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Quality Assessment of Sachet Water Sold and Consumed in Ishiagu, Ivo Local Government Area of Ebonyi State, Nigeria

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Abstract

This study presents the result of a quality assessment of some sachet water sold and consumed in Ishiagu. Four sachets from each Triplicate batch of the six different brands of 50 cL sachet water were sampled from commonly patronized retail shops by the inhabitants of the study areas, physically examined and assessed for their physicochemical and microbiological parameters using standard analytical procedures to ascertain the level of compliance with World Health Organization (WHO) and National Agency for Food and Drug Administration and Control (NAFDAC) standards for drinking water. The results of the physicochemical analyses showed that the pH value ranged from 6.20 ± 0.02 to 7.60 ± 0.23, temperature ranged from 25.8 ± 0.01˚C to 27.6 ± 0.33˚C, electrical conductivity ranged from 11.11 ± 0.78 $\mu S \cdot cm^{-1}$ to 26.45 ± 1.02 $\mu S \cdot cm^{-1}$, total dissolved solids ranged from 5.11 ± 0.01 $m \cdot gL^{-1}$ to 16.77 ± 1.01 $m \cdot gL^{-1}$, total alkalinity ranged from 19.53 ± 0.64 $m \cdot gL^{-1}$ $CaCO_3$ to 33.50 ± 0.29 $m \cdot gL^{-1}$ $CaCO_3$, total hardness ranged from 12.11 ± 1.22 $m \cdot gL^{-1}$ $CaCO_3$ to 28.78 ± 0.40 $m \cdot gL^{-1}$ $CaCO_3$, calcium ion ranged from 4.60 ± 0.11 $m \cdot gL^{-1}$ to 10.88 ± 0.35 $m \cdot gL^{-1}$, magnesium ion ranged from 0.20 ± 0.11 $m \cdot gL^{-1}$ to 0.35 ± 0.45 $m \cdot gL^{-1}$, sodium ranged from 3.05 ± 0.08 $m \cdot gL^{-1}$ to 3.78 ± 0.10 $m \cdot gL^{-1}$, potassium ranged from 0.43 ± 0.11 $m \cdot gL^{-1}$ to 0.75 ± 1.00 $m \cdot gL^{-1}$, chloride ranged from 7.34 ± 0.40 $m \cdot gL^{-1}$ to 12.44 ± 0.22 $m \cdot gL^{-1}$ in all the locations. However, the physicochemical parameters studied were within WHO and NAFDAC standards except for some chemical parameters like Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, and Cl^{-} that need to be elevated to meet the minimum allowable standards quality for drinking water. For the microbiological analysis, the results obtained indicated zero presence of bacterial colonies for both tests of total plate count (TPC) and total coliform count (TCC) in most of the sachet water brands. Although, some traces of cultivable bacteria were found in some sachet water in

Amagu, Amonye, and Ihietutu locations. Nevertheless, the level of TPC and TCC in all the six-sachet water investigated at various locations was significantly below the standard permissible limit. This clearly indicated that most of the sachet water sold and consumed in Ishiagu is of good microbiological quality and thus suitable for human consumption.

Subject Areas

Environmental Chemistry, Environmental Sciences

Keywords

Sachet Water, Physicochemical, Microbiological, Quality Assessment, Ishiagu

1. Introduction

Water is a universal solvent with numerous applications in daily life. It is an essential solvent for human nutrition, and a key parameter influencing the survival and growth of microorganisms in food and other microbial environments [1]. The scarcity of safe and potable drinking water is widespread, posing significant health risks to man. According to [2], approximately 80% of diseases and over 30% of mortality rates are primarily attributed to limited access to safe drinking water in developing nations of the world. Nigeria faces challenges similar to those of other developing countries in providing safe water services. Despite nearly five decades of establishment, Nigeria's water resources department had achieved little progress in 2019, with only 70% of the population accessing safe drinking water [3]. In 2021, the access to safe drinking water declined to 67% [4]. As the country's population and industries continue to grow, a significant imbalance between water demand and supply is experienced, resulting in the existing scarcity. Some recent studies by [5]-[7] have substantiated the insufficient nature of the country's water supply. The failure of the government to provide adequate, safe drinking water has created a void that the private sector is filling, primarily driven by commercial interests. They offer packaged water alternatives to Nigeria's unreliable municipal water supply, including sachet water popularly known in Nigeria as "pure water". Sachet water production has increased significantly and is popular among middle and low-income communities. Sachets water is readily available and affordable, but there are concerns about its purity, hygienic environment and storage conditions. Its preservation method and improper vendor handling have a dual impact, affecting both the quality and safety of the product thereby leading to health problems of the ignorant consumers [8]. Sachet water has been studied and reported in Nigeria to contain bacteria such as *Pseudomonas* sp*., oocysts of Cryptosporidia* sp., *Klebsiella* sp., *Bacillus* sp., and *Streptococcus* sp. [8]-[15], causing infectious disease such as typhoid, diarrhea, cholera, Tuberculosis, etc. despite efforts made by the National Agency for Food and Drug Administration and Control (NAFDAC) in Nigeria to enforce compliance with internationally defined drinking water guidelines. With the recent increase in the consumption of sachet water in major cities and towns of Nigeria due to the lack of portable drinking water, there is a need to investigate the quality and prevalence of possible contaminants in this water that may have toxicological effects on humans when consumed.

In Ishiagu town, however, good quality drinking water is not always readily available to inhabitants. The municipal water supply from the State Water Cooperation is currently out of operation, resulting in the booming of sachet water retail businesses in the state and nationwide. Consequently, these retailers or vendors are often seen storing and displaying sachet water on the bare floor. These bags of sachet water may be there for weeks until they are sold. This work is therefore aimed at investigating the quality of sachet water stored and sold in Ishiagu, Ivo Local Government Area of Ebonyi State, Nigeria.

2. Materials and Methods

2.1. Study Design

To achieve the aim of this study, only retail shops were considered because they supply directly to consumers. The physicochemical and microbiological properties of sachet water were examined, and the results were compared with WHO and NAFDAC standards. Meanwhile, NAFDAC standard for drinking water is a collaborative effort with the Nigerian Standard for Drinking Water Quality (NSDWQ). In turn, NAFDAC uses this standard as a basis for regulating and enforcing the quality of packaged water products in Nigeria.

2.2. Study Area

Ishiagu and Akaeze are two towns that make up the Ivo Local Government Area of Ebonyi State, Nigeria. Ishiagu has the largest area in Ivo with about 450 km^2 and supports an estimated population of over two hundred and fifty thousand people [16]. It lies between latitude 5˚56’56” to 5˚57’1” N and longitude 7˚34’32” to 7˚34’57” E. The temperature range is 26.5 - 27.5˚C [17] [18]. Ishiagu is one of the economically important towns in Ebonyi State, located on the plains of the South-eastern Savannah belt in Nigeria. Its relevance is basically due to agricultural, Lead-Zinc mines, and hard rock (aggregate) quarrying activities that have been ongoing in the area since the 1950s [16]. It has federal establishments like Federal College of Agriculture, and Federal College of Forest Resources Management. The inhabitants of the area and the surroundings are mostly farmers, stone dealers, students, and public servants.

2.3. Sources of Data

Data for this study were obtained from two main sources; primary and secondary data. The primary data includes the 50 cL sachet water samples sourced from various locations of the Eight different selected communities of Ishiagu such as Amagu, Ameze, Amonye, Amokwe, Ihie, Ihietutu, Ngwogwo, Okue, while the secondary data are those documents that contain the set sets standards for water quality which was obtained from the regulatory agencies. Meanwhile, the factories producing these sachet water sources their raw water from underground, precisely boreholes.

2.4. Sample Collection

Here, [1] method was adopted with little modification. Four sachets from each Triplicate batch of the six different brands of 50 cL sachet water with the National Agency for Food and Drug Administration and Control (NAFDAC) certification were purchased randomly from the commonly patronized retail shops by the inhabitants of the selected study communities. These six brands of sachet water selected for this study are frequently supplied, most widely sold, consumed, and recognized in Ishiagu. They have a dominant presence in the local market and are therefore considered representative of the commonly available sachet water in the area. The retail shops were expressed in an average of 4 sub-samples randomly selected in each location. The label information of the samples was examined physically according to the method described by [19]. All samples were collected in 2 L sterilized plastic bottles, while the pH and some other physical parameters were measured *in situ*. The plastic bottles were properly labeled according to the brand SW1, SW2, SW3, SW4, SW5, and SW6. The samples were kept in a mini cooler with ice packs and transported to the Federal College of Agriculture laboratory within the region where the sample analyses were carried out within 12 hours of collection.

2.5. Water Quality Analysis

The physical, chemical, and microbial quality of the water samples were analyzed as follows.

2.5.1. Physical Analysis of the Sachet Water Sample

During sampling, the pH, temperature, total dissolved solid (TDS), and electrical conductivity (EC) were measured *in situ* with the aid of a portable digital HANNA multi-purpose meter (Model: HI9813-6) immediately after calibration.

2.5.2. Chemical Analysis of the Sachet Water Sample

Total Alkalinity (TA) was determined by Titrimetric method. 50 ml of the water sample was introduced into a 250 ml conical flask, 2 - 3 drops of phenolphthalein indicator were added, and the mixture was titrated against the 0.02N H_2SO_4 (in the burette) till a color change from pink to colorless is observed, the titre value was recorded (V_{ph}). Then with the same sample, 2 - 3 drops of methyl orange indicator were added, and the titration was continued till the colour changed from yellow to pink. The titre value was also recorded (V_{mo}). For consistent results, 3 replicates were done for each sample. Total alkalinity was calculated as follows:

$$\text{Total Alkalinity}\left(\text{as mg.CaCO}_3/\text{L}\right)=\frac{\left(V_{ph}+V_{mo}\right)\times 0.02\times 50\times 1000}{V} \tag{1}$$

where V = volume of water sample, and 50 is the equivalent weight of $CaCO_3$.

