

PHYSICOCHEMICAL AND HEAVY METALS PROFILE OF SACHET WATER BRANDS FROM SELECTED VENTURES IN ABUJA MUNICIPAL AREA COUNCIL OF THE FEDERAL CAPITAL TERRITORY, ABUJA, NIGERIA

O. A. Saliu¹, O. A. Idowu^{1*}, G. Enejioko¹, M. D. Adams² and H. Tijjani¹

¹Department of Environmental Health Science, National Open University of Nigeria, Abuja

²Clinical Biochemistry, Phytopharmacology and Biochemical Toxicology Research Laboratory (CBPBT-RL),

Department of Biochemistry, Baze University, Abuja 900108, Nigeria

*Corresponding email: aidowu@noun.edu.ng

ABSTRACT

Sachet water (SW) is an alternative source of drinking water among many households in Nigeria, and water contamination by heavy metals is a public health concern. This study assessed the physicochemical, lead, iron, and zinc contents of SW samples purchased within the Abuja Municipal Area Council (AMAC), Abuja. Ten bags of SW were purchased from 10 SW ventures within AMAC, labelled A-J, and transported to the laboratory. Three SW from each bag were randomly selected for physicochemical and heavy metal content analysis using a standard protocol. The total dissolved solids, total hardness, and electrical conductivity ranged from 10.75-115.7 mg/L, 0.08-0.64 mg/L, and 7.5-236.1 μ S/cm respectively, and were lower than the WHO standard, while the values of the biochemical oxygen demand (BOD), chemical oxygen demand (COD), and dissolved oxygen (DO) ranged from 7.4-10.5 mg/L, 32.5-37.5 mg/L, and 8.4-11 mg/L respectively, and exceeded the WHO threshold. The pH values varied across the samples and were below the WHO threshold. The concentrations of Zn (0.0685-0.2677 mg/L), Fe (0.3774-5.942 mg/L), and Pb (0.0572-0.2331 mg/L) varied across all the SW, with Zn content falling below the WHO threshold, while the Fe and Pb contents exceeded the threshold for drinking water. The study suggests SW contamination by heavy metals, especially Pb, and other physicochemical markers (BOD, COD, and DO), thus recommending stricter enforcement of regulatory standards for Pb content, BOD, DO, and COD in SW, improved water treatment technologies, and better maintenance of water distribution infrastructure towards actualizing the SDG No. 6 (clean water and sanitation).

Keywords: Sachet water, Heavy metals, Physicochemical parameter, AMAC, Sustainable Development Goal No. 6.

INTRODUCTION

Sachet water (popularly called 'pure water') is a packaged, sealed nylon bag of drinking water, mostly prevalent in Nigeria. It is a cheap and accessible source of water where public water supply is inadequate, although its quality can be compromised due to unregulated practices along the production line (Stoler, 2012; EPA, 2021). Sachet water (SW) serves as an affordable, accessible, and convenient alternative to unreliable piped water supplies, particularly for urban and poor communities, thereby improving access to safe drinking water and reducing the burden of water-borne illnesses. The lack of access to clean drinking water portends significant environmental and health risks due to contamination from poor hygiene, packaging challenges, and inadequate treatment, leading to clinical conditions like typhoid, ulcer, diarrhea, among others. The presence of heavy metals, chlorine, other elements, bacteria, and high nitrate levels is prevalent in sachet water, posing dangers, especially to vulnerable groups like children, with prolonged storage threatening the microbial load (Ibemesim, 2014).

Heavy metals are elemental materials that occur in nature with high densities that may be of importance at low levels but become harmful at higher concentrations, causing various health and environmental issues. A few

examples are lead (Pb), mercury (Hg), and cadmium (Cd), which are predominantly released from industrial processes, mining, and other direct and indirect human activities. Exposure to heavy metals leads to bioaccumulation in living organisms and major organ damage, interrupting normal cellular processes and potentially causing neuronal diseases. Lead (Pb) mostly occurs in nature as a highly toxic heavy metal found in the Earth's crust that poses significant global public health and environmental risks. Its presence in water and its widespread use in other products like paints, batteries, and plumbing, as well as from industrial processes, lead to human and environmental exposure. Young children are particularly vulnerable, suffering permanent harm to their developing nervous systems, while adults face risks of high blood pressure, cardiovascular issues, and kidney damage. There is no safe level of Pb exposure, and preventative measures focus on reducing lead sources in the environment and promoting safer practices (Jomova *et al.*, 2025).

