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Environmental And Public Health Assessment Of The Bacterial And Physicochemical Quality Of Sachet Drinking Water In Ughelli North Local Government Area, Delta State

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ABSTRACT
Sachet water has become a major source of drinking water in many Nigerian communities due to challenges associated with access to safe and portable water. This study assessed the bacteriological and physicochemical quality of sachet water sold in Ughelli North LGA, Delta State, Nigeria, to determine its suitability for human consumption. Ten sachet water brands (B1–B10) were randomly collected and analyzed via standard methods prescribed by the American Public Health Association (APHA, 2017). The bacterial assessment focused on total bacterial count, total coliforms and faecal coliforms while physicochemical parameters examined included pH, temperature, total dissolved solids (TDS), electrical conductivity, turbidity, phosphate and many others. Microbiological analysis revealed that all samples were free from faecal coliforms; however, total coliforms range (0.001–0.70 MPN/100 mL), total viable counts range (0.59-1.63 **x** 10^2 cfu/ml). Bacteria identified were *Bacillus* spp*, Klebsiella* spp*, Staphylococus aureus, Micrococcus* spp *and Pseudomonas aeruginosa* indicating environmental and post-production contaminations. Results showed that pH values ranged from 6.02 to 7.38, which fell within the WHO acceptable limits. Temperature (7.10°C–28.10°C) reflected ambient environmental conditions. TDS (9.00–104.00 mg/L) and conductivity (0.48–207 µS/cm) were low, suggesting good palatability and minimal ionic concentration. Turbidity ranged from 0.00 to 0.17 NTU, while nitrate (0.29–2.46 mg/L) and sulphate (0.08–3.63 mg/L) were all indicating low mean values across the ten brands. In contrast to the satisfactory physicochemical profiles, the bacteriological evaluation revealed significant public health vulnerabilities. This emphasizes an urgent need for enhanced quality control, stricter hygiene practices and continuous regulatory monitoring.
Keywords: Sachet water, Bacterial, Coliforms, Assessment, Contamination.

INTRODUCTION

Access to safe drinking water is a fundamental human right and a critical determinant of global public health development (World Health Organization [WHO], 2022). Public health data consistently demonstrates that drinking water quality directly influences waterborne disease transmission dynamics, population morbidity, and overall mortality rates. Consuming microbiologically and chemically safe water effectively mitigates the systemic burden of enteric infections, serving as a primary determinant of positive public health outcomes. This is particularly critical in low- and middle-income countries (LMICs) where centralized public utilities and regulatory infrastructure are severely limited (WHO,

2022). Potable water must strictly comply with established microbiological, physical, and chemical criteria to ensure safety for human consumption. To safeguard populations, international and national regulatory frameworks such as the World Health Organization guidelines and the Nigerian Standard Organization for Drinking Water Quality prescribe health-based maximum permissible limits for microbial indicators and chemical constituents. Unwavering compliance with these standards represents the primary defense against waterborne outbreaks (WHO, 2022; Standards Organization of Nigeria [SON], 2007).

In Nigeria, rapid urbanization and population growth have severely outpaced municipal infrastructure development, leading to a chronic deficit in public water utility supply. To bridge this demand-supply gap, sachet-packaged water popularly termed "pure water" has emerged as the dominant source of potable water for households across urban and semi-urban communities. The widespread adoption of sachet water is driven by its high convenience, affordability, and ubiquitous accessibility, making it the preferred choice over municipal water schemes that are frequently unreliable, contaminated, or entirely non-existent (Mohammed et al., 2023). Market surveys indicate that over 70% of urban Nigerian households rely on sachet water as their primary daily drinking source, resulting in the nationwide consumption of millions of liters daily (Omole et al., 2015). Consequently, this commodity has evolved from a commercial convenience into a critical component of national water security and public health sustainability.

Despite its socio-economic utility, the sachet water industry presents severe regulatory and epidemiological challenges. The production landscape is highly fragmented and predominantly informal, characterized by thousands of small-scale entrepreneurs operating with varying degrees of technical competence. As a consequence, quality control mechanisms and compliance with statutory safety benchmarks vary widely across production facilities (National Agency for Food and Drug Administration and Control [NAFDAC], 2023; Mohammed et al., 2023). Serious public health concerns persist regarding the microbiological and physicochemical integrity of these products. Contamination vectors are multi-faceted, stemming from poor source-water protection, faulty filtration systems, unhygienic factory handling, substandard packaging materials, and improper post-production storage conditions during distribution.

Recent empirical investigations continue to highlight these persistent contamination risks and identify significant oversight gaps within the production-to-retail supply chain (Agbasi et al., 2024). Because a substantial portion of small-scale producers bypass formal regulatory oversight, consumers are routinely exposed to potential pathogenic and chemical hazards. Given the immense volume of daily consumption, any systemic failure in sachet water quality control poses a catastrophic threat to public health, capable of triggering widespread epidemics of waterborne illness. Therefore, a comprehensive evaluation of the microbiological and physicochemical quality of sachet-packaged water is imperative to quantify consumer exposure risks and inform targeted regulatory interventions. The aim of study was to assess the microbial and physicochemical quality of sachet drinking water in Ughelli north, Delta State, and evaluate potential environmental and public health risks associated with consumption of these water products.

MATERIALS AND METHODS

Description of the Study Area

This research was conducted in Ughelli, a prominent urban and socio-economic hub situated within the Ughelli North Local Government Area (LGA) of Delta State, Nigeria. Geopolitically located within the South-South zone and geographically embedded in the Niger Delta region, this area features diverse ecological zones that span from freshwater swamp forests to lowland rainforests. The Ughelli North LGA lies approximately between latitudes 5°30′N and 6°00′N, and longitudes 5°30′E and 6°00′E. It covers an estimated terrestrial land area of about 818 km² and supports a dense population driven by commercial and agricultural activities (National Population Commission [NPC], 2006; Delta State Government, 2020). The reliance on packaged water in this region is pronounced due to the socio-economic dynamics and localized environmental challenges impacting natural water resources.

Sample Collection and Sampling Technique

A cross-sectional survey utilizing a randomized sampling technique was deployed to assess the quality of commercially distributed sachet water within Ughelli town. A total of ten distinct brands of sachet water, designated as samples B1 through B10, were purchased from various retail outlets and local vendors across the study area. To guarantee the precision, reliability, and reproducibility of the downstream analytical data, three replicates were collected for each individual brand.

