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ENVIRONMENTAL ASSESSMENT OF AL-HILLAH RIVER POLLUTION AT BABIL GOVERNORATE (IRAQ)

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Abstract: In this study, the environmental characteristics of Al-Hillah River were studied using geoinformatics applications, which is one of the geospatial techniques (GST). Applying this methodology, a geographic information system was developed, and it was supplied with laboratory data for the physical and chemical properties of 16 parameters for 2021. These data were linked to their spatial locations, using radar imagery of the Digital Elevation Model (Shuttle Radar Topography Mission), and Landsat ETM+7 satellite image. The results indicated that Al-Hillah River was affected by the liquid discharges of factories, cities, and farms spread on its sides, especially in the cities of Sadat Al-Hindiya, Al-Hillah, and Al-Hashimiyah. The seasonal changes in the climate affected some characteristics, including water temperature, pH, turbidity, total dissolved solids, and total hardness. The study showed that the concentration of sulfate (SO_4) has risen above the permissible limits for the waters of Iraqi rivers. There are relatively high hardness and alkalinity values, but they were within the permissible limits. The study also showed that most of the results of environmental parameters that were used in the laboratory, were within the permissible limits of Iraqi water, except for sulfates. The justification for conducting this study is to help government agencies and decision-makers to adopt a correct vision for development projects that serve Babil Governorate. Also, it is the first time that the environmental characteristics of Al-Hillah River are studied using geoinformatics applications.

Keywords: environmental modeling; spatial analysis; water pollution; Al-Hillah River

1. Introduction

Freshwater resources are indispensable, and important for supporting habitats, maintaining hydrological balance, and securing the needs of human societies for multiple uses (El-Zeiny

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& El-Kafrawy, 2017; Y. Li et al., 2022). Water pollution is one of the crucial environmental problems at the global level (Balla et al., 2022). International studies conducted in universities and advanced research centers indicate that industrial settlements, agricultural areas, and urban population centers in cities are the most important sources of river pollution (Oseke et al., 2021). The above-mentioned human activities mainly affect the quality of surface water resources, due to the discharge of effluents containing industrial chemicals, fertilizers, and agricultural pesticides, as well as the high concentration of chemicals in wastewater (Milijašević Joksimović et al., 2018; Yan et al., 2015). It has become necessary for humans to act with a high level of responsibility toward environmental systems to preserve and sustain them (Ethaib et al., 2022).

The Tigris and Euphrates, as well as Al-Hillah rivers in Iraq, are reflecting a clear image of the recent rise in human activities in the environment in which they live, especially with the aquatic system. The Iraqi rivers, including Al-Hillah River, suffer from an increase in pollutants, especially in recent years (Hassan et al., 2017). The number of factories, cultivated land, used fertilizers, population, and urban development has increased significantly. This increase led to an increase in the pollutants raised especially liquid ones (Al-Suhili & Al-Mansori, 2017). Moreover, agriculture uses fertilizers and pesticides, which raise the concentrations of nitrate, phosphate, and heavy metals in water bodies degrading the water quality (Y. Li et al., 2022). Population growth leads to an increase in water demand and pollution (Al-Mansori, 2017). As a result, the aquatic ecosystem may be endangered if water resources are not managed more effectively (Obais & Al-Fatlawi, 2012). The assessment of water quality, which also aims to determine the types and sources of pollutants in water, suggests a strategy for sustainable water management, improving human health, and other economic and social challenges (Son et al., 2020).

Humans have partial responsibility for water scarcity and its vulnerability to pollution (Al-Ani, 2019; Maaroof et al., 2021). Human activities are among the most important sources of pollution in the aquatic environment (Salman et al., 2013). The problem statement is defined by comprehending the characteristics of the spatial relationship between the diverse human activities placed on the two banks of the Al-Hillah River. The significance of geoinformatics application is in creating geodatabases by constructing geo-environmental models based on laboratory data, field monitoring, remote sensing information (satellite and radar images), and topographic maps.

Multiple studies investigated the physical and chemical properties of Al-Hillah River that are affected by human activities. Salman et al. (2013) studied bacterial indicators in the water and sediments of Al-Hillah River. Manii and Saud (2018) studied the contamination of the sediments of Al-Hillah River with heavy metals using pollution indicators. Al-Suhili and Al-Mansori (2017) studied some parameters of the water quality of Al-Hillah River using iterative analysis. According to a study by Manea et al. (2019), heavy metals were detected in the soil and sediments of the Al-Hillah River by environmental geochemical evaluation. All these studies, and many others, dealt with the environmental characteristics and water quality indicators of Al-Hillah River, using laboratory and field methods. There is no previous study on this subject using geoinformatics applications.

The objectives of the research are to identify the characteristics of the various human activities established on the banks of Al-Hillah River and related to water pollution in it. As a result, research of novel techniques for identifying pollution sources and for assisting in the creation of a sustainable river management system found the potential for employing geographic information systems to create a geo-environmental model of Al-Hillah River's affected by pollution.

