QUALITY ASSESSMENT OF SACHET AND BOTTLED WATER SOLDIN GBOKO, BENUE STATE, NIGERIA.

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ABSTRACT
The quality of selected sachet and bottled water produced and sold within Gboko town, Benue State was investigated to determine their Shelf life. Eight brands of sachet water and four brands of bottled water samples were collected from different manufacturers within 24 hours and stored at ambient temperature. Sub-samples were drawn from the stock samples at intervals of three weeks up to a period of 15 weeks and subjected to physical, chemical and microbial examination. Results for physical and chemical analysis revealed that all the samples examined were wholesome by the 12th week of study except, samples K4and B4 (Wishden sachet and bottled water) which had iron contents of 0.50 mg/L and 0.53 mg/L respectively which were above WHO Standard value of 0.30 mg/L. Total and Escherichia coliforms appeared in all sachet water samples and three bottled water samples analyzed within the first 6 weeks but were no longer detected in any of the samples from the 12th week to the end of the investigation period. The highest total coliform of 21 MPN/100mL and Escherichia coli of17 cfu/100mL were recorded on the first day of production of sachet water. It was concluded that some sachet water products consumed in Gboko were not safe for drinking within the first 12 weeks of production. It was recommended that sachet and bottled water produced and consumed in Gboko can be used from the 3 and 12 weeks after production respectively up to 15 weeks. However, there is need to investigate the shelf life beyond 15 weeks to determine the actual shelf life which may be more than 15 weeks.

Keywords: *Physico-chemical Quality, Coliforms, Gboko, Sachet and Bottled Water, Shelf life.*

1. INTRODUCTION
Water is an essential part of human nutrition, both directly as drinking water or indirectly as constituent of food. In addition to other applications in daily life, water is not only essential for life; it also remains the most important medium of illness and infant mortality in many developing countries and even in technologically more advanced countries [1]. It is also a key parameter influencing survival and growth of microorganisms in food and other microbial environments.

The need to define the quality of water has developed with the increasing demand for water which is suitable for specific uses and conforms to desired quality [2]. Although water quality and water quantity are inextricably linked, water quality deserves special attention because of its implications on public health and quality of life [3]. Good quality drinking water is not always readily available to man. For instance, high counts of coliform bacteria and elevated levels of zinc,

lead, iron, calcium and manganese were observed in some drinking water samples in Ibeno Local Government Area of Akwa Ibom State, Nigeria [4]. Similarly, [5] reported high levels of zinc and iron in public taps and boreholes in a rural community in Kwara State, Nigeria. Unavailability of good quality drinking water is well spread and has serious health implications to man. According to [6], 80% of all diseases and over 30% of deaths are related to drinking water in developing nations of the world.

Different researchers have tried to assess sachet and bottled water quality in Nigeria. The prevalence of bacteria in packaged sachet water sold in Nnewi, South East Nigeria was studied by [7]. The prevalence of bacteria isolated from the analyzed samples was *Escherichia coli* (36%), *Streptococcus faecalis* (19.4%), *Klebsiella pneumonia* (19.4%) and *Staphylococcus aureus* (25%). In general, both total coliform count and faecal coliform count were above the acceptable limits in some of the samples analyzed.

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The chemical and bacteriological quality of packaged water sold in Ibadan, the capital of Oyo State was assessed by [8]. They reported that while the physical parameters were within WHO limits for drinking water quality, 30% of the samples showed rather poor chemical quality. The dominant bacteria isolated were *Websiellasp, Streptococcus faecalis and Pseudomonas aeruginosa*. The quality of sachet water consumed in Kano metropolis was investigated by [7]. The concentrations of metals (Zn, Pb, Fe, and Cu), conductivity, dissolved solids and hardness were within the WHO permissible limits. However, some of the pH values were above the WHO threshold limits.

The effect of storage on the quality of sachet water produced within Port Harcourt metropolis, Nigeria was investigated by [10]. They reported that 60% of the brands analyzed met the WHO limit for drinking when stored at ambient temperature within four week period. However, storage beyond this period led to diminished aesthetic quality of sachet water and increased proliferation of bacteria to a level deleterious to human health. A study by [11] on the microbiological quality of sachet water vended in Ondo state, Nigeria revealed that, some of the samples were unsafe for human consumption due to the presence of *Escherichia coli (E.coli)*. Other bacteria encountered in the water samples included *Enterobacteraegenes*, *Staphylococcus aureus* and *Streptococcus faecalis*.

