Study of the Physicochemical Characteristics of some Valleys and Estuaries in the City of Mosul/Iraq

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INTRODUCTION

Aquatic ecosystems face several challenges due to the industrial, agricultural, and social developments taking place in the world, as these systems are exposed to pollution resulting from the discharge of municipal, industrial, and agricultural wastes (Al-Saffawi & Al-Maathi, 2017). In past eras, a restricted impact was recorded on the rivers due to human activities, as this is consistent with the low population density in addition to the simplicity of the activities that were practiced by humans (Al-Sarraj, 2013). However, at the present time, as a result of population growth, industrial and agricultural expansion, adding to the lack of planning in building cities, water sources suffer from great pollution (Kannah & Shihab, 2022). Therefore, rivers and streams have become the main repository for large quantities of different types of waste (Shihab, 2021). The issue of providing potable water is a global issue, as approximately 844 million people in the world do not have the opportunity to obtain potable water (Al-Mtewti, 2018). Given that...
statistics elucidated that the percentage of water consumption during the period (1990-1995) has increased six-times, which is equivalent to more than double the rate of population increase, one third of the world’s population will face serious water crises in 2025, because of the increasing need of water associated with the increase in the world’s population (Al-Saffawi & Al-Maathi, 2017).

Water quality is considered one of the very important issues in the world, in general, and in Iraq, in particular, due to the limited water resources in Iraq and its geographical location within the dried and semi-dried region (Saghir, 2017), as dry and semi-dried areas constitute 90% of the area of Iraq (Shabib, 2020). In a speech by the spokesman for the Iraqi ministry of water resources, the water reserve has now reached extremely critical stages, and that the water revenues that come to Iraq today are 30% of its actual entitlement (Al-Assadi, 2023), and here it is mandatory to note that the reason behind this is the policies of the countries in the neighborhood. Water scarcity has caused a disaster regarding the biodiversity in rivers and marshes (Makki, 2023).

The Tigris River is the only surface water resource in the city of Mosul; its water is used for various human, industrial, and service uses (Al-Sarraj et al., 2014). The discharges of the Tigris River water in the city of Mosul is estimated at about (300) m³/second (Al-yazichi & Mahmood, 2018). While, the amount of liquid waste thrown into the Tigris River within the city of Mosul is estimated at approximately (500,000) m³/day (Mustafa & Jankeer, 2007), which may lead to a change in the river’s physical, chemical, and biological properties, causing an increase in the amount of suspended materials and the concentration of chemical elements, adding to experiencing changes in the amount of dissolved oxygen since the latter depends on the type and quantity of pollutants released (Al-yazichi & Mahmood, 2018).

In fact, the danger in the Tigris River in the city of Mosul is in the large quantities of sewage reaching the river (Al-Rawi, 2005). Individual abuse has reached the point of some citizens discharging water septic tanks to the public drainage network, and this in turn will exacerbate the problem in addition to the risk of the transmission of epidemics and diseases (Al-Saffawi, 2018; Al-Mashhadany, 2019).

It is mandatory, as a result of the river’s pollution and low levels, efforts must be intensified to reduce these pollutants by continuously conducting environmental studies on liquid pollutants that flow into water sources. These studies would address the effects of pollutants and find the best ways to treat them (Al-Saffawi & Al-Maathi, 2014; 2017).

Therefore, the current study aimed to evaluate the physicochemical characteristics of some wastewater valleys and sewages that drain their water into the Tigris River in the city of Mosul.
MATERIALS AND METHODS

Description of the study area

The current study was conducted in the laboratories of the College of Environmental Sciences and the laboratories of the College of Science at the University of Mosul. The study area included six sites on both the sides of the Mosul City (Table 1).

<table>
<thead>
<tr>
<th>Location</th>
<th>Downstream</th>
<th>Longitude</th>
<th>Latitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>First site</td>
<td>Wadi Akkab</td>
<td>36°22'04&quot; N</td>
<td>43°06'20&quot; E</td>
</tr>
<tr>
<td>Second site</td>
<td>Kara saray</td>
<td>36°21'11&quot; N</td>
<td>43°07'28&quot; E</td>
</tr>
<tr>
<td>Third site</td>
<td>The medan</td>
<td>36°20'44&quot; N</td>
<td>43°08'11&quot; E</td>
</tr>
<tr>
<td>Fourth site</td>
<td>The khuser</td>
<td>36°20'51&quot; N</td>
<td>43°08'26&quot; E</td>
</tr>
<tr>
<td>Fifth site</td>
<td>Dandan</td>
<td>36°20'07&quot; N</td>
<td>43°08'46&quot; E</td>
</tr>
<tr>
<td>Sixth site</td>
<td>Danville</td>
<td>36°19'25&quot; N</td>
<td>43°10'14&quot; E</td>
</tr>
</tbody>
</table>

Samples collection

Samples were collected in the study area on a regular basis (Table 1), starting from September till November 2023. In fact, the samples were collected to conduct laboratory tests and analysis using clean and well-washed glass bottles with 1000ml of distilled water. For the determination of dissolved oxygen (DO) and the biological oxygen demand (BOD₅), samples were stored in special bottles with a capacity of 500ml that were used to collect them without creating air bubbles. In addition, bottles were then kept in boxes away from light until the samples were measured (APHA & WCPE, 1998).

