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Quality Assessment of Selected Sachet Water Sold in Otukpo Metropolis of Benue State, Nigeria

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Abstract— *Access to potable water has been reported as a major challenge facing the residents of Otukpo LGA of Benue State. The present study carried out a quality assessment of sachet water collected in triplicates from five water producing companies in five different locations (A-E) within Otukpo metropolis. Standard bacteriological and physicochemical analyses were carried out. Results were compared with the WHO standard guideline for potable water. A total of eight (8) species of bacteria were found. Location A had the least average number of bacterial species (1.3 species) in its sachet water while location E had the highest number of 4.3 species. Number of bacterial species found in sachet was location dependent ($P<0.05$). Klebsiella spp was the most frequently occurring contaminant (60%) while Micrococcus spp., Shigella spp. and E. coli each had a percentage occurrence of 40%. Total heterotrophic count and total coliform count (in cfu/ml) exceeded WHO permissible limits for potable water in all samples, although bacterial load significantly varied from sample to sample ($P<0.05$). Thus, all sachet water samples collected from the E location (E1, E2 and E3) were heavily loaded with bacterial contaminants, followed by those collected from the B location (B1, B2 and B3). Consequently, E1 had the highest MPN of >1600/100ml followed by 900/100ml in E2 and E3. All sachet water samples were assigned "unsatisfactory" status using WHO classification of MPN indices where MPN values are >10/100ml. Exceptionally, C1 had MPN of 9/100ml and assumed the "suspicious" status. The study found slight insignificant variation in physicochemical parameters. Properties such as pH, temperature, electrical conductivity, total dissolved solid, turbidity, total hardness, nitrate, chloride, and carbonate appeared normal within their respective permissible limits. However, the compromised bacteriological quality rendered the sachet water samples unsafe for drinking. Therefore, urgent stakeholders' intervention is recommended.*

Keywords— *Health safety, quality assessment, sachet water, standards.*

I. INTRODUCTION

Water is very essential to living things as 70% of the protoplasmic content of the cell is water (NIS, 2011). Access to safe drinking water supply is one of the goals of the United Nations. This is challenged by the rising human population and anthropogenic activities such as industrialization and urbanization with continued impacts on water quality through contamination**.** Water contamination happens when undesirable materials with possibilities to undermine human and other common frameworks find their ways into waterways, lakes, wells, streams, boreholes or even held new water in homes and industries (Shar *et al.*, 2021). Thus both the quantity and quality of water are affected by an increase in anthropogenic activities. The overall safety of drinking water depend on the physico-chemical and microbiological characteristics. Pollution either physical or chemical causes changes to the quality of the receiving water body and about 80% of all the diseases in human beings are caused by water (WHO, 2018). Scarcity of clean and safe water is a general problem in Africa where water borne infections such as cholera, dysentery and typhoid are common.

There are numerous water manufacturing factories in Nigeria who are into the business of supplying drinking water packed in sachets and bottles to meet the demand of the people. The major source used by the factories is the underground water supply through boreholes. The qualities of packaged water generally are not guaranteed and at times pose health problems to consumers who rely on them as a drinking source (Sohonou *et al*., 2017). Physical, biological and chemical contaminants occur in drinking water throughout the world which could possibly threaten human health. Determining the health effects of these contaminants is difficult, especially researching and learning how different contaminants react in the body to damage cells and cause illness (Ogunbode *et al.*, 2016; Vijay *et al*., 2017). Therefore, the quality of water produced by manufactures cannot be compromised for public health safety reasons. Standard guidelines issued by regulating bodies must be adhered to. According to the WHO (2018), all sources of drinking water must be safe. Over the years, many companies are not licensed by NAFDAC and their activities are often unregulated.

Otukpo community is the second largest town in Benue State located in the middle belt region of Nigeria with an estimated population of 359, 600 as at 2016 with an annual population growth rate of 3%. Access to drinking water is one of the major challenges of the Idoma people as it is in many parts of Africa. While there are many reports on the quality of surface and underground water in many parts of Benue State (Akaahan *et al.*, 2016; Shar *et al.*, 2021), there is insufficient data on the overall quality and safety of drinking water sold in sachets to people in Otukpo LGA and by extension, Benue State at large. The aim of this study was to assess the physicochemical and bacteriological quality of sachet water produced by different factories within Otukpo metropolis and to determine the safety level of the water samples using WHO standard guideline/permissible limits for drinking water.

