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Environmental Study on the Quality of Raw Water from the Tigris River Used in Water Purification Plants in Mosul City

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ABSTRACT

The current study examined the quality of raw Tigris River water used in water purification plants located on both sides of the river within the city of Mosul. Monthly water samples were collected from sites within the New Right Water Project purification plant. A range of physical, chemical, and biological tests were conducted on these samples. The results revealed clear variations in the measured values and concentrations over the study period and across the sampled sites. In October, the water quality parameters recorded the following average values: water temperature at 21.15°C, total dissolved salts at 206.44mg/ L, electrical conductivity at 413.11µS/ cm, turbidity at 7.38 NTU, and pH at 7.50. Additionally, the concentrations of total hardness, calcium hardness, and magnesium hardness were 78.44, 28.62, and 49.82mg/ L (as calcium carbonate), respectively. The concentrations of major negative ions were also measured in October, with nitrate at 0.18mg/ L, phosphate at 0.22mg/ L, sulfate at 24.86mg/ L, and chloride at 7.99mg/ L.

INTRODUCTION

Water is an essential source of life. Therefore, cities and civilizations are located in places where water is available **(Al-Kubaisi & Ebrahim, 2004)**. The water consumed by humans must be safe, easily accessible, and free of all types of pollution **(Al-Hashemi & Al-Jayashi, 2023)**. Water is characterized by its constant quantity on Earth, since it is constantly renewed through the hydrological cycle. However, as a result of population growth and urban, industrial, and agricultural development, water systems have faced numerous challenges due to their exposure to pollution resulting from the discharge of municipal, industrial, and agricultural waste **(Al-Hadedi *et al*., 2024)**. Water pollution leads to the deterioration of water quality, thus disrupting its ecosystem in one way or another. This weakens its ability to perform its role naturally, and it loses its economic value when used by humans. Water quality depends on its physical, chemical, and biological properties, which are the basis for determining whether water is suitable for use for a specific purpose or cannot be used until after the necessary steps are taken. With specific treatments to modify these properties, standard specifications for water quality have been established for various uses **(Salih & Hassan, 2018)**. These standards must meet specific criteria required by health authorities, including the World Health Organization. These standards are not absolute, but rather general and may change depending on treatment costs and local conditions **(Kudher *et al*., 2015)**.

Most Arab countries, including Iraq, are exposed to environmental water pollution, which poses significant risks, especially in industrial areas with intensive activities **(Al-Saffawi *et al*., 2018; Mohammed *et al*., 2025)**. In the 1980s and earlier, Iraq enjoyed efficient water systems **(Timman, 2018)**. However, water resources have witnessed significant deterioration recently due to a lack of attention. The last twenty years have been marked by a significant deterioration in Iraq's natural environment, Iraq's water has been polluted, ranging from drinking water and rivers to groundwater, in addition to declining water quantities. This is due to the multiple sources of pollution and the lack of strategies to develop the foundations for providing clean water. This is also a result of climate change and the actions taken by neighboring countries on the sources of shared rivers, including polluting them, building dams on them, and ignoring the rules of international river law without taking into account Iraq's water share. The Tigris River is considered one of the most important freshwater resources in Iraq, as it passes in the city of Mosul, which is the largest city in northern Iraq and uses the Tigris River as the main source for daily uses **(Al-Yazichi & Mahmood, 2008)**. The amount of pollutants in the Tigris River increases as it passes through Mosul due to the estuary water that is directly dumped into the river without treatment, in addition to the destruction and collapse of buildings, roads and bridges in Mosul as a result of the conditions that it experienced, which led to an increase in wastewater and pollutants toward the Tigris River, which led to a change in its physical, chemical and biological properties **(Al-Sarraj, 2019)**. All of these matters negatively affected the lives of citizens. Therefore, the need arose, in proportion to the urban development in various areas of life, to have purification stations that provide potable water for humans, in addition to paying attention to its quality and keeping pace with modern industries, with the necessity of using the latest methods, means and raw materials and preparing qualified personnel for it **(Al-Hamdany, 2015)**. It was necessary to conduct a study on the water drawn from the Tigris River before filtration, as well as on the treated water supplied to consumers as potable water, to assess its compliance with international water quality standards. This was achieved by performing various tests on the water and using an effective sterilizing agent **(Al-Emam, 2012)**. The water purification plants in the city of Mosul face numerous challenges due to population growth and rapid urban expansion, along with the deterioration in the quality of raw water supplied to the stations. Moreover, these purification plants have remained unchanged over time, lacking the development needed to keep pace with global water quality standards—ultimately affecting their efficiency.

