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The Impact of Storage on the Quality of Sachet Water Produced in Amassoma, Nigeria

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Abstract

Inadequate storage may affect the quality of sachet water; hence, this study was designed to determine the impact of storage on sachet water quality produced in Amassoma. To achieve this aim, 100 sachet water samples were randomly collected on the day of production and 10 sachets were sent to the laboratory within 24 hours for analysis to serve as control. The remaining 90 samples, 45 each were stored at room and atmospheric temperatures respectively. At the intervals of week-4, week-8 and week-12, ten sub-samples each was randomly drawn from the respective 45 samples stored at both room and atmospheric temperatures and were sent to the laboratory for analysis. The T-test and ANOVA analyses show that the observed variations in some of the quality parameters were not significant. Also, all the physico-chemical parameters except pH were within the WHO thresholds for potable water. However, all the samples show traces of total coliform and faecal coliform counts in the storage periods, while the control samples tested positive for *Escherichia coli.* It is therefore recommended that the National Agency for Food, Drug Administration and Control should step-up it's monitoring of sachet water companies to ensure that standard production procedures are maintained.
Keywords: Indoor, Outdoor, Quality, Sachet water, Storage

1. Introduction

The inadequate provision of potable water by the Nigerian governments (federal, state and local) for the citizens has given rise to the patronage of other water sources (boreholes, sachet water, rainwater, river/stream and well) which quality may not be guaranteed. In Nigeria, sachet water and borehole water have become veritable sources of both domestic and drinking water because of their accessibility and perceived quality by a significant number of the people. Sachet water introduction into the Nigerian market was enthusiastically received by a lot of people as a viable alternative to the costlier bottled water, which was beyond the reach of many Nigerians, particularly the poor. This reception gave rise to a thriving sachet water business, which has provided hundreds of million litres of drinking water to Nigerians over the years (Ogundipe, 2008).

The expected financial returns from this business encouraged the production of packaged drinking water by private enterprises that have limited knowledge on the basic quality requirements and standard production practices (Okpako, Osuagwu, Duke & Ntui, 2009; Edema, Atayese & Bankole; 2011). Hence, studies have shown that some of the sachet water and borehole water sources are veritable channels for the spread of water borne diseases (Akinde, Nwachukwu & Ogamba, 2011; Ohwo & Abotutu, 2014; Ojekunle *et al*, 2015) because they contain pathogens, which could cause public health challenges.

Pathogens could be introduced into sachet water by several ways, which include poor production and packaging, poor treatment and inappropriate handling and storage. The quest by sachet water production enterprises to be on top of competition and regularly meet their customers demand has led to the production of large quantity of sachet water which is stored in their respective factories awaiting purchase. During storage of the sachet water at the factory or by the respective retail customers in their stores, or at the consumer home, pathogens could be introduced into the sachet water depending on how long and under what hygienic condition the water is stored. This probably informed the National Agency for Food, Drug Administration and Control (NAFDAC) to set an eight-week shelf life for sachet water in Nigeria.

This regulation is hardly complied with and enforced thereby exposing the public to avoidable health burden. In addition, NAFDAC did not prescribe the mode of storage of the sachet water for the recommended eight-week shelf life. This could mislead the consumers of sachet water to assume that the quality of sachet water is adequate for drinking as long as it has not exceeded the shelf life irrespective of the mode of storage. For instance, a study by Duwiejuah, Cobbina and Akrong (2013) has revealed that total heterotrophic bacterial re-growth was observed in sachet water of different brands after just three weeks of storage. In addition, the study also revealed that there was significant difference ($p < 0.05$) in total coliform counts of sachet water stored under

the sun and in the refrigerator.

Similarly, Woods (2010) reported that there was significant deterioration on the microbiological quality of most of the tested sachet water samples when stored at temperatures higher than refrigeration temperature. For example, total coliform counts in sachet water stored over six months period increased from 118-182% at normal atmospheric temperatures, 112-154% at room temperatures and decreased by 74-92% at refrigeration temperatures. This same trend was also recorded with faecal coliform counts. This is an indication that the mode of storage could have significant impact on the quality of sachet water. Unfortunately, the most popular methods of sachet water storage in Nigeria and Amassoma in particular are indoor and outdoor, which may expose the water to quality degradation. In the light of the above, this study was designed to determine the impact of storage on sachet water quality produced in Amassoma and whether the quality met the World Health Organization (WHO) standard for potable water.

