Quality Assessment of Sachet and Bottled Water in Ogbomoso Metropolis, Nigeria

ABSTRACT

Background: Access to potable water has become a difficult task in many countries of the world including Nigeria. In Nigeria, the government is trying her best to make water supply available to the masses but till now this vision has never been accomplished. If those living in urban areas could not have access to water supply by government, what is the fate of the people living in rural areas? This has led to the increase usage of sachet and bottled water as portable drinking water.

Aim: The aim of this study was to investigate the quality of sachet and bottled water produced and/or sold in Ogbomoso metropolis, Nigeria.

Place and Duration of Study: This research was carried out in Ogbomoso and Ibadan both in Oyo State Nigeria between November 2018 and February, 2019.

Methodology: Twenty sachet and five bottled drinking water brands; making a total of 25 brands from different manufacturers were used for this study. They were purchased randomly from local markets, shops and street vendors within Ogbomoso metropolis. They were clearly marked for easy identification, and transported to the Quality Assurance Laboratory of Water Corporation, Eleyele, Ibadan for immediate analysis. The samples were examined physically and information on the packages were recorded. Each product was carefully opened to avoid contamination. The physical, chemical and bacteriological qualities as well as the mineral composition of all samples were analyzed using standard methods and results were compared with the recommended WHO/NIS guidelines for quality water.

Results: Physical examination indicated that all the sampled water were registered with NAFDAC but 50 % of the sachet water had no manufacturing and expiry dates. The results of physical, chemical and bacteriological qualities as well as the mineral composition of sachet and bottled drinking water analyzed showed that 90 % of the values were within the guideline of WHO/NIS for quality water.

Conclusion: Though, the average temperature values of both the sachet and bottled drinking water samples were significantly above the WHO/NIS standard, it did not have any effect on their microbiological quality properties. Total coliforms, faecal coliforms and enterococci bacteria that principally characterize drinking water quality were not present in any of the water samples. Generally, the results obtained in this study indicated that sachet and bottled drinking water produced and/or sold in Ogbomoso metropolis were of good quality and hygienic for consumption.

Keywords: *Sachet and bottled water, quality assessment, WHO/NIS guidelines, Ogbomoso*

1. INTRODUCTION

Water is one of the most important natural resources known on earth [1]. Water of good quality is important to human physiology and man's continued existence depends very much on its availability [2]. Before water can be described as potable, it has to comply with certain physical, chemical and microbiological standards, which are designed to ensure that the water is potable and safe for drinking. Potable water is defined as water that is free from contaminants, such as disease causing microorganisms and harmful chemical substances [3]. The importance of potable water supply in the socioeconomic life of the public cannot be over emphasized. Often, source and portability of water supply reflects on the health conditions of communities. Water meant for consumption should be free from pollution, acceptable and safe. Indeed the quality of the water sources should not exceed the maximum limits specified in the water quality guidelines [4]. Sachet drinking water was introduced into the Nigerian markets as a less expensive means of accessing drinking water than bottled water [5]. There has been countless number of diseases outbreak and poisoning around the world resulting from the consumption of untreated or poorly treated drinking water [6]. Several studies on the quality of sachet water have reported violation of international quality standards [7, 8, 9]. According to the Institute of Public Analysts of Nigeria (IPAN), 50 % of the sachet water sold in the streets of Lagos may not be fit for consumption [10]. The possibility that the same situation may be applicable to other cities in the country such as Ogbomoso and its environs prompted this study.

2. MATERIALS AND METHODS

2.1. Study Area

Ogbomoṣo is a city in Oyo State, south-western Nigeria, on the A_1 highway. It was founded in the mid-17th century. The population was approximately 645,000 in 2006 census. The majority of the people are members of the Yoruba ethnic group [11]. Ogbomoso has three degree-granting institution of higher learning. Ladoke Akintola University is named for the illustrious Ogbomoso son and Premier of the old Western Nigeria, Samuel Ladoke Akintola (SLA), The Nigerian Baptist Theological Seminary, one of the oldest institutions of higher learning in Nigeria offers degree programs in theology, sociology and philosophy, Bowen University Teaching Hospital Ogbomoso a first-class Christian Teaching Hospital marked by excellence and godliness for the training of doctors and other medical professionals [11]. Ogbomoso is an urban centre and the production and consumption of bread is very high.

2.2. Sampling of Sachet and Bottled Water

Twenty sachet and five bottled drinking water brands; making a total of 25 brands from different manufacturers were used for this study. These are the most popular and consumed brands in Ogbomoso. Triplicate batches of each brand were purchased randomly from local markets, shops and street vendors within Ogbomoso Metropolis. The samples were clearly marked for easy identification, and transported to the Quality Assurance Laboratory of Water Corporation, Eleyele, Ibadan the Oyo state capital for immediate analysis. The samples were examined physically and information on the packages were recorded. Each product was carefully opened to avoid contamination. For bottled water, the cap of each bottle was carefully removed to avoid touching the opening. In the case of sachet water, an edge of the package was cut with a sterilized scissors and carefully placed in a sterilized beaker. The physical, chemical and bacteriological parameters as well as mineral composition were determined by taking water directly from the original package (sachet or bottle) and tested. Twenty-five (25) bottled samples and one hundred (100) sachet water samples were analyzed, with five (5) samples from each brand for a total 125 samples.

2.3. Physical Examination of Sachet and Bottled Water

Physical examination of labeling information was carried out according to the method described by Oyeku *et al,* [12].