The health and socio-economic implication of sachet water in Ibadan Nigeria were assessed by [12]. They reported that the physical parameters were within the WHO limits for drinking water quality, except for pH. Some chemical parameters were also within the WHO limits. However, aluminum, fluoride and cyanide were not within the WHO limits. Bacteriological analysis showed that 5 or 6.4% of the samples tested fielded bacterial growth. Bacterial isolated included; *Klibsiellasp*, *Streptococcus faecalis*, and *Pseudomonas aeruginosa*. The quality of packaged water in Uyo metropolis, south eastern Nigeria was assessed by [13]. All the samples tested gave negative results for the bacteria species investigated, implying that there was no fecal contamination of the samples. However, chemical constituents such as ammonia had concentrations above acceptable limits in some samples. On the other hand, [14] reported that most physic-chemical parameters of sachet water in Zaria, Nigeria conform to the both World Health Organization (WHO) and Nigerian Standards (NIS) permissible limits for drinking water. While 100% of the sachet water samples did not conform to the WHO standards with respect to microbial quality.

This packaged water is relatively affordable and convenient and has increasingly become popular. The need to investigate the quality of packaged water therefore becomes imperative. Thus, this research is set up to investigate the quality of packaged water produced and sold in Gboko town with a view to determine the Shelf life.

2. MATERIALS AND METHODS
2.1 Area of Study
Gboko town located in the central area of Benue State, Nigeria, is the headquarters of Gboko Local Government Area and the Tiv nation. It is located on longitude9°0'18'' East and latitude 7°19'30''North. The town has a total area of about 1835km² and population of about 361,325 based on the 2006 national population census. The average rainfall of about 1400mm annually and temperature of about 22°C - 38°C are experienced in the area. The town is also divided into four parts; Gboko South, Gboko North, Gboko East and Gboko West.

2.2 Sample Collection
Eight different brands of 50cL sachet water and 4 different brands of 75 cL bottled water samples with National Agency for Food and Drug Administration and Control(NAFDAC) certification were purchased from the study area. The samples were labeled as shown in Table 1.

Table 1: Samples of water collected

Sample	Source
K1	Barna Sachet Water
K2	Fresh life Sachet Water
K3	GTM Sachet Water
K4	Wishden Sachet Water
K5	Cool Sachet water
K6	Paulest Sachet Water
K7	Desire Sachet Water
K8	Galens Sachet Water
B1	Barna Bottled Water
B2	Fresh Life Bottled Water
B3	GTM Bottled Water
B4	Wishden Bottled Water

Two bags of each brand of sachet water containing twenty sachets each and 2 crates of each brand of bottled water containing twelve bottles each were procured at different prices within 24 hours of production and taken to Benue State Water Board Laboratory, Makurdi for analyses. A total of 168 samples from a pool of 320 samples of sachet water

and 84 samples out of the 96 samples of bottled water were used for the analyses. The samples were stored at room temperature. The physico-chemical and microbial quality of the water samples were determined at intervals of three weeks up to a period of 15 consecutive weeks.

2.3 Water Quality Analyses

2.3.1 Determination of Turbidity: Procedure

This was determined using a portable turbidity meter (Model: TN-100/T-100 produced by EUTECH Company) according to standard methods as described in the manual. The meter was calibrated by standardizing with distilled water and the sample placed inside the cell holder. The read/enter key was then pressed and the value of turbidity read directly in NTU. The test was performed twice on each sample and average values recorded.

2.3.2 Determination of suspended solids (SS)

The concentration of suspended solids was determined using direct reading spectrophotometer (DR/2000) from HACH Company, according to the standard methods described in the manual. The programme number (630) for suspended solids was entered and the wavelength was adjusted to 810 nm. A blank of 25 ml deionized water was measured into the sample cell and placed into the cell holder. The light shield was closed. The zero key was pressed, and the reading displayed 0.00 mg/L. The blank was then removed, 25 mL of water was measured using the sample cell bottle and placed into the cell holder and the light shield closed. The READ/ENTER key was pressed and the SS value read directly in mg/L. The test was performed twice on each sample and average values recorded.

2.3.3 Determination of Total Dissolved Solids (TDS):

Total dissolved solid was determined with a TDS meter (Model 50150 from HACH Company). The probe was rinsed with distilled water followed by the water sample to be tested. The rinsed probe was allowed to stabilize in the sample for 1 min after which the TDS value was read directly in mg/L. The test was performed in duplicates on all the samples and average values recorded.