2. The Study Area

Amassoma community is geographically located within latitudes 4^{O} 57' and 4^{O} 58' North of the Equator and longitude 6^{O} 9' and 6^{O} 10' East of the Greenwich meridian. It is one of the largest communities in Southern Ijaw Local Government Area of Bayelsa State, Nigeria, and the host community of the Niger Delta University (Figure 1). Amassoma lies on a coastal plain with a mean height of about 15 meters above sea level, and drained by the Nun River. It experiences humid semi-hot equatorial climate of the Af type of Koppen's classification system (Alagoa, 1999) with two distinct seasons-rainy and dry. The average annual precipitation is about 4000mm, with over 70 per cent of humidity and mean monthly temperature of about 27^{O}C. A significant area of Amassoma is made up of wetland and comprises of fresh-water swamp forest.

In spite of the abundant surface water and large stock of groundwater resources in Amassoma, the government has failed to provide public water utility for the people. Hence, the major sources of domestic and drinking water supply in Amassoma are borehole, river/stream, rainwater and sachet water. Of these sources of water supply, a significant number of the population depend more on borehole and sachet water for drinking due to their perceived quality and accessibility. The popularity of the sachet water has led to the establishment of a sachet water packaging enterprise in Amassoma. This company currently has a significant market share of the sachet water soled in Amassoma, hence it was selected for the study, as any quality breach will have a significant health impact on the population.

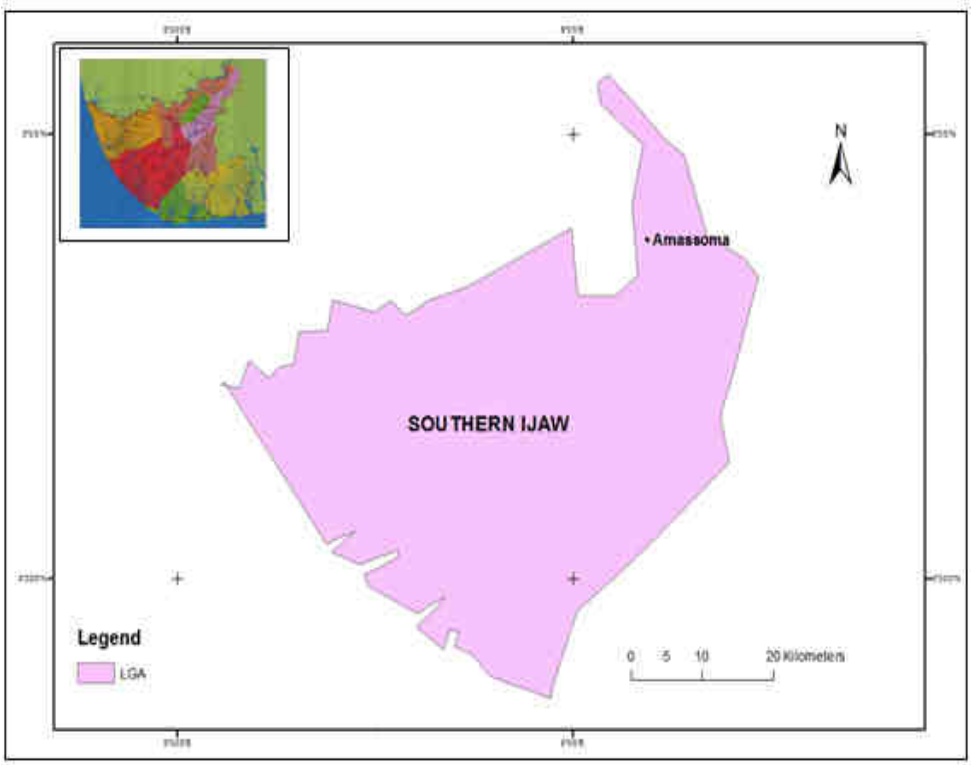

Figure 1: Amassoma in Southern Ijaw Local Government Area of Bayelsa State

3. Method of Study

The study focused on the determination of the impact of storage on the quality of sachet water produced in Amassoma. The study adopted the survey research method, which involved the sampling, storage and laboratory analysis of sampled sachet water. The sampling of the sachet water was preceded by a reconnaissance survey to determine the number of sachet water enterprise in Amassoma. The survey revealed that only one sachet water packaging enterprise was located in Amassoma, hence, the sachet water samples were obtained from there. The population for the study comprises of all the sachet water packaged in a day by the company (2000 pieces), from which 100 samples (which comprises of five bags of 20 pieces each) were sampled on the day of production, using the simple random sampling technique. Out of the 100 samples, 10 sachets were sent to the laboratory for analysis within 24 hours of production to serve as control.

