

Public Health Risk Evaluation of Heavy Metal Pollution and Physicochemical Characteristics of River Water in Sayidna and Bolidna, Karu LGA, Nasarawa State, Nigeria

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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 Sayidna and Bolidna (SAB), Karu LGA of Nasarawa State. The heavy metal content and physicochemical properties of the water samples, which were collected from three locations within SAB RW were analyzed using Atomic Absorption spectroscopy and standard methods respectively. While the mean concentration of Cadmium, Nickel, Lead, and Zinc was higher than the WHO standard, the concentration of Chromium 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 SO₄ fell below the WHO standard while those of DO, BOD and TDS were found above the set WHO limit. The high level of Ni, Zn, Cd 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.

KEYWORDS: Sayidna River Water, Bolidna River Water, Public Health Risk, Heavy Metal, Physicochemical Characteristics.

I. 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. 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 contaminants of water bodies are of global burden and therefore a matter of serious public and environmental health concern. 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). A community on the search light is Sayidna and Bolidna.

Sayidna and Bolidna are two communities domiciled within Kodape (Auta Balefi) of the Karu Local Government Area of Nasarawa State. The communities are somewhat rural and known to engage mainly in agricultural practices with dependence on river water for their daily water need. Sayidna and Bolidna river water are also located within the Kodape/Auta Balefi 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.

Heavy metals are metallic chemical element that has a relatively high density and is toxic or poisonous at low concentrations (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). 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). 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. Previous studies on river water in the Karu LGA of Nasarawa State include those by Opaluwa (2023) who examined the availability and influence of heavy metal in some locations within Karu Local Government Area of Nasarawa State, Nigeria as well as Kana (2022) who assessed the effect of groundwater quality in Tudun Wada part of Karu LGA of Nasarawa State. Despite these studies, no one has specifically touched on the evaluation of contents of Sayidna and Bolidna river water with a bid to help actualize the SDG No. 6 which emphasized on a clean and safe water for all. Therefore, this study was designed to examine the heavy metal content and physicochemical characteristics of Sayidna and Bolidna river water in order to create awareness about the river water with a view to tackling public/and or environment health problems arising from the water bodies.

II. LITERATURE REVIEW

Access to clean and potable drinking water is a fundamental human need and a critical public health requirement. In many rural and peri-urban communities, rivers serve as the primary or only source of water for drinking, cooking, and domestic use. However, untreated river water is often contaminated by physical, chemical, and biological pollutants, making it unsafe for direct consumption (Edefo, 2025). Ensuring access to safe drinking water from river sources is therefore essential for improving health, reducing poverty, and promoting sustainable development. Some challenges of using river water as a drinking water sources include water contaminations which could arise from industrial discharge, human/animal waste, agricultural runoff, sediments and debris; health risks which might predispose to clinical conditions like dysentery, typhoid fever, diarrhea, cholera and gastrointestinal infections; seasonal variability which brings about changes in River water quality and quantity often change with seasons of the year (rainy and dry seasons with varying levels of contaminations) (Debajyoti et al., 2024). Access to clean and portable water to water-stressed communities like Sayidna and Bolidna could lead to increased health-care costs, reduced productivity and school attendance, slow social and economic development as well as greater burden on women and children who mostly spend long hours fetching water from streams/rivers. Treatment options for river water in water-stressed communities include preliminary treatment (like screening and sedimentation), filtration processes (using sand and household filters), disinfection methods (including boiling, chlorination, solar disinfection [SODIS]) as well as advanced treatment approaches (involving the use activated carbon filters and membrane filters/UV treatment for improved pathogen removal) (Okafor et al., 2024).