Lead toxicity, also regarded as lead poisoning, is a situation where the body accumulates lead, leading to damage in major systems like the nervous and renal systems. High levels can cause severe symptoms like convulsions and coma, while even low-level chronic exposure can result in intellectual disability, behavioral changes, high blood pressure, and kidney

problems (Michael *et al.*, 2016; Togunde *et al.*, 2018; Taiwo *et al.*, 2023). Iron toxicity (poisoning) occur from ingestion of excess iron and from contaminated water, food and other allied sources which cause severe stomach disorder (vomiting, diarrhea, pain): followed by a deceptive calm period, then potentially shock, liver failure, metabolic acidosis, and multi-organ damage, often fatal without immediate care, especially in children. It is a serious medical emergency requiring immediate treatment, often with chelation therapy, to remove excess iron and support vital functions, as it damages cells, the GI tract, liver, heart, and other organs (Fraga and Oteiza, 2002). Zinc toxicity occurs from excessive zinc intake, often over 40 mg/day from contaminated water intake, high-dose supplements/products, zinc-containing denture adhesives, inhalation of metal-based fumes. These factors cause nausea, vomiting, diarrhea, and impairing copper/iron absorption, leading to anemia, weakened immunity, and neurological disorders like nerve damage with chronic high intake or exposure to zinc fumes (metal fume fever). Symptoms range from acute gastrointestinal distress (vomiting, cramps) to chronic problems like copper deficiency and suppressed immune function, with treatment involving removing the zinc source and seeking medical care (Schoofs *et al.*, 2024).

Physiochemistry encompasses the physical and chemical components of metal, material or substance. It is important for water quality assessment because they reveal water's physical (temperature, turbidity, colour), chemical (pH, dissolved oxygen, hardness, nutrients, metals, BOD/COD), and aesthetic (odor, taste) properties, indicating its safety, suitability for drinking, agriculture, industry, and health for aquatic life, acting as vital indicators of pollution, ecosystem health, and treatment needs (Mishra *et al.*, 2023). This is achieved by comparing the measured values (like pH, TDS, DO) with stipulated standards.

The Abuja Municipal Area Council (AMAC) is the local government area responsible for the central, metropolitan, and administrative heart of Nigeria's Federal Capital Territory (FCT), including the capital city of Abuja. It is controlled by an elected chairman that serves as the home for most federal institutions, ministries, departments, agencies, and key urban districts, with a population of approximately 1.96 million people (Agbai and Okey, 2024). The continuous rise of sachet water (SW) ventures, and the high rate of purchase of SW by residents in AMAC call for urgent concern regarding the supply of safe and clean water, free from toxins, including lead, Zinc, and iron contaminations.

Documented reports include a study by Makwe and Ukah (2025) on the risk assessment relating to heavy metals in water sample collection from Gwagwalada, FCT, Abuja, as well as an earlier report by Akin-Osanaiye and Izuakor (2022) on SW from the Bwari area council of the FCT, Abuja. Danraka *et al.* (2022) examined the elements present in sachet and bottled water collected within Abuja metropolis. Segun *et al.* (2021) reported the safety and quality of drinking water

obtained from the Piwoyi community of the FCT. Muhammad and Ujoh (2012) reported the chemical quality of water sources in sixteen settlements within AMAC, FCT. Abejide *et al.* (2023) reported the heavy metal contaminants in sachet water randomly collected within Abuja Metropolis. Magaji (2020) studied the sachet water quality within the Gwagwalada Area Council of the FCT. Given these studies, there is a dearth of information on the assessment of lead content in sachet water consumed in AMAC of the FCT, Abuja, creating a research gap, hence this study. This study also aims to support the drive to achieve Sustainable Development Goal (SDG No. 6), which emphasizes global and equitable access to safe and affordable drinking water for all (WHO, 2017; UNICEF, 2024).

MATERIALS AND METHODS

Study Area

The research covered three locations (Wuse, Garki, and Karu) within the Abuja Municipal Area Council (AMAC). AMAC is one of the six area councils of the Federal Capital Territory (Figure 1) and is situated between north latitude $7^{\circ}49'$ to $8^{\circ}49'$ of the equator and east longitude $7^{\circ}07'$ to $7^{\circ}33'$ of the Greenwich Meridian (Adeyemi *et al.*, 2007). This region is characterized by a high prevalence of sachet water consumption, driven by its affordability and widespread availability. Areas such as Wuse, Garki, and Karu were notably significant due to their high residential density and numerous vendors selling sachet water, making them the focal point for this study.