Out of the remaining 90 sachet water samples, 45 each were stored at room and atmospheric temperatures respectively. At the intervals of week-4, week-8 and week-12, ten sub-samples each was randomly drawn from the respective 45 samples stored at both room and atmospheric temperatures and were sent to the laboratory for analysis in a cooler box. To determine the sachet water quality, both physico-chemical and biological parameters where analyzed. The parameters include pH, electrical conductivity, total dissolved solid (TDS) total suspended solid (TSS), turbidity, nitrate, phosphate, fluoride, calcium, chloride, lead, iron and zinc. Others are total coliform counts, faecal coliform, *Escherichia coli* (E.coli) and *salmonella spp*

The physico-chemical and biological characteristics of the water samples were analyzed using standard methods. The pH was measured with an ATI-Orion pH meter, while TDS, TSS, electrical conductivity and turbidity were measured respectively using conductivity and photometric methods and a 214 A turbidity meter. Flame photometry and silver nitrate titrimetric methods were respectively used to determine calcium and chloride levels using the methods described by APHA (2005). Nitrate, phosphate and fluoride were determined with a UV/Visible spectrophotometer in accordance with APHA 4500. Heavy metals such as lead (Pb), Iron (Fe), and zinc (Zn) were determined with the aid of the Atomic Absorption Spectrophotometer (AAS) at 283, 248 and 213.9 nm wavelengths respectively. Membrane filtration technique was used to determine total and faecal coliforms, *Escherichia coli* (E.coli) and *salmonella* spp in accordance with APHA 9222B, 9222D, 9260F and 9215B.

The measured results were compared with the WHO thresholds for potable water. The data were analyzed with the aid of descriptive statistics, Student's t-test and analysis of variance (ANOVA). The Student t-test was used to determine whether there was significant difference between the sachet water qualities of samples stored indoor and outdoor for the respective storage periods (week-4, week-8 and week-12); while the ANOVA was used to determine whether there was significant variation in the sachet water quality among the indoor samples and outdoor samples respectively, for the storage periods (week-4, week-8 and week-12).

4. Results and Discussion

4.1 Physical Parameters of the Sachet Water

The mean concentration of selected quality parameters of sampled sachet water stored at different locations and time-period are presented in Table 1. The values of electrical conductivity of the sampled sachet water ranges from 55.8 to 63.0 µs/cm. The lowest value (55.8 µs/cm) was recorded on the indoor samples on week-4, while the highest value (63.0 µs/cm) was recorded on week-12 in the outdoor samples. On the other hand the control sample (day 1) had a value of 57.7 µs/cm. Apart from the indoor values of 55.8 µs/cm on week-4, which is lower than the control value of 57.7 µs/cm, all the other values increased consistently from week-4 outdoor through week-8 to week-12 indoor and outdoor respectively. Similar pattern was also reported by
Duwiejuah et al (2013) were the values of electrical conductivity increased from week-1 to week-8. This shows that storage influences the conductivity of sachet water. Although there was an increase in the value of conductivity throughout the duration of the study, however, all the values were within the 1000 µs/cm WHO threshold for potable water.

The pH values vary inconsistently throughout the study period and between the indoor and outdoor samples. The values of the pH ranges from 6.19 to 6.96, which are both recorded on week-4 outdoor and indoor, respectively. This shows that the highest pH variability occurs on week-4. Apart from the week-4 indoor pH value (6.96) and that of day 1 (control sample), with a pH value of 6.55, all the other pH values are below the WHO thresholds of 6.5 – 8.5. This shows that the water becomes more acidic during the storage period, which could influence the

level of solubility and toxicity of materials, bacterial population growth and diversity in sachet water (Ojekunle, et al, 2015), which may render it unfit for human consumption.

The concentrations of total dissolved solids (TDS) in all the sachet water samples either indoor or outdoor and throughout the storage period are within the WHO 500 mg/l threshold for potable water. The TDS values range from 27.9 to 31.5 mg/l, with the lowest value recorded on week-4, indoor samples, while the outdoor samples on week-12 had the highest value (31.5 mg/l). The other samples except indoor values on week-4 have TDS values higher than the control value of 28.8 mg/l. In all cases the outdoor TDS values are respectively higher than their indoor counterparts as shown in Table 1. This is probably due to the exposure of the outdoor samples to dustier environment. The fact that week-12 outdoor samples have the highest values for both EC and TDS is not coincidental; it just reveals that the water samples contain more dissolved solids than other samples. Isikwue and Chikezie (2014) also reported similar findings in their study.

