Received: October 06, 2025

Revised: October 13, 2025

Accepted: October 14, 2025

Assessment of Physicochemical Characteristics of Water and Sediments from Wupa River Abuja, Nigeria

Ibrahim, Umar Faruok [1*] | Ndanusa, Abdullahi Hassan[1] | Mohammed Sani Sambo Datsugwai[2] |Ahmed, Zainab Musa[1] | Ibrahim, Mohammed Ibrahim[2] | Ajiya, Aina'u Musa[1] | Ibrahim, Aliyu Ahmed[3] | Omotosho Azeez Olalekan[2]

[1]Department of Biochemistry and Biotechnology, Nile University of Nigeria, Abuja, Nigeria.

[2]Department of Microbiology, Nile University of Nigeria, Abuja, Nigeria

[3]Department of Chemistry, Ibrahim Badamasi Babangida University, Lapai, Nigeria

Corresponding Author's Name: Ibrahim, Umar Faruok

Corresponding Author's E-mail: umaribm@gmail.com

ABSTRACT

Heavy metal pollution of aquatic ecosystems poses a significant environmental issue, particularly in rivers exposed to industrial and domestic effluent discharges. This study assessed the physicochemical characteristics of water and sediments from Wupa River, Abuja, Nigeria. Three stations were selected to represent different levels of anthropogenic impact: Station 1 (upstream, reference site), Station 2 (effluent discharge point from Wupa wastewater treatment plant), and Station 3 (downstream of the discharge). Water and sediment samples were collected in triplicates and analyzed using standard methods and procedures. Key water quality results included temperature (28.00–29.33 °C), pH (7.81–8.06), conductivity (0.15–0.20 µS/cm), turbidity (5.92–7.57 NTU), chloride (105.32–118.71 mg/L), nitrate (17.92–20.86 mg/L), sulphate (0.15–0.27 mg/L), and chemical oxygen demand (1.52–2.32 mg/L). Detected heavy metals in water included cadmium (0.10–0.12 mg/L), copper (0.01–0.04 mg/L), iron (0.57–0.83 mg/L), nickel (0.11–0.15 mg/L), lead (0.98–1.04 mg/L), and zinc (0.02–0.03 mg/L). Sediment analysis revealed copper (0.13–0.28 mg/L), nickel (0.02–0.18 mg/L), zinc (0.03–0.05 mg/L), cadmium (0.004–0.01 mg/L), lead (5.09–5.69 mg/L), and iron (2.00–5.65 mg/L). The elevated levels of lead and iron in sediments, and detectable concentrations of cadmium and nickel in water, suggest significant contamination associated with effluent discharge. These findings highlight the need for effective wastewater management and regular monitoring to safeguard aquatic ecosystems and public health in communities dependent on the Wupa River.

KEYWORDS: Wupa River, physicochemical parameters, heavy metals, effluent, water quality, sediment

DOI: *https://doi.org/10.5455/NJEAS.288505*

© 2025 | Nile University of Nigeria

1 | INTRODUCTION

Water is essential for sustaining life, yet millions of people globally lack access to clean and safe sources, increasing their vulnerability to waterborne diseases [1]. Water serves as a medium for the propagation of human-associated pathogens, underscoring the importance of adequate, secure, and accessible supplies [2]. Improving access to potable water results in immense health and socio-economic benefits [3]. Surface waters are under growing pressure from industrial, domestic, and agricultural pollution, leading to nutrient enrichment, eutrophication, and contamination by toxic substances such as heavy metals. Heavy metals are particularly concerning because they are non-biodegradable, bioaccumulate in aquatic organisms, and pose long-term ecological and public health risks [4,5].

Since the industrial revolution, water pollution from untreated sewage and industrial effluents has become a global issue, with severe consequences for ecosystems and human health [6,7]. Urban rivers are particularly vulnerable due to population growth, rapid urbanization, and economic expansion [8]. Contaminants introduced include nutrients, pathogens, and toxic substances, all of which can threaten public health and biodiversity [9]. Unlike organic pollutants, heavy metals are non-biodegradable and can bioaccumulate in aquatic organisms, entering the food chain and posing long-term ecological and health risks [10]. They may also form organic complexes, increasing their toxicity [11]. Common heavy metals of concern in effluent-impacted rivers include cadmium, lead, chromium, zinc, and copper [12]. Their persistence and ability to bioaccumulate exacerbate the risk of eutrophication, oxygen depletion, and aquatic life mortality [13,14].

