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Sustainable Management Strategies of the Water Pollution of the Euphrates River Within Ramadi City West of Iraq

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ABSTRACT

The Euphrates River is a vital resource in Iraq, meeting the population's needs, agriculture, and industry. This study aimed to analyze the physical and chemical properties of the river water in Ramadi during two different periods (January and August) by sampling from selected points along the river. Industrial waste is the main source of pollution, with agricultural and domestic waste coming in second and third, respectively, according to eight months of monitoring the wastewater entering the river. The study also uncovered significant changes in the physical and chemical properties of the water, such as temperature, electrical conductivity, turbidity, and metal concentration, reflecting the seasonal effects of the waste. The study concluded that investing in environmental technology and sustainable urban planning could reduce pollution and protect the river basin from encroachment. The study's key findings include water temperatures exceeding 30℃, surpassing the allowable limits by 5℃, and turbidity values reaching 25 NTU, indicating significant physical property changes. From a chemical perspective, the study showed that the river water tends to be alkaline most days of the year, with calcium levels rising to 81 mg/L.

1. INTRODUCTION

The Euphrates River is one of the largest rivers in the Middle East and Southwest Asia. It originates in Turkey and is formed by the confluence of several tributaries. It flows southeast through Syria and the western, central, and southern parts of Iraq, reaching the city of Al-Qurna, where it joins the Tigris River to flow into the Shatt al-Arab [1]. Many dams were built along the Euphrates River to store and secure water levels suitable for processing irrigation projects and canals used for various agricultural, industrial, and municipal purposes [2, 3]. During the years of measuring the water quality of the Euphrates River, a steady increase in the salinity of the river water was observed, as well as an increase in the concentration of chemical pollutants and the level of oils in it. This is due to the return of agricultural drainage water from the giant farms of the upstream countries, especially Turkey, to the river without treatment [4, 5]. In addition, the dumping of liquid factory waste with partial treatment and sometimes without treatment into the river leads to the concentrations of pollutants, especially heavy elements, reaching levels that exceed the permissible limits according to the standard specifications [6]. The annual flow of the Euphrates River within Iraqi territory has witnessed a noticeable change in recent years due to climate change and also due to large dams and irrigation projects implemented by the Turkish and Syrian sides [7, 8]. This river's flow rate has decreased by about 50% in recent years compared to its revenues before 1990 (Figure 1) [9]. Most of the major cities in Iraq are located on the banks of the Euphrates River and depend on its water for all domestic, industrial and agricultural uses [10].

Any pollution of the river water directly affects the population, creating a real problem that requires intervention to mitigate its aggravation [11, 12]. There are many sources of pollution of the Euphrates River, including agricultural drainage water, improperly treated sewage water, and water used in various industrial processes along the Euphrates River inside and outside Iraq [13, 14]. This water that returns to the Euphrates River may be chemically and physically polluted, leading to a deterioration in the quality of the water and thus making it unfit for human use as shown in Figure 2 [15]. Therefore, it has become necessary to implement sustainable management strategies for the Euphrates River water to maintain its quality for human use and mitigate this pollution to protect the quality of the river water [16].

Several studies have been conducted on water quality in Iraqi rivers. Saod et al. [17] monitored and analyzed water quality at different sites along the Euphrates River in Anbar Governorate to evaluate the Water Quality Index (WQI) in terms of spatial variation. The Canadian Council of Ministers for the Environment Water Quality Index (CCME WQI) was used to evaluate the water quality of drinking water within Babil Governorate to determine its compliance with Iraqi specifications in terms of physical and chemical properties [18]. Satam et al. [19] analyzed samples of Euphrates River water in Fallujah city to detect environmental pollutants and

their impact on water quality. Al-Shujairi et al. [20] use the water quality data for the Tigris River obtained from the Ministry of Environment to evaluate the reliability of water quality data and the possibility of using this data to help decision makers on the subject of water quality in water resources management. This study focuses on monitoring physical and chemical pollutants resulting from various human activities in the Euphrates River within the city of Ramadi, western Iraq (Figure 3) [21]. The Euphrates River in Ramadi City faces major challenges related to pollution due to the increase in population, agricultural and industrial activities in the region, which poses a major threat to the suitability of water for domestic use. Therefore, it has become necessary to implement sustainable management strategies for the Euphrates River to maintain the quality of its water for human use and mitigate this pollution to maintain the quality of the river water. This study aims to conduct physical and chemical analyses of the Euphrates River water in Ramadi City, to assess its suitability for human use. The chemical and physical pollution in the Euphrates River will be estimated, and the suitability of the river water for human uses, such as drinking and agriculture, will be assessed.

