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The Impact of Water Pollutants on the Hydrological Characteristics of the Euphrates River in the City of Nasiriyah

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Abstract: Water Pollution: Water pollution constitutes one of the significant challenges facing urban areas in most countries across the globe. Technological changes and industrialization have resulted in the use of significant amounts of water to support and maintain industrial processes, aside from the amounts used for domestic and agricultural purposes. Consequently, the amounts and types of waste and residue arising from such use have ended up affecting natural sources of water, namely surface and groundwater, upon disposal into such sources without prior treatments. This has resulted in modifications to the quantities and quality attributes associated with water, with consequent environmental influences adversely affecting the use of water for various purposes. The study established the existence of various factors influential in shaping the hydrological property attributes associated with water, symbolized by the geological structure and surfaces, as well as the modification attributed to the influences of environmental elements for potentially increasing the challenge associated with water pollution in the Euphrates River. The study also established the forms and sources associated with such pollutions, alongside the modifications to the various levels and forms associated with the use of water arising from modifications to its hydrological property attributes. The study also explained various important approaches associated with curtailing such levels and forms associated with water pollution and its harmful environmental influences.

Keywords: Water Pollution, Quantitative and Qualitative Features, Agricultural Pollution, Thermal Pollution.

1. Introduction:

Water resources in the area of study are facing evident variations in hydrological properties because of climatic changes, the predominance of drought, and the reduction in water flows due to the water policies practiced by neighboring countries, which regulate the share of water entering Iraq, in contradiction to international agreements regarding joint water resources. Moreover, water resources are also facing contamination and wastes originating from human, industrial, and agricultural activities, because of water use in those sectors, as well as the high need for water in different life aspects. Additionally, because of the rise in the need to use clean water in fulfilling the growing needs of population, internationally as well as regionally, it has contributed to exacerbating the problem. Since the problem is of high importance, serious, and has effective impacts, this study will address the detection of the most significant contaminants in water, as well as sources, factors influencing the rise in water pollution in Euphrates River. It also seeks to examine the main climatic characteristics in the study area for the period (2012–2023), as well as the key changes in the quantitative and qualitative characteristics of water and their effects on water uses, in addition to exploring treatment methods.

1.1 Research Problem:

(Do water pollutants have an impact on the hydrological characteristics of the Euphrates River?)

Secondary Problems:

- Do water pollutants vary, and what are their main sources?
- Are there factors that contributed to the expansion of pollution in the Euphrates River in the city of Nasiriyah?
- What are the most significant changes in the hydrological characteristics of the Euphrates River?
- Are there available capabilities that could limit water pollutants and reduce their effects in the study area?

1.2 Research Hypothesis:

(Water pollutants have an effect on the quantitative and qualitative hydrological characteristics of the Euphrates River.)

- Water pollutants vary, and their sources are multiple, including human, industrial, and agricultural sources.
- Several factors have contributed to the pollution of the Euphrates River in the city of Nasiriyah.
- The most significant changes with regard to water are the quantitative and qualitative changes that have appeared in the Euphrates River.
- The area has human resources which can be utilized to reduce the pollutants in water, as well as minimize the possible impacts.