Source: Ajayi *et al.* (2022)

Figure 1: Map of AMAC detailing the study area

Reagents, Chemicals, and Apparatus

All the consumables, chemicals, and other materials utilized in this study were obtained from Dunn Labortechnik GmbH, Germany, and they are analytically graded stocks. The apparatus used in the study includes test tubes, 300 ml BOD bottles, beakers, a weighing balance, sample bottles, a measuring cylinder, and a hot plate.

Collection of Sachet Water Samples

Ten (10) sampling brands were selected based on several criteria to ensure comprehensive coverage of sachet water producers and distribution points within AMAC. These criteria included the presence of various sachet water brands, volume of sales, and geographic diversity to reflect different areas of AMAC. Locations were chosen to represent a mix of high-traffic urban markets and quieter suburbs and vendors, ensuring that the sample collection reflected both popular and less common sources of sachet water. Table 1 presents the

ventures' names, location, coordinates, and volume of sachet water samples collected within AMAC. Ten (10) bags of sachets of water were purchased from the different sachet water ventures and transported from the point of purchase to the laboratory, and were appropriately labelled A-J. Samples of water were collected directly into 100 ml bottles after washing the bottles properly and rinsing them with the water sample collected. The water sample bottles were shaken and processed for further analysis.

Table 1: Location and characteristics of sachet water ventures collected in AMAC, FCT

SID	Venture Name	Volume (cl)	Location	Latitude	Longitude
A	Mira Cool Natural Water	50	4 Borno Street, Area 10, Garki, Abuja	9.039666	7.481385
B	Aquarcity Table Water	50	Plot 2, Phase 3, Nyanya, Abuja	9.059044	7.578554
C	Aristo Table Water	50	Suite 3, Yasuha Plaza, Wuse Zone 2, Abuja	9.077977	7.476578
D	Astra Water	50	Suite 4, Dan Sarari Plaza, Wuse Zone 4, Abuja	9.067573	7.473917
E	Dabson Fresh Table Water	50	Plot M15, Cadastral Zone, Kubwa, Abuja	9.177202	7.311679
F	Maglan Water	60	Aco Estate, Sabo, Airport Road, Lugbe	8.951341	7.325786
G	Gera Life Water	50	Plot 97, Phase AA3 Layout, Kuje, Abuja	9.052487	7.484142
H	Gohen Living Waters	60	18 Djibouti Crescent, Wuse Zone 2, Abuja	9.081644	7.488262
I	Libra Ventures Limited	50	Plot 73 A, Associated Estate, Karmo, Abuja	9.066049	7.379085
J	Mohsha Nigeria Limited	50	73 Hill Top Mohsha Road, Karu, Abuja	9.056979	7.49942

SID = Sample ID

Preparation of Sample and Digestion

Before sample preparation, clean beakers to be used for analysis were washed with distilled water, rinsed, and soaked in 8% solution of HCl-HNO₃ for 48 hours. The digestion of sachet water was carried out by adopting the protocol previously described by Sastre *et al.* (2002). A known volume (7 ml) of Conc. HNO₃ was added to 70 ml of the preserved sachet water sample. A control, which contained a mixture of 70 ml of distilled water and 7 ml of HNO₃, was also set up. The solution was then covered with a glass, gently heated in a Bunsen burner, followed by gradual digestion of the entire solution. The solution was then evaporated to a semi-solid state and air-dried to coolness. A known volume (7 ml) of 2:2 Conc. HCl was gently added to the digested sachet water sample, followed by warming and filtration into a 50 ml standard flask, and this was then made up to the marked level with distilled water.

Determination of Zinc, Iron, and Lead

The digested sachet water sample was thereafter measured for the presence of the desired heavy metals (Zn, Fe, and Pb) using a flame atomic absorption spectrophotometer (Analytik Jena novAA 800, China). The AAS was initially calibrated by preparing different concentrations (0, 0.5, 1.0, 2.0, 5.0 mg/L) of the heavy metal from the stock solution. A linear calibration curve, which measures the absorbance of each standard solution of the metal, was prepared by plotting the graph of Absorbance vs. Concentration. The calibration blank consisted of all reagents used in sample preparation, but no analyte (water sample), while the reagent blank consisted of all reagents through the entire sample preparation process.

