AJBAR Vol. 5(5), October 2026: 202-216, ISSN: 2811-2881

Arid Zone Journal of Basic and Applied Research
Faculty of Science, Kashim Ibrahim University
Maiduguri, Nigeria

Journal homepage: https://www.azjournalbar.com

Research Article

Ecotoxicological Profile and Heavy Metal Bioaccumulation Risks in Two Peri-Urban Rivers of Kwali, FCT-Abuja, Nigeria

Moses Dele Adams
Clinical Biochemistry, Phytopharmacology and Biochemical Toxicology Research Laboratory (CBPBT-RL), Department of Biochemistry, Baze University, Abuja 900108, Nigeria
*Corresponding author's Email: moses.adams@bazeuniversity.edu.ng, doi.org/10.55639/607.020100159

ARTICLE INFO:
Keywords:
Dabi river,
Bako river,
Public health risk,
Heavy metal,
Physicochemical.

ABSTRACT

A clean and safe water supply is crucial as it prevents morbidity and mortality among the populace of the communities we live. Therefore, in a bid to help actualize the SDG No. 6 (Water Safety for All), this study seeks to determine the heavy metal content and physicochemical characteristics of river water (RW) from selected locations in Dabi and Bako (DAB), Kwali Area Council (KAC) of FCT, Abuja. The heavy metal content and physicochemical properties of the water samples, which were collected from three locations within DAB RW were analyzed using Atomic Absorption spectroscopy and standard methods respectively. While the mean concentration of Cadmium, Nickel and Lead was higher than the WHO standard, the concentration of Chromium and Zinc was low. The level of Copper and Iron was found within the WHO limit. The physicochemical properties of the RW showed that pH, TH, Conductivity, TSS, Cl, Alkalinity and SO_4 fell below the WHO standard while those of DO, BOD and TDS were found above the set WHO limit. The high level of Cd, Ni and Pb in the RW could induce tissue damage leading to hepatotoxic/cardiovascular diseases. The high BOD, TDS and DO values are indicative of the presence of organic and inorganic pollutants respectively. The RW may not be completely 'safe' for domestic activities. Caution should be exercised, by the target populace, on the usage. The study may serve as baseline information with which future environmental impact assessment of anthropogenic activities could be progressively monitored in the study area

Corresponding author: Moses Dele Adams, **Email**: moses.adams@bazeuniversity.edu.ng
Department of Biochemistry, Baze University, Abuja 900108, Nigeria

INTRODUCTION

Access to clean and portable source of water is vital for the growth, development, wellbeing and sustenance of any community as water is most essential for life. The available sources of water determine the quality of water for the community (Edefo, 2025). The sources of water include tap water, underground water, rain water, well water, river water among others. River water is one of the major sources of water for drinking and other domestic and agricultural/industrial activities (Gao *et al*., 2023). The need for portable and accessible drinking water, from river water is on the rise due to population explosion, shortage of government interventions coupled with the contamination of the water bodies with contaminants such as personal care products, pesticides, herbicides, and heavy metals, amongst

a myriad of biological and physicochemical contaminants (Whelan *et al*., 2022). The contaminats of water bodies are of global burden and therefore a matter of serious public and environmental health concern (Okafor *et al*., 2024). This is because communities with abundant and safe water sources tend to have better public health outcomes and a higher quality of life, while populations without access to clean and safe water sources face serious health risks from several waterborne diseases caused by poor water quality (Lanrewaju *et al*., 2022; Debajyoti *et al*., 2024). A community on the search light is Dabi and Bako.

Dabi and Bako are two communities domiciled within the Sheda community of Kwali Area Council (KAC) of the Federal Capital territory, Nigeria. The communities are somewhat rural-to peri urban known to engage mainly in agricultural practices with dependence on river water for their daily water need. Dabi and Bako river water are also located within the Gwagwalada-Kwali Sheda axis. The water body is bedeviled with dumping of domestic waste, as well as other agricultural and industrial matters, creating for need for investigation into the safety or toxicity of its use by members of the community, as their major source of water supply (Ajayi *et al*., 2022). KAC is a local government administrative region in the southwestern part of the Federal Capital Territory (FCT), Abuja, Nigeria. It was established on October 1, 1996. The Area Council has a total landmass of about 1,700 Square Kilometers. The Area Council is the country home of the Late Famous Dr. Ladi Kwali whose image adorn the twenty Naira Note. According to the 2006 census, the Area Council has about 85,837 population and the settlement pattern is disperse with the ten geopolitical wards of Kwali Central (Sheda), Yebu, Yangoji, Dabi, Dafa, Kundu, Wako, Bako, and Kilankwa. The main ethnic groups include the Gbari, Bassa, Abawa, Gbagyi, Hausa amongst a sprinkling of other minority ethnic groups (Ajayi *et al*., 2022).

