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ASSESSMENT OF PHYSICO-CHEMICAL AND MICROBIOLOGICAL QUALITY OF SOME PACKAGED (SACHET) WATER SOLD IN GOMBE METROPOLIS

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ABSTRACT

Access to safe and clean drinking water is a fundamental necessity for human health and well-being. In Nigeria, a country with a rapidly growing population and diverse geographical regions, ensuring the provision of clean and potable water poses significant challenges. The goal of this research is to assess the quality of ten (10) brands of sachet water available in Gombe metropolis. The samples were tested physiochemically and microbiologically, including a total aerobic mesophilic bacteria plate count, mold/yeast count, several tube fermentation techniques, and an *E. coli* test. The findings of the physicochemical study revealed that most parameters such as taste (unobjectionable), temperaturewere within the World Health Organization (WHO) and local/national regulatory body Nigerian Standard for Drinking Water Quality (NSDWQ) standard limits (acceptable range) for drinking water quality. The lowest and highest pH recorded was 7.5 (A, C, F) and 8 (I) while for turbidity, the highest and lowest values of 1.61NTU (A) and 0 NTU (I). For total dissolve solids, 102mg/l for sample F was highest value attained. Total Suspended Solids had 49mg/l for sample C as the highest value which falls within the acceptable range. Total hardness recorded the highest value of 159 for sample D exceeding the recommended limit allowed.The Total Aerobic Mesophilic Bacteria Plate Count (TAMBPC) found that four (4) water samples (B, G, J and I) had counts of 117, 287, 157 and 377cfu/100ml respectively that exceeded the NSDWQ standard (100 cfu/100mL). The mould/yeast count for four water samples (A, J, G and I) were 1, 1, 2 and 3cfu/100ml respectively thus higher than the regulatory agencies' limit (zero cfu/100mL), while the coliform test was satisfactory for just two (2) water samples (H and E). The *E. coli* test also came back positive for two (2) water samples (G and I), making them unsafe to drink. The majority of the sachet water samples failed microbiological examinations in the study, with the exception of two (2) sachet water (Hand E) that met NSDWQ/ WHO standards. The presence of faecal coliform especially *E. coli* has several health implications hence proper treatment and purification of the sachet (packaged) water is recommended.

Keywords: NSDWQ, TAMBPC, Sachet water, *E. coli*., faecal coliform

INTRODUCTION

Water is necessary for the survival and existence of all living organisms on Earth, and it covers around 71% of the Earth's surface (Gerhardt *et al.,* 2004). Water is valuable to man in a multitude of ways, including transportation (moving goods from one country to another via seas, oceans, and rivers), recreation (such as swimming and skating), and nutrition. It is also used for electricity, as a mineral resource, and for household activities such as cleaning, cooking, bathing, and so on (Oluwasanmi *et al.,* 2020). For human health benefits, a sufficient quantity of chemically and microbiologically pure water is required (Ramanuj *et al.,* 2018).

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The fundamental purpose of municipal water is to produce and distribute clean drinking water. Piped water is minimally supplied in urban areas and inaccessible in rural regions in Nigeria (Ahmed *et al.,* 2020). The importance and contribution of locally sourced low-cost alternative drinking water initiatives to long-term access in rural and urban environments in developing nations cannot be understated (Dos Santos *et al.,* 2017). In Nigeria, where the public drinking water supply is intermittent, one such local solution is drinking water delivered in polythene packages. Although sachet water is widely available and reasonably priced, there are concerns about its quality. Any commercially processed water that is manufactured, packed, and marketed in sealed food-grade containers for human use is classified as packed (sachet) water (Osikanm *et al.,* 2020). The production of sachet water in Nigeria began in the late 1990s. Today, Nigeria's phenomenal rise in technology and development has made sachet water production the country's fastest-growing business. The sanitary environment and conditions under which the majority of the water in sachets is produced have been questioned. Unfortunately, current water and sanitation statistical data do not provide enough reliable information about the quality of water provided to communities, homes, and institutions. It is difficult to both measure the current scope of the problem and compare results over time and across countries, especially given the uncontrollable influx into the water production industry and the fact that surveys of drinking water quality and sanitation frequently use different methods (Bidhuri and Khan, 2020). The fact that errors in the manufacturing and distribution process, insufficient water treatment and purification, a lack of enforcement of stringent measures by local/national regulatory bodies, and their negligence all play a role in packaged water contamination (Bidhuri and Khan, 2020), necessitates the study of these packaged water parameters as such research can provide insight into the quality of packaged water sold in Gombe metropolis.

