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PARASITOLOGICAL AND BACTERIOLOGICAL EVALUATION OF SELECTED VENDED SACHET WATER IN SABO METROPOLIS, KADUNA STATE, NIGERIA

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ABSTRACT
Sachet water, often known as pure water, is a primary source of drinking water for Nigerians in the lower and middle classes. In most nations throughout the world, the sale and consumption of sachet water is fast increasing. The purpose of this study was to evaluate the parasitological and bacteriological qualities of a few different sachet water brands in Sabo Metropolis. Data was collected from 30 different sachet water brands at five different sites in Sabo Metropolis, Kaduna State, using a random sample approach. The samples were physically examined, and data from the packaging was recorded. To avoid contamination, each package was carefully opened. All samples were tested for physical, chemical, and bacteriological characteristics, as well as mineral composition, using established procedures, and the findings were compared to the WHO/NIS quality water criteria. The physical properties of the sachet water brands examined in Sabo metropolis (temperature, pH, color, conductivity, total suspended particles, turbidity, and total dissolved solids). The lowest and maximum temperatures measured in the sachet water were 27.10 and 30.20°C, respectively. The sachet water has a pH range of 6.53 to 8.40. Almost all of the water samples examined parasitologically included debris. Eight (26.67%) of the 30 different kinds of sachet water tested had parasites. The results also indicated that water samples obtained and studied from Sabon Tasha, Kamazou, and Karji regions had the highest frequency of parasites 2 (33.33%) each, while Barnawa and Mararaba Riddo areas had the lowest prevalence of parasites 1 (16.67%). Ova of *Taenia* 1 (12.5%), Ova of Hookworm 2 (25.0%), Cyst of *Entamoeba* sp 4 (37.5%), Ova of *Ascaris* sp 1 (12.5%), and Cyst of *Gardia lamblia* 1 (12.5%) were among the parasites found. Hawkers' improper handling of sachet water contributes significantly to the spread of water-borne parasite diseases. Regulators such as the National Agency for Food and Drug Administration and Control (NAFDAC) and the Standard Organization of Nigeria (SON) must actively supervise sachet water companies and ensure that they follow their rules.

***Keywords**: Salmonella typhi**, Sabo, Sachet water, Kamazou**, Entamoeba sp**.*

INTRODUCTION
Drinking water safety is a worldwide public health problem. According to the World Health Organization (WHO), 1.1 billion people worldwide do not have access to clean drinking water. Furthermore, polluted

water is responsible for 80% of infections and one-third of fatalities in underdeveloped nations (WHO, 2011). In Nigeria, the incidence of acute watery diarrhoea is estimated to be 4.9 episodes per year, with roughly 200,000 diarrhoea-related fatalities of children under the age of five occurring on a daily basis (United Nations, 2012). As a result, the quality of drinking water must be prioritized, as it is crucial for preserving good health and a society's overall socioeconomic growth.

Fresh drinking water is a natural resource that all humans require for their existence and survival (Abdullahi *et al.*, 2010). Potable drinking water is a crucial pillar in disease prevention and control (WHO, 2010; Isa *et al.*, 2013). The importance of safe drinking water in a community's socioeconomic existence cannot be overstated. Because microbiological contamination of water is the major cause of disease outbreaks in many communities, particularly in impoverished nations, the source and potability of water supply often has an impact on community health. One of the key problems for safe water supply is the spread of illness through drinking water (Ahmed *et al.*, 2004; Popoola *et al.*, 2007). Contaminated water is a global public health problem that puts individuals at risk of a variety of illnesses, including diarrhoea and other illnesses, as well as chemical poisoning (Okonko *et al.*, 2000; Isa *et al.*, 2013). When supply is regularly disrupted and shortages occur, availability of drinkable water becomes a concern in many developing nations (Popoola *et al.*, 2007).

