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Effect of Medical City Complex Effluents on the Physicochemical Properties of the Tigris River Water

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Abstract
Ecosystem and human health is largely dependent on the quality of water. Aspects of water quality are influenced by many different physicochemical parameters. The purpose of this study was to investigate the effect of Medical City Complex effluents (MCC) on the physicochemical characteristics of the Tigris River. Three samples were taken monthly from June to November 2025. Site 1 was located above MCC on Sarafiya Bridge, Site 2 was located near MCC effluents, while Site 3 was located below MCC effluents on the river dock along Mutanabbi Street. Samples from each sampling site were analyzed, using the standard methods. The study found that most chemical characteristics of water quality at all three sites were relatively consistent and therefore indicate a generally good quality, while there were substantial differences between sites 1 and 2 with respect to turbidity, conductivity, nitrate, and phosphate concentrations. Because Site 2 appeared to be influenced by surface runoff, municipal wastewater, or other anthropogenic activities, the results of this study underscore the need for continual monitoring of nutrient enrichment and suspended solids to protect the ecological integrity of the water bodies and to prevent water quality problems associated with eutrophication from occurring. Overall, the water quality is acceptable for aquatic organisms; however, targeted interventions and ongoing monitoring of sites with relatively high concentrations of nutrients and turbidity are recommended to maintain ecological balance and protect water use.
Keywords: Tigris River; Medical City pollutants; Hospital wastewater; Physicochemical water quality; Turbidity; Conductivity; Nutrients.

1. Introduction

Ecological systems rely heavily on rivers; they are also important locations for human habitation and support the use of freshwater for people, agriculture, and industry[1]. The Tigris River in Iraq has been and remains an essential source of freshwater for drinking and the survival of the many people who live along its banks[2]. Unfortunately, through the rapid growth of urban areas, the population, and the lack of proper management of wastes being discharged into the river, the Tigris has experienced the effects of increased environmental pollution over the last several decades[3]. Among the main sources of pollution are discharges from hospitals, manufacturers, and municipal sources that have not treated or only partially treated the wastewater before disposal[4]. Discharge of wastewater into the Tigris River includes many different pollutants, including chemicals, biologicals, and pharmaceuticals, and these can have a negative impact on the quality of the water, and therefore the ability to sustain life in the river and surrounding areas[5, 6].

The composition of medical wastewater is very complex and cause for concern, as it includes an estimated amount of detergent, disinfectant, pharmaceuticals, diagnostic chemicals, heavy metals, pathogens, and hundreds of other organic materials[7]. If these contaminants are not properly treated prior to their release into surface waters, they can significantly alter the water's physicochemical properties, adversely affect aquatic habitats, and present risks to the health and welfare of surrounding communities and ecosystems[8]. Medical City Complex (MCC) in Baghdad is one of the largest hospitals in this area, with large volumes of wastewater generated every day; a substantial amount will make its way to the Tigris River, creating concerns about how that impacts the water quality[9].

River water physicochemical characteristics such as temperature, pH, turbidity, dissolved oxygen, electrical conductivity, nutrient concentrations, and total dissolved solids are important indicators of the pollution state of the river and the health of its ecosystem[10]. Any changes in these parameters may reflect changes in the chemical makeup of the water as a result of outside inputs, such as medical waste[11]. For instance, high levels of turbidity could indicate an increase in particulate matter or microbial contamination, whereas low levels of nitrates or phosphates could indicate that waters have experienced eutrophication, therefore causing a change in the balance of the ecosystem [12]. The levels of dissolved oxygen will also affect the ability of some fish species to survive and distribute themselves throughout the river. Conductivity levels will also indicate a change in the number of dissolved ions in the water, which may be due to the increase of chemical effluents[13].

Since the Tigris River's strategic importance and direct influence on the welfare of residents living in Baghdad make it essential to study the effects of Medical City discharge on Tigris River water quality, understanding how pollutants affects physiochemical properties of the Tigris River will help researchers and policymakers identify areas of concern, develop appropriate regulations, and develop effective wastewater management strategies[14]. In spite of the number of studies on general water pollution levels of Tigris River water, very few studies specifically focused on medical complex discharges, which are high-level and specialized contaminants[15]. A study on this aspect will be critical to providing better public health protection, sustainable use of Tigris water, and preserving the ecological balance of the Tigris River[16]. This study seeks to assess the effects of pollutants discharged from MCC on the physicochemical characteristics of Tigris River Water through the comparison of physicochemical characteristics of Tigris River Water at various sampling locations and quantifying the relationships between physicochemical characteristics and the level of influence of medical effluents.