Total Hardness (TH) was determined using EDTA method, by introducing 50 ml of the water sample into a 250 ml conical flask to which 2 ml of ammonium buffer solution (pH 10.0) was added. 2 drops of Eriochrome Black T indicator were added, and the mixture was titrated with 0.01 N Ethylenediaminetetraacetic acid (*EDTA*) till the color changes from wine red to blue. Then the titre value (V_{EDTA}) was recorded. The total hardness is expressed in terms of calcium carbonate equivalent in mg/L as follows:

$$\text{Total Hardness}\left(\text{mg.CaCO}_3/\text{L}\right)=\frac{V_{EDTA}\times 0.01\times 50\times 1000}{V} \quad (2)$$

Calcium, (Ca^{2+} in mg/L) concentration present in the water sample was determined using the same titration method, by introducing 50 ml of the water sample into a conical flask to which 4 ml of 0.01 NaOH buffer solution was added to raise the pH of the final solution up to range of 12 to 13. 1 ml of muroxide indicator was also added and the solution was thoroughly mixed and titrated with standard 0.01 N EDTA solution with continuous stirring till the colour changed from pink to purple at the end point, the titre value was recorded. Calcium present in the sample from the above titration was calculated as follows:

$$\text{Calcium}\left(\text{mg.Ca}^{2+}/\text{L}\right)=\frac{V_{EDTA}\times 400.8}{V} \quad (3)$$

where V_{EDTA} = Volume of EDTA consumed for the sample (ml).

The magnesium, (Mg^{2+} in mg/L) concentration present in the water sample can be deducted from the relationship of the total hardness as shown in Equation (6) below:

$$\begin{aligned}&\text{Total Hardness}\left(\text{mg/L as CaCO}_3\right)\\&=\text{Calcium Hardness}\left(\text{mg/L as CaCO}_3\right)+\text{Magnesium Hardness}\left(\text{mg/L as CaCO}_3\right) \quad (4)\\&=\ 2.50\times\text{Calcium conc.}\left(\text{mg/L as Ca}^{2+}\right)+4.12\times\text{Magnesium conc.}\left(\text{mg/L as Mg}^{2+}\right)\end{aligned}$$

Substitute the values of Equation (2) and (3) into Equation (4) gives the Magnesium conc. (mg/L as Mg^{2+}) present in the water sample.

Chloride ion (Cl^-) was determined using Argentometric method by pipetting 50 ml of the water sample into 250 ml conical flask. 1 ml of freshly prepared potassium chromate (K_2CrO_4) solution indicator was added and titrated against standard 0.0282 N silver nitrate ($AgNO_3$) solution. Shake the solution till it changes from yellow to red at the end point. The titration was repeated three times for concurrent volume to be obtained. A reagent blank titration was also carried out in parallel to the sample titration, and the concentration of chloride was calculated using the following formula:

$$\text{Chlorides in mg/L}=\frac{\left(V_S-V_B\right)\times N\times 35.45\times 1000}{V} \quad (5)$$

V_S = Silver nitrate solution, in ml for water sample titration, V = volume of the sample taken (ml).

V_B = Silver nitrate solution, used for blank titration (ml), N = Normality of the silver nitrate solution.

Sodium (Na^+) and potassium (K^+) in the water sample were determined using flame photometric method [20]. The flame photometer was calibrated using the standard solution 10, 20, 30, 40 and 50 ppm prepared from 1000 ppm stock solution of sodium and potassium. Other parts of the instrument parameters were adjusted, precautional measures were put in place to ensure optimum performance and accurate flame tuned. Blank was aspirated. Thereafter after the instrumental calibration, 100 ml of each water sample collected were run into the flame photometer. The photometric emission values of sodium and potassium detected by the photometer was recorded, the values were traced in the calibration curve plotted against the standard solution concentration in ppm (mg/L), thereby obtaining the actual concentration of sodium (Na^+. mg/L) and potassium (K^+. mg/L) in the water sample.

$$\left[\mathrm{Na}^{+}\right]\ \mathrm{mg/L} = \left(\frac{\text{Absorbance Na}}{\text{Slope Na}}\right) + \text{Intercept Na} \tag{6}$$

$$\left[\mathrm{K}^{+}\right]\ \mathrm{mg/L} = \left(\frac{\text{Absorbance K}}{\text{Slope K}}\right) + \text{Intercept K} \tag{7}$$

2.5.3. Microbiological Analysis of the Sachet Water Sample

1) Preparation of Culture media

For each brand of sachet water from each location, a designated edge of the sachet was disinfected with 70% ethanol, then aseptically opened using sterile scissors, and its contents transferred to a sterile measuring cylinder [21]. The culture media used includes Nutrient agar and M-Endo agar. They were all prepared according to the Manufacturers' instruction and specifications.

Preparation and Sterilization of Nutrient Agar (NA): 25.0 g of Nutrient agar powder was weighed into 1 liter of distilled water. The mixture was heated and stirred constantly until completely dissolved. The dissolved agar was autoclaved at 121˚C for 20 minutes and was allowed to cool at 50˚C. After the pH has been verified (7.0 ± 0.2), 25 mL of NA was poured into each sterile plate and allowed to solidify at room temperature (25˚C).

Preparation and Sterilization of M-Endo Agar (MEA): 40.0 g of M-Endo agar powder was weighed into 1 liter of distilled water. The mixture was heated and stirred constantly until fully dissolved. The dissolved agar was transferred to autoclave containers, sealed and was autoclaved at 121˚C for 20 minutes. Afterward, it was allowed to cool at 50˚C and the pH verified (7.0 ± 0.2), then 25 mL of MEA was later poured into each sterile plate and allowed to solidify at room temperature (25˚C).

2) Pour Plate Technique

This analysis was carried out using pour plate method by [22]. 1 ml of each sachet water sample was diluted and 1 ml of an appropriate dilution was inoculated on 15 mL sterile Nutrient agar (which provides a general estimate of microbial load) into plates and incubated at 35˚C for 72 hours, after which visible colonies were counted, and results were expressed in cfu/ml as follows:

$$\text{Total Plate count}\left(\text{CFU/mL}\right) = \frac{\text{No. of colonies}}{\text{Vol. of water sample}\left(\text{mL}\right)} \times DF \quad (8)$$

Using dilution factor of 1:10, gave $DF = 10$, therefore,

$$\text{Total Plate count}\left(\text{CFU/mL}\right) = \frac{\text{No. of colonies}}{\text{Vol. of water sample}\left(\text{mL}\right)} \times 10 \quad (9)$$

3) Membrane Filtration Technique

For coliform count, this membrane filtration method described by [23] was strictly followed. Inside aseptic conditions, membrane filtration apparatus was set and disinfected with 70% ethanol. 100 mL water sample was filtered through the membrane (cellulose) filter of pore size 0.45 µm. With the help of sterile forceps, the filter paper was transferred to M-Endo agar plates. The M-endo agar plates were marked and were incubated at 37˚C for 24 ± 2 hours. The observed colonies counted at this stage are presumed to be Coliform bacteria in the initial filtrated 100mL water sample. This was calculated as follows:

$$\text{Total Coliform count}\left(\text{CFU/100mL}\right) = \frac{\text{No. of TC colonies}}{\text{Vol. of water sample }\left(\text{mL}\right)} \times DF \times 100 \quad (10)$$

where TC is total coliform, DF is the dilution factor. But, since the water sample is undiluted, $DF = 1$ (*i.e* $DF = 1:1$), Therefore, the total coliform bacteria per 100 mL of undiluted water is given as:

$$\text{Total Coliform count}\left(\text{CFU/100mL}\right) = \frac{\text{No. of TC colonies}}{\text{Vol. of water sample }\left(\text{mL}\right)} \times 100 \quad (11)$$

2.6. Data Analysis

Data generated from the laboratory analyses were recorded and analyzed using Microsoft Excel 365 data spread sheet. Results were presented as mean ± standard deviations. ANOVA (Analysis of variance) was used to compare mean values of the parameters at $p < 0.05$.

3. Results and Discussion

The National Agency for Food, Drug Administration and Control (NAFDAC) in Nigeria requires that all the labeling of food and drugs must be accurate and informative. The labeling should include contact information, manufacturer's name, manufacturing date, NAFDAC registration number, batch number, expiry date (Best before date) and nutritional information [24] [25]. The result of the physical examination of the sachet water investigated in this study is presented in Table 1. It revealed that all the sachet water investigated had 100% compliance in term of the product names, manufacturing addresses, and NAFDAC number. This information is crucial as it tells the consumer whether the water sample remains within its safe consumption period or has exceeded its shelf life. However, all the sachet water were observed to be without batch number, manufacturing date, expiry date and mineral composition on their labelling. The act of non-compliance by the water production factories even though they were duly certified to operate as evident in the NAFDAC registration provided in this present study is a source of great concern as the packaged water sold to the entire public is liable to cause health risk when consumed.

Table 1. Results of physical examination of sachet water brands sold and consumed in Ishiagu, Nigeria.

Water Sample	Product Name	Manufacturer Address	Manufacturering Date	Batch No.	Expiry Date	NAFDAC No.	Mineral Composition
NAFDAC/WHO	+	+	+	+	+	+	+
SW1	+	+	-	+	-	+	-
SW2	+	+	-	-	-	+	-
SW3	+	+	-	+	-	+	-
SW4	+	+	-	+	-	+	-
SW5	+	+	-	-	-	+	-
SW6	+	+	-	+	-	+	-

Where, + = Indicated – = Not indicated.