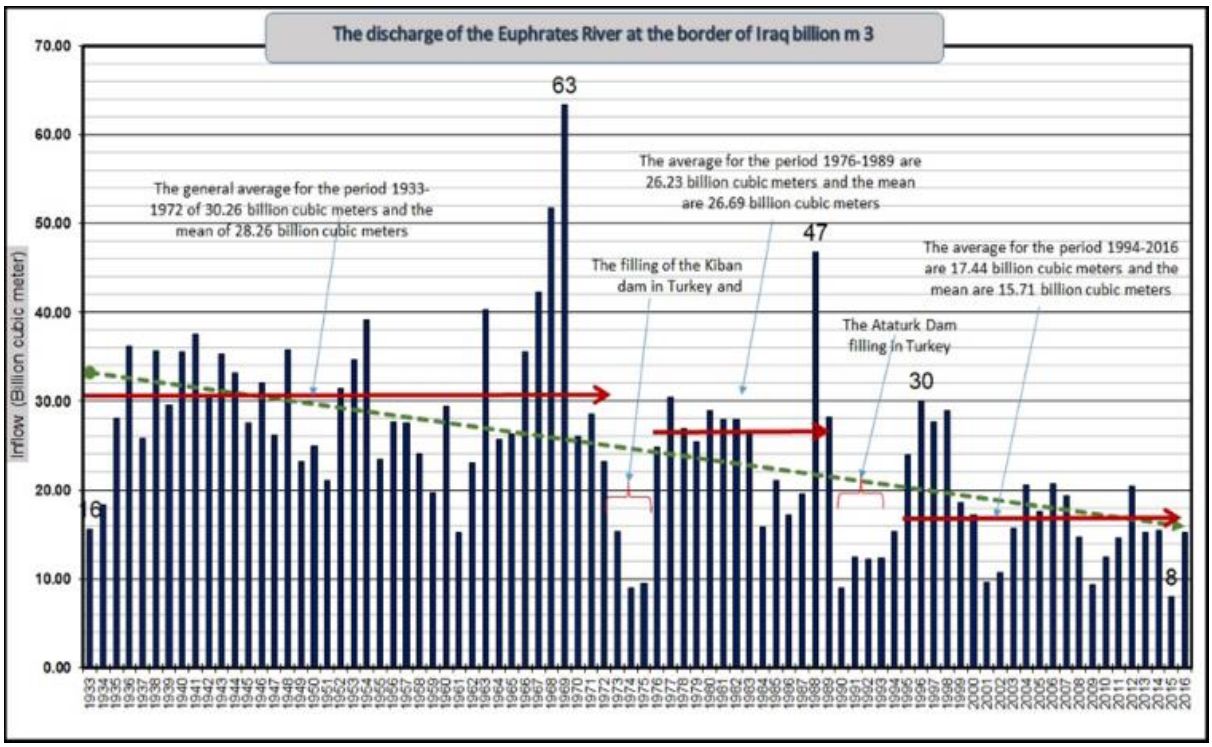

Figure 1. Annual discharge of Euphrates River entering Iraq

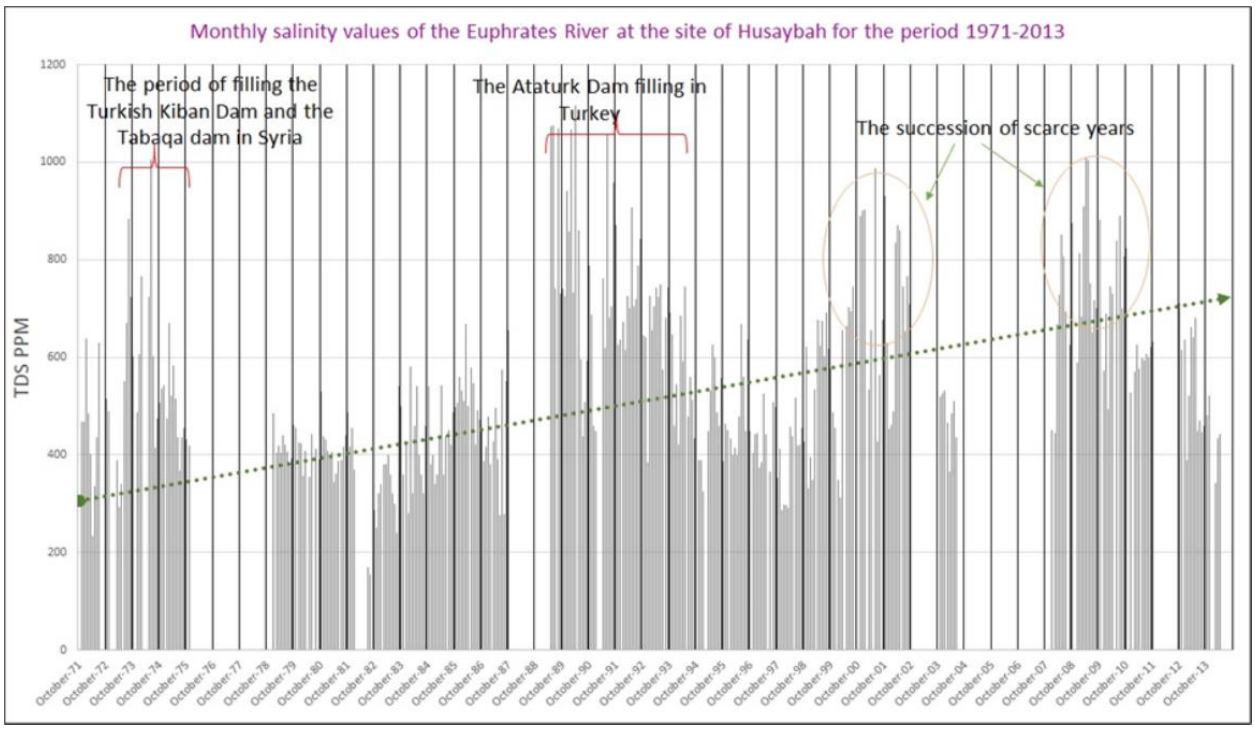