2. Materials and Methods

2.1. Sample collection

Water samples were obtained monthly from June to November 2025. Water samples were collected from three sites located along the Tigris River: Site 1 was located above MCC on Sarafiya Bridge, Site 2 was located about 500 m near MCC effluents, while Site 3 was located below MCC effluents on the river dock along Mutanabbi Street (**Figure 1**).

All samples were collected in 1 L dark glass Winkler bottles, and plastic containers were placed in a cool box to prevent exposure to sunlight and preserve their physicochemical properties. Winkler bottles and plastic containers were put in a cool box to prevent exposure to sunlight in order to preserve their physicochemical properties[17, 18].

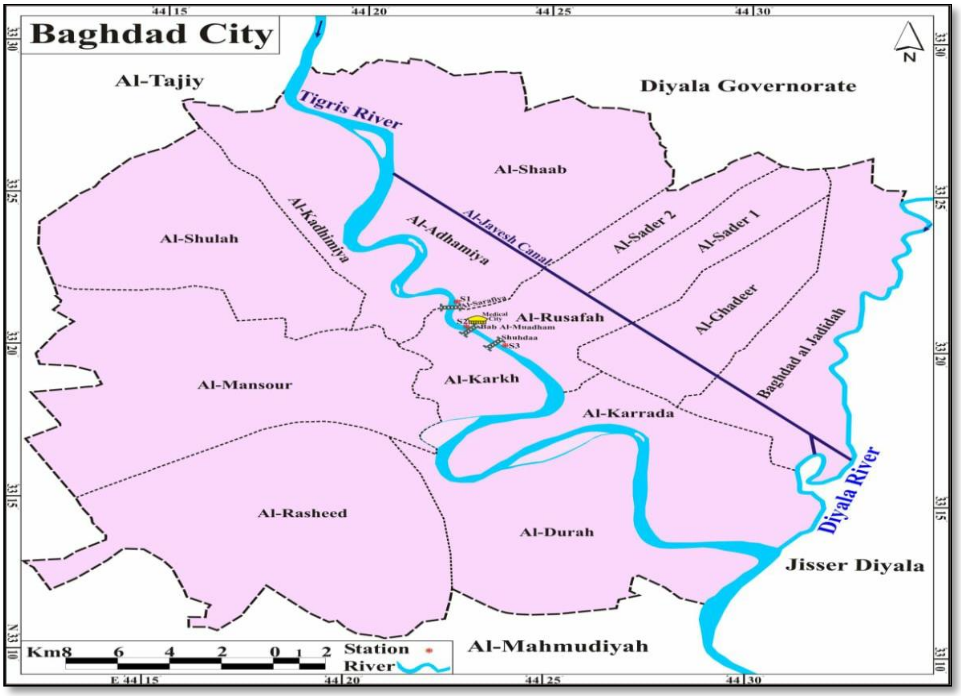

Figure 1. Map showing the studied site on the Tigris River.

2.2. Field measurements

Air and water temperature at each site were recorded using a digital thermometer[19]. Electrical conductivity and salinity were measured directly by using a portable conductivity/salinity meter (Hanna Instruments HI9835, Romania) and expressed in ‰ and µS/cm[20], respectively. Total Dissolved Solids were measured directly in the field using a portable TDS meter (Hanna Instruments HI98301, Romania) and expressed in g/L[21].

2.3. Laboratory measurements

Turbidity was measured in the laboratory using a turbidity meter (Hach 2100P Portable Turbidimeter, USA) and expressed in NTU (Nephelometric Turbidity Units)[22]. pH values were measured using a calibrated pH meter (Hanna Instruments HI2211 Bench pH Meter, Romania) according to[23] standards. The Winkler titration method was used to determine DO levels, and DO concentrations are typically reported in mg/L[24].

The BOD_5 result was determined by keeping a sample at 25°C in a closed container for five days, followed by DO titration using the same technique of the Winkler test. The BOD_5 value represents the amount of oxygen consumed from the sample during the five days[25].

The Ascorbic Acid method was used for reactive phosphate determination, and reactive phosphates were reported as mg/L[26] using a UV–Visible Spectrophotometer (Shimadzu UV-1800, Japan).

Total hardness was measured by EDTA titration, and results were expressed as mg/L $CaCO_3$[27]. Calcium concentration was determined by EDTA titration using murexide indicator after sample alkalization[28]. Magnesium concentration was calculated mathematically from the difference between total hardness and calcium concentrations[29].