Therefore, it is essential to continuously monitor and analyze water quality **(Al-Sultan, 2019)**, particularly concerning raw river water and the processes of filtration, purification, and sterilization, to achieve the desired quality and quantity of potable water. Additionally, raising public awareness about water consumption, hygiene, and environmental health is crucial to creating a healthy environment in line with the goals pursued by developed countries **(Al-Hamdany, 2015)**. As a result of the above, the objectives of the study were as follows:

1. To examine certain physical and chemical properties of the raw water entering the project, as well as the water passing through the sedimentation, filtration, and chlorination units.
2. To assess these properties in selected neighborhoods on the right side of the river by collecting water samples from areas near the project, followed by those at a moderate distance, and finally from neighborhoods located at the far end of the project's supply network.
3. To evaluate the water quality in both the project units and the residential neighborhoods by comparing the results with international standards for potable water.

MATERIALS AND METHODS

1. Study area

To achieve the objectives of the current study, the New Al-Yamani Water Project, located on the right bank of the Tigris River, was selected. This purification plant supplies approximately 65% of the neighborhoods on the right bank of Mosul with potable water.

2. Sampling

Monthly water sample collection began in October 2024 and continued through December 2024.

3. Sample types

To analyze selected physical and chemical properties, water samples were collected from each of the designated sites using 2.0-liter polyethylene bottles. The bottles were thoroughly rinsed with water before sample collection.

4. Measurement methods

The measurement methods used in the current study were based on standardized procedures from **APHA (2017)**. A summary of each method is provided below. Field parameters, including water temperature, turbidity, pH, electrical conductivity (EC), and total dissolved solids (TDS), were measured on-site, while all other parameters were analyzed in the laboratory.

- **Temperature**: Measured in the field using a graduated alcohol thermometer (−10 to 110°C). The thermometer was immersed in the water sample for several minutes before recording the reading.

- **pH**: Measured on-site using a Hanna Instruments HI 8424 field pH meter.

- **Turbidity**: Measured using a turbidity meter.

- **Electrical Conductivity (EC)**: Measured in μS/cm using a HANNA HI 9811-5 EC field meter.

- **Total Dissolved Solids (TDS)**: Measured in mg/L using a TDS meter (model: Conductivity.TDS.°C Hold).

- **Total Hardness (mg/L as $CaCO_3$)**: Indicates the presence of bivalent cations, mainly calcium and magnesium. Measured using the EDTA titration method with Eriochrome Black T (EBT) as the indicator.

- **Calcium Hardness (mg/L as $CaCO_3$)**: Represents the concentration of divalent calcium ions. Measured using the EDTA titration method with murexide as the indicator.

- **Magnesium Hardness (mg/L as $CaCO_3$)**: Calculated using the formula: *Magnesium hardness = Total hardness − Calcium hardness*

- **Nitrate Ion (NO_3^-)**: Measured by the ultraviolet (UV) method using a spectrophotometer. A known volume of the sample was treated with 1 mL of 1N HCl, then measured at wavelengths of 220 and 270nm. The difference in absorbance was used to determine the concentration using a standard calibration curve.

- **Orthophosphate Ion (PO_4^{3-})**: Determined using the stannous chloride method and a UV-vis spectrophotometer. A known volume of the sample was mixed with 1mL of ammonium molybdate and two drops of stannous chloride. Measurement was conducted at a wavelength of 690nm and the concentration was determined using a standard curve.

- **Sulfate Ion (SO_4^{2-})**: Measured using the turbidimetric method with a spectrophotometer. The sample was treated with 1 mL of 1:1 HCl and an adequate amount of barium chloride. The resulting turbidity was measured at 420nm, and the concentration was calculated using a standard calibration curve.