MATERIALS AND METHODS

Study Area

Gombe State is one of the six northeastern states of Nigeria. It is located between latitude $9^0\,30^0$ and 12^0 N and longitude $8^0\,45$ E and $11^0\,45^0$ E of Green. This study was only limited to Gombe metropolis thus sachet water (packaged water) samples for analysis were collected from different areas within Gombe metropolis/town.

Sample Collection

Sample collection was carried out at the manufacturing company for all brands of sachet water. Ten (10) different brands of sachet water were collected from their various manufacturing companies within Gombe metropolis. One (1) bag containing 20 pieces of freshly packaged sachet water was purchased from each sales point and hence transported to the laboratory for both physicochemical and microbiological analysis. Water sachet brands are assigned keys below;

Keys	Samples
G1	A
G2	B
G3	C
G4	D
G5	E
G6	F
G7	G
G8	H
G9	I
G10	J

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Determination of Experimental Methods

Physical and chemical parameters

The water samples were physiochemically examined within six hours of being collected. The test for all variables was carried out in replicates and the average of three readings was taken (Ademoroti, 1996).

Temperature

The temperature of the water sample was measured using an electronic temperature meter (Ecosense product: pH100). The thermometer was immersed in water for roughly 20 seconds, according to Ademoroti (1996).

pH

The pH was determined using a digital pH meter (Ecosense product: pH100), which was calibrated first with distilled water and subsequently with buffers of pH 4.7 and 14.

Conductivity, Total Dissolved Solids*, and *Total Suspended Solids

Conductivity, Total Dissolved Solids, and Total Suspended Solids were determined by methods described by APHA (2017) and USEPA (2007).

Total Hardness

Total hardness was evaluated in the water sample using the titrimetric method provided by APHA (2017).

Taste and Odour

An organoleptic test was performed on the various sachet water samples to assess whether flavours and aromas were present or missing. The smell, flavour, and odour of the water samples made them unpleasant.

Chloride

Mohr's method (2002) was employed in the determination of chloride in the sachet water samples.

Total Alkalinity

The total alkalinity of the water samples was determined using the method described by APHA (1998).

Bacteriological Parameters

The Total Aerobic Mesophilic Bacteria Plate Count (Total Viable Count) was calculated following the method published by APHA (2017). The mould and yeast were counted using the APHA (2017) techniques. To detect fungi, the antibiotic chloramphenicol was added to Potato-Dextrose Agar (PDA) following sterilization to prevent the growth of bacterial contamination.

Coliform testing employing multiple tube fermentation includes both total and faecal coliform assays. The multiple-tube fermentation method reported by APHA (2005), Adetunde and Glover (2010) was used. Prepare the selective and differential medium according to the manufacturer's instructions and Sterilize the medium if necessary. Label the 10 fermentation tubes per sample with the appropriate sample identification code or number. Using aseptic techniques, dispense 10 ml of the selective and differential medium into each fermentation tube. Inoculate each fermentation tube with 10 ml of the water sample using a sterile pipette. Be careful not to introduce air bubbles. Carefully invert each fermentation tube to mix the sample with the medium. Ensure that the Durham tube within each fermentation tube is completely filled with medium. Incubate the fermentation tubes in an incubator set at 35°C for 24 to 48 hours. After incubation, observe the fermentation tubes for gas production and color change. If gas bubbles are present, it indicates the production of gas by coliform bacteria.

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Examine the color of the selective and differential medium in the fermentation tubes. Depending on the medium used, a color change may indicate the presence of coliform bacteria.

RESULTS AND DISCUSSION

Physico-Chemical Assessment

Ten (10) brands of sachet water samples were collected within Gombe metropolis and analyzed for both physico-chemical and microbial assessments. The physical evaluation of the sachet water samples in Table 1 depicts that all the water samples had a neutral taste and odour. The pH values ranged from 7.4 to 8.00 ± 0.03, with G10 having the lowest pH of 7.4 and G9 having the highest pH of 8.00. The pH values measured differ greatly. The pH values of all water samples were within the required range of NSDWQ/WHO drinking water quality guidelines, which varied from 6.5 to 8.5 (citation). A pH of 7 or above is considered somewhat alkaline. The electrical conductivity (EC) of the sachet water samples ranged from 62.03 to 224.00 ± 0.03 s/cm (sample G9). The EC value was low in comparison to the maximum of 1000 s/cm advised by the NSDWQ and WHO for drinking water. The degree of conductivity of water is determined by the concentration of ions present. Low electrical conductivity readings, according to Ndinwa *et al.* (2012), indicate a low concentration of dissolved salts in the water.