The results of the physical, chemical and microbiological qualities of sachet water analyzed were compared with the recommended NAFDAC/WHO guidelines for quality water as presented in **Tables 1-8**.

Table 2. Physicochemical and microbiological quality of sachet water brands sold and consumed in Amagu, Ishiagu.

Brands / Parameters	SW1	SW2	SW3	SW4	SW5	SW6	NAFDAC 2021	WHO 2021
pH	6.60 ± 0.43	6.50 ± 0.05	7.60 ± 0.23	6.40 ± 0.66	6.20 ± 0.02	7.10 ± 0.34	6.5 - 8.5	6.5 - 8.5
Temp (˚C)	26.3 ± 1.01	26.3 ± 0.76	25.8 ± 0.32	26.4 ± 1.22	26.7 ± 0.72	25.8 ± 0.01	20 - 30˚C	20 - 25˚C
EC (μS/cm)	11.56 ± 0.42	11.78 ± 2.11	16.26 ± 1.44	12.24 ± 0.11	12.65 ± 0.00	26.23 ± 0.11	≤ 250	≤ 400
TDS ($m \cdot gL^{-1}$)	14.34 ± 0.06	12.54 ± 1.02	5.82 ± 1.22	5.76 ± 0.01	14.23 ± 1.22	14.53 ± 0.32	≤ 250	≤ 300
TA ($m \cdot gL^{-1}$ $CaCO_3$)	20.42 ± 0.01	20.52 ± 0.02	30.21 ± 0.11	23.81 ± 0.00	19.53 ± 0.64	31.40 ± 1.22	30 - 200	200
TH ($m \cdot gL^{-1}$ $CaCO_3$)	26.62 ± 0.01	21.71 ± 1.22	17.73 ± 0.34	28.20 ± 0.11	12.69 ± 2.11	20.31 ± 0.88	50 - 200	100 - 300
Ca^{2+} ($m \cdot gL^{-1}$)	10.12 ± 0.35	8.25 ± 0.62	6.74 ± 0.54	10.72 ± 1.02	4.82 ± 1.01	7.72 ± 0.00	30 - 200	30 - 200
Mg^{2+} ($m \cdot gL^{-1}$)	0.32 ± 0.99	0.26 ± 1.11	0.22 ± 0.10	0.34 ± 0.00	0.15 ± 1.22	0.25 ± 0.63	10 - 50	30 - 50
Na^{+} ($m \cdot gL^{-1}$)	2.34 ± 0.34	2.67 ± 0.73	2.42 ± 0.01	2.04 ± 0.10	1.45 ± 1.22	2.12 ± 0.53	20 - 200	≤200
K^{+} ($m \cdot gL^{-1}$)	0.45 ± 01.00	0.53 ± 0.02	0.55 ± 0.00	0.46 ± 1.22	0.54 ± 0.11	0.43 ± 0.50	1 - 10	≤200

Continued

Cl^- ($m \cdot gL^{-1}$)	10.43 ± 2.02	8.37 ± 0.56	11.64 ± 0.22	7.37 ± 2.11	7.54 ± 0.66	10.04 ± 1.24	20 - 200	250
TPC (CFU/mL)	3.0 ± 0.25	0	12.0 ± 0.02	0	0	4.0 ± 0.01	≤100	≤100
TCC (CFU/100mL)	0	0	0	0	0	0	0	0

Results are presented as mean ± standard deviation where n = 3. Data were statistically compared with WHO/NAFDAC standard at $p < 0.05$.

Table 3. Physicochemical and microbiological quality of sachet water brands sold and consumed in Ameze, Ishiagu.

Parameters \ Brands	SW1	SW2	SW3	SW4	SW5	SW6	NAFDAC 2021	WHO 2021
pH	6.70 ± 1.11	6.40 ± 0.63	7.50 ± 0.88	7.10 ± 0.00	6.50 ± 0.10	7.10 ± 0.01	6.5 - 8.5	6.5 - 8.5
Temp (˚C)	26.5 ± 1.42	26.2 ± 0.01	26.9 ± 0.63	26.7 ± 0.36	26.3 ± 0.47	26.8 ± 0.04	20 - 30˚C	20 - 25˚C
EC (µS/cm)	12.03 ± 0.43	11.45 ± 0.16	16.22 ± 1.11	12.35 ± 0.01	12.68 ± 0.42	16.30 ± 0.62	≤ 250	≤ 400
TDS ($m \cdot gL^{-1}$)	8.66 ± 1.22	8.81 ± 1.21	5.11 ± 0.01	5.16 ± 0.00	13.2 ± 0.02	12.45 ± 0.61	≤ 250	≤ 300
TA (mgL^{-1} $CaCO_3$)	20.45 ± 0.11	20.56 ± 0.22	30.32 ± 0.01	23.93 ± 0.03	20.33 ± 0.13	20.05 ± 0.53	30 - 200	200
TH ($m \cdot gL^{-1}$ $CaCO_3$)	26.74 ± 0.00	21.77 ± 2.12	17.66 ± 0.06	28.62 ± 1.22	12.11 ± 1.22	19.54 ± 0.11	50 - 200	100 - 300
Ca^{2+} ($m \cdot gL^{-1}$)	10.16 ± 0.24	8.27 ± 0.02	6.71 ± 0.25	10.88 ± 0.00	4.60 ± 0.11	7.43 ± 0.10	30 - 200	30 - 50
Mg^{2+} ($m \cdot gL^{-1}$)	0.32 ± 1.22	0.26 ± 0.44	0.21 ± 0.56	0.35 ± 0.45	0.15 ± 0.28	0.24 ± 0.01	10 - 50	30 - 50
Na^+ ($m \cdot gL^{-1}$)	2.30 ± 0.25	2.54 ± 0.24	2.45 ± 0.63	2.14 ± 0.22	2.18 ± 0.65	2.21 ± 0.04	20 - 200	≤ 200
K^+ ($m \cdot gL^{-1}$)	0.65 ± 0.03	0.62 ± 0.04	0.70 ± 0.02	0.53 ± 0.00	0.62 ± 0.45	0.52 ± 0.56	1 - 10	≤ 200
Cl^- ($m \cdot gL^{-1}$)	9.44 ± 0.01	8.56 ± 0.01	11.60 ± 0.96	8.35 ± 1.22	7.34 ± 0.40	10.35 ± 1.11	20 - 200	250
TPC (CFU/mL)	0	0	0	0	0	0	≤100	≤100
TCC (CFU/100mL)	0	0	0	0	0	0	0	0

Results are presented as mean ± standard deviation where n = 3. Data were statistically compared with WHO/NAFDAC standard at $p < 0.05$.

Table 4. Physicochemical and microbiological quality of sachet water brands sold and consumed in Amonye, Ishiagu.

Parameters \ Brands	SW1	SW2	SW3	SW4	SW5	SW6	NAFDAC 2021	WHO 2021
pH	6.70 ± 0.24	6.40 ± 1.00	7.10 ± 1.08	7.10 ± 0.35	6.80 ± 0.10	7.10 ± 0.67	6.5 - 8.5	6.5 - 8.5

Continued

Temp (˚C)	26.7 ± 0.11	26.7 ± 0.10	26.2 ± 0.38	26.9 ± 0.04	26.7 ± 0.01	27.1 ± 1.00	20 - 30˚C	20 - 25˚C
EC (µS/cm)	11.11 ± 0.78	12.33 ± 0.00	15.87 ± 0.73	12.43 ± 0.20	12.04 ± 0.22	24.83 ± 1.02	≤250	≤400
TDS (m·gL^{-1})	14.46 ± 0.38	12.01 ± 0.07	7.77 ± 0.04	7.64 ± 0.39	15.44 ± 1.00	16.5 ± 0.22	≤250	≤300
TA (m·gL^{-1} $CaCO_3$)	20.51 ± 1.00	20.32 ± 0.92	30.4 ± 0.01	23.53 ± 1.00	20.11 ± 0.23	31.68 ± 1.11	30 - 200	200
TH (m·gL^{-1} $CaCO_3$)	26.33 ± 0.00	21.22 ± 1.03	17.46 ± 0.38	28.64 ± 2.01	12.19 ± 3.01	20.62 ± 1.72	50 - 200	100 - 300
Ca^{2+} (m·gL^{-1})	10.01 ± 0.47	8.064 ± 0.22	6.63 ± 0.01	10.88 ± 0.35	4.63 ± 0.37	7.84 ± 0.88	30 - 200	30 - 50
Mg^{2+} (m·gL^{-1})	0.32 ± 0.21	0.26 ± 0.37	0.21 ± 0.11	0.35 ± 0.02	0.15 ± 0.06	0.25 ± 1.03	10 - 50	30 - 50
Na^+ (m·gL^{-1})	2.54 ± 0.02	2.44 ± 0.40	2.41 ± 0.43	2.06 ± 0.03	2.23 ± 0.35	2.65 ± 0.10	20 - 200	≤200
K^+ (m·gL^{-1})	0.43 ± 0.11	0.58 ± 0.83	0.60 ± 1.02	0.61 ± 0.01	0.65 ± 0.22	0.59 ± 0.01	1 - 10	≤200
Cl^- (m·gL^{-1})	10.15 ± 0.47	8.54 ± 0.10	11.68 ± 1.22	7.89 ± 0.01	7.47 ± 0.25	10.46 ± 1.03	20 - 200	250
TPC (CFU/mL)	0	0	0	5.0 ± 0.02	0	0	≤100	≤100
TCC (CFU/100mL)	0	0	0	0	0	0	0	0

Results are presented as mean ± standard deviation where n = 3. Data were statistically compared with WHO/NAFDAC standard at $p < 0.05$.