Physical tests

Electrical conductivity (EC)

The EC was measured in the field using a pH & EC meter, type HANNA INSTRUMENTS, model HI-98129, Romanian origin, and the reading was calculated from the device directly after setting the temperature at 25°C and in the unit of µs/cm.

Turbidity

Turbidity was measured in the laboratory-wise after well shaking to the sample using a turbidity meter, type WTW, model TURB 750 IR, of German origin, and was
measured in units (NTU), as the device is calibrated with special standard solutions and different turbidity values.

**Total dissolved solid (T.D.S)**

Total dissolved solids were measured in the field using a Chinese TDS meter and are measured in mg/l.

**Total suspended solid (T.S.S)**

Total suspended solids were measured in the laboratory using a filter disc after drying it at a temperature of 103-105°C for an hour to get rid of moisture. The filter disc was weighed after cooling using a sensitive electronic balance. A certain volume of the mixed sample was placed on top of the filter disc; the disc was dried again and weighed. As a result, the total suspended solids value was calculated according to the following law:

\[ T.S.S_{mg/l} = (A - B) \times 10^6 V_{ml} \]

A: The weight of the filter disc after the sample was passed.

B: Weighing the filter disc before passing the sample.

V: Sample volume.

**Chemical tests**

**pH**

The pH was measured in the field using a pH & EC meter, type HANNA INSTRUMENTS, model HI-98129, Romanian origin, and the reading was calculated from the device directly after calibrating the device with buffer solutions.

**Dissolved oxygen in water (DO)**

Dissolved oxygen was measured in the laboratory using a DO meter electrode, type WTW, model Oxi 3310, of German origin, after placing the model in a clean, well-washed glass beaker with distilled water; it is measured in mg/L.

**Biological oxygen demand (BOD₅)**

The biological oxygen demand was measured in the laboratory using an OxiTop device, type WTW, model IS 12, of German origin. For this test, special glass bottles with a magnetic stirrer were used, then an appropriate volume of the sample was placed, depending on the amount of expected sample contamination, and according to Table (2). Three grains of (NaOH) were added to the plastic piece, then the bottles tightly closed
with the plastic cap, and the device was returned to zero and was placed in the incubator at a temperature of 20 °C for five days. The BOD$_5$ value was obtained by the law:

\[
\text{BOD}_5 \text{mg/l} = \text{Reading Day Five} \times \text{Factor}
\]

**Table 2**: Factor values for calculating BOD$_5$

<table>
<thead>
<tr>
<th>Sequence</th>
<th>BOD$_5$ Expected (mg/l)</th>
<th>Appropriate model size (ml)</th>
<th>Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0-40</td>
<td>432</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>0-80</td>
<td>365</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>0-200</td>
<td>250</td>
<td>5</td>
</tr>
<tr>
<td>4</td>
<td>0-400</td>
<td>164</td>
<td>10</td>
</tr>
<tr>
<td>5</td>
<td>0-800</td>
<td>97</td>
<td>20</td>
</tr>
<tr>
<td>6</td>
<td>0-2000</td>
<td>43.5</td>
<td>50</td>
</tr>
<tr>
<td>7</td>
<td>0-4000</td>
<td>22.7</td>
<td>100</td>
</tr>
</tbody>
</table>

**Total hardness (T.H)**

The total hardness was laboratoryly measured by a titration with Na$_2$EDTA, where a certain volume of the sample and 1ml of buffer solution (buffer) were added. A pH value reached (10), then a little dry index (EBT) Eriochrome Black T, was added, followed by a slow titration with a solution of Na$_2$EDTA while shaking until the color changed from red to blue. The total hardness value was calculated in terms of CaCO$_3$ by the following equation:

\[
T.H_{(mg/l)} \text{ as CaCO}_3 = \frac{V \times \text{eq.wt} \times N \times 1000}{\text{Sample volume (ml)}}
\]

V: Volume of filtered Na$_2$EDTA flushed.

eq.wt: Equivalent weight of calcium carbonate.

N: Standardize solution Na$_2$EDTA.