2.4. Determination of Physical Qualities

Temperature was measured using Standard Method 2550 B: Laboratory and Field Methods, using a multipurpose pH meter (HANNA pH 209, U.S.A) adjusted for temperature in Degrees Celsius (^oC), as detailed in Standard Methods for the Examination of Water and Wastewater [13]. Colour was determined using Standard Method 2120 C: Spectrophotometric Method, with an ultra violet (U.V.) spectrophotometer (HACH LANGE DR 5000, U.S.A.) expressed in hazen units (HU), according to Standard Methods for the Examination of Water and Wastewater [13]. The turbidity was measured using Standard Method 2130 B: Nephelometric Method, by turbidimeter (HACH 2100P, U.S.A) in Nephelometric Turbidity Units (NTU), as explained in Standard Methods for the Examination of Water and Wastewater [13]. Conductivity was determined using Standard Method 2510 B: Laboratory Method, via a conductivity meter (JENWAY 4510, U.K) in micro-Siemens per centimeter (μs/cm), as detailed in Standard Methods for the Examination of Water and Wastewater [13]. Total dissolved solids (TDS) and total suspended solids (TSS) were determined using Standard Methods 2540 B: Total Dissolved Solids Dried at 103 –105 °C and 2540 D: Total Suspended Solids Dried at 103–105 °C, respectively. The units were expressed in mg/L according to Standard Methods for the Examination of Water and Wastewater [13].

2.5. Determination of Chemical Qualities

Alkalinity was determined using Standard Method 2320 B: Titration Method in mg/L, as explained in Standard Methods for the Examination of Water and Wastewater [13]. Total hardness and calcium hardness were determined using Standard Method 2340 C: EDTA Titrimetric Method and Standard Method 3500-Ca-B: EDTA Titrimetric Method, respectively, as detailed in Standard Methods for the Examination of Water and Wastewater [13]; expressed in mg/L. Chloride was analysed using Standard Method 4500-Cl–B: Argentometric Method in mg/L, and pH measured using Standard Method 4500-H+ B: Electrometric Method, by a multipurpose pH meter (HANNA pH 209, U.S.A), according to Standard Methods for the Examination of Water and Wastewater [13].

2.6. Determination of Minerals and Heavy Metals in Sachet and Bottled Water

The following minerals and heavy metals; Calcium (Ca), Cadmium (Cd), Chloride (Cl), Chromium (Cr), Copper (Cu), Iron (Fe), Potassium (K), Manganese (Mn), Sodium (Na), Lead (Pb) and Zinc (Zn) were determined for each water sample using Atomic absorption spectrophotometry (Buck Scientific, VPG 210) procedure as reported by Oyelola *et al*., [14] and Olaoluwa *et al*., [15].

2.7. Determination of Bacteriological Qualities

Total coliform and faecal coliform organism numbers were determined using Standard Method 9221 B: Standard Total Coliform Fermentation Technique. Heterotrophic bacteria were enumerated using Standard Method 9215 C: Spread Plate Method, according to Standard Methods for the Examination of Water and Wastewater [13]. Gallenkamp, Economic Incubator Size 2, England was used. The number of colony forming organisms was counted manually, and again, bottles inspected for the formation of acids and gases in vial.

2.8. Statistical Analysis

Data were subjected to analysis using Graph Pad Prism, version 6.0. Results were presented as mean ± standard deviations. One way Analysis of Variance (ANOVA) followed by Turkey's test was used for comparison of the mean. Differences between the experimental mean and WHO/NIS standard values were considered to be significant at $p<0.05$.

3. RESULTS AND DISCUSSION

Table 1: Physical Examination of Sachet and Bottled Water Brands produced and/or sold in Ogbomoso, Nigeria

Water Samples	Product Name	Manufacturer Address	Batch Number	Manufacturing Date	Expiry Date	NAFDAC Number	Mineral Composition
WHO/NIS	+	+	+	+	+	+	+
Sachet Water							
A	+	+	–	+	+	+	–
B	+	+	–	+	+	+	–
C	+	+	–	–	–	+	–
D	+	+	–	+	+	+	–
E	+	+	–	+	+	+	–
F	+	+	–	–	–	+	–
G	+	+	–	–	–	+	–

H	+	+	–	+	+	+	–
I	+	+	–	–	–	+	–
J	+	+	–	+	+	+	–
K	+	+	–	–	–	+	–
L	+	+	–	+	+	+	–
M	+	+	–	+	+	+	–
N	+	+	–	–	–	+	–
O	+	+	–	+	+	+	–
P	+	+	–	–	–	+	–
Q	+	+	–	+	+	+	–
R	+	+	–	–	–	+	–
S	+	+	–	–	–	+	–
T	+	+	–	–	–	+	–
Bottled Water							
U	+	+	+	+	+	+	–
V	+	+	+	+	+	+	–
W	+	+	+	+	+	+	–
X	+	+	+	+	+	+	–
Y	+	+	+	+	+	+	–

+ indicates present while – indicates absent

Table 2: Physical Qualities of Sachet and Bottled Water Brands produced and/or sold in Ogbomoso, Nigeria