Communities in Nigeria acquire their potable water in the form of sachet water, sometimes known as "pure water," due to a lack of clean drinking water. Given that it is relatively inexpensive, accessible, and typically regarded to be of higher quality, it is the most popular source of drinking water in Nigeria (Stoler, 2012). Drinking water industries in Nigeria, which are mostly owned by private institutions, obtain water from surface or underground sources, and both types of water can be contaminated by biological and chemical pollutants originating from point and nonpoint sources, so various treatment processes are usually applied.

Bacterial growth in drinking water is influenced by a variety of factors such as assimilated organic carbon concentrations, limiting nutrients, disinfectant concentrations, pipe material, packaging nylons, and a variety of other variables such as pH, temperature, hardness, and redox potential, which regulates microorganism growth on pipe surfaces (Lehtola *et al.*, 2002; Ollos *et al.*, 2003). Opportunistic pathogens make up a large portion of the microorganisms found in water distribution systems. The presence of large numbers of opportunistic pathogens in drinking water is a reason for worry since these bacteria can infect particular groups of people (newborn babies, the ill, and the elderly) (Bitton, 2005).

Quality drinking water must not contain Escherichia coli or thermotolerant coliform bacteria, *Giardia* worms, viruses, *Cryptosporidium* spp, *Legionella pneumophila*, *Entamoeba hystolitica*, or other opportunistic pathogens such as *Clostridium* sp., *Klebsiella* sp., or *Pseudomonas* sp., according to WHO guidelines (WHO, 2011). The guideline went on to say that the water should be tested for highly virulent pathogens like *Salmonella typhi*, *Shigella dysenteriae*, and *Vibrio cholerae*, which cause typhoid, bacillary dysentery, and cholera, respectively, and are caused by high levels of organic decay and fermentation in tropical waters. All of these bacteria must not be present in drinking water, therefore sources of packaged water are submitted to laboratory testing by public analysts, in which no bacteria must be identified or detected in each 100ml water sample.

Various investigations on sachet water from various places have found that sachet drinking water in Nigeria is not pure (Oladipo *et al.*, 2009; Afiukwa *et al.*, 2010; Edema *et al.*, 2011; Akpoborie, and Ehwarimo, 2012; Onilude *et al.*, 2013). Sharp procedures, poor vendor hygiene, a dirty atmosphere, and non-compliance with WHO/NAFDAC rules are all blamed (Omalu *et al.*, 2010). For the sake of public health, it is critical that the quality of sachet water sold be regularly checked.

Waterborne illnesses are also challenging to treat due to the emergence of antibiotic resistance. Antibiotics work by interfering with peptidoglycan, protein, and nucleic acid production (inhibition of nucleotide metabolism, inhibition of RNA polymerase or DNA gyrase) or by disrupting cell membrane integrity (Russel, 2002). Antibiotic usage is frequently linked to increasing bacterial resistance to these drugs, particularly in the hospital context (Swartz, 1997). The goal and goals of this study are to assess parasites and bacteria in several sachet water brands offered in Sabo, Kaduna State, Nigeria.

MATERIALS AND METHODS

2.1. Study area

The study areas include five (5) different locations of Sabo axis (Sabo Tasha, Barnawa, Mararaba Rido, Kamazou and Karji).

Kaduna State is a state of the Federal Republic of Nigeria located in the northwestern geopolitical zone of the country. It takes its name for the capital of Kaduna, hence it is usually referred to as Kaduna State to distinguish the two. It is ranked 4th by land area and 3rd by population in Nigeria. The state capital was the former capital city of the British protectorate of Northern Nigeria region (1923–1966) after Zungeru (1903–1923) and Lokoja (1897–1903). Other major urban areas include Zaria, Kagoro, Kafanchan, Kachia, Nok, Makarfi, Birnin Gwari and Zonkwa.

Kaduna is one of the largest centres of education in Nigeria. The slogan of the state is *Center of Learning* because of the presence of many institutions like Ahmadu Bello University (established 1962). There are many government schools, include primary schools and secondary schools. All secondary schools in Kaduna are owned by the state government, federal government or private organizations. There are many tertiary institutions in the state.

Physical parameters

Sensory analysis was carried out on the sachet water samples to determine the odour and general appearance. The pH of each water sample was also checked using a pH meter (Jenway, 2010).