Table 5. Physicochemical and microbiological quality of sachet water brands sold and consumed in Amokwe, Ishiagu.

Brands / Parameters	SW1	SW2	SW3	SW4	SW5	SW6	NAFDAC 2021	WHO 2021
pH	6.50 ± 0.00	6.70 ± 0.21	7.20 ± 0.01	7.10 ± 0.20	7.20 ± 0.02	7.10 ± 0.03	6.5 - 8.5	6.5 - 8.5
Temp (˚C)	26.1 ± 0.23	26.2 ± 0.02	26.9 ± 0.22	27.1 ± 0.04	26.5 ± 1.02	27.6 ± 0.33	20 - 30˚C	20 - 25˚C
EC (µS/cm)	12.1 ± 0.82	12.44 ± 0.23	14.75 ± 0.00	12.34 ± 0.41	12.44 ± 2.04	14.53 ± 0.47	≤250	≤400
TDS (m·gL^{-1})	13.42 ± 0.47	13.53 ± 0.47	10.05 ± 0.46	10.6 ± 1.28	13.46 ± 0.64	15.49 ± 0.10	≤250	≤300
TA (m·gL^{-1} $CaCO_3$)	20.53 ± 0.32	20.50 ± 0.11	30.35 ± 0.74	24.46 ± 1.02	20.56 ± 0.58	25.87 ± 0.33	30 - 200	200
TH (m·gL^{-1} $CaCO_3$)	26.99 ± 0.01	24.32 ± 1.00	20.11 ± 0.02	26.77 ± 0.57	16.57 ± 1.02	19.99 ± 0.58	50 - 200	100 - 300
Ca^{2+} (m·gL^{-1})	10.26 ± 0.37	9.24 ± 1.33	7.64 ± 0.01	10.17 ± 1.02	6.29 ± 0.00	7.59 ± 0.75	30 - 200	30 - 50

Continued

Mg^{2+} (m·gL⁻¹)	0.33 ± 0.55	0.29 ± 0.10	0.24 ± 0.44	0.32 ± 0.54	0.20 ± 0.11	0.24 ± 0.55	10 - 50	30 - 50
Na^{+} (m·gL⁻¹)	2.30 ± 0.64	3.02 ± 0.00	2.45 ± 0.46	2.44 ± 0.70	2.48 ± 0.78	2.88 ± 0.57	20 - 200	≤ 200
K^{+} (m·gL⁻¹)	0.75 ± 1.00	0.66 ± 0.26	0.72 ± 0.22	0.67 ± 0.40	0.68 ± 0.22	0.63 ± 0.22	1 - 10	≤ 200
Cl^{-} (m·gL⁻¹)	9.05 ± 2.83	8.67 ± 0.77	11.57 ± 0.02	9.58 ± 0.11	7.43 ± 0.25	10.58 ± 0.75	20 - 200	250
TPC (CFU/mL)	0	0	0	0	0	0	≤100	≤100
TCC (CFU/100mL)	0	0	0	0	0	0	0	0

Results are presented as mean ± standard deviation where n = 3. Data were statistically compared with WHO/NAFDAC standard at $p < 0.05$.

Table 6. Physicochemical and microbiological quality of sachet water brands sold and consumed in Ihie, Ishiagu.

Brands / Parameters	SW1	SW2	SW3	SW4	SW5	SW6	NAFDAC 2021	WHO 2021
pH	6.70 ± 0.57	6.50 ± 0.22	7.30 ± 0.13	6.80 ± 0.21	6.30 ± 0.23	7.10 ± 0.21	6.5 - 8.5	6.5 - 8.5
Temp (˚C)	26.4 ± 0.70	26.3 ± 0.23	25.8 ± 0.43	26.4 ± 0.00	26.40 ± 0.43	26.60 ± 0.32	20 - 30˚C	20 - 25˚C
EC (μS/cm)	11.54 ± 0.03	11.69 ± 0.64	16.3 ± 0.15	12.3 ± 0.46	12.72 ± 0.11	24.11 ± 0.22	≤250	≤400
TDS (m·gL⁻¹)	15.26 ± 0.06	14.36 ± 0.21	6.78 ± 0.15	5.66 ± 0.13	14.50 ± 0.00	16.77 ± 1.01	≤250	≤300
TA (m·gL⁻¹ $CaCO_3$)	20.41 ± 0.57	20.52 ± 0.00	30.21 ± 0.20	23.47 ± 0.13	19.56 ± 0.12	31.46 ± 0.23	30 - 200	200
TH (m·gL⁻¹ $CaCO_3$)	26.73 ± 0.32	21.75 ± 0.02	17.44 ± 0.14	28.29 ± 0.35	12.70 ± 0.56	20.35 ± 0.45	50 - 200	100 - 300
Ca^{2+} (m·gL⁻¹)	10.16 ± 0.51	8.27 ± 0.22	6.63 ± 0.32	10.75 ± 0.60	4.83 ± 0.12	7.73 ± 1.40	30 - 200	30 - 50
Mg^{2+} (m·gL⁻¹)	0.32 ± 0.02	0.26 ± 0.10	0.21 ± 0.40	0.34 ± 0.25	0.15 ± 0.22	0.25 ± 1.11	10 - 50	30 - 50
Na^{+} (m·gL⁻¹)	2.78 ± 0.32	2.67 ± 0.12	2.42 ± 0.45	2.33 ± 1.04	2.33 ± 0.56	2.55 ± 0.23	20 - 200	≤ 200
K^{+} (m·gL⁻¹)	0.45 ± 0.35	0.53 ± 0.16	0.45 ± 0.55	0.47 ± 2.00	0.54 ± 1.22	0.50 ± 0.80	1 - 10	≤ 200
Cl^{-} (m·gL⁻¹)	10.41 ± 0.22	9.14 ± 0.22	11.62 ± 1.04	7.37 ± 0.46	7.54 ± 0.46	10.31 ± 0.46	20 - 200	250
TPC (CFU/mL)	0	0	0	0	0	0	≤100	≤100
TCC (CFU/100mL)	0	0	0	0	0	0	0	0

Results are presented as mean ± standard deviation where n = 3. Data were statistically compared with WHO/NAFDAC standard at $p < 0.05$.

Table 7. Physicochemical and microbiological quality of sachet water brands sold and consumed in Ihietutu, Ishiagu.

Parameters \ Brands	SW1	SW2	SW3	SW4	SW5	SW6	NAFDAC 2021	WHO 2021
pH	6.60 ± 0.54	6.40 ± 0.02	7.30 ± 0.01	6.45 ± 0.01	6.84 ± 0.21	6.67 ± 0.12	6.5 - 8.5	6.5 - 8.5
Temp (˚C)	26.20 ± 0.54	26.90 ± 0.42	26.30 ± 0.19	26.70 ± 0.34	26.80 ± 0.55	26.80 ± 0.52	20 - 30˚C	20 - 25˚C
EC (µS/cm)	12.11 ± 1.02	11.27 ± 0.46	16.30 ± 0.22	12.33 ± 0.12	12.46 ± 0.01	26.34 ± 0.03	≤250	≤400
TDS ($m \cdot gL^{-1}$)	13.60 ± 0.23	13.35 ± 0.44	6.57 ± 0.22	5.54 ± 0.18	13.75 ± 0.42	15.53 ± 0.12	≤250	≤300
TA ($m \cdot gL^{-1}$ $CaCO_3$)	21.40 ± 0.15	20.99 ± 0.57	30.33 ± 0.23	23.81 ± 0.34	22.44 ± 0.50	25.35 ± 0.50	30 - 200	200
TH ($m \cdot gL^{-1}$ $CaCO_3$)	26.63 ± 0.43	22.32 ± 0.22	21.46 ± 0.24	28.78 ± 0.40	16.46 ± 0.12	20.75 ± 0.05	50 - 200	100 - 300
Ca^{2+} ($m \cdot gL^{-1}$)	10.12 ± 0.23	8.48 ± 0.70	8.15 ± 0.18	10.94 ± 0.57	6.25 ± 0.00	7.89 ± 0.05	30 - 200	30 - 50
Mg^{2+} ($m \cdot gL^{-1}$)	0.32 ± 0.76	0.27 ± 0.65	0.26 ± 1.01	0.35 ± 0.19	0.19 ± 0.57	0.25 ± 0.00	10 - 50	30 - 50
Na^{+} ($m \cdot gL^{-1}$)	2.31 ± 0.50	2.52 ± 0.30	2.45 ± 0.03	2.22 ± 0.01	2.31 ± 0.32	3.10 ± 0.60	20 - 200	≤ 200
K^{+} ($m \cdot gL^{-1}$)	0.63 ± 0.45	0.63 ± 0.46	0.63 ± 0.34	0.59 ± 0.10	0.70 ± 0.83	0.62 ± 0.02	1 - 10	≤ 200
Cl^{-} ($m \cdot gL^{-1}$)	9.15 ± 0.01	8.46 ± 0.89	11.56 ± 0.04	8.45 ± 0.10	8.36 ± 0.52	10.62 ± 0.32	20 - 200	250
TPC (CFU/mL)	4.0 ± 0.23	15.0 ± 0.11	2.0 ± 0.16	0	0	0	≤100	≤100
TCC (CFU/100mL)	0	2.0 ± 0.04	0	0	0	0	0	0

Results are presented as mean ± standard deviation where n = 3. Data were statistically compared with WHO/NAFDAC standard at $p < 0.05$.

Table 8. Physicochemical and microbiological quality of sachet water brands sold in Ngwogwo, Ishiagu.