Water Samples	**Temperature (^{o}C)**	**Colour (HU)**	**Conductivity (µs/cm)**	**TSS (mg/L)**	**Turbidity (NTU)**	**TDS (mg/L)**
WHO/NIS	**25**	**0-15**	**0-1000**	**–**	**0-5**	**1000**
Sachet Water						
A	27.90±4.14	ND	111.90±11.36	ND	0.27±0.04	84.28±7.26
B	29.40±4.96	ND	86.30±5.31	ND	0.25±0.03	29.86±3.46
C	27.60±3.38	ND	66.60±4.44	ND	0.73±0.05	47.16±2.08

D	27.80±4.21	ND	80.10±8.36	ND	0.45±0.02	42.26±3.21
E	28.30±3.87	ND	58.50±7.44	ND	0.22±0.03	62.18±4.27
F	28.20±4.24	ND	92.40±9.64	ND	0.23±0.04	73.35±6.02
G	28.60±4.03	ND	52.90±3.49	ND	0.24±0.03	80.60±6.45
H	28.40±3.61	ND	78.80±4.87	ND	0.14±0.00	15.83±2.42
I	28.60±3.42	ND	75.50±6.23	ND	0.21±0.01	24.42±2.06
J	29.80±4.03	ND	67.70±2.58	ND	0.24±0.01	42.33±3.25
K	28.70±3.92	ND	93.20±10.85	ND	0.20±0.01	67.43.±4.37
L	30.24±3.82	ND	136.40±7.38	ND	0.36±0.04	53.45±3.34
M	29.90±4.44	ND	83.00±11.43	ND	0.97±0.03	42.38±2.34
N	28.80±4.03	ND	28.30±2.41	ND	0.29±0.03	54.25±4.37
O	30.40±4.32	ND	36.40±3.10	ND	0.25±0.02	58.48±2.8947
P	29.10±3.92	ND	132.40±14.19	ND	0.22±0.02	11.56±1.46
Q	28.70±3.08	ND	69.30±4.90	ND	0.37±0.02	63.34±6.41
R	29.30±3.45	ND	68.00±3.44	ND	0.18±0.01	60.54±3.32
S	28.50±3.92	ND	47.20±3.02	ND	0.26±0.01	48.38±2.30
T	27.50±3.37	ND	87.40±5.28	ND	0.49±0.02	46.64±2.34
Bottled Water						
U	29.30±3.84	ND	64.32±8.09	ND	0.12±0.00	28.24±3.22
V	28.60±3.39	ND	99.40±10.32	ND	0.22±0.01	55.64±3.32
W	27.60±3.40	ND	36.60±2.04	ND	0.13±0.00	61.90±3.28
X	29.80±3.93	ND	98.40±6.39	ND	0.13±0.02	55.33±3.91
Y	28.60±3.48	ND	121.70±2.58	ND	0.11±0.02	84.15±9.68

Results are presented as mean ± standard deviation where n = 5. Data were statistically compared with WHO/NIS standard at $p<0.05$. – means no standard value provided for the parameter. ND = Not Detected; TSS = Total Suspended Solids and TDS = Total Dissolved Solids

Table 3: Chemical Qualities of Sachet and Bottled Water Brands produced and/or sold in Ogbomoso, Nigeria

Water Samples	pH	Total Hardness (mg/L)	Alkalinity (mg/L)
WHO/NIS	**6.5-8.5**	**–**	**500**

Sachet Water			
A	6.57±0.18	42.20±4.40	8.00±1.00
B	6.61±0.20	35.80±2.50	48.00±3.00
C	6.56±0.52	6.10±1.30	22.00±2.00
D	6.56±0.83	7.30±1.60	16.00±0.00
E	6.62±0.77	8.30±0.60	22.00±2.00
F	7.00±0.72	16.40±2.40	55.00±5.00
G	6.78±0.82	12.40±0.80	42.00±3.00
H	6.66±0.37	38.00±7.50	42.00±2.00
I	7.02±0.12	24.50±2.00	64.00±12.00
J	6.82±0.73	24.00±1.90	42.00±9.00
K	6.48±0.31	16.40±3.40	6.00±1.00
L	6.92±0.39	62.40±8.60	42.00±3.00
M	7.12±0.73	26.20±3.80	8.00±0.00
N	6.82±0.27	53.00±5.30	33.00±6.00
O	6.58±0.92	48.40±3.50	16.00±2.00
P	6.96±0.24	38.00±2.80	38.00±2.00
Q	7.20±0.72	38.40±2.90	42.00±6.00
R	6.53±0.40	32.80±3.30	28.0±1.00
S	7.03±0.09	80.00±5.30	8.00±1.00
T	6.73±0.11	42.30±6.10	84.00±8.00
Bottled Water			
U	6.83±0.08	16.00±2.10	14.00±1.00
V	7.00±0.52	10.30±0.90	74.00±8.00
W	7.12±0.68	4.40±0.28	24.00±4.00
X	6.66±0.25	25.00±4.60	42.00±3.00
Y	7.03±0.35	34.30±3.30	62.00±0.00

Results are presented as mean ± standard deviation where n = 5. Data were statistically compared with WHO/NIS standard at $p<0.05$. – indicates no standard value provided for the parameter.