2.2. Collection of samples

Thirty (30) different brands of 50cl vended sachet water were purchased randomly from hawkers within five (5) different locations (Sabo Tasha, Barnawa, Mararaba Rido, Kamazou and Karji) of Sabo Metropolis. Sachet water samples were macroscopically observed for taste, colour and pH tested according to the World health organization (WHO) Standard. Table 1 show the summary of vended sachet water from different locations in Sabo area, Southern Kaduna, Nigeria. It showed the area of collection and the frequency of sample collected respectively.

2.3. Wet mount preparation

A drop of suspended sediment was placed on a clean glass slide; it was cover with cover slip and examined microscopically using x10 and x40 objective lenses. A drop of suspended sediments was placed on a drop of iodine solution using Pasteur pipette. The mixture was cover with cover slip and examined microscopically using x10 and x40 objective lenses, respectively (Cheesbrough, 2010).

2.4. Modified Ziehl Nelsen techniques

A drop of each sediment was placed on a labeled slide and spread in a thin uniform smear using a Pasteur pipette. It was fixed in methanol for two minutes. The slides were stain with cold carbol fuschin for fifteen minutes and wash off with water. Slides were decolorized with 1% acid alcohol for 10 s, it was rinsed with water. Slides were counterstained with methylene blue for 5mins and rinsed with water. Slides were examined using high power objective lens (x100) according to Cheesbrough (2010).

Culture media

The culture media used include Nutrient agar (Oxoid) to determine the total viable bacterial count, Eosin Methylene Blue agar (LAB M) to enumerate *Escherichia coli*, MacConkey agar (Oxoid) for coliform count and Salmonella-Shigella agar for the determination of *Salmonella* and *Shigella* counts. Culture media were all prepared according to the respective Manufacturers‟ specification and sterilized in an autoclave at 121oC at 15 psi for 15 minutes.

Enumeration and isolation of bacteria

A 1 ml aliquot of each water sample was inoculated aseptically on each of the sterilized agar using the pour-plate method. The plates were incubated for 24 h at 37°C, after which visible colonies were counted and expressed in cfu/ml. Distinct colonies were selected and purified by repeated streaking on Nutrient agar plates. Pure cultures were preserved on agar slants at 5^{o}C and renewed at 2-weekly intervals.

Characterization and identification of isolates

Morphological characterization

The colony of the pure cultures of each bacterial isolates was observed for morphological features using Bergey's Manual of Determinative Bacteriology. Cell shape was determined under X100 objective of the light microscope after Gram staining procedure. Gram staining was carried out as described by Olutiola *et al*. (1991).

RESULTS

Table 1: Summary of sachet water produced or sold in Sabo area, Southern Kaduna, Nigeria.

CODE	SACHET WATER SAMPLED	AREAS OF COLLECTION
SW1	Mims water	Kamazou
SW2	Pelia	Kamazou
SW3	Keystone	Kamazou
SW4	Nokite	Kamazou
SW5	Jugate	Kamazou
SW6	Alheri pure water	Kamazou
SW7	K-Danrimi Table water	Sabo Tasha
SW8	Iya Ganiyat Pure Water	Sabo Tasha
SW9	Dima water	Sabo Tasha
SW10	Afrielin water	Sabo Tasha
SW11	Today water	Sabo Tasha
SW12	Thalj water	Sabo Tasha
SW13	Muhabba water	Barnawa
SW14	Ket water	Barnawa
SW15	Lasena Artesian water	Barnawa
SW16	Voici Table water	Barnawa
SW17	Kc Pure water	Barnawa
SW18	De Timmy water	Barnawa
SW19	Mercy water	Mararaba Rido
SW20	Tofkan water	Mararaba Rido
SW21	NJWR	Mararaba Rido
SW22	Icy water	Mararaba Rido
SW23	Manaz water	Mararaba Rido
SW24	White ware water	Mararaba Rido
SW25	Almasha water	Karji
SW26	Kristel water	Karji
SW27	Kb table water	Karji
SW28	Iza water	Karji
SW29	Bran and Luebe water	Karji
SW30	Gee Links table water	Karji