2.3.4 Determination of Temperature

EUTECH Instruments digital pH meter was used for the test.

2.3.5 Determination of pH

The EUTECH Instruments digital pH meter was used. The meter was calibrated using different buffer solutions of pH 12.1, 10.1, 7.0 and 4. The electrode was immersed in the water sample and the steady value of pH read. Readings were taken in duplicates and average values recorded.

2.3.6 Determination of Total Hardness

The Hardness test Kit Model HA -4P-MG-L was used. Five mL of water sample was measured using a plastic tube and poured into the mixing bottle, 3 drops of buffer hardness solution was added and swirled to mix. One drop of ManVer hardness indicator solution was added. Ethylene diamine tetra acetic acid (EDTA) titrant was added, drop by drop into the mixing bottle and the mixture swirled, to allow for uniform mixing as each drop of the EDTA solution was added until a change in colour of the mixture from pink to blue was observed. The hardness in mgL^{-1} as calcium carbonate ($CaCO_3$) was calculated by multiplying the number of drops added by a factor of 20. The test was performed twice on each sample and average values recorded.

2.3.7 Determination of Iron

The FerroVer method described in HACH model DR/2000 spectrophotometer manual was used for the test. The meter was first adjusted to mg/Fe Fv'. A sample cell (the blank) was filled with 25 mL of deionized water and placed in the cell holder and the display adjusted to 0.00 mg/L Fe Fv. Another sample cell was then filled with 25 mL of the sample and the contents of one FerroVer reagent powder pillow added and swirled to mix. The prepared sample was then placed in the cell holder and the light shield closed. This displayed the results in mg/L Fe. The test was done twice on each sample and mean values recorded.

2.3.8 Determination of Manganese

The Periodateoxidate method described in HACH DR/2000 spectrophotometer manual was used to determine the manganese (Mn) concentration. The meter was first adjusted to manganese periodateoxidate. The contents of one buffer powder pillow, citrate type and one sodium periodate powder pillow were added to a cell filled with 25 mL of test sample and swirled to mix. A blank was placed in the cell holder and the meter adjusted to '0.00 mg/L Mn H'. The prepared sample was then placed in the cell holder and the light shield closed and the displayed results in 'mg/L Mn' read. The test was performed twice on each sample and average values recorded.

2.3.9 Determination of Total Coliform Bacteria

This was determined using the Most Probable Number (MPN) approach according to [15]. 10 mL of MacConkey broth were poured each in 15 bottles using sterile syringe. Inverted Durham tubes were inserted in each of the bottles. The bottles were then covered and autoclaved for 15 minutes at 121^{0}C. They were then removed and placed in a sterile environment. 10 mL of the water sample was inoculated in the first five bottles. One mL of water sample was inoculated in the second five bottles, while 0.1mL of water was inoculated in the last five bottles. The bottles were kept in an incubator and observed at the end of 48 hours. The number of positive bottles, indicated by colour change and gas formation in each of the rolls was recorded and the bacteria load determined from the Most Probable Number (MPN) table.

2.3.10 Determination of E.coli

15 g of Cystine – Lactose – Electrolyte Deficient Medium (CLED) was dissolved in 1 litre of distilled water in a conical flask and autoclaved at 121^{0}C for 15 minutes and allowed to cool. The top of the conical flask was wrapped with foil to prevent contamination. The experiment was done in a sterile environment. The prepared CLED was dispensed into petri dish and allowed to set. One mL of the water sample was inoculated on the prepared CLED and kept in an incubator for 48 hours at 37°C. Yellow, opaque colonies with slightly deeper coloured centre about 1.25 mm diameter were identified, counted and recorded.
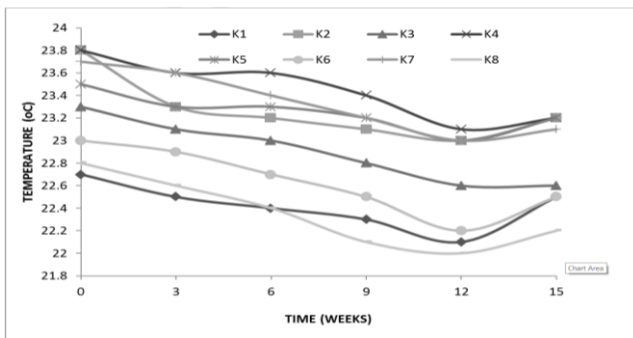
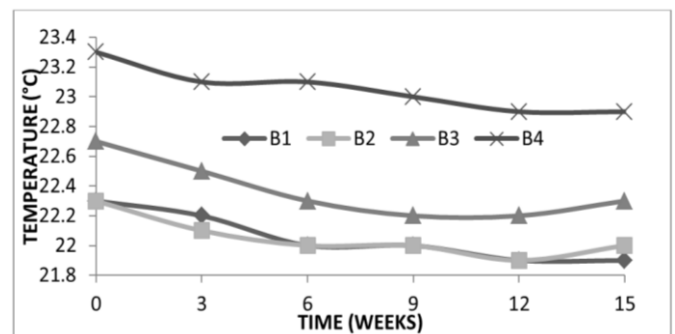Figure 1: Temperature Values of sachet water in 15 weeks period