II. MATERIALS AND METHODS

Study Area

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Otukpo metropolis is the headquarter of the Idoma people. Otukpo LGA is one of the 23 LGAs of Benue State located in the middle belt axis of Nigeria. The geographic coordinate is 7'11'35N-8'8'47E within an area of 1,385 km^2 (Figure 1). It had a population of 266, 411 people as at 2006 census (NPC 2006) with an annual population change of 3%. It was projected as 359, 600 people as at 2016 (NPC, 2016).

Sample Collection

Sachet water samples were collected in triplicates from five water producing companies randomly chosen from five different locations (A-E) within Otukpo metropolis. Information was obtained on the name of company, location, sample code, date and time of sample collection. A total of 15 sachet water samples were packaged in separate sterile bag tagged A1- E3 respectively and transported to the laboratory for bacteriological and physicochemical analyses.

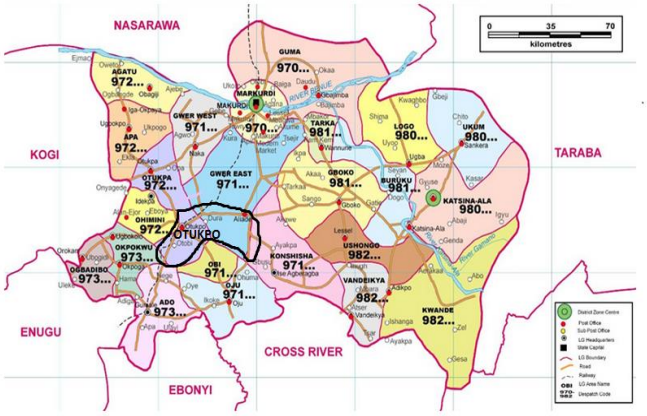

Figure 1: Map showing the study area within Benue State

Bacteriological Assessment

Sample inoculation

Sample inoculation was done by adding 1ml of water suspension on nutrient agar, MacConkey agar and *Salmonella-Shigella* agar (SSA). Incubation was done at 37^{0}C for 24hours (Abdullahi *et al.*, 2010).

Cultural and Biochemical Characterization

Morphological observations were recorded on the culture media. These include the colour, shape and outline of the colony as well as shape of each bacterium. Motility test was done by adding a drop of peptone water on a glass slide containing bacterial colony covered with a slip and viewed under the microscope with high power objective lens (Cheesbrough, 2006). Discreet colonies were sub-cultured on Nutrient agar plate for biochemical test (Hedderwick *et al.*, 2010). Identification of bacteria species was done using standard microbiological procedures for each of the following biochemical tests: Gram staining, catalase, citrate, urease, indole and hydrogen sulphide tests (Cheesbrough, 2006). All identified isolates were recorded per water sample.

Direct Plate Count and Membrane Filtration Methods

Serial dilution, pour plates techniques and incubation (37^{o}C for 24 hours) methods employed (Cheesbrough, 2006). Visible colonies on the plates were counted using Colony Counter and Membrane Filtration methods (Metricel® Black PES 0.45µm membrane disc filter). Total Heterotrophic Counts (THC) and Total Coliform Count (TCC) were recorded in cful/ml (colony forming unit per mililitre (Cheesbrough, 2006).

Most Probable Number (MPN) Water Testing

The methods of Cheesbrough (2006) and Adeiza *et al.* (2018) were used. In the presumptive test, five and ten tubes of double and single strength MCA (McConkey agar) respectively were taken from each water sample. Exactly 10ml and 1ml of water sample were added to each of the five and ten tubes respectively while 0.1ml was added to the remaining five tubes of single strength MCA broth. Incubation was done at 37^{o}C for 24 hours. Number of positive tubes was compared. In the confirmatory test, a loopful of medium was transferred from each of the fermented tube in the presumptive test to (i) 3ml of lactose broth in a sterile tube (ii) an agar slant (iii) 3ml of tryptone water. The lactose broth was incubated at 37^{o}C for 24-48 hours and inspected for gas formation. Gram's stain was added to the agar slant to check for Gram negative bacilli without spore formation. Tryptone water was incubated at 44.5^{o}C for 18-24 hours followed by addition of 0.1ml Kovac's reagent and observed for red colour formation to indicate indole positive reaction. In the completed test, a loopful from lactose broth tube was streaked into Eosin methylene blue agar and incubated at 44.5^{o}C for 24 hours. The values of MPN were estimated per 100ml of water sample (Adeiza *et al.*, 2018).