- **Chloride Ion (Cl^-)**: Measured using the argentometric method with silver nitrate. A known volume of the sample was treated with 1mL of potassium chromate indicator, then titrated with 0.0141 N silver nitrate until a color change from yellow to brick red occurred. A blank test using distilled water was also conducted for accuracy. The concentration was then calculated in mg/l using the following equation:

$$Cl(mg/l) = \frac{(A - B) \times N \times 35450}{ml\ of\ sample}$$

A = Volume of silver nitrate solution used to titrate the sample

B = Volume of silver nitrate solution used to titrate the distilled water

N = Molarity of silver nitrate solution (0.0141 N)

RESULTS AND DISCUSSION

1. Physical properties

1.1. Water temperature

The results in Table (1) indicate that the highest recorded temperature was 21.15 °C in October, while the lowest was 12.35°C in November. This variation can be attributed to seasonal changes in ambient temperature and the interaction between raw water and the structural components of the liquefaction plant, where heat exchange occurs. The temperature of the water is also influenced by air temperature **(Sabawi & Kannah, 2023)**. The elevated temperature in October is related not only to ambient conditions but also to increased microbial activity, which leads to higher oxygen consumption for decomposing organic matter. Conversely, the lower temperature in November reflects reduced microbial activity, which impacts the decomposition process **(Manhan, 2004; Al-Sarraj, 2019)**.

1.2. Total dissolved solids (TDS)

As shown in Table (1), the highest TDS value was 210.11mg/ L in December, while the lowest was 205.89mg/ L in November. The elevated TDS levels are likely due to longer water residence times in sedimentation basins and lower Tigris River water levels during this period **(Mohammed *et al.*, 2021)**.

1.3. Electrical conductivity (EC)

According to Table (1), the highest EC value was recorded in December at 420.55 µS/cm, while the lowest was 412.44 µS/cm in November. The increase in EC during December can be attributed to significant wastewater runoff entering the river from surrounding valleys and rainfall-induced surface flushing, which carries salts into the water body. Notably, there was no observed difference between the EC of raw water entering the liquefaction plant and the treated water, indicating that the treatment process lacks a mechanism for salt removal. As a result, the quality of the treated water closely mirrors that of the raw water, especially in terms of pollutants not targeted by the treatment units **(Mustafa, 2011; Al-Hamdany, 2015)**.

1.4. Turbidity

The highest turbidity level was observed in October at 7.38 NTU, while the lowest was 3.57 NTU in December, as shown in Table (1). This difference may result from sediment accumulation in the station's tanks and pipelines due to irregular cleaning and maintenance **(Sabawi & Kannah, 2023; Hmoshi *et al.*, 2024)**. Turbidity is also influenced by rainfall and temperature. High October temperatures and low river flow led to increased turbidity due to waste discharge and sediment suspension. In contrast, lower December temperatures, higher water levels, and faster flow helped disperse suspended solids, reducing turbidity **(Al-Zurf, 2024)**. It is worth noting that turbidity values remained within the acceptable range set by the World Health Organization.

The turbidity removal efficiencies of the sedimentation and filtration units were also assessed. In October, the sedimentation tanks had a removal efficiency of 43.07%, while filtration tanks achieved 11.32%. In November, the efficiencies were 9.97% and 16.43%, respectively. By December, sedimentation tanks achieved 18.18%, while filtration tanks significantly improved to 61.43%.

1.5. pH

According to Table (1), the highest pH value (8.28) was recorded in November, while the lowest (7.32) occurred in December. The slight alkalinity observed is attributed to the presence of bicarbonate ions (HCO_3^-) in the water **(Alsaffawi *et al.*, 2018)**.

However, the biological breakdown of organic materials can release carboxylic and mineral acids, which may slightly lower the pH **(Al-Taee, 2021; Al-Soyffe *et al.*, 2022)**.