Heavy metal pollution continues to escalate due to urbanization, industrialization, and poor waste management practices [15]. Industries often discharge wastewater without treatment, releasing large amounts of toxic metals such as lead, chromium, nickel, cadmium, mercury, and arsenic [16]. Such discharges result in contamination of rivers and sediments, which serve as sinks for these metals and can later reintroduce them into the aquatic system under changing environmental conditions [17].

Despite the existence of the Wupa wastewater treatment plant, limited data exist on the extent of heavy metal contamination in the adjoining Wupa River and its potential impacts on aquatic ecosystems and nearby communities. This study therefore evaluated the physicochemical parameters and heavy metal concentrations in both water and sediments of Wupa River, Abuja. The findings provide insight into effluent-induced contamination, environmental health implications, and the need for improved wastewater management to safeguard public health.

2.0 | MATERIALS AND METHODS

2.1 Description of Study Area

Wupa River lies between Longitude 7°17’00″E and 7°22’12″E and Latitude 8°56’48″N and 9°01’48″N. It is part of the Jabi River watershed in Abuja, spanning approximately 16 km. The river is relatively narrow, with a maximum dry season width of 10–20 m. The catchment area experiences temperatures ranging from 27–36°C, with an average of 29°C, and rainfall of 10–68 mm monthly during 2021 [2].

2.2 Sampling Stations and Period

Samples were collected bi-weekly for two months (October–November 2024). Although the sampling period was short, it coincided with the dry season when effluent discharges are concentrated and rainfall dilution is minimal, providing a representative picture of contamination levels. Water and sediment samples were collected in triplicates at each station to ensure statistical reliability and representativeness.

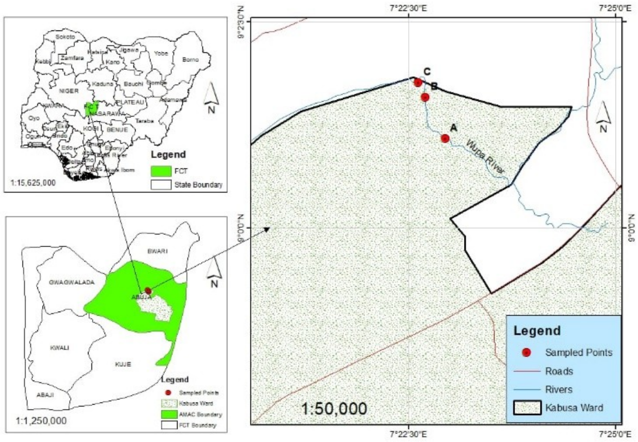

Figure 1. Map of the Federal Capital Territory showing the location of the Wupa River and sampling stations.

2.3 Sample Collection

Water samples were collected with 1 L plastic bottles, pre-rinsed with distilled water and the sample water. Vertical column sampling (30 cm depth) was used. Bottles were labeled and transported to the laboratory for analysis. Sediment samples were collected from the same stations, stored in clean containers, and transported under cold conditions.

2.4 Physicochemical Analyses

Water quality parameters, including temperature, pH, conductivity, and turbidity, were determined using standard methods [18]. Temperature, pH, and conductivity were measured using a multiparameter probe (HI 98129, HANNA). Turbidity was measured using a turbidimeter.

2.5 Heavy Metal Analyses

Heavy metals (Cd, Cu, Fe, Ni, Pb, Zn) were quantified using Atomic Absorption Spectrophotometry (AAS). Standard solutions were prepared by serial dilution of 1000 ppm stock solutions. Calibration curves were generated, and concentrations were calculated based on absorbance values.

3 | RESULTS AND DISCUSSIONS

3.1 Physicochemical Parameters of Water

The physicochemical parameters of water sample collected from effluent impacted Wupa River is shown in table 1. Water temperature ranged between 28.00 ± 0.70 °C and 29.33 ± 1.05 °C, within tropical freshwater limits. pH values (7.81–8.06) indicated slightly alkaline conditions, exceeding WHO's acceptable range (6.5–7.5). Conductivity values were low (0.15–0.20 µS/cm), below the WHO permissible limit of 125 µS/cm. Turbidity ranged between 5.92–7.57 NTU, lower than the WHO threshold (<40 NTU). Chloride levels were high (105.32–118.71 mg/L), while nitrate concentrations (17.92–20.86 mg/L) remained within WHO standards. COD values (1.52–2.32 mg/L) indicated moderate organic pollution.