Table 2: Physical Examination of Sachet Water Brands produced or sold in Sabo Metropolis

Sachet Water Code	Product Name	Manufacturer address	Batch Number	Manufacturing Date	Expiry Date	NAFDAC Number	Mineral Composition
SW1	+	+	-	-	+	+	-
SW2	+	+	-	-	+	+	-
SW3	+	+	-	-	+	+	-
SW4	+	+	-	-	+	+	-
SW5	+	+	-	-	+	+	-
SW6	+	+	-	-	+	+	-
SW7	+	+	-	-	+	+	-
SW8	+	+	-	-	+	+	-
SW9	+	+	-	-	+	+	-
SW10	+	+	-	-	+	+	-
SW11	+	+	-	-	+	+	-
SW12	+	+	-	-	+	+	-
SW13	+	+	-	-	+	+	-
SW14	+	+	-	-	+	+	-
SW15	+	+	-	-	+	+	-
SW16	+	+	-	-	+	+	-
SW17	+	+	-	-	+	+	-
SW18	+	+	-	-	+	+	-
SW19	+	+	-	-	+	+	-
SW20	+	+	-	-	+	+	-
SW21	+	+	-	-	+	+	-
SW22	+	+	-	-	+	+	-
SW23	+	+	-	-	+	+	-
SW24	+	+	-	-	+	+	-
SW25	+	+	-	-	+	+	-
SW26	+	+	-	-	+	+	-
SW27	+	+	-	-	+	+	-
SW28	+	+	-	-	+	+	-
SW29	+	+	-	-	+	+	-
SW30	+	+	-	-	+	+	-

Keys:
+ = Present
– = Absent

Biochemical characterization

This was carried out according to standard techniques described by Olutiola *et al*. (1991). Biochemical tests carried out include; Oxidase test, Indole test, Urease test, Methyl red test, Voges Proskauer and tests for the fermentation of different sugars. Bacterial isolates were identified using Bergey's Manual of Determinative Bacteriology.

Identification of isolates

The isolates were identified using Bergey's Manual of Determinative Bacteriology (Buchanan and Gibbon, 1974).

Physical Examination of Sachet Water Brands produced or sold in Sabo Metropolis

The results of the physical examination of the various sachet water brands produced or sold in Sabo metropolis and environs revealed that all the sachet water brands studied had 100% compliance in term of the product names, manufacturing addresses, expiry dates, and NAFDAC number. However, all the sachet water brands studied were observed to be without Batch number, manufacturing dates, and mineral composition on their labeling. This information is very essential, as they tell the consumer whether the water sample is still within its shelf life or not (Table 2).

Physical parameters of sachet water brands produced or sold in Sabo Metropolis

Table 3 showed the physical qualities (temperature, pH, colour, conductivity, total suspended solids, turbidity and total dissolved solids) for the sachet brands investigated within Sabo metropolis. The standard temperature of drinking water according to WHO is 25 °C. The sachet water analyzed has 27.10 and 30.20°C as the lowest and highest temperature respectively. The pH of the sachet water ranged from 6.53 to 8.40. The pH of sachet waters analyzed is within the standard range of pH (6.5-8.5) for quality water recommended by WHO.

Table 3: Physical parameters of sachet water brands produced or sold in Sabo Metropolis