Table 1. Physical and Chemical properties of the water of the studied sites during the study months

	Sites / Indicator	S1	S2	S3	S4	S5	S6	S7	S8	S9	Mean
October	Temp. (C°)	22.7	22.9	22.4	22.2	21.8	22.8	18.9	18.4	18.3	21.15
	TDS (mg/l)	208	209	208	208	207	208	208	202	200	206.44
	EC (µS/cm)	416	418	416	416	415	416	416	404	401	413.11
	Turb. (NTU)	22.6	15	8.54	7.77	6.89	2.35	0.53	0.93	1.79	7.38
	pH	6.93	7.52	7.54	7.46	7.31	7.31	7.75	7.88	7.83	7.50
November	Temp. (C°)	14.7	14.5	14.3	14.2	14.2	14.4	8.9	8.2	7.8	12.35
	TDS (mg/l)	203	202	202	202	203	203	216	209	213	205.89
	EC (µS/cm)	406	404	405	405	407	407	433	419	426	412.44
	Turb. (NTU)	5.3	7.22	6.5	6.27	5.24	1.9	0.77	0.84	1.52	3.95
	pH	8.5	8.56	8.48	8.39	8.18	8.16	8.13	8.07	8.06	8.28
December	Temp. (C°)	14.8	14.5	14.6	14.2	14.2	14.5	13.6	14.2	15.6	14.5
	TDS (mg/l)	206	205	206	206	207	211	216	215	219	210.11
	EC (µS/cm)	412	411	413	413	415	422	431	430	438	420.55
	Turb. (NTU)	10.2	4.95	4.05	5.16	1.99	1.5	1.42	0.79	2.04	3.57
	pH	6.94	7.14	7.16	7.2	7.13	6.84	7.55	7.91	8.01	7.32

2. Chemical properties

2.1. Total hardness, calcium hardness, and magnesium hardness

The results shown in Table (2) demonstrate a clear variation in hardness values between October and the subsequent months of November and December. Total hardness was highest in October at 78.44mg/ l, while it was lower in November at 56.89mg/ l and slightly lower still in December at 56.44mg/ l, measured as $CaCO_3$. Calcium hardness peaked in October at 11.47 mg/l, while the lowest value of 6.19 mg/l was recorded in December. Similarly, magnesium hardness reached its maximum in October at 12.10 mg/l and its minimum in November at 9.46mg/ l.

This variation in hardness values can be attributed to the accumulation of salts in sedimentation basins and the lack of regular maintenance or cleaning of water tanks **(Ali, 2016)**. Additionally, the presence of salts in the raw water is influenced by the surrounding soil composition and the geological pathways the river traverses, as well as by incoming wastewater **(Al-Hamdany & Al-Saffawi, 2018; Jaafer & Al-Saffawi, 2020; Mohtfer & Al-Saffawi, 2022; Al-Hadedi *et al.*, 2024)**. The same reasoning applies to calcium and magnesium hardness, both of which vary due to wastewater influx containing high concentrations of these elements **(Al-Taee, 2022; Al-Hadedi *et al.*, 2024)**.

2.2. Nitrate Ion (NO_3^-)

The results in Table (3) indicate that the highest average nitrate ion concentration was 0.65 mg/l in December, while the lowest was 0.18mg/ l in October. The increased concentration in December is attributed to multiple sewage discharges, surface runoff from agricultural lands, and soil erosion caused by rainfall. These sources often contain organic and synthetic fertilizers rich in nitrogen compounds. The lower concentration observed in October may be due to higher temperatures, which promote microbial activity that consumes nitrogen compounds **(Fadhel & Hamid, 2018)**.

2.3. Orthophosphate Ion (PO_4^{3-})

The highest level of orthophosphate ion, 0.33mg/ l, was recorded in November, while the lowest, 0.12mg/ l, occurred in December, as shown in Table (3). The elevated value in November may be attributed to fertilizers and detergents that reached the water, as orthophosphate is the main component of both **(Al-Masawi *et al.*, 2024)**. The lower value in December likely resulted from dilution caused by rainfall **(Fadhel & Hamid, 2018)**.

2.4. Sulfate Ion (SO_4^{2-})

According to Table (3), the highest sulfate concentration was recorded in November at 64.24mg/ l, while the lowest was 24.86mg/ l in October. Sulfate levels vary based on geological formations the river passes through, as well as inputs from domestic, industrial, and agricultural waste. Biological decomposition of organic materials also contributes sulfate compounds, such as carboxylic and mineral acids **(Al-Saffawi *et al.*, 2018)**. The elevated sulfate level in November can be explained by increased pollutant runoff from rainfall, bird droppings prevalent at the sampling sites, and delays in cleaning the sedimentation basins.

