JASEM ISSN 1119-8362

Full-text Available Online at
www.ajol.info and
www.bioline.org.br/ja

J. Appl. Sci. Environ. Manage. *October* 2017
Vol. 21 (6) 1203-1211

The effect of storage on Physical, Chemical and Bacteriological characteristics of Sachet and bottled water marketed in Ibadan Metropolis, Oyo State. Nigeria

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ABSTRACT: This study assessed the changes in physical, chemical and bacteriological quality of drinking water stored for a period of three months. Ten (10) different companies' water samples each of bottled water (B) and sachet water (S) were randomly selected for the study around Ibadan Metropolis. Experimental method was used to check the levels of the different parameters in each of the samples within first week (W) of production and after three months (M) of storage. The results obtained were subjected to both descriptive and inferential statistic. The concentration of total suspended solid were noticed in higher quantity in sachet water; $S3_M$, $S4_M$, $S5_M$ and $S7_M$ with values of 1.75±0.35, 1.90±0.14, 1.35±0.21, and 1.55±0.07 mg/L respectively. Total dissolved solid showed increased in all sample analysed after storage as with other chemical element except that lead showed decreased with storage. Almost all the parameters analysed had concentrations within the SON/WHO Standards except pH with samples: $B1_W$ (6.11±0.07), $B2_W$ (6.19±0.01), $B10_M$ (6.45±0.35), $S2_W$ (6.45±0.07), $S7_W$ (5.70±0.14), $S9_W$ (5.80±4.10) and $S10_W$ (5.30±0.00) which were slightly acidic and below the 6.5 minimum standards. There was also growth of Coliform Count of 0.001±0.00 after 3 months of storages in two bottled water ($B5_M$ and $B6_M$). The study concluded that storage of potable water for 3 months should changes in the physical, chemical and bacteriological parameters and the intrusion of heavy metal such as Pb in some potable water portray a great deal of harm to consumer when consumed.

https://dx.doi.org/10.4314/jasem.v21i6.35
Keywords: Bacteriological Parameters, Bottled water, Coliform Count, Lead, Storage, Sachet water

Water is the elixir of life and abounds on earth but this vast natural resource has been depleted and turned into a scarce commodity with increased usage catering to the needs of ever expanding population. There is almost a global shortage of water and ranked as world's most urgent need especially as it relate to supply and maintenance of clean drinking water (Abdudu et al., 2013). Also, according to Janan et al, 2012, water an essential for life, is the most widely distributed and abundant non-gaseous substance in nature and hence it had determined the pattern of human settlement throughout history because of its importance. The availability of water varies widely with local geological condition, neither ground water nor surface water has ever been chemically pure, since water contains small amount of gases, mineral and organic matter of natural origin. Water is the single abundant substance in the human body, making up to 60% of an adults weight and up to 80% of an infant weight.

Furthermore, water is the most vital liquid for maintaining life on the earth. About 97% water is exists in oceans that is not suitable for drinking and only 3% is fresh water wherein 2.97% is comprised by glaciers and icecaps and remaining little portion of 0.3% is available as a surface and ground water for human use. Importantly, clean, affordable and safe drinking water is a basic need for good health and it is also a necessary right of humans (Muhammad et al., 2013). According to Uduma (2014), he stated that water of adequate purity which is the life blood of our species, is of vital importance in the existence of life while health experts stress that we should drink two litres of water a day.

The provision of clean and safe drinking water is one of the major infrastructural problems in Nigeria and that is because majority of the people do not have access to reliable potable water sources. This leaves the people to depend on other sources of water such as streams, rivers, and groundwater. These other sources are not always hygienically good for domestic use, making them more vulnerable to water related diseases (Kwasi et al., 2003). He also Opined that most of these water sources in the dry season dry up or reduced in quantity hence, compelling people in those communities to revert to drinking from unwholesome sources which make them vulnerable to water related diseases. It is generally perceived that wells, springs and boreholes are "clean" sources of water. Although it is true that soil generally function to attenuate microorganisms by simple filtration mechanism sorptions, especially larger bacteria and protozoa, pollution of groundwater by microorganisms, including those of public health significance do occur (Ashbolt and Veal, 1994; Stanley et al., 1998).

The quest for cheap and readily available source of potable water has led to the emergence of sachet water. Packaged water is defined as any potable water processed and offered for sale in sealed food grade bottles or other appropriate containers for human consumption. (Food and Drug Administration, 2002). With the attendant increase in potable water (sachet or bottle water) consumption, there has arisen a growing concern over the chemical and bacteriological quality of these products. As a result bottle or sachet water like any other food product, must be processed and packaged under aseptic conditions. Packaged water however is generally not sterile, being collected from almost every available water source, ranging from rain water to tanker delivered water most of which are rusty and unwashed. Contaminants are also introduced during manufacturing and consumer handling (Warburton and Austin, 1997). Irrespective of their sources, these products are susceptible to microbial contamination, also in the absence of sterilization procedures such as pasteurization and thermal sterilization for the treatment of pure water increase their susceptibility to contamination by both autochthonous bacterial flora, exogenous contaminating microbes, as well as a variety of other contaminants including mineral salts, organic pollutants, heavy metals and radioactive residues. The quality of drinking water is a powerful determination of health, hence assurance of drinking water safety is a foundation; for the prevention and control of water borne diseases.