Physico-chemical Assessment of Water Samples

Temperature and pH of water samples were determined *in situ* with the aid of a combined potable digital HANNA instrument (APHA 46) with a sensitive electrode dipped in the sample for 5 seconds. Temperature readings were taken in degree Celsius. Odour and taste were also observed and recorded on the field while all other parameters were assessed in the laboratory. The water conductivity was measured using a combined conductivity/pH/T meter Hanna instrument model HI 8014. The meter probe was dipped by more than half into the glass jar containing water sample. The reading was recorded for the conductivity as displayed on the meter (Iman and Balarabe, 2012). Total dissolved solid (TDS) and hardness were measured in mg/L using Palintest conductivity meter and Hardicol tcolorimetric test respectively. Turbidity and colour were determined using the Photometer. The standard formazin turbidity solution was used and the result was expressed in Nephelometric Turbidity Units (NTU) and True Colour Unit (TCU) of platinum/cobalt colour scale (Pt/Co scale) respectively. All readings were taken in triplicates. Amount of nitrate, chloride and carbonate was quantified using Hanna instruments HI 83200 benchtop multiparameter photometer. Result was expressed in mg/L. All readings were taken in triplicates (Iman and Balarabe, 2012).

Data Analysis

Data collected were analysed on the Minitab (17.0) software for descriptive statistical tools. One way ANOVA and Chi-square tests were applied at 95% confidence limit (P≤0.05). The WHO standard permissible limit served as a reference guide for water quality parameters.

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III. RESULTS

Table 1 gives the cultural and biochemical identities of the bacterial isolates. A total of eight (8) species of bacteria were identified including: *Bacillus* spp., *Staphylococcus* spp, *Klebsiella* spp., *Escherichia coli*, *Micrococcus* spp., *Proteus* spp., *Enterobacter* spp. and *Shigella* spp. In terms of distribution (Table 2), number of contaminants ranged from 1 contaminant in samples A2 and A3 to 5 contaminants in sample E1. Only one sample (B3) had no contaminant. Location A had the least average number of bacterial species (1.3 species) in its sachet water while location E had the highest number of 4.3 species (Figure 2). Number of bacterial species found in sachet was location dependent ($P<0.05$). *Klebsiella* spp was the most frequently occurring contaminant where it was found in 60% of samples. *Micrococcus* spp., *Shigella* spp. and *E. coli* each had a percentage occurrence of 40% while other species fell below 30%. Therefore, level of contamination significantly depend on the type of bacteria ($\chi^2 = 42.65$, $P<0.05$).

TABLE 1: Cultural and Biochemical Characterization of Bacterial Isolates

Colony colour	Colony shape	Elevation	Morphology	Gram'staining	Motility test	Catalase test	Citrate test	Urease test	Indole test	Bacteria
White	Circular	Flat	Rod	+	+	+	+	-	-	*Bacillus* spp.
Cream	Circular	Raised	Cocci	+	-	+	+	-	-	*Staphylococcus* spp.
Mucoid pink	Circular	Raised	Rod	-	-	+	+	+	-	*Klebsiella* spp.
Pink	Regular	Raised	Rod	-		+	-	-	+	*Escherichia coli*
Cream	Regular	Raised	Cocci	+	-	+	-	-	-	*Micrococcus* spp.
Pale	Regular	Raised	Rod	-	-	-	+	+	-	*Proteus* spp.
Pink	Regular	Raised	Rod	-		+	+	+	-	*Enterobacter* spp.
Pale	Circular	Raised	Rod	-	-	+	-	-	-	*Shigella* spp.