Parameters \ Brands	SW1	SW2	SW3	SW4	SW5	SW6	NAFDAC 2021	WHO 2021
pH	7.10 ± 0.50	7.10 ± 0.21	7.40 ± 0.02	6.80 ± 0.34	7.30 ± 0.01	7.60 ± 0.03	6.5 - 8.5	6.5 - 8.5
Temp (˚C)	26.50 ± 0.02	26.70 ± 0.03	26.80 ± 0.20	26.80 ± 0.03	26.40 ± 0.00	26.90 ± 0.03	20 - 30˚C	20 - 25˚C
EC (µS/cm)	11.53 ± 0.22	11.76 ± 0.46	16.28 ± 0.02	12.33 ± 0.33	12.58 ± 0.22	22.43 ± 1.00	≤ 250	≤ 400
TDS ($m \cdot gL^{-1}$)	15.74 ± 0.45	14.93 ± 1.22	7.52 ± 0.41	7.68 ± 0.05	15.24 ± 0.66	16.58 ± 0.44	≤ 250	≤ 300

Continued

TA (m·gL⁻¹ $CaCO_3$)	20.44 ± 1.03	20.57 ± 0.57	30.27 ± 0.56	23.71 ± 0.23	19.83 ± 0.15	33.50 ± 0.29	30 - 200	200
TH (m·gL⁻¹ $CaCO_3$)	26.73 ± 0.22	21.73 ± 0.11	17.77 ± 0.10	28.40 ± 0.06	12.39 ± 0.34	20.71 ± 0.02	50 - 200	100 - 300
Ca^{2+} (m·gL⁻¹)	10.16 ± 0.04	8.25 ± 0.64	6.75 ± 0.22	10.79 ± 0.25	4.71 ± 0.05	7.87 ± 0.08	30 - 200	30 - 50
Mg^{2+} (m·gL⁻¹)	0.32 ± 1.04	0.26 ± 0.44	0.22 ± 0.02	0.34 ± 0.04	0.15 ± 0.00	0.25 ± 0.61	10 - 50	30 - 50
Na^{+} (m·gL⁻¹)	3.76 ± 0.05	3.07 ± 0.10	3.45 ± 0.22	3.78 ± 0.10	3.05 ± 0.08	3.16 ± 0.32	20 - 200	≤ 200
K^{+} (m·gL⁻¹)	0.65 ± 1.03	0.62 ± 0.32	0.72 ± 0.05	0.67 ± 0.06	0.64 ± 0.53	0.57 ± 0.30	1 - 10	≤ 200
Cl^{-} (m·gL⁻¹)	12.43 ± 1.00	12.35 ± 0.23	12.44 ± 0.22	10.33 ± 0.46	11.75 ± 1.04	10.04 ± 1.01	20 - 200	250
TPC (CFU/mL)	0	0	0	0	0	0	≤100	≤100
TCC (CFU/100mL)	0	0	0	0	0	0	0	0

Results are presented as mean ± standard deviation where n = 3. Data were statistically compared with WHO/NAFDAC standard at $p < 0.05$.

Table 9. Physicochemical and microbiological quality of sachet water brands sold and consumed in Okue, Ishiagu.

Parameters \ Brands	SW1	SW2	SW3	SW4	SW5	SW6	NAFDAC 2021	WHO 2021
pH	6.70 ± 0.03	6.80 ± 0.50	6.50 ± 0.05	6.30 ± 0.11	6.50 ± 0.02	6.70 ± 0.04	6.5 - 8.5	6.5 - 8.5
Temp (˚C)	26.30 ± 1.01	26.20 ± 0.44	26.40 ± 0.01	27.30 ± 0.01	27.10 ± 0.20	26.90 ± 0.13	20 - 30˚C	20 - 25˚C
EC (μS/cm)	12.57 ± 0.10	11.38 ± 0.33	16.75 ± 0.02	12.30 ± 0.45	12.63 ± 1.01	26.45 ± 1.02	≤ 250	≤ 400
TDS (m·gL⁻¹)	13.35 ± 1.01	13.55 ± 1.11	6.10 ± 0.40	6.05 ± 0.22	12.78 ± 0.11	15.48 ± 2.00	≤ 250	≤ 300
TA (m·gL⁻¹ $CaCO_3$)	21.55 ± 0.04	20.84 ± 0.22	30.39 ± 0.11	23.98 ± 0.35	20.38 ± 0.56	25.44 ± 0.01	30 - 200	200
TH (m·gL⁻¹ $CaCO_3$)	26.80 ± 0.03	21.79 ± 0.11	17.58 ± 0.15	28.66 ± 0.32	12.16 ± 0.34	20.48 ± 0.11	50 - 200	100 - 300
Ca^{2+} (m·gL⁻¹)	10.18 ± 0.22	8.28 ± 0.43	6.68 ± 1.02	10.89 ± 0.44	4.62 ± 0.05	7.78 ± 0.21	30 - 200	30 - 50
Mg^{2+} (m·gL⁻¹)	0.33 ± 0.48	0.26 ± 0.04	0.21 ± 0.20	0.35 ± 0.45	0.15 ± 0.30	0.25 ± 0.21	10 - 50	30 - 50
Na^{+} (m·gL⁻¹)	2.36 ± 0.22	2.54 ± 0.00	2.48 ± 1.04	2.25 ± 1.11	2.83 ± 1.00	2.45 ± 0.27	20 - 200	≤ 200
K^{+} (m·gL⁻¹)	0.69 ± 0.33	0.67 ± 0.06	0.70 ± 0.03	0.71 ± 0.20	0.65 ± 0.33	0.63 ± 0.24	1 - 10	≤ 200

Continued

Cl^- ($m{\cdot}gL^{-1}$)	8.84 ± 0.40	8.56 ± 1.03	11.43 ± 1.04	8.65 ± 0.34	7.44 ± 0.03	10.34 ± 0.33	20 - 200	250
TPC (CFU/mL)	0	0	0	0	0	0	≤100	≤100
TCC (CFU/100mL)	0	0	0	0	0	0	0	0

Results are presented as mean ± standard deviation where n = 3. Data were statistically compared with WHO/NAFDAC standard at $p < 0.05$.

In assessing the physicochemical qualities of the sachet water brands investigated, the pH of water plays an important role in controlling microorganisms and ensuring human health. Basically, the pH value is a good indicator of whether water is hard or soft. The pH of pure water is 7. In general, water with a pH lower than 7 is considered acidic, and with a pH greater than 7 is considered basic [26]. Consuming water with extremely high or low pH levels can cause digestive issues, respiratory problems, and even cancer. Therefore, monitoring the pH of water is important to keep it in check for a wide variety of applications. From the analysis results in Tables 1-8, the pH values of the sachet water in the various sampling locations range from 6.20 ± 0.02 to 7.60 ± 0.23. The highest pH values (levels) of 7.60 ± 0.23, 7.50 ± 0.88, 7.10 ± 1.08, 7.20 ± 0.01, 7.30 ± 0.13, 7.30 ± 0.01, 7.60 ± 0.03, and 6.80 ± 0.50 were recorded in SW3 at Amagu (Table 2), SW3 at Ameze (Table 3), SW3 at Amonye (Table 4), SW3 at Amokwe (Table 5), SW3 at Ihie (Table 6), SW3 at Ihietutu (Table 7), SW6 at Ngwogwo (Table 8), and SW2 at Okue (Table 9) station, respectively. The lowest pH values of 6.20 ± 0.02, 6.40 ± 0.63, 6.40 ± 1.00, 6.50 ± 0.00, 6.30 ± 0.23, 6.40 ± 0.02, 6.80 ± 0.34, and 6.30 ± 0.11 were recorded in SW5 at Amagu (Table 2), SW2 at Ameze (Table 3), SW2 at Amonye (Table 4), SW1 at Amokwe (Table 5), SW5 at Ihie (Table 6), SW2 at Ihietutu (Table 7), SW4 at Ngwogwo (Table 8), and SW4 at Okue (Table 9) station, respectively. The SW3 brand significantly recorded pH increase in more stations. However, the mean pH of the six-sachet water analyzed is significantly within the NAFDAC/WHO acceptable limit range (6.5 - 8.5) for quality water at $P<0.05$. It is very important to state that drinking water with pH values within regulatory guidelines is unlikely to pose health risks like acidosis [27].

The temperature of drinking water is important because it influences the physical, chemical and biochemical properties of water. Warm or high-water temperatures between 4˚C to 60˚C enhance the growth of micro-organisms by increasing their enzyme activities [17], but higher temperatures above 60˚C can destroy pathogens. From the analysis results in Tables 1-8, the mean temperatures of the sampled sachet waters in all the locations range from 25.8 ± 0.01˚C to 27.6 ± 0.33˚C. The highest temperature values (levels) of 26.7 ± 0.72˚C, 26.9 ± 0.63˚C, 27.1 ± 1.00˚C, 27.6 ± 0.33˚C, 26.60 ± 0.32˚C, 26.9 ± 0.42˚C, 26.9 ± 0.03˚C, and 27.30 ± 0.01˚C were recorded in SW5 at Amagu (Table 2), SW3 at Ameze (Table 3), SW6 at Amonye (Table 4), SW6 at Amokwe (Table 5), SW6 at Ihie (Table 6), SW2 at

Ihietutu (Table 7), SW6 at Ngwogwo (Table 8), and SW4 at Okue (Table 9) station, respectively. Likewise, the lowest temperature values of 25.8 ± 0.01˚C, 26.20 ± 0.01˚C, 26.20 ± 0.38˚C, 26.10 ± 0.23˚C, 25.80 ± 0.43˚C, 26.20 ± 0.54˚C, 26.40 ± 0.00˚C, and 26.20 ± 0.44˚C were recorded in SW6 at Amagu (Table 2), SW2 at Ameze (Table 3), SW3 at Amonye (Table 4), SW1 at Amokwe (Table 5), SW3 at Ihie (Table 6), SW1 at Ihietutu (Table 7), SW5 at Ngwogwo (Table 8), and SW2 at Okue (Table 9) station, respectively. The SW6 brand significantly recorded temperature increase in more stations. Nevertheless, the mean temperatures of the six-sachet water analyzed are significantly within the NAFDAC/WHO acceptable limit value range (20 - 30˚C) for quality water at $p < 0.05$ and are like those reported by [26] [28]. Moreover, these temperatures fell within the optimal growth temperature (20 - 45˚C) for mesophilic bacteria [29].