*Study Area***:** The study was carried out in Ibadan, capital of Oyo state in southwest Nigeria. Ibadan has a population of over 3 million (based on the 2006 National Population Census), it is the most populous city in the State, and the third most populous city in Nigeria, after Lagos and Kano; it is the country's largest city by geographical area. At Nigerian independence, Ibadan was the largest and most populous city in the country, and the third in Africa after Cairo and Johannesburg.

Geographically, Ibadan lies in Latitude N007^{0}23’16” and Longitude E003^{0}53’47”. Ibadan is located 128 km inland northeast of Lagos and 530 km southwest of Abuja, the Federal Capital, and is a prominent transit point between the coastal region and the areas in the hinterland of the country. Ibadan had been the centre of administration of the old Western Region since the days of the British colonial rule, and parts of the city's ancient protective walls still stand to this day. The principal inhabitants of the city are the Yorubas, as well as various communities from other parts of the State.

MATERIALS AND METHOD

*Sampling***:** Ten (10) brands of bottled and ten (10) brands of sachet water each with NAFDAC certification were randomly collected in different strategic parts of Ibadan in bags within 24hours of production. Some of the samples were analyzed within the first week of production while others were stored for three (3) months at ambient temperature. Sub-samples were drawn from the stock samples in duplicates for Physical, chemical and bacteriological analysis.

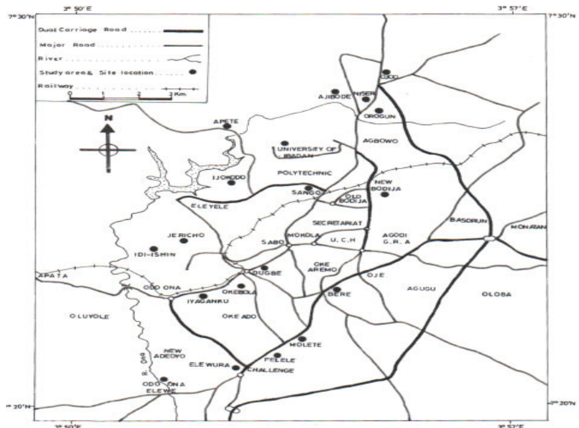

Figure 1: Map showing the different Locations of Ibadan Metropolis

Physical, Chemical and Bacteriological properties of the water samples were tested within the first week of production and after three months of storage.

pH: The pH values were determined using the calibrated WTW 323 pH meter, at the laboratory. The probe was rinsed with distilled water and immersed in the samples. Readings were recorded after stabilization.

Total Suspended Solid (TSS): Marked evaporating crucibles (eg; A1, B1, etc) were heated in an oven and cooled in a desiccator. The clean crucibles were weighed with an analytical balance. 20ml of each of the samples was measured with a measuring cylinder, poured into each crucible and placed on the water bath to evaporate to dryness. Upon drying, the crucibles were, removed and placed in an oven at 105^{o}C for one hour after which they were cooled in a desiccator for 20 minutes and reweighed using an analytical balance. The weights were recorded as A2, B2, etc. The differences in the weights i.e A2-A1, B2-B1, etc., were calculated as total solids. Ts (mg/L) = (Weight of Sample in Dish – Weight of empty Dish)

Total Dissolved Solids (TDS): TDS was determined using Gravimetric method (APHA, 1998) in which the sample is vigorously shaken and a measured volume transferred into a 100ml graduated cylinder by means of a funnel. The sample was filtered through a glass fibre filter and a vacuum applied for about three minutes to ensure that water was removed as much as possible. The sample was washed with deionised water and suction continues for at least three minutes. The total filtrate was transferred (with washings) to a weighed evaporating dish and evaporated to dryness on a water bath. The evaporated sample was dried for at least one hour at 180°C. The dried sample was cooled in a desiccator and weighed. Drying and weighing process was repeated until a constant weight was obtained.

Turbidity: Turbidity was measured using the HACH 2100 AN turbidimeter. The cuvette was rinsed with distilled water and filled with the sample. The procedure was repeated for each and the blank. The cuvette was placed into the instrument's light cabinet and covered with the light shield. After stabilization, turbidity value was read and recorded.

Total Hardness: EDA Titrimetric Method: A 100ml of the water sample was put into a 250ml conical flask. Two drops of Erichrome black T indicator was added. The content in the conical flask was titrated against a standard EDTA solution (0.01M) until the contents of the flask changed from wine-red to blue at the end point. Titration was repeated until a consistent titre was obtained. The value of the average titre was recorded (APHA, 1998). Calculations: Total Hardness as $CaCO_3$ (mg/L) = titre value x 20.