Stringent aseptic protocols were enforced during collection to prevent external or cross-contamination. Freshly sealed commercial sachets were handled using sterile gloves and immediately transferred into clean, insulated iceboxes containing pre-chilled ice packs. This thermal mitigation was used to preserve sample integrity and suppress post-collection microbial proliferation during transit. All gathered samples were conveyed immediately to the laboratory for concurrent physicochemical and bacteriological evaluations.

Physicochemical Analysis

The physical and chemical characterization of the sachet water samples was executed in strict accordance with the validated standard procedures recommended by the American Public Health Association (APHA, 2017) and the World Health Organization (WHO, 2022). Active acidity (pH) was determined electrometrically using a pre-calibrated Hanna HI 98107 digital pH meter. The electrical conductivity (EC) and total dissolved solids (TDS) were quantified simultaneously utilizing a digital Hach HQ40d Portable Conductivity/TDS Meter. Sample turbidity, which serves as an indicator of water clarity and suspended particulate matter, was evaluated using a Hach 2100Q Portable Turbidimeter. To maintain strict analytical quality control, all measurements for each brand replicate were performed in triplicate. The resulting data points were used to calculate mean values.

Bacteriological Analysis

The bacteriological profile of the sachet water brands was investigated to identify potential pathogenic contamination and evaluate overall sanitary quality. The target bacteriological parameters included total heterotrophic bacterial counts, total coliforms, and faecal coliforms. All laboratory analyses were conducted according to established microbiological guidelines outlined by Cheesbrough (2016) and the World Health Organization (WHO, 2022). Total and faecal coliform counts were determined using the standard multiple-tube fermentation (MPN) index. Sterile McCartney bottles, pipettes, test tubes, and Durham tubes were prepared alongside MacConkey broth (Oxoid, UK) as the selective nutrient medium. A standard three-dilution series was set up by inoculating 10 mL, 1 mL, and 0.1 mL volumes of each water sample into triplicate sets of broth tubes. The inoculated matrices were incubated at 37 °C for 24 to 48 hours within a Memmert incubator (Model IN30). Tubes exhibiting both distinct acid production (color change) and gas accumulation within the Durham tubes were recorded as positive for total coliforms. Total heterotrophic bacterial populations were quantified using the standard Pour Plate Method (APHA 9215 B). Aliquots of 1 mL from each water sample were combined with 9 mL of sterile distilled water in sterilized test tubes to create serial dilutions up to 1:10. These dilutions were plated on sterile Nutrient Agar (Oxoid, UK) and incubated at 37 °C for 24 hours. Resulting colonies were enumerated using a digital colony counter and expressed as colony-forming units. Pure cultures of the bacterial isolates were systematically characterized and identified using the morphological, staining, and biochemical criteria set forth in Bergey's Manual of Systematic Bacteriology.

Data Analysis

The collected experimental data were compiled and analyzed using SPSS version 25.0 software. Quantitative results were presented as mean ± standard error (SE). Results were also presented in graphs. Finally, the mean experimental values were compared directly against the maximum permissible thresholds established by the World Health Organization (WHO, 2022) to calculate regulatory compliance rates.

RESULTS AND DISCUSSIONS

The pH values in Table 1 showed noticeable variation across the different sachet water brands. The guideline range set by the World Health Organization is 6.5 to 8.5, so the pH results can be assessed against this standard. Brand 1 recorded the highest pH (7.38 ± 0.01), brand 8 had the lowest pH (6.02 ± 0.04). All the brands fell well within the acceptable range and reflect neutral to slightly alkaline water. Although, some brands fell slightly below the guideline.

The temperature values also showed only slight variation across the sachet water brands, and all measurements fell well below the World Health Organization recommended maximum of 34 °C. Brand 4 recorded the highest temperature at 28.10 ± 4.21 °C and the lowest temperature was observed in brand 1 (27.10 ± 0.02 °C). All the brands are within acceptable limit indicating stable temperature conditions across the samples.

The Total Dissolved Solids (TDS) values varied widely across the sachet water brands, but all remained below the World Health Organization limit of 600 mg/l. Brand 1 recorded the highest TDS at 104.00 ± 2,42 mg/l, which is clearly higher than all other brands.

The conductivity values measurements remained below the World Health Organization limit of 1000 µS/cm. The turbidity values were very low across all sachet water brands and fell far below the permissible limit of 5.00 NTU. The total hardness values were far below the permissible limit of 200.00 mg/l set by the World Health Organization. Brand 1 recorded the highest hardness at 7.13 ± 0.02 mg/l, the lowest value was observed in brand 9 (0.89 ± 0.02 mg/l),