The WHO recommends a maximum turbidity content of 5.0 NTU in drinking water. Sample G1 had the greatest turbidity value of 1.61 NTU, while sample G9 had the lowest (0 NTU), showing that the water was not turbid. Turbidity has been shown to influence the taste, odour, and colour of water (Opafola *et al.,* 2020). All of the water samples had the same unobjectionable taste/odour, which is consistent with the NSDWQ/WHO standards. However, Atiku *et al.* (2008) discovered that high temperatures promote the growth of microorganisms. As a result, problems with taste, odour, colour, and corrosion may worsen. The temperature of the sachet water in this trial ranged from 29.2 to 29.9^{0}C. Temperature variations were seen in all samples, which may be attributable to storage conditions, as reported by Kharat *et al.* (2017). Throughout the investigation, the temperature remains within the optimal growth range for mesophilic bacteria, including human pathogens.

TDS and TSS levels ranged from 22 to 175 mg/l and 11 to 49 mg/l, respectively. This result is lower than the maximum limit allowed by WHO (2005) (500 mg/L). Higher total dissolved solids have been shown to lower water clarity, which may contribute to decreased photosynthetic activities and may lead to an increase in water temperature (Mir *et al.,* 2023), which was not the case in this investigation. Because the TDS is less than 2000 mg/L, the water is unlikely to cause laxative effects in consumers (Radfard *et al.,* 2019). Low TDS water consumption in humans, on the other hand, may cause health problems such as goitre, hypertension, ischemic heart disease, and so on, especially in the presence of poor eating habits (Akpen *et al.,* 2018). Total suspended solids (TSS) levels were relatively low in all samples, falling within the WHO (2005) acceptable range.

Chloride ions are non-accumulative poisons that, if consumed in large quantities over time, can pose a health risk. The World Health Organization (2011) advised a maximum chloride ion content of 250 mg/L in drinking water. The chloride ion values in the water samples were 0 mg/L. The free radical chlorine concentration ranged between 0.07 and 0.2 mg/l. Higher concentrations of

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chloride ions are thought to cause taste difficulties.

Hardness gives palatability to water. It has been suggested that moderately hard water containing sufficient calcium is essential for normal growth and health. However, high values of hardness arising from elevated levels of magnesium sulphate are undesirable (Omer, 2019). According to Atiku *et al.* (2018), hardness is divided into four categories: soft (0 - 60mg/l), moderate (60 - 120mg/l), hard (121-180mg/l), and very hard (180mg/l and above). The branded sachet drinking water samples tested were either moderately or hard (mean total hardness varied from 71 to 159 mg/L). The mean total hardness values in all of the samples were within the WHO (2011) recommended range of 0-500 mg/L. Importantly, because no standard values were provided by WHO, the hardness contents obtained for the sachet drinking water brands do not necessarily indicate that the water poses a health risk. Total alkalinity ranged from 40 to 90 mg/l, which is under the WHO 2011 limit of 100 mg/l.

Table 1: Physico-chemical parameters of ten (10) brands of Sachet (packaged) Water sold within Gombe metropolis