TABLE 2: Distribution of bacterial contaminants in water samples

Sachet Water Sample ID	*Klebsiella* spp.	*Micrococcus* spp.	*E. coli*	*Staphylococcus* spp.	*Proteus* spp.	*Enterobacter* spp.	*Shigella* spp.	*Bacillus* spp.	Contaminants
A1	+	+							2
A2			+						1
A3			+						1
B1	+			+					2
B2			+		+	+			3
B3									0
C1	+	+							2
C2	+	+							2
C3	+	+			+				3
D1	+			+			+	+	4
D2	+	+					+		3
D3		+		+	+		+		4
E1	+		+			+	+	+	5
E2			+			+	+	+	4
E3	+		+		+		+		4
Frequency	9	6	6	3	4	3	6	3	
Relative proportion	60%	40%	40%	20%	26.7%	20%	40%	20%	

χ^2 (Distribution of contaminants and water sample) = 42.65, P=0.00 (P<0.05)

Table 3 gives the estimates of bacterial load in water samples using two methods: Direct Plate Count (DPC) and Membrane Filtration (MF) methods. All values of THC (total heterotrophic count) and TCC (total coliform count) exceeded WHO permissible limits for potable water. In DPC method, THC significantly varied from $40.0\pm4.0 \times 10^3$ cfu/ml (sample C3) to $252.0\pm4.0 \times 10^3$ cfu/ml (sample E3) as against <500 cfu/ml regulatory limit. Also, TCC was between $9.0\pm1.0 \times 10^3$ cfu/ml (sample C3) and $140.0\pm8.0 \times 10^3$ cfu/ml (sample E1) as against standard zero (0) limit of coliform for potable water. In MF method, THC ranged from $48.0\pm0.0 \times 10^3$ cfu/ml (sample C3) to $291.0\pm7.0 \times 10^3$ cfu/ml (sample E1). Also, TCC ranged from 10.5±1.5 cfu/ml (sample C3) and $108.0\pm4.0 \times 10^3$ cfu/ml (sample E1). Variation in level of bacterial load is shown in Figures 3 and 4. In the two methods used, THC was higher than TCC but complimentary. From the graphs, water samples from location A and C contained the lowest amount of bacterial load whereas samples from location E were heavily loaded with heterotrophic and coliform bacteria, followed by samples from B. Bacterial load was location dependent ($P<0.05$).

The above outcome was supported by the presumptive, confirmatory and completed MPN tests where activities of bacteria such as gas formation, indole production and growth with green metallic sheen were mostly observed in water samples E1-E3 and B1-B2 (Table 4). Therefore, sample E1 had the highest MPN of >1600/100ml followed by 900/100ml in samples E2 and E3. All water samples were assigned "unsatisfactory" status using WHO classification of MPN indices for samples whose MPN values are >10/100ml. The only exception was sample C1 that had MPN value of 9/100ml thus assigned the "suspicious" status. There was no water

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sample considered as "satisfactory" as none met the WHO permissible limit of 2.2/100ml MPN value.