Table 4: Mineral Composition of Sachet and Bottled Water Brands produced and/or sold in Ogbomoso, Nigeria

Water Samples	Ca (mg/L)	Cd (mg/L)	Cl (mg/L)	Cr (mg/L)	Cu (mg/L)	Fe (mg/L)	K (mg/L)	Mg (mg/L)	Mn (mg/L)	Na (mg/L)	Pb (mg/L)	Zn (mg/L)
WHO/NIS	0–50	0.003	250	0.05	2.00	0.30	0–12	50	0.50	200	0.01	5.00
Sachet Water												
A	2.86±0.27	ND	12.62±2.03	0.02±0.00	1.00±0.05	0.03±0.00	1.83±0.03	15.29±3.82	0.02±0.00	17.24±3.48	ND	0.21±0.06
B	4.63±0.82	ND	6.22±1.23	0.01±0.00	1.29±0.06	0.01±0.00	1.28±0.08	16.28±2.99	0.02±0.00	6.03±1.92	ND	0.37±0.03
C	1.86±0.13	ND	4.38±0.67	0.02±0.00	1.43±0.11	ND	5.62±1.10	12.64±3.29	0.01±0.00	13.21±3.72	ND	0.14±0.02
D	3.26±0.37	ND	22.48±1.21	0.01±0.00	1.19±0.06	ND	2.83±0.00	17.28±3.29	0.03±0.00	12.34±2.84	ND	0.28±0.03
E	3.84±0.63	ND	32.35±5.27	0.01±0.00	1.17±0.07	0.03±0.00	7.73±0.08	18.22±2.22	ND	4.32±1.00	ND	0.21±0.05
F	3.29±0.94	ND	4.73±1.04	0.01±0.00	0.03±0.00	0.01±0.00	2.84±0.03	15.76±3.46	ND	27.00±7.62	ND	0.22±0.06
G	3.82±0.82	ND	8.27±2.00	ND	0.05±0.00	0.01±0.00	3.62±0.05	10.84±2.11	0.04±0.00	19.07±4.28	ND	0.28±0.08
H	3.95±0.75	ND	4.23±0.63	0.03±0.00	1.52±0.20	0.02±0.00	2.31±0.32	13.13±2.83	0.02±0.00	8.29±2.98	ND	0.26±0.02
I	2.54±0.09	ND	2.63±0.34	0.02±0.00	0.87±0.02	0.00±0.00	1.75±0.02	16.28±3.91	0.01±0.00	4.52±1.28	ND	0.32±0.03
J	1.78±0.04	ND	8.62±2.11	0.03±0.00	1.17±0.03	0.02±0.00	2.08±0.13	12.71±3.19	0.02±0.00	32.45±3.28	ND	0.17±0.06
K	2.65±0.52	ND	2.34±0.82	0.01±0.00	1.08±0.04	ND	2.56±0.16	19.25±4.72	0.08±0.02	11.89±2.63	ND	1.06±0.00
L	2.32±0.86	ND	1.35±0.10	0.01±0.00	1.68±0.12	0.06±0.01	3.00±0.11	12.45±2.86	0.02±0.00	4.27±1.20	ND	0.78±0.08
M	2.86±0.18	ND	3.29±0.46	ND	1.31±0.21	0.01±0.00	3.21±0.53	18.14±3.27	0.03±0.01	3.52±0.58	ND	0.68±0.06
N	4.26±0.42	ND	26.45±3.78	0.01±0.00	1.20±0.08	0.01±0.00	2.29±0.06	11.02±3.11	0.02±0.00	3.28±1.23	ND	0.93±0.04
O	4.00±0.89	ND	14.28±1.82	0.02±0.00	0.06±0.01	0.03±0.00	2.06±0.06	22.84±5.39	0.11±0.01	5.38±1.11	ND	0.19±0.07

P	4.42±0.79	ND	21.01±6.19	0.03±0.00	0.07±0.01	0.04±0.00	6.83±1.08	19.28±4.02	0.01±0.00	5.73±2.10	ND	0.26±0.10
Q	1.88±0.16	ND	1.28±0.11	0.01±0.00	1.28±0.11	0.01±0.00	0.92±0.07	29.64±7.23	ND	13.26±2.72	ND	0.09±0.01
R	1.98±0.08	ND	4.63±0.88	0.02±0.00	1.14±0.06	0.01±0.00	2.17±0.08	11.56±2.98	0.04±0.00	5.37±1.22	ND	0.46±0.12
S	3.33±0.42	ND	12.49±2.62	0.01±0.00	1.16±0.09	0.01±0.00	2.69±0.18	16.27±3.07	0.02±0.00	10.10±2.32	ND	0.42±0.10
T	3.92±0.28	ND	6.26±1.44	0.01±0.00	1.21±0.08	0.05±0.00	2.53±0.12	16.38±3.00	0.02±0.00	6.38±1.89	ND	0.78±0.05
Bottled Water												
U	4.86±1.02	ND	8.03±1.22	0.02±0.00	0.25±0.04	ND	2.78±0.23	12.28±2.98	0.01±0.00	4.73±0.82	ND	0.18±0.00
V	2.68±0.28	ND	1.37±0.12	ND	0.18±0.09	0.02±0.00	4.87±0.09	19.23±4.32	0.02±0.00	5.63±1.21	ND	0.42±0.11
W	2.84±0.31	ND	6.74±1.04	0.02±0.00	1.01±0.06	0.03±0.00	0.87±0.04	13.93±3.02	ND	4.38±1.00	ND	0.38±0.08
X	3.27±0.22	ND	2.65±0.09	0.02±0.00	1.06±0.10	ND	3.27±0.21	13.76±2.84	0.02±0.00	12.35±2.32	ND	0.54±0.14
Y	3.86±0.37	ND	5.33±1.20	0.01±0.00	0.03±0.00	0.01±0.00	2.65±0.08	18.32±3.87	0.01±0.00	14.37±3.03	ND	0.19±0.01

Results are presented as mean ± standard deviation where n = 5. Data were statistically compared with WHO/NIS standard at $p<0.05$. ND = Not Detected.

