

Bioaccumulation Study of Cadmium, Copper, and Zinc in the Waters of the Main Drain River Using Nile Tilapia *Oreochromis aureus* as Bioindicators of Pollution in Al-Nasiriyah City

Maryam Waleed Jabbar  , Kamil Kadimim Fahad 

^{1, 2} Department of Animal Production, College of Agriculture and Marshes, University of Thi-Qar

¹ E-mail: Maryam.post2025@utq.edu.iq

E-mail: kamil@utq.edu.iq

Abstract

Bioaccumulation of cadmium, copper, and zinc in the waters of the Main Drain River in Thi-Qar Province was assessed using Nile tilapia, *Oreochromis aureus*, as a bioindicator, alongside analysis of the physical and chemical parameters affecting water quality. The results revealed marked seasonal variation in environmental factors. Water temperature ranged from 17.3 to 27 °C which inversely influenced dissolved oxygen concentrations that varied between 7.8 and 10.8 mg/L, with the highest values recorded during the colder months. The pH values ranged from neutral to slightly alkaline 7.07–8.5 which is suitable for fish growth. Turbidity total dissolved solids, and electrical conductivity showed elevated levels in certain months, reflecting the influence of agricultural drainage water and waste discharge on water quality. Concentrations of cadmium and copper showed seasonal fluctuations, with the highest levels occurring during months influenced by agricultural and industrial activities, whereas zinc remained relatively stable. Cadmium poses the greatest risk due to its high toxicity even at low concentrations, while copper and zinc are essential at trace levels but become toxic at elevated concentrations. The results indicate that Nile tilapia serve as an effective bioindicator for monitoring heavy metal pollution due to their capacity for bioaccumulation. The data also point to significant environmental pressure in the Main Drain River resulting from human activities. It is recommended to strengthen regular monitoring and reduce untreated discharges to preserve aquatic ecosystems and support the sustainability of fish farming.

I. Introduction

Water contamination with heavy metals is a serious environmental problem due to its hazardous impacts. The discharge of waste into surface waters, such as the Main Drain River and lakes, leads to the accumulation of toxic elements, with their concentrations varying according to the source and nature of pollution (Ibrahim *et al.*, 2020). Rivers are exposed to heavy metal pollution from domestic, agricultural, and industrial discharges, which disrupts the ecological balance of aquatic systems. Pollution by these elements is a major environmental concern due to their ability to bioaccumulate and the difficulty of detecting and controlling them at low concentrations (Fahad, 2014). Recent studies on the Euphrates River in Al-Nasiriyah Governorate for the period 2022–2023 reported that heavy metal concentrations in the water followed the order Cu > Cd > Zn. Higher values were recorded at southern sites compared to northern ones, likely due to the discharge of untreated pollutants, indicating an increase in contamination toward the river mouth (Ateshan & Misnan, 2025). Heavy metal concentrations are influenced by environmental factors such as water temperature, pH, and turbidity (Al-Najjar *et al.*, 2014). Copper and zinc are essential for biological processes in living organisms when present within natural limits, but exceeding these limits makes them toxic pollutants. In contrast, cadmium is toxic at all concentrations and has no known biological function. Elevated levels of these metals indicate a decline in water quality, and water pollution remains one of the main challenges facing ecosystems, limiting the suitability of water for various uses (Jouda & Fahad, 2023).