Electrical Conductivity is an indicator of the presence of dissolved and suspended solids in water quality. Water with high ions, mineral content or inorganic dissolved solids such as Chloride, nitrate, sodium, magnesium, calcium, and iron tends to have higher conductivity. From the analysis results in Tables 1-8, the electrical Conductivities (EC) of water samples in all the locations range from 11.11 ± 0.78 $\mu S \cdot cm^{-1}$ to 26.45 ± 1.02 $\mu S \cdot cm^{-1}$. The highest EC values (levels) of 26.23 ± 0.11 $\mu S \cdot cm^{-1}$, 16.30 ± 0.62 $\mu S \cdot cm^{-1}$, 24.83 ± 1.02 $\mu S \cdot cm^{-1}$, 14.75 ± 0.00 $\mu S \cdot cm^{-1}$, 24.11 ± 0.22 $\mu S \cdot cm^{-1}$, 26.34 ± 0.03 $\mu S \cdot cm^{-1}$, 22.43 ± 1.00 $\mu S \cdot cm^{-1}$, and 26.45 ± 1.02 $\mu S \cdot cm^{-1}$ were recorded in SW6 at Amagu (Table 2), SW6 at Ameze (Table 3), SW6 at Amonye (Table 4), SW3 at Amokwe (Table 5), SW6 at Ihie (Table 6), SW6 at Ihietutu (Table 7), SW6 at Ngwogwo (Table 8), and SW6 at Okue (Table 9) station, respectively. Likewise, the lowest EC values of 11.56 ± 0.42 $\mu S \cdot cm^{-1}$, 11.42 ± 0.16 $\mu S \cdot cm^{-1}$, 11.11 ± 0.78 $\mu S \cdot cm^{-1}$, 12.10 ± 0.02 $\mu S \cdot cm^{-1}$, 11.54 ± 0.03 $\mu S \cdot cm^{-1}$, 11.27 ± 0.46 $\mu S \cdot cm^{-1}$, 11.53 ± 0.22 $\mu S \cdot cm^{-1}$, and 11.38 ± 0.33 $\mu S \cdot cm^{-1}$ were recorded in SW1 at Amagu (Table 2), SW2 at Ameze (Table 3), SW1 at Amonye (Table 4), SW1 at Amokwe (Table 5), SW1 at Ihie (Table 6), SW2 at Ihietutu (Table 7), SW1 at Ngwogwo (Table 8), and SW2 at Okue (Table 9) station, respectively. The SW6 brand significantly recorded an EC increase in more stations. Nevertheless, the mean electrical conductivity of the six-sachet water analyzed is significantly below the NAFDAC/WHO acceptable range (≤250 - 400 $\mu S \cdot cm^{-1}$) for quality water at $p < 0.05$. This might be that the sachet waters analyzed contain fewer amounts of dissolved ions or salts, because the more ions that are present, the higher the conductivity of water, and the fewer ions that are in the water, the less conductive it is. Moreover, according to [30], conductivity values below 50 μScm^{-1} are regarded as low, those between 50 - 600 μScm^{-1} are said to be medium while values above 600 μScm^{-1} are high.

Total dissolved solids (TDS) encompass the total concentration of dissolved ion particles, including minerals, salts, and metals, that are smaller than 2 micons (0.002 mm) in size. Consuming water with high TDS levels can lead to kidney problems, high blood pressure, and other cardiovascular issues. From the analysis results in Tables 1-8, the total dissolved solids (TDS) of water samples in all the locations range from 5.11 ± 0.01 m·gL^{-1} to 16.77 ± 1.01 m·gL^{-1}. The highest TDS values (levels) of 14.53 ± 0.32 m·gL^{-1}, 12.45 ± 0.61 m·gL^{-1}, 16.50 ± 0.22 m·gL^{-1}, 15.49 ± 0.10 m·gL^{-1}, 16.77 ± 1.01 m·gL^{-1}, 15.53 ± 0.12 m·gL^{-1}, 16.58 ± 0.44 m·gL^{-1}, and 15.48 ± 2.00 m·gL^{-1} were recorded in SW6 at Amagu (**Table 2**), SW6 at Ameze (**Table 3**), SW6 at Amonye (**Table 4**), SW6 at Amokwe (**Table 5**), SW6 at Ihie (**Table 6**), SW6 at Ihietutu (**Table 7**), SW6 at Ngwogwo (**Table 8**), and SW6 at Okue (**Table 9**) station, respectively. On the other hand, the lowest TDS values of 5.76 ± 0.01 m·gL^{-1}, 5.11 ± 0.01 m·gL^{-1}, 7.64 ± 0.39 m·gL^{-1}, 10.05 ± 0.46 m·gL^{-1}, 5.66 ± 0.13 m·gL^{-1}, 5.54 ± 0.18 m·gL^{-1}, 7.52 ± 0.41 m·gL^{-1}, and 6.05 ± 0.22 m·gL^{-1} were recorded in SW4 at Amagu (**Table 2**), SW3 at Ameze (**Table 3**), SW4 at Amonye (**Table 4**), SW3 at Amokwe (**Table 5**), SW4 at Ihie (**Table 6**), SW4 at Ihietutu (**Table 7**), SW3 at Ngwogwo (**Table 8**), and SW4 at Okue (**Table 9**) station, respectively. The SW6 brand significantly recorded more TDS increase in more of the stations, suggesting high salts and minerals which must have contributed to the EC levels observed in the station. However, the mean TDS of the six-sachet water analyzed are significantly below the NAFDAC/WHO acceptable range (≤250 - 300 m·gL^{-1}) for quality water at $p < 0.05$.

Total alkalinity (TA) is a measure of the capacity of the water to neutralize acids [17]. It is also a measure of all dissolved carbonates, bicarbonates and hydroxide in water. From the analysis results in **Tables 1-8**, the total alkalinities (TA) of water samples in all the locations range from 19.53 ± 0.64 m·gL^{-1} $CaCO_3$ to 33.50 ± 0.29 m·gL^{-1} $CaCO_3$. The highest TA values (levels) of 31.40 ± 1.22 m·gL^{-1} $CaCO_3$, 30.32 ± 0.01 m·gL^{-1} $CaCO_3$, 31.68 ± 1.11 m·gL^{-1} $CaCO_3$, 30.35 ± 0.74 m·gL^{-1} $CaCO_3$, 31.46 ± 0.23 m·gL^{-1} $CaCO_3$, 30.33 ± 0.23 m·gL^{-1} $CaCO_3$, 33.50 ± 0.29 m·gL^{-1} $CaCO_3$, and 30.39 ± 0.11 m·gL^{-1} $CaCO_3$, were recorded in SW6 at Amagu (**Table 2**), SW3 at Ameze (**Table 3**), SW6 at Amonye (**Table 4**), SW3 at Amokwe (**Table 5**), SW6 at Ihie (**Table 6**), SW3 at Ihietutu (**Table 7**), SW6 at Ngwogwo (**Table 8**), and SW3 at Okue (**Table 9**) station, respectively. On the other hand, the lowest TA values of 19.53 ± 0.64 m·gL^{-1} $CaCO_3$, 20.05 ± 0.53 m·gL^{-1} $CaCO_3$, 20.11 ± 0.23 m·gL^{-1} $CaCO_3$, 20.50 ± 0.11 m·gL^{-1} $CaCO_3$, 19.56 ± 0.12 m·gL^{-1} $CaCO_3$, 20.99 ± 0.57 m·gL^{-1} $CaCO_3$, 19.83 ± 0.15 m·gL^{-1} $CaCO_3$, and 20.38 ± 0.56 m·gL^{-1} $CaCO_3$ were recorded in SW5 at Amagu (**Table 2**), SW6 at Ameze (**Table 3**), SW5 at Amonye (**Table 4**), SW2 at Amokwe (**Table 5**), SW5 at Ihie (**Table 6**), SW5 at Ihietutu (**Table 7**), SW5 at Ngwogwo (**Table 8**), and SW5 at Okue (**Table 9**) station, respectively. Here, SW6 and SW3 brands of sachet water significantly recorded TA increase in more of the stations, suggesting high salts and minerals which must have contributed to the TDS levels observed in the stations. However, the mean TA of the six-sachet water analyzed was significantly below the NAFDAC/WHO acceptable range (30 - 200 m·gL^{-1}) for quality water at $p < 0.05$. This present investigation was similar with studies earlier reported [26] [31] [32].