Table 1: Physicochemical Parameters Of Sachet Water Compared With WHO

parameters	Sachet water brand										WHO
	Metosyl (B1)	P.A. (B2)	Paidem/ (B3)	Zinotex (B4)	Jo-Rox/ (B5)	Rukebe/ (B6)	Hons/ (B7)	U.P.E. (B8)	U. S./ (B9)	Jeez/ (B10)	
pH	7.38±0.01	7.14±0.24	7.01±1.16	6.13±0.04	6.70±0.02	6.19±0.02	6.24±0.04	6.02±0.04	6.53±0.03	6.41±0.02	6.5-8.5
Temperature	27.10±0.02	27.40±0.12	27.70±4.82	28.10±4.21	27.50±7.24	27.60±8.94	27.20±4.45	27.90±5.28	27.30±6.08	27.40±8.24	<34
TDS	104.00±2.42	21.00±4.21	32.00±6.67	66.00±6.21	16.00±3.36	12.00±4.20	14.00±4.41	9.00±5.63	9.00±1.18	13.00±2.14	<600
Conductivity	207.00±3.61	40.00±6.61	0.48±0.02	129.00±6.67	30.00±5.51	23.00±4.21	26.00±6.21	36.00±4.19	17.00±2.04	25.00±5.02	<1000
Turbidity	<0.01±0.00	0.17±0.03	0.00±0.00	<0.01±0.01	<0.01±0.01	0.30±0.01	0.01±0.01	<0.01±0.01	<0.01±0.01	<0.01±0.01	5.00
Colour	Unobject	Unobject	Unobject	Unobject	Unobject	Unobject	Unobject	Unobject	Unobject	Unobject	Unobject
Odour	Unobject	Unobject	Unobject	Unobject	Unobject	Unobject	Unobject	Unobject	Unobject	Unobject	Unobject
Total hardness	7.13±0.02	2.26±0.23	3.91±0.07	4.38±0.03	1.67±0.04	1.14±0.03	1.39±0.04	1.94±0.02	0.89±0.02	1.21±0.02	200.00
Chloride	12.97±0.16	2.56±0.21	1.42±0.03	8.19±0.17	1.94±0.05	1.52±0.02	1.73±0.03	2.36±0.08	1.13±0.04	1.61±0.04	200,00
Sulphate	3.63±0.01	0.77±0.01	0.08±0.01	2.46±0.82	0.74±0.03	0.05±0.02	0.65±0.02	0.83±0.02	0.38±0.02	0.54±0.01	250.00
Nitrate	0.29±0.02	0.05±0.02	0.08±0.01	2.46±0.82	0.74±0.03	0.55±0.02	0.65±0.02	0.83±0.02	0.38±0.02	0.54±0.01	50.00
Phosphate	<0.01±0.01	<0.01±0.01	1.571±0.26	<0.01±0.01	<0.01±0.01	<0.01±0.01	<0.01±0.01	<0.01±0.01	<0.01±0.01	<0.01±0.01	N/A
Sodium	5.22±0.51	1.03±0.01	0.50±0.04	3.29±0.61	0.78±0.02	0.61±0.02	0.70±0.02	0.95±0.02	0.45±0.01	0.25±0.01	200.00
Potassium	1.66±0.01	0.33±0.02	0.60±0.02	1.05±0.03	0.24±0.02	0.20±0.01	0.22±0.01	0.31±0.01	0.15±0.01	0.08±0.01	N/A
Calcium	1.74±0.02	0.52±0.01	0.58±0.02	0.94±0.02	0.33±0.02	0.24±0.02	0.30±0.01	0.42±0.02	0.18±0.01	0.25±0.02	70.00
Magnessium	1.68±0.03	0.24±0.03	0.30±0.01	0.49±0.03	0.20±0.01	0.13±0.01	0.16±0.02	0.22±0.01	0.11±0.01	0.15±0.02	30.00