Heavy metals are metallic chemical element that has a relatively high density and is toxic or poisonous at low concentrations (Zhang *et al*., 2023; Oshukunuofa *et al*., 2024). Heavy metals are also regarded as trace elements owing to their availability in minute concentrations (ppb range to less than 10ppm) in several environmental matrices (Udongwo and Sambo, 2022). Heavy metals are defined as metal elements that have a considerably high weight in comparison to water (Fergusson, 1990; Singh *et al*., 2024). With the relationship between their density and toxic effect, heavy metals also include metalloids, like arsenic, which have the capacity to cause toxic effect at low concentration during exposure. Most heavy metals have a high atomic number, atomic weight and a specific gravity greater than 5. Heavy metals include some metalloids, transition metals, basic metals, lanthanides, and actinides (Okere *et al*., 2022; Udochukwu *et al*., 2025). Examples of heavy metals include lead, mercury, cadmium, sometimes chromium. The types of heavy metals include ferrous metal, non-ferrous, noble metals among others.

Physiochemistry encompasses the physicochemical components of metal, material or substance (Okere *et al*., 2014). It is employed to examine the physical and chemical characteristics of a substance with information on the BOD, DO, TH, pH, conductivity, TSS, TDS among others. Physicochemical characteristics refer to the physical and chemical properties of water that determine its quality, suitability for drinking, irrigation, industrial use, and aquatic life (Obagha *et al*., 2025). River water quality is influenced by natural processes such as weathering and erosion, as well as human activities including agriculture, urbanization, and industrial discharge. The physical characteristics include taste, odour, temperature, electrical conductivity, colour, turbidity, total suspended solids (TDS) while the chemical characteristics are dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), alkalinity, total hardness (TH), total dissolved solid (TDS) in addition to nutrients/chemicals constituents like nitrates, phosphates, chlorides, sulphates (Abali *et al*., 2023).

A few previous studies on river water in the FCT include those by Amlabu *et al*. (2026). Who assessed the availability of heavy metal contamination and seasonal differences of river in Gwagwalada Area Council. Adejuwon *et al*. (2025) who investigated the water quality of Jabi Lake, AMAC, FCT-Abuja. Ozoude *et al*. (2026) who studied water suitability in some sites within Bwari Area Council of the FCT as well as

Nwangene *et al*. (2022) who examined the physiochemistry and bacteriology of ground water in Bwari axis of Dutse, Bwari Area Council of the FCT. In Kubwa Bwari axis, Useh *et al*. (2016) analyzed the physiochemistry of water sources within Kubwa-Bwari Area Council of the FCT-Abuja. The study by Ibrahim *et al*. (2015) on physicochemical examination of groundwater in Kuje Area Council of the FCT. Ja'afar *et al*. (2023) investigated the physicochemical status of River Wupa in FCT-Abuja. Despite these studies to the best of knowledge on river water in the area councils of FCT, no study has specifically touched on the evaluation of contents of Dabi and Bako river water of the KAC with a bid to help actualize the SDG No. 6 which emphasized on a clean and safe water for all. This indicates a vital research gap that needs to be filled. Therefore, this study was designed to examine the heavy metal content and physicochemical characteristics of Dabi and Bako River water, of KAC, in order to create awareness about the river water with a view to tackling public/and or environment health problems arising from these water bodies.

MATERIALS AND METHODS

Materials

Study area

The research covered Dabi and Bako River water (RW) axis found within Sheda community of Kwali, Kwali Area Council of the FCT. Kwali is one of the six area councils (Bwari, AMAC, Kuje, Gwagwalada, Abaji) of the Federal Capital Territory, Abuja, Nigeria (Figure 1) and situated between latitude 8.8835° N (8° 53' 0.46" N) of the equator and longitude 7.0186° E (7° 01' 6.89" E) of the Greenwich Median (Ahmad, 2023).