Mean temperature ranged from 28.00 ± 0.70 in Station C to 29.33 ± 1.05 in Station A. pH mean value ranged from 7.81 ± 0.04 in Station C to 8.06 ± 0.21 in Station A. Conductivity mean value ranged from 0.15 ± 0.53 in Station C to 0.20 ± 0.05 in station A. Resistivity mean value ranged from 4918.66 ± 1040.6 in Station A to 5323.00 ± 571.91 in Station C. Total dissolved solid mean value ranged from 0.09 ± 0.01 in Station C to 0.10 ± 0.02 in Station A. Salinity mean value ranged from 0.09 ± 0.01 in Station B and C to 0.09 ±0.02 in Station A. Turbidity mean value ranged from 5.92 ± 2.75NTU in Station B to 7.57 ± 1.36NTU in Station C. Chlorine mean value ranged from 105.32 ± 3.80 in Station B to 118.71 ± 0.70 in Station 118.71 ± 0.70 in Station C. Nitrate mean value ranged from 17.92 ± 042 in Station C to 20.86 ± 1.24 in Station A. Sulphate mean value ranged from 0.15 ± 0.01 in Station C to 0.27 ± 0.02 in Station A. Chemical oxygen demand mean value ranged from 1.52 ± 0.08 in Station A to 2.32 ± 0.35 in Station B.

Table 1: Physicochemical parameters of water sample collected from Wupa River

Parameters	Station A	Station B	Station C	P-value	WHO acceptable Limit
Temp. (°C)	28.83 ± 0.20	29.33 ± 1.05	28.00 ± 0.70	p>0.05	40
pH	8.06 ± 0.21	7.90 ± 0.04	7.81 ± 0.04	p>0.05	6.5-7.5
Conduct. (µS/Cm)	0.20 ± 0.05	0.20 ± 0.02	0.15 ± 0.53	p>0.05	125
Resistivity (Ω.m)	4918.66 ± 1040.6	4971.66 ± 616.54	5323.00 ± 571.91	p<0.05	
TDS (mg/L)	0.10 ± 0.02	0.10 ± 0.01	0.09 ± 0.01	p>0.05	500
Salinity (mg/L)	0.09 ±0.02	0.09 ± 0.01	0.09 ± 0.01	p>0.05	0.00001
Turbidity (NTU)	6.18 ± 2.69	5.92 ± 2.75	7.57 ± 1.36	p<0.05	<40
Chlorine (mg/L)	110.64 ± 5.53	105.32 ± 3.80	118.71 ± 0.70	p>0.05	
Nitrate (mg/L)	20.86 ± 1.24	20.63 ± 0.30	17.92 ± 042	p<0.05	50
Sulphate (mg/L)	0.27 ± 0.02	0.20 ± 0.01	0.15 ± 0.01	p<0.05	
COD (mg/L)	1.52 ± 0.08	2.32 ± 0.35	2.06 ± 0.05		

3.2 Physicochemical Parameters of Sediment

The physicochemical parameters of sediment sample collected from effluent impacted Wupa River is shown in table 2. Sediment pH (7.69–7.95) was slightly alkaline. Conductivity values (0.02–0.03 µS/cm) were low. Total nitrogen ranged from 0.49–0.77%, organic carbon 1.16–1.43%, and organic matter 2.01–2.46%. Available potassium ranged from 2.32–3.49%.

Mean sediment temperature ranged from 29.66 ± 0.75 in Station C to 30.70 ± 1.30 in Station A. Sediment pH mean value ranged from 7.69 ± 0.28 in Station B to 7.95 ± 0.25 in Station C. Conductivity mean value ranged from 0.02 ± 0.01 in Station B to 0.03 ± 0.07 in station C. Resistivity mean value ranged from 29633.12 ± 5953 in Station C to 40666.67 ± 1411 in Station B. Total dissolved solid mean value and Salinity mean value recorded 0.01 ± 0.00 mg/L across all the sampling stations. Total Nitrogen mean value ranged from 0.49 ± 0.03 in Station C to 0.77 ± 0.03 in Station B. O.C mean value ranged from 1.16 ± 0.05 in Station B to 1.43 ± 0.09 in Station A. O.M mean value ranged from 2.01 ± 0.00 in Station B to 2.46 ± 0.15 in Station A. Available Potassium mean value ranged from 2.32 ± 0.11 in Station B to 3.49 ± 0.03 in Station A.