1.3 Research Objectives:

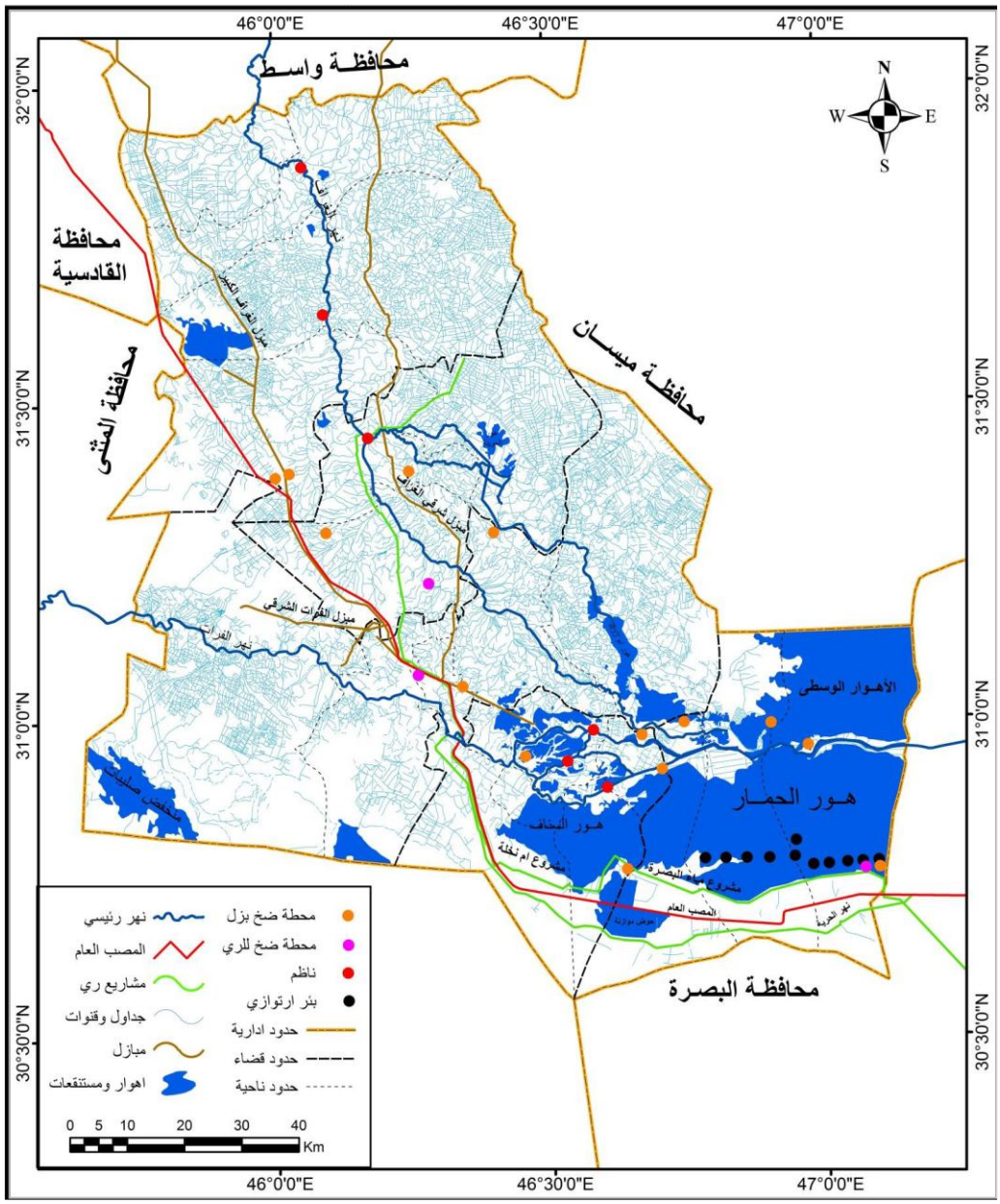
- To examine the phenomenon of water pollution within the Euphrates River within the city of Nasiriyah.
- To deterile the crucial forms of pollution and their primary sources.
- To analyze the significant changes occurring in the quantitative and qualitative aspects of water.
- To determine the most significant approaches to combat the issue of water pollution.

1.4 Location and Boundaries of the Study Area:

The study is defined by the following boundaries:

- **Spatial Boundaries:** The spatial boundaries of the study include the city of Nasiriyah, which lies between the latitudes (30.5° – 31.10°) north and the longitudes (46.15° – 48°) east. Administratively, it is bordered to the north by the district of Al-Gharraf, to the south by Al-Fadhlia, to the east by Sayyid Dakhil, and to the west by Al-Batha, as shown in Map (1).
- **Temporal Boundaries:** The temporal boundaries of the study are represented by the time period extending from (2012–2023) for climatic data, where the data represent the district of Nasiriyah, the center of Dhi Qar

Appendix (1)
Map (1): The Administrative Boundaries of the Study Area



Source: The researcher based on: Ministry of Water Resources, General Commission for Survey, Map Production Department, Digital Unit, *Administrative Map of Iraq for the year 2011*, Scale (1/1,000,000).