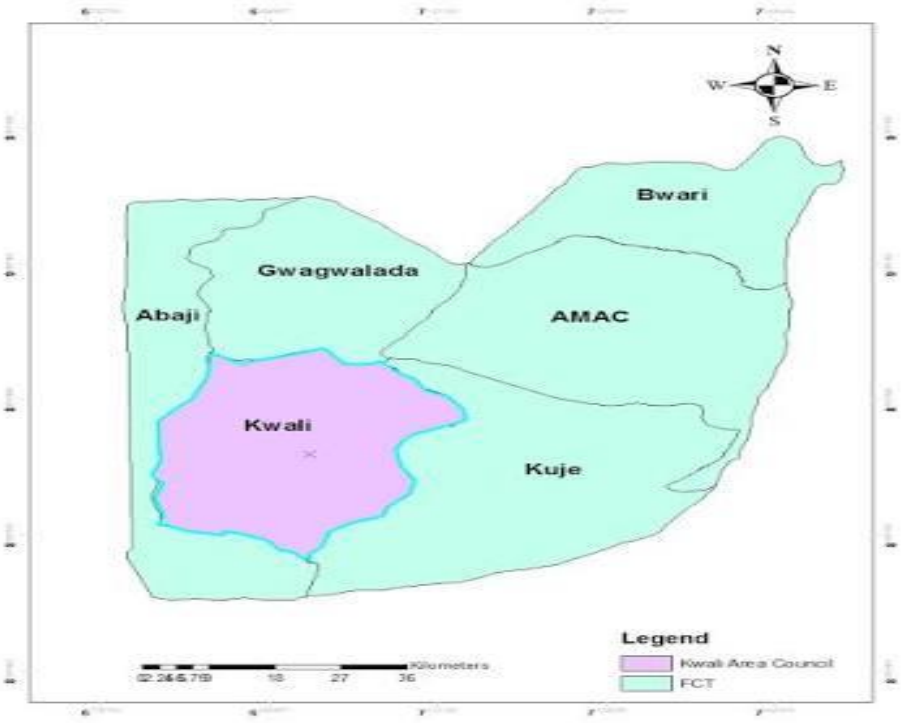


Figure 1: Map Showing Kwali and other Area Councils of the FCT
Source: Ahmad (2023)

Reagents, chemicals and apparatus

All the chemicals and reagent used in the study were procured from JHD China and are of analytical grade. The apparatus used in the study includes sample bottles, measuring cylinder, beaker, hot plate, cover glass, weighing balance, crucible and thermometer.

Methods

Collection of river water sample

A known volume (200 cm^3) of river water sample were collected randomly from three locations within Dabi and Bako river water, both of which are located within Sheda environs of Kwali. 5 cm^3 of Conc. HNO_3 were added for preservation (APHA, 2022). The river water samples were collected in a clean sample container in three different locations within each study area (river).

Determination of heavy metal content of Dabi and Bako river water

Preparation of sample

The glass wares and plastics which were washed and soaked in a 9% mixture of HCl – HNO_3 for three days were rinsed with distilled water. Stock solutions of the heavy metals to be determined were prepared using 9 cm^3 of nitric acid and diluted to the level of a 1-liter volumetric flask from which the required standard solution of the metals was prepared by a known dilution factor; for the specified heavy metals based on their various standard solutions.

Sample digestion

Water digestion was conducted by applying the protocol of Sastre *et al*. (2002). Exactly 2 cm^3 of concentrated HNO_3 was added to 80 cm^3 of preserved river water sample. The mixture was thereafter covered with a glass, heated slowly using a Bunsen burner and successively added until digestion was achieved. The mixture was thereafter evaporated to semi-solid and cooled. About 4 cm^3 of 1:1 Concentrated HCl was gradually added to the digested water sample, warmed, filtered in 50 cm^3 standard flask and made up to the marked level with distilled water.

Sample measurement

The digested river water sample was thereafter measured for the presence of the specified heavy metals, using an atomic absorption spectrophotometer (AAS VGB 210 System). The assessment of the digested river water sample was carried out in triplicate using the AAS analyzer. Intrinsic substances added were adopted as the standards and were used for standardizing the AAS machine (Adeyemi and Ojekunle, 2021). All triplicate readings were noted.

Determination of physicochemical characteristics of Dabi and Bako river water

***pH and conductivity*:** pH and conductivity were determined using a Hanna Instruments HI 9813-6N pH/EC/TDS Meter. The pH meter was calibrated before the electrodes were inserted into the sample for measurement.

***Total dissolved solids (TDS)*:** An empty container was weighed; 60 ml of river water was measured, filtered and added into the container. The filtered sample was heated to dryness, cooled and reweighed with the container, until a constant mass was obtained and the readings was recorded.

$$Total\ Dissolved\ Solids\ (mg/L) = \frac{W1 - W2\ X\ 1000}{Sample\ Volume\ (ml)}$$

Where:

W1 = weight of dried residue + container,

W2 = weight of empty container

***Total suspended solids (TSS)*:** A filtered river water sample quantity of 50 mL was oven-dried in a beaker. The difference in the weight of the empty beaker and the oven dried content was used to estimate the TSS (Sluiter *et al*., 2008).