Table 2: Physicochemical parameters of sediment sample collected Wupa River

Parameters	Station A	Station B	Station C	P-value
Temp. (°C)	30.70 ± 1.30	29.70 ± 0.55	29.66 ± 0.75	p>0.05
pH	7.73 ± 0.04	7.69 ± 0.28	7.95 ± 0.25	p>0.05
Conduct. (µS/Cm)	0.03 ± 0.01	0.02 ± 0.01	0.03 ± 0.07	p>0.05
Resistivity (Ω.m)	31536.67 ± 5737	40666.67 ± 1411	29633.12 ± 5953	p<0.05
TDS (mg/L)	0.01 ± 0.00	0.01 ± 0.00	0.01 ± 0.00	p>0.05
Salinity (mg/L)	0.01 ± 0.00	0.01 ± 0.00	0.01 ± 0.00	p>0.05
T.N (%)	0.53 ± 0.02	0.77 ± 0.03	0.49 ± 0.03	p<0.05
O.C (%)	1.43 ± 0.09	1.16 ± 0.05	1.37 ± 0.04	p>0.05
O.M (%)	2.46 ± 0.15	2.01 ± 0.00	2.37 ± 0.07	p>0.05
Available P (%)	3.49 ± 0.03	2.32 ± 0.11	2.65 ± 0.07	p<0.05

3.3 Heavy Metals in Water

The result of the heavy metals of water sample collected from effluent impacted Wupa River is shown in figure 2. Cadmium mean value ranged from 0.10 ± 0.01mg/L in station A to 0.12 ± 0.00 mg/L in station C. Copper mean value ranged from 0.01 ± 0.01 mg/L in station C to 0.04 ± 0.02 mg/L in station B. Iron mean value ranged from 0.57 ± 0.23 mg/L in station C to 0.83 ± 0.26 mg/L in station A. Nickel mean value ranged from 0.11 ± 0.01 mg/L in station A to 0.15 ± 0.10 mg/L in station B. Lead mean value ranged from 0.98 ± 0.86 mg/L in station A to 1.04 ± 0.64 mg/L in station C. Zinc mean value ranged from 0.02 ± 0.00 mg/L in station C to 0.03 ± 0.00 mg/L in station A.

Cadmium ranged from 0.10–0.12 mg/L, above WHO's guideline (0.002 mg/L). Copper levels (0.01–0.04 mg/L) were within permissible limits (1.3 mg/L). Iron (0.57–0.83 mg/L) exceeded the 0.3 mg/L guideline. Nickel (0.11–0.15 mg/L) surpassed the 0.1 mg/L limit. Lead (0.98–1.04 mg/L) greatly exceeded the 0.01 mg/L threshold. Zinc concentrations (0.02–0.03 mg/L) remained below the permissible limit (0.12 mg/L).

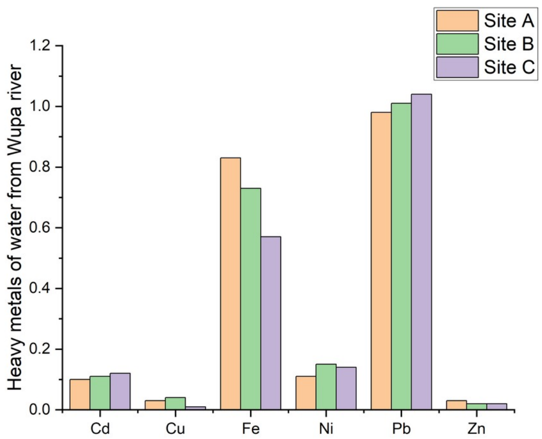

Figure 2: Mean Concentration of heavy metals in Wupa River

3.4 Heavy Metals in Sediments

The result of the heavy metals of Sediment sample collected from effluent impacted Wupa River is shown in figure 3. Copper mean value ranged from 0.13 ± 0.03mg/L in station A to 0.28 ± 0.06mg/L in station B. Nickel mean value ranged from 0.02 ± 0.02mg/L in station A to 0.18 ± 0.12mg/L in station B. Zinc mean value ranged from 0.03 ± 0.04mg/L in station A to 0.05 ± 0.04 mg/L in station B and C. Cadmium mean value ranged from 0.004 ± 0.05mg/L in station C to 0.01 ± 0.01mg/L in station A. Lead mean value ranged from 5.09 ± 5.38 mg/L in station A to 5.69 ± 1.61 mg/L in station C. Iron mean value ranged from 2.00 ± 1.77 mg/L in station A to 5.65 ± 2.03 mg/L in station C.

Sediments showed copper (0.13–0.28 mg/L), nickel (0.02–0.18 mg/L), zinc (0.03–0.05 mg/L), cadmium (0.004–0.01 mg/L), lead (5.09–5.69 mg/L), and iron (2.00–5.65 mg/L). Lead and iron accumulated at higher levels than WHO standards, indicating long-term contamination.