Determination of Physicochemical Parameters

Biochemical oxygen demand, chemical oxygen demand, and dissolved oxygen

Biochemical oxygen demand (BOD) in the sachet water was analyzed using the dilution method as described by Ademoroti (1996). A known volume (10 ml) of the water sample was measured separately and added to two different 300 ml BOD bottles. Two different blanks consisting of 10 ml of distilled water were also prepared in two different 300 ml BOD bottles. All the BOD bottles were filled up to the top with a dilution water prepared from a mixture of 9 ml of each of calcium chloride, magnesium sulphate, ammonium chloride, phosphate buffer, ferric chloride, and sodium sulphite into a beaker containing 10 litres of water. The BOD bottles were corked immediately without any air bubbles seen inside the bottles. One BOD bottle containing the water sample and another for the blank were incubated at 20°C immediately and were analyzed for BOD using a meter, while the other two BOD bottles were analyzed for BOD at the end of the 5 days. BOD value was calculated using the expression in equation 1.

$$\text{BOD in mg/L} = \frac{(DO1 - DO2) \times \text{Dilution Factor}}{\text{Volume of Sample}} \dots\dots\dots (\text{Eqn. 1})$$

Where: DO1 initial dissolved oxygen value on day zero, and DO2 is the final dissolved oxygen on day 5, Dilution factor = 300 ml/(volume of sample)

Dissolved Oxygen Demand

Chemical oxygen demand (COD) was determined in the sachet water samples by adopting the standard protocol of Ademoroti (1996). To 10 ml of the water

sample, 2 ml of a 36.4% $MnSO_4 \cdot H_2O$ solution was added by placing the pipette tip into the sample to allow oxygen to enter the solution through droplets of solution. This was followed by the addition of 2 ml of the alkali-iodide-azide reagent to the sample and the mixture was allowed to react with the dissolved oxygen in the sample using the pipette, and was allowed to stand for the precipitate to settle at the bottom. 2 ml of Conc sulfuric acid was added near the surface of the sample and the mixture was mixed thoroughly to allow precipitate dissolve. A known volume (203 ml) of the BOD sample was transferred to an Erlenmeyer flask and titrated with sodium thiosulfate solution (0.025N) using a starch indicator until the blue colour disappears, and the titre value was recorded. This procedure was repeated for the blank.

Total Hardness

Exactly 40 ml of the sachet water sample was pipetted into a conical flask, to which 2 ml of ammonium buffer and 2-3 drops of Eriochrome black T indicator were added. The mixture was titrated against standard 0.02 M EDTA until the wine-red color of the solutions turned to pale blue at the end point. The total hardness was calculated using the formula in equation 2.

$$\text{Total Hardness} = \frac{\text{Volume of EDTA} \times N \times 50}{\text{Volume of Sample Taken}} \times 1000 \dots\dots\dots (\text{Eqn. 2})$$

Where: N = normality

Total Alkalinity

A known volume (10 ml) of the sachet water sample was pipetted into a conical flask. Three drops of methyl orange indicator were added and titrated with 0.1M NaOH to give an orange color. Alkalinity was calculated using the formula in equation 3.

$$\text{Total Alkalinity} = \frac{\text{Total volume of test reagent} \times 50,000 \times N}{\text{Volume of Sample}} \dots\dots\dots (\text{Eqn. 3})$$

pH and Electrical Conductivity

pH and electrical conductivity were determined in the sachet water sample using a Hanna pH meter (HI 9813-6N, Colorado, USA). The pH meter was calibrated before the electrodes were inserted into the sample for measurement.

Total Dissolved Solids

An empty container was weighed, and 50 ml of sachet water was measured, filtered, and added to the container. The filtered sachet water sample was heated to dryness, cooled, and reweighed with the container until a constant mass was obtained, and the readings

were recorded. The total dissolved solid was estimated using the formula in equation 4.

$$\text{Total Dissolved Solids (mg/L)} = \frac{W_1 - W_2 \text{ Sample}}{\text{Volume (ml)}} \times 1000 \dots\dots\dots (\text{Eqn. 4})$$

Where: W_1 = weight of dried residue + container,
 W_2 = weight of empty container

Data Analysis

Data were presented as the mean of three determinations \pm SD. Significant difference was obtained by Analysis of Variance (ANOVA) and Duncan’s Multiple Range Test at $p < 0.05$ level of confidence with the use of SPSS 29.0 statistical application (Statistical Package for Social Sciences, Inc., Chicago, IL, USA).