NOTE: Unobject-PERMISSIBLE; N/A- NOT AVAILABLE

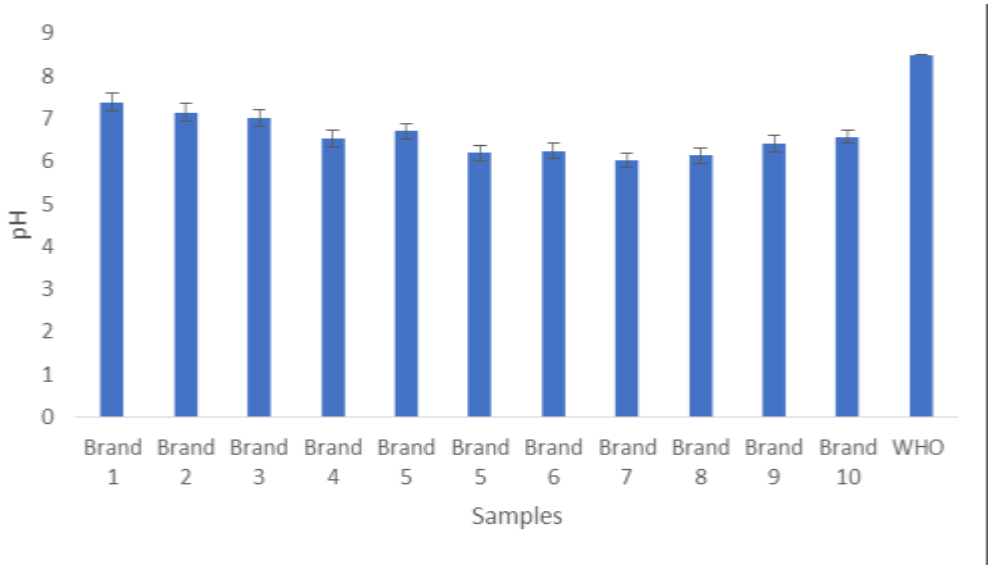

Fig 1: Variation in pH across the different sachet water brands

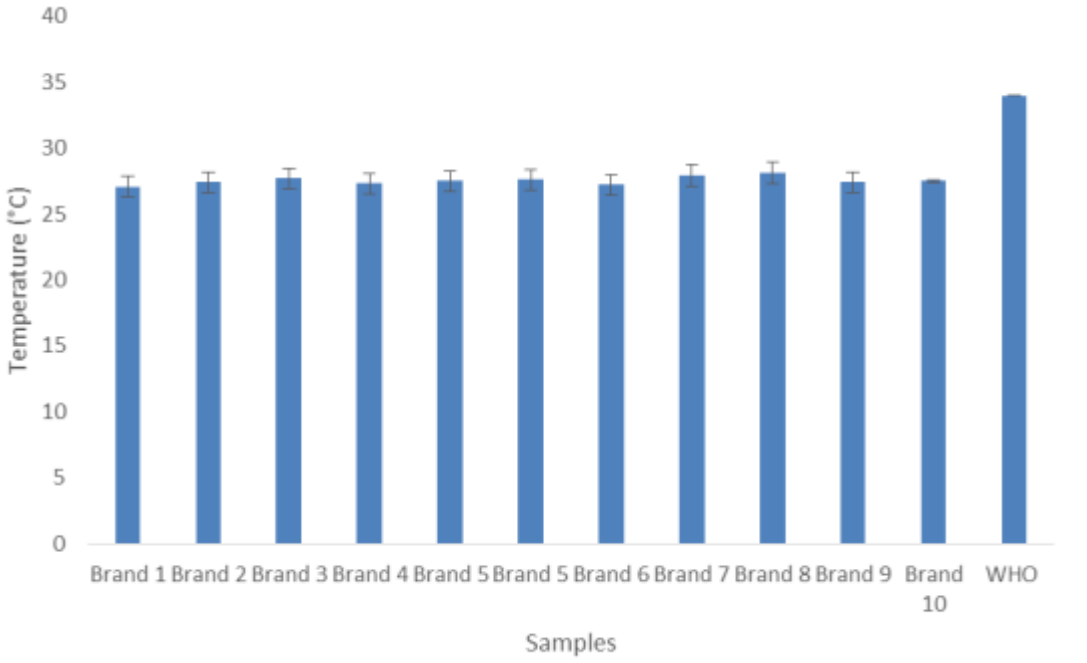

Fig 2: Variation in Temperature across the different sachet water brands

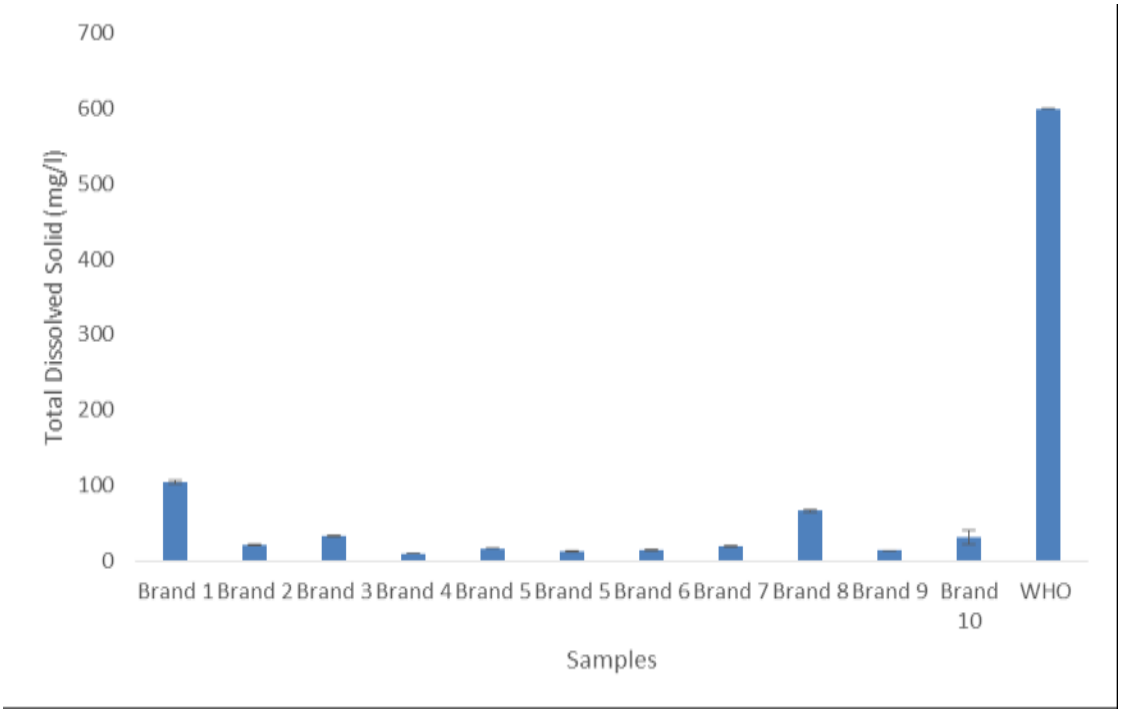

Fig 3: Variation in total dissolved solids across the different sachet water brands