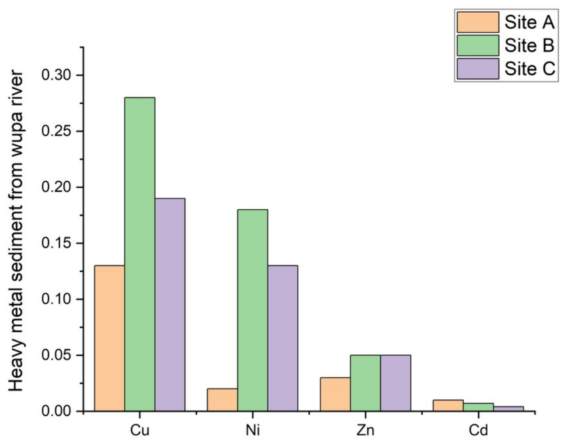

Figure 3a: Mean Concentration of heavy metals in Wupa sediment

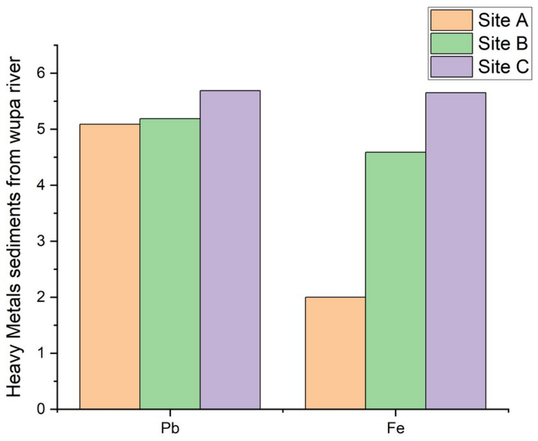

Figure 3b: Mean Concentration of heavy metals in Wupa sediment

DISCUSSION

The physicochemical assessment revealed that Wupa River generally exhibited acceptable temperature and turbidity, but pH, nitrate, and chlorine levels indicated anthropogenic influence. The slightly alkaline pH suggests buffering effects from effluents or geochemical factors, consistent with studies in other Nigerian rivers [19]. Elevated turbidity, although below WHO limits, still indicates sediment disturbance, similar to observations in South African rivers impacted by effluents [20].

The assessment of water quality revealed that the mean temperatures across the sampling stations ranged from 28.00 ± 0.70°C to 29.33 ± 1.05°C. These values fall within acceptable limits for tropical freshwater systems [14], although they are slightly higher than the 26–28°C reported for the Ogun River [13]. This temperature elevation in the Wupa River may be attributed to localized thermal influences from industrial effluents and wastewater discharge. Elevated temperatures are known to reduce dissolved oxygen (DO) levels by increasing the kinetic energy of water molecules, which reduces the solubility of oxygen, thereby potentially creating stressful conditions for sensitive aquatic species [14].

The pH values of the water samples ranged from 7.81 to 8.06, indicating a slightly alkaline environment. This is above the WHO guideline range of 6.5–7.5 and may result from buffering effects due to industrial effluents or natural geochemical processes [16]. Similar pH ranges have been documented in other effluent-impacted Nigerian rivers, such as the New Calabar River [17], suggesting that alkaline conditions are common in such settings. It is important to note that alkaline pH can alter the bioavailability of heavy metals by forming insoluble hydroxides or other precipitates, thereby reducing their bioavailability, potentially exacerbating their toxicity to aquatic organisms [21,22]

Conductivity measurements ranged from 0.15 ± 0.53 µS/cm to 0.20 ± 0.05 µS/cm, which are substantially below the WHO permissible limit of 125 µS/cm [19] These low conductivity values indicate a low concentration of dissolved ions, possibly due to dilution effects or the absence of significant saline intrusions. In contrast, higher conductivity values have been reported in rivers such as the Kaduna River, where increased anthropogenic activities have led to values exceeding 250 µS/cm [9]. The low conductivity in the Wupa River may affect the nutrient availability for aquatic life by limiting ion exchange capacity. Turbidity levels varied between 5.92 ± 2.75 NTU and 7.57 ± 1.36 NTU. Although these levels are below the WHO threshold of 40 NTU, they still reflect moderate sediment disturbance. Comparatively, the Olifants River in South Africa exhibited turbidity levels greater than 15 NTU due to significant industrial and municipal discharge [20]. Elevated turbidity reduces light penetration, thereby potentially affecting photosynthesis and primary productivity within the river ecosystem.

Heavy metal analysis confirmed contamination. Elevated lead and iron concentrations in both water and sediments are particularly concerning due to their persistence and toxicity. The levels observed exceeded WHO standards and are consistent with findings in other Nigerian rivers [21,22]. Lead contamination poses neurological risks to humans, while iron enrichment can alter aquatic biodiversity [23]. Nickel and cadmium concentrations also exceeded permissible limits, suggesting industrial and agricultural sources [24].