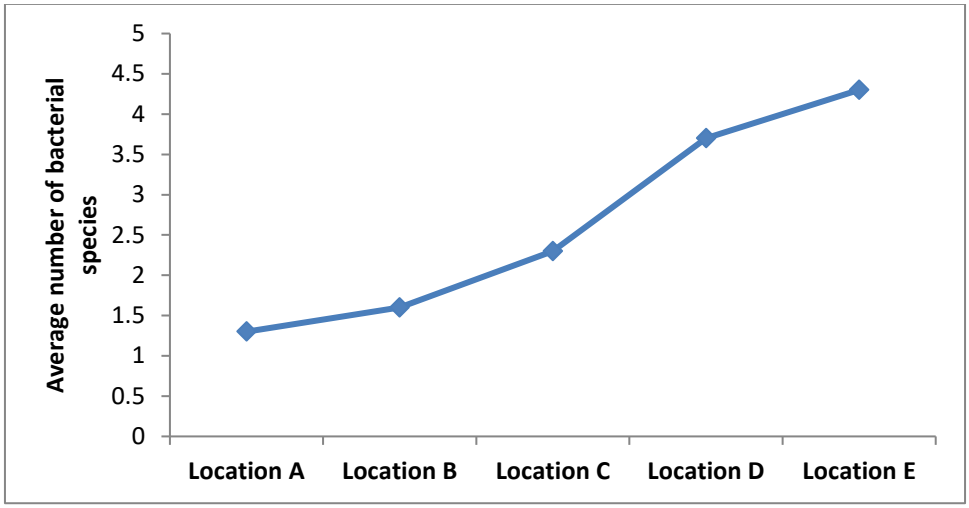

Figure 2: Number of bacterial species found in sachet water in five locations

TABLE 3: Bacterial load using Direct Plate Count and Membrane Filtration methods

Sample ID	Direct Plate Count (DPC)		Membrane Filtration (MF)	
	THC (10^3 cfu/ml)	TCC (10^3 cfu/ml)	THC (10^3 cfu/ml)	TCC (10^3 cfu/ml)
A1	92.0±4.0	34.0±2.0	187.0±11.0	30.0±2.0
A2	76.0±0.0	12.0±0.0	122.0±6.0	11.5±3.5
A3	94.0±2.0	15.5±0.5	168.0±4.0	24.0±2.0
B1	120±4.0	44.0±0.0	204.0±12.0	54.5±1.5
B2	124±0.0	54.0±2.0	220.0±8.0	68.0±4.0
B3	118±2.0	32.0±0.0	186.0±2.0	46.0±2.0
C1	60.0±4.0	23.5±1.5	68.0±4.0	29.0±3.0
C2	46.0±2.0	11.5±0.5	62.0±6.0	16.0±0.0
C3	40.0±4.0	9.0±1.0	48.0±0.0	10.5±1.5
D1	80.0±4.0	18.5±2.5	120.0±4.0	32.5±0.5
D2	66.0±2.0	16.5±1.5	110.0±2.0	26.0±2.0
D3	84.4±4.0	12.0±0.0	130.0±2.0	29.0±3.0
E1	252.0±00	140.0±8.0	291.0±7.0	108.0±4.0
E2	240.0±4.0	106±2.0	274.0±2.0	94.0±2.0
E3	252.0±4.0	92.0±4.0	290.0±2.0	106.0±2.0
WHO	<500	0	<500	0

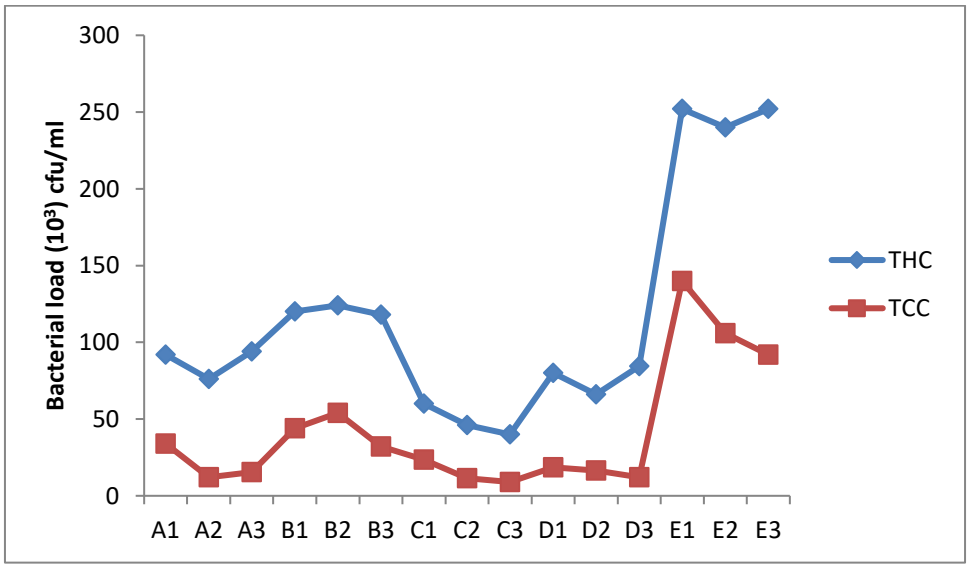

Figure 3: Varied level of THC and TCC of bacteria using Direct Plate Count

χ^2 (Total heterotrophic count and location) = 85.74, P=0.00 (P<0.05)

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χ^2 (Total coliform count and location) = 51.5, P=0.00 (P<0.05)
Legend:
THC= Total heterotrophic count
TCC= Total coliform count