2. Study area

Al-Hillah River is located in the Babil Governorate, which is one of the governorates in central Iraq within the region of Middle Euphrates between longitudes 44°16′11.9″E–44°46′31.5″E and latitudes 32°03′14.5″N–32°43′44.3″N as shown in Figure 1 (Alkawaz & Al-Zubaidi, 2020). The river flows through several districts and sub-districts, namely Sadat Al-Hindiya, Al-Hillah, Al-Hashimiyah, Al-Medhatiya, and Al-Shomali district, and ends in Al-Qadisiyah Governorate (Manii & Saud, 2018). Al-Hillah River branches off from the Euphrates at 602 km, within the territory of the Babil Governorate, at 300 m from the front of Al-Hindiya dam (Alkawaz & Al-Zubaidi, 2020). Al-Hillah River extends for a distance of 104 km towards the southeast in line with the slope of the area’s surface and it ends at the administrative border between the provinces of Babil and Al-Qadisiyah as illustrated in Figure 2 (Manii & Saud, 2018).

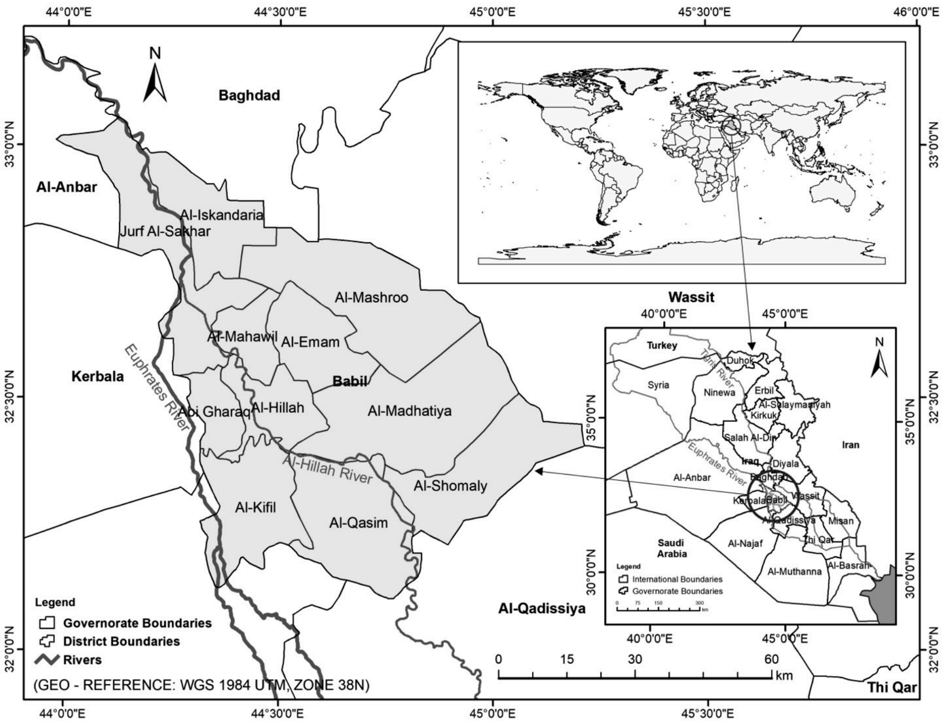

Figure 1. The location of Al-Hillah River at the Babil Governorate.

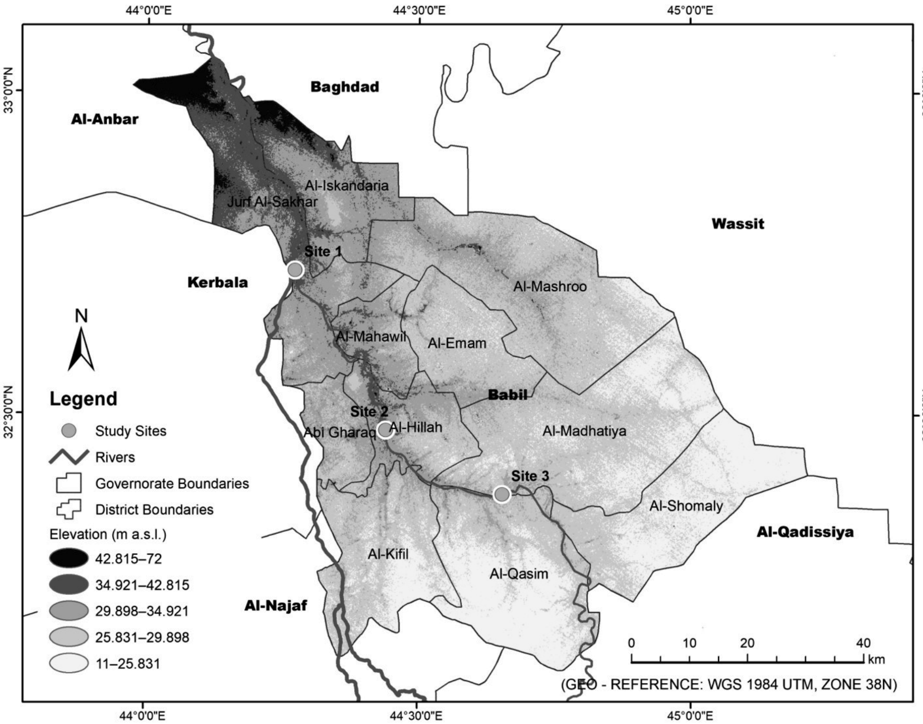

Figure 2. Study sites of Al-Hillah River course at Babil Governorate.