Nitrate concentration was measured by UV spectrophotometry at 220 nm and 275 nm using a UV–Visible Spectrophotometer (Shimadzu UV-1800, Japan). The absorbance correction method was applied to eliminate organic interferences, and results were expressed in mg/L[30].

Total alkalinity was determined by titration using 0.025N sulfuric acid and methyl orange indicator. Results were expressed in mg/L as $CaCO_3$[23].

To determine TSS, a 0.45-µm filter paper was used to filter 100 mL of a water sample. The filter paper was weighed before filtration and after drying at 103–105°C using a hot air oven

(Memmert UN55, Germany), then cooled in a desiccator and reweighed using an analytical balance (Sartorius Entris II, Germany; sensitivity 0.0001 g). The mass difference was calculated to determine TSS[31].

2.4. Statistical analysis

Data analysis was conducted using[32] to evaluate how sampling month and location influenced the physical and chemical characteristics of the samples. Significant differences between the means of the samples were determined by performing a least significant difference (LSD) test.

3. Results

The air temperature ranged between 24.3 and 35.3 ºC, 27.3 and 40.7 ºC, and 29.5 and 42.7 ºC at Sites 1, 2, and 3, respectively (**Table 1** and **Figure 2**). The water temperatures at Sites 1, 2, and 3 were 21.5–30 ºC, 22.6–34.5 ºC, and 22.4–31.5 ºC, respectively (**Table 1** and **Figure 3**). There were no significant differences in air and water temperature value among all three sites ($P \leq 0.05$). Additionally, the pH levels across all three sites were consistent and did not show any significant discrepancy (**Table 1** and **Figure 4**).

Table 1. Descriptive analysis for physicochemical parameters across the three study sites on the Tigris River. Minimum and maximum (First Line), mean and standard deviation (Second Line)

Variable	S1	S2	S3	L.S.D.
Air temperature (ºC)	24.3 – 35.3 32.33 ±2.89	27.3 – 40.7 35.58 ±4.63	29.51 – 42.7 35.80 ±4.92	3.922 NS
Water temperature (ºC)	21.5 – 30.0 27.45 ±3.66	22.6 – 34.5 29.82 ±5.07	22.4 – 31.5 28.58 ±3.48	3.063 NS
Turbidity (NTU)	2.18 – 18.21 9.89 ±2.08 b	7.02 – 43.37 14.79 ±5.71 a	3.42 – 12.67 9.89 ±3.51 b	4.152 *
Conductivity (µS/cm)	955 - 1270 1078.8 ±237.5 b	992 - 1328 1275.5 ±98.6 a	978 - 1246 1111.0 ±116.4 b	133.48 *
pH	7.2 – 7.87 7.55 ±0.62	7.2 – 7.6 7.53 ±0.79	7.5 – 7.6 7.53 ±0.68	0.389 NS
BOD (mg/L)	1.1 – 3.50 2.13 ±0.29	0 – 3.8 2.27 ±0.44	0.5 – 5.0 2.25 ±0.39	0.364 NS
DO (mg/L)	4.2 – 7.1 5.28 ±0.61	0 – 5.4 4.21 ±0.38	3.4 – 5.7 4.57 ±0.66	1.284 NS
Salt (‰)	0.03 – 0.06 0.043 ±0.02	0.04 – 0.10 0.072 ±0.03	0.04 – 0.10 0.063 ±0.02	0.040 NS
Total Hardness (mg/L)	380 – 528 426.67 ±71.5	296 - 640 443.00 ±45.09	272 - 532 401.00 ±58.6	41.95 NS
Ca^{+2} (ppm)	73.11 -200.4 116.39 ±26.7	80.16 – 208.41 128.76 ±45.2	72.14 – 180.36 108.70 ±27.3	33.17 NS
Mg^{+2} (ppm)	1.08 – 63.16 30.37 ±15.48	4.66 – 41.69 26.12 ±8.92	3.24 – 60.70 28.21 ±14.05	7.62 NS
NO^{-3} (ppm)	0.24 – 1.01 0.506 ±0.23 ab	0.275 – 1.35 0.690 ±0.36 a	0.257 – 0.517 0.402 ±0.25 b	0.208 *
TDS (g/L)	0.477 – 0.635 0.539 ±0.18	0.496 – 0.960 0.637 ±0.28	0.489 – 0.623 0.554 ±0.21	0.184 NS
PO_4^{-2} (ppm)	0.0084 – 0.0163 0.012 ±0.003 b	0.00 – 0.4113 0.074 ±0.022 a	0.00 – 0.0360 0.0149 ±0.004 b	0.039 *
TSS (g/L)	0.006 – 0.16 0.091 ±0.04	0.025 – 0.10 0.127 ±0.06	0.00 – 0.25 0.089 ±0.04	0.061 NS
Total Alkalinity (mg/L)	61.00 – 201.3 139.28 ±41.78	61.00 – 439.2 181.98 ±72.55	48.8 – 183.00 145.38 ±49.61	47.52 NS

Means having with the different letters in same column differed significantly.
* ($P \leq 0.05$), NS: Non-Significant.