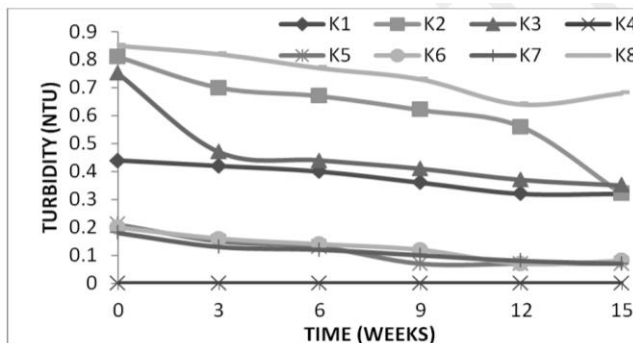Figure 2: Temperature values of bottled water in 15 weeks period

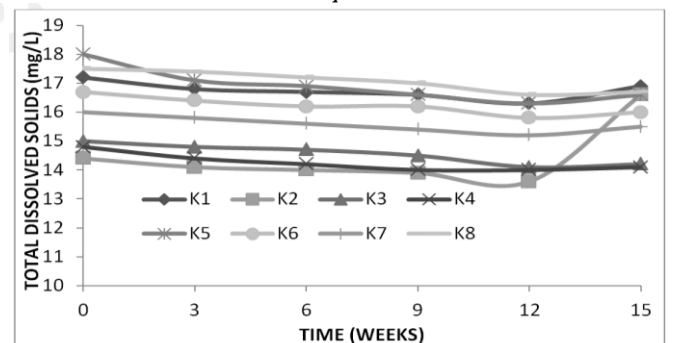Figure 3: Turbidity of Sachet Water as a function of Time

Figure 4: Total Dissolved Solids of Sachet Water as a function of Time
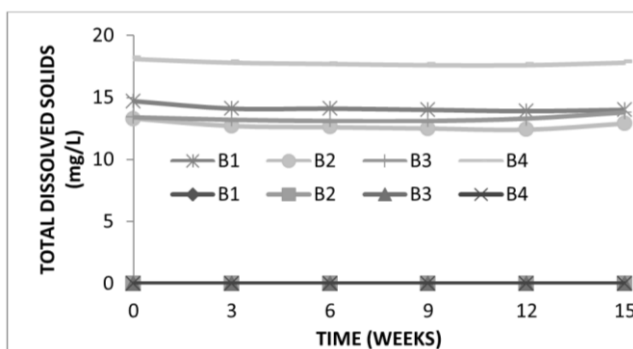

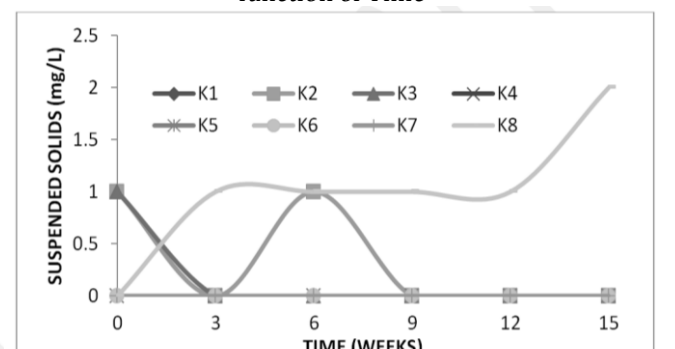Figure 5: Total Dissolved Solids of Bottled water as a function of Time

Figure 6: Total Suspended Solids Concentration of Sachet Water as a function of Time

3. RESULTS AND DISCUSSIONS

The temperature of the sachet and bottled water samples ranged from 22°C – 23.8°C (Figures 1 and 2). Variations in temperature were observed in all the samples, which may be attributed to the storage condition as suggested by [16]. The temperature fall within the optimal growth range for mesophilic bacteria, including human pathogens throughout the period of investigation.