The control and the indoor samples for week-4 were free of total suspended solid (TSS). This is an indication that the water was well filtered before packaging. However, there was a little trace (0.01 mg/l) of TSS on the remaining samples from outdoor week-4 through indoor and outdoor week-8 and week-12 respectively. However, the values of all the samples were within the WHO 5 mg/l threshold for potable water. Turbidity values of the sachet water samples ranged from 0.01 to 0.05 NTU; with the lowest value (0.01 NTU) recorded on day 1 (control), while the highest value (0.05 NTU) was recorded on week-4, outdoor sample. The relatively low recorded values are attributable to the level of filtration of the water before packaging. High level of turbidity could interfere with the effectiveness of disinfection and provides a veritable medium for microbial growth (Ohwo, 2012). It may also indicate the presence of pathogens that could cause nausea, cramps and diarrhea (Ohwo, 2014). All the recorded values of turbidity are within the WHO 5 NTU threshold for potable water supply. The turbidity values are relatively higher in the outdoor samples throughout the study duration than the indoor values, although the differences were not pronounced (Table 1). Duwiejuah *et al* (2013) also reported similar findings and they concluded that storage conditions and temperature has no effect on turbidity of sachet water.

4.2 Chemical Parameters of the Sachet Water

The impact of heavy metal pollution of water could be a serious threat to public health because of the associated consequences on those who consume such water without adequate treatment. For instance, the Standard Organization of Nigeria ((2007) had noted that the consumption of heavy metal polluted water above the WHO thresholds for potable water could cause cancer, central and peripheral nervous disorder, mental development in infants, neurological disorder and interference with vitamin D metabolism amongst other impacts. Hence, their level of concentration on drinking water is of great concern to regulatory authorities and health practitioners.

The acceptable WHO standard of calcium concentration in potable water is 200 mg/l. The concentration of calcium in all the sachet water samples range from 4.23 to 7.24 mg/l, which shows that they are all within the WHO threshold for potable water supply. The control value was 5.60 mg/l, while the lowest value (4.23 mg/l) was measured on week-4, indoor samples and the highest value (7.24 mg/l) was measured on week-8, indoor samples. The negligible concentration of calcium in all the sachet water samples may be attributable to filtration of the water before packaging. For instance, Morr *et al* (2006) reported that 89.4% of calcium could be removed from water using Brita® filter as revealed by several studies. It should be noted at this point that adequate calcium intake is essential for achieving peak bone mass and subsequent prevention of osteoporosis (Nordin, 2000), hence reasonable concentration should be in potable water.

The chloride values in the sachet water range from 8.00 to 17.00 mg/l. Week-4 indoor samples had the lowest value (8.00 mg/l), while week-12 indoor samples had the highest values (17.00 mg/l) of chloride concentration. The chloride values decreased from 11.00 mg/l (control sample) to 8.00 mg/l and 9.00 mg/l indoor and outdoor respectively in week-4. The values later increased in week-8 and week-12. Chloride is known to increase the conductivity of water and its corrosiveness. Hence, the low chloride concentrations partly explain the low electricity conductivity (EC) of the sachet water. All the sachet water samples have concentrations below the 250 mg/l WHO threshold for potable water.

Nitrate values in the sachet water were uniform and unchanged from the control (day 1) samples throughout the duration of the study and irrespective of the storage locations (indoor or outdoor). The value of 0.01 mg/l was maintained throughout, which suggest that the concentration of nitrate in the sachet water was not influenced by storage. This value (0.01 mg/l) was within the WHO 50 mg/l threshold for potable water. Phosphate values ranged from 0.00 to 0.02 mg/l. The control value of (0.00 mg/l) was maintained in both indoor and outdoor

samples for week-4 and slightly increased to 0.02 and 0.01 in the indoor and outdoor samples respectively for week-8 and week 12. These values are all within the WHO 10 mg/l threshold for drinking water. These values show that storage has negligible impact on phosphate concentration in sachet water. Similar patterns of concentration were also recorded in fluoride and iron concentration in the sachet water throughout the study period. Apart from indoor and outdoor samples on week-4 where the values of fluoride were 0.02 mg/l and 0.00 mg/l respectively, all the other samples maintained the 0.01 mg/l value that was measured on day 1 (control) sample. In the case of iron, the values range from 0.00 to 0.02 mg/l. The lowest value (0.00 mg/l) was measured in the control sample and outdoor sample on week-8. There was however negligible increases to 0.02 and 0.01 in indoor and outdoor samples respectively in week-4 and week 12. All the recorded values for both fluoride and iron are respectively within the WHO thresholds of 0.5mg/l and 0.3 mg/l. Both lead and zinc were not detected in all the samples throughout the study duration.