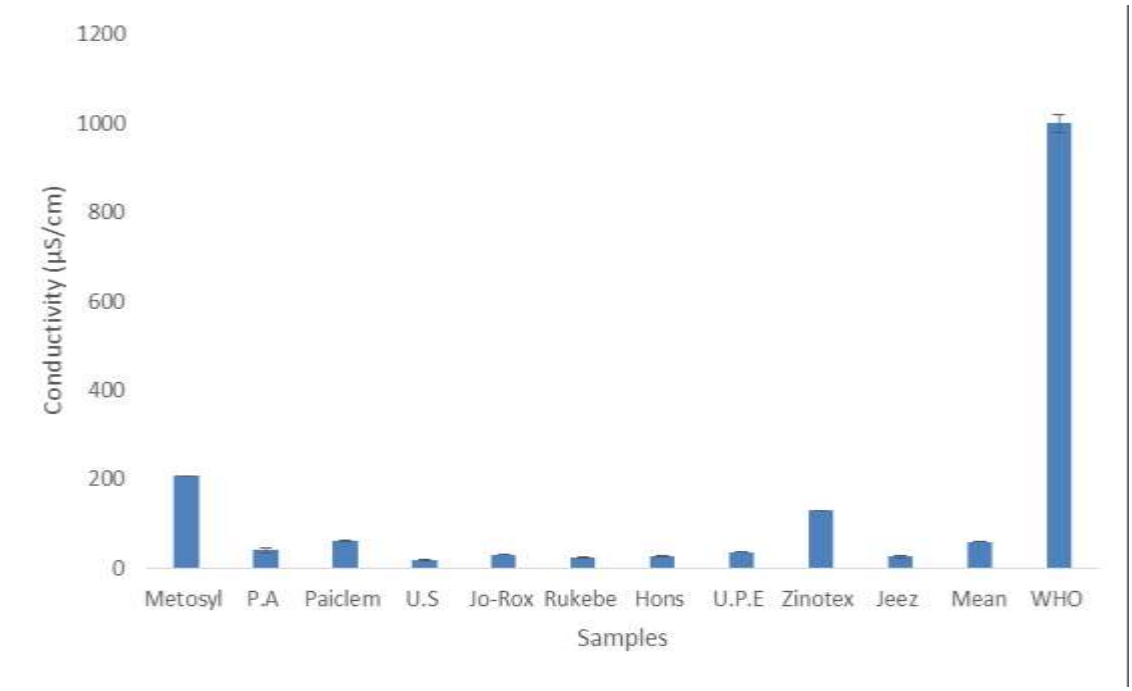

Fig 4: Variation in conductivity across the different sachet water brands

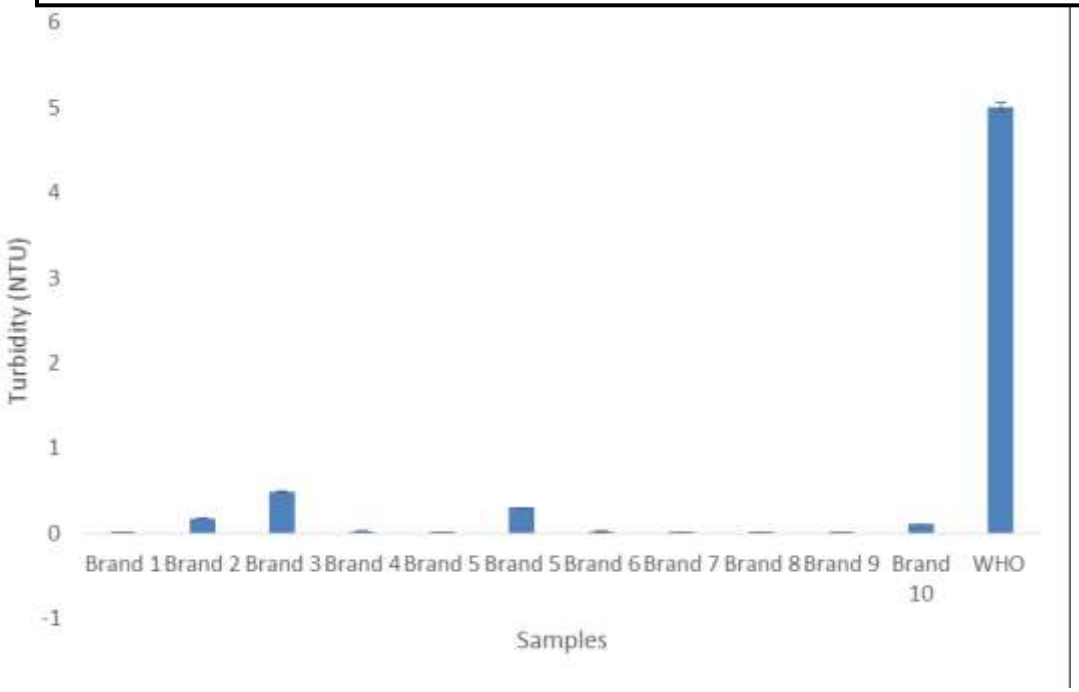

Fig 5: Variation in turbidity across the different sachet water brands

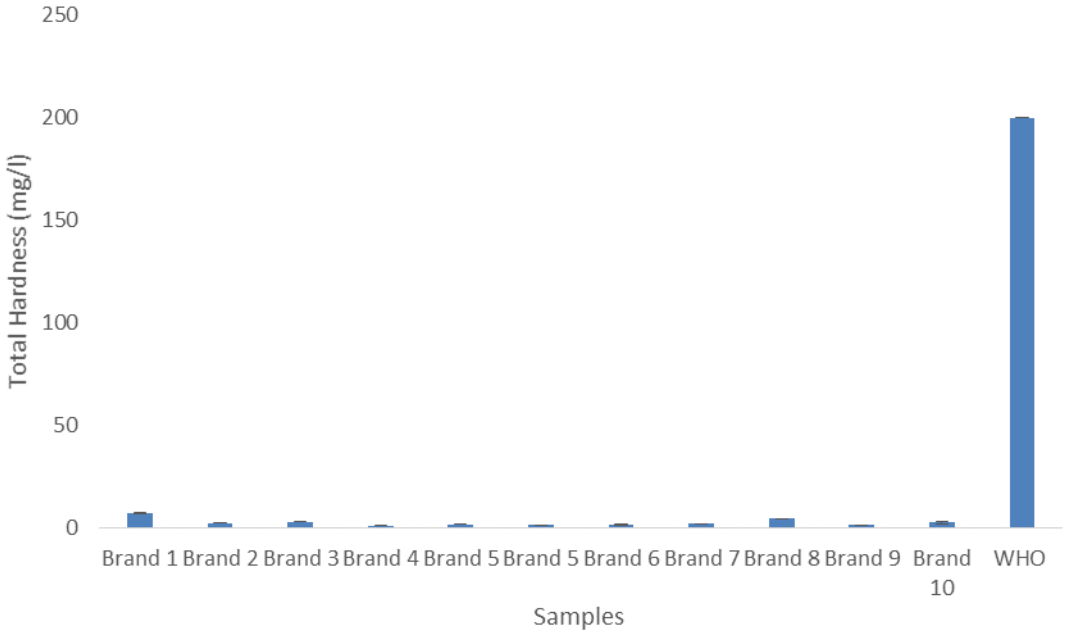

Fig 6: Variation in total hardness across the different sachet water brands

The chloride concentration values remain far below the World Health Organization limit of 200 mg/l. The sulphate concentrations showed relatively low values across all sachet water brands when compared with the World Health Organization limit of 250 mg/l. brands. The nitrate concentrations were very low across all sachet water brands and are far below the World Health Organization limit of 50 mg/l. The sodium and Potassium concentrations were far below the World Health Organization limit, indicating minimal mineral contribution from all samples. The calcium and Magnesium concentration values were below the World Health Organization limit of 70 mg/l.