Table 5: Bacteriological Qualities of Sachet and Bottled Water Brands produced and/or sold in Ogbomoso, Nigeria

Water Samples	Bacteria Counts (CFU/100ml)	Total Coliform (CFU/100ml)	Faecal Coliform (CFU/100ml)
WHO/NIS	0.00	0.00	0.00
Sachet Water			
A	ND	ND	ND
B	ND	ND	ND
C	ND	ND	ND
D	ND	ND	ND
E	ND	ND	ND
F	ND	ND	ND
G	ND	ND	ND
H	ND	ND	ND
I	ND	ND	ND
J	ND	ND	ND
K	ND	ND	ND
L	ND	ND	ND
M	ND	ND	ND
N	ND	ND	ND
O	ND	ND	ND
P	ND	ND	ND
Q	ND	ND	ND
R	ND	ND	ND
S	ND	ND	ND
T	ND	ND	ND
Bottled Water			
U	ND	ND	ND
V	ND	ND	ND
W	ND	ND	ND
X	ND	ND	ND
Y	ND	ND	ND

Number of samples per brand = 5; ND = not detected (i.e. no gas produced, or no growth detected, i.e. 0.00 CFU/100 ml).

Water is one of the indispensable resources for the continued existence of all living things including man and adequate supply of fresh and clean drinking water is a basic need for all human beings [16]. With the recent increase in the consumption of sachet and bottled water in major cities and towns of Nigeria due to lack of portable drinking water, there is need to investigate the prevalence of possible contaminants in these water that may have toxicological effect on human when consumed. According to World Health Organization (WHO), diarrheal diseases account for an estimated 4.1 % of the total daily global burden and are responsible for the deaths of 1.8 million people every year. It was estimated that 88 % of that burden is attributable to unsafe water supply, sanitation and hygiene [17]. The National Agency for Food, Drug Administration and Control (NAFDAC), the agency responsible for regulating drugs, foods and chemicals in Nigeria requires that all the labeling of food and drugs must be informative and accurate. This information required on labeling include manufacturer's name, contact information, batch number, nutritional information, manufacturing date, expiration date (Best before date) and NAFDAC registration number [18, 19]. The result of the physical examination of the sachet and bottled water investigated in this study is presented in Table 1. It was observed that all the bottled water samples exhibit 100 % compliance as regard the product names, manufacturers' addresses, manufacturing and expiry dates, batch number and NAFDAC registration number as these information were clearly written on their labeling. However, none of the bottled water brand analyzed indicates the mineral compositions of the water. It was also observed that all the sachet water studied had 100 % compliance in term of the product names, manufacturing addresses, and NAFDAC number. However, 80 % of them had 'L' with their NAFDAC number, which implies that they might still be under listing. This is consistent with the findings of Airaodion *et al.* [9] who reported the assessment of sachet and bottled water quality in Ibadan, Nigeria. Only 10 out of the 20 sachet water analyzed representing 50 % had manufacturing and expiry date. These information are very essential, as they tell the consumer whether the water sample is still within its shelf life or not. Furthermore, all the sachet water studied was observed to be without batch number and mineral composition on their labeling. Batch number is essential for any product especially when there is need to recall a product from the market in the event of discovery of any abnormality with the product [7]. The act of noncompliance by the water production factories as rightly observed in this present study is a source of great concern, as the packaged water sold to the entire populace in Ogbomoso and its environ are likely to pose health risk when consumed. It has been reported that substantial number of sachet water manufacturers that resist compliance to best practices laid down by the authorities do not have the license to operate [20, 21]. It is however very worrisome that this is not the case with this present study as all the water manufacturers were duly certified to operate as evident in the NAFDAC registration number provided. The question here is, 'how did they get registered by NAFDAC without compliance to their guidelines?' It might be that they produced the samples given to NAFDAC to meet their guidelines before registration or they forged the NAFDAC registration number in their labels. This should be a source of great concern to NAFDAC and other regulatory agencies in Nigeria.

The results of physical, chemical and bacteriological qualities as well as the mineral composition of sachet and bottled drinking water analyzed were compared with the recommended WHO/NIS guidelines [22, 23] for quality water. Table 2 showed the physical qualities (temperature, colour, conductivity, total suspended solids, turbidity and total dissolved solids) for the sachet and bottled water brands investigated. The standard temperature of drinking water according to WHO/NIS is 25 ^{o}C. Temperature is a measure of the average thermal energy of a substance [7]. The sachet water analyzed has 27.50 and 30.40 ^{o}C as the lowest and highest temperature respectively. The average temperature of the twenty sachet water analyzed is 28.77 ^{o}C which is significantly higher than the WHO/NIS standard value for quality water. Similarly, the temperature of the bottled water analyzed ranged from 28.60 to 29.80 ^{o}C with an average of 29.53 ^{o}C. This was also significantly higher than the WHO/NIS standard value for quality water at $P<0.05$. This result is similar to the 27.40 and 30.70 ^{o}C for the lowest and highest temperature for sachet water and 28.30 and 30.40 ^{o}C for lowest and highest temperatures for bottled water respectively reported by Airaodion *et al.* [9]. This could be due to high temperature of 27 to 34 ^{o}C in Ibadan and 28 to 34 ^{o}C in Ogbomoso during the period of this study. However, these temperatures for both sachet and bottled drinking water fell within the optimal growth temperature (20–45 ^{o}C) for mesophilic bacteria [24]. The microbiological characteristics of drinking water are related to temperature through its effects on water-treatment processes and its effects on both growth and survival of microorganisms [17]. This result is also similar to that of Danso-Boateng and Frimpong [25] who reported 28.94 ^{o}C and 28.81 ^{o}C respectively for average temperatures of plastic sachet and bottled water brands produced and/or sold in Kumasi, Ghana. According to Onweluzo and Akuagbazie [26], temperatures within this range are favourable for maximum growth of mesophyll bacteria including human diseases causing agents. This phenomenon has the tendency to promote the development of undesirable taste and odour in water with time [26]. However, a report by State Water Quality Control Board in Canada indicated that the survival time in water of the cysts and ova of parasitic worms such as *Schistosoma* ova is shortened by higher temperatures between 29 to 32 ^{o}C [27].