The mean turbidity values for the sachet water samples ranged between 0-0.85 NTU (Figure 3) while all the bottled water samples recorded 0.00 NTU value for turbidity. This implies that all samples were within the [17] standard of 5.0 NTU set for Drinking water. The low values of turbidity measured are in line with the physical observation of the samples which revealed clear and colourless samples, without particulate matter.

The Total Dissolved Solids (TDS) values recorded ranged between 13.60-18.10mg/L for sachet water samples and 12.40-18.10mg/L for bottled water samples (Figures 4 and 5). These were within the WHO standard of not more than 500 mg/L for drinking water. This further suggests that the water will not have laxative effects on consumers because the TDS is less than 2000 mg/L [18]. However, low TDS water consumption in humans could lead to some health challenges such as goiter, hypertension, ischemic, heart disease, etc., especially, in the presence of poor dietary habits [19].

Total suspended solids (TSS) values were generally low in all the samples. All the bottled water samples recorded 0.00mg/L which is the WHO recommended standard. However, as shown in Figure 6, some of the sachet water samples namely; K2, K3 and K8 did not fall within the WHO limits, K8 recorded a maximum value of 2mg/L at the 15th week.
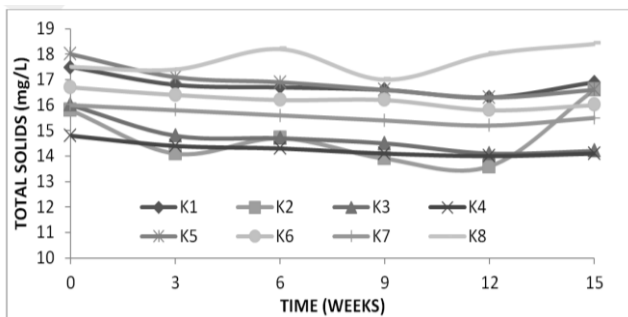

Figure 7: Total Solids of Sachet Water as a function of Time
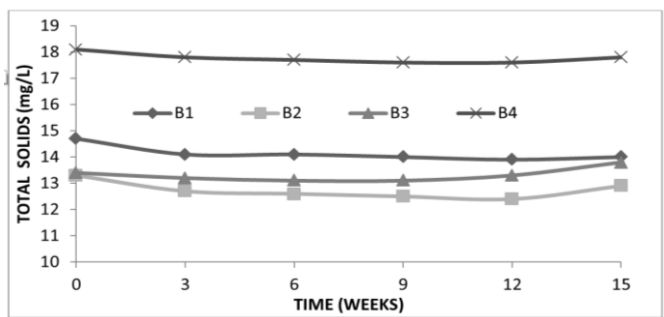

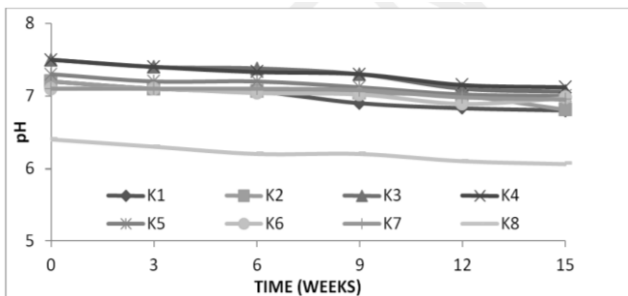Figure 8: Total Solids in bottled Water as a function of Time

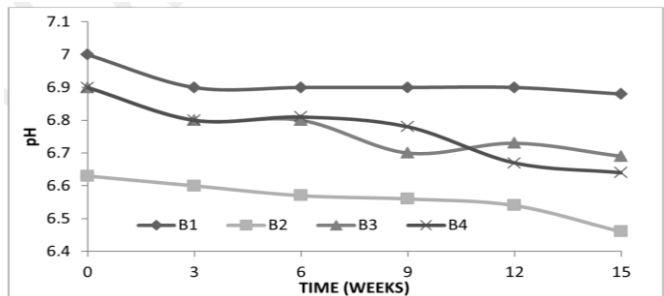Figure 9: pH Values of Sachet Water as a function of Time