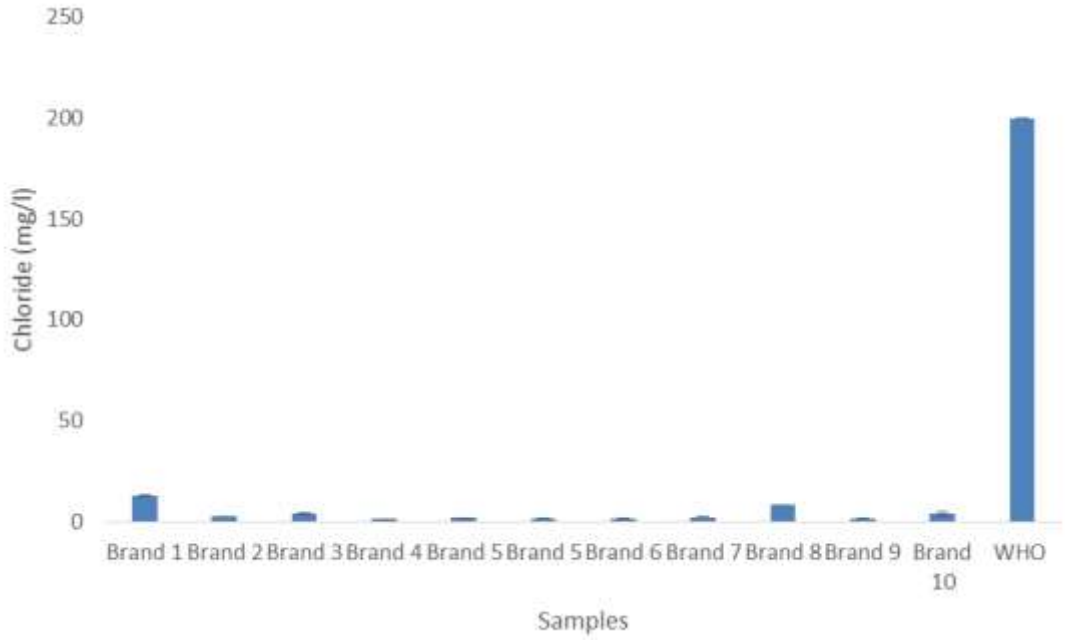

Fig 7: Variation in chloride across the different sachet water brands

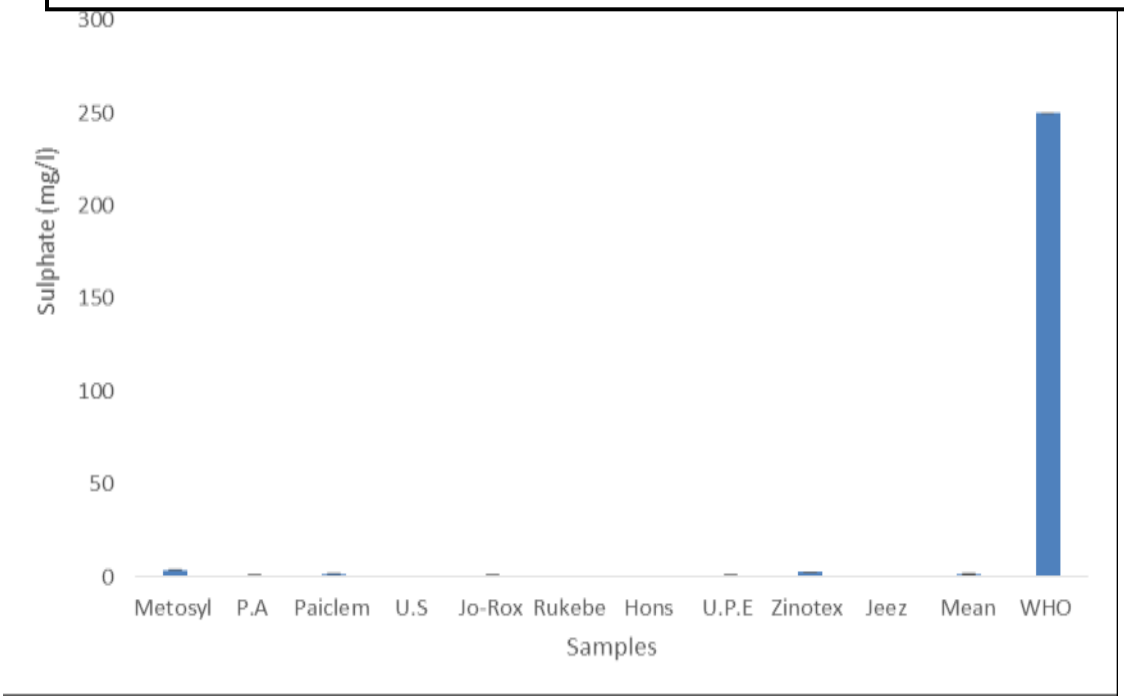

Fig 8: Variation in sulphate across the different sachet water brands

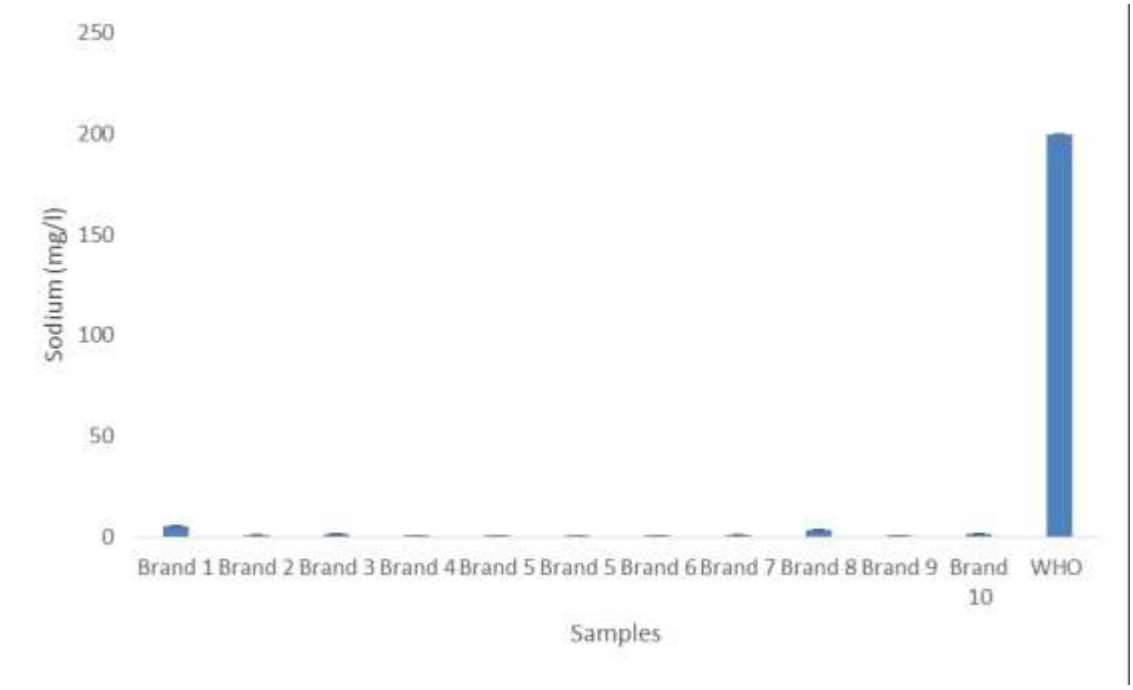

Fig 9: Variation in sodium across the different sachet water brands

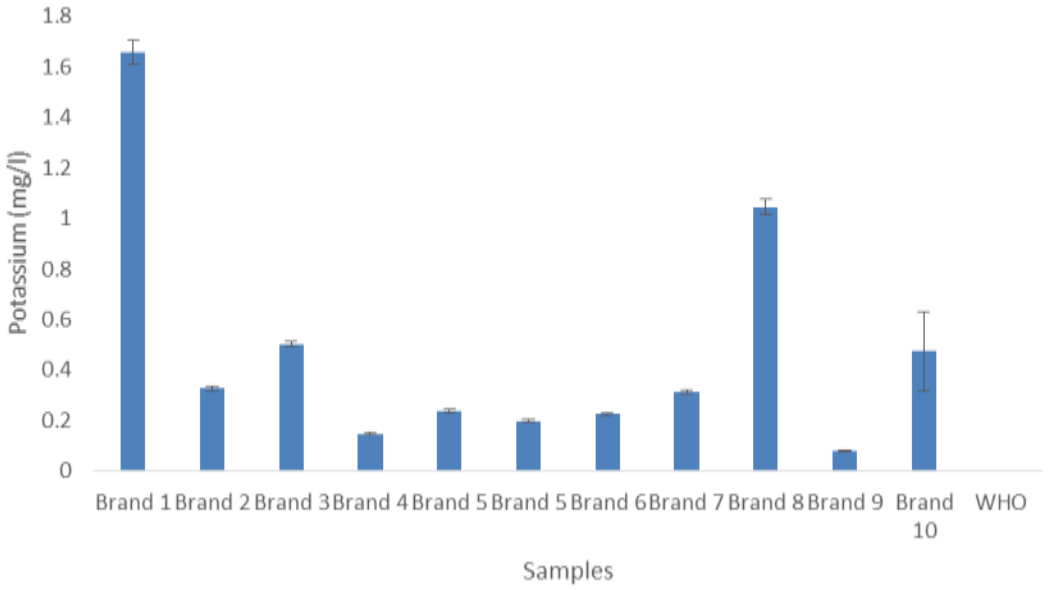

Fig 10: Variation in potassium across the different sachet water brands

Microbiological analysis showed that all samples were free from faecal coliforms, confirming that there was no direct faecal contamination as shown in table 2 below. However, total coliforms were detected in some samples (0.10 ± 0.00 to 0.70 ± 0.20 MPN/100 mL), indicating occasional post-production contamination. Total viable counts (0.59±0.01 to 1.63±0.05 × 10^2 cfu/mL) observed were relatively low, their presence indicates microbial contamination and does not fully comply with the WHO guideline that drinking water should be free from objectionable microbial contamination and adequately protected from health risks.

Table 2: Microbiological Quality Of Sachet Water

Sample ID	Total Coliform Count (MPN/100ml)	Feacal Coliform Count (MPN/100ml)	Total Viable Count (cfu/ml (x $10^{2)}$)	Isolates
B1	<0.1± 0.00	ND	0.63±0.02	*Bacillus spp*
B2	0.20 ± 0.01	ND	1.17±0.04	*Staphylococcus aureus*
B3	0.70± 0.20	ND	1.28±0.03	*Micrococcus spp Staphylococcus aureus; Klebsiella spp.*
B4	<0.1 ± 0.00	ND	0.94±0.01	*Bacillus spp*
B5	<0.1 ± 0.00	ND	1.03 ±0.02	*Pseudomonas aeruginosa*
B6	0.40 ± 0.02	ND	1.52±0.02	*Micrococcus spp Bacillus spp*
B7	0.20± 0.01	ND	1.34±0.03	*Klebsiella spp.*
B8	<0.1 ± 0.00	ND	0.59±0.01	*Bacillus spp*
B9	0.40± 0.02	ND	1.63±0.05	*Staphylococcus aureus; Bacillus spp*
B10	<0.1 ± 0.00	ND	0.81±0.02	*Micrococcus spp*

DISCUSSION

Physicochemical properties provide fundamental insight into the aesthetic quality, stability, and consumer acceptability of drinking water. In this study, the observed temperatures of the ten sachet water brands (B1–B10) in Ughelli were relatively uniform. This homogeneity indicates that environmental conditions during retail storage and distribution were identical, mirroring surrounding tropical climatic trends rather than manufacturing differences (Yang et al., 2023). While temperature does not directly measure contamination, higher ambient values can promote opportunistic microbial proliferation if baseline or post-treatment contamination exists. Turbidity levels were exceptionally low across all brands, reflecting efficient particulate filtration and sediment removal. This aligns with findings by Eludoyin and Olanrewaju (2021), who noted that Nigerian sachet water typically exhibits high clarity due to the widespread commercial deployment of microfiltration and reverse osmosis systems.