Heavy metals are elements with high atomic weight and density that are toxic even at low concentrations. In river water, heavy metals are a major environmental concern because they persist, bioaccumulate, and biomagnify through aquatic food chains. Rivers receive heavy metals from natural processes (weathering of rocks) and anthropogenic activities, making them vulnerable to contamination (Udochukwu et al., 2025). The major sources of heavy metal contamination in river water include industrial effluents (textile, steel, oil refineries, tanneries discharge untreated waste); mining activities (coal mining and gold mining (using mercury and cyanide); agriculture (fertilizer and pesticide runoff) as well as domestic waste and sewage (general urban runoff) (Zhang et al., 2023). Heavy metals in river

water, like lead (Pb), cadmium (Cd), mercury (Hg), arsenic (As), and chromium (Cr), are toxic pollutants from natural and industrial sources (mining, textiles, agriculture) that accumulate in sediments and bioaccumulate up the food chain, causing severe health issues such as cancer, kidney/liver damage, neurotoxicity, and cardiovascular problems, impacting aquatic life and humans through ingestion and contact. Heavy metals in river water pose serious ecological and public health risks due to their persistence and toxicity. Heavy metal toxicity could portend serious health effect including bioaccumulation which occur by the build-up in sediments and organisms, magnifying up the food chain (biomagnification), carcinogenic issues (mediated by arsenic, chromium (VI) linked to various cancers (skin, lung, urinary tract) as well as harmful effect on vital body organs: kidneys, neurons (nerve cells), lungs as well as cardiovascular and skin diseases (Singh et al., 2024). Another factor essential for river water quality assessment is the physicochemical characteristics.

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).

Sayidna and Bolidna communities are rural settlements located in Karu Local Government Area (LGA) of Nasarawa State, Nigeria. Karu LGA lies in the western part of Nasarawa State and shares close proximity with the Federal Capital Territory (Abuja), which has influenced population growth and development patterns in the area. These communities are predominantly rural and agrarian, with residents mainly engaged in farming, fishing, and small-scale trading. Like many rural communities in Nasarawa State, Sayidna and Bolidna face infrastructural challenges, particularly in access to safe and potable drinking water, healthcare facilities, and improved sanitation. As a result, nearby river and surface water sources are commonly used for domestic purposes, especially during the dry season when alternative sources are scarce (Ojo-Ebenezer and Fakunle, 2024). The dependence on untreated river water exposes residents to waterborne diseases and highlights the need for improved water supply systems, water treatment interventions, and community-based water management strategies in Sayidna and Bolidna communities. The Sayidna and Bolidna rivers are surface water bodies that receive water mainly from rainfall, surface runoff, and small tributaries. Community members depend heavily on these rivers throughout the year, with increased usage during the dry season when alternative water sources dry up. In addition to domestic use, the rivers support farming activities, fishing, and livestock watering, making them vital to local livelihoods.

Karu Local Government Area (LGA) is one of the thirteen LGAs in Nasarawa State, located in the western part of the state. It is strategically positioned along the boundary with the Federal Capital Territory (FCT), Abuja, making it one of the fastest-growing and most urbanized areas in the state. Karu LGA has experienced rapid population growth due to its proximity to Abuja, attracting civil servants, traders, and migrants (Mshelia et al., 2025). The area comprises a mix of urban, semi-urban, and rural communities, including settlements such as Mararaba, New Karu, Ado, Sayidna, and Bolidna. While urban centers are expanding, many rural communities still lack adequate basic infrastructure. The major economic activities in Sayidna and Bolidna communities are agriculture, trade/commercial activities as well as artisan and informal activities. Residents of these communities largely depend on rivers, streams, hand-dug wells and boreholes for their water supply. A few social infrastructures in the communities are education (primary and secondary schools), basic primary healthcare centers and transportation (with fairly good road networks).

Previous studies by Rilwan et al 2025 gave a comprehensive analysis of heavy metals in both water and sediment on the health of the ecosystem in the management of potential risks while the study by Osuagbalende and Bako (2017) who collected water samples from stream wells and bore-hole at Uke, Auta-Balefi, Karu, all from Karu Local Government Area of Nasarawa State observed that the metals were within the WHO standard. Given these studies, there is no visible documentation on the heavy metal content and physicochemical property of the river water of Sayidna and Bolidna, which

are communities deprived of portable water and a nearly total dependence on river water, with its attendant morbidity and mortality rate. This study therefore seeks to assess the heavy metal content, physicochemical characteristics of Sayidna and Bolidna river water and provide useful health information to prevent potential water borne diseases in the study area.