RESULTS AND DISCUSSION

Findings from the physicochemical analysis of the sachet water are presented in Table 2. The pH of the sachet water (SW) samples B (6.11), C (6.05), D (5.88), E (6.0), F (6.17), G (5.94), H (5.95), I (5.89), J (6.01) fell below the WHO limit, except for the sachet water sample A, which fell within the WHO standard with a pH value of 6.6. The values obtained for total alkalinity (TA) varied across all the SW samples and mostly were within the acidic range. Biochemical oxygen demand (BOD), chemical oxygen demand (COD), and dissolved oxygen (DO) of all the analyzed SW samples were higher than the WHO standard. The total dissolved solids (TDS), total hardness (TH), and electrical conductivity (EC) of all the SW samples were below the WHO threshold (Table 2).

Table 3 depicts the concentrations of Zinc (Zn), Iron (Fe), and Lead (Pb) in the SW samples collected from the locations within AMAC, respectively. The concentration of Zn in the SW samples purchased from the ten locations within AMAC was below the WHO standard for drinking water. The sample B sachet water had the highest (0.598 mg/L) Zn concentration, while sample J recorded the lowest (0.018 mg/L) Zn concentration, but Zn was absent in the SW sample of F. The SW obtained from Gohen Living Water (H), Libra Ventures (I), and Mohsha Nigeria Limited (J) contained no Fe content, while the SW samples of A, B, C, D, E, F, and G contained iron levels that exceeded the WHO threshold for drinking water. The concentration of Pb in all the SW samples (A-J) obtained within AMAC was higher than the WHO standard for drinking water, with sample A having the highest Pb concentration (0.233 mg/L) and sample D having the lowest concentration (0.056 mg/L).

Table 2: Physicochemical analysis of sachet water samples purchased within the AMAC

Parameter	Samples										WHO Standard
	A	B	C	D	E	F	G	H	I	J	
pH	6.6	6.11	6.05	5.88	6.0	6.17	5.94	5.95	5.89	6.01	6.5 - 8.5
DO (mg/L)	11	11	11	11	8.4	11	11	9.4	11	11	5
TDS (mg/L)	10.75	56.06	17.29	41.5	115.7	3.01	41.81	26.49	42.76	42.19	500
EC (µS/cm)	21.97	114.4	35.27	84.6	236.1	7.5	84.94	54.03	87.1	86.17	1000
BOD (mg/L)	9.5	9.8	10	9.8	7.4	10.5	10.2	8.4	9.5	10.4	5
COD (mg/L)	36.5	35.8	36.3	36.8	32.5	37.5	36.3	34.5	33.8	35.9	10
TH (mg/L)	0.08	0.64	0.24	0.48	1.2	0.12	0.6	0.21	0.52	0.52	150
TA (mg/L)	6	4	2	1	1.8	4.5	1.5	1.6	1.2	1.9	NSNS

DO = Dissolved oxygen; TDS = Total dissolved solid; EC = Electrical conductivity; BOD = Biochemical oxygen demand; COD = Chemical oxygen demand; TH = Total hardness; TA = Total alkalinity; NSNS = No specific numerical standard by WHO; WHO = World health organization; A = Mira Cool Natural Water; B = Aquarcity Table Water; C = Aristo table Water; D = Astra Table Water; E = Dabson Fresh Table Water; F = Maglan Water; G = Gera Life Water; H = Gohen Living Water; I = Libra Ventures; J = Mohsha Nigeria Limited; WHO (2022)

Table 3: Concentration of Zinc (Zn), Iron (Fe), and Lead (Pb) in sachet water samples obtained within AMAC

SID	Zn Conc. (mg/L)	WHO Standard (2022)	Fe Conc. (mg/L)	WHO Standard (2022)	Pb Conc. (mg/L)	WHO Standard (2022)
A	0.268±0.01*	5.00	0.935±0.02	0.3	0.233±0.03	0.01
B	0.598±0.00*		5.942±0.00		0.113±0.01	
C	0.069±0.01		1.257±0.01		0.057±0.01	
D	0.171±0.02*		1.216±0.01		0.056±0.02	
E	0.119±0.01*		1.059±0.01		0.092±0.01	
F	–		0.767±0.02		0.087±0.01	
G	0.035±0.00		0.377±0.01		0.154±0.00	
H	0.100±0.03		–		0.078±0.02	
I	0.036±0.01		–		0.133±0.03	
J	0.031±0.01		–		0.121±0.01	