Chloride (Cl^-): A 100ml of the water sample was measured into a 250ml conical flask and 3 drops of potassium dichromate indicator was added to the contents of the the flask. The content in the conical flask was titrated against standardized silver nitrate solution, stirring constantly, to the end point which is indicated by a permanent red colour. The volume of the titre was recorded (APHA, 1998). Calculation: Chloride, mg/L = titre value x 10

Calcium: EDTA Titrimetric Method: When EDTA is added to water containing both calcium and magnesium, it combines first with the calcium that is present. Calcium can be determined directly using EDTA when the pH is made sufficiently high so that the magnesium is largely precipitated as the hydroxide and an indicator is used which combines with calcium only.

Determination: 50ml of sample was pipetted, and 2.0 ml of NaOH solution was added. It was stirred and 0.1 -0.2g of the murexide indicator added. It was then titrated immediately after the addition of the indicator. EDTA titrant was added slowly, with continuous stirring until the colour changes from salmon to orchid purple. The end point was checked by adding 1 or 2 drops of titrant in excess to make sure that no further colour change took place. It was ensured that not more than 15ml EDTA was required for the titration.

Calculations: Ca (mg/L) = A x B x 400.8

Volume of sample

Where A = ml of EDTA titrant used = ml of standard calcium solution ml of EDTA titrant

The results were expressed as mg/L Ca to 3 significant figures (APHA, AWWA, WEF 1995).

Determination of Total Coliform Bacteria: Water samples from each of the six sampling site were analysed for the presence of coliform bacteria using the membrane filtration method.100ml of each of the water samples were separately filtered through 0.45µm pore size membrane filter (millipore).

Determination of total coliform (TC) was done by incubating the membrane filter on Hichrome media at 37°C for 24 hours and determined as colony forming unit per 100ml (APHA, 1998).

Statistical Analysis: The data obtained from the analysis of the water samples were subject to unpaired t-test to determine whether there was significant difference in the concentration of the parameters tested within the first week of production and after storage for three months.

RESULTS AND DISCUSSIONS

Ten (10) samples of bottled water analysed within the first week of production were labeled with the following symbols: $B1_W$, $B2_W$, $B3_W$, $B4_W$, $B5_W$, $B6_W$, $B7_W$, $B8_W$, $B9_W$ and $B10_W$. While those stored for the period of three months before analysis were labeled: $B1_M$, $B2_M$, $B3_M$, $B4_M$, $B5_M$, $B6_M$, $B7_M$, $B8_M$, $B9_M$ and $B10_M$. Furthermore, the ten (10) samples of sachet water analysed within the first week of production were labeled: $S1_W$, $S2_W$, $S3_W$, $S4_W$, $S5_W$, $S6_W$, $S7_W$, $S8_W$, $S9_W$ and $S10_W$. While those stored for the period of three months before analysis were labeled: $S1_M$, $S2_M$, $S3_M$, $S4_M$, $S5_M$, $S6_M$, $S7_M$, $S8_M$, $S9_M$ and $S10_M$. From Tables 1A-1B and 2A-2B, the colour and appearance of all the water samples were colourless and odourless within the first week of production. However, some of the samples became cloudy after three (3) months of storage (samples $S3_M$ and $S5_M$). This may not be far from the increase in turbidity of the samples after the storage period.

The temperatures measured for all the samples as shown in tables 1A-1B and 2A-2B both within first week of production and after three (3) months of storage reflected the ambient temperature of the environment. That of Bottled water ranged from 24.15-27.00^{o}C (week 1) and 25.50-26.85^{o}C (3 months), while that of sachet water ranged from 24.25-27.10^{o}C (week 1) and 25.90-28.85^{o}C (3 months). This is in line with the findings of Isikwue, et al 2014,; ambient temperature (surrounding air temperature) influences the temperature of water samples during the period of analysis i.e the ambient temperature (surrounding air temperature) influenced the temperature of water samples during the period of analysis.

According to WHO report (1996), the microbiological characteristics of drinking water are related to temperature through its effects on water-treatment processes and its effects on both growth and survival of microorganisms. Consequently, growth of nuisance microorganisms is enhanced by warm water conditions and could lead to the development of unpleasant tastes and odours. Based on the results of the analysis, there was no significant ($p>0.05$) difference in the temperature of bottled water after storage, but for sachet water samples, there was a significant ($p<0.05$) difference in the temperature after the storage period.