III. METHODOLOGY

A. Materials

(a). Study Area

The research covered Sayidna and Bolidna river water (RW) axis found within Kodape/Auta Balefi communities of Karu. Karu is among the thirteen Local Government Areas of Nasarawa State, Nigeria (Figure 1) and situated between latitude 9.0167 of the equator and longitude 7.5833, 111 N 9' 0" E 7 3 4' 60" of the Greenwich Median (Adeyemi et al., 2007).

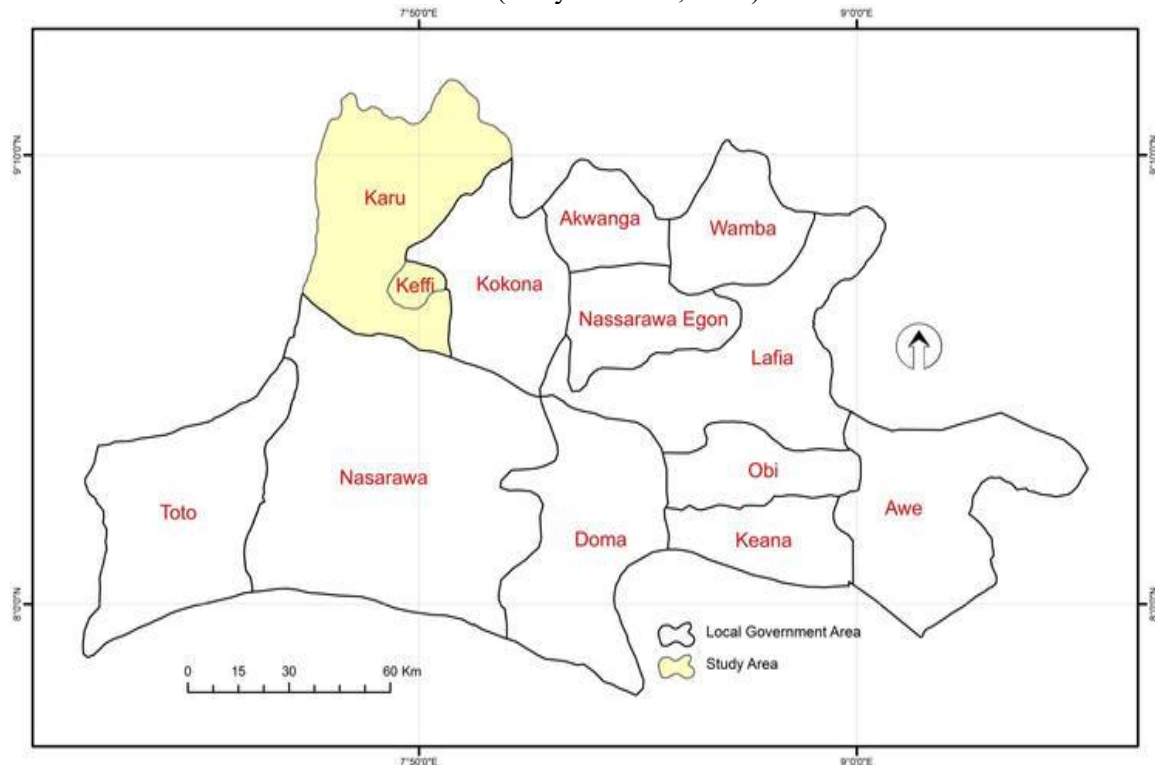


Figure 1: Map of Nasarawa State Highlighting the Study Area (Karu) and other LGAs
Source: Aremu et al (2011)

(b). 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.

B. Methods

(a). Collection of River Water Sample

A known volume (200 cm³) of river water sample were collected randomly from three locations within Sayidna and Bolidna river water, both of which are located within Kodape/Auta Balefi environs of the Karu LGA of Nasarawa State. 5 cm³ of Conc. HNO₃ 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).