Samples	Taste/ odour	pH	Temperature ^{0}C	EC µs/cm	Turbidity (NTU)	FRC (mg/L)	TDS (mg/L)	TSS (mg/L)	TA (mg/L)	TH (mg/L)	Chloride (mg/L)
G1	UO	7.5 ± 0.03d	29.7 ± 0.03a	114 ± 0.33e	1.61± 0.00a	0.1 ± 0.00d	22 ± 0.33j	12 ± 0.33g	90 ± 0.33b	80 ± 0.00e	0
G2	UO	7.7 ± 0.03bc	29.9 ± 0.13a	97 ± 0.58g	0.05 ± 0.00g	0.17 ± 0.00b	26 ± 0.58i	11 ± 0.00h	70 ± 0.00c	80 ± 0.29e	0
G3	UO	7.5 ± 0.03cd	29.7 ± 0.07a	224 ± 0.33a	0.6 ± 0.00e	0.2 ± 0.00a	175 ± 0.00a	49 ± 0.33a	40 ± 0.00f	80 ± 0.00e	0
G4	UO	7.8 ± 0.03b	29.8 ± 0.03a	141 ± 0.33b	0.82 ± 0.01c	0.1 ± 0.00d	116 ± 0.33b	25 ± 0.33cd	90 ± 0.33b	159 ± 0.33a	0
G5	UO	7.7 ± 0.03b	29.7 ± 0.1a	82 ± 0.58h	0.02 ± 0.00h	0.2 ± 0.00a	56 ± 0.33f	26 ± 0.00c	95 ± 0.00a	100 ± 0.00c	0
G6	UO	7.5 ± 0.03cd	29.6 ± 0.03ab	131 ± 0.33c	0.69 ± 0.00d	0.2 ± 0.00a	102 ± 0.00c	29 ± 0.00b	50 ± 0.00e	87 ± 0.33d	0
G7	UO	7.7 ± 0.03b	29.2 ± 0.00c	120 ± 0.58d	0.67 ± 0.00d	0.15 ± 0.00c	98 ± 0.00d	22 ± 0.58e	55 ± 0.00d	158 ± 0.33b	0
G8	UO	7.6 ± 0.03bcd	29.6 ± 0.03ab	101 ± 0.33f	0.36 ± 0.01f	0.09 ± 0.00e	77 ± 0.58e	24 ± 0.00d	40 ± 0.33f	87 ± 0.00d	0
G9	UO	8 ± 0.03a	29.4 ± 0.03bc	62 ± 0.33j	0 ± 0.00i	0.2 ± 0.00a	43 ± 0.00h	19 ± 0.33f	90 ± 0.00b	71± 0.00g	0
G10	UO	7.4 ± 0.03d	29.6 ± 0.00ab	76 ± 0.33i	1.23 ± 0.00b	0.07 ± 0.00f	54 ± 0.33g	22 ± 0.00e	50 ± 0.00e	74 ± 0.33f	0
***WHO**	UO	6.5-8.5	Ambient	1000	5	-	500	500	100	100	250
****NSDWQ**	UO	6.5-8.6	Ambient	1000	5	0.20-0.25	500	-	-	150	100

Data are presented as Mean ± Standard Error (n = 3). Values with the same superscript letter(s) along the same column are not significantly different ($p<0.05$). EC- Electrical Conductivity, FRC- Free Radical Chlorine, TH- Total Hardness, TDS- Total Dissolved Solid, TSS- Total Suspended Solid, UO- unobjectionable

* World Health Organization (WHO, 2004).

** Nigerian Standard for Drinking Water Quality (NSDWQ, 2007).

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Bacteriological Assessment

The results of the total aerobic mesophilic bacteria plate count, mould/yeast plate count, coliform test (total and faecal coliform), and *E. coli* test for the ten (10) different brands of the sachet (packaged) water samples studied are shown in Table 2. Mould/yeast was missing in 6 brands and ranged from 1 to 3cfu/100mL in the other samples, revealing the lowest and highest values for total aerobic mesophilic bacterial plate count as 19 and 377 cfu/100mL. Furthermore, the presumptive test for total coliform and confirmatory test for faecal coliform revealed negative for two (2) sachet water samples (H and E) and positive for the remaining eight (8) (A, B, C, D, F, G, J and I) respectively. The *E. coli* test, which is an important test for identifying faecal contamination, was negative for eight (8) brands, whereas two (2) brands (I and G) were positive.

According to Mao *et al.* (2018), residual chlorine in water maintains a protective residue and controls bacterial development in water. The bacteria count in H and E water samples with a residual chlorine value of 0.20 mg/L, which is within the SON standard, is 17 and 22 cfu/100mL, respectively. Importantly, effective water disinfection methods such as chlorination, ozonation, and ultraviolet radiation ensure the elimination or drastic reduction of bacteria load in the water, particularly in drinking water. Bacteria may be present due to inappropriate handling, processing and purifying techniques, or unsanitary handling after manufacture (Asuk *et al.,* 2018).

The results for most of the physicochemical parameters lower than the limits set by NSDWQ /WHO. WHO guidelines allow no mould/yeast in drinking water, however, local/national regulatory authorities such as NSDWQ allow a maximum of one (1). Table 2 shows that six (6) water samples (B, H, C, D, E, and F) met the WHO standard, two (2) water samples (A and J) had 1 cfu/100mL, and two (2) water samples (G and I) had 2 and 3 cfu/100mL, respectively, which were higher than both the WHO and NSDWQ limits. This is also indicative of inadequate water disinfection during the treatment and purification operations. Except for two samples (H and E), all ten (10) sachet water samples tested negative for the coliform test (total and faecal coliform).