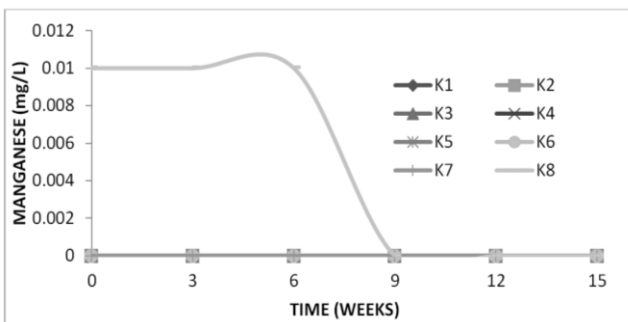Figure 10: pH Values of bottled Water as a function of Time.

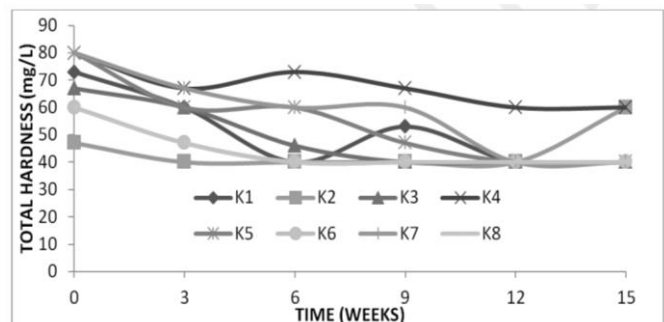Figure 11: Manganese Concentration of Sachet Water as a function of Time

Figure 12: Total Hardness Concentration of Sachet Water as a function of Time

Throughout the period of the investigation, total solids (TS) for all samples examined were within the WHO recommended value of 1000 mg/L. The maximum value obtained for sachet water was 18.4 mg/L while that of bottled water was 18.1 mg/L (Figures 7 and 8).Total solids is the sum of TDS and TSS. It is obvious that TDS, which is in dissolved form, contributed higher proportion of the TS compared to TSS, given that the concentration of TSS was generally low in all the samples.

pH values of sampled sachet and bottled water were presented in Figures 9 and 10. All the samples gave pH values within the recommended limits of 6.5- 8.5 for drinking water [17] indicating that they are safe for human consumption except sample K8 which was below the limits (slightly acidic). The highest value observed in sachet water was 7.50 in samples K3 and K4 on the first day of the test while the least value observed in sachet water was 6.06 in sample K8 in the 15th week. In the bottled water samples, all the samples were within the WHO recommended range throughout the investigation period.
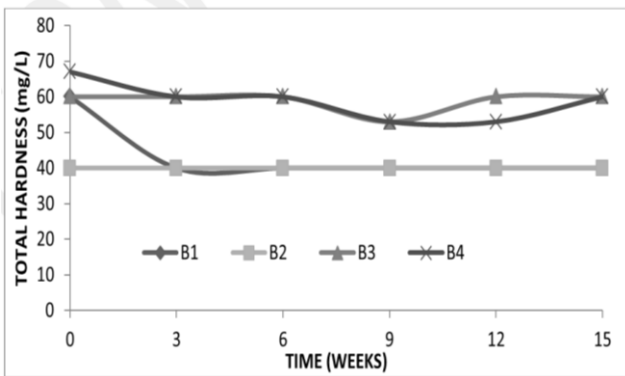

Figure 13: Total Hardness Values of bottled Water in 15 week period
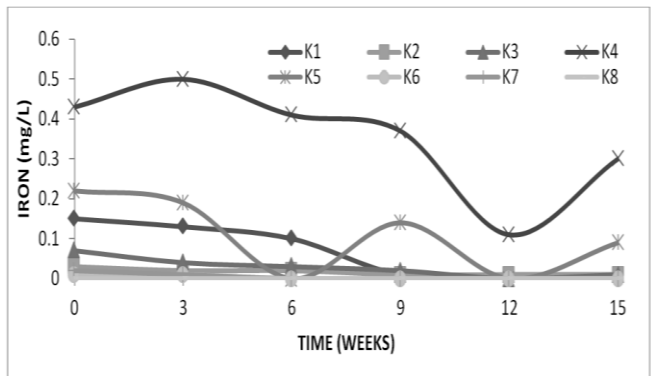