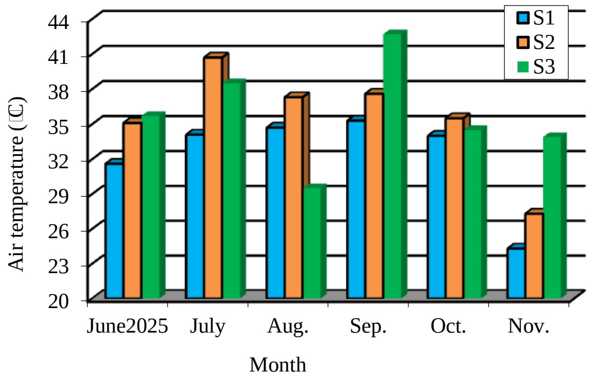

Figure 2 Variation of Air temperature (ºC)

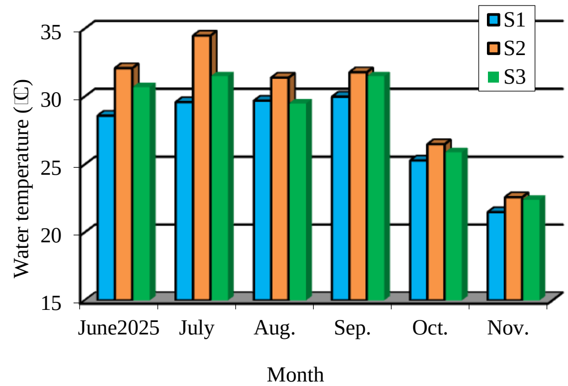

Figure 3. Variation of Water temperature (ºC)

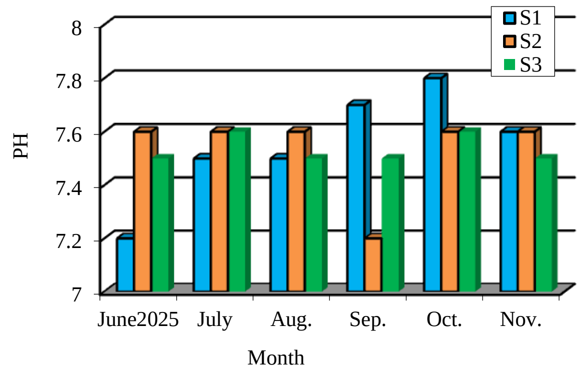

Figure 4. Variation of pH

The turbidity of each site varied significantly, with Site 2 having the greatest turbidity (average 14.79 ± 5.71 NTU) (**Table** and **Figure 5**). There were no significant differences between sites 1 and 3, which differed significantly from site 2 ($P \leq 0.05$), both averaging 9.89 NTU, whereas the electrical conductivity recorded averaged 1275.5 ± 98.6 μS/cm. There were no significant differences between sites 1 and 3, which differed significantly from site 2 ($P \leq 0.05$) (**Table 1** and **Figure 6**). Although there were slight variations in the salinity and total dissolved solids (TDS) at the different sites, statistical testing found no significant difference.