Figure 2. Water salinity of Euphrates River entering Iraq

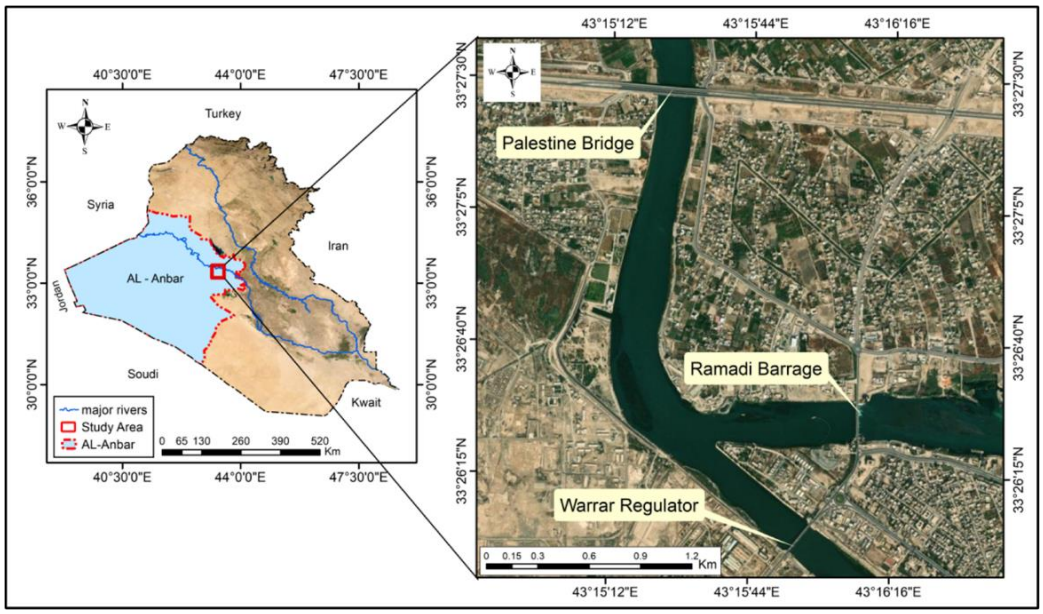

Figure 3. The location of the study area after [21]