Total Hardness (TH) is a measure of water's mineral content, which affects its ability to form soap scum through the precipitation of calcium and magnesium salts. From the analysis results in **Tables 1-8**, the analyzed sachet water samples had total hardness range from 12.11 ± 1.22 m·gL^{-1} $CaCO_3$ to 28.78 ± 0.40 m·gL^{-1} $CaCO_3$ in all the locations. The highest TH values (levels) of 28.20 ± 0.11 m·gL^{-1} CaCO3, 28.62 ± 1.22 m·gL^{-1} CaCO3, 28.64 ± 2.01 m·gL^{-1} $CaCO_3$, 26.99 ± 0.01 m·gL^{-1} $CaCO_3$, 28.29 ± 0.35 m·gL^{-1} $CaCO_3$, 28.78 ± 0.40 m·gL^{-1} $CaCO_3$, 28.40 ± 0.06 m·gL^{-1} $CaCO_3$, and 28.66 ± 0.32 m·gL^{-1} $CaCO_3$, were recorded in SW4 at Amagu (Table 2), SW4 at Ameze (Table 3), SW4 at Amonye (Table 4), SW1 at Amokwe (Table 5), SW4 at Ihie (Table 6), SW4 at Ihietutu (Table 7), SW4 at Ngwogwo (Table 8), and SW4 at Okue (Table 9) station, respectively. On the other hand, the lowest TH values of 12.69 ± 2.11 m·gL^{-1} $CaCO_3$, 12.11 ± 1.22 m·gL^{-1} $CaCO_3$, 12.19 ± 3.01 m·gL^{-1} $CaCO_3$, 16.57 ± 1.02 m·gL^{-1} $CaCO_3$, 12.70 ± 0.56 m·gL^{-1} $CaCO_3$, 16.46 ± 0.12 m·gL^{-1} $CaCO_3$, 12.39 ± 0.34 m·gL^{-1} $CaCO_3$, and 12.16 ± 0.34 m·gL^{-1} $CaCO_3$ were recorded in SW5 at Amagu (Table 2), SW5 at Ameze (Table 3), SW5 at Amonye (Table 4), SW5 at Amokwe (Table 5), SW5 at Ihie (Table 6), SW5 at Ihietutu (Table 7), SW5 at Ngwogwo (Table 8), and SW5 at Okue (Table 9) station, respectively. Here, SW6 brand significantly recorded TH increase in more of the stations, while SW5 brand recorded low TH content in all stations. However, the mean THs of the six-sachet water analyzed were significantly below the NAFDAC and WHO acceptable range (50 - 200 m·gL^{-1} and 100 - 300 m·gL^{-1} respectively) for quality water at $p < 0.05$. Also, based on classification in terms of $CaCO_3$ m·gL^{-1} by [33], water quality ranges from 0 - 75 m·gL^{-1} (soft), 75 - 150 m·gL^{-1} (moderately hard), 150 - 300 m·gL^{-1} (hard), and above 300 m·gL^{-1} (very hard). It is classified in terms of $CaCO_3$ m·gL^{-1} with respect to water quality by Sawyer and Mc Carty, (1967) in the range of; 0 - 75 m·gL^{-1} (soft), 75 - 150 m·gL^{-1} (moderately hard), 150 - 300 m·gL^{-1} (hard), and above 300 m·gL^{-1} (very hard). Thus, the analyzed water samples fall into "soft" category and is considered very soft water. While it's not harmful to health, it may lack essential minerals such as calcium and magnesium and may increase microbial growth due to low alkalinity.

Calcium (Ca^{2+}) measures the concentration of dissolved calcium ions, which is biologically active form. Calcium plays a key role in bone formation and development [34]. Consuming water with adequate calcium levels can help support bone health and reduce the risk of osteoporosis. But excessive calcium consumption above standard limit can lead to kidney stone, hardening of arteries, and interference with iron absorption. In this study, calcium ions range from 4.60 ± 0.11 m·gL^{-1} to 10.88 ± 0.35 m·gL^{-1} in all the stations. The highest Ca^{2+} values of 10.12 ± 0.35 m·gL^{-1}, 10.88 ± 0.00 m·gL^{-1}, 10.88 ± 0.35 m·gL^{-1}, 10.26 ± 0.37 m·gL^{-1}, 10.75 ± 0.60 m·gL^{-1}, 10.12 ± 0.23 m·gL^{-1}, 10.79 ± 0.25 m·gL^{-1}, and 10.18 ± 0.22 m·gL^{-1}, were recorded in SW1 at Amagu (Table 2), SW4 at Ameze (Table 3), SW4 at Amonye (Table 4), SW1 at Amokwe (Table 5), SW4 at Ihie (Table 6), SW1 at Ihietutu (Table 7), SW4 at Ngwogwo (Table 8), and SW1 at Okue (Table 9) station, respectively. On the other hand, the lowest Ca^{2+} values of 4.82 ± 1.01 m·gL^{-1}, 4.60 ± 0.11 m·gL^{-1}, 4.63 ± 0.37 m·gL^{-1}, 6.29 ± 0.00 m·gL^{-1}, 4.83 ± 0.12 m·gL^{-1}, 6.25 ± 0.00 m·gL^{-1}, 4.71 ± 0.05 m·gL^{-1}, and 4.62 ± 0.05 m·gL^{-1} were recorded in SW5 at Amagu (**Table 2**), SW5 at Ameze (**Table 3**), SW5 at Amonye (**Table 4**), SW5 at Amokwe (**Table 5**), SW5 at Ihie (**Table 6**), SW5 at Ihietutu (**Table 7**), SW5 at Ngwogwo (**Table 8**), and SW5 at Okue (**Table 9**) station, respectively. Here, SW5 brand significantly recorded Ca^{2+} decrease in more of the stations. According to [35] [36] standards, the permissible range of calcium in drinking water is 50 - 200 mg/L and 50 mg/L respectively. However, the mean Ca^{2+} of the six-sachet water investigated were significantly below the NAFDAC and WHO given standards quality water at $p < 0.05$. This is like the low level of calcium reported for packaged water by [26] [37]. According to [34], an adult within the age bracket of 19 - 50 years requires 1000mg Ca^{2+}. The result of this water analysis signifies that only approximately 0.3% of calcium dietary reference can be fulfilled when 2 liters of packaged water are consumed daily.

Magnesium (Mg^{2+}) measures the concentration of dissolved magnesium ions, which is biologically active form. It is an essential nutrient just like calcium, sodium, and potassium needed for proper functioning of living organisms. It is the 8th most abundant element on earth crust and natural constituent of water [38]. Consuming water with high magnesium levels helps muscle and nerve functions, bone health, heart rhythm regulation, and energy production, but excessive magnesium consumption can lead to diarrhea, nausea and vomiting, etc. According to NAFDAC/WHO standards, the permissible range of magnesium in water should be 10-50 $m\cdot gL^{-1}$. In this present study, magnesium concentration in sachet water ranges from 0.20 ± 0.11 $m\cdot gL^{-1}$ to 0.35 ± 0.45 $m\cdot gL^{-1}$ in all the stations. The highest Mg^{2+} values of 0.34 ± 0.00 $m\cdot gL^{-1}$, 0.21 ± 0.56 $m\cdot gL^{-1}$, 0.35 ± 0.02 $m\cdot gL^{-1}$, 0.33 ± 0.55 $m\cdot gL^{-1}$, 0.34 ± 0.25 $m\cdot gL^{-1}$, 0.35 ± 0.19 $m\cdot gL^{-1}$, 0.34 ± 0.04 $m\cdot gL^{-1}$, and 0.35 ± 0.45 $m\cdot gL^{-1}$ were recorded in SW4 at Amagu (**Table 2**), SW3 at Ameze (**Table 3**), SW4 at Amonye (**Table 4**), SW1 at Amokwe (**Table 5**), SW4 at Ihie (**Table 6**), SW4 at Ihietutu (**Table 7**), SW4 at Ngwogwo (**Table 8**), and SW4 at Okue (**Table 9**) station, respectively. On the other hand, the lowest Mg^{2+} values of 0.15 ± 1.22 $m\cdot gL^{-1}$, 0.15 ± 0.28 $m\cdot gL^{-1}$, 0.15 ± 0.06 $m\cdot gL^{-1}$, 0.20 ± 0.11 $m\cdot gL^{-1}$, 0.15 ± 0.22 $m\cdot gL^{-1}$, 0.19 ± 0.57 $m\cdot gL^{-1}$, 0.15 ± 0.00 $m\cdot gL^{-1}$, and 0.15 ± 0.30 $m\cdot gL^{-1}$ were recorded in SW5 at Amagu (**Table 2**), SW5 at Ameze (**Table 3**), SW5 at Amonye (**Table 4**), SW5 at Amokwe (**Table 5**), SW5 at Ihie (**Table 6**), SW5 at Ihietutu (**Table 7**), SW5 at Ngwogwo (**Table 8**), and SW5 at Okue (**Table 9**) station, respectively. It is observed that SW5 brand significantly recorded Mg^{2+} decrease in more stations. However, the mean Mg^{2+} of all the six-sachet water investigated were significantly below the NAFDAC and WHO given standards for quality water at $p < 0.05$. This signifies that magnesium concentration is not enough in the sachet water brands analyzed.