Table 1. Coordinates and description of the study sites

Sites	Coordinates		Elevation (m a.s.l.)	Description
	Longitude	Latitude		
Site 1	44°16′19.9″E	32°43′31.8″N	31.77	Sadat Al-Hindiya town is located on the Euphrates River in Iraq, and part of Al-Hillah River at the beginning of its branching from the Euphrates River, to the south of Al-Musayyib city and 80 km south of Baghdad, with a population of 33,900 as of 2018. This site collects the liquid waste of residential neighborhoods and agricultural areas.
Site 2	44°26′24.2″E	32°28′39.9″N	29.60	Al-Hillah city is located in central Iraq on Al-Hillah branch of the Euphrates, 100 km south of Baghdad, has an estimated population of about 970,000 in 2015, and is the capital of the Babil Governorate. This site collects the liquid waste of the old residential neighborhoods, the city's grand market, and the Marjan Hospital.
Site 3	44°39′14.5″E	32°22′42.3″N	26.30	Al-Hashimiyah town is located in the south of Babil Governorate—Iraq, 130 km south of Baghdad. This site collects liquid waste from residential neighborhoods and agricultural areas.

Note. From *Central Statistical Organization Iraq (CSO)* by CSO, 2023, (https://www.cosit.gov.iq/ar/1129-aas). In the public domain.

3. Data and methodology

There are many human activities of water including industrial, agricultural, and urban on both sides of Al-Hillah River (Aziz & Al-Robai, 2012). These uses lead directly or indirectly to pollution of the river (Al-Suhili, 2018), discharging large quantities of wastewater into the river, its source factories, farms, and cities. It is possible to study Al-Hillah River and identify the properties of the pollutants and their sources by collecting water samples from the middle of the river at a depth of 15 cm, from three sites along the river in 2021 (Table 1) and (Figure 2 and 3). These samples were examined in the laboratory, according to 16 parameters (Table 2), and the pollution rates were identified according to the limitations of Regulation No. 25 on the preservation of rivers and public waters from pollution (1967). Land uses on both sides of the river was determined by using geoinformatics techniques, Geographic Information Systems (GIS), Remote Sensing (RS), and GPS, as shown in Figure 4.

Table 2. Parameters used to measure Al-Hillah River samples

Parameters	Symbol	Normal limit	Unit
Water temperature	WT	35	°C
Electrical conductivity	EC	2000	μS/cm
Total dissolved solids	TDS	1500	mg/l
Turbidity	Turb	10–18	NTU
pH	pH	6.5–8.5	-
Dissolved oxygen	DO	5	mg/l
Phosphate	PO_4	0.4	mg/l
Nitrate	NO_3	15	mg/l
Calcium	Ca	200	mg/l
Magnesium	Mg	50	mg/l
Sodium	Na	200	mg/l
Potassium	K	20	mg/l
Total hardness	TH	500	mg/l
Sulfates	SO_4	300	mg/l
Chloride	Cl	200	mg/l
Total alkalinity	TA	200	mg/l

A spatial database of Al-Hillah River was created by developing a geo-environmental model within the GIS environment by analyzing Landsat 7 satellite image with a resolution of 15 m for the American satellite for the year 2021 issued by the U. S. Geological Survey (n.d.). The study area's Digital Elevation Model, type Shuttle Radar Topography Mission, which was downloaded from the EarthExplorer web application (U. S. Geological Survey, n.d.), had a spatial resolution of 30 m. Moreover, topographic maps were used on a scale of 1:50,000 and 1:100,000 issued by the Iraq Geological Survey (n.d.) in 1990. Spatial matching (overlay) is an important way to understand the overlapping spatial complex (Maaroof & Kareem, 2020). Through the materials mentioned above, spatial models were built that lead us to understand the spatial overlapping relationships that which is applied to Al-Hillah River pollution—the main water resource for the residents of Babil Governorate (Laniak et al., 2013; Maaroof, 2022). To build the geo-environmental model of Al-Hillah River, the following geographic information programs were used: ArcGIS Pro (Version 2.8), ArcGIS Desktop (ArcMap and ArcScene; Version 10.8), ArcGIS Earth (Version 1.10), QGIS (Version 3.12.1), Global Mapper (Version 11), Surfer (Version 21), and SAS.Planet (Version 19.1).

The water temperature was monitored at the study sites during the sampling period using a multimeter in certain laboratory tests, manufactured by HANNA Instruments. A multimeter device was also used to measure pH after calibrating the device with calibration solutions to measure water samples directly in the field. The same device above was the multimeter used to measure electrical conductivity directly in the field. The total dissolved solid was measured using a meter made by HANNA Instruments (Walker & Ullery, 2002). The acid modifying method also used the Winkler method to measure dissolved oxygen in the water. Placing the bottle in an inclined position of about 10 cm, sealing the bottle inside the water, and adding 1−2 ml of aqueous manganese sulfate solution were the steps used to fill transparent bottles directly from the place where the Winkler was used. After one minute 1–2 ml of alkaline iodide reagent was added with a good shake, then 1–2 ml of sulphuric acid was added to finish dissolving. Total alkalinity was measured by titrating 100 ml of water sample with sulfuric acid (0.02 N) after adding methyl orange and phenolphthalein as reagents (Clesceri et al., 1999).