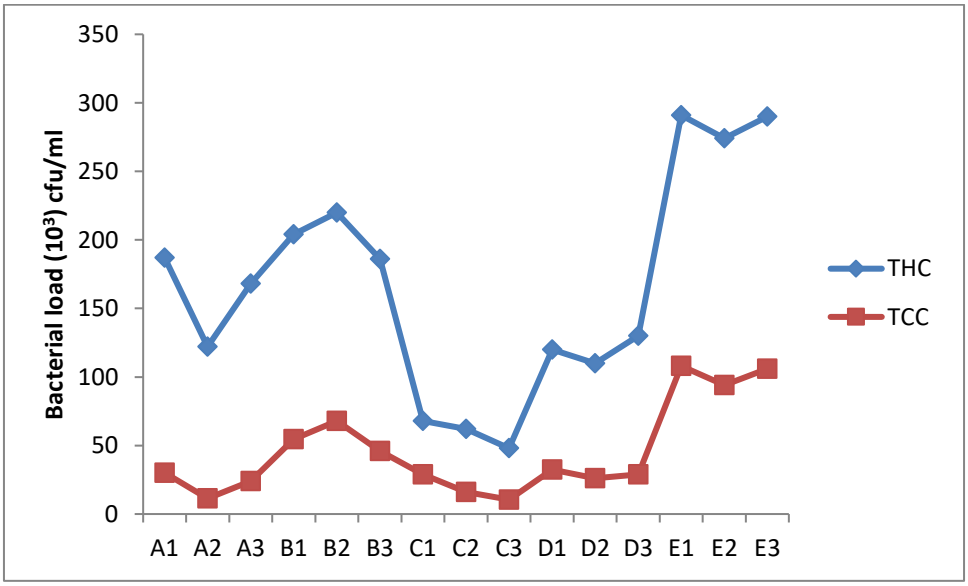

Figure 4: Varied level of THC and TCC of bacteria using Membrane Filtration

χ^2 (Total heterotrophic count and location) = 76.8, P=0.00 (P<0.05)
χ^2 (Total coliform count and location) = 49.6, P=0.00 (P<0.05)
Legend:
THC= Total heterotrophic count
TCC= Total coliform count

TABLE 4: Most Probable Number (MPN) of bacteria in water samples

Water Sample ID	Gas formation	Gram – ve Bacilli	Indole production	Growth with green metallic sheen	Combination of positive tubes	MPN/100ml	Status
A1	-	-	-	-	3-2-1	17	Unsatisfactory
A2	-	-	-	-	3-0-1	14	Unsatisfactory
A3	-	-	-	-	3-2-1	17	Unsatisfactory
B1	+	-	-	+	5-3-1	110	Unsatisfactory
B2	+	+	+	+	5-3-3	170	Unsatisfactory
B3	-	-	-	-	4-4-0	33	Unsatisfactory
C1	-	-	-	-	2-2-2	9	Suspicious
C2	-	-	-	-	2-3-0	12	Unsatisfactory
C3	-	-	-	-	2-3-0	12	Unsatisfactory
D1	-	-	-	-	4-4-0	33	Unsatisfactory
D2	-	-	-	-	4-3-1	27	Unsatisfactory
D3	-	-	-	-	3-2-0	14	Unsatisfactory
E1	+	+	+	+	5-5-5	>1600	Unsatisfactory
E2	+	+	+	+	5-5-3	900	Unsatisfactory
E3	+	+	+	+	5-5-3	900	Unsatisfactory
WHO limit						2.2	Satisfactory

WHO Classification
0= excellent; 1-3= satisfactory; 4-10= suspicious
Above 10-unsatisfactory

Tables 5 and 6 give the result of the physicochemical parameters of sachet water samples of the study area. Values of parameters tested varied from sample to sample. Slight variation was observed in some physicochemical parameters such as pH, temperature, electrical conductivity, total dissolved solid, turbidity, total hardness, nitrate, chloride, and carbonate. However, the observed differences were not significant and therefore not tied to location (P>0.05). Physicochemical parameters of all water samples were normal and within their respective regulatory permissible limits. Mean pH value was between 6.98± 0.00 and 7.02±0.23 and therefore nearly neutral (pH =7) for all samples. There was slight and insignificant fluctuation (P>0.05) in mean temperature value ranging from 21.5±0.70 in B1 to 27.4±0.19 in D1. The lowest value recorded for electrical conductivity (0.60 µs/cm), total dissolved solid (30.1 mg/L), colour (0.97 TCU) and water hardness (11.0

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mg/L) were obtained in A2 whereas the highest values for these parameters were 1.7 µs/cm, 60.67 mg/L, 2.07 TCU and 18.37 mg/L respectively across other water brands. Sample C2 had the least turbidity value (0.07 NTU). As obtained in mg/L, nitrate content was highest in A1 (2.30±0.00) and E1 (2.30±0.15) while carbonate was highest in E1 (19.23±0.29). Sample A2 had the highest amount of chloride (19.57±0.03) while A1 had the least (12.73±0.07).