II. Materials and working methods

The present study was conducted in the Main Drain River, a branch of the Euphrates River located in Thi-Qar Governorate, southern Iraq, at the geographic coordinates 31°05'24.09 N and 46°14'47.60 E. Water samples were collected from the study sites for heavy metal analysis and physicochemical testing. Each sample was stored in 250 mL polyethylene plastic containers. Air temperature was measured periodically during sample collection using a mercury thermometer calibrated from 0 to 100 °C. Readings were taken in the morning and in shaded conditions to ensure accuracy, and the results were expressed in degrees Celsius. Water temperature was measured during sample collection using a mercury thermometer calibrated from 0 to 100 °C. The thermometer was submerged in the water during measurement to ensure an accurate reading. pH values were measured using a pH meter calibrated with buffer solutions of pH 4, 7, 9 prior to analysis. Dissolved oxygen concentration was measured using an oxygen meter, and the results were expressed in mg/L. Electrical conductivity was measured using a conductivity meter calibrated with standard solutions, and the results were expressed in $\mu\text{S}/\text{cm}$. Total dissolved solids were measured using a TDS meter calibrated with standard solutions, and the results were expressed in mg/L. Turbidity was measured using a turbidity meter, and the results were expressed in NTU. Heavy metal extraction from water samples For digestion, 250 mL of each water sample was evaporated at 80 °C until dryness. The residue was digested by adding 6 mL of a 1:1 mixture of concentrated hydrochloric acid (HCl) and concentrated nitric acid (HNO_3), then heated at 80 °C and evaporated nearly to dryness. Subsequently, 4 mL of a 1:1 mixture of concentrated perchloric acid (HClO_4) and hydrofluoric acid (HF) was added, and the solution was evaporated again to near dryness. The residue was dissolved in 20 mL of 0.5 M dilute HCl and left for 10 min. The sample was centrifuged at 3000 rpm for 20 min, and the supernatant was transferred to a 25 mL volumetric flask. The final solution was stored in polyethylene bottles until analysis by flame atomic absorption spectrometry. Results were expressed in $\mu\text{g}/\text{L}$. Concentrations of heavy metals were determined from the standard calibration curve using the equations reported by [Al-Tai, 1999]. Heavy metal concentrations in the studied samples were determined using a flame atomic absorption spectrophotometer (FAAS), model Pye Unicam AA500, of UK origin. Standard solutions for the analyzed elements were prepared following the procedure recommended by the American Public Health Association [APHA]. Concentrations were calculated using the equation described by Al-Marmadi [2003] [2021].

III. Results and discussion

Table 1 presents the temperature data recorded over the study months. The results show a clear seasonal fluctuation in the physicochemical properties of water in the Main Outfall Drain, Thi Qar. Air temperature ranged from 15.0 to 30.0 °C, and water temperature ranged from 17.3 to 27.0 °C. The highest water temperature was recorded in October, followed by a gradual decline to January. This pattern is expected, as water temperature is influenced by air temperature and sampling times, and is consistent with the findings of [Kelany *et al.*, 2024]. The results here differ from those of Dakheel and Al-Abdan for the Euphrates River between Al-Shanafiyah and Nasiriyah. Their study found high values for all physical and chemical properties, with clear seasonal variation. The CCME WQI values ranged from 62.2 to 74.7, which means the water was of medium quality. [2025] The difference is due to the nature of the water bodies. The Shatt al-Arab and Euphrates River are affected by thermal discharge and freshwater, while the main estuary is a transitional area affected by saltwater intrusion and high evaporation. This raises the water's heat capacity and delays the highest water temperature until October.



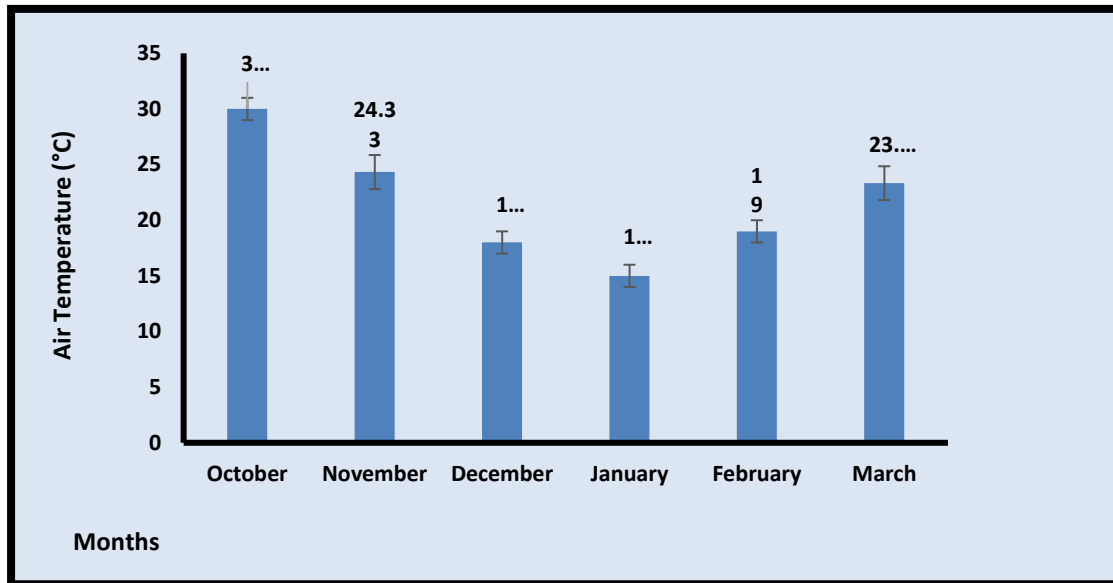


Figure 1. Mean air temperature (°C) during the study period.