Sachet water brands	Tempt (^oC)	pH	Colour	EC (µs/cm)	TSS (mg/L)	Turbidity (NTU)	TDS (mg/L)
SW1	29.2	8.25	0.00	78.9	0.00	0.34	62.2
SW2	29.4	7.52	0.00	78.6	0.00	0.36	57.21
SW3	28.5	7.06	0.00	94.5	0.00	0.24	78.19
SW4	28.1	6.89	0.00	55.7	0.00	0.14	62.18
SW5	27.0	6.53	0.00	96.9	0.00	0.21	25.35
SW6	27.5	7.40	0.00	89.6	0.00	0.29	22.6
SW7	29.7	7.20	0.00	87.4	0.00	0.25	52.83
SW8	28.2	8.20	0.00	82.5	0.00	0.22	54.54
SW9	27.1	8.40	0.00	72.4	0.00	0.37	52.21
SW10	29.5	7.20	0.00	115.7	0.00	0.18	56.12
SW11	29.6	6.90	0.00	122.5	0.00	0.26	29.72
SW12	30.2	7.50	0.00	105.3	0.00	0.97	18.12
SW13	28.1	7.00	0.00	67.3	0.00	0.2	32.1
SW14	29.4	7.50	0.00	99.5	0.00	0.11	68.63
SW15	29.2	8.10	0.00	98.6	0.00	0.15	52.15
SW16	28.5	7.65	0.00	101.4	0.00	0.14	77.82
SW17	27.2	7.20	0.00	92.1	0.00	0.16	78.36
SW18	27.6	8.20	0.00	67.3	0.00	0.97	43.11
SW19	27.6	7.50	0.00	109.8	0.00	0.27	58.13
SW20	29.2	7.20	0.00	65.4	0.00	0.25	80.55
SW21	29.1	6.80	0.00	87.2	0.00	0.73	47.2
SW22	29.4	8.30	0.00	135.3	0.00	0.45	61.9
SW23	28.3	7.50	0.00	125.6	0.00	0.22	39.28
SW24	28.4	6.75	0.00	65.4	0.00	0.23	13.61
SW25	30.1	7.02	0.00	56.5	0.00	0.49	15.75
SW26	27.3	8.29	0.00	53.2	0.00	0.32	18.7
SW27	29.4	7.20	0.00	45.9	0.00	0.45	16.4
SW28	29.1	6.81	0.00	66.9	0.00	0.53	19.7
SW29	28.2	8.25	0.00	80.4	0.00	0.62	17.5
SW30	29.1	6.90	0.00	89.5	0.00	0.41	15.2

Keys: *EC = Electrical Conductivity*
TSS = Total Suspended Solids and TDS = Total Dissolved Solids.

The result of this study also indicated that no colour was present in sachet water investigated. The electrical conductivity values obtained for sachet water investigated were within the range of WHO standard conductivity (0-1000µs/cm) for quality water. Sachet water investigated in this study showed that no suspended solids were present in them to be detected. The turbidity of both sachet water was within the range given by WHO (0-5 NTU). This could account for the reason why total suspended solids (TSS) were not detectable in all the brands of sachet water analyzed, which is good for consumption. However, the sachet water samples were more turbid. Some solids were found to have dissolved in sachet water investigated but they were far below the permissible level of total dissolved solids (TDS) value (1000 mg/L) of WHO.

Distribution of Protozoan and helminthes parasites detected in vended sachet water in Sabo Metropolis

The parasitological examination of 30 different brands of sachet water samples produced or sold in Sabo metropolis showed that almost all the water samples contain debris. Of the 30 different brands of sachet water examined, 8 (26.67%) harboured parasites. Table 4 shows the distribution of protozoan and helminthes parasites detected in sachet water produced or sold in Sabo Metropolis in relation to locations. The result showed that water samples collected and investigated from Sabon Tasha, Kamazou, and Karji areas had the highest prevalence of parasites 2 (33.33%) respectively, while the least prevalence of parasites were recorded from Barnawa and Mararaba Riddo areas with 1 (16.67%) respectively. The parasites detected were Ova of *Taenia* 1 (12.5%), Ova of Hookworm 2 (25.0%), Cyst of *Entamoeba* sp 4 (37.5%), Ova of *Ascaris* sp 1 (12.5%) and Cyst of *Gardia lamblia* 1 (12.5%).

Bacteriological analysis of Sachet Water produced or sold in Sabo Metropolis

The bacteria isolated from the investigated sachet water samples were denoted using a positive (+) sign while those bacteria not found in some of the sachet water samples were shown using a negative (-) sign (Table 5).