Tables 1A-1B and 2A-2B showed that the conductivity values of the samples ranged from 97.50-175.00µs/cm (week 1) and 98.00-178.10µs/cm (3months) for bottled water samples while that of sachet water ranged from 60.98-117.35µs/cm (week) and 63.10-121.05 µs/cm (3 months) – all these values were within the acceptable standards. Also, tables 3-4 showed that the average value of all the samples of bottled water within first week of production and after three months of storage was 125.73±27.10µs/cm and 126.79±27.71µs/cm respectively while that of sachet water was 87.16±22.62µs/cm and 89.00±22.10µs/cm respectively. This showed an average increase in conductivity of the majority of the samples after storage. Although samples B2, S7 and S9 showed the reverse to this trend i.e. it decreased from 130.25±0.35 to 127.25±0.21µs/cm, 97.20±0.00 to 94.65±0.49µs/cm and 109.30±0.28 to 106.00±0.28µs/cm after the three months storage period. The increased conductivity could be as a result of increase in the amount of dissolved materials in the water during the period of storage. This is because conductivity values express the amount of dissolved solids in the water sample; it is a measure of ability of water to conduct electricity. Value depends on the concentration and degree of dissociation of electrolytes and it gives a good idea of the amount of dissolved material in the water. Dissolved solids can affect the suitability of water for domestic, industrial and agricultural uses. At higher levels, drinking water may have unpleasant taste or odour or may cause gastrointestinal distress. However, there was no significant ($p<0.05$) difference in conductivity of both the bottled water and sachet water samples at after the three months storage period.

The turbidity of the samples ranged from 0.31±0.01NTU to 0.76±0.01NTU (week 1) and 0.35±0.01NTU to 0.78±0.01NTU (3 months) and 0.39±0.01NTU to 1.05±0.07NTU (week1) and 0.74±0.02NTU to 1.85±0.21NTU (3 months) for bottled and sachet water respectively. Also, the average values showed that there was an increase in the turbidity of the samples after three months of storage. However, the values for five of the bottled water samples remained the same after three months of storage: B4 (0.40±0.00NTU), B6 (0.72±0.01NTU), B7 (0.45±0.01NTU), B8 (0.45±0.01NTU) and B10 (0.43±0.01NTU) but all the values were within the limits of WHO and SON (Tables 1A-1B and 2A-2B). High levels of turbidity can protect microorganisms from the effect of disinfection and can stimulate bacterial re-growth (WHO 2008).

High levels of turbidity indicate problems with treatment processes particularly coagulation, sedimentation and filtration. Turbidity is the physical property of water which reduces light transmission due to absorbance and scattering by solid particles in suspension. Materials that cause turbidity include: clay, silt, finely divided organic and inorganic matter, soluble coloured organic compounds, plankton and microscopic organisms. These can come from soil erosion, excess nutrients, various wastes and pollutants and the action of bottom feeding organisms. Such particles absorb heat in the sunlight, thus raising water temperature, which in turn lowers dissolved oxygen levels. Turbidity affects acceptability, selection and efficiency of treatment processes, particularly the efficiency of disinfection with chlorine since it exerts a chlorine demand, protects microorganisms and may also stimulate the growth of bacteria (Isikwue and Chikezie, 2014) There was no significant ($p>0.05$) difference in the Turbidity of bottled water after storage. But for sachet water samples, there were significant ($p<0.05$) difference in the Turbidity after the storage period

The average values for the total hardness of all the bottled water samples within first week of production and after three months of storage were 25.67±5.57mg/L and 27.90±6.05mg/L respectively while that of sachet water were 33.77±3.51mg/L and 36.85±4.79mg/L.

Table 1A: Comparison of Results of Physical, Chemical and Bacteriological Parameters of Samples of Bottled Water within First Week of Production and After Three (3) Months of Storage

SAMPLES	PARAMETERS						
	Appearance	Odour	Temp. (^{0}C)	Conduct. (μs/cm)	Turbidity (NTU)	Total Hardness (mg/L)	(TSS) (mg/L)
B1$_{W}$	CL	OL	25.55±0.07	175.00±0.00	0.31±0.01	18.00±0.00	0.00
B1$_{M}$	CL	OL	25.80±0.28	178.10±0.14	0.35±0.01	19.85±0.21	0.00
B2$_{W}$	CL	OL	26.30±0.07	130.25±0.35	0.37±0.01	17.35±0.21	0.00
B2$_{Ms}$	CL	OL	25.50±0.00	127.25±0.21	0.39±0.00	20.80±0.28	0.00
B3$_{W}$	CL	OL	24.15±0.21	109.50±0.00	0.53±0.02	32.35±0.21	0.00
B3$_{M}$	CL	OL	25.25±0.35	111.30±0.14	0.55±0.01	37.30±0.14	0.00
B4$_{W}$	CL	OL	26.25±0.35	120.00±0.00	0.40±0.00	23.25±0.35	0.00
B4$_{M}$	CL	OL	26.60±0.28	120.50±0.71	0.40±0.00	20.85±0.21	0.00
B5$_{W}$	CL	OL	24.90±0.14	97.50±0.71	0.76±0.01	25.40±0.14	0.00
B5$_{M}$	CL	OL	25.00±0.00	98.00±0.00	0.78±0.01	28.40±0.85	0.10
B6$_{W}$	CL	OL	26.95±0.78	98.25±1.06	0.72±0.01	28.00±0.00	
B6$_{M}$	CL	OL	26.60±0.14	99.55±1.91	0.72±0.01	30.45±0.35	0.10
B7$_{W}$	CL	OL	25.90±0.14	117.00±0.00	0.45±0.01	31.50±0.00	0.00
B7$_{M}$	CL	OL	26.35±0.21	118.65±0.92	0.45±0.00	31.15±0.21	0.00
B8$_{W}$	CL	OL	25.50±0.14	117.40±0.57	0.45±0.00	33.00±0.00	0.00
B8$_{M}$	CL	OL	25.90±0.14	118.10±0.85	0.45±0.01	35.35±0.49	0.00
B9$_{W}$	CL	OL	27.00±0.42	172.00±0.00	0.37±0.01	24.75±0.35	0.00
B9$_{M}$	CL	OL	26.85±0.07	174.40±0.85	0.39±0.01	26.20±0.28	0.00
B10$_{W}$	CL	OL	26.25±0.35	120.40±0.28	0.43±0.01	23.10±0.14	0.00
B10$_{M}$	CL	OL	26.60±0.14	122.00±1.41	0.43±0.01	28.65±0.49	0.00
WHO STD	CL	OL	35-40	1000.00	5.00	100.00	-
SON STD	CL	OL	Ambient	1000.00	5.00	-	-