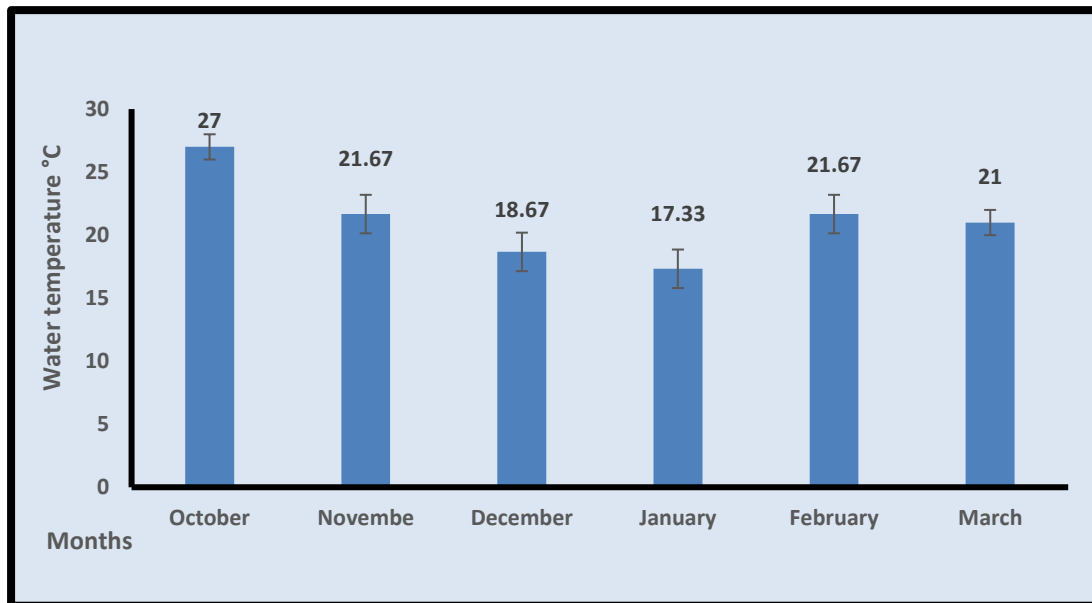


Figure 2. Mean water temperature (°C) during the study period.

Dissolved oxygen concentrations in the Main Outfall Drain showed a significant seasonal variation. The highest value, 10.83 ± 0.76 mg/L, was recorded in January at the lowest water temperature of 17.33 ± 1.53 °C. The lowest values, 7.83 ± 0.76 mg/L, occurred in October and March, corresponding with higher water temperatures. These results are consistent with those reported by Zhang *et al.* [$P \leq 0.05$] [2025] Seasonal changes in dissolved oxygen in surface water are primarily driven by temperature, with the lowest levels in summer and autumn and the highest in winter and spring. This pattern reflects the inverse relationship between water temperature and oxygen solubility. The findings differ in part from those of Rajwa-Kuligiewicz *et al.*, who noted that temperature does not always have a direct effect on dissolved oxygen [2015].