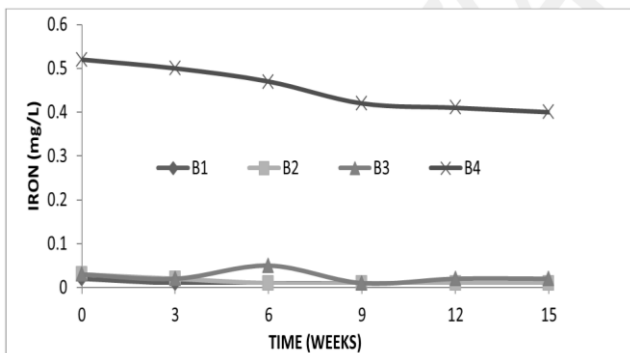Figure 14: Iron Concentration of Sachet Water as a function of Time

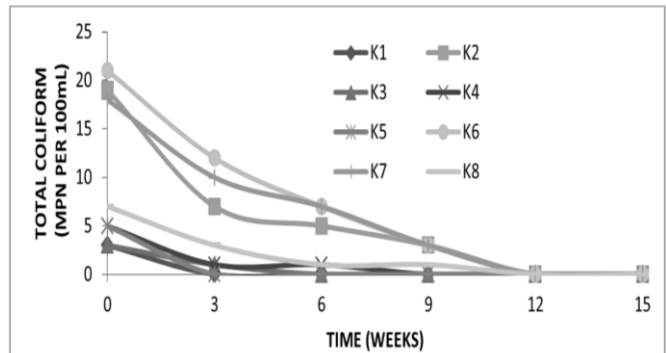Figure 15: Iron Concentration of Bottled Water as a function of Time.

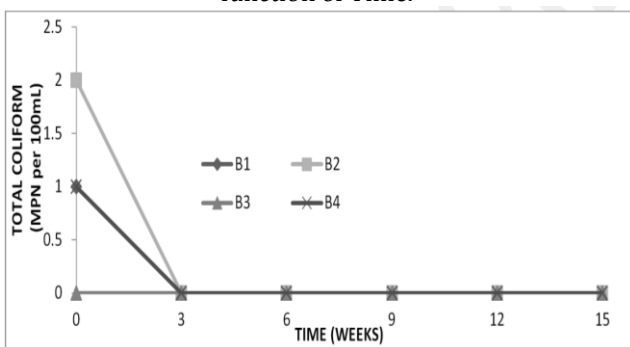Figure 16: Total Coliform Values in Sachet Water in 15 week period.

Figure 17: Total Coliform Values of Bottled Water in 15 week Period
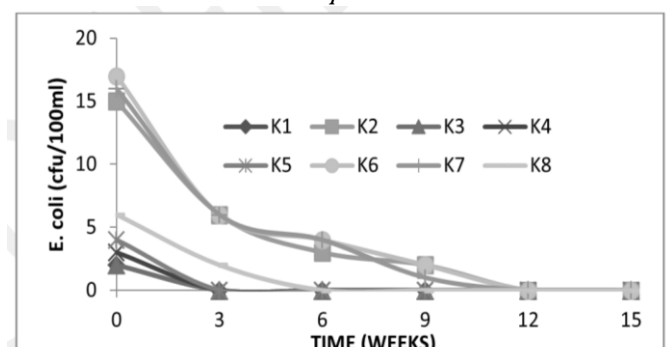

Figure 18: E. coli Values of Sachet Water as a Function of time.

The entire bottled water samples had manganese concentration of 0.00 mg/L. The concentration of manganese in sachet water as presented in Figure11 was also within WHO standard for manganese in drinking (0.00- 0.01 mg/L). This indicates that, all samples were safe for consumption in terms of manganese content. The total hardness of the sachet water samples ranged from 40- 80 mg/L, while that of bottled water samples were within the range of 40- 60 mg/L (Figures12 and 13). These were within the WHO limit of 500 mg/L for drinking water.

With respect to iron content, all the sachet water samples showed the presence of iron except sample K8 which had 0.00mg/L. All samples were within the WHO limit of 0.30 mg/L for drinking water, except sample K4 which had iron concentrations of 0.37- 0.50mg/L (see Figure 14). Bottled water samples were also all within the WHO limit, except sample B4 which had a very high value of 0.52mg/L (see Figure 15). It follows that samples K4 and B4 were not safe for consumption because they indicated a very high presence of iron. The high iron content may be because, the treatment process does not involve iron removal given that, both K4 and B4 are from the same source.