***Biochemical oxygen demand (BOD) and dissolved oxygen (DO)*:** BOD in the river water was determined by the difference in the dissolved oxygen (DO) levels of river water before incubation and five days after incubation. BOD of the collected river water water was assessed using the dilution method. Dilution water was prepared by adding 9 ml of each of these solutions: calcium chloride, magnesium sulphate, ammonium chloride, phosphate buffer, ferric chloride and sodium sulphite into a beaker containing 10 L of water. A known quantity of the river water was topped up with dilution water to 1 L mark level of a standard flask. Two 400 mL amber bottles were filled to the brim with diluted water. One of the bottles was incubated at 25 ^0C for 5 days. concentrated sulphuric acid, alkali-iodide-azide reagent and $MnSO_4$ solution, were added into the other amber bottle. The amount of DO in the river water was obtained via iodometric titration. For dissolved oxygen at day zero (DO_0), 40 mL aliquot of the solution was titrated against sodium thiosulphate solution using starch

solution as indicator, until a colourless endpoint was gotten. At the end of the 5 days, the sample picked from incubator was brought out; dissolved oxygen at day five after incubation (DO_6) was determined by following the same procedure used for the determination of DO_0. A blank was prepared in a beaker for DO_0. (Aniyikaiye *et al*., 2019). Another blank was prepared in an amber bottle and incubated with the sample for DO_6.

***Sulphate and chloride*:** Sulphate and chloride in the river water was determined using specified standard protocols (Udo *et al*., 2009).

***Sulpate*:** First, the concentration of the sulphate in the sample was determined, the reading of sulphate was divided by 10 and an amount of silver sulfate equivalent to the amount of sulphate was added. Three ml of the sample was taken in centrifuge test tube and the volume was completed to 10 ml with distilled water. The tube was centrifuged for 10 min until solution was clear. Five ml of the clear solution was taken in glass evaporating dish, put on water bath, evaporated to dryness and it was cooled. One ml of phenoldisulphonic acid was added after 10 min. then 10 ml of water was added and was transferred to 100 ml volumetric flask and was made alkaline by the addition of conc. NH_4OH, diluted to volume and was mixed. The absorbance at 410 nm was measured by using BioBase UV-VIS Spectrophotometer and glass cells.

Preparation of standard calibration curve: by taking volumes of 0.00 to 12 ml from the standard solution of KNO_3 into glass evaporating dishes and treating as above omitting the addition of silver sulfate.

***Chloride*:** The analysis for chloride was done by taking 3 ml of sample in a volumetric flask, and diluting to 100ml distilled water, transferring into 250 ml conical flask. Add 5.0 ml conditional reagents, mixing in stirring apparatus, during stirring, add spoon full $NaCl_2$ crystals (about 0.2 – 0.3 g). Begin timing immediately, stirring for 1 min. at constant speed. Immediately after stirring period has ended (at 30 sec intervals 4 min) pour solution in 4 cm sample silica cell. Measure the absorbance at 450 nm by using BioBase Model UV-VIS Spectrophotometer. Preparation of standard calibration curve: by taking volumes of 0.00 to 5.0 ml interval 0.5 ml from the standard solution of sodium sulfate in volumetric flask, and dilute to 100 ml distilled water. Treating standard solution with specified amount of all reagents as above procedure. Set the spectrophotometer at zero by using distilled water as blank.

***Total hardness*:** Exactly 40 ml of the river water sample is pipetted into a conical flask, to which 2 ml of ammonium buffer and 2-3 drops of Eriochrome black T indicator was added. The mixture was titrated against standard 0.02 M EDTA until the wine-red colour of the solutions turned to pale blue at the end point.

$$Total\ \text{H}ardness = \frac{Volume\ of\ EDTA \times N \times 50 \times 1000}{Volume\ of\ Sample\ taken}$$

Where, **N** = normality

Data analysis

Results were presented as the mean of three replicates ± SD. Statistical difference was gotten by descriptive comparison of the replicate means with the WHO limit

RESULTS

Table 1 shows that the mean concentration of zinc in Dabi and Bako (DAB) river water (RW) was significantly *($p<0.05$)* lower than the WHO standard.