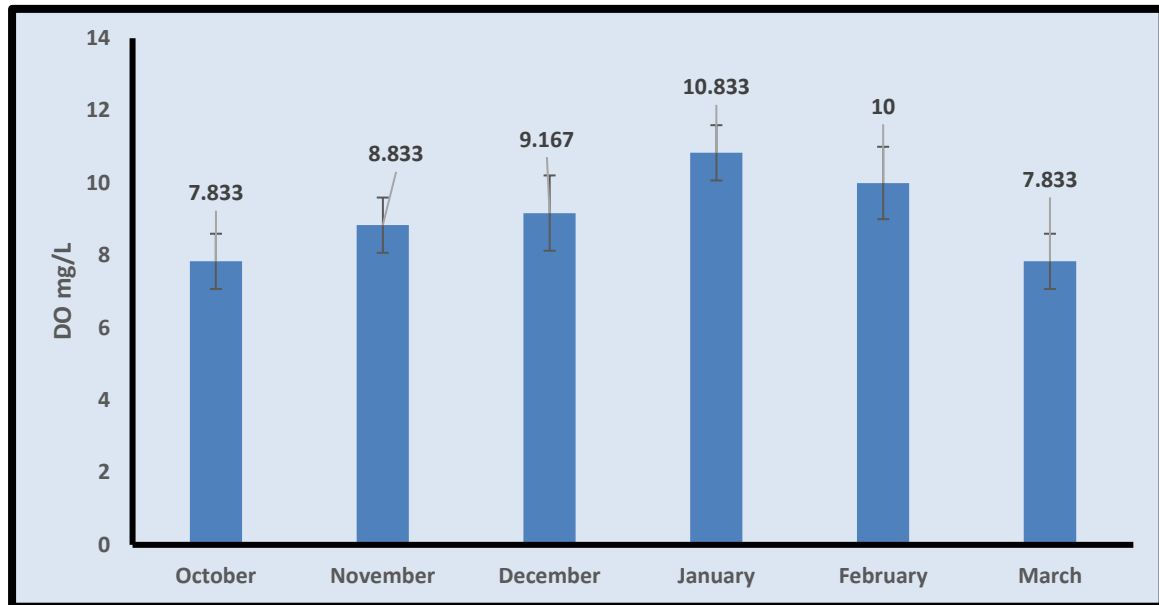


Figure 3. Dissolved oxygen concentration (mg/L) during the study period.

In this study, pH values ranged from 7.07, the lowest in November, to 8.50, the highest in December, falling within the neutral to slightly alkaline range. The lower pH recorded in November may indicate increased organic leachates or the entry of waters with an acidic nature. In contrast, the higher pH in December could be linked to active algal growth or the influence of alkaline salts. These results are consistent with Abbood et al. (2014), who reported that keeping pH within a moderate range is essential because large deviations disrupt ion balance, respiration, and metabolism in fish. They also agree with (Abdulrazzak, 2025) who found that pH values in the Euphrates River at Ramadi, Hillah, Karbala, Najaf, Diwanayah, Samawah, and Nasiriyah were within the permissible limits of Iraqi standards for river water.

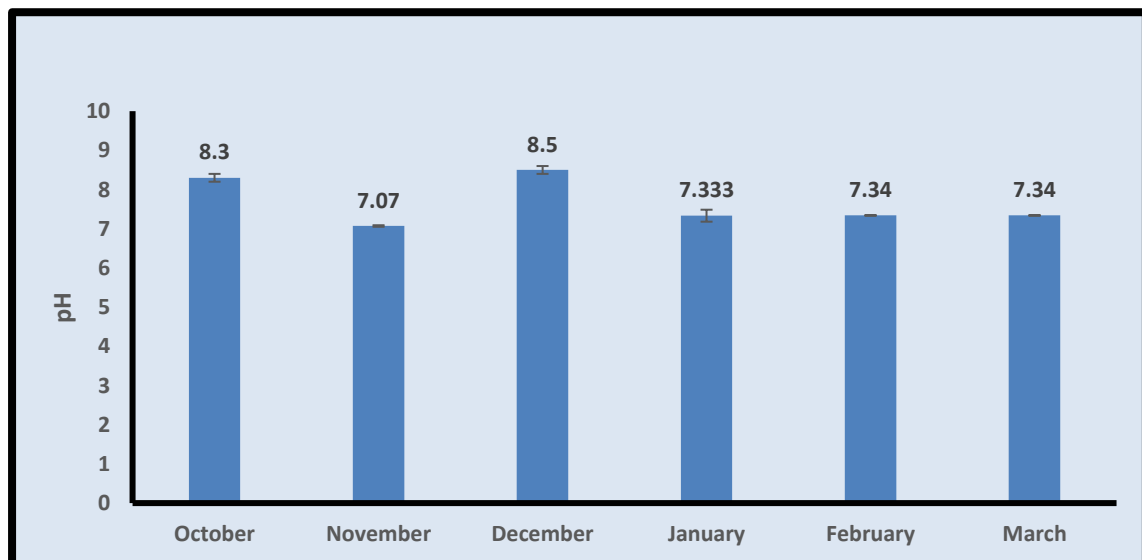


Figure 4. pH values during the study period.