The result of this study indicated that no colour was present in both sachet and bottled water investigated as shown in table 2. This means that all the water brands were free from dissolved humic acids [25]. The conductivity values obtained for both sachet and bottled water investigated were within the range of WHO/NIS standard conductivity (0-1000 μs/cm) for quality water. Conductivity is a measure of water's capability to pass electrical flow. This ability is directly related to the concentration of ions in the water [28]. These conductive ions come from dissolved salts and inorganic materials such as alkalis, chlorides, sulfides and carbonate compounds [29]. Compounds that dissolve into ions are also known as electrolytes [30]. The more ions that are present, the higher the conductivity of water. Likewise, the fewer ions that are in the water, the less conductive it is. Distilled or deionized water can act as an insulator due to its very low (if not negligible) conductivity value [31]. Sea water, on the other hand, has a very high conductivity. Ions conduct electricity due to their positive and negative charges [28]. When electrolytes dissolve in water, they split into positively charged (cation) and negatively charged (anion) particles. As the dissolved substances split in water, the concentrations of each positive and negative charge remain equal. This means that even though the conductivity of water increases with added ions, it remains electrically neutral [31]. The average conductivity of the sachet water analyzed is higher than that of the bottled water. This might be that the bottled water brands analyzed contain fewer amounts of dissolved ions or salts than the sachet water brands. This result is in contrast with the report of Airaodion *et al.* [9] who reported higher average conductivity value for bottled water than sachet water.

Both sachet and bottled water analyzed in this study showed that no suspended solids were present in them to be detected. The turbidity of both sachet and bottled water were within the range given by WHO/NIS (0 – 5 NTU). This could account for the reason why total suspended solids (TSS) were not detectable in all the brands of sachet and bottled water analyzed, which is good for consumption. However, the sachet water samples were more turbid when compared with the bottled water samples analyzed. This might be attributed to the fact that, the bottled water passes through series of filters, or efficient filter medium during production to remove suspended clay particles, trace elements and suspended solids compared to the sachet water [25]. This result corresponds to the findings of Airaodion *et al.* [9] who reported the assessment of sachet and bottled water quality in Ibadan, Nigeria.

Some solids were found to have dissolved in both sachet and bottled waters investigated but they were far below the permissible level of total dissolved solids (TDS) value (1000 mg/L) of WHO/NIS. TDS combine the sum of all ion particles that are smaller than 2 microns (0.0002 cm) [32]. This includes all of the disassociated electrolytes that make up salinity concentrations, as well as other compounds such as dissolved organic matter. In "clean" water, TDS is approximately equal to salinity [33]. In wastewater or polluted areas, TDS can include organic solutes (such as hydrocarbons and urea) in addition to the salt ions [33]. TDS concentrations outside of a normal range can cause a cell to swell or shrink. This can negatively impact aquatic life that cannot compensate for the change in water retention. While TDS measurements are derived from conductivity, some states, regions and agencies often set a TDS maximum instead of a conductivity limit for water quality [34]. TDS can also affect water taste, and often indicates a high alkalinity or hardness [33].

The result of the chemical qualities (pH, total hardness, and alkalinity) of sachet and bottled drinking water brands investigated in this study are presented in table 3. The pH of the sachet water ranged from 6.53 to 7.20 while that of the bottled water ranged from 6.66 to 7.12. The pH of both the sachet and bottled water analyzed are within the standard range of pH (6.5-8.5) for quality water recommended by WHO/NIS. This result is similar to the 6.48 to 7.12 as pH of sachet and 6.62 to 7.00 as pH for bottled water respectively reported by Airaodion *et al.* [9]. It is very important to state that the water samples with pH within the regulatory guideline values do not have any probability of posing health issues such as acidosis [35]. 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. The normal range for pH in surface water systems is 6.5 to 8.5, and the pH range for groundwater systems is between 6 and 8.5. Alkalinity is a measure of the capacity of the water to resist a change in pH that would tend to make the water more acidic [36]. The measurement of alkalinity and pH is needed to determine the corrosiveness of the water. In general, water with a pH less than 6.5 could be acidic, soft, and corrosive [37]. Acidic water could contain metal ions such as iron, manganese, copper, lead, and zinc. In other words, acidic water contains elevated levels of toxic metals. Acidic water can cause premature damage to metal piping, and have associated aesthetic problems such as a metallic or sour taste [37]. It can also stain laundry and cause "blue-green" colour staining on sinks and drains. More importantly, there is health risks associated with these toxins [36]. The primary way to treat the problem of low pH water is with the use of a neutralizer.