2. METHODOLOGY

The data used in this paper were obtained from the Euphrates River in Ramadi City. The sampling process was carried out from the Euphrates River downstream of Ramadi barrage before the water treatment plant intake of Ramadi City. The sampling process was carried out in the summer during August and winter during January to simulate the different environmental conditions of water quality during one year. The collected samples were analyzed to evaluate the physical and chemical properties of the river water, such as temperature, electrical conductivity, turbidity, pH, nitrate levels, calcium levels, total hardness, total dissolved solids, sulfates, and chlorides. The obtained data were analyzed to evaluate the pollution in the Euphrates River water based on the recorded values and compared with local and international environmental standards and measures. The most important physical and chemical properties that are relied upon when evaluating water quality in rivers are the following:

2.1 Physical properties

2.1.1 Temperature

Temperature is a crucial factor affecting water quality, influenced by various factors, including weather conditions, water velocity, impurities, and suspended particles. The allowable temperature range, according to global standards, is 5°C to 25°C. In the study, temperature values for January were recorded at an average of 15°C, staying within acceptable limits. However, in August, the recorded temperature reached 30°C, exceeding global and local permissible limits. This increase can be attributed to higher summer temperatures and human water usage.

2.1.2 Electrical conductivity

Electrical conductivity measures water's ability to conduct electricity at a temperature of 25°C. It is expressed in Microsiemens per centimeter (µS/cm). Conductivity values increase with higher salt concentrations and are directly proportional to the concentration and valency of soluble ions in the water. During the study, electrical conductivity values were measured at 458 µS/cm in August, compared to 571 µS/cm in January. These values are elevated, primarily due to industrial wastewater discharge and sedimentation.

2.1.3 Turbidity

Turbidity is a measure of water's optical property, influenced by the concentration and size of suspended particles. Turbidity units are expressed in Nephelometric Turbidity Units (NTU). The acceptable turbidity range according to the World Health Organization and Iraqi standards is 5-25 NTU. The recorded values for the Euphrates River in Ramadi were 21.2 NTU in January and 25 NTU in August, remaining within permissible limits and indicating typical turbidity.

2.2 Chemical properties

2.2.1 Acidity and alkalinity

It is defined as the measurement of water capacity on the standard pH scale, with values ranging from 0 to 14, where neutrality is achieved at a value of 7, representing the purest form of water that balances acidity and alkalinity. While values below 7 indicate acidity, values above 7 indicate alkalinity. The recorded values in Ramadi were 7.8 in January and 7.7 in August, remaining within permissible limits and indicating water suitability for various uses, including drinking [22].

2.2.2 Nitrates

Nitrates in water often come from sources such as fertilizers, agricultural runoff, and industrial activities. The permissible nitrate concentration, according to local and international standards, is 50 mg/L. The study found nitrate levels at 2.1 mg/L in both January and August, well within permissible and even favorable limits due to reduced agricultural activity. The main reason for the low levels of nitrates in the study area and their remaining within the permissible limits is the low agricultural activity in the study area and the reliance on organic fertilizers due to the high cost of chemical fertilizers, according to farmers.

2.2.3 Calcium

Calcium is a numerical expression of the concentration of Calcium in water. It is a key element in all living organisms and is sourced from rocks and minerals. Calcium levels in water are influenced by the surrounding environment. The acceptable calcium concentration is 75 mg/L. During the study, calcium levels ranged from 65 mg/L in January to 81 mg/L in August, indicating a noticeable increase in August, possibly due to reduced dilution and increased environmental factors.

2.2.4 Magnesium

It is a numerical expression of the concentration of magnesium in water. Limestone and dolomite rocks are the primary sources of magnesium. Additionally, clay minerals assist in the dissolution of magnesium in water due to the presence of Ca_2 ions. Therefore, the magnesium concentration increases as a result of rock dissolution, which can have a negative impact on human health. However, it is essential for plant growth and is used in fertilizers. The methods of irrigation and sewage discharges contribute to increased magnesium levels in the river, causing adverse effects on the water. Locally, a magnesium concentration of 50 mg/L is permissible. Through analysis, it was determined that the recorded values in January were 35 mg/L, while they decreased to 30 mg/L in August, remaining within acceptable limits [23].