Table 4: Distribution of Protozoan and helminthes parasites detected in vended sachet water in Sabo Metropolis

Location	No. examined	No. positive	Ova of *Taenia* sp	Ova of Hookworm	Cyst of *Entamoeba* sp	*Ascaris* sp	*Gardia lamblia*
Sabon Tasha	6 (20.0)	2 (33.33)	1 (50.0)	0 (0.00)	1 (50.0)	0 (0.00)	0 (0.00)
Barnawa	6 (20.0)	1 (16.67)	0 (0.00)	1 (100.0)	0 (0.00)	0 (0.00)	0 (0.00)
Mararaban Rido	6 (20.0)	1 (16.67)	0 (0.00)	0 (0.00)	1 (100.0)	0 (0.00)	0 (0.00)
Kamazou	6 (20.0)	2 (33.33)	0 (00.0)	1 (50.0)	1 (50.0)	0 (0.00)	0 (00.0)
Karji	6 (20.0)	2 (33.33)	0 (0.00)	0 (00.0)	0 (00.0)	1 (50.0)	1 (50.0)
Total	30 (100)	8 (26.67)	1 (12.5)	2 (25.0)	3 (37.5)	1 (12.5)	1 (12.5)

Table 5: Bacteriological analysis of Sachet Water produced or sold in Sabo Metropolis

Sachet water brands	*Salmonella Typhi*	*Bacillus subtilis*	E. coli	*Staphylococcus aureus*	*Vibrio Cholerae*	*Pseudomonas aeruginosa*	*Klebsiella Pneumonia*
SW1	+	+	-	+	+	-	+
SW2	+	+	-	+	+	-	-
SW3	+	+	+	+	-	+	+
SW4	-	+	-	+	+	+	+
SW5	+	+	-	+	+	-	-
SW6	+	+	+	+	+	+	+
SW7	+	+	+	+	-	+	+
SW8	-	+	-	-	+	+	+
SW9	-	+	-	-	-	-	-
SW10	+	+	+	-	+	+	+
SW11	+	+	-	-	-	+	+
SW12	+	+	-	-	+	+	+
SW13	-	+	+	-	+	-	-
SW14	+	+	-	-	+	-	-
SW15	+	+	+	-	+	+	+
SW16	-	+	+	+	-	+	+
SW17	-	+	-	+	+	+	+
SW18	+	+	-	+	+	-	-
SW19	+	+	-	+	-	+	+
SW20	+	+	+	+	-	+	+
SW21	-	+	-	+	+	+	+
SW22	+	+	-	-	-	+	+
SW23	+	+	+	-	+	-	-
SW24	-	+	-	-	-	+	-
SW25	+	+	+	-	+	+	-
SW26	-	+	-	+	-	+	-
SW27	-	+	+	-	+	-	-
SW28	+	+	+	-	-	+	+
SW29	+	+	-	-	+	+	+
SW30	+	+	-	+	-	-	-

Keys:
+ = Present
– = Absent

DISCUSSION

Diarrhoeal illnesses are responsible for 1.8 million fatalities per year, according to the World Health Organization (WHO). They account for 4.1% of the total daily world burden. Unsafe water supplies, sanitation, and hygiene are thought to be responsible for 88% of the burden (WHO, 2020). The National Agency for Food, Drug Administration and Control (NAFDAC), Nigeria's regulatory agency for medicines, foods, and chemicals, mandates that all food and drug labels be informative and accurate. Manufacturer's name, contact information, batch number, nutritional information, production date, expiration date (Best before date), and NAFDAC registration number are all needed on labels (Dada, 2009; Musa *et al.*, 2014).

In Nigeria, the continued selling and indiscriminate consumption of bottled drinking waters is a public health concern (Oyedeji *et al.*, 2010). In most nations throughout the world, the sale and consumption of bottled water is fast increasing. The usage of packaged fluids, notably bottled and sachet drinking water, has increased dramatically in Nigeria (Umeh *et al.,* 2020; Oyedeji *et al.*, 2010). The increased demand for these drinking water products can be attributed to a number of factors, including the lack of or inaccessibility of reliable, safe municipal water in urban areas; the perception that high-quality natural spring water and drinking water provide a healthy, refreshing, and great-tasting alternative to high-calorie soft drinks and ordinary tap water; and the products' convenience, which allows them to meet the needs of any lifestyle when needed (Oyedeji *et al.*, 2010; Airaodion *et al.*, 2019).