(b). Determination of Heavy Metal Content of Sayidna and Bolidna River Water

i. Preparation of Sample

The glass wares and plastics which were washed and soaked in a 9% mixture of HCl – HNO₃ for three days were rinsed with distilled water. Stock solutions of the heavy metals to be determined were prepared using 9 cm³ 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.

ii. Sample Digestion

Water digestion was conducted by applying the protocol of (Sastre et al., 2002). Exactly 2 cm³ of concentrated HNO₃ was added to 80 cm³ 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 cm³ of 1:1 Concentrated HCl was gradually added to the digested water sample, warmed, filtered in 50 cm³ standard flask and made up to the marked level with distilled water.

iii. 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. A recovery study was also conducted on the river water samples to understudy the entire process by spiking the river water samples with a known amount of solution (1.5 cm³) of the heavy metal to be evaluated before digestion, in order to ascertain the recovery process (Adeyemi and Ojekunle, 2021). All triplicate readings were noted.

(c). Determination of Physicochemical Characteristics of Sayidna and Bolidna River Water

- i. **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.
- ii. **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.

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

Where:

W1 = weight of dried residue + container,

W2 = weight of empty container

- iii. **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).
- iv. **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 °C for 6 days. concentrated sulphuric acid, alkali-iodide-azide reagent and MnSO₄

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 (DO₀), 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 6 days, the sample picked from incubator was brought out; dissolved oxygen at day six after incubation (DO₆) was determined by following the same procedure used for the determination of DO₀. A blank was prepared in a beaker for DO₀. (Aniyikaiye et al., 2019). Another blank was prepared in an amber bottle and incubated with the sample for DO₆.

- iv. **Sulphate and Chloride:** Sulphate and chloride in the river water was determined using specified standard protocols (Udo et al., 2009).
- v. **Sulphate:** 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. NH₄OH, 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 KNO₃ into glass evaporating dishes and treating as above omitting the addition of silver sulfate.
- vi. **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 NaCl₂ 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.
- vii. **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.

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

Where, N = normality

(d). Data Analysis

Resultss were presented as the mean of three estimates ± SD. Statistical difference was gotten by analysis of variance and Duncan’s Multiple Range Test at 5% level of confidence with the use of SPSS 23.0 Application (Statistical Package for Social Sciences, Inc., Chicago, IL, USA).

IV. RESULTS AND DISCUSSION

The mean concentration of zinc in Sayidna and Bolidna (SAB) river water (RW) was significantly ($p < 0.05$) lower than the WHO standard (Table 1).

Table 1: Concentration of Zinc (mg/L) in Sayidna and Bolidna river water

	Sample 1	Sample 2	Sample 3	Mean±SD	WHO standard (mg/L)
Bolidna R/water	0.077	0.867	0.924	0.623±0.174 ^b	3.0 ^a
Sayidna 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

The mean concentration of copper in SAB RW compared ($p > 0.05$) favourably well with the WHO limit (Table 2).

Table 2: Concentration of Copper (mg/L) in Sayidna and Bolidna river water

	Sample 1	Sample 2	Sample 3	Mean±SD	WHO standard (mg/L)
Bolidna R/water	1.947	2.045	2.189	2.060±0.127 ^a	2.0 ^a
Sayidna 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 Sayidna and Bolidna RW reduced significantly ($p < 0.05$) low when compared with the WHO limit (Table 3).

Table 3: Concentration of Nickel (ppm) in Sayidna and Bolidna river water

	Sample 1	Sample 2	Sample 3	Mean±SD	WHO standard (ppm)
Bolidna R/water	0.092	0.095	0.099	0.095±0.004 ^b	0.05 ^a
Sayidna R/water	ND	ND	ND	-	0.05 ^a

Mean ± SD are values obtained from three determinations. Test values (Mean±SD) with superscript (b) different from their respective WHO standard (a) across the row are significantly different ($p < 0.05$)
SD = Standard deviation; **R** = River; **ND** = Not Detected; **WHO** = World health Organization

The mean concentration of iron in Sayidna and Bolidna river water compared well ($p > 0.05$) with the WHO limit (Table 4).