Sediments acted as sinks for heavy metals, accumulating higher concentrations than water samples. This agrees with reports that sediments store pollutants that may later become bioavailable under environmental changes [25-29]. The high levels of lead (up to 5.69 mg/L) and iron (up to 5.65 mg/L) highlight the long-term contamination burden in the river system.

The presence of cadmium in both water (0.10 ± 0.01 mg/L to 0.12 ± 0.00 mg/L) and sediment (0.004 ± 0.05 mg/L to 0.01 ± 0.01 mg/L) is particularly concerning due to its high toxicity. Cadmium exposure has been linked to severe health issues, including kidney damage, bone demineralization, and carcinogenic effects [30, 31]. The slightly elevated levels of cadmium at Station C point to potential contamination from industrial sources, such as battery production and phosphate fertilizers.

Significant spatial variations in heavy metal concentrations were observed across the sampling stations. Station A generally recorded lower levels compared to Stations B and C, implying that pollution sources are more concentrated downstream where industrial activities and wastewater discharges are more prevalent. This gradient is consistent with previous studies that have demonstrated increased heavy metal accumulation downstream due to the cumulative effects of effluent discharges [28, 29]. The implications of these findings are substantial. High concentrations of heavy metals in both water and sediment can lead to bioaccumulation and biomagnification in the food chain, adversely affecting aquatic organisms and potentially leading to declines in fish populations. Furthermore, the consumption of contaminated water or fish may result in serious health issues in humans, including neurological disorders, organ damage, and developmental problems in children [32, 33].

These results underscore the urgent need for stricter effluent management, improved wastewater treatment, and regular monitoring of Wupa River. Without intervention, heavy metal bioaccumulation may pose risks to fisheries, aquatic life, and communities dependent on the river.

4 | CONCLUSION

This study revealed that Wupa River is moderately impacted by effluents from the Wupa wastewater treatment plant, resulting in elevated concentrations of heavy metals, particularly lead, iron, nickel, and cadmium. Although most physicochemical parameters were within acceptable limits, heavy metal concentrations exceeded WHO guidelines, posing both ecological and public health risks. Long-term exposure to these metals through water use and fish consumption may lead to neurological, renal, and developmental health effects. Continuous monitoring, stricter wastewater regulation, and community awareness programs are therefore essential to protect both the environment and public health.**Acknowledgement:** Special appreciation to the management of Nile University of Nigeria.

Funding Statement: "The author(s) received no specific funding for this study".

Author Contributions: The authors confirm contribution to the paper as follows: **Ibrahim U.F:** Conceptualizing, writing original draft and preparation and investigation. **Ibrahim U.F, Ajiya AM, SSD Mohammed & Ndanusa AH:** Visualization, Writing reviewing and editing. **Ahmed ZM, Omotosho O.A, Ibrahim, AA:** Methodology, Formal analysis, Resources, Validation. **Ibrahim MI, Ndanusa AH.:** Investigation, Resources, Project administration and Supervision.

Conflicts of Interest: "The authors declare that they have no conflicts of interest to report regarding the present study".

References

1. Adamu, K. M. Mohammed, Y. M., Ibrahim, U. F., Abdullahi, I. L., & Jimoh, Y. O. (2022). Assessment of some physical, chemical and biological parameters of Lake Dangana, Niger State, Nigeria. The Zoologist, 20, 133-140. https://doi.org/10.4314/tzool.v20i1.17

2. Ibrahim, U.F., Omotosho, O.A, Abdulrasheed, M., Kanki, H., Ndanusa, A.H., Ibrahim, M.I & Tunau R.A. (2025). Mycoremediation of Heavy Metals from Wupa River Using Aspergillus niger and Aspergillus fumigatus. South Asian Journal of Research in Microbiology, 19(3), 12-21. https://doi.org/10.9734/sajrm/2025/v19i3422

3. Mohammed, Y. M., Arimoro, F. O., Ayanwale, A. V., Adamu, K. M., Ismail, A., Umar, M., & Kanki, H. (2020). Assessment of some physicochemical parameters of Moussa stream, Bida, Niger State Nigeria. Journal of Public Health and Environmental Pollution. 4(2), 020-024.