Table 1: Concentration of Zinc (mg/L) in Dabi and Bako river water

	Sample 1	Sample 2	Sample 3	Mean±SD	WHO standard (mg/L)
Dabi R/water	0.077	0.867	0.924	0.623±0.174[b]	3.0[a]
Bako R/water	0.079	0.888	0.992	0.650±0.049[b]	3.0[a]

Mean ± SD are values obtained from three determinations. Test values (Mean±SD) with superscript (b, c) different from their respective WHO standard (a) across the row are significantly different (p<0.05)

SD = Standard deviation; **R** = River; **WHO** = World health Organization

Table 2 indicates that the mean concentration of copper in DAB RW compared *(p>0.05)* favourably well with the WHO limit.

Table 2: Concentration of Copper (mg/L) in Dabi and Bako river water

	Sample 1	Sample 2	Sample 3	Mean±SD	WHO standard (mg/L)
Dabi R/water	1.947	2.045	2.189	2.060±0.127[a]	2.0[a]
Bako R/water	1.992	2.501	2.092	2.195±0.270[a]	2.0[a]

Mean ± SD are values obtained from three determinations. Test values (Mean±SD) with superscript (b, c) different from their respective WHO standard (a) across the row are significantly different (p<0.05)
SD = Standard deviation; **R** = River; **WHO** = World health Organization
The mean concentration of nickel in Dabi and Bako RW increased significantly *(p<0.05)* when compared with the WHO limit (Table 3).

Table 3: Concentration of Nickel (ppm) in Dabi and Bako river water

	Sample 1	Sample 2	Sample 3	Mean±SD	WHO standard (ppm)
Dabi R/water	0.092	0.095	0.099	0.095±0.004[b]	0.05[a]
Bako R/water	0.085	0.088	0.082	0.085±0.002[b]	0.05[a]

Mean ± SD are values obtained from three determinations. Test values (Mean±SD) with superscript (b, c) different from their respective WHO standard (a) across the row are significantly different (p<0.05)

SD = Standard deviation; **R** = River; **WHO** = World health Organization

The mean concentration of iron in Dabi and Bako river water compared well *(p>0.05)* with the WHO limit (Table 4).

Table 4: Concentration of Iron (mg/L) in Dabi and Bako river water

	Sample 1	Sample 2	Sample 3	Mean±SD	WHO standard (mg/L)
Dabi R/water	0.456	0.642	0.569	0.556±0.094[a]	0.5[a]
Bako water	0.557	0.524	0.472	0.518±0.012[a]	0.5[a]

Mean ± SD are values obtained from three determinations. Test values (Mean±SD) with superscript (b, c) different from their respective WHO standard (a) across the row are significantly different (p<0.05)

SD = Standard deviation; **R** = River; **WHO** = World health Organization

The mean concentration of lead in DAB river water was significantly *(p<0.05)* higher than the WHO limit (Table 5).

Table 5: Concentration of Lead (mg/L) in Dabi and Bako river water

	Sample 1	Sample 2	Sample 3	Mean±SD	WHO standard (mg/L)
Dabi R/water	10.107	10.105	10.008	10.073±0.057[b]	0.01[a]
Bako R/water	9.023	9.004	9.008	9.012±0.010[b]	0.01[a]

Mean ± SD are values obtained from three determinations. Test values (Mean±SD) with superscript (b, c) different from their respective WHO standard (a) across the row are significantly different (p<0.05)

SD = Standard deviation; **R** = River; **WHO** = World health Organization

The mean concentration of cadmium in Dabi and Bako river water was significantly *(p<0.05)* higher than the WHO limit (Table 6).

Table 6: Concentration of Cadmium (ppm) in Dabi and Bako river water

	Sample 1	Sample 2	Sample 3	Mean±SD	WHO standard (ppm)
Dabi R/Water	1.965	1.943	1.935	1.948±0.012[b]	0.2-1.8[a]
Bako R/water	1.998	1.973	1.952	1.974±0.015[b]	0.2-1.8[a]

Mean ± SD are values obtained from three determinations. Test values (Mean±SD) with superscript (b, c) different from their respective WHO standard (a) across the row are significantly different (p<0.05)

SD = Standard deviation; **R** = River; **WHO** = World health Organization

The mean concentration of chromium in Dabi and Bako RW was significantly *(p<0.05)* lower than the WHO standard (Table 7).