Table 1B: Comparison of Results of Physical, Chemical and Bacteriological Parameters of Samples of Bottled Water within First Week of Production and After Three (3) Months of Storage

	(TDS) (mg/L)	pH	Calcium (Ca) (mg/L)	Lead (Pb) (mg/L)	Chloride (Cl) (mg/L)	Coliform Specie Count
B1$_{W}$	39.00±0.00	6.11±0.07	16.39±0.02	0.001	37.47±0.35	0.00
B1$_{M}$	39.95±0.21	7.01±0.01	13.00±0.00	0.00	37.78±0.04	0.00
B2$_{W}$	39.25±0.35	6.19±0.01	16.95±0.07	0.001	37.69±0.02	0.00
B2$_{Ms}$	40.35±0.49	6.92±0.04	11.70±0.14	0.00	37.95±0.01	0.00
B3$_{W}$	24.25±0.35	7.25±0.07	18.05±0.07	0.001	36.81±0.01	0.00
B3$_{M}$	25.90±0.14	7.95±0.21	10.25±0.21	0.00	37.00±0.14	0.00
B4$_{W}$	70.00±0.00	6.73±0.04	17.65±0.21	0.001	36.10±0.00	0.00
B4$_{M}$	70.75±0.21	6.93±0.04	17.75±0.49	0.00	36.70±0.57	0.00
B5$_{W}$	59.00±0.71	6.86±0.01	17.80±0.00	0.001	36.28±0.04	0.00
B5$_{M}$	60.40±0.57	7.35±0.21	12.60±0.14	0.002	37.50±0.28	0.001
B6$_{W}$	49.25±0.35	6.87±0.01	16.33±0.46	0.00	35.83±0.11	0.00
B6$_{M}$	51.50±0.28	7.60±0.28	12.95±1.34	0.00	35.98±0.04	0.001
B7$_{W}$	69.25±0.35	7.25±0.04	18.23±0.04	0.001	35.10±0.14	0.00
B7$_{M}$	69.45±0.07	6.55±0.35	18.35±0.01	0.00	35.10±0.14	0.00
B8$_{W}$	40.50±0.00	7.74±0.06	20.35±0.21	0.001	34.35±0.21	0.00
B8$_{M}$	41.40±0.14	8.00±0.00	17.63±0.25	0.001	34.80±0.42	0.00
B9$_{W}$	37.50±0.00	6.84±0.02	18.18±0.25	0.001	40.05±0.07	0.00
B9$_{M}$	38.25±0.35	7.50±0.28	15.40±0.28	0.00	40.13±0.04	0.00
B10$_{W}$	38.25±0.35	6.73±0.01	18.00±0.00	0.001	40.15±0.07	0.00
B10$_{M}$	32.45±0.07	6.45±0.35	20.45±0.49	0.00	40.75±0.35	0.00
WHO STD	500.00	6.50-8.50	200.00	-	250.00	100.00
SON STD	500.00	6.50-8.50	-	0.01	250.00	10.00

This also indicated an average increase in total hardness after the three months of storage. Although, the values decreased in four of the samples (B7: 23.25±0.35 to 20.85±0.21mg/L, B7: 31.50±0.21 to 31.15±0.21mg/L, S1: 34.10±0.14 to 33.85±0.07mg/L and S7: 26.05±0.92 to 25.05±0.21mg/L) but all the values were within the acceptable limit of WHO. No significant $p<0.05$ difference in the Total hardness of all the samples after storage. Total hardness is an indication of the presence of calcium and magnesium salts in water. High presence of magnesium and calcium is attributable to the geological formation of the source of the water samples (Isikwue and Chikezie, 2014)

Donato et al., 2003 reported that soft water (that is water low in calcium and magnesium) is associated with increased morbidity and mortality from cardiovascular diseases (CVDs) compared to hard water as well as water high in magnesium. Studies also suggest that the intake of soft water, that is water low in calcium, may be associated with high risk of fracture in children (Verd et al., 1992). According to Rubenowitz et al., 2000, only a few months exposure may be sufficient consumption time effects from water that is low in magnesium and/or calcium.