A = Mira Cool Natural Water; B = Aquarcity Table Water; C = Aristo table Water; D = Astra Table Water; E = Dabson Fresh Table Water; F = Maglan Water; G = Gera Life Water; H = Gohen Living Water; I = Libra Ventures; J = Mohsha Nigeria Limited; WHO (2022)
 Values with * superscript are statistically different (p<0.05) down the column

The assessment of relevant profiles of sachet water, including heavy metal content and physicochemical properties, among others, can provide reference information to expand the knowledge base on the safety of drinking water. The assessment can also be of public and environmental health importance as it identifies possible contaminants domiciled in sachet water, which may predispose consumers to water-related morbidity and, in extreme cases, mortality. Biochemical oxygen demand (BOD) is the measure of oxygen required by microbes to catabolize the organic matter present in water. The BOD of all the SW samples from this study was above the required threshold. This can promote microbial growth in the water samples due to the availability of oxygen. Elevated BOD levels in water can indirectly affect humans, including promoting clinical conditions such as typhoid, cholera, and dysentery caused by the microorganisms (Ugwu *et al.*, 2024). Chemical oxygen demand (COD) is also a crucial water quality parameter that measures the quantity of oxygen required to chemically oxidize pollutants in water in the presence of a potent chemical oxidizing agent (Bawa *et al.*, 2024). Therefore, it may

serve as an indicator for water pollution. The high COD level, which exceeded the WHO standard in this study, could indicate that the SW contains a high level of organic pollutants, possibly originating from the source of the water used for the production of the SW by the ventures. Dissolved oxygen (DO) is a measure of the quantity of oxygen gas that is dissolved in water and is freely available to aquatic organisms for respiration and gaseous exchange. The high DO level observed in the SW samples may be beneficial for aquatic organisms (Adamu *et al.*, 2024). Total suspended solids (TDS) are the combination of all organic and inorganic substances dissolved in water (Adejuwon *et al.*, 2025). It is also an important indicator of the quality of water because it reflects the concentration of dissolved substances in the water (Omer, 2019). The TDS level, which falls below the WHO standard for this study, indicates that the SW may not be essentially harmful. However, the intake of low-TDS sachet water for a long period can lead to increased electrolyte imbalance and diuresis. Additionally, a low TDS in water indicates low alkalinity, capable of causing a pH swing and poor buffering capacity of water.

Total hardness (TH) is the concentration of divalent calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions present in a water sample. The presence of these two prominent ions causes water hardness, affects water taste, its dissolution with soap, and its ability to form water scales. The low TH of the sachet water observed in the study may lead to unpleasant water taste and an increased risk of cardiovascular diseases. Electrical conductivity (EC) is a measure of the ability of water to conduct electrical current. EC is dependent on the quantity of dissolved ions (metals, salts, minerals) present in water (Oguike and Adam, 2024). The EC values, which fall below the WHO standard for quality sachet water, as observed in this study, suggest that the water probably lacks the essential nutrients required for human health and well-being. The low EC values of the SW from this current study are in consonance with the findings of Akin-Osanaye and Izuekor (2022) for SW collected in the Bwari Area Council of FCT, Abuja. pH is a measure of the alkalinity or acidity of a solution. In this study, the pH values of the sachet water sample B-J were below the WHO standard. This can have significant effects on the biological systems. The low pH level renders the water acidic, increasing the affinity of water to bind with metals like Pb, Zn, Co, and Zn, thereby making it toxic. The ingestion of such metals can result in severe health conditions like gastrointestinal irritation and dental erosion. Additionally, the pH value of drinking water below the acceptable standard can also disrupt ionic balance and those of other metabolic processes, such as osmoregulation (water and salt homeostasis), respiration, and metabolism. The pH values in this study were lower than the values reported by Magaji (2020) and those reported by Akin-Osanaye and Izuekor (2022) in SW from Gwagwalada and Bwari Area Councils of Abuja, respectively. Total alkalinity (TA), also known as buffering capacity gives an insight into the ability of water to neutralize acids. It is a measure of the capacity of water to resist pH changes when an acid is added. Alkalinity is basically mediated by the availability of hydroxides (OH^-), carbonates (CO_3^{2-}), and bicarbonates (HCO_3^-). The major factors that affect TA are geological conditions as well as vegetation (Aremu *et al.*, 2011; Okpara *et al.*, 2024). Although there is no standard acceptable threshold for TA in drinking water, the TA varied across the SW samples for this study. This may not be disconnected from the geological conditions of the water source used in the production of the sachet water from the locations where the SW samples were purchased.