2. Water (Its Pollutants and Sources) and the Factors Affecting Its Characteristics

2.1 Water Pollutants and Their Sources:

Water pollution can be defined as any alteration occurring in the chemical, physical, or biological characteristics of water as a result of discharging human, agricultural, and industrial waste into it without treatment, meaning any change that affects water purity in all seasons (2). This leads to the deterioration of water quality and quantity characteristics, consequently reducing its suitability for various life uses and increasing the demand for clean, fresh water free from pollutants. Based on this, the most important human water pollutants and their sources can be identified as follows:

2.1.1 Urban Pollutants:

These are among the human pollutants that contribute to water contamination, such as wastewater containing many organic and chemical compounds resulting from the discharge of domestic sewage

(3), as well as wastewater from governmental facilities such as hospitals and other official institutions, which are discharged into the Euphrates River without treatment. This occurs despite the capabilities possessed by the governorate and its ability to treat such pollutants. However, they are discharged into the Euphrates River in noticeable and large quantities, causing pollution of the river, especially in the city center, where wastewater is discharged directly through pipes that, in some areas—such as the Al-Jazirah side—reach diameters of (90 cm), all under the supervision of environmental protection authorities. Solid waste, such as garbage and animal remains from slaughterhouses, also contributes to increasing pollution levels, causing changes in the hydrological characteristics of the water.

2.1.2 Industrial Pollutants:

Industrial activities play a significant role in increasing water pollution and altering its quantitative and qualitative characteristics. This comprises the use of cooling water in power production stations, oil refineries, machine cooling, and raw material processing at oil fields, all of which are released into the Euphrates River without processing, thus increasing amounts of pollutants in it. For instance, thermal stations for power production in Nasiriyah contribute to increasing amounts of salt and decreasing oxygen amounts within water discharged into the river. Investigations have shown that thermal stations contribute about (81%) to total thermal water considering large amounts required for cooling processes. It is calculated that for a production capacity of (1000 megawatts), a power plant consumes about (2 million liters) per minute for cooling purposes (4).

2.1.3 Agricultural Pollutants:

These would be the pollutants originating from agricultural drainage, like pesticides, organic chemicals, and other chemicals from the use of fertilizers. Agriculture is one of the major activities taking place in the region, and the water used for agricultural purposes, such as irrigation, comprises the largest proportion of the water used among other uses. Due to the primitive methods used in agricultural operations, which rely on surface irrigation combined with a lack of effective drainage canals and the difficulty of disposing of excess water, farmers often discharge this water—along with its pollutants—into nearby rivers and waterways. It is estimated that the total fertilizers supplied to farmers in the study area during 2022 reached (6985.476 tons), including (5331.166 tons) of urea fertilizer and (1654.310 tons) of DAP fertilizer (5). Additionally, groundwater and drought contribute to increasing soil salinity, which in turn raises the salinity of the Euphrates River.

Water pollutants are also classified according to their sources into physical pollution, which occurs due to changes in standard water properties such as temperature, salinity, or the increase of suspended organic or inorganic matter, including factory cooling water; chemical pollution, which results from increased industrial and agricultural activities involving toxic metals such as lead and mercury or fertilizers, pesticides, acids, and others; biological pollution, which occurs due to the rise of microorganisms that cause diseases such as parasites, bacteria, and viruses; and radioactive pollution resulting from radioactive leakage (6). These classifications are consistent with the types of pollutants and their sources mentioned earlier.