Table 7: Concentration of Chromium (ppm) in Dabi and Bako river water

	Sample 1	Sample 2	Sample 3	Mean±SD	WHO standard (ppm)
Dabi R/Water	0.028	0.045	0.055	0.043±0.001[b]	0.5[a]
Bako R/water	0.092	0.025	0.075	0.064±0.002[b]	0.5[a]

Mean ± SD are values obtained from three determinations. Test values (Mean±SD) with superscript (b, c) different from their respective WHO standard (a) across the row are significantly different (p<0.05)

SD = Standard deviation; **R** = River; **WHO** = World health Organization

The physicochemical characteristics of Dabi and Bako river water revealed that the pH, total hardness (TH), conductivity, total suspended solid (TSS), chloride, alkalinity and sulphate were below the WHO standard. However, the result revealed that the dissolved oxygen (DO), biochemical oxygen demand (BOD) and total dissolved solid (TDS) were above the WHO limit (Table 8).

Table 8: Physicochemical characteristics of Dabi and Bako river water

Parameter	DRW (mg/L)	BRW (mg/L)	WHO Standard	Remark
pH	4.6	4.5	6.5-8.5	Below Limit
DO (mg/L)	11.2	11.48	5	Above Limit
BOD (mg/L)	12.4	11.27	5	Above Limit
TH (mg/L)	8.3	4.6	150	Below Limit
Condu. (µS/cm)	51.3	277	1000	Below Limit
TDS (mg/L)	507.3	510.2	500	Above Limit
TSS (mg/L)	148	137	250	Below Limit
Cl (mg/L)	23.8	43.7	250	Below Limit
Alkalinity	376	336	250	Below Limit
SO_4 (mg/L)	2.01	1.73	3	Below Limit

TSS = Total Suspended Solids; **TDS** = Total Dissolved Solids; **SO_4** = Sulphate; **DO =** Dissolved Oxygen; **BOD=** Biochemical Oxygen Demand; **Condu. =** Conductivity; **TH =** Total Hardness; **Cl =** Chloride; **DRW =** Dabi River Water; **BRW =** Bako River Water; **WHO =** World Health Organization

DISCUSSION

Zinc (Zn) is an essential mineral and chemical element vital for immune function, wound healing, DNA synthesis, and growth, found in foods like meat, shellfish, and legumes, and used industrially for galvanizing steel; it's a bluish-white, brittle metal that forms a protective oxide layer, crucial for health but must be obtained through diet as the body does not store excess zinc (Hussain *et al*., 2022). The low concentration of zinc than the WHO specification in this study could lead to zinc deficiency, causing impaired cellular metabolism, weakened immunity, and physiological dysfunction. The lowered zinc level might also predispose to disruption in epidermal cellular integrity, sensory and cognitive impairments, immune system failure, stunted growth and development as well as other reproductive and metabolic dysfunction (Sankhla *et al*., 2019).

Nickel (Ni) is an essential trace element in the human body. It is important for enzyme function, hormonal activity, lipid metabolism, and red blood cell formation, potentially acting as a cofactor for calcineurin and influencing cGMP signaling for blood pressure and kidney health, though its precise roles are still being researched. It is involved in processes like iron absorption, bone strength, and protecting cells from oxidative damage. The high mean concentration of nickel than the WHO set limit, in this study, may lead to gastrointestinal problems, kidney and liver damage, neurological issues, reproductive problems, compromised immune function, and allergic reactions, including systemic contact dermatitis (Feezan *et al*., 2025). A long-term, high-level exposure to nickel could also be associated with an increased risk of certain cancers, particularly of the respiratory tract (though this link is strongest for inhalation exposure).

Lead (Pb) is a non-essential, toxic heavy metal with no known biological function that has caused widespread environmental contamination throughout human history. Pb toxicity represents one of the most persistent environmental health challenges, with no safe exposure threshold identified (Mishra *et al*., 2025). The mean concentration of lead which was observed to be higher than that of the WHO reference point in this study may disrupts essential cellular functions by mimicking vital minerals like calcium and zinc, damaging nearly every organ, especially the brain, kidneys, and blood-forming system. A high exposure to lead also lead to developmental issues in children. It may also predispose to anaemia, neurological disorders, and cardiovascular problems, with chronic exposure leading to severe, often irreversible, health effects (Generalova *et al*., 2025).