In terms of microbial quality, both sachet and bottle water sold in Gboko exhibited variable characteristics. The Total coliform count was very high in the sachet water on the first day of production, the least count was in samples K1, K3, K4, K5 and K8, which was 3, 3, 5, 5 and 7 MPN per 100mL respectively, while the highest count was in K2, K6 and K7, which was 19, 21 and 18 MPN per 100mL respectively. Packaged water consumed in some parts of Oyo State also contained bacteria as reported by [8]. Similar result was reported by [13] in a study on the quality of packaged water in Uyo metropolis, Nigeria. This contamination is traceable to improper disinfection or use of contaminated sachets for packaging. In bottled water, samples B1, B2 and B4 showed little traces that disappeared completely by the 12th week, but sample B3 was completely free from bacteria (Figures 16 and 17).

High values of *E. coli* counts were recorded on the first day of production of sachet water. Samples K1 and K3 had 2 cfu, which was the least number. Samples K4, K5 and K8 had 3, 4 and 6 cfu respectively. Samples K6 and K7 recorded the highest values of 17 cfu and 16 cfu respectively (Figure 18). This finding suggests that, some sachet water products produced and consumed in Gboko are not safe for drinking before 12 weeks after production Figure 19 show that all the bottled

water samples had 1 cfu except sample B3 that showed no trace of *E.coli* in it. It was observed that after three weeks of storage, the bacteria completely disappeared in all the bottle water samples but still showed traces in some of the sachet water sample such as K2, K6, K7 and K8 up to the 9th week but completely disappeared in the 12th week. This observation is in line with [15] report that indicator organism's loose viability in fresh water environment with time. However, [10] reported proliferation of bacteria in sachet water in Port Harcourt when stored beyond 4 weeks.

In general, the bottle water brands were of better microbial quality compared to sachet water similar to [20] findings that larger proportion of sachet water showed positive coliform counts compared to bottled water sold in Ibadan town. Contamination of packaged drinking water may result from the raw source of water, treatment employed and handling during production. The results of the microbial tests revealed that, it is better to store sachet and bottled water in Gboko for 12 and 3 weeks respectively after production, before consumption, to avoid the risk of bacterial contamination.
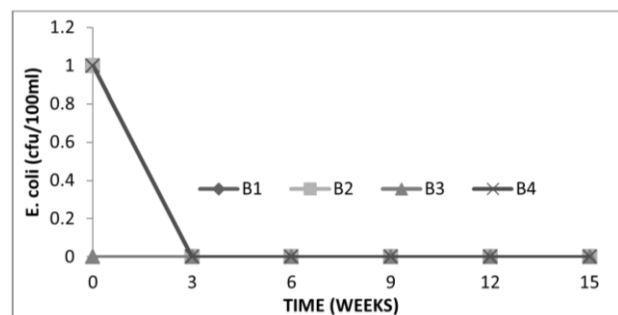

Figure 19:E.coli Values of Bottled Water as a Function of time

4. CONCLUSIONS

The field sampling and laboratory analysis of sachet and bottled water in Gboko metropolis reveals that all the samples analysed were satisfactory in terms of physical characteristics, in the sense that they all met the WHO recommended standard for drinking water in terms of colour, odour, temperature, turbidity, total dissolved solids, total suspended solids and total solids and could be consumed for as long as 15 weeks if stored at room temperature. With respect to chemical characteristics, all the sachet and bottled water samples met the WHO recommended standard for manganese and total hardness in drinking water. Sample K4 and B4 (Wishden sachet and bottled water) showed very high content of iron which is far greater

than the WHO recommended value for iron in drinking water.

In terms of the microbial characteristics, most of the sachet water samples contained coliform bacteria and *E.coli*, which disappeared by the 12 week of storage. The bottled water samples became free of bacteria after 3 weeks of storage, hence is safe for human consumption after 3 weeks of production. It was recommended that sachet and bottled water, produced and consumed in Gboko can be used after 3 weeks (in the case of bottle water) and 12 weeks (in the case of sachet water) of production respectively, and the water is safe up to 15 weeks after production. However, there is need to investigate the Self life beyond 15 weeks to determine the actual Shelf life which may be more than 15 weeks, based on the results of this research.

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