Sodium (Na^{+}) measures the concentration of dissolved sodium ions, which is biologically active form. It plays a crucial role in maintaining proper bodily functions and is a vital mineral in our daily diets. Excessive sodium salt intake above the desirable limit can aggravate high blood pressure, heart disease, cardiovascular disease and kidney problems. From the analysis results in **Tables 1-8**, sodium ions range from 3.05 ± 0.08 m·gL^{-1} to 3.78 ± 0.10 m·gL^{-1} in all the stations. The highest Na^+ values of 2.67 ± 0.73 m·gL^{-1}, 2.54 ± 0.24 m·gL^{-1}, 2.06 ± 0.03 m·gL^{-1}, 3.02 ± 0.00 m·gL^{-1}, 2.78 ± 0.32 m·gL^{-1}, 3.10 ± 0.60 m·gL^{-1}, 3.78 ± 0.10 m·gL^{-1}, and 2.83 ± 1.00 m·gL^{-1} were recorded in SW2 at Amagu (**Table 2**), SW2 at Ameze (**Table 3**), SW4 at Amonye (**Table 4**), SW2 at Amokwe (**Table 5**), SW1 at Ihie (**Table 6**), SW6 at Ihietutu (**Table 7**), SW4 at Ngwogwo (**Table 8**), and SW5 at Okue (**Table 9**) station, respectively. Likewise, the lowest Na^+ values of 1.45 ± 1.22 m·gL^{-1}, 2.14 ± 0.22 m·gL^{-1}, 2.65 ± 0.10 m·gL^{-1}, 2.30 ± 0.64 m·gL^{-1}, 2.33 ± 0.56 m·gL^{-1}, 2.22 ± 0.01 m·gL^{-1}, 3.05 ± 0.08 m·gL^{-1}, and 2.25 ± 1.11 m·gL^{-1} were recorded in SW5 at Amagu (**Table 2**), SW4 at Ameze (**Table 3**), SW6 at Amonye (**Table 4**), SW1 at Amokwe (**Table 5**), SW5 at Ihie (**Table 6**), SW4 at Ihietutu (**Table 7**), SW5 at Ngwogwo (**Table 8**), and SW4 at Okue (**Table 9**) station, respectively. These values obtained are low when compared to 7.79 - 51.43mg/L and 11.55 - 51.43mg/L reported for sachet and bottled water in Bolgatanga municipality Ghana [39]. Moreover, the mean concentrations of Mg^{2+} in all the six-sachet water investigated were significantly low and below the NAFDAC and WHO given standards (≤200 m·gL^{-1}) for quality water at $p < 0.05$, exceeding this range could be harmful.

Potassium (K^+) measures the concentration of dissolved potasium ions, which is biologically active form. It is one of the essential nutrients and electrolyte needed for the body to function normally and help maintain fluid and blood volume in the body. Consuming little potassium and too much sodium in the body could lead to higher blood pressure but increasing potassium intake can reduce risk of heart diseases, stroke and blood pressure in hypertensive person [40] [41]. The present results in **Tables 1-8** revealed that potassium ions in study areas ranges from 0.43 ± 0.11 m·gL^{-1} to 0.75 ± 1.00 m·gL^{-1} in all the stations. The highest K^+ values of 0.55 ± 0.00 m·gL^{-1}, 0.70 ± 0.02 m·gL^{-1}, 0.65 ± 0.22 m·gL^{-1}, 0.75 ± 1.00 m·gL^{-1}, 0.54 ± 1.22 m·gL^{-1}, 0.70 ± 0.83 m·gL^{-1}, 0.72 ± 0.05 m·gL^{-1}, and 0.71 ± 0.20 m·gL^{-1} were recorded in SW3 at Amagu (**Table 2**), SW3 at Ameze (**Table 3**), SW5 at Amonye (**Table 4**), SW1 at Amokwe (**Table 5**), SW5 at Ihie (**Table 6**), SW5 at Ihietutu (**Table 7**), SW3 at Ngwogwo (**Table 8**), and SW4 at Okue (**Table 9**) station, respectively. On the other hand, the lowest K^+ values of 0.43 ± 0.50 m·gL^{-1}, 0.52 ± 0.56 m·gL^{-1}, 0.43 ± 0.11 m·gL^{-1}, 0.63 ± 0.22 m·gL^{-1}, 0.45 ± 0.35 m·gL^{-1}, 0.59 ± 0.10 m·gL^{-1}, 0.57 ± 0.30 m·gL^{-1}, and 0.63 ± 0.24 m·gL^{-1} were recorded in SW6 at Amagu (**Table 2**), SW6 at Ameze (**Table 3**), SW1 at Amonye (**Table 4**), SW6 at Amokwe (**Table 5**), SW1 at Ihie (**Table 6**), SW4 at Ihietutu (**Table 7**), SW6 at Ngwogwo (**Table 8**), and SW at Okue (**Table 9**) station, respectively. It is observed that SW6 brand of the sachet water significantly recorded K^+ decrease in more stations. However, the mean concentration of K^+ in all the six-sachet water investigated were significantly below the NAFDAC and WHO given standards permissible limits of 10 m·gL^{-1} and ≤ 200 m·gL^{-1} respectively for quality water at $p < 0.05$.

Chloride (Cl^-) is found naturally through the dissolution of salts such KCl, $CaCl_2$, $MgCl_2$, HCl from volcanic geothermal activities, including table salt

(NaCl). Other sources of chloride include seawater, freshwater, industrial waste, sewage, etc. Chloride usually occurs in greater concentration in groundwater than in surface water. It is crucial for various metabolic activities in the human body, and less harmful on public health [42]. The present results in **Tables 1-8** revealed that chloride ions in study areas ranges from 7.34 ± 0.40 $m·gL^{-1}$ to 12.44 ± 0.22 $m·gL^{-1}$ in all the stations. The highest Cl^- values of 11.64 ± 0.22 $m·gL^{-1}$, 11.60 ± 0.96 $m·gL^{-1}$, 11.68 ± 1.22 $m·gL^{-1}$, 11.57 ± 0.02 $m·gL^{-1}$, 11.62 ± 1.04 $m·gL^{-1}$, 11.56 ± 0.04 $m·gL^{-1}$, 12.44 ± 0.22 $m·gL^{-1}$, and 11.03 ± 1.04 $m·gL^{-1}$ were recorded in SW3 at Amagu (**Table 2**), SW3 at Ameze (**Table 3**), SW3 at Amonye (**Table 4**), SW3 at Amokwe (**Table 5**), SW3 at Ihie (**Table 6**), SW3 at Ihietutu (**Table 7**), SW3 at Ngwogwo (**Table 8**), and SW3 at Okue (**Table 9**) station, respectively. On the other hand, the lowest Cl^- values of 7.37 ± 2.11 $m·gL^{-1}$, 7.34 ± 0.40 $m·gL^{-1}$, 7.47 ± 0.25 $m·gL^{-1}$, 7.43 ± 0.25 $m·gL^{-1}$, 7.37 ± 0.46 $m·gL^{-1}$, 8.36 ± 0.52 $m·gL^{-1}$, 10.04 ± 1.01 $m·gL^{-1}$, and 7.44 ± 0.33 $m·gL^{-1}$ were recorded in SW4 at Amagu (**Table 2**), SW5 at Ameze (**Table 3**), SW5 at Amonye (**Table 4**), SW5 at Amokwe (**Table 5**), SW5 at Ihie (**Table 6**), SW4 at Ihietutu (**Table 7**), SW5 at Ngwogwo (**Table 8**), and SW5 at Okue (**Table 9**) station, respectively. It is also observed that SW3 and SW5 brand significantly recorded Cl^- increase and decrease respectively in all stations. However, the mean concentration of Cl^- in all the six-sachet water investigated were significantly below the NAFDAC and WHO given standards permissible limit of 200 $m·gL^{-1}$ and ≤ 250 $m·gL^{-1}$ respectively for quality water at $p < 0.05$. Meanwhile, chloride values observed in this study were lower when compared to the range of 5.05 - 18.97 mg/L reported for sachet water in Ghana [39] and 2.94-19 mg/L reported for processed drinking water in Turkey [43].

Finally, for the microbiological analysis, the results obtained indicated zero presence of bacterial colonies for both tests of total plate count (TPC) and total coliform count (TCC) in most of the sachet water brands as shown in **Tables 1-8**. Although, some traces of cultivable bacteria were found in sachet water SW1, SW3, and SW6 at Amagu (**Table 2**) with values of 3.0 ± 0.25 CFU/mL, 12.0 ± 0.02 CFU/mL, and 4.0 ± 0.01 CFU/mL, respectively. Some were found in sachet water SW4 at Amonye (**Table 4**) with value of 5.0 ± 0.02 CFU/mL, while others were found in sachet water SW1, SW2, and SW3 at Ihietutu (**Table 7**) with values of 4.0 ± 0.23 CFU/mL, 15.0 ± 0.11 CFU/mL, and 2.0 ± 0.16 CFU/mL, respectively. The total coliform was found to be present (with value 2.0 ± 0.04 CFU/mL) only in sachet water SW2 obtained at Ihietutu (**Table 7**). These traces signify bad water quality which may have emanated from improper storage and handling by the retailers, while the remaining samples were free of coliform contamination. Nevertheless, the level of TPC and TCC in all the six-sachet water investigated at various locations were significantly below the NAFDAC and WHO given standards permissible limit of ≤100 CFU/mL and 0 CFU/100mL respectively for quality water at $p < 0.05$. This clearly indicated that most of the sachet water sold and consumed in Ishiagu is of good microbiological quality, and thus suitable for human consumption.

4. Conclusion

Physical examinations of all the sachet water investigated were observed to be without manufacturing date, expiry date and mineral composition on their labelling. The non-compliance by the water production factories, despite holding valid NAFDAC registration as provided in this present study, is a source of great concern as the packaged water sold to the entire public is liable to cause health risks when consumed. The results of the physicochemical and microbiological parameters of the sachet water studied were within WHO and NAFDAC standards except for some chemical parameters like Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, and Cl^{-} that need to be elevated in concentration to meet the minimum allowable standards quality for drinking water. The study suggested that some of the packaged water supplies sold in Amagu (SW1, SW3, SW6), Amonye (SW6), and Ihietutu (SW1, SW2, SW3) locations require storage in cool, shaded environments and vendor training on proper handling practices. Therefore, it is recommended that regulatory agencies should regularly inspect and enhance the evaluation process for sachet water to ensure its safety and quality for human consumption, thereby preventing waterborne diseases associated with contaminated drinking water. This study's results can be applied to other states in Nigeria and be referenced in further research in other notable West African countries where sachet water is mainly consumed such as Ghana, Liberia, Sierra Leone, and Guinea.

Conflicts of Interest

The authors declare no conflicts of interest.

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