Table 4: Concentration of Iron (mg/L) in Sayidna and Bolidna river water

	Sample 1	Sample 2	Sample 3	Mean±SD	WHO standard (mg/L)
Bolidna R/water	0.456	0.642	0.569	0.556±0.094 ^a	0.5 ^a
Sayidna 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) 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 SAB river water was significantly ($p < 0.05$) higher than the WHO limit (Table 5).

Table 5: Concentration of Lead (mg/L) in Sayidna and Bolidna river water

	Sample 1	Sample 2	Sample 3	Mean±SD	WHO standard (mg/L)
Bolidna R/water	10.107	10.105	10.008	10.073±0.057 ^b	0.01 ^a
Sayidna 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,d,e,f) 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 Sayidna and Bolidna river water was significantly ($p<0.05$) higher than the WHO limit (Table 6).

Table 6: Concentration of Cadmium (ppm) in Sayidna and Bolidna river water

	Sample 1	Sample 2	Sample 3	Mean±SD	WHO standard (ppm)
Bolidna R/Water	1.965	1.943	1.935	1.948±0.012 ^b	0.2-1.8 ^a
Sayidna 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 findings. Test values (Mean±SD) with superscript (a, b, c, d, e, f) differing from their individual WHO specified range (a) across the row are sufficiently not the same ($p<0.05$). **SD** = Standard deviation; **R** = River; **WHO** = World health Organization

The mean concentration of chromium in Sayidna and Bolidna RW was significantly ($p<0.05$) lower than the WHO standard (Table 7).

Table 7: Concentration of Chromium (ppm) in Sayidna and Bolidna River Water

	Sample 1	Sample 2	Sample 3	Mean±SD	WHO standard (ppm)
Bolidna R/Water	0.028	0.045	0.055	0.091±0.011 ^b	0.5 ^a
Sayidna R/water	0.092	0.025	0.075	0.142±0.010 ^b	0.5 ^a

Mean ± SD are values obtained from three findings. Test values (Mean±SD) with superscript (a, b, c, d, e, f) differing from their individual WHO specified range (a) across the row are sufficiently not the same ($p<0.05$). **SD** = Standard deviation; **R** = River; **WHO** = World health Organization

The physicochemical characteristics of Sayidna and Bolidna 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 Sayidna and Bolidna River Water

Parameter	SRW (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; **SO₄** = Sulphate; **DO** = Dissolved Oxygen; **BOD**= Biochemical Oxygen Demand; **Condu.** = Conductivity; **TH** = Total Hardness; **Cl** = Chloride; **SRW** = Sayidna River Water; **BRW** = Bolinda River Water; **WHO** = World Health Organization

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 doesn't store excess (Hussain et al., 2022). The high zinc concentration in the river than the WHO standard could cause irritation on the digestive/gastrointestinal system leading to stomach cramps, diarrhea, nausea and vomiting. It could also lead to immune suppression with reduced white blood cell function, impaired wound healing and increased susceptibility to diseases. The high mean concentration of zinc also interferes with the absorption of crucial minerals (like copper, iron, calcium and magnesium) in the extracellular circulation (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 signalling 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 ggastrointestinal 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 an essential trace mineral that plays a crucial role in carbohydrate, lipid, and protein metabolism by enhancing insulin's action, helping the body use sugar for energy and regulate blood fats. It works with insulin through a molecule called chromodulin to improve glucose uptake into cells, potentially benefiting blood sugar control and lipid profiles. Chromium also supports the immune system and may have antioxidant properties, with benefits seen mainly in deficient individuals (Okorie et al., 2024). In the present study, the low concentrations of chromium in river water below the World Health Organization (WHO) standard is generally considered safe and potentially beneficial, as Cr is an essential trace element for human health. A low mean chromium concentration is an important trace element that helps the body use sugar, protein, and fat. A low chromium level forms a vital component of the "glucose tolerance factor" (GTF), an organic complex that enhances the action of insulin, helping to regulate blood sugar levels. It also plays a vital role in lipid metabolism, helping to lower blood cholesterol and triglyceride levels (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 roles in numerous cellular processes, from gene regulation to cell growth, requiring strict body regulation to balance essential functions and prevent toxicity (Madjar and Vasile-Scaeteanu, 2025). The mean iron concentration, in this study, in the river water, that fell within the World Health Organization (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 the biological system. The guideline is based on aesthetic issues (taste, smell, colour, staining) rather than health concerns (Rushdi et al., 2023).