Cadmium (Cd) is a soft, silvery-white chemical element. It is a toxic heavy metal known for accumulating in the body, primarily harming the kidneys, bones, and lungs, classified as a human carcinogen. The high mean cadmium level than the WHO standard could results in serious health hazard due to its high toxicity and tendency to accumulate in the body over decades. Long-term exposure primarily damages the kidneys, bones, and lungs and is linked to an increased risk of various cancers. An acute exposure to cadmium could lead to gastrointestinal irritation, abdominal pain, nausea, diarrhea and vomiting (Geology *et al*., 2016). In severe cases, liver damage, renal failure, and potentially death. Chronic exposure to cadmium could lead to kidney damage with damage renal tubules, impairing their ability to reabsorb essential proteins, calcium, and other nutrients, leading to proteinuria (excess protein in urine), glucosuria, aminoaciduria and progressive renal dysfunction. A high cadmium level could interfere with calcium and vitamin D metabolism, leading to bone demineralization and softening causing osteoporosis (reduced bone density) and osteomalacia (softening of bones) and increased risk of fractures, bone pain, and skeletal deformities, famously characterized by "itai-itai" disease. A high cadmium level has also been linked with lung cancer via inhalation, some studies suggest an increased risk of kidney, prostate, bladder, and breast cancers with long-term exposure. A high cadmium concentration is associated with an increased risk of high blood pressure (hypertension), atherosclerosis, and heart disease by promoting inflammation and oxidative stress in the cardiovascular system (Charkiewicz *et al*., 2023).

Chromium (Cr) is a trace metal that stimulates the immunity function of the biological system. It exhibits antioxidant property by neutralizing the action of free radicals in the biological system (Okorie *et al*., 2024). In the present study, the low concentration of chromium in the river water when compared with the WHO standard, is generally considered safe and potentially beneficial, as Cr is an essential element for human health and wellbeing (Georgaki *et al*., 2023).

Iron (Fe) is a vital mineral crucial for oxygen transport via hemoglobin and myoglobin, energy metabolism, DNA synthesis, immune function, and hormone production, playing key role in numerous cellular processes (Madjar and Vasile-Scaeteanu, 2025). The mean iron concentration, in this study, in the river water, that fell within the WHO standard, is generally considered safe and poses no health risks to man. The moderate range of iron is crucial for human health, because the moderate level forms a component of hemoglobin, which transports oxygen in the blood. It is required for the regulation of minimal iron absorption in the digestive tract and does not easily absorb excessive amounts of iron from water since most required iron is derived from food sources. The moderate iron concentration is beneficial since consuming water with iron moderate concentrations within the WHO threshold does not cause adverse health effects for cells of the biological system (Rushdi *et al*., 2023).

Copper (Cu) is an important trace mineral that act as a cofactor for normal enzyme activity. The mean copper concentration, which fell within the WHO standard in this study, are considered safe and pose no health risk for man because of its free radical scavenging potential, formation of RBCs and maintenance of the health of the nervous, connective tissues and bones. The moderate copper amount forms a vital component that supports the immune system (Teschke *et al*., 2024).

Dissolved oxygen (DO) is essential for aquatic organisms. It is the amount of free, gaseous oxygen (O_2) in water, required for aquatic life and a key indicator of water quality, entering water from the atmosphere and aquatic plants (photosynthesis). DO levels are affected by temperature (colder water holds more) and turbulence, impacting everything from fish health to pollutant breakdown, with low levels signalling poor water quality and stress on ecosystems (Ja'afar *et al*., 2023). The high DO content which was above the WHO standard, observed in this study, may harm aquatic life by causing gas bubble disease (blockages in fish), it disrupts ecosystems through algal blooms leading to crashes, promotes metal release from sediments, and can corrode pipes, while in drinking water it improves taste but accelerates corrosion. These elevated levels usually signal intense photosynthesis or pollution (nutrients),

creating imbalances, though some organisms benefit temporarily.

Biological Oxygen Demand (BOD) measures the amount of dissolved oxygen used by microbes to break down organic matter in water, thus indicating the level of organic pollution. A high BOD means more oxygen is consumed, depleting it for fish and plants, making it a key indicator for assessing wastewater treatment effectiveness and water quality. It is measured as BOD5 (5-day BOD) in milligrams per litre (mg/L) at 20°C, with higher values signalling greater pollution (Gbekley *et al*., 2023). Therefore, the high BOD level which was higher than the WHO standard observed in this study could mean that microbes are consuming too much dissolved oxygen (DO) to break down organic waste, causing hypoxia (low oxygen), which stresses and kills fish, reduces biodiversity by favouring tolerant species, creates foul odours, and makes water unsafe for humans and recreation. It often signals other pollution like pathogens and nutrients, leading to algal blooms, habitat degradation, and altered nutrient cycles, impacting entire aquatic ecosystems and human health.

