeera Al-Muhammadiyah station because of its proximity to residential communities and the influence of untreated sewage, as well as the impact of fish farming waste from cages located in the area (field observation).These factors contribute to oxygen consumption, an increase in biological oxygen demand, and a subsequent increase in the RPI values.Additionally, the movement of boats and fishing activities in the area further exacerbated the increase in pollutant concentrations.

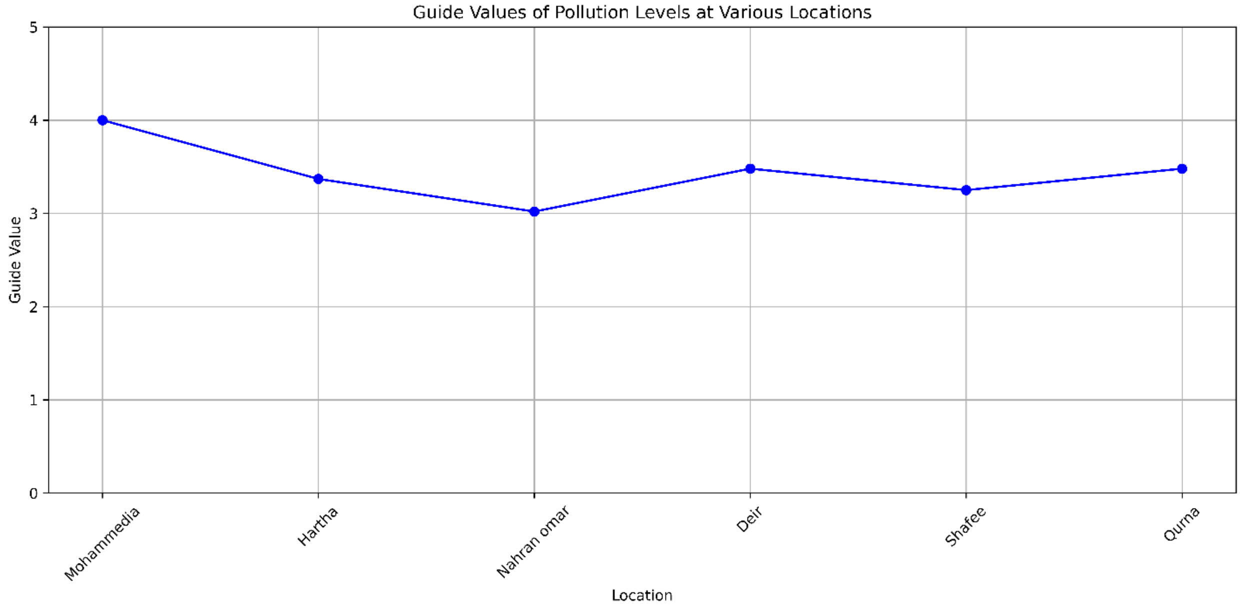

Figure3 Annual averages of RPI at the study stations and Shatt al-Arab (northern part) from October 2017 to September 2018

4. Conclusions

The effectiveness of the River Pollution Index (RPI) in assessing pollution levels and water quality of the northern Shatt Al-Arab River was confirmed in this study. According to the RPI classification, the river is classified as "Moderately Polluted" based on the RPI values found in this study. It is crucial to recognize that the RPI is a single indicator and might not fully convey the intricacy of the ecological health of the river.A more thorough understanding of the state of the river might be possible with long-term monitoring and other biological and chemical markers included in future studies.However, the RPI provides a useful foundation for determining problem regions, setting priorities for action, and directing management plans to safeguard this essential freshwater resource.The long-term health and resilience of the ecosystem around the Shatt Al-Arab River depends on focused initiatives to reduce pollution sources and encourage sustainable behaviors, which this study emphasizes are essential.

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