From the results obtained in the study, the alkalinity of sachet water ranged from 6.00 – 84.00 mg/L while that of bottled water ranged from 14.00 – 62.00 mg/L. Though values of alkalinity of the bottled samples were below that of sachet samples, all were below the WHO/NIS standard of 500 mg/L. This present investigation was similar with studies earlier reported by Airaodion *et al.* [9], Aremu *et al*. [36] and Edimeh *et al*. [37].

The total hardness of sachet water in this study ranged from 6.10 – 80.00 mg/L while those of bottled water ranged from 4.40 – 34.30 mg/L. It is important to note that the hardness contents obtained for the sachet and bottled drinking water in this study does not necessarily indicate that the water poses a health risk as no standard values were given by WHO/NIS [9].

The result of mineral composition of sachet and bottled water investigated in this study are presented in table 4. Calcium is the 5th most abundant element on the earth crust and is very important for human cell physiology [36]. About 95 % of calcium in human body is stored in bones and teeth. High deficiency of calcium in humans may cause rickets, poor blood clotting, bones fracture etc. and the exceeding limit of calcium produced cardiovascular diseases. Calcium plays a key role in bone formation and development [38]. According to WHO [17] standards, its permissible level in drinking water is 50 mg/L. In this study, a range of 1.78 – 4.63 mg/L of calcium was observed in sachet water while a range of 2.68 – 4.86 mg/L was observed for calcium in bottled water. Calcium present in both sachet and bottled water investigated were below the permissible level by WHO/NIS. This is similar to the low level of calcium reported for packaged water in Abraka and Warri, Nigeria by Ndinwa *et al.* [39] and in sachet and bottled water in Ibadan by Airaodion *et al.* [9]. Adult within the age bracket of 19 – 50 years requires 1000 mg Ca^{2+} [38]. The result of this water analysis signifies that only approximately 0.3 % of calcium dietary reference can be fulfilled when 2 litres of this packaged water are consumed daily. Extensive consumption of these brands of water over some period might be associated with some health issues because of the minute presence of calcium. It is advisable that water with high quantity of calcium within the permissible limit should be consumed always [38]. Although there are no established proof on adverse health effects attributed to excess calcium in drinking water but excess calcium ions is known to cause water hardness [40].

Chloride is mainly obtained from the dissolution of salts of hydrochloric acid as table salt (NaCl), $NaCO_3$ and added through industrial waste, sewage, sea water etc. Surface water bodies often have low concentration of chlorides as compare to ground water. It has key importance for metabolic activity in human body and other main physiological processes [8]. High chloride concentration damages metallic pipes and structure, as well as harms growing plants. In this study, chloride ions concentration was observed to vary from 1.28– 32.35 mg/L for bottled water while the chlorine level for sachet water ranged from 1.37 – 8.03 mg/L. The result is appreciably within the WHO guideline value of maximum permissible concentration of 250 mg/L desirable for drinking water. This limit has been laid down primarily based on taste considerations. However, no adverse health effect on humans has been reported from intake of water containing even higher concentrations of chloride. But higher concentration of chloride ions in drinking water can add its taste to the water [9]. The value of chloride observed in this study is similar to the 1.42 – 9.00 mg/L reported for sachet and bottled water marketed in Bauchi metropolis, Nigeria but was higher than 0.31-3.03 mg/L reported for sachet water analysis in Warri and Abraka, Nigeria [39]. On the other hand, chloride values observed in this study were lower when compared to the range of 5.05 – 18.97 mg/L and 8.95 – 24.80 mg/L reported for sachet and bottled water respectively in Ghana [40] and 2.94 – 19 mg/L for processed drinking water in Turkey [41].

Copper occurs naturally in water in only minute quantity (few micrograms per liter) in drinking water [22]. The WHO/NIS guideline value for copper in drinking water is set at a maximum of 2.00 mg/L. In all the sachet and bottled water samples investigated, none of the samples analyzed was observed to contain this trace element higher than the stipulated concentration. While the sachet water was observed to be within 0.03 – 1.68 mg/L the bottled water was found to have a copper level that varied from 0.03 – 1.06 mg/L. One obvious fact with these results is that the sachet water tends to contain more copper than the bottled water. This corresponds to the findings of Airaodion *et al.* [9]. High level of copper is not desirable in drinking water as it could cause gastrointestinal disorder [23].

Iron as a trace element was not detected in three (samples C, D and K) of the twenty sachet water representing 15 % while in the remaining 85 %, the concentration was observed to vary from 0.01 – 0.06 mg/L. Among the five bottled water analyzed, three representing 60 % were observed to contain iron at a concentration of 0.01 – 0.03 mg/L while 40 % of the bottled water produced and/or sold in Ogbomoso metropolis does not contain any trace of iron as it was undetected. These observed values are lower than the recommended limit of 0.3 mg/L stipulated by World Health Organization (WHO) for drinking water. High concentrations of iron can affect the acceptability of drinking water, and should be given adequate priority during the processing of drinking water [22].