It is clear from the above that water pollutants vary and come from multiple supplying sources. Some originate from daily human activities, such as domestic pollutants represented by sewage and wastewater from service institutions like hospitals; others arise from agricultural activities, such as irrigation water containing fertilizers, pesticide residues, salts, and others; and others result from industrial activities such as salts and cooling water discharged from power plants and factories, which cause thermal pollution

2.2 Factors Affecting Water Characteristics

2.2.1 Geological Structure:

Studying the geological structure of any area is of great importance because it helps identify the type of soil particles and thus determine their mechanical, chemical, and physical properties. The geological structure also influences the quantitative and qualitative characteristics of water. The study area lies within the Mesopotamian Plain, which consists of clay, sand, and silt deposits resulting from the floods

of the main rivers—namely the Tigris and Euphrates—as well as aeolian deposits. These occur in layers of varying thickness ranging between (5–15 m), extending over wide areas that reach more than (100 km) from the city of Nasiriyah to the east of the Euphrates River channel for a distance of about (25 km) towards the west and southwest (7).

2.2.2 Surface Features:

Flatness and low slope are the dominant characteristics of the surface features in the study area. The maximum elevation in the Mesopotamian Plain reaches (9.5 m) above sea level in its northern parts, whereas the minimum elevation is (3.6 m) in its southern parts due to the decrease in river-transported sediments moving southward. The flat and gradually sloping nature of the plain from north to south, combined with the slope of the Western Plateau towards the east, contributes to slowing river flow and therefore increasing the amount of water infiltrating into the ground. In addition, larger amounts of water are lost due to evaporation, especially during the hot season, which contributes to changes in water characteristics in the study area.

2.2.3 Climatic Characteristics:

The climatic elements witnessed significant changes in their monthly and annual averages during the study period, affecting water characteristics and its usage. To identify the most important climatic elements and their trends, these elements were studied and their averages analyzed at the (Nasiriyah) station for the period (2012–2023), as follows:

➢ **Temperature:** Temperature is one of the most important climatic elements affecting most other climatic factors, in addition to its significant influence on the quantitative and qualitative characteristics of water and, consequently, increasing its pollution. Table (1) indicates a rise in the monthly averages of temperature starting from March, with July recording the highest monthly average at (39.8°C), due to increased solar radiation. High temperatures affect the increase in reaction rates and the dissolution of elements in water. They also enhance chemical and physical weathering along riverbanks, during which iron oxides transform into iron hydroxide, which dissolves quickly in water.

Moreover, high summer temperatures, which last for nearly nine months, extend the agricultural season, increasing irrigation water use for long periods and in large quantities. This leads to increased agricultural waste, including pollutants that enter rivers and waterways. High temperatures also increase water demand, especially for domestic, industrial, and agricultural purposes, reducing river levels due to high consumption. Furthermore, increased temperature raises the rate of chemical reactions, gas dissolution, and oxygen consumption, thus affecting the qualitative characteristics of river water.

Table (1) Monthly and Annual Averages of Climatic Elements at Nasiriyah Station for the Period (2012–2023)

Month	Temperature (°C)	Rainfall (mm)	Evaporation (mm)	Humidity (%)
January	12.6	21.2	77.4	58.6
February	15.8	15.3	103.8	49.3
March	21.2	20.2	180.8	38.8
April	26.2	16.5	229.8	31.6
May	32.6	3.7	348.7	24.8
June	37.2	0	508.6	16.2
July	39.8	0	573.9	16.1
August	38.3	0	421.6	18.3
September	35.1	0	332.4	23.1
October	28.1	7.2	212.6	32.6
November	19.4	21.9	115.2	50.1
December	14.5	21.5	62.5	55.8
Annual Average	26.6	–	–	34.6
Total	–	127.5	3167.3	–

Source: Researcher based on: Republic of Iraq, Ministry of Transport and Communications, General Authority for Meteorology and Seismic Monitoring, Climate Department, Unpublished Data, 2023.

Table (1) also indicates a decrease in monthly averages beginning in September, with January recording the lowest average of (12.6°C) due to reduced solar radiation and the lower angle of sunlight incidence. Lower temperature leads to less evaporation and loss of water "The annual average attained was 26.6°C in the Nasiriyah station".