Results of the analysis within the first week of production, showed that all the water samples had no suspended solids but after three months of storage there was a little indication of TSS in some of the two of the bottled (B5$_{M}$: 0.10±0.00, B6$_{M}$: 0.10±0.00mg/L) and four out of the ten (10) sachet water samples (S3$_{M}$:1.75±0.35mg/L, S4$_{M}$: 1.90±0.14mg/L, S5$_{M}$: 1.35±0.21mg/L, S7$_{M}$: 1.55±0.07mg/L) which averaged as 0.02±0.04mg/L and 0.66±0.86mg/L respectively. Although no significant ($p>0.05$) difference in the TSS of bottled water after storage. But for sachet water samples, there was a significant ($p<0.05$) difference in the TSS after the storage period

The average values of the TDS in the bottled water and sachet water samples within first week of production were 46.63±14.99mg/L and 58.44±16.73mg/L respectively and after three months of storage the average values increased to 47.04±15.37mg/L and 61.38±16.99mg/L respectively.

Table 2A: *Comparison of Results of Physical, Chemical and Bacteriological Parameters of Samples of Sachet Water within First Week of Production and After Three (3) Months of Storage*

SAMPLES	PARAMETERS						
	Appearance	**Odour**	**Temp. (^{0}C)**	**Conduct. (µs/cm)**	**Turbidity (NTU)**	**Total Hardness (mg/L)**	**(TSS) (mg/L)**
$S1_W$	CL	OL	25.70±0.00	65.40±0.57	0.73±0.04	34.10±0.14	0.00
$S1_M$	CL	OL	28.85±0.07	66.10±0.57	0.81±0.01	33.85±0.07	0.00
$S2_W$	CL	OL	24.80±0.00	78.98±0.67	0.69±0.01	34.80±0.42	0.00
$S2_M$	CL	OL	26.10±0.14	81.80±0.57	0.74±0.02	40.90±0.85	0.00
$S3_M$	Cloudy	OL	26.10±0.14	120.40±0.57	1.60±0.14	38.00±0.28	1.75±0.35
$S4_W$	CL	OL	25.00±0.00	60.98±1.03	0.98±0.04	32.55±0.21	0.00
$S4_M$	Cloudy	OL	26.45±0.07	63.10±0.99	1.85±0.21	37.55±0.21	1.90±0.14
$S5_W$	CL	OL	23.95±0.07	89.85±0.92	0.78±0.01	38.95±0.21	0.00
$S5_M$	CL	OL	26.60±0.28	97.45±0.35	1.05±0.07	41.60±0.99	1.35±0.2
$S6_W$	CL	OL	25.65±0.21	66.98±0.74	0.44±0.02	32.20±0.28	0.00
$S6_M$	CL	OL	26.65±0.35	69.14±0.51	0.85±0.07	37.08±0.88	0.00
$S7_W$	CL	OL	26.40±0.57	97.20±0.00	0.81±0.01	26.05±0.92	0.00
$S7_M$	CL	OL	25.90±0.14	94.65±0.49	1.24±0.05	25.05±0.21	1.55±0.07
$S8_W$	CL	OL	24.75±0.07	117.35±0.21	0.53±0.01	31.45±0.21	0.00
$S8_M$	CL	OL	25.90±0.28	121.05±0.07	0.84±0.06	35.35±0.64	0.00
$S9_W$	CL	OL	27.15±0.07	109.30±0.28	0.39±0.01	36.27±0.06	0.00
$S9_M$	CL	OL	26.20±0.28	106.00±0.28	0.79±0.01	40.05±0.07	0.00
$S10_W$	CL	OL	24.25±0.35	66.33±0.53	0.49±0.01	36.23±0.08	0.00
$S10_M$	CL	OL	26.75±0.07	70.30±0.57	0.78±0.01	39.10±0.28	0.00
WHO STD	CL	OL	35-40	1000.00	5.00	100.00	-
SON STD	CL	OL	Ambient	1000.00	5.00	-	-

Table 2B: *Comparison of Results of Physical, Chemical and Bacteriological Parameters of Samples of Sachet Water within First Week of Production and After Three (3) Months of Storage*