The concentrations of all the selected chemical parameters are within the WHO thresholds for potable water supply. This is an indication that the groundwater source from which the company obtains its raw water supplies is probably free of heavy metal pollution, or the adoption of standard procedures for the treatment of heavy metals. Similar findings and conclusions were also reached by Ojekunle *et al* (2015) in their study of the 'effects of storage on sachet water quality in Ogun State, Nigeria'. This means that health burdens associated with the consumption of water polluted by heavy metals may be rear with those that rely on the sachet water brand for drinking.

4.3 Biological Parameters of the Sachet Water

Total coliform counts have been used widely as a major indicator for the presence or absence of pathogenic bacteria in drinking water (Ohwo, 2014); hence, the absence of total coliform counts in drinking water is assumed to be free from pathogenic bacteria (Ohwo, 2012). Unfortunately, the test revealed the presence of total coliform counts, as the test values range from 1.8 to 110 MPN/100ml. The highest value (110 MPN/100ml) was recorded on day 1 (control sample); while the indoor sample for week-4, had 2.0 MPN/100ml and the lowest value (1.8 MPN/100ml) was recorded respectively in outdoor samples for week-4, indoor and outdoor samples for week-8 and week-12. This result shows that the sachet water was contaminated and may not be safe for human consumption, as the WHO threshold recommends total absence in potable water. The fact that the control samples had the highest value (110 MPN/100ml) of total and faecal coliform counts is an indication that the sachet water could have been contaminated during the course of production or the use of poor raw water source with poor disinfection or both.

The drastic drop of the recorded values of both total and faecal coliform counts after week-4 may be attributable to the fact that indicator organisms loose viability during storage over time (Ojekunle *et al*, (2015). Similar studies for instance, Mberekpe and Eze (2014) reported the presence of coliform in all the brands of water samples collected from day one; while Ojekunle, *et al* (2015) reported that faecal coliforms were detected in 50% of the brands of sachet water analyzed at the beginning of the study. However, after 8 weeks of storage, total coliforms and faecal coliforms were no longer detected except in one sample, which had 13cfu/ml coliform bacteria and equally tested positive for faecal coliform. A further confirmatory test for the presence of *Escherichia coli* (E coli) and *Salmonella spp* revealed that the control sample (day 1) tested positive for *Escherichia coli* and negative for *salmonella spp* (Table 1). However, as from week-4 to week-12 of storage, *Escherichia coli* tested negative in all the samples; while salmonella spp was equally negative in all the samples throughout the storage periods from week-4 to week-12, for indoor and outdoor samples respectively.

Table 1: Mean Concentration of Analyzed Physico-chemical and Biological Characteristics of Sachet Water at Different Storage Location and Duration

Parameter/Unit	Week-4		Week-8		Week-12		Control (Day 1)	WHO Standard
	Indoor	Outdoor	Indoor	Outdoor	Indoor	Outdoor		
EC (µs/cm)	55.8	58.5	58.3	61.1	60.2	63.0	57.7	1000
pH	6.96	6.19	6.31	6.39	6.29	6.35	6.55	6.5-8.5
TDS (mg/l)	27.9	29.3	29.2	30.6	30.0	31.5	28.8	500
TSS (mg/l)	0.00	0.01	0.01	0.01	0.01	0.01	0.00	5
Turb (NTU)	0.02	0.05	0.02	0.04	0.03	0.05	0.01	5
Calcium (Ca) (mg/l)	4.23	4.73	7.24	6.72	7.12	6.90	5.60	200
Chloride (Cl) (mg/l)	8.00	9.00	14.0	13.0	17.0	15.5	11.00	250
Nitrate (NO_3) (mg/l)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	50
Phosphate (PO_4) (mg/l)	0.00	0.00	0.02	0.01	0.02	0.01	0.00	10
Fluoride (mg/l)	0.02	0.00	0.01	0.01	0.01	0.01	0.01	0.5
Lead (Pb) (mg/l)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Iron (fe) (mg/l)	0.02	0.01	0.01	0.00	0.02	0.01	0.00	0.3
Zinc (Zn) (mg/l)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3
Total coliform counts (MPN/100ml)	2.0	1.8	1.8	1.8	1.8	1.8	110	0
Faecal coliform (MPN/100ml)	1.8	1.8	1.8	1.8	1.8	1.8	110	0
Escherichia coli	NIL	NIL	NIL	NIL	NIL	NIL	Positive	Negative
Salmonella spp	NIL	NIL	NIL	NIL	NIL	NIL	NIL	Negative