Turbidity in the present study ranged from 1.31 NTU in February to 162.33 NTU in November. The peak in November likely reflects increased surface runoff, resuspension of sediments, and inputs from agricultural, organic, or bottom disturbances. High turbidity reduces light penetration and can affect gill function and feeding behavior in fish (Abbood et al., 2014). These results differ from AL-Zamili (2016), likely due to differences in the water bodies studied. His work was conducted in marsh waters that are more protected from suspended solids and human and agricultural activity, compared with the flowing waters of the Tigris River.

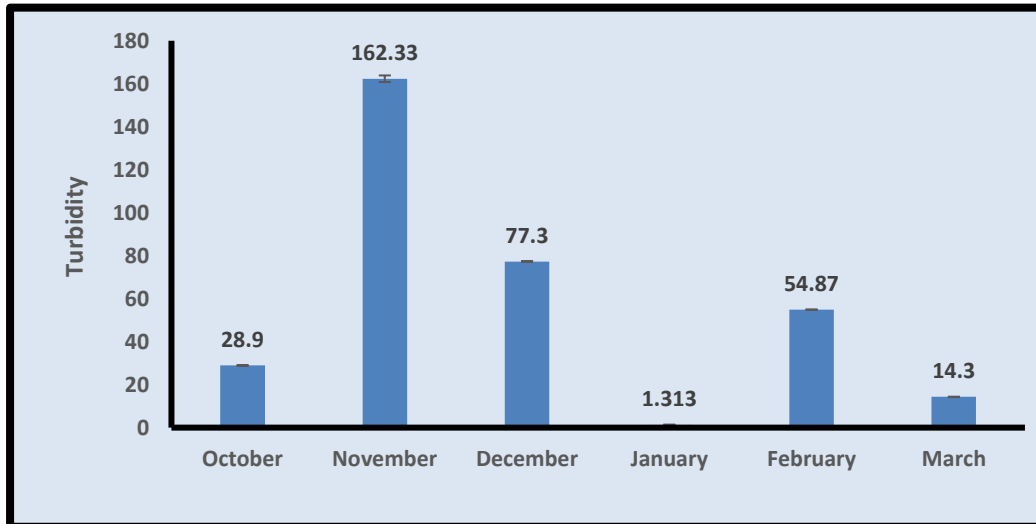


Figure 5. Turbidity (NTU) during the study period.

Total dissolved solids (TDS) in the present study were high in October (7764.67 mg/L) and November (6521.00 mg/L), then declined sharply in December (780.00 mg/L), January (818.00 mg/L), and March (784.00 mg/L). This pattern indicates a clear influence of dissolved salts and agricultural drainage water in the Al-Masab Al-Aam River, which is known in Iraq to receive agricultural, industrial and domestic wastewater. Iraqi studies have shown that TDS is one of the main factors affecting the deterioration of water quality in the Al-Masab Al-Aam River. These results are consistent with (Abbood et al., 2014).