4. Ibrahim, U.F., Omotosho, A.O., Abdulrasheed, M., Jibrin, M.B., Ndanusa, H.A., Ibrahim, M.I., Musa, Z.B., & Mohammed, Y.M. Bioremediation of some heavy metals from Wupa River using Bacillus subtillis and Pseudomonas putida. Sahel Journal of Life Sciences FUDMA (SAJOLS). 3(2), 10-18. https://doi.org/10.33003/sajols-2025-0302-02

5. Dey, S., Uddin, M. S., amd Manchur, M. A. (2017). Physicochemical and bacteriological assessment of surface water quality of the Karnaphuli River in Bangladesh. Journal of Pure and Applied Microbiology, 11(4), 1721-1728

6. Whitehead, P. G., Bussi, G., Peters, R., Hossain, M. A., Softley, L., Shawal, S., and Alabaster, G. (2019). Modelling heavy metals in the Buriganga River System, Dhaka, Bangladesh: Impacts of tannery

pollution control. Science of the Total Environment, 697, 134090.

7. Hoque, S. F., Peters, R., Whitehead, P., Hope, R., and Hossain, M. A. (2021). River pollution and social inequalities in Dhaka, Bangladesh. Environmental Research Communications, 3(9), 095003.

8. Rajeshkumar, S., Liu, Y., Zhang, X., Ravikumar, B., Bai, G., and Li, X. (2018). Studies on seasonal pollution of heavy metals in water, sediment, fish and oyster from the Meiliang Bay of Taihu Lake in China. Chemosphere, 191, 626-638.

9. Dadi-mamud, N.J., Mohammed, A.P., Aliyu, D.A., Anyadike, M.C. & Joseph, J. (2020). Assessment of Eichhornia Crassipes (Water Hyacinth) as Bio-Accumulator of Contaminants in Domestic Wastewater of Makera And Chanchaga Drains. Science World Journal, 15(3), 1597-6343

10. Ibrahim, U.F., Adamu, K.M., Mohammed, S.S.D., Chukwu, M.N. & Umar H.F. (2023). Utilization of Bacillus subtilis and Aspergillus niger for the Bioremediation of Heavy Metals in the WUPA Wastewater Treatment Plant, Abuja. The 2nd International Conference on Multidisciplinary Engineering and Applied Sciences (ICMEAS-2023).1-5. https://doi.org/10.1109/ICMEAS58693.2023.10379287.

11. Kouame, K.V., Meite, L., Adjiri, O. A., Yapi, D.A.C. & Tidou, A. S. (2016). Bioaccumulation of Heavy Metals from Wastewaters (Pb, Zn, Cd, Cu and Cr) in Water Hyacinth (Eichhornia crassipes) and Water Lettuce (Pistia stratiotes). International Journal of Chemical Technology Research Journal, 9(2), 189-195.

12. Hayyat, M.U., Nawaz, R., Irfan, A., Al-Hussain, S.A., Aziz, M., Siddiq, Z., Ahmad, S. & Zaki, M.E.A. (2023). Evaluating the Phytoremediation Potential of Eichhornia crassipes for the Removal of Cr and Li from Synthetic Polluted Water. International Journal of Environmental Research and Public Health, 20, 3512. https://doi.org/10.3390/ijerph20043512

13. Dedeke, G. A., Iwuchukwu, P. O., Oladosu, O. O., Aladesida, A. A., Afolabi, T. A., Bamgbola, A. A., & Ayanda, O. I. (2018). Physicochemical parameters of Ogun River sample at selected points during the rainy season. Munis Entomology & Zoology, 13(2), 427-440.

14. Bulbul-Ali M, Mishra D. (2022) Impact of temperature on dissolved oxygen in aquatic systems. International Journal of Hydrology Science and Technology, 12(3), 321-330.

15. Wei, Y., Jiao, Y., An, D., Li, D., Li, W., & Wei, Q. (2019). Review of dissolved oxygen detection technology: From laboratory analysis to online intelligent detection. Sensors, 19(18), 3995.

16. Embiriekah, S., Ahwedg, E., Elmalimadi, M., Elramalli, N. E., Al-Zailiq, S., Al-Ahrash, S., & Safar, M. (2024). The Physical and Chemical Properties Study to Evaluate the Quality of Bottled Drinking Water Offered in Misurata Markets. The North African Journal of Scientific Publishing (NAJSP), 41, 41-56.

17. Ekeng, E. E. (2024). Analyzing the Effect of Physicochemical Processes of Calabar River on Coastal Hydraulic Structures: A Case Study of Calabar River. International Journal of Research and Innovation in Applied Science, 9(8), 519-531.

18. APHA. Standard Methods for the Examination of Water and Wastewater. 23rd ed. Washington, DC: American Public Health Association; 2017.