Total dissolved solids (TDS) is the measure of all inorganic and organic substances/matter (like dissolved salts, minerals, metals, carbonates) in liquid, indicating water quality, taste, and suitability for various uses, measured typically in milligrams per litre (mg/L) or parts per million (ppm). While essential minerals contribute to a good TDS, excessive levels can signal pollution or cause scaling, affecting equipment and aquatic life, with ideal drinking water levels often cited around 300-500 ppm (Akpojivi and Okoro, 2025). The high TDS above WHO guidelines observed in this study for river water could negatively affect health as it causes digestive, kidney, and other tissue damage. It also impacts on appliances through scaling, making water unpalatable (bitter/salty), and harming aquatic life by blocking sunlight and depleting oxygen, thus disrupting the ecosystem. In addition, the high TDS level of the RW might affect the suitability of the water for irrigation.

pH describes the acid or basic profile of a water sample. A neutral river water has a pH of 6.5 to 8.5. An extreme pH value could affect aquatic life and river management activities. The pH of river water which fall below the WHO standard in this study may lead to corrosion. In humans, it could predispose to irritation of the eyes, skin, and mucous membranes, gastrointestinal irritation, dental erosion and leaching of toxic metals (Olusegun *et al*., 2022).

Total hardness (TH) indicates the level of magnesium ion and calcium ion in water. A hard water lower than the permissible WHO limit can predispose to clinical conditions. The low TH level of the river water in this study, when compared with the WHO standard, could result from reduced intake of calcium and magnesium as well as cardiovascular disorders (Dubey, 2002).

Conductivity is a measure of the ability of water to conduct electric current. This ability is relative to the quantity of ions present in water sample. The conductive ions are derived from dissolved salts and inorganic materials such as alkalis, chlorides, sulfides and carbonate compounds. Water conductivity also reflects the quantity of dissolved ionic salts and minerals present in it. The low conductivity of river water observed in this study could indicate very low mineral content (often demineralized or very soft water). Furthermore, the lowered conductivity level might lead to bone mineral loss and cardiovascular diseases (Chukwura-Osoagba *et al*., 2025).

Total suspended solids (TSS) describes the non-settleable solid particles present in water sample. TSS disrupts normal aquatic life owing to the effect of solid particles that introduce toxic compounds. It also affects water turbidity thus decreasing the penetrating of sunlight into water bodies (Edegbene *et al*., 2025). The lowered TSS of the river water observed in this study might not cause potentials adverse health risk to man. Also, the low TSS level indicates less likelihood of waterborne diseases like diarrhea, cholera, dysentery as well as fewer particulates that reduces irritation of the gastrointestinal tract. Furthermore, the lowered TSS level could trigger many bacteria, viruses, and parasites to attach themselves to the non-settleable/suspended particles.

Chloride (Cl) is a mineral naturally found in various foods, but our main dietary source is sodium chloride, otherwise known as table salt. Chloride carries an electric charge and therefore

is classified as an electrolyte, along with sodium and potassium. Chloride is present in natural water in the form of sodium, calcium and magnesium salts. Cl^- is widely distributed in natural water and is present in almost all surface waters, but the content varies widely from 10 to 20 mg/L in river water to 19,000 mg/L in seawater. It is mostly used to indicate sewage or industrial contamination. The low chloride than the WHO standard in this study is mostly neutral/beneficial/not harmful to man as it facilitates the maintenance of normal electrolyte balance in the biological system (Bashir *et al*., 2012).

Alkalinity is a measure of the acid-neutralizing capacity of water and is usually determined by titration against sulfuric acid to the endpoint of the acid-base reaction. In river waters, the carbonate species predominate and an endpoint of about pH 4.5 marks the consumption of bicarbonate in solution. Alkalinity also measure the ability of water to neutralize acid mostly due to bicarbonates, carbonates, and hydroxides (Dawuda *et al*., 2025). The low alkalinity level observed in the present study may not cause harm to human health but might lead to possible mild taste issue with the water. The indirect health effects of the lowered alkalinity level include increased water acidity, pH instability, increased corrosion of pipes and reduced effectiveness of water treatment.

Sulphate (SO_4) is a naturally occurring ion in river water where they exist as salt of sulfuric acid. The low SO_4 level observed in this study has no potential risk on human health as SO_4 gives water a more pleasant taste, encouraging adequate water intake (Sukarjo *et al*., 2025). However, it could lead to indirect effect on the biological system (reduced gastrointestinal disorders).

CONCLUSION

Findings from the study suggest that Dabi and Bako river water may not be completely 'safe' for domestic and other agricultural/industrial use. Caution should be exercised, by the target populace, on the usage. The present study may therefore serve to create public health awareness to forestall morbidity and mortality and as a baseline information with which future environmental impact assessment of anthropogenic activities could be progressively monitored in the study area.

ACKNOWLEDGEMENTS

Special thanks go to the laboratory staff of the Biochemistry Department, Baze University Abuja, Nigeria for their technical input in this study.

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