The presence of coliform groups in these water samples often indicates that the water was contaminated with faecal pollutants of human or animal origin. Other, more harmful microorganisms may be present (Abdel-Gawad *et al.,* 2020) because the coliform group is frequently recognized as an indicator organism indicating the presence of pathogens in food or water samples. The faecal coliform test (*E. coli* test) is also integral in water analysis as a positive coliform test (presumptive test) may imply non-faecal contamination. Table 2, highlight various results of the faecal coliform test (*E. coli* test) carried out on ten (10) brands of water samples; national regulatory agencies (SON and NAFDAC) stipulate zero as the permissible limit for the presence of *E. coli* in drinking water.

According to Aladese and Pondei (2002), the presence of coliform bacteria, particularly *Escherichia coli,* in water simply indicated faecal pollution and the potential for bacterial infections. While the other eight (8) water samples tested negative for *E. coli*, two (2) water samples (G and I) tested positive. *Escherichia coli* contamination in drinking water has been linked to a multitude of illnesses, including cholera, typhoid fever, gastroenteritis, and diarrhoea (Aladese and Pondei, 2021). Dangerous enteric pathogens such as *Shigella, Salmonella,* and

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Campylobacter species are frequently present in environments where *E. coli* is present (Anas *et al.,* 2021).

Azzam *et al.* (2017) stated that for chlorinated water, 90% of samples analyzed within a year should have a zero *E. coli* count per 100 mL; however, in the event of contamination, it should not exceed 5 *E. coli* count per 100 mL; otherwise, investigation on the equipment and water system should be made, and the cause of contamination should be corrected. Regularly eating tainted sachet water can have disastrous effects on one's health because people are more likely to contract water-borne illnesses. Additionally, poor drinking water will decrease consumer trust in those brands or products, which will result in complaints and, more importantly, waterborne disease outbreaks. It may be "poor water" in the sachet water that is frequently referred to as "Pure water."

Table 2: Results of microbiological analysis of ten (10) brands of sachet water sold in Gombe metropolis

Test	Limit	A	B	C	D	E	F	G	H	I	J
TAMBPC cfu/100ml	100	69	117	19	33	22	24	287	61	377	157
Mold/Yeast cfu/100ml	0	1	0	0	0	0	0	0	2	1	3
Coliform test (DS/SS)											
(Presumptive)	-	+/+	+/+	-/-	+/+	+/+	-/-	-/+	+/+	+/-	+/+
(Confirmatory)	-	+/+	-/+	-/-	+/+	+/+	-/-	+/+	+/+	+/+	+/+
E.coli test	-	-	-	-	-	-	-	-	+	-	+

TAMBPC = Total Aerobic Mesophilic Bacteria Plate Count
CFU = Colony forming units
+ = signifies positive result (Fermentation occurs, turbidity due to growth in the medium, change in colour and gas production in Durham tubes)
- = signifies a Negative result (No fermentation, no turbidity due to growth, no colour change and no gas production in the Durham tubes)
DS = Double strength of MacConkey broth
SS = Single strength of MacConkey broth

CONCLUSION

The lack of good portable water for public supply is a known major problem in the Gombe metropolis, as it is in most Nigerian urban centres. The contamination of sachet water with harmful microorganisms, including E. coli, which is an indicator of fecal contamination, highlights serious shortcomings in the production, handling, and storage practices of these packaged drinking water products. Consuming such contaminated water can lead to the transmission of waterborne diseases and pose a significant threat to the well-being of the population.

These findings underscore the urgent need for improved quality control measures and stricter adherence to regulatory guidelines for sachet water production in Nigeria. Proper treatment and purification processes must be implemented to ensure the elimination of harmful microorganisms and the delivery of safe drinking water to consumers. Further, it is crucial for regulatory agencies, water suppliers, and stakeholders in the sachet water industry to collaborate and take immediate actions to address the contamination issues. This may involve enhancing sanitation practices, implementing regular monitoring and testing protocols, and enforcing stricter

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quality standards. Public awareness campaigns should also be conducted to educate consumers about the potential risks associated with consuming contaminated sachet water and to encourage them to make informed choices regarding safe water sources.

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