Lead (Pb) exposure can occur through dietary ingestion, inhalation, or via contaminated water. Pb has no biological importance, and even at low concentrations, it is very toxic to the body (Arise *et al.*, 2015). It can predispose to kidney, reproductive, and neurological damage in adults (Okere *et al.*, 2022). This is achieved via impairment of cell-mediated immune response as well as delay in attaining puberty, low birth weight, reduced sperm quality, high risk of miscarriage, and hormonal imbalance, respectively (Yisa *et al.*, 2024).

The Pb content for this study was found to be above the WHO threshold for drinking water. The concentration of lead across the SW samples for this study was lower than the findings of Abejide *et al.* (2023) for sachet water. High levels of Pb content are associated with neurological disturbance, delayed neuronal conduction, reduced intelligence quotient, and altered behavioral issues in children and adults. Elevated levels of Pb are also associated with cardiovascular and renal disturbances, presenting with high blood pressure and glomerular filtration abnormalities. A high blood Pb concentration can trigger the onset of anemia since Pb interferes with heme production via downregulation/inhibition of the enzyme ferrochelatase, causing microcytic anemia. Pb has also been implicated in the suppression of the reproductive and immunological systems.

Zinc (Zn) is the second most abundant metal in the body after iron. It plays a major role as a cofactor for the normal catalytic activity of enzymes and as a transcription factor. It is incorporated into the enzyme carbonic anhydrase for the regulation of carbon dioxide and into carboxypeptidase for protein catabolism. Zn also participates in the normal functioning of the immune system and in gene expression (Saliu *et al.*, 2024). Zn affects the normal functioning of the innate and adaptive immunity. It may hamper the growth and development of children, leading to stunted growth and impaired cognitive function. The Zn concentration, which falls below the WHO standard in this study, is consistent with the study of Abejide *et al.* (2023). A low Zn level can alter normal testosterone synthesis, causing hypogonadism (Yisa *et al.*, 2025).

Iron (Fe) is an essential chemical element for life owing to its involvement in the transport of oxygen in blood via hemoglobin. In this study, the presence of Fe in the SW of sample A-G had concentrations that were above the WHO acceptable limit for drinking water. The Fe contents in this study were higher than those reported by Magaji (2020) for SW from the Gwagwalada Area Council of Abuja. Conversely, there was no iron detected in the SW samples H-J (from Gohen Living Venture, Libra Venture, and Mohsha Nigeria Limited Venture, respectively). This finding is consistent with the report of Akin-Osanaye and Izuekor (2022), who reported that absence of iron in SW collected from Bwari Area Councils of Abuja. An absence of iron or a low iron level will result in a low hemoglobin concentration and a reduced amount of oxygen being delivered to tissues/organs for metabolism. The deficiency of Fe in the body is associated with anemia, a clinical condition characterized by low blood iron levels. The absence or low iron level is also associated with immune system weakness, which can increase susceptibility to pathogens and infections. Low levels of Fe are also known to affect the normal growth rate and cognitive or motor developmental stages in children (Oshukunuofa *et al.*, 2024). Conversely, high iron level is considered to be associated with toxicity (Okere *et al.*, 2014).

CONCLUSION

The study revealed alterations in the physicochemical profile of all the sachet waters, especially the biochemical oxygen demand, chemical oxygen demand, dissolved oxygen, and Pb content, which exceeded the recommended standard, irrespective of the ventures. The study concludes that such alterations may affect the quality of the water, posing a serious health risk to consumers. The study recommends strict enforcement of regulatory standards for improved water quality and better maintenance of water distribution infrastructure towards actualizing the Sustainable Development Goal No. 6 (clean water and sanitation).

Conflict of interest: The authors declare no conflict of interest with respect to this study.

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