2.5. Chloride Ion (Cl^-)

As shown in Table (3), the highest chloride ion level was 8.88 mg/l in December, while the lowest was 7.99 mg/l in October. However, there was no significant variation in chloride levels across the months studied. This is primarily because the Tigris River naturally contains lower chloride concentrations compared to groundwater, which typically has higher chloride levels **(Al-Emam, 2012)**.

Table 2. Total hardness and calcium and magnesium hardness of the water of the studied sites during the study months

	Sites / Indicator	S1	S2	S3	S4	S5	S6	S7	S8	S9	Mean
October	T.H (mg/l)	100	102	86	92	96	96	48	42	44	78.44
	Ca.H (mg/l)	48	48	44.8	41.6	32	32	6.4	3.2	1.6	28.62
	Mg.H (mg/l)	52	54	41.2	50.4	64	64	41.6	38.8	42.4	49.82
November	T.H (mg/l)	64	64	62	56	56	50	52	52	56	56.89
	Ca.H (mg/l)	25.6	25.6	19.2	17.6	17.6	12.8	12.8	12.8	17.6	17.95
	Mg.H (mg/l)	38.4	38.4	42.8	38.4	38.4	37.2	39.2	39.2	38.4	38.93
December	T.H (mg/l)	62	62	60	56	54	52	54	54	54	56.44
	Ca.H (mg/l)	22.4	22.4	16	16	12.8	11.2	12.8	12.8	12.8	15.47
	Mg.H (mg/l)	39.6	39.6	44	40	41.2	40.8	41.2	41.2	41.2	40.97

Table 3. Nitrate, phosphate, sulfate, and chloride ions for the water of the studied sites during the months within the study period

	Sites / Indicator	S1	S2	S3	S4	S5	S6	S7	S8	S9	Mean
October	$NO3^{-1}$ (mg/l)	0.0983	0.0945	0.106	0.106	0.0798	0.102	0.101	0.493	0.411	0.18
	$PO4^{-3}$(mg/l)	0.291	0.307	0.387	0.298	0.251	0.246	0.064	0.073	0.062	0.22
	$SO4^{-2}$(mg/l)	11.095	6.698	7.129	7.388	7.819	8.077	74.198	53.164	48.164	24.86
	Cl^{-1} (mg/l)	5.998	7.997	9.997	9.997	7.997	7.997	11.996	5.998	3.999	7.99
November	$NO3^{-1}$ (mg/l)	0.169	0.249	0.975	0.475	0.489	0.546	0.558	0.671	0.519	0.52
	$PO4^{-3}$(mg/l)	0.312	0.303	0.314	0.398	0.309	0.314	0.314	0.309	0.428	0.33
	$SO4^{-2}$(mg/l)	60.405	67.302	62.129	69.026	67.302	61.267	62.129	63.853	64.715	64.24
	Cl^{-1} (mg/l)	11.996	11.996	5.998	5.998	5.998	5.998	7.997	7.997	9.997	8.22
December	$NO3^{-1}$ (mg/l)	0.516	0.531	0.542	0.749	0.531	0.493	0.998	0.573	0.93	0.65
	$PO4^{-3}$(mg/l)	0.273	0.13	0.061	0.071	0.108	0.112	0.125	0.108	0.11	0.12
	$SO4^{-2}$(mg/l)	36.008	65.491	41.784	36.181	46.009	41.784	30.233	41.009	36.009	41.61
	Cl^{-1} (mg/l)	11.996	11.996	7.997	7.997	7.997	7.997	7.997	7.997	7.997	8.88

CONCLUSION AND RECOMMENDATIONS

Conclusion:

1. Several physical and chemical characteristics of the study sites exhibited significant variations in their values and concentrations across the different months of the study period.

2. In certain months, some of these parameters exceeded the international limits established by the World Health Organization (WHO).

Recommendations:

1. Undertake more comprehensive studies on this project, including the measurement of heavy metal concentrations in the water.

2. Investigate the presence of microorganisms within the study area, with particular attention to identifying any potentially pathogenic species.

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