➢ **Rainfall:** Rainfall amounts have recorded a remarkable drop in their values measured monthly and annually due to a lack of precipitation during the rain season (winter). This is a result of a low number of frontal depressions that have reached Iraq and affected water properties and pollution concentration. From Table (1), it can be observed that rainfall starts in October and progresses systematically to reach its highest peak in December at (21.5mm) considering that frontal depressions characterized Iraq's weather during this period. The values for rainfall decrease beginning from February and reach their lowest point in May at (3.7mm) considering that a low number of depressions have reached Iraq.

Low rainfall results in low water inflow and discharge in rivers, causing a change in water quality because of a lack of renewal, as rainwater is an important source of recharge in rivers. Rainfall is also a contributor to changing levels of water quality in rivers, as it helps in transferring clay sediments from the sides of the rivers to the mainstream, thus causing high levels of salinity and turbidity. The annual rainfall average attained was 127.5 mm at Nasiriyah.

➢ **Evaporation:** The evaporation rates have also experienced an increment in their rates because of the rise in temperature and the reduction in the levels of rainfall and humidity, which impacted negatively on the rates of changes in the quantitative and qualitative properties of water, and hence its uses. From Table (1) above, it is evident that the rates of evaporation rise steadily from April to July, with July registering the highest rate of (573.9 mm) as a result of an increment in temperature and a reduction in cloud cover. High rates of evaporation lead to drought, water scarcity, low water levels, and augmented water losses, resulting in changes to the qualitative properties of river water. The high rates of evaporation also result in an increment in the levels of chemical elements, salts, and minerals present on the soil surface, which is then transported to rivers as water infiltrates into the soil and trickles into river wateraways, and as water permeates the soil and flows into waterways. The least rates of evaporation occurred during the cold period, with the lowest rate occurring during the month of December, registering (62.5 mm) as a result of low temperatures and high relative humidity, which prevailed during that month. The mean annual rate of evaporation was (3167.3 mm).

➢ **Relative Humidity:** Relative humidity is one of the elements that influence the evaporation rate of water bodies. As the relative humidity increases, the rate of evaporation decreases, and conversely. According to Table (1), the maximum average relative humidity for the month occurred in January, at (58.6)% due to the low temperatures, while the minimum average relative humidity for the month occurred in July at (16.1)%. The low humidity of the atmosphere along with the high temperatures, particularly during the hot season, leads to increased rates of evaporation and aridity. Therefore, there will be a reduction in the volume of the river's water, while the concentration of the pollutants will increase because the volume of the water will be less. Furthermore, the relative humidity's annual average at the Nasiriyah station was (34.6)%.

2.2.4 Natural Vegetation

Natural vegetation is one of the elements that contribute to the characteristics of water resources. This vegetation slows down the movement of water, particularly near the banks and channels, which enhances the process of sedimentation, accumulation of suspended particles, algae development, river turbidity, and pollutant concentration in the water. Water vegetation in rivers, channels, and swamps, such as papyrus, reeds, water lentils, and water hyacinth, leads to the loss of water, either through evaporation from the vegetation or following the decomposition of the root and vegetative portions. This enhances the concentration of pollutants in the water, thus lowering the quality and utility of the water.

3. Indicators of Changes in Water Characteristics and Treatment Methods

3.1 Indicators of Changes in the Hydrological Characteristics of the Study Area

The Euphrates River is among the most significant water resources and one of the key water sources that support human activities in the area. However, as a result of high climatic changes, low rainfall, low inflow into rivers, low water levels in rivers, and the loss of large water surfaces, besides the discharge of human wastes (agricultural, industrial, and domestic) into rivers without any treatment, water characteristics have changed, making it unsuitable for different human uses. The list of changes in water characteristics in Euphrates River in this study area includes:

- **Decrease in Water Quantity:**

The retention of rainfall in some seasons and its fluctuation in others in the main river catchment areas, as well as the dams and reservoirs constructed by neighboring countries at the river sources, contributed to variations in river discharges, reduced inflows, and lowered water levels. This exacerbated drought and water deficits, affecting most areas of Iraq, including the study area. Table (2) shows that the annual average water inflow in the Euphrates River during the period (2010–2021) reached (2.83 billion m^3/year). It also indicates variations in water inflow rates from one period to another, which significantly contributed to lower water levels and quantities. This is attributed to climatic changes, reduced rainfall, and increased evaporation due to higher temperatures, as well as the water management at the Hindiyah Dam, which affects river discharge that also varies annually. Table (2) shows that the annual average water discharge reached (90 m^3/s) during the period (2010–2021).

It is evident that water inflows in the Euphrates River vary from year to year and season to season due to the reasons mentioned above. River discharges also declined and fluctuated in conjunction with the variations in water inflows, in addition to the effect of the 250 branches of the Euphrates in Nasiriyah city, which significantly contributed to the reduction of river discharge and water levels and expanded the scope of changes in the quantitative water characteristics, thus increasing pollutant concentrations in the river water.

Table (2) Annual Water Discharge (m^3/s) and Annual Water Inflow (billion m^3) of the Euphrates River for the Period (2010–2021)

Water Year	Annual Discharge (m^3/s)	Annual Water Inflow (billion m^3)
2010	63	1.98
2011	66	2.08
2012	61	1.92
2013	96	3.02
2014	126	3.97
2015	53	1.67
2016	82	2.58
2017	89	2.80
2018	62	1.95
2019	94	2.96
2020	126	3.97
2021	110	3.46
Average	90	2.83

Source: Researcher, based on: Ministry of Planning, Central Statistical Organization, *Environmental Statistics of Iraq, Water Quantity and Quality*, 2023.

- **Deterioration of Water Quality Characteristics:**

The reduction in water inflows, low river discharge, and decreased water levels in the main rivers, along with the impact of industrial and domestic solid and liquid waste discharged into rivers without treatment, have led to the deterioration of water quality characteristics (chemical and physical). This

negatively affected water suitability for human use in various economic sectors including agriculture, industry, and domestic purposes, causing significant environmental problems affecting human life.

Table (3) shows that the average pH of raw water in Dhi Qar province reached (7.8 mg/L). Cations such as calcium (Ca) recorded (239 mg/L) and magnesium (Mg) recorded (102.3 mg/L), while sodium (Na) reached (294.0 mg/L). These values are high and exceed the permissible limits for water suitability in the Iraqi aquatic environment (see Table 4). The high values are attributed to low water quantities due to prevailing drought conditions and to pollutants from sewage, industrial and domestic waste, as well as the misuse of fertilizers and pesticides.

Anions such as chlorides (Cl) recorded (392.7 mg/L) and sulfate ions (SO_4) recorded (848.1 mg/L), which are also above the permissible limits for water use in Iraq. Dissolved solids (TDS) in the water reached (2056.2 mg/L), and electrical conductivity (EC) reached (3236.4 µS/cm), all indicating increased water salinity.

Table (3) also shows that total hardness (TH) reached (1014.1 mg/L) and turbidity (TUR) recorded (41.3 mg/L).

It is evident that there have been changes in the quantitative water characteristics due to the decline in river inflows and discharge in the study area, which led to decreased river levels, deterioration of water quality, and reduced efficiency and suitability for various uses.

Table (3) Chemical and Physical Examination Results of Raw Water from the Euphrates River in the Study Area for 2023

Variable	Unit	Dhi Qar
pH	mg/L	7.8
Calcium (Ca)	mg/L	239.0
Magnesium (Mg)	mg/L	102.3
Sodium (Na)	mg/L	294.0
Chloride (Cl)	mg/L	392.7
Sulfate (SO_4)	mg/L	848.1
Total Dissolved Solids (TDS)	mg/L	2056.2
Electrical Conductivity (EC)	µS/cm	3236.4
Potassium (K)	mg/L	11.7
Turbidity (TUR)	mg/L	41.3
Total Hardness (TH)	mg/L	1014.1

Source: Researcher, based on: Ministry of Planning, Central Statistical Organization, *Environmental Statistics of Iraq: Water Quantity and Quality*, 2023.