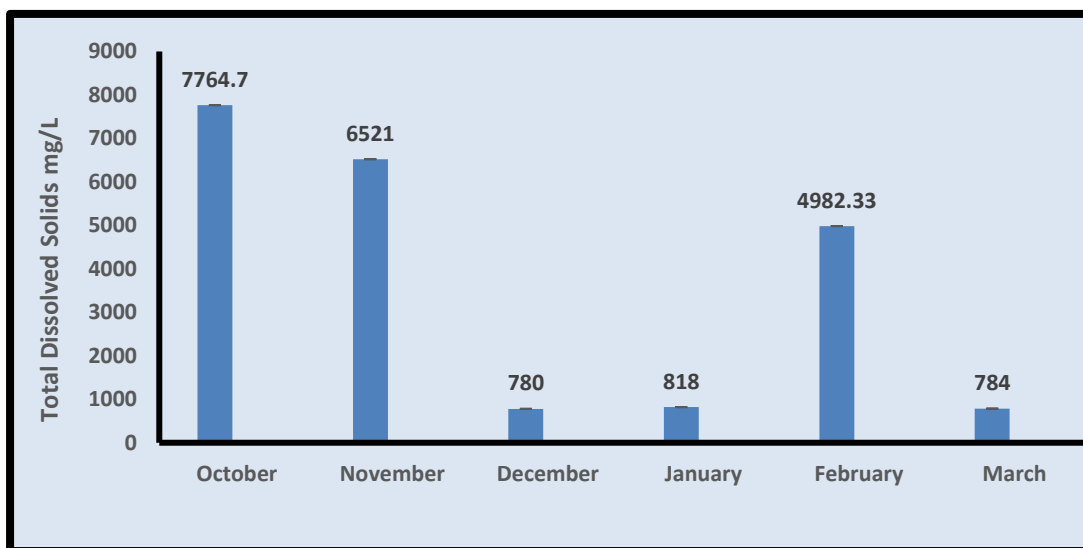


Figure 6. Total dissolved solids (mg/L) during the study period.

Electrical conductivity in the present study varied widely, ranging from 1154.33 $\mu\text{S}/\text{cm}$ as the lowest value to 12730.00 $\mu\text{S}/\text{cm}$ as the highest. These results agree with Abbood *et al.* (2014), who reported poor water quality in the Al-Masab Al-Aam River due to high dissolved salts and electrical conductivity, and attributed this to agricultural drainage inputs. They described the river water as degraded with limited suitability for aquatic life. In contrast, the findings differ from those of (Alshehri *et al.*, 2021) who noted that pollution is not always the direct cause of high EC. In some rivers, elevated electrical conductivity can occur naturally due to the geological composition of the soil, independent of pollution.

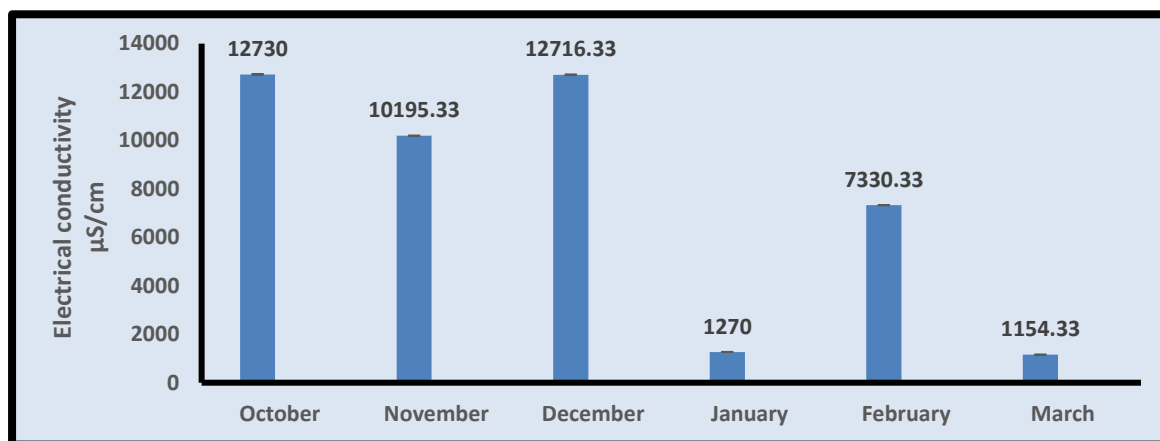


Figure 7. Electrical conductivity ($\mu\text{S}/\text{cm}$) during the study period.

Table 1. Concentrations of heavy metals in water \pm standard deviation across the study months.

Months	Air temp. $^{\circ}\text{C}$	Water temp. $^{\circ}\text{C}$	D.O Mg/L	E.C Mg/L	TDS ppT	Tur. NTU	pH
October	± 30.00 a1.00	27.00 ± 1.00 a	± 7.833 0.764b	± 8.300 0.1b	28.90 \pm 0.10 d	7764.67 \pm 2.082a	12730.00 \pm 0.100a
November	24.33 ± 1.53 b	± 21.67 1.528b	± 8.833 0.764b	± 7.070 0.02d	± 162.33 1.528a	6521.00 \pm 0.100b	10195.33 \pm 1.59e
December	18.00 1.00 \pm c	18.67 ± 1.528 bc	± 9.167 1.041ab	± 8.500 0.1a	± 77.30 0.10b	780.00 \pm 0.100f	12716.33 \pm 0.100b
January	15.00 ± 1.00 d	17.33 \pm 1.528 c	± 10.833 0.764 a	± 7.333 0.153c	± 1.313 0.006f	818.00 \pm 0.1000d	1270.00 \pm 0.100c
February	19.00 1.00 \pm c	21.67 \pm 1.528b	± 10.00 1.00a	± 7.340 0.010c	± 54.87 0.058c	4982.33 \pm 1.59c	7330.33 ± 1.59 f
March	23.33 1.52 \pm b	± 21.00 1.000 b	7.833 \pm 0.764b	± 7.34 0.010c	± 14.30 0.10 e	± 784.00 1.000 e	1154.33 \pm 1.59d
Significance	0.05	0.05	0.05	0.05	0.05	0.05	0.05