**Calcium hardness (Ca H.)**

Calcium hardness was measured in laboratory using the filtration method Na$_2$EDTA by adding a certain volume of the sample and 2ml of NaOH solution, followed by a little dry meroxide indicator. The sample was filtered with Na$_2$EDTA and shaked...
until the color changed from violet to pink and subsequently blue. The value of calcium hardness was calculated in terms of CaCO$_3$ through the following equation:

$$ Ca_{H.(mg/l)} \text{ as } CaCO_3 = V \times eq.wt \times N \times 1000 \ \text{Sample volume (ml)} $$

V: Volume of filtered Na$_2$EDTA flushed.

eq.wt: Equivalent weight of calcium.

N: Standardize solution Na$_2$EDTA.

**Magnesium hardness (Mg H.)**

Magnesium hardness was calculated through estimating the difference between total hardness and calcium hardness according to the following equation:

$$ Mg \ H._{mg/l} = (T.H - Ca \ H.) $$

### RESULTS AND DISCUSSION

**Table 3.** The lower and upper limits and average of the physicochemical indicators at the sites during the study period

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Wadi Akkab</th>
<th>Kara saray</th>
<th>The</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Min</td>
<td>Max</td>
<td>Mean</td>
<td>Min</td>
</tr>
<tr>
<td>Esuariest</td>
<td>Turb (NTU)</td>
<td>pH</td>
<td>EC</td>
<td>TDS (mg/l)</td>
</tr>
<tr>
<td>Wadi Akkab</td>
<td>5.5</td>
<td>34.8</td>
<td>16.8</td>
<td>1097</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>7.3</td>
<td>7.2</td>
<td>1204</td>
</tr>
<tr>
<td></td>
<td>1147.6</td>
<td>486</td>
<td>48.3</td>
<td>1147.6</td>
</tr>
<tr>
<td>Kara saray</td>
<td>16</td>
<td>79</td>
<td>40.5</td>
<td>6.7</td>
</tr>
<tr>
<td></td>
<td>6.7</td>
<td>7</td>
<td>6.8</td>
<td>641</td>
</tr>
<tr>
<td></td>
<td>568.3</td>
<td>568.3</td>
<td>68.6</td>
<td>6.8</td>
</tr>
<tr>
<td></td>
<td>710</td>
<td>79</td>
<td>135</td>
<td>6.4</td>
</tr>
<tr>
<td></td>
<td>225</td>
<td>256</td>
<td>256</td>
<td>6.8</td>
</tr>
</tbody>
</table>
Turbidity values showed a clear difference between the study sites. Its maximum rate reached 199.6 NTU in Al-Mwdan estuaries, while its lowest rate was recorded in Wadi Akkab, with a value of 16.8 (Table 3 & Fig. 1) when compared with the parameters in Table (4), which shows the measure of water clarity in terms of turbidity (Water watch, 1997). It was noticed that, the Qarasaray, Al-Midan, and Dandan estuaries fall within the dirty water classifications based on turbidity levels, while low turbidity values were observed in the Wadi Akkab, Al-Khusar, and Danveli estuaries, where the water of these estuaries was classified as good water according to turbidity. The reason for the high turbidity values in the Al-Midan estuary was due to the presence of the fish market (Souq Al-Midan) near this estuary, which drains highly turbid waste water in addition to rainfall in some months during the current study.

<table>
<thead>
<tr>
<th>Category</th>
<th>Turbidity (NTU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 10</td>
<td>excellent</td>
</tr>
<tr>
<td>10 – 30</td>
<td>dūgo</td>
</tr>
<tr>
<td>More than 30</td>
<td>Bad</td>
</tr>
</tbody>
</table>

Table 4. The relationship between water clarity and turbidity values (Water watch, 1997)
Fig. 1. Average turbidity values (NTU) for sites under study during the investigation period

The pH values

The results of the study showed that the pH levels during the study period were between 6.6 & 7.2) (Fig. 2), which are within the normal values of water. The current outcome coincides with the findings of Al-Saffawi and Al-Maathi (2017) concerning the qualitative assessment of the effluents of Wadi Akkab, as the pH values of the valley water ranged between 6.1 & 7.4 and agrees with those of Shehab (2017) who confirmed during his study conducted on the environmental effects of excreta on the water of the Tigris River in the city of Mosul that the pH values were within the ideal range, ranging between 7.3 & 8.2.

Electrical conductivity (EC)

Electrical conductivity rates showed a noticeable increase in the Dandan Estuary, where the value was 1702.3µs/ cm, and the lowest rate was recorded in the Qarasaray Estuary (568.3) µs/cm (Fig. 3). This is related to the nature of the excreta, which contains various types of salts. This finding concurs with that of Al-Hadidi (2018) who detected
noted an increase in the electrical conductivity values in the Tigris River for the city of Mosul, and attributed it to the increased concentration of pollutants resulting from the discharge of municipal, agricultural and industrial wastes into the river directly without any prior treatment.