Eight (26.67%) of the 30 different kinds of sachet water tested had parasites. *Entamoeba* sp 3 (37.5%) was found to be the most common of the five (5) damning parasites found. Our findings indicate that some of our sachet water contains a considerable amount of faecal pollutants. This is consistent with the findings of a Ghanaian research by Kwakye-Nuako et al. (2007), which found protozoan parasites in sachet drinking water. The presence of parasites in the analyzed sachet water, however, is in contrast to a research conducted by Ekwunife et al. (2010) in Awka, Southeastern Nigeria, which found no protozoan parasites in sachet drinking water. This was in contrast to the findings of Egwari et al. (2005) in Lagos, southwest Nigeria, who detected no enteric pathogens or *Entamoeba coli* in their bacteriology investigation of sachet water. *Entaemoeba coli* and other enteric pathogens were found on the exterior sachet surfaces of samples taken from cooling receptacles, according to Egwari et al. (2005) in Lagos, Nigeria (pail, basin, wheel barrow, and refrigerator). It's hardly unexpected that some of the packs examined in this investigation contained hookworm eggs. Improper processing and purification techniques, unclean handling after manufacturing, the pathogens' tiny size, which allows them to escape filtration, and their resistance to physical water treatment chemicals and disinfectants might all have contributed to this finding (Kwakye-Nuako *et al.*, 2005).

Several investigations on the microbiological quality of bottled and sachet water have found that international quality requirements have been broken (Oyedeji *et al.,* 2010; Airaodion *et al.,* 2020). In a Canadian investigation, total coliforms were found in 3.7 percent of the samples while more than 100 colonies of heterotrophic bacteria were found in 23.3 percent of the 3460 samples (Warburton *et al.*, 1998). In a similar research on bottled water brands in Trinidad, total coliforms were found in 18 of the 344 samples tested, while Escherichia coli was found in five of the samples, and colonies of *Enterococcus faecalis* were sometimes found in the samples (Bharath *et al.*, 2003). Sachet water quality testing in Nigeria has been reported (Adekunle *et al.*, 2004; Onifade *et al.*, 2008; Dada, 2009; Oyedeji *et al.*, 2010). However, the parasitological quality of the different brands of sachet water produced and promoted by local and global corporations is little documented in scholarly literature.

Waterborne infections remain a serious public health concern, particularly in underdeveloped countries (Oyedeji *et al.,* 2010; Umeh *et al.,* 2019). In the developing world, drinking water polluted with pathogenic bacteria of faecal origin poses a substantial health danger, particularly in isolated rural communities and industrial locations (Davies-Colley *et al.*, 2001). Water-borne diarrhoeal illnesses are responsible for about 3 million fatalities each year, primarily among newborns and young children in impoverished areas in Africa, Asia, and South America (Anon, 1997). The high frequency of illnesses including diarrhoea, typhoid fever, cholera, and bacillary dysentery among the population has been linked to the intake of contaminated water and unsanitary water production procedures (Mead *et al.,* 1999). When faecal pollutants reach the water supply, the most serious type of water contamination occurs (Oyedeji *et al.*, 2010).

All of the bottled water samples were found to be 100 percent compliant in terms of product names, manufacturer's addresses, production and expiration dates, batch number, and NAFDAC registration number, which were all clearly shown on their labeling. However, the mineral contents of the water are not indicated on any of the bottled water brands studied. It was also observed that all the sachet water studied had 100% compliance in term of the product names, manufacturing addresses, and NAFDAC number. This information is 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 (Ibrahim *et al.,* 2015). 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 Ibadan metropolis 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 (NNwidu *et al.*, 2008; Olaoye and Onilude, 2009). 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 and bacteriological qualities of sachet water analyzed were compared with the recommended WHO guidelines (WHO, 2001) for quality water. Table 3 showed the physical qualities (temperature, pH, colour, conductivity, total suspended solids, turbidity and total dissolved solids) for the sachet water brands investigated. The standard temperature of drinking water according to WHO is 25°C. Temperature is a measure of the average thermal energy of a substance (Ibrahim *et al.,* 2015). The sachet water analyzed has 27.10 and 30.20°C as the lowest and highest temperature respectively.