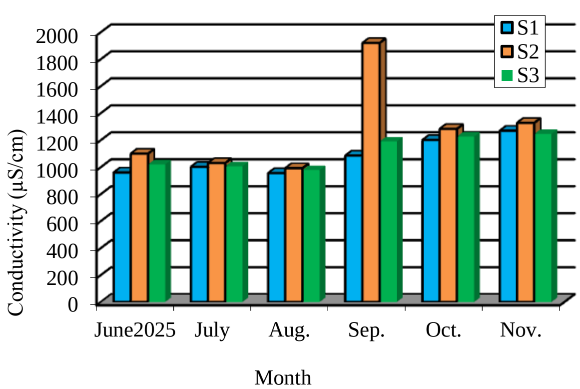

Figure 5. Variation of Conductivity

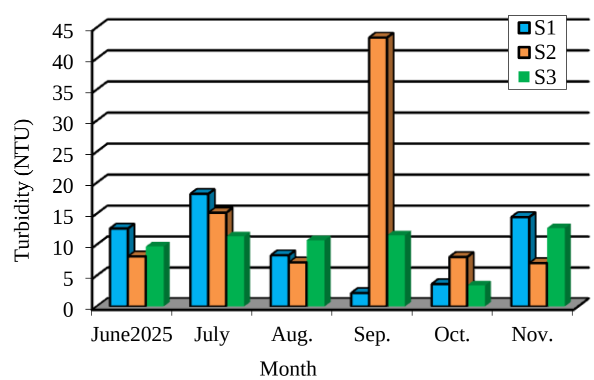

Figure 6. Variation of Turbidity

For dissolved oxygen (DO) concentrations, in general, Site 1 had more DO than Sites 2 and 3. No significant difference between any sites ($P \leq 0.05$), (**Table 1** and **Figure 7**). On a scale of 0-10 for biological oxygen demand (BOD) (**Table 1** and **Figure 8**), all sites had relatively low biological demand likewise with the salinity of all samples from each site; the only difference in salinity between all the sites was that Site 2 was significantly higher than sites 1 and 3 (**Table 1** and **Figure 9**). Total hardness (**Table 1** and **Figure 10**), as well as the concentrations of both calcium and magnesium, are not significantly different between the three sites, which suggests that they all contain the same weak alkaline character (**Table 1** and **Figures 11 and 12**).

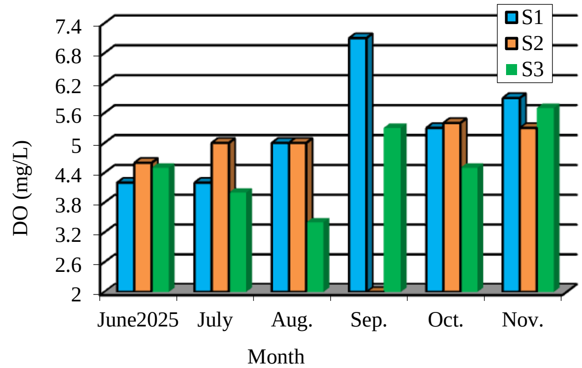

Figure 7. Variation of DO.