**Fig. 3. Average EC values for sites during the study period**

**Total dissolved solid (T.D.S)**

Total dissolved solids rates were high in the Dandan Estuary, reaching 760mg/ l, and their lowest rate was registered in the Karasaray Estuary, reaching 261.6mg/ l (Fig. 4). The total dissolved solids value depends on the electrical conductivity value and water temperature, which is directly proportional to the electrical conductivity and temperature (Bhat et al., 2018).

**Fig. 4. Average T.D.S values for sites during the study period**
Total suspended solid (T.S.S)

The results of the study showed that the highest rate of total suspended solid was in the Medan Estuary, which was 180mg/l. In fact, the value surpassed the Iraqi allowed limits for disposal, which were set at 60mg/l, as the maximum permissible limit (Abawi & Hassan, 1990). While, the lowest rate was recorded in Wadi Akkab Estuary, where it reached 48.3mg/l (Fig. 5). Actually, the value of suspended solids depends on the nature of the excreta, which depends on human activity (Ahmed, 2015).

![Fig. 5. Average T.S.S values for sites during the study period](image)

Dissolved Oxygen in water (DO)

The lowest concentration of dissolved oxygen appeared in the Al-Khawsar and Wadi Akkab Rivers, as their rates reached 0.7mg/l (Fig. 6). This is close to the values recorded in the study of Al-Taee (2022) conducted on the Al-Khawsar River, where she recorded the lowest value with 0.00mg/l, while the highest value for the dissolved oxygen was in the Al-Midan, Qarasray, and Dandan Estuaries, where the rates reached 1.38, 1.36, and 1.29mg/l, respectively (Fig. 7). This can be traced back to the increased solubility of dissolved oxygen in water, as well as the relative decrease in the viability of microorganisms and thus the less oxygen consumption (APHA & WCPE, 1998).
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Biological oxygen demand (BOD₅)

The results showed a high increase in BOD₅ rates in the Al-Maydan and Dandan estuaries, which respectively reached 341 and 297.3mg/l (Fig. 7) due to the huge amount of organic wastes leading to an increase in the activity of microorganisms decomposing these wastes (Al -Saffawi & AL-Taay, 2013). Whereas, the lowest rate was evaluated in the Al-Khosar River, which amounted to 26.6mg/ l (Fig. 7). Upon comparing the results with the Iraqi limits allowed for draining, being 40mg/ l as the highest value for BOD₅ (Abawi & Hassan, 1990), it was observed that most BOD₅ values for the sites under study exceeded the permitted limits.
Total hardness (T.H)

The water hardness showed a clear difference in its rates, as its lowest rate was in the Danveli Valley, with a value of 148.33 mg/l, and its highest value was in the Dandan Estuary, reaching a value of 313.3 mg/l (Fig. 8). These results are close to the results obtained by Al-Taee (2022) in her study about the Al-Khosar River, where the total hardness value reached 533 mg/l during the autumn season. In fact, the increase in the values was due to the nature of the sediments and discharged wastewater, especially that the domestic water contains table salt, impure salts, and in autumn it is rich in calcium and magnesium salts (Al-Mashhadany, 2023).

Fig. 8. Average T.H values for the sites during the study period

Calcium hardness (Ca H.)

The study showed the lowest rate of observed calcium hardness in the Danveli Valley, reaching 64 mg/l, while the highest rate was observed in the Dandan Estuary, reaching 165.3 mg/l (Fig. 9). These results are similar to what was found in the study of Al-Mashhadany (2023) addressing Wadi Akkab, where the rate at one of its sites was recorded at 166 mg/l during summer. Actually, is due to what is released from sewage water containing high concentrations of calcium and drained into the Al-Khosar River (Al-Taee, 2022).
Magnesium hardness (Mg H.)

The results showed a clear difference in the values of magnesium hardness, as its lowest rate in the Al-Khusradh stream reached 59.6mg/ l, and its highest rate in the Dandan estuary reached a value of 148mg/ l (Fig. 10). These values are close to those reported in the study of Al- Taee (2022) examining the Al-Khosar Stream, where her study rate reached 159.7mg/ l in the second station of the Al-Khosar River.

CONCLUSION

It was deduced that, most of the physicochemical characteristics exceeded the safeguards at some study sites. The concentration values of the biological oxygen demand and suspended solids surpassed the permissible limits for
release into rivers. The pH values were within the normal range at all study sites and throughout all the months of the year. A low concentration of dissolved oxygen was detected in water. In addition, a distinct increase was recorded in turbidity and hardness values at some study sites and during some months. Thus, it is recommended to continuously investigate the water quality of the Tigris River to eliminate pollutants and determine the best ways to acquire a healthy environment for the sake of the aquatic organisms and human.

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