Table (4) Iraqi Standards for Water Quality Suitable for Aquatic Environment

Variable	Property	Allowed Limit (mg/L)
pH	–	6.5–8.5
Electrical Conductivity (EC)	µS/cm	2000
Total Dissolved Solids (TDS)	mg/L	1500
Sodium (Na^+)	mg/L	35
Calcium (Ca^{2+})	mg/L	200
Magnesium (Mg^{2+})	mg/L	50
Chloride (Cl^-)	mg/L	200
Sulfate (SO_4^{2-})	mg/L	200

Source: Researcher, based on: Central Organization for Standardization and Quality Control, *Iraqi Standard Specification No. 2270/14*, 2006.

3.2 Water Pollution Treatment Methods

- Wastewater treatment and heavy water - Establishment of treatment plants to separate solid pollutants, floating materials, and organic matter through biological treatment to reduce levels of pollutants, stabilize water quality, and decrease organic content.
- **Industrial waste treatment:** The substances that are thrown by industries into the water courses or sewer networks must be previously treated through processes of purification, decantation of solid and metallic particles, extraction of floating oils, or chemical treatment.
- Adopt modern irrigation techniques, especially in agricultural usage of water, with drip and sprinkler irrigation replacing the traditional ones that cause less water loss and are relatively more effective.
- The design of unified heavy water drainage networks to cover the whole area of study in order to separate light water from heavy water to let the organic matter sediment and be used as organic fertilizer, while the treated and oxidized water is used for irrigation.
- Enacting laws and regulations that would keep environmental pollution to a minimum through enforcement by way of penalties and fines on those violating the law for environmental protection.4. Conclusions

4.1 Results

- Various kinds of water pollutants were identified within the study area: domestic pollutants consisting of wastewater and heavy water coming from service facility sources such as hospitals; agricultural pollutants like irrigation water with fertilizers, pesticide residues, and salts from farms; industrial pollutants carried by salts, cooling water from power plants and factories causing thermal pollution. The study showed that such plants contributed to an estimated 81% of total thermal water because of high water utilization for cooling purposes.
- The water characteristics in the study area are subjected to change under several factors, including geological composition, surface features, climate elements, and natural vegetation, which all influence quantitative and qualitative characteristics of water in a direct or indirect manner.
- Climatic elements affect water pollution and alter some characteristics of water seasonally. For instance, high temperatures increase chemical reactions and dissolve gases and consume dissolved oxygen, while rainfall increases salinity and turbidity by transporting clay sediments into river systems.
- An alteration in the amount of Euphrates water was observed to take place hydrologically, according to climatic changes and fluctuating water inflows which averaged 2.83 billion m^3 during the study period, when river discharge averaged 90 m^3/s, expanding the scope of pollution.
- Qualitative water characteristics also deteriorated. Laboratory results compared with Iraqi environmental standards showed reduced efficiency and suitability for human use.
- Avoiding water contamination in the Euphrates by linking heavy water discharge pipes to treatment plants for purification before disposal or making networks that wastewater and heavy water be transported to the main treatment plants such as Al Amel outlet.

4.2 Recommendations

1. Consistency in establishing a unified heavy water drainage network that is separated from rainwater systems would reduce pressure on existing networks, ensure continuity of operations, and utilize rainwater directly as a source of clean water.
2. Require factories and industrial facilities to establish treatment units for effluent purification before discharge.
3. Rationalize water use through optimal management and modern irrigation methods instead of traditional techniques.

4. Address water deficits by recycling heavy water, wastewater, and domestic effluents through filtration and sediment removal for reuse in irrigation and public cleaning.
5. Raise public awareness about water conservation and preventing domestic, industrial, and agricultural waste from entering rivers and canals.
6. Foster collaboration among government institutions, universities, and research centers to develop strategies for water conservation and pollution mitigation.

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