Copper (Cu) is an important trace mineral that act as a cofactor for enzymes. It is vital for energy production (cytochrome C oxidase), antioxidant defense (SOD), iron metabolism, neurotransmitter synthesis (dopamine), collagen formation, and maintaining blood vessels, nerves, bones, and the immune system, leveraging its ability to shuttle electrons in redox reactions for various bodily functions. 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 involvement in the formation of red blood cells and in the maintenance of the health of the nervous system as well as that of the connective tissues and bones. The moderate copper amount forms a vital component that supports the immune system. The body uses copper to produce enzymes that protect cells from free-radical (ROS) damage (Teschke et al., 2024).

Dissolved oxygen (DO) is essential for aquatic organisms. It is the amount of free, gaseous oxygen (O₂) 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 a 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 issue damage. It also impacts on appliances through scaling, making water unpalatable (bitter/salty), and harming aquatic life by blocking sunlight and depleting oxygen, disrupting ecosystems. The high TDS level of the RW could affect the suitability of the water for irrigation.

pH indicates the acidity or alkalinity of a water solution on a logarithmic scale on which 7 is neutral, lower values are more acid and higher values more alkaline. A natural river water typically has a pH between 6.5 and 8.5. An extreme pH values harms aquatic life and affect treatment processes. The pH of river water which fall below the WHO standard in this study may lead to corrosion. Irritation of the eyes, skin, and mucous membranes, Gastrointestinal irritation, dental erosion and leaching of toxic metals (Olusegun et al., 2022).

Total hardness (TH) is the concentration of calcium (Ca^{2+}) and magnesium (Mg^{2+}) in drinking water. Water with hardness lower than commonly recommended by WHO (often < 60 mg/L as CaCO_3 , i.e., very soft water) can have health and practical implications, mostly indirect. The lowered TH level of the river water in this study, when compared with the WHO standard could lead to reduced intake of calcium and magnesium and probable cardiovascular effects (Dubey, 2022). Conductivity is a measure of the ability of water to pass electrical current/flow. This ability is directly related to the concentration of ions in the water. These conductive ions come from dissolved salts and inorganic materials such as alkalis, chlorides, sulfides and carbonate compounds. The conductivity of water also reflects the quantity of dissolved ions (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) are defined as non-settleable solid particles found in water. TSS interferes with aquatic life as solid particles can include toxic compounds and produce turbidity that decreases the penetration of sunlight into the water (Edegbene et al., 2025). The lowered TSS of river water observed in this study might not cause potentials adverse health risk to man. The lower TSS level also indicates lower likelihood of waterborne diseases like diarrhea, cholera, dysentery as well as fewer particulates that reduces irritation of the gastrointestinal tract. However, the lowered TSS level could trigger many bacteria, viruses, and parasites to attach 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 humans as it might facilitate 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 a harm to human health but might lead to a possible mild taste issue with the water. The indirect health effects of the lowered alkalinity level include increased water acidity and 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 salts 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 effects on the biological system (reduced gastrointestinal disorders).

V. CONCLUSION

Findings from the study suggest that Sayidna and Bolidna river water may not be completely 'safe' for domestic and other agricultural/industrial use. Caution should be exercised, by 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.

VI. REFERENCES

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