The current study showed seasonal variations in cadmium, copper, and lead concentrations in the Main Outfall Drain water over the study months, as presented in Table 2. The lowest concentration was 0.0004 ± 0.0002 mg/L in January, while the highest reached 0.032 ± 0.0003 mg/L in October. Elevated levels were recorded in the early months and remained relatively high in the following months. Cadmium concentrations were generally very low, close to the detection limit, and are typically attributed to industrial wastewater, fertilizers, waste, and agricultural activities. The relative increase in October is likely due to higher discharge from agricultural drainage or industrial effluents, especially at the start of the planting season. Later, some cadmium may be removed through deposition in bottom sediments. Fish are sensitive to cadmium accumulation. The results are consistent with (Authman *et al.*, 2015) who reported that cadmium shows seasonal variation and is strongly associated with agricultural and industrial activities. They also partly agree with (Yunus *et al.*, 2015). Table 2 shows that copper concentrations fluctuated notably. The highest value was 0.218 ± 0.0002 μ g/L in November, while the lowest was 0.002 ± 0.0002 μ g/L in December. Copper is an essential element in trace amounts but becomes toxic at elevated concentrations. The increase in copper is attributed to multiple sources, including agricultural pesticides, industrial waste, and corrosion of metal pipes. A rise in concentration during a specific month may indicate a temporary pollution event. Copper directly affects fish gills by damaging tissue and disrupting gas exchange, in addition to impacting enzymes and vital processes. These findings are consistent with previous work (Niu *et al.*, 2024), which noted that copper shows clear temporal fluctuations in aquatic systems due to changes in its sources. Results from Table 2 indicate that zinc levels remained relatively low and stable compared to other metals, with only minor statistically significant differences between months. While zinc is essential for biological functions, high concentrations can be toxic. The stability of zinc levels suggests that its sources are more consistent than those of copper and cadmium, or that biological and environmental processes regulate its variation in water. Tilapia has a relative ability to regulate internal zinc concentrations, making it less sensitive to fluctuations compared to cadmium. These results agree with previous findings (Authman *et al.*, 2015), which showed that zinc typically exhibits less variation than other heavy metals in aquatic systems. Another study (Skorbiłowicz *et al.*, 2023) reported that zinc can fluctuate significantly in some polluted environments due to variations in industrial discharge, but this pattern was not clearly observed in the present study.

Table 2: Heavy metal concentrations in water \pm standard deviation during the study period.

Months	Cadmium	Copper	Zinc
October	$0.0003 \pm 0.032a$	$0.0003 \pm 0.017a$	$0.0002 \pm 0.027d$
November	$0.0002 \pm 0.024b$	$0.0003 \pm 0.004b$	$0.0002 \pm 0.218a$
December	$0.0002 \pm 0.006c$	$0.0002 \pm 0.001d$	$0.0002 \pm 0.002f$
January	$0.0002 \pm 0.0004c$	$0.0002 \pm 0.002c$	$0.0002 \pm 0.007e$
February	$0.0003 \pm 0.0005c$	$0.0002 \pm 0.002c$	$0.0003 \pm 0.065b$
March	$0.0003 \pm 0.006 c$	$0.0002 \pm 0.002c$	$0.0003 \pm 0.045c$
Significance	0.05	0.05	0.05

IV. Conclusions

The results indicated seasonal variation in the physicochemical properties of the Main Outfall Drain water in Thi-Qar Governorate. Turbidity, total dissolved solids, and electrical conductivity increased during certain months due to agricultural drainage discharges and waste inputs. Heavy metal concentrations showed significant differences among months, with cadmium and copper serving as indicators of ongoing pollution. It is concluded that the drain is subject to anthropogenic environmental pressure, and the study recommends strengthening periodic water monitoring and limiting untreated discharges to maintain water quality.



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