Potassium is a necessity for the sustenance of a biological system. It is an essential nutrient in intracellular fluid, acid-alkaline balance, osmotic pressure regulation, muscular contraction and nerve impulse conduction [25]. This mineral element was detected in all the packaged water studied. The concentration of potassium varied from 0.92 – 7.73 mg/L and 0.87 – 4.87 mg/L for sachet and bottled water respectively. The observed value in this present study is satisfactorily within the guideline value by WHO/NIS. This result is similar to the findings of Airaodion *et al.* [9]. Potassium is silver white alkali which is highly reactive with water. Potassium is necessary for living organism functioning hence found in all human and animal tissues particularly in plants cells. The total potassium amount in human body lies between 110 and 140 g. It is vital for human body functions like heart protection, regulation of blood pressure, protein dissolution, muscle contraction, nerve stimulus etc. Potassium deficiency is rare but may lead to depression, muscle weakness, heart rhythm disorder etc. [8].

Magnesium is the 8th most abundant element on earth crust and natural constituent of water. It is essential for proper functioning of living organisms and found in minerals like dolomite, magnetite etc. Human body contains about 25 g of magnesium (60 % in bones and 40 % in muscles and tissues). According to WHO/NIS standards, the permissible level of magnesium in water should be 50 mg/L [9]. In this present study, magnesium in sachet water ranged from 10.84 – 29.64 mg/L while that of bottled water ranged from 12.28 – 19. mg/L. Magnesium present in both sachet and bottled water analyzed were below the permissible level by WHO/NIS.

Manganese is present in water. In this study, three (sample E, F and Q) of the twenty sachet water analyzed representing 15 % and one (sample W) of the five bottled water analyzed representing 20 % gave no result for manganese. This could be that they contained no manganese or that it was present in the samples in residual amount that could not be detected by the reagent [42, 43]. Other sachet water analyzed contain between 0.01 and 0.11 mg/L of manganese while the bottled water had between 0.01 and 0.02 mg/L of manganese. These values were below the guideline value of 0.50 mg/L set by WHO/NIS. Large quantity of manganese influences taste in water and encourage the growth of bacteria; though not hazardous but are very unpleasant. Large doses of manganese have also been reported to cause lethargy, irritability, headache, sleeplessness, and leg weakness. This might lead to development of psychological symptoms such as aggressiveness, unaccountable laughter, impulsive acts and absent-mindedness. These in the long run usually result into a Parkinson–like disease [22].

The WHO/NIS guidelines value stipulates a maximum concentration level of sodium in drinking water to be 200 mg/L. The Sodium concentration level in both sachet and bottled water produced and/or sold in Ogbomoso metropolis analyzed in this study was within this set guideline value. Analysis of the results showed that the sodium concentration of sachet water ranged between 3.28 – 32.45 mg/L in this present study while the bottled water brands varied from 4.38 – 14.37 mg/L. The value observed in this study is low when compared to 7.79 – 51.43 mg/L and 11.55 – 51.43 mg/L reported for sachet and bottled water in Bolgatanga municipality, Ghana [40]. Sodium has the tendency of affecting the taste of water meant for consumption when its concentrations are above the threshold limit value [40].

Zinc is another example of trace element present in water. The results of this study showed that all the sachet and bottled water samples investigated were observed to contain appreciable quantity of this trace element. The sachet water was observed to have a zinc concentration that ranged from 0.09 – 1.06 mg/L while the bottled water was observed to vary from 0.18 – 0.54 mg/L. Analysis of these results clearly depicts that the values obtained were within the permissible level of 5 mg/L recommended by WHO/NIS. High concentrations of zinc in water are responsible for stringent tastes in water which are essentially not desirable [8].

The presence of heavy metals such as cadmium (Cd) and lead (Pb) were not detected in all the analyzed water samples. The results showed that the level of metals in all the brand of sampled water was within the recommended range set by World Health Organization (WHO) and Nigeria Industrial Standard (NIS). The implication of this result is that the manufacturers of these brands of sachet and bottled water obtained raw water from chemically good sources. Chromium was not detected in two (sample G and M) of the twenty sachet water analyzed representing 10 % and one (sample V) of the five bottled water analyzed. This could be that they contained no chromium or that it was present in the samples in residual amount that could not be detected by the reagent [42, 43]. Other sachet water analyzed contain between 0.01 and 0.03 mg/L of chromium while the bottled water had between 0.01 and 0.02 mg/L of chromium. These values were below the guideline value of 0.05 mg/L set by WHO/NIS for chromium in quality water.

Results obtained in this study indicated that both sachet and bottled water produced and/or sold in various part of the Ogbomoso Metropolis are free from microbiological contaminants, as shown in Table 5. Total coliforms, faecal coliforms and enterococci were not isolated in any of the twenty-five sampled water. The presence of total coliforms in treated drinking water is a measure of its general sanitary quality whereas the indication of faecal contamination is measured by the presence of faecal coliforms [44]. WHO/NIS limit is that none should be detected in drinking water [22, 23]. This clearly indicated that both sachet and bottled water produced and/or sold in Ogbomoso are of good microbiological quality, and thus suitable for human consumption.

4. CONCLUSION

The physical, chemical and bacteriological properties as well as mineral composition of the twenty selected sachet water and the five bottled drinking water brands sold and/or produced in

Ogbomoso metropolis were analyzed successfully. Though, the average temperature values of both the sachet and bottled drinking water samples were significantly above the WHO/NIS standard, it did not have any effect on their microbiological quality properties. Total coliforms, faecal coliforms and enterococci bacteria that principally characterize drinking water quality were not present in any of the water samples. Generally, the results obtained in this study indicated that sachet and bottled drinking water produced and/or sold in Ogbomoso metropolis were of good quality and hygienic for consumption.

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