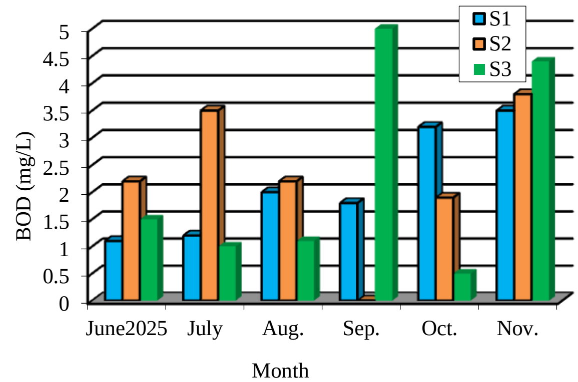

Figure 8. Variation of BOD

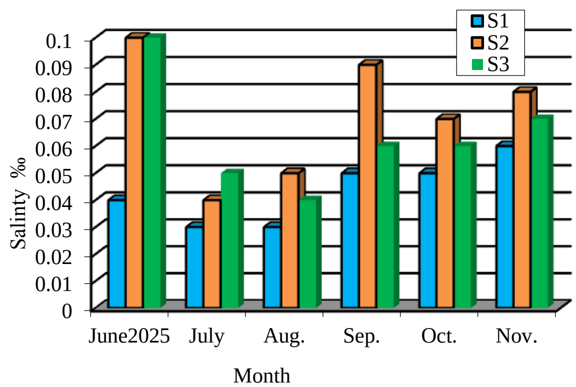

Figure 9. Variation of salinity**.**

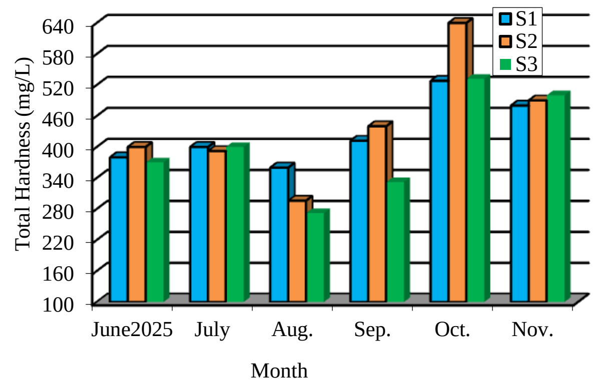

Figure 10. Variation of Total Hardness**.**

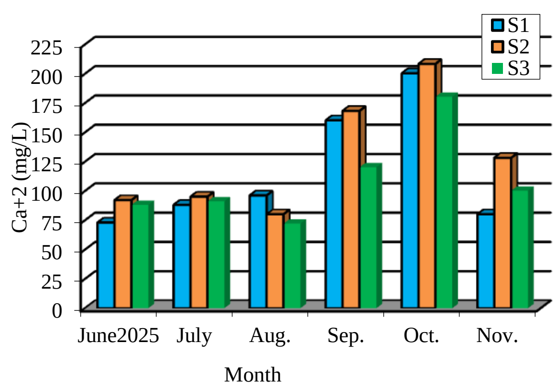

Figure 11. Variation of Ca^{+2}

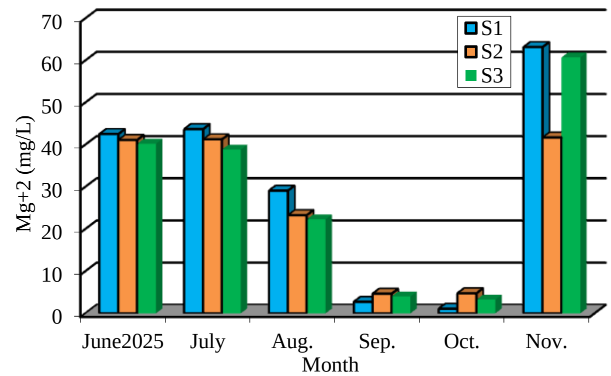

Figure 12. Variation of Mg^{+2}

The findings of nitrate indicate that site 2 had the highest average concentration of 0.690 mg/L. There were no significant differences between sites 1 and 3, which differed significantly from site 2 ($p \leq 0.05$) (**Table 1** and **Figure 13**). In addition to higher nitrate concentrations, phosphate concentrations also exhibited a similar pattern of large variance among locations: site 2 had a substantially higher mean concentration than both site 1 and site 3 (0.074 mg/L) (**Table 1** and **Figure 14**), while sites 1 and 3 had significantly lower phosphate concentrations than site 2 ($P \leq 0.05$). Overall, these were two of only three parameters that demonstrated a statistically significant difference ($P \leq 0.05$) across study sites.

There were no significant differences between total suspended solids (TSS), total dissolved solids (TDS) (**Table 1** and **Figures 15** and **16**), and total alkalinity at the three locations (**Table 1** and **Figure 17**). However, although the TSS readings were moderately variable from site to site, the total alkalinity over the three sites has been identified as having a very wide range of values, with no statistical significance. According to the results of this research, it is evident that discharges from MCC effluent have a measurable effect on all chemical water quality parameters that were tested for the Tigris River. In addition to elevated values of BOD, turbidity, total dissolved solids, and nutrients (nitrate and reactive phosphate) where the discharge occurs, indicating the introduction of organic material and nutrients at elevated levels to the river, these additions to the river will contribute to accelerated rates of eutrophication of the river water and lower levels of light penetration and primary productivity of plant species in the river.

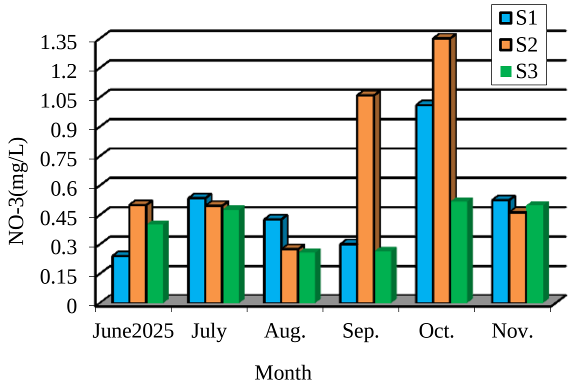

Figure 13. Variation of NO^{-3}.