2.2.5 Total hardness

Calcium and magnesium are among the primary causes of water hardness. Natural sources of hardness include limestone, which dissolves in water upon contact. The water's hardness depends on geological formations through which the water passes, as well as agricultural runoff and untreated sewage entering the river through canals. Water hardness is crucial in assessing water suitability for human consumption. An increase in hardness affects water properties, such as color, taste, and odor. The maximum hardness allowed is 500 mg/L. Analysis of river water shows hardness values of 265 in January and 305 in August, which are moderate values according to water quality standards.

2.2.6 Total dissolved solids

Total dissolved solids (TDS) refer to a group of completely dissolved salts that move through the rock pores in water. TDS can impact water properties and, subsequently, plants and soil due to salt accumulation. TDS levels vary seasonally within the city of Ramadi. In the winter months, represented by January, the TDS concentration is 303 mg/L, while in the summer month of August, it recorded 365 mg/L.

2.2.7 Sulfates

Gypsum rocks are the primary source of sulfate ions due to their solubility in water. Waters from sewage discharges, untreated sewage, and groundwater contribute to increased sulfate levels in river water. The chemical content of Iraq's internal waters primarily depends on four positive ions: calcium, magnesium, sodium, and potassium, as well as four negative ions: bicarbonates, carbonates, chlorides, and sulfates. The permissible sulfate concentration is 250 mg/L. Water analysis revealed values of 110 mg/L in January and varying values of 190 mg/L in August, all within acceptable limits.

2.2.8 Chloride

Chlorine is used as a water disinfectant, and when the water returns to the river, it leads to an increase in chloride ion concentration. Chlorine is highly soluble in water and is found in limestone and gypsum rocks widely. It can have a significant impact on human health and agricultural crops when present in excessive amounts. The international and local allowable chloride concentration is 250 mg/L. Concentrations of chloride ions varied between 70 and 130 mg/L in the months of January and August, all within permissible limits [24].

3. RESULTS AND DISCUSSION

To determine the suitability of Euphrates River water for various uses, it is crucial to analyze its qualitative characteristics, as they indicate the water's quality and purity, and serve as a fundamental measure for different applications. After reviewing the sample results, it becomes evident that most elements remain within permissible limits, except for calcium and temperature in August. Furthermore, electrical conductivity was elevated due to the increase in total dissolved solids (Figure 4). There is a relationship between chemical and physical factors and the sampling times, as some chemical elements increase with rising temperatures and decreasing flow.

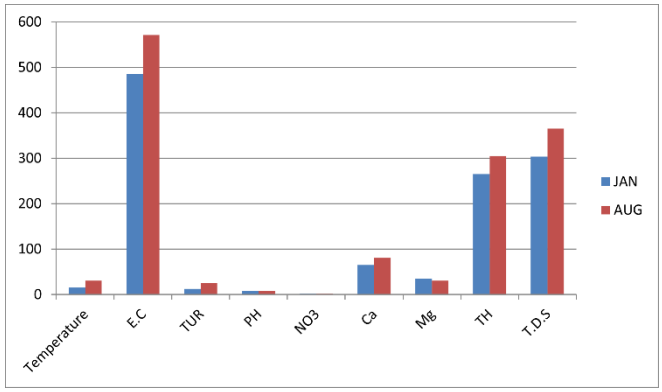

Figure 4. Qualitative analysis of the water of the Euphrates River in Ramadi City

The same pattern is observed for other chemical elements, except for magnesium, which increases in the winter months. Therefore, the water quality is suitable for various activities, excluding instances where calcium levels and temperatures need consideration, as shown in Table 1.

Table 1. Laboratory analysis of the Euphrates River in Ramadi City

Month	Temp.	EC.	TUR.	PH.	NO_3	Ca	Mg	Th	TDS
Jan.	15	458	12.2	7.8	2.1	65	35	265	303
Aug.	30	571	25	7.7	2.1	81	30	305	365

It was observed that in January, the temperature was 15 degrees Celsius, while it rose to 30 degrees Celsius in August. This indicates an increase in temperature during the second month, reflecting seasonal variations in water temperature. Regular monitoring of water temperature is advisable to ensure its compatibility with various uses. In January, the electrical conductivity value was 458 Microsiemens per centimeter (μS/cm), which increased to 571 μS/cm in August. This points to an increase in water conductivity between the two months, suggesting an increase in salinity or mineral concentration in the water.