19. Eboagu, N. C., Ajiwe, V. E., & Odidika, C. C. (2019). Physicochemical parameters of water from selected boreholes utilized as potable water. International Journal of Environmental Science and Technology, 16, 3605-3614.

20. Rasifudi, L., Addo-Bediako, A., Bal, K., & Swemmer, T. M. (2018). Distribution of benthic macroinvertebrates in the Selati River of the Olifants River system, South Africa. African Entomology, 26(2), 398-406.

21. Maishanu, F., Adamu, K. M., & Mohammed, M. Y. (2022). Anthropogenic impact on some water quality characteristics of Wupa River Federal Capital Territory, Abuja, Nigeria. Issues in Biological Sciences and Pharmaceutical Research, 10(3), 30.

22. Davies, I. C., & Ekperusi, A. O. (2021). Evaluation of heavy metal concentrations in water, sediment and fishes of New Calabar River in Southern Nigeria. Journal of Limnology and Freshwater Fisheries Research, 7(3), 207-218.

23. Wiśniowska, E., & Włodarczyk-Makuła, M. (2018). The effect of selected acidic or alkaline chemical agents amendment on leachability of selected heavy metals from sewage sludge. Science of The Total Environment, 633, 463-469.

24. Naz, M., Dai, Z., Hussain, S., Tariq, M., Danish, S., Khan, I. U., ... & Du, D. (2022). The soil pH and heavy metals revealed their impact on soil microbial community. Journal of Environmental Management, 321, 115770.

25. Ibanga, L.B., Nkwoji, J. A., Usese, A. I., Onyema, I. C., & Chukwu, L. O. (2019). Hydrochemistry and heavy metals concentrations in sediment of Woji creek and Bonny estuary, Niger Delta, Nigeria. Regional Studies in Marine Science, 25, 100436.

26. Ibrahim, U.F., Ndanusa, A.H., Ibrahim, A.A., Ibrahim, M.I., Shuaibu, S., Olokpo, S.O., & Mohammed, Y.M. (2025). Physicochemical Characteristics, Molecular Characterization of Bacteria and Fungi Isolates found in Nile Stream, Abuja Nigeria. Duste Journal of Pure and Applied Sciences (DUJOPAS), 10(4c). https://doi.org/10.4314/dujopas.v10i4c.6

27. Ibrahim, U.F, Adamu, K.M, Mohammed, S.S.D., Chukwu, M.N., & Mabekoje, O.O. (2024). Bioremediation of Selected Heavy Metals from Industrial Influent Collected at Wupa Wastewater Treatment Plant, Abuja. Nile Journal of Engineering and Applied Science, 2 (1), 212-223. https://doi.org/10.5455/NJEAS.193825

28. Pandey, J., & Singh, R. (2017). Heavy metals in sediments of Ganga River: up-and downstream urban influences. Applied Water Science, 7, 1669-1678.

29. Mokarram, M., Saber, A., & Sheykhi, V. (2020). Effects of heavy metal contamination on river water quality due to release of industrial effluents. Journal of Cleaner Production, 277, 123380.

30. Reyes-Hinojosa, D., Lozada-Pérez, C. A., Cuevas, Y. Z., López-Reyes, A., Martínez-Nava, G., Fernández-Torres, J., ... & Martínez-Flores, K. (2019). Toxicity of cadmium in musculoskeletal diseases. Environmental Toxicology and Pharmacology, 72, 103219.

31. Ma, Y., Su, Q., Yue, C., Zou, H., Zhu, J., Zhao, H., ... & Liu, Z. (2022). The effect of oxidative stress-induced autophagy by cadmium exposure in kidney, liver, and bone damage, and neurotoxicity. International Journal of Molecular Sciences, 23(21), 13491.

32. Edegbene, A.O., El Yaagoubi, S., Mohammed, Y.M., Harrak R, Edegbene Ovie T.T., Azmizem, A., Errochdi, S., Olatunji, O.E., Keke, U.N., Sankoh, A.A., Abubakar, M.D., Irefo, A.L, Ibrahim, U.F., and El Alami, M. (2025) Advancing trait-based biomonitoring approach for freshwater ecosystems assessment in Africa: current status, challenges, and future directions. Frontiers in Environmental Science. 13:1652525. https://doi.org/10.3389/fenvs.2025.1652525

33. Ibrahim U.F., Adamu K.M., Mohammed S.S.D., Chukwu M.N., & Mohammed A.P. (2025). Assessment of heavy metals bioremediation potential of microbial isolates collected from Wastewater Treatment Plant Abuja. Nile Journal of Health Sciences 1(1), 21-30