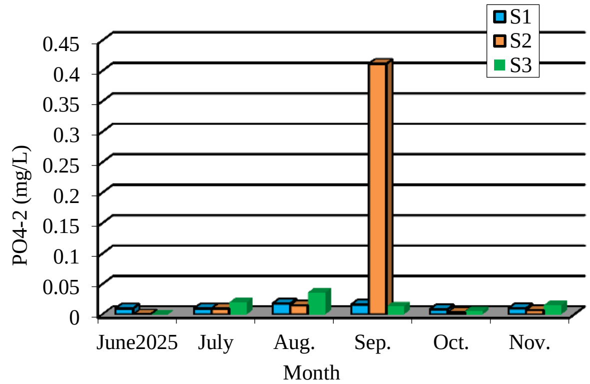

Figure 14. Variation of PO_4^{-2}

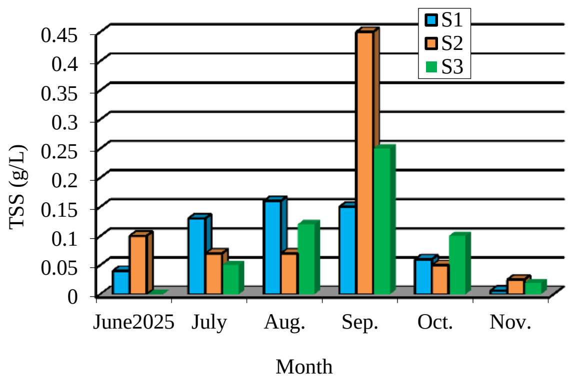

Figure 15. Variation of TSS

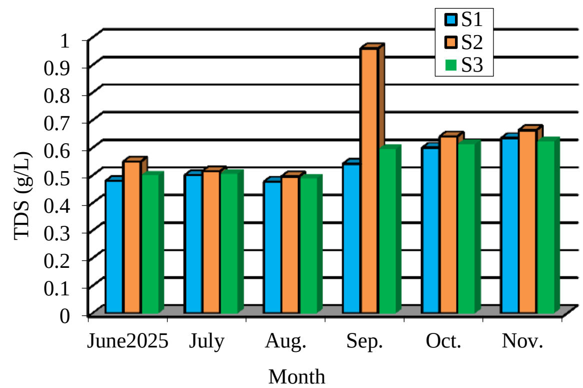

Figure 16. Variation of TDS.

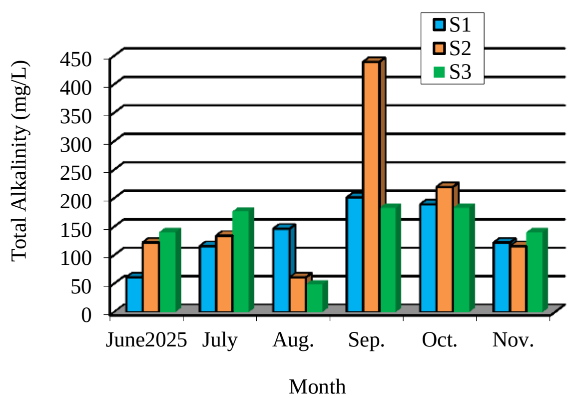

Figure 17. Variation of Total Alkalinity

In some instances, lower dissolved oxygen levels were indicated near the point of discharge, which would indicate possible increases in microbial activity and decomposition of organic matter; thus, this can create a bio-stress event for organisms that inhabit the river. In addition to the elevated levels of dissolved inorganic solids due to industrial discharge, the increase in conductivity and salinity levels will have a potential impact on the ionic balance (i.e., changes in pH and kinematic viscosity) of the river ecosystem. In conclusion, this study confirms that effluents produced from MCC impact a number of Tigris River water quality parameters; the study meets the goals of the researchers and provides the impetus for the development of effective methods of treating MCC effluents to maintain the ecological health of the river.

4. Discussion

Physico-chemical analysis carried out at the river near three selected sites showed marked variations between each site, suggesting that hospital waste is having a very substantial impact on river quality. Although average air and water temperature readings from all three sites were found to be within a similar range, the measurements remained statistically insignificant. These temperature results are in agreement with earlier studies of urban rivers, where wastewater discharge generally does not result in temperature changes unless it has been through an industrial cooling system[33]. Similarly, the average pH values obtained from each of the three sites continued to be very close to weak alkaline. The result of numerous studies conducted previously on this river showed no difference in average pH value at either of the three sites tested here[34, 35].

The increase in turbidity at the discharge point provides evidence of an influx of suspended fine particulate material and organic matter into the river, consistent with previous studies examining the effect of hospital wastewater on surface waters[16, 36, 37]. In contrast, TSS did not differ significantly across the sampling stations; thus, it may be possible that increased turbidity was primarily due to fine colloidal or dissolved solids rather than larger granule-sized material. This is consistent with worldwide river monitoring programs assessing the effect of wastewater on river turbidity and TSS[31, 38].

Compared to the location of the effluent outfall, the locations of where the water discharged have higher electrical conductivity (EC). This indicates that there are dissolved ions present in the water from saline materials, chemicals, and disinfectants used at medical facilities that are contributing to higher amounts of electrical conductivity at these locations. These results are consistent with findings of other researchers in the immediate area[9,39], as well as internationally[39, 40]. The total dissolved solids (TDS) and salinity levels are not significantly different from one another because the river rapidly dilutes the total dissolved solids (TDS) to below detectable limits, while the chemical concentrations from the medical facilities will only comprise a small portion of the overall chemical loads entering the river[40, 41].