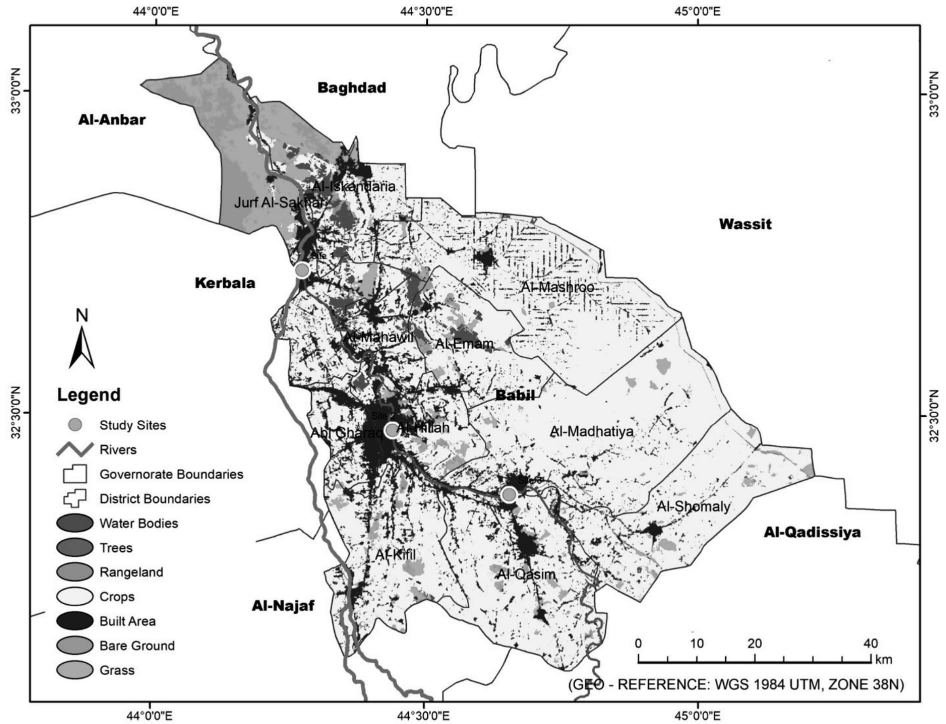

Figure 3. Land Use Land Cover of Al-Hillah River course at Babil Governorate.

4. Results and discussion

4.1. Physical properties

4.1.1. Water temperature

The water temperature during the study period ranged from 33.5 °C in September at site 1 which is the highest value, to 14 °C in March at site 2 which is the lowest value (Figure 4).

Seasonal changes in water temperature were evident due to changes in air temperature during the seasons (Al-Akam & Manii, 2021). It reached its maximum during summer and autumn 28.1 °C in site 1, while the lowest value was 19.6 °C during the winter for the same site (Table 3). The rest of the values depended on the seasonal variation of the climate of the study area.

4.1.2. Electrical conductivity

This value depends on the concentration and quality of ions present in the water and the temperature of the water (Thirumalini & Joseph, 2009). The values of this parameter ranged from 927 to 1,228 μS/cm during the study period (Figure 4 and Table 3). The lowest value was recorded in site 3 and reached 927 μS/cm during March. The highest value was recorded in site 2 and reached 1,228 μS/cm in December. The rise in site 2 is due to the wastewater and industrial waste that contains high concentrations of table salt, which causes a rise in the electrical conductivity values.

4.1.3. Total dissolved solids

Among the factors causing the increase in the concentration of total dissolved solids in Al-Hillah River are natural hydrological processes, untreated municipal water, industrial water, irrigation water, and rainfall (Al-Mansori, 2015). The highest value of this parameter was 789.5 mg/l during December in site 2, and the lowest value was 601.4 mg/l during January for the same site (Figure 4 and Table 3). The increase in total dissolved solids values during the winter season is attributed to the increase in runoff of water accompanied by an increase in the concentration of soluble salts, as well as fertilizers, untreated wastewater, sewage, decaying plants, and dead animals, and erosion of river banks.