This could be due to high temperature of 27 to 34°C in Sabo and environs during the period of this study. However, these temperatures for sachet water fell within the optimal growth temperature (20 – 45°C) for mesophilic bacteria (Prescott *et al.,* 1999). 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 (WHO, 1993). This result is like that of Danso-Boateng and Frimpong (2013) who reported 28.94°C and 28.81°C respectively for average temperatures of plastic sachet and bottled water brands produced and/or sold in Kumasi, Ghana. According to (Onweluzo and Akuagbazie, 2010), 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 (Onweluzo and Akuagbazie, 2010). 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°C (McKee and Wolf, 1963).

The result of this study also indicated that no colour was present in sachet water investigated. This means that all the water brands were free from dissolved humic acids (Danso-Boateng and Frimpong, 2013). The conductivity values obtained for both sachet water investigated were within the range of WHO standard conductivity (0-1000μs/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 (Wetzel, 2001). These conductive ions come from dissolved salts and inorganic materials such as alkalis, chlorides, sulfides and carbonate compounds. Compounds that dissolve into ions are also known as electrolytes. The more ions that are present, the higher the conductivity of water.

The pH of the sachet water ranged from 6.53 to 8.40. The pH of sachet water analyzed is within the standard range of pH (6.5-8.5) for quality water recommended by WHO. 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 like as acidosis (Asamoah and Amorin, 2011). 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 (Aremu, 2011).

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 (Edimeh *et al.,* 2011). 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 (Edimeh *et al.,* 2011).

Sachet 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 (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 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 (Danso-Boateng and Frimpong, 2013).

The result of the bacteriological characteristics showed that Gram negative bacteria were dominant in the sachet water investigated. The bacterial identification revealed the presence of seven (7) isolates; *Escherichia coli, Salmonella typhi, Pseudomonas aeruginosa, Klebsiella pneumoniae, Vibrio cholerae, Staphylococcus aureus* and *Bacillus subtilis* (Tables 5). This may be attributed to contamination from storing tanks, pipes, personnels. The coliforms isolated were an indication of the contamination of the pond water with faecal materials. The faecal material may be as a result of source of water used, personnel's working therein, and poor sanitary level septic tanks. The diverse groups of bacteria isolated from these sachet waters are in line with the report of (McKee and Wolf, 1963) and (Wetzel, 2001) who reported similar organisms in the microbiological study of El-quanter fish pond. The presence of pathogenic microorganisms especially *Salmonella typhi, Escherichia coli* and *Vibrio cholerae* can lead to the transmission of water borne diseases such as, Diarrhoea, Typhoid fever, Cholera. The presence of *Salmonella typhi and Escherichia coli* in water or food indicates the possible presence of causative agents of many gastrointestinal diseases (Umeh *et al.,* 2020).

CONCLUSION

The parasitological and bacteriological properties of the thirty selected sachet water brands sold and/or produced in Sabo metropolis were analyzed successfully. Though, the average temperature values of sachet drinking water samples were significantly above the WHO standard. This study shows that some sachet water in our markets could serve as possible routes of transmission of protozoan parasites. Therefore, Infections caused by these parasitic protozoa and helminthes organisms should critically be considered potential waterborne diseases in our environment. Like other countries, we need to implement measures and regulations that would critically minimize and control the spread of waterborne diseases (Current *et al.,* 1991). Epidemiological and risk assessment approaches will undoubtedly boost our understanding of the occurrence, survival and transport of these organisms. Regardless of these measures, the possibility of contaminated water causing significant diseases still remains due to problems associated with water purification and distribution.

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