Water samples collected from the river at the time and place described had dissolved oxygen (DO) concentrations that varied according to location, but differences between sites were not statistically significant. The lack of statistically significant difference may be attributed to the fact that as organic matter is discharged from the hospital, it may become diluted or dispersed prior to being tested, and thus its impact on oxygen levels is limited[42]. The observed pattern also corresponds to other reported cases of rivers receiving hospital effluent that exhibit high flow or rapid mixing, in which consistent deficits in DO were not detected[43]

The discharge site exhibited a meaningful increase in the nutrient parameters nitrate (NO_3^-) and phosphate (PO_4^{3-}). Nutrient enrichment at a point of discharge indicates the presence of wastewater influences, which likely include pharmaceutical by-products, detergent compounds, and biological materials typical within the hospital waste stream[44]. This is congruent with both regional studies conducted on the Tigris River) and global studies concerning nutrient loading of hospital wastewater discharges and their associated risks for causing eutrophication[45-49].

Across all study sites, there were no significant differences in the concentration of major cations (Ca^{2+} and Mg^{2+}), total hardness, and total alkalinity. Therefore, these water quality metrics seem to reflect the geological and hydrological context of the Tigris River rather than any episodic inputs from hospitals[50], which is consistent with previous work that has shown that these mineral parameters vary little throughout the length of the Tigris River in Baghdad[51, 52].

As a result, the physiochemical parameters' spatial distribution is a strong indicator that hospital discharges impact directly turbidity, dissolved ionic species, and nutrient enrichment. However, temperature (T), pH, dissolved oxygen (DO), hardness, and all commonly found inorganic ions are not generally affected by hospital discharge; thus, there is no significant difference between the parameters outside of hospital discharge and those within hospital discharges. The selective pattern of impact is reflected in the results from other studies conducted both domestically and abroad[53].

Measured physical and chemical parameters have been compared against Iraqi environmental standards for surface waters and international standards (such as World Health Organization (WHO) standards for drinking water). The majority of measured parameters (including pH, hardness, salinity, and dissolved oxygen) were within acceptable levels. However, some at Site 2 (turbidity, nitrate, and phosphate) are at or near maximum allowable limits. While the measured values for turbidity, nitrate, and phosphate were not considered to indicate acute pollution, they could continue to contribute to a gradual degradation of water quality over time, and whether or not they meet the applicable standard in the future will depend upon continued discharge into the environment at Site 2.[54]. These results serve to underscore the need for regular monitoring of MCC effluents so as to assure continued compliance with both national and international water quality standards. As this study primarily assessed only the physicochemical parameters of hospital wastewater, which can also contain pharmaceutical residues, disinfectants, pathogenic organisms, and antibiotic-resistant bacteria, and saw an increase in nutrient and organic load levels from the MCC discharge point, these findings could be indirectly influencing the potential presence of biologically active contaminants. Altogether, the chronic exposure of communities using water from the Tigris River for any form of domestic, agricultural, or recreational use to MCC effluents may have serious implications for their health and wellbeing. In addition, the long-term accumulation of pharmaceutical compounds in the aquatic environment is thought to have played a significant role in the rise of antimicrobial resistance and the promotion of ecological toxicity[55]. It is therefore recommended that additional research be done to assess both the biological and the pharmaceutical contaminants contained in the MCC effluents.

5. Conclusion

The current research showed that the Medical City Complex (MCC)'s effluent has a localized effect but makes a significant contribution to the physicochemical characteristics of Tigris River water, although most of the parameters evaluated were within acceptable limits. However, at the effluent discharge point, increased turbidity, electrical conductivity, nitrates, and phosphates indicate anthropogenic impacts via nutrient enrichment of the Tigris River due to the MCC's hospital wastewater. Since MCC effluent can be measured as putting pressure on the water environment, if not properly managed, it could contribute to eutrophication. Thus, the authors highly recommend treatment of all hospital wastewater prior to discharge. They also recommend that the Tigris River be monitored on a regular basis for turbidity, conductivity, nutrients, and dissolved oxygen. Future studies of the Tigris River should consider emerging contaminants such as prescription drugs and other personal care products to give a complete assessment of the long-term ecological risks and aid in the sustainable management of the river.

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Conflict of Interest

The authors declare that they have no conflicts of interest."

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No founding.

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