The turbidity value in January was 12.2 Nephelometric Turbidity Units (NTU), which increased to 25 NTU in August. This indicates an increase in turbidity or solid impurities in the water during the second month, implying an increase in solid impurities or particles in the water during this period.

For Chemical Properties in various seasons, the pH values were similar, with a pH of 7.8 in January and 7.7 in August. This suggests stability in the water's acidity levels, signifying that the water is alkaline to neutral, which is considered suitable for most uses. The nitrate level (NO_3) in January, was 2.1 milligrams per liter (mg/L), and it remained the same in August. This indicates a consistent nitrate level in the water during both months, implying a moderate number of organic pollutants in the water. The calcium value recorded was 65 mg/L in January and 81 mg/L in August. As for magnesium, it was 35 mg/L in January and 30 mg/L in August. This indicates an increase in calcium content and a decrease in magnesium content during the second month, suggesting a change in the mineral composition of the water. This is an indicator that the calcium level exceeds the allowed limit in both months, and this ratio needs to be monitored, controlling the sources of calcium to maintain water quality. In January, the total hardness was 265 mg/L, which increased to 305 mg/L in August. This indicates an increase in total hardness during the second month. The total dissolved solids (T. D. S.) in January were 303 mg/L, and it increased to 365 mg/L in August. This suggests an increase in the total dissolved solids content in the water during the second month. The data shows variations in temperature, electrical conductivity, turbidity, and some chemical elements in the waters of the Euphrates River in the city of Ramadi during the studied months (January and August). These variations indicate significant effects of industrial, agricultural, and urban emissions on the quality of the Euphrates River water in Ramadi. They result in increased salinity, turbidity, and mineral concentration in the water, leading to changes in mineral composition. These changes reflect seasonal effects that affect water quality and its potential uses, contributing to understanding pollution and developing appropriate solutions.

From all of the above, and to obtain water that meets the standard specifications from the Euphrates River in the city of Ramadi, sustainable control strategies for pollution control of the Euphrates River in Ramadi must be implemented through the following:

1) Improving Wastewater Treatment: Develop wastewater treatment plants to effectively remove impurities and pollutants before discharging water into the river.
2) Promote Environmentally Friendly Agricultural Practices: Provide guidance and technical support to farmers to adopt sustainable agricultural practices, reduce the use of harmful agricultural chemicals, improve irrigation water management, encourage crop diversity, and cultivate locally adapted varieties.
3) Water Quality Monitoring: Establish a periodic and continuous water quality monitoring system, publish data and reports, and involve the local community in water quality monitoring and field data collection.
4) Community Participation and Environmental Education: Promoting community involvement in decision-making and environmental actions through the formation of local environmental committees, consulting with local residents, organizing awareness campaigns and workshops for citizens regarding the importance of preserving the Euphrates River and mitigating pollution, and encouraging environmental education in schools and universities.
5) Legislation and Laws: Enact strict environmental laws to preserve the quality of the river water and regulate the activities of factories and agriculture. Implement strategies for monitoring and law enforcement.
6) International and Local Collaboration: Enhance cooperation with the countries sharing the Euphrates River basin and relevant governmental bodies to develop joint strategies for preserving the river's water quality.
7) Invest in Environmental Technology: Support research and development in environmental technology to develop innovative solutions for pollution control and river water purification.
8) Sustainable Urban Planning: Promote sustainable urban planning for the city, considering the protection of water basin areas and minimizing negative environmental impacts.
9) Utilizing Alternative Water Sources: Explore and efficiently utilize alternative water sources, such as treated wastewater and groundwater.

4. CONCLUSIONS

The following conclusions were obtained from this research:

1) The Euphrates River has been affected by decreasing inflow and rising temperatures in the summer season leading to increased total dissolved solids (TDS) and pollution levels.
2) Research results indicate varying levels of pollution in the Euphrates River waters in the city of Ramadi, with some elements exceeding permissible limits.
3) Pollution sources include wastewater, agriculture, and polluting industries.
4) International and local cooperation and the development of joint strategies are needed to preserve the quality of the Euphrates River's water.
5) It is recommended to improve wastewater treatment and monitor industrial emissions to control pollution.

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