TABLE 5: Physical Properties of Sachet Water Samples

Sample ID	pH	Temp (^{O}C)	EC (µs/cm)	TDS (mg/L)	Turbidity (NTU)	Colour (TCU)	Total Hardness (mg/L)	Odour	Taste
A1	6.99 ±0.03	22.53 ±0.23	0.73 ±0.00	60.67 ±1.35	0.6 ±0.03	1.73 ±0.00	16.55 ±0.15	Odourless	Tasteless
A2	6.97 ± 0.07	23.35 ±0.33	0.60 ±0.03	30.1 ±0.90	0.12 ±0.00	0.97 ±0.00	11.00 ±0.00	Odourless	Tasteless
B1	7.00 ± 0.03	21.5 ±0.70	0.83 ±0.00	51.0 ±1.10	0.8 ±0.00	1.90 ±0.01	14.38 ±0.33	Odourless	Tasteless
B2	7.00 ± 0.00	22.53 ±0.23	1.13 0.03	64.7 ±0.00	0.23 ±0.00	1.80 ±0.03	20.10 ±0.00	Odourless	Tasteless
C1	7.00± 0.07	24.37 0.19	0.63 ±0.023	31.7 ±0.05	0.23 ±0.00	2.03 ±0.00	14.58 ±0.67	Odourless	Tasteless
C2	7.02 ±0.23	22.53 ±0.20	0.73 ±0.01	45.7 ±1.33	0.07 ±0.01	1.00 ±0.00	12.20 ±0.00	Odourless	Tasteless
D1	7.02 ± 0.00	27.4 ±0.19	1.03 ±0.00	70.3 ±0.33	0.5 ±0.06	1.83 ±0.03	15.90 ±0.33	Odourless	Tasteless
D2	6.98 ± 0.00	22.60 ±0.30	1.07 ±0.03	34.7 ±0.00	0.67 ±0.00	1.90 ±0.00	13.33 ±0.15	Odourless	Tasteless
E1	6.98 ± 0.00	21.67 ±0.10	0.87 ±0.02	37.0 ±0.22	0.63 ±0.00	2.07 0.01	15.00 ±0.00	Odourless	Tasteless
E2	6.98 ± 0.00	25.83 ±0.75	0.7 ±0.00	37.0 ±0.20	1.0 ±0.00	2.00 ±0.00	18.37 ±0.67	Odourless	Tasteless
PL	**6.5-8.5**	**NS**	**0.5-1.5**	**<1000**	**<5**	**<15**	**NS**	**Odourless**	**Tasteless**
P-value	P>0.05	P>0.05	P>0.05	P>0.05	P>0.05	P>0.05	P>0.05		

PL= permissible limit of WHO; NS= Not stated

TABLE 6: Chemical Properties of Sachet Water Samples

Sample ID	Nitrate (mg/L)	Chloride (mg/L)	Carbonate (mg/L)
A1	2.30±0.00	12.73±0.07	12.57±0.23
A2	0.80±0.00	19.57±0.03	11.03±0.03
B1	2.10±0.00	18.27±0.09	11.57±0.15
B2	1.33±0.03	15.57±0.20	12.90±0.06
C1	1.27±0.03	13.23±0.20	13.27±0.29
C2	0.60±0.12	19.47±0.07	11.67±0.19
D1	2.07±0.07	16.37±0.26	12.83±0.03
D2	1.43±0.09	15.37±0.39	11.50±0.15
E1	2.30±0.15	19.53±0.75	17.30±0.25
E2	1.73±0.09	11.67±0.70	19.23±0.29
WHO PL	**50**	**<250**	**NS**