(TDS) (mg/L)	pH	Calcium (Ca) (mg/L)	Lead(Pb) (mg/L)	Chloride (Cl) (mg/L)	Coliform Specie Count
45.08±5.41	6.66±0.01	15.50±0.42	0.008±0.00	50.14±0.06	0.00
50.05±0.07	7.63±0.39	13.58±0.32	0.004±0.00	50.60±0.28	0.00
45.20±5.52	6.45±0.07	14.90±0.14	0.006±0.00	50.90±0.14	0.00
50.20±0.14	7.35±0.21	13.30±0.42	0.003±0.00	51.50±0.85	0.00
80.25±0.21	7.85±0.07	14.50±0.42	0.00	53.95±1.63	0.00
36.05±0.07	6.63±0.25	18.20±0.14	0.001±0.00	55.10±3.11	0.00
40.90±0.85	7.20±0.14	17.35±0.49	0.00	57.35±0.21	0.00
68.65±0.35	6.94±0.07	15.25±0.07	0.009±0.00	54.30±0.00	0.00
76.15±1.06	7.88±0.11	14.75±0.07	0.008±0.00	55.60±0.57	0.00
50.25±0.07	7.97±0.04	15.85±0.07	0.009±0.00	56.60±0.14	0.00
49.60±0.57	7.20±0.14	14.40±0.57	0.006±0.001	56.95±0.21	0.00
83.68±0.60	5.70±0.14	17.30±0.42	0.009±0.00	55.20±0.57	0.00
87.40±0.00	7.63±0.18	19.10±0.14	0.006±0.00	57.35±0.92	0.00
71.55±0.49	7.70±0.14	19.35±0.07	0.009±0.00	57.10±0.14	0.00
71.55±0.21	7.65±0.07	17.20±0.00	0.004±0.00	58.60±0.57	0.00
68.85±0.49	5.80±4.10	16.80±0.14	0.005±0.00	54.20±0.28	0.00
66.40±0.14	7.18±0.04	14.25±0.21	0.002±0.00	54.38±0.11	0.00
40.60±0.14	5.30±0.00	22.55±0.21	0.01±0.00	50.60±0.14	0.00
41.25±0.35	6.68±0.18	22.85±1.20	0.007±0.00	58.80±0.14	0.00
500.00	6.50-8.50	200.00	-	250.00	100.00
500.00	6.50-8.50	-	0.01	250.00	10.00

The values however reduced in three of the water samples (B10, S6 and S9) and it remained the same in only one of the samples – S8 (Tables 1 and 2) and as expected all the values were within the WHO and SON permissible limits. Analysis showed that there was no significant ($p<0.05$) difference in the TDS of all the samples after storage.

The pH of majority of the samples analysed were within the permissible limits of SON and WHO except for $B1_W$ (6.11±0.07) and $B2_W$ (6.19±0.01) which were below the minimum requirement of 6.5 (Table 1). Also, results from Table 2, the pH of samples $S2_W$, $S7_W$, $S9_W$ and $S10_W$ were below 6.5 i.e. 6.45±0.07, 5.70±0.14, 5.80±4.10 and 5.30±0.00 respectively. Results of the t-test showed that there was no significant difference in the pH of bottled water samples and there was a significant difference in that of sachet water after storage. pH is one of the parameters that addresses the aesthetic quality of water such as taste which has no serious health significance (WHO, 1996).

The pH values for two of the bottled water samples were slightly below the acceptable limits (Table 3) while three of the sachet water samples were also below the acceptable limits (Table 4). However, the average value for the pH for bottled and sachet water samples within first week of production and after three months of storage were: (6.86±0.49, 6.68±0.90) and (7.23±0.54, 7.43±0.37) respectively and these are within the acceptable limits. Continuous consumption of such samples of water with pH below the acceptable limits (acidic pH) is capable of causing acidosis (Asamoah and Amorin 2011).

From Tables 3 and 4, average calcium concentration of the bottled water samples between week 1 and after three months of storage were 17.79±1.15mg/L and 15.01±3.38mg/L respectively while those of sachet water samples analysed were 17.11±2.39mg/L and 16.13±3.02mg/L respectively. This accounted for an average decrease in the concentration of calcium in the samples after storage for three months. Two of the bottled water samples were exception to this rule (samples B5 and B10). There was a significant ($p<0.05$) difference in the calcium concentration of the bottled water samples after storage while the sachet water samples showed no significant ($p>0.05$) difference in the calcium concentration after storage.

The increase in calcium concentration after storage could also be as a result of the increase in Total Hardness of the water samples since total hardness is an indication of the presence of calcium and magnesium salts in water.

Table 3: Comparison of Average values for Bottled Water within One Week of Production and after Three (3) Months of Storage

PARAMETER	Average Value within One Week of Production $(B1-B10)_W$	Average Value after Three (3) Months of Storage $(B1-B10)_M$	WHO Standard	SON Standard
Appearance	Colourless	Colourless	Colourless	Odourless
Odour	Odourless	Odourless	Colourless	Unobjectionable
Temperature (^{0}C)	25.88±0.89	26.05±0.65	35-40	Ambient
Conductivity (µs/cm)	125.73±27.10	126.79±27.71	1000	1000
Turbidity (NTU)	0.48±0.15	0.49±0.15	5	5
Total Hardness (TH) (mg/L)	25.67±5.57	27.90±6.05	100	-
Total Suspended Solids (TSS) (mg/L)	0.00	0.02±0.04	-	-
Total Dissolved Solids (TDS) (mg/L)	46.63±14.99	47.04±15.37	500	500
pH.	6.86±0.49	7.23±0.54	6.5-8.5	6.5-8.5
Calcium (Ca) (mg/L)	17.79±1.15	15.01±3.38	200	-
Lead (Pb) (mg/L)	0.0009±0.0004	0.0003±0.0007	-	0.01
Chloride (Cl) (mg/L)	36.98±1.92	37.37±1.94	250	250
Coliform Specie Count	0.00	0.0002±0.0004	100	10