Electrical conductivity (EC) and Total Dissolved Solids (TDS) varied slightly among brands but remained uniformly low. Lower values indicate aggressive multi-stage membrane purification that removes dissolved ionic salts, while slight elevations in certain brands suggest differences in groundwater aquifer geochemistry or less intensive demineralization (Brenner et al., 2020). This uniform low-TDS profile demonstrates that Ughelli producers prioritize absolute purity over mineral retention (Kekes et al., 2023). However, prolonged consumption of demineralized drinking water may adversely affect mineral and nutrient intake, highlighting the importance of maintain adequate concentrations of essential minerals such as calcium and magnesium in drinking water (Sunardi et al. 2024). The pH values fell within the acceptable neutral range, indicating chemical stability. Minor acidic trends in specific samples are likely tied to dissolved carbon dioxide or unbuffered groundwater characteristics typical of the Niger Delta (Afolabi et al., 2023). Similarly, total hardness, calcium, and magnesium levels were low, confirming extensive demineralization. Anion profiles including chloride, sulfate, and nitrate were minimal to undetectable across all samples. These low concentrations establish that the deep borehole sources

utilized by producers are well-protected from saline intrusion, industrial waste, or agricultural fertilizer runoff (Agbasi et al., 2024; Omokaro et al., 2024).

The low turbidity, stable neutral pH, and minimal concentrations of key anions (nitrates, sulfates, and chlorides) indicate that the deep groundwater aquifers utilized by local manufacturers are well-protected and undergo highly efficient mechanical filtration, particularly via reverse osmosis. However, this intensive purification has led to widespread demineralization, resulting in uniformly low levels of essential dietary cations such as calcium and magnesium, which compromises the nutritional value of the water.

Total coliform bacteria serve as vital indicator organisms for evaluating the sanitary quality of drinking water, as their presence signals potential treatment failures, inadequate disinfection, or post-treatment contamination. Although coliforms themselves are not always pathogenic, they frequently coexist with disease-causing microorganisms, making their detection a severe warning of potential health risks. Consequently, international guidelines mandate the complete absence of total coliforms in potable water, requiring immediate investigation and corrective action whenever they are detected to protect public health.

This specific study revealed significant variation in total coliform counts across different sachet water brands in Ughelli North, highlighting discrepancies in treatment efficiency, source water protection, and post-production hygiene. While several brands complied with microbiological safety standards by recording zero detectable coliforms proving the effectiveness of filtration, chlorination, or ultraviolet disinfection others exhibited elevated bacterial levels. Beyond coliforms, the study identified specific bacterial strains such as *Bacillus spp.*, *Staphylococcus aureus*, *Micrococcus spp.*, *Klebsiella spp.*, and *Pseudomonas spp.*, which point to environmental contamination, poor handler hygiene, and potential biofilm formation within production equipment.