PL= permissible limit; NS= Not stated

IV. DISCUSSION

The eight species of bacteria reported in this work are clinically important from the public health point of view and therefore cannot be overlooked. They have been implicated in causing gastroenteritis, diarrhoea and food poisoning among other diseases. Also, cases of multi drug resistance by these pathogens have been reported (Jacob and Cohen, 2016; Feglo and Sakyi, 2012; Hernández-Cortez *et al.*, 2017; Jamal *et al.*, 2018; Mir *et al.*, 2018). Meanwhile, WHO has clearly defined pure and safe drinking water of an area as any 100 water samples without pathogens (WHO, 2018). These pathogens were previously reported to cause water related disease outbreaks with many casualties across many communities in Nigeria (Abdullahi *et al.*, 2010; Ruma *et al.*, 2014; Shobowale *et al.*, 2016, Obioma *et al.*, 2017; Adeiza *et al.*, 2018). The presence of *E. coli* and *Shigella* was an indication of faecal contamination of water sources and it is the most frequently occurring etiologic agent of diarrhea (Onyemaechi and Ejikeme, 2018; Elum *et al.*, 2022). *Bacillus*, *Staphylococcus* and *Proteus* had been reported to possess toxins capable of causing food poisoning (Elum *et al.*, 2022). *Klebisella* was among the most frequently reported enterogenic pathogens associated with opportunistic infections in immuno-compromised individuals as a common microbiota of the respiratory tract (Obioma *et al.*, 2017). A study carried out by Tanimu *et al.* (2011) linked the occurrence of contaminants found in reservoirs supplying drinking water to the people of Kaduna South to the wastes generated along the supply chain. In terms of bacteriological assessment, sachet water from location E was mostly affected followed by those collected from location B.

The WHO standard does not permit any viable pathogenic bacterium cell to be present in drinking water because if the water is allowed to stand for more days, such a pathogen could multiply rapidly over time to increase the load. This position

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aligns with other reports stating that bacterial load in drinking is a function of time taken to store such samples in any conducive environment (Prescott *et al.*, 2005; Amer and Abdel-Gawad, 2012). The presence of faecal coliforms in the water samples is indicative of water borne diarrheahenic bacteria. In the two methods used, THC was higher than TCC but complimentary. WHO set regulatory limits for total heterotrophic count that must exceed 500 cfu/ml while total coliform count was set at zero. By exceeding standard limits, the affected sachet water samples are unsafe for drinking. Result was consistent with the work of Agyo *et al.* (2020) who carried out a bacteriological quality of water in private wells and boreholes in Makurdi Metropolis, Benue State, Nigeria.

The managers of the affected sachet water factories are advised to ensure regular treatment and sterilization of water gadgets and equipment from time to time. Factory workers should be trained on public health safety, hygiene and regulatory requirement in the water production cycle. Measures should be put in place to keep drinking water free from bacterial contaminants. According to the Nigerian Industrial Standard for drinking water qualities (NIS, 2011), drinking water must not be allowed to stand for a lengthy time before being sold to the public. All production cycle should be monitored for strict for compliance to standard guideline to prevent occurrence of water borne diseases. This view is topical among stakeholders as strategies to prevent enteric diseases (Monney *et al.*, 2014; Adesegun *et al.*, 2020). The above strategies are in line with the position of the WHO and UN on drinking water supply (WHO, 2018).

Physicochemical parameters of all water samples were normal and within their respective regulatory permissible limits. Similar findings on stability of physicochemical properties of drinking were reported in other places (Rahmanian *et al.*, 2011; Tanimu *et al.*, 2011). The pH is an important variable in water quality assessment as it influences biological and chemical activities in the water as a measure of acid balance. Water temperature could be attributed to the differences in time of collection of samples as some sachet water bags were left in the open and might be affected by sunlight since all temperature measurement was done *in situ*. Although there is no standard permissible limit for water temperature, it may directly or indirectly impact on the parameters tested. Determination of nitrate plus nitrite in water gives a general indication of the nutrient status and level of organic pollution. Chloride and carbonate ions are generally present in natural waters. A high concentration occurs from chloride and carbonate rich geological formations, otherwise high content may indicate pollution by sewage or some industrial wastes or an intrusion of sea water or other saline waters (Monney *et al.*, 2014). Chlorination of water is a common chemical disinfectant recommended in water treatment within a particular limit. All water factories seem to have adhered to regulatory standard on the physical and chemical properties of water produced or it could be as a result of the nature of the underground water source in the area or the absence of pollutants in the underground water source.

V. Conclusion and Recommendation

A total of eight (8) pathogenic species of bacteria were found in water samples. Total heterotrophic count and total coliform count (in cfu/ml) and MPN value (in 100ml) exceeded WHO permissible limits for potable water in all samples, although bacterial load significantly varied from sample to sample ($P<0.05$). In terms of bacteriological assessment, sachet water from location E was mostly affected followed by those collected from location B Physicochemical parameters appeared normal within their respective permissible limits but the compromised bacteriological quality rendered the sachet water samples unsafe for drinking. There is need to ensure that all sachet water companies comply with regulatory standards. Hence, strict monitoring and enforcement are recommended.

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