Source: Author's fieldwork, 2017

In order to determine whether there was significant difference between the measured values of selected quality parameters between indoor and outdoor samples during the respective storage periods (week-4, week-8 and week-12), the Student's t-test was used and the calculated values are presented in Table 2. From the table it was revealed that there was no significant deference between the quality values of indoor and outdoor samples in the three selected time periods; as the calculated values are less than the table values respectively (Table 2). This means that storage did not significantly affect the quality of the sachet water. In the same vein, the analyses of variance (ANOVA) also shows that there was no significant variation in the quality of indoor and outdoor samples, respectively in the selected time periods (week-4, week-8 and week-12) as shown in Tables 3 and 4. The calculated F value for indoor samples was 0.021, with a table value of 3.19 (Table 3); while outdoor calculated F value was 0.015, with a table value of 3.19 (Table 4). This means that irrespective of the storage period the quality of the sachet water did not change significantly.

Table 2: Calculated T-test Values between Indoor and Outdoor Samples of the Storage Periods

Storage Period	Calculated Value	Table Value	D.F	Decision
Week-4	0.828	2.120	16	Not significant
Week-8	0.984	2.120	16	Not significant
Week-12	0.740	2.120	16	Not significant

For $\alpha = 0.05$, the critical value for t with d.f. (16) is 2.120

Table 3: Analysis of Variance Table for Indoor Values between the Storage Periods

Source	SS	D.F	Mean Square	F
Explained	SS Between = 9.83	J - 1 = 2	SS Between / (J-1) = 4.92	MS Between / MS Within = 0.021
Error (Residual)	SS Within = 11076.59	N - J = 48	SS Within / N – J) = 230.76	
Total	SS Total = 11086.42	N – 1 = 50	SS Total / (N-1) = 221.73	

For $\alpha = 0.05$, the critical value for F with d.f. (2, 48) is 3.19

Table 4: Analysis of Variance Table for Outdoor Values between the Storage Periods

Source	SS	D.F	Mean Square	F
Explained	SS Between = 7.32	J - 1 = 2	SS Between / (J-1) = 3.66	MS Between / MS Within = 0.015
Error (Residual)	SS Within = 12109.62	N - J = 48	SS Within / N – J) = 252.28	
Total	SS Total = 12116.94	N – 1 = 50	SS Total / (N-1) = 242.34	

For α = 0 .05, the critical value for F with d.f. (2, 48) is 3.19

5. Conclusion

The study has revealed that the observed variations in some of the selected quality parameters of the sachet water were negligible. For instance, the calculated t-test results between indoor and outdoor samples for week-4 (0.828), week-8 (0.984) and week-12 (0.740) were all below the t critical value of 2.120 at 0.05 significant levels. Similarly, the calculated ANOVA values for indoor (0.021) and outdoor (0.015) were less than the F critical value of 3.19 at 0.05 significant levels, which means that the variations were not statistically significant.

It was also revealed that all the physico-chemical parameters except the pH values were within the WHO thresholds for potable water. However, the same cannot be said of the biological parameters, as all the samples, control, indoor and outdoor show traces of total coliform and faecal coliform counts in the storage periods. Surprisingly, the control samples had the highest values (110 MPN/100ml) for both total coliform and faecal coliform counts and also tested positive for *Escherichia coli*, which probably shows that all is not well with the production process. However, after storage for four weeks and beyond both the total coliform and faecal coliform counts reduced significantly to 1.8 MPN/100ml in both indoor and outdoor samples. The acidic nature and the poor biological state of the sachet water, which is above the zero WHO threshold for potable water means that the water is not safe for human consumption. It is therefore recommended that the National Agency for Food, Drug Administration and Control (NAFDAC) should step-up it's monitoring of the production process of approved sachet water companies to ensure that standard procedures and proper disinfection are carried out before the water is sold to the public. In addition, the public should be well educated on hygienic storage of sachet water before usage.

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