Table 4: Comparison of Average values for Sachet Water within One Week of Production and after Three (3) Months of Storage

PARAMETER	Average Value within One Week of Production $(S1-S10)_W$	Average Value after Three (3) Months of Storage $(S1-S10)_M$	WHO Standard	SON Standard
Appearance	Colourless	Colourless	Colourless	Odourless
Odour	Odourless	Odourless	Colourless	Unobjectionable
Temperature (^{0}C)	25.37±0.10	26.55±0.86	35-40	Ambient
Conductivity (µs/cm)	87.16±22.62	89.00±22.10	1000	1000
Turbidity (NTU)	0.69±0.23	1.06±0.39	5	5
Total Hardness (TH) (mg/L)	33.77±3.51	36.85±4.79	100	
Total Suspended Solids (TSS) (mg/L)	0.00	0.66±0.86	-	-
Total Dissolved Solids (TDS) (mg/L)	58.44±16.73	61.38±16.99	500	500
Ph	6.68±0.90	7.43±0.37	6.5-8.5	6.5-8.5
Calcium (Ca) (mg/L)	17.11±2.39	16.13±3.02	200	-
Lead (Pb) (mg/L)	0.0067±0.0033	0.004±0.003	-	0.01
Chloride (Cl) (mg/L)	53.79±2.47	55.51±28.85	250	250
Coliform Specie Count (cfu/ml)	0.00	0.00	100	10

Average concentration of lead (Pb) in the bottled and sachet water samples within first week of production were 0.0009±0.0004mg/L and 0.0067±0.0033mg/L respectively and after three months of storage, the average concentration decreased slightly to 0.0003±0.0007mg/L and 0.004±0.003mg/L respectively. Sachet water sample (S5) had the highest lead concentration both within first week of production (0.009±0.00mg/L) and after three months of storage (0.008±0.00mg/L). It showed significant ($p<0.05$) difference in the Lead concentration of the bottled water samples after storage while the sachet water samples showed no significant ($p>0.05$) difference in the Lead concentration after storage

Average level of chloride in the bottled water samples between week 1 and after three months of storage showed a slight increase i.e. from 36.98±1.92mg/L to 37.37±1.94mg/L and that of sachet water samples also increased from 53.79±2.47mg/L to 55.51±28.85mg/L. The sample with the highest chloride concentration was $S10_M$ with 58.80±0.14mg/L while the sample with the lowest chloride concentration was $B8_W$ with 34.35±0.21mg/L. This may indicate that the major purification/disinfection used in the sachet water sold in Ibadan Metropolis is mainly chlorination since the bottled water sample with highest chlorine concentration (40.75±0.35mg/L) was lower than the sachet water with the lowest chlorine concentration (50.14±0.06mg/L). T-test result also showed that there was no significant ($p>0.05$) difference in the chlorine concentration of all the samples after storage. Result of analysis of all the samples (both bottled and sachet) within week 1 showed no growth of coliform. This however changed after the three months of storage as two of the bottled, $B5_M$ and $B6_M$ both accounted for Coliform Count of 0.001±0.00 water samples showing slight growth of Coliform. There was no significant ($p>0.05$) difference in the TCC of the bottled water samples after the storage period. Total coliforms are widely used as indicators of the general sanitary quality of treated drinking water (Ashbolt et. al, 2001) and consequently, WHO limit is that it should not be detected by any means.

Total coliforms counts in water samples can however be affected by temperature and the nature of packaging material used. This is in agreement with findings by (Efiuvwevwere and Eka 1991, Paine 1992 and Enaighe et. al., 2004) which noted that polythene sachet is more permeable to air than glass and plastic bottles. Permeability to gases such as oxygen, carbon (IV) oxide and water vapour has been reported to affect the growth and survival of microorganisms in packaged food. And also, the presence of coliform may be an indication of poor treatment or contact with surface water sources (Isikwue and Chikezie, 2014)

However, considering the results of the analysis discussed above, it shows that storage affects sachet water more than bottled water, this is because from the t-test carried out on the results, 36.36% of the sachet water samples showed significant difference in the parameters analysed within the first week of production and after three months of storage while 18.18% of bottled water showed significant difference in the parameters analysed after the three months storage period. Also, out of the six samples whose pH values were below the 6.5 minimum requirement, three of the samples whose pH values were far below 6.5 (i.e. acidic): 5.70±0.14, 5.80±4.10, 5.30±0.00 were sachet water samples.

*Conclusion***:** Attention must be paid to the little quantity of Pb presence in both bottled and sachet water. Bottled water showed changes after 3 months of storage as suspended solid were found presence is some of it which were not presence in the first week and finally the growth of E-coli was encourage during the storage of these potable water. Finally, this research work showed that sachet water sold in Ibadan Metropolis tends to be affected more than bottled water after storage for three months. Results of the t-test carried confirmed a higher significant difference in the sachet water samples than the bottled water.

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