Original Research Article

The Effects of Storage on the Physicochemical Properties of the Sachet Water Produced, Sold and Consumed Within Owerri Metropolis, Imo State

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ABSTRACT

Access to potable drinking water is a problem in Owerri metropolis. This has led to the proliferation of sachet water and to the outbreak of water borne diseases in various parts of Owerri metropolis. The aim of the study was to assess the effects of storage on the Physico-chemical quality of the sachet water produced, sold and consumed within Owerri metropolis. Fifteen sachet water brands were investigated for a period of four months. They were collected within 24 hours of production and stored at ambient temperature for four months. Samples were taken on monthly basis for Physico-chemical analysis using APHA and WHO analytical methods. pH values increased in all brands to acceptable WHO limits within 8 weeks of storage and gradually decreased toward the end of the experiment. While dissolved oxygen, chlorine, alkalinity and biochemical oxygen demand values decreased, temperature, calcium, magnesium, total hardness, total solid, total dissolved solid and electrical conductivity increased. The difference in values between the initial and final values was statistically significant ($p < 0.05$). Results from the research indicates that 63% of the brands analyzed met the WHO guideline limit for drinking when stored at ambient temperature within eight weeks period. However, storage beyond this period led to diminished potability quality of sachet water.

Key words: Sachet water, Potability, Physico-chemical Properties, Storage, Owerri metropolis

INTRODUCTION

Water is one medium through which pathogenic organisms are spread. Sachet or packaged water, which is the major means of drinking water in Nigeria, is not exempted of deadly organisms, due to its microbial substance. [1]

Unsafe water supply and unhygienic environment are fingered as the cause of over 70 percent diseases in the developing countries. [1] An example is Mr. Theophilus Ikpekiri, a resident of Yenegoa, the capital of Bayelsa State, who is fond of drinking chilled sachet water. He started experiencing symptoms of fever and visited her doctor who diagnosed typhoid fever, caused by *Salmonella typhi.*

Professor Amobi Ilika, the Director of Community and Public Medicine at the Nnamdi Azikiwe Teaching Hospital (NAUTH), Nnewi, Anambra State, in March 2013, when in a civic presentation, cautioned that sachet water exposed to heat is capable of exposing the drinkers to cancerous materials.

Professor Ilika was of the view that polythene bags made of synthetic petroleum deteriorates water in them, because the

polythene bags are weather-susceptible. He averred that some of the sun ray or heat melts some of the synthetic petroleum into the water. He enthused that the materials that will drop into the water are called carcinogenic. Not only that, the polythene bags also build-up germs and microorganisms.

There are also traces of other microbial pathogens connected with water pollution which include Salmonella, Shigella, Vibrio, Campylobacter, Yersinia, Cryptosporidium and *Giardia species*, according to the experts, and they are not farfetched in this type of water. [2] The highlight of this is that vendors of the sachet water are not technically and scientifically grounded on handling and producing sachet water through storage and handling.

Water, which is essential to human being, has recorded immeasurable years of neglect in Nigeria by the successive governments, hence leaving the supply of drinking water in the country in undependable hands of sachet water producers. [3] The populace loves this brand