These findings are consistent with broader research across Nigeria and other developing regions, which consistently documents highly variable microbiological safety in packaged water due to uneven regulatory enforcement. The presence of these bacterial species remains a major public health concern, as it poses a risk of gastrointestinal infections, particularly for vulnerable populations, and undermines consumer confidence. Ultimately, despite the water meeting standard pH levels, the widespread bacterial variability emphasizes an urgent need for enhanced quality control, stricter regulatory monitoring, and more consistent hygienic practices among sachet water producers.

CONCLUSION AND RECOMMENDATIONS

This study provides a comprehensive evaluation of the physicochemical and bacteriological quality of sachet-packaged water distributed across Ughelli, Delta State. The physical and chemical assessments demonstrate that all ten sampled brands (B1–B10) comply with the permissible limits established by the World Health Organization (WHO) and the Nigerian Standard for Drinking Water Quality (NSDWQ). In contrast to the satisfactory physicochemical profiles, the bacteriological evaluation revealed significant public health vulnerabilities. The presence of heterotrophic bacteria and the detection of total coliforms in select brands indicate critical lapses in microbial safety. These microbiological failures point directly to inadequate post-treatment sanitation, poor structural maintenance of borehole wellheads, faulty ultraviolet (UV) sterilization lamps, or unhygienic manual handling during mechanical heat-sealing. Because over 70% of the population relies on sachet water as their primary source of daily hydration, the presence of coliforms and other environmental species of bacteria poses an immediate threat of waterborne diarrheal outbreaks, undermining public health security in the region. Strict adherence to regulatory practices, mandatory factory sanitation maintenance, infrastructural protection, public awareness and vendor training and mineral remanufacturing or balancing thereby optimizing both the taste and nutritional profile of the water are highly recommended to secure the safety of sachet water consumers in Ughelli.

REFERENCES

Afolabi, O. O., Wali, E., & Nwankwoala, H. O. (2023). Hydrogeochemical process of ions in roundwater of communities along Southern-axis Atlantic Ocean in Bayelsa, Nigeria. Water Science, 37(1), 399-408. https://doi.org/10.1080/23570008.2023.2285124.

Agbasi, J. C., Ezugwu, A. L., Omeka, M. E., Ucheana, I. A., Aralu, C. C., Abugu, H. O. & Egbueri, J. C. (2024). More about making profits or Providing Safe Drinking Water? A state-of-the-art review on sachet water contamination in Nigeria. *Journal of Environmental Science and Health, Part C* 42(4), 255–297. Doi; 10.1080/26896583.2024.2319009

Brenner, A., Persson, K. M., Russell, L., & Rosborg, I. (2020). Technical and Mineral Level effects of water treatment, corrosion control. In *Drinking Water Minerals and Mineral Balance: Importance, Health Significance, Safety Precautions* (2nd ed., pp. 127-148) Springer International Publishing. DOI:10.1007/978-3-030-18034-8-6.

Cheesbrough, M. (2016). District laboratory practice in tropical countries, Part 2 (2nd ed.). ambridge University Press.

Delta State Government (2020). *Delta State Development Profile*. Asaba: Ministry of Economic Planning.

Eludoyin, A. O. & Olanrewaju, O. E. (2021). Water supply and quality in sub-Saharan Africa. In Clean Water and Sanitation: Encyclopedia of the UN Sustainable Development Goals (pp897-913). Springer International Publishing. https://doi.org/10.1007/978-3-319-70061- 8-166-1

Kekes, T., Tzia, C.M & Kolliopoulos, G. (2023). Drinking and Natural Mineral Water: Treatment and Quality – Safety Assurance, Water, 15(13), 2325.https//doi.org/10.3390/w15132325

Mohammed, S.E. Durumin-Iya, N. I., Abubakar, A. S., Ayanda, O, S., Badamasi, H., Ahmadu, M., & Aderibigbe, D.O. (2023). Fragmented regulations and quality control variances in informal packaged water factories. Journal of Chemical Society of Nigeria,48(4),104-115. https://doi.org/10.46602/jcsn.v48i4.913

National Population Commission (NPC) (2006). *Population and Housing Census of the Federal Republic of Nigeria*: 2006 Census. Abuja, Nigeria: National Population Commission

National Agency for Food and Drug Administration Control NAFDAC). (2023). *Guidelines for packaged water production in Nigeria*. National Agency for Food and Drug Administration and Control, Abuja, Nigeria.

Nigerian Standard for Drinking Water Quality (NSDWQ). (2015). NIS 554: 2015. Standards Organization of Nigeria (SON).

Nigeria consumes over 2.5bn litres of sachet water annually - FG. (2026). Authority Newspaper.

Omokaro, G., Idama, V., Aireughian, E. O., & Michael, I. (2024). Water resources, pollution, integrated management and practices in Nigeria. An overview. *American Journal of Environmental Economics*, *3*(1), 5-18. https://doi.org/10.54536/ajee.v3i1.2593.

Omole, D. O., Ndambuki, J. M., & Balogun, K. (2015). Consumption of sachet water in Nigeria: Quality, public health and economic perspectives. African Journal of Science, Technology, Innovation and Development,7(1),45-51.https://doi.org/ 10.1080/20421338.2014.979654.

Standards Organisation of Nigeria (SON). (2015). *Nigerian Standard for Drinking Water Quality*. Abuja, Nigeria.

Sunardi, D., Chandra, D. N., Medise, B. E., Manikam, N, R. M., Friska, D., Lestari, W., & Insani, P. N. C. (2024). Health effects of alkaline, oxygenated, and demineralized water compared to mineral water among healthy population: A systematic review. *Reviews on Environmental Health*. 39(2), 339-349.https://doi.org/10.1515/reveh-2022-0057.

World Health Organization (WHO). (2022). *Guidelines for Drinking-water Quality* (4th ed., incorporating 1st–3rd addenda). Geneva: WHO.

Yang, Z., Cheng, D., Su, B., Ji, C., Huang, J., Li, H., & Zhang, K. (2023). Study on the optimization of temperature uniformity in the oven under the forced convection mode. *Scientific Reports*, *13*(1), 12486. https://doi.org/ 10.1038/s41598-023