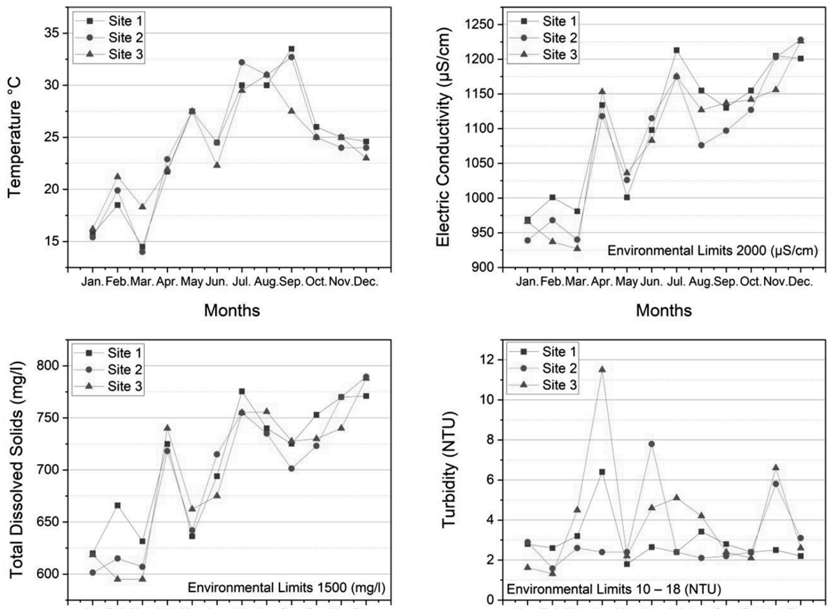

Figure 4. Average monthly values of water temperature, electrical conductivity, total dissolved solids, and turbidity at the study sites on Al-Hillah River.

Table 3. The physical properties of Al-Hillah River at study sites, average seasonal and annual values

Parameters	Seasons				Annual
	Winter	Spring	Summer	Autumn	
Site 1					
Water temperature	19.6	21.2	28.1	28.1	24.2
Electrical conductivity	1,057	1,038	1,155	1,163	1,103
Total dissolved solids	685	664.2	736.5	749.4	708.7
Turbidity	2.5	3.8	2.82	2.5	2.9
Site 2					
Water temperature	19.7	21.4	29.2	27.2	24.3
Electrical conductivity	1,045	1,028	1,122	1,142	1,084
Total dissolved solids	668.6	655	735	731.4	697.5
Turbidity	2.5	2.4	4.1	3.4	3.1
Site 3					
Water temperature	20.1	22.5	27.6	25.8	24
Electrical conductivity	1,043	1,038	1,128	1,145	1,088
Total dissolved Solids	667.1	665.8	728	732.5	698.3
Turbidity	1.84	6.06	4.6	3.7	4.05

4.1.4. Turbidity

The results indicated that the highest turbidity value was 11.5 NTU in site 3 during April, and the lowest value was 1.58 NTU in site 2 during February (Figure 4 and Table 3). The reason for the increase in turbidity in the waters of Al-Hillah River in all the study sites during the spring season is attributed to a group of factors, foremost of which are dust storms that bring large amounts of dust. Also, the high temperature in this season leads to melting snow and an increase in the volume of discharge to the Euphrates River, including Al-Hillah River. This results in further soil erosion in nearby watersheds, as well as the impact of untreated wastewater and suspended solids.

4.2. Chemical properties

4.2.1. pH

The water bodies in Iraq are characterized by pH values close to eight, which is an indication of the presence of carbonates and bicarbonates (AbdAl-Hussein, 2015). The results indicate that the pH values of the study sites ranged from 6.3 to 8.2 mg/l, where the lowest value was recorded in site 3 during December. The highest value was in the same site in September (Figure 5). It can also be noted the variation in pH values during the seasons, increases in the summer and autumn seasons, and decrease in the winter and spring seasons for all locations (Table 4).

For all sites, the pH value tended to be alkaline throughout the study period, and the monthly changes in the values were minimal (Al-Suhili & Al-Mansori, 2017). High acidity during summer and autumn, mainly is caused by the rate of photosynthesis due to the dense blooming of phytoplankton and this leads to the consumption of large amounts of carbon dioxide in the water. The pH values decrease during the winter and spring seasons due to precipitation. The concentration of carbon dioxide in wastewater and biodegradation products of organic matter increases acidity and thus decreases the pH value.

4.2.2. Dissolved oxygen

The concentration of dissolved oxygen in the water is one of the indicators of the state of the water body (Al-Ani, 2019). It is necessary for all living organisms and for the chemical processes that occur in the water (Kannel et al., 2007). Its annual average concentration in the study sites was 8.1, 8.07, and 7.4 mg/l, respectively (Table 4). Its values ranged during the months between 5 mg/l in site 3 during October, which is the lowest value, and 11.1 mg/l in site 2 during April, which is the highest value (Figure 5). The decrease in dissolved oxygen values during September and October for all sites is due to the high-water temperature resulting from the high air temperature, which led to the expulsion of dissolved gases. Concentrations of organic matter, bacteria, and other microbes in wastewater are rising. This in turn increases the decomposition processes, resulting in the consumption of dissolved oxygen in the water. There is an increase in dissolved oxygen levels in May in all sites. This may be due to the high concentration of phytoplankton recorded during this period. As a result, photosynthesis increases and oxygen values increase.

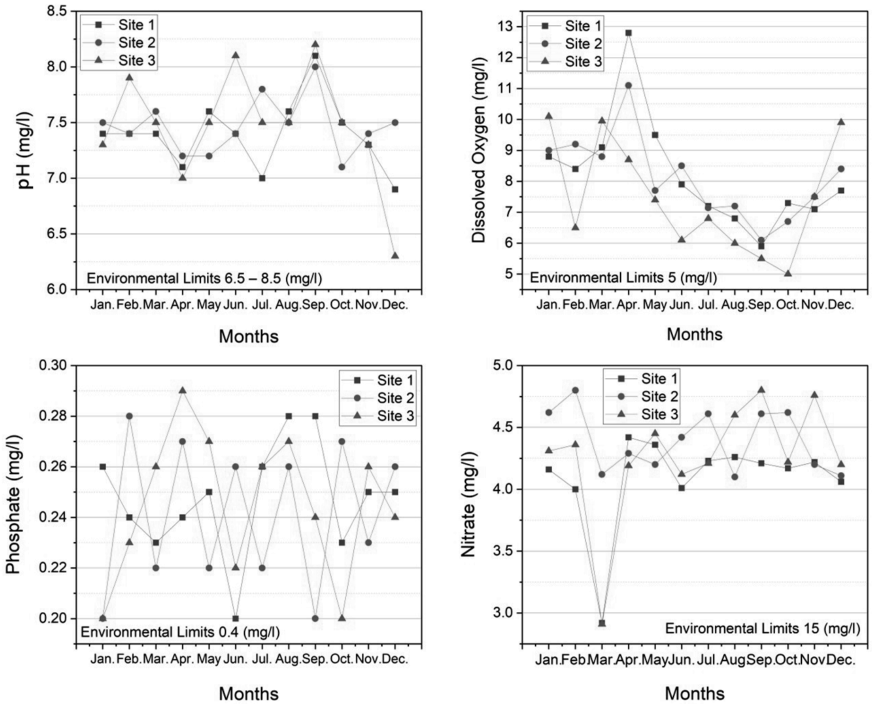

Figure 5. Average monthly values of pH, dissolved oxygen, phosphate, and nitrate at the study sites on Al-Hillah River.

Table 4. The chemical properties of Al-Hillah River at the study sites, average seasonal and annual values

Parameters	Seasons				Annual
	Site 1				
	Winter	Spring	Summer	Autumn	
pH	7.2	7.3	7.3	7.6	7.35
Dissolved oxygen	8.3	10.4	7.3	6.7	8.1
Phosphate	0.25	0.24	0.24	0.25	0.24
Nitrate	4.07	3.9	4.16	4.2	4.08
Calcium	83.6	85.3	110.3	110.7	97.4
Magnesium	34.9	33.7	33.1	39.5	35.3
Sodium	67.7	69.2	64.9	71.2	68.2
Potassium	3.7	3.8	4.1	3.9	3.8
Total hardness	362.7	364	425.9	444.5	399.2
Sulfates	333.1	325.3	313.9	347.5	329.9
Chloride	110.8	112.2	113.1	120.2	114.07
Total alkalinity	92	116	106	99	103
	Site 2				
Parameters	Seasons				Annual
	Winter	Spring	Summer	Autumn	
pH	7.4	7.3	7.5	7.5	7.4
Dissolved oxygen	8.8	9.2	7.6	6.7	8.07
Phosphate	0.24	0.23	0.24	0.23	0.23
Nitrate	4.51	4.2	4.3	4.4	4.3
Calcium	88.6	93.03	112.8	111.4	101.4
Magnesium	36.08	33.8	32.1	35.4	34.3
Sodium	70.9	65.9	60.7	69.6	66.7
Potassium	3.7	3.5	3.5	3.8	3.6
Total hardness	369.7	367.7	414.1	420.3	392.9
Sulfates	331.4	342	324.4	323.9	330.4
Chloride	105.8	116.7	105.8	116.8	111.2
Total alkalinity	106	113	98	108	106
	Site 3				
Parameters	Seasons				Annual
	Winter	Spring	Summer	Autumn	
pH	7.1	7.3	7.7	7.6	7.4
Dissolved oxygen	8.8	8.6	6.3	6	7.4
Phosphate	0.22	0.27	0.25	0.23	0.24
Nitrate	4.29	3.85	4.31	4.5	4.2
Calcium	88.8	88.1	110.9	114.7	100.6
Magnesium	33.1	31.8	29	35.1	32.2
Sodium	76.3	69.03	56.8	67.7	67.45
Potassium	3.8	3.9	3.4	3.6	3.6
Total hardness	362.5	358.6	405.5	438.9	391.3
Sulfates	332.7	362.1	332.8	335.7	340.8
Chloride	114.3	117.4	101.2	119	112.9
Total alkalinity	104	110	91	98	100.75

4.2.3. Phosphate

An increase in its percentage leads to an overgrowth of algae and other aquatic plants, which leads to the phenomenon of eutrophication (Isiuku & Enyoh, 2020). Domestic sewage and agricultural effluents with fertilizers and industrial wastewater are the main sources of phosphorus, as high phosphorous concentration indicates pollution (Isiuku & Enyoh, 2020). The highest phosphate values, 0.28, 0.28, and 0.29 mg/l, were recorded for August, February, and April at site 1, 2, and 3, respectively. Although the lowest values were recorded in June, January, and October at site 1, 2, and 3, respectively, the highest values were recorded in March (Figure 5). The high phosphate values in some study sites may be attributed to the increased release of cleaning materials rich in phosphate compounds from urban areas to Al-Hillah River course. There is also the effect of phosphorus-rich wastewater, agricultural waste, and fertilizers containing phosphorus compounds. In addition to the high temperatures in some months that destroy algae and plant cells.

4.2.4. Nitrate

The main sources of nitrate pollution in the river are household waste, chemical fertilizers, sewage, industrial waste, and decomposing plant and animal matter (Picetti et al., 2022). The results indicate an increase in nitrate values in June in site 2 to 4.80 mg/l, and a decrease in March in site 3, reaching 2.91 mg/l (Figure 5). Seasonally, the results indicate a high nitrate rate in winter at site 2 amounted to 4.51 mg/l, and decreased in the spring in site 3 where it reached 3.85 mg/l (Table 4). The change in the concentration of nitrates during the study period is due to many reasons, including changes in the amount of water, plant growth seasons, temperature, the addition of pollutants, and denitrification processes.

4.2.5. Calcium and magnesium

The results of the study showed that the highest value of calcium 124.8 mg/l was recorded for July and August in site 2 and 3. The lowest value (68.6 mg/l) was recorded for January in site 2 (Figure 6), and this indicates the high concentrations in the summer, and their decrease in the winter (Table 4). The high values of calcium during the summer may be due to the lack of consumption by phytoplankton due to their reduced presence during this season. In addition, as human activity (domestic, industrial, and agricultural) increases, more liquid waste is thrown into the Al-Hillah River. Also, the results indicate a high concentration of magnesium in site 1 which reached 46.9 mg/l in November and a decrease in site 2 which reached 25.7 mg/l in July (Figure 6). This indicates a high concentration in winter and a decrease in summer (Table 4), as a result of decreased drainage of the Al-Hillah River during winter. This leads to an increase in concentration, as well as erosion of this element from surrounding farmland due to rainfall.

4.2.6. Sodium and potassium

The values of sodium and potassium ions for Al-Hillah River in the study sites ranged from 54.3 to 82.2 mg/l and from 3.1 to 4.8 mg/l, respectively (Figure 6). The lowest value of sodium was recorded in site 3 during July and the highest value in the same site during December. The rise in this site may be attributed to the direct impact of the water enriched by residential and industrial waste containing table salt. The lowest value of potassium was recorded in site 2 during March and the highest value in site 1 during December. The reason for the rise in this site may be due to the effect of agricultural wastewater and the remnants of chemical fertilizers.

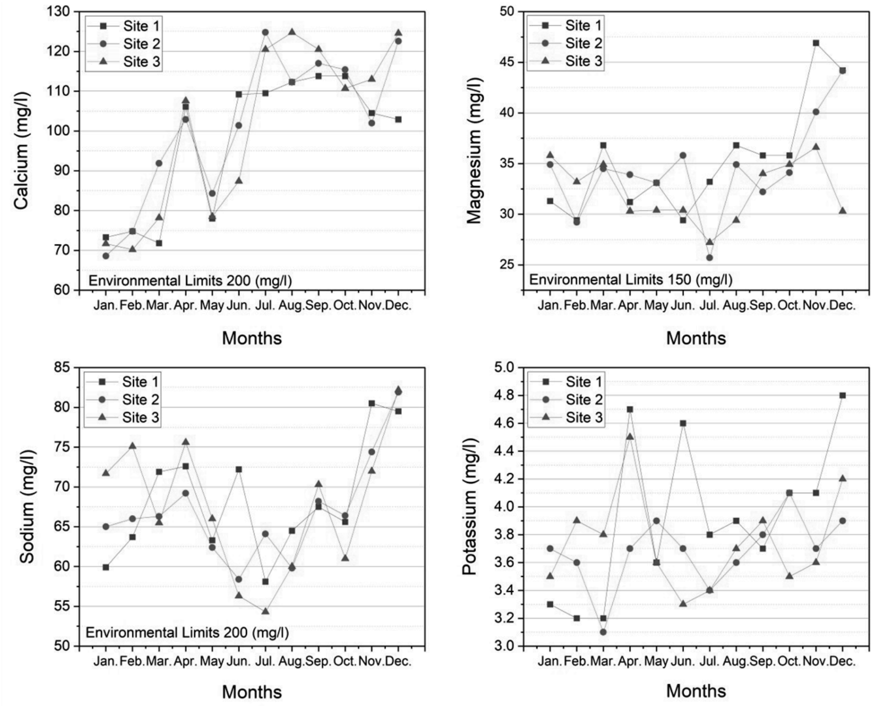

Figure 6. Average monthly values of calcium, magnesium, sodium, and potassium of Al-Hillah River at the study sites, by months.

4.2.7. Total hardness

The highest value of the total hardness was 468 mg/l at site 1 in December. While it reached 312.4 mg/l in site 1 in February, which is the lowest value (Figure 7). The rise in total hardness values in some sites and a particular season may be due to the increased drainage of agricultural water during this period to the river. The high groundwater levels, which drain into the river carrying a lot of positive and negative ions, are the other issue.

4.2.8. Sulfates

Sulfates are found in water bodies as a result of the dissolution of minerals of sedimentary rocks containing gypsum, anhydrite, and shale, or as a result of dumping agricultural and industrial waste and sewage into rivers (X. Li et al., 2015). The highest sulfate value in the study area was 380.2 mg/l at site 3 in May, while the lowest value was 273 mg/l at the same location in February (Figure 7). The high values of sulfates in Iraqi rivers are common environmental phenomena, due to the prevalence of gypsum salts in Iraqi lands. Furthermore, it accelerates the breakdown of organic substances and the usage of animal waste and agricultural fertilizers.

4.2.9. Chloride

Chloride ion occurs naturally in water as a result of the weathering process of igneous and sedimentary rocks. It is also found in industrial and civil waste and wastewater. The increase in its concentration leads to damage to the aquatic ecosystem, by affecting the physiological activities of living organisms (Manea et al., 2019). The highest value of chloride was recorded during December in site 3, reaching 138 mg/l, while the lowest value was recorded in site 2 during January, reaching 90.8 mg/l (Figure 7). The high chloride values in all study sites during the winter season are a result of the discharge of untreated sewage from the cities (Sadat Al-Hindiya, Al-Hillah, and Al-Hashimiyah) fertilized with organic matter into the river, and the winter precipitation. This is in a line with the results of this study, which indicate that it rises in winter and decreases in summer.

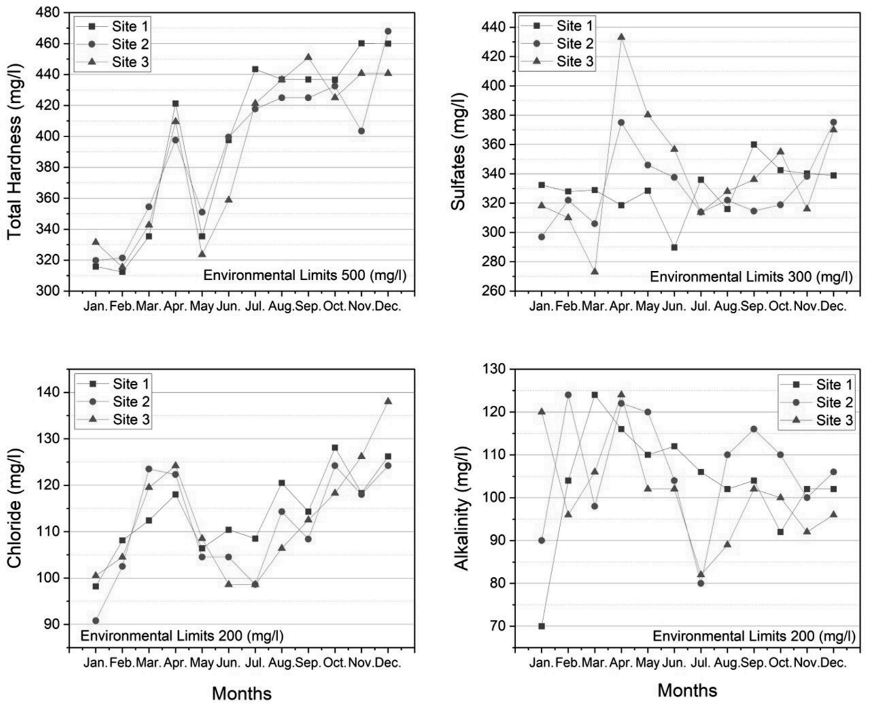

Figure 7. Average monthly values of total hardness, sulfates, chloride, and total alkalinity of Al-Hillah River at the study sites, according to the months.

4.2.10. Total alkalinity

Total alkalinity values were high in the winter and spring, while their decrease was noted in the late summer, and all sites recorded a value of 124 mg/l, which is the highest value during February, March, and April. The values of this parameter varied in all sites according to months and seasons (Figure 7 and Table 4).

The study area is distinguished by its high levels of bicarbonate alkalinity, and these high levels can be linked to the organic material's decomposition processes, which accelerate the conversion of insoluble calcium carbonate to bicarbonate. Alkalinity is reduced as a result of the consumption of bicarbonate by phytoplankton during photosynthesis.

5. Conclusion

The novelty of this study is in the use of geoinformatics to build a geographic information system employing geospatial databases in order to examine the environmental parameters of Al-Hillah River. The results indicated that the river was affected by the liquid wastes from industrial establishments, cities, and agricultural areas built on both sides of the river. The values of temperature, turbidity, total dissolved solids, and total hardness were affected by the seasonal trend changes. Site 1 and 2 are among the most exposed sites to the effects of sewage and industrial water, which is discharged directly into the river. It was noted that the concentration of sulfates exceeded the permissible limits for Iraqi rivers. The water in Al-Hillah River was hard and alkaline but within acceptable limits. The wastewater impacted pH value decrease. The dissolved oxygen of the river water did not fall below the critical limit for the livelihood of fish and aquatic organisms, despite the effect of the wastewater. Increasing the use of detergents and expelling nitrogen waste through sewers has led to an increase in nutrients in river. The authors advise the creation of filtration stations for the polluted water that is dumped from urban, industrial, and agricultural areas based on the environmental evidence for Al-Hillah River described in this study. The local government in Babil Governorate is creating an integrated plan for the Al-Hillah River's sustainable environmental development that takes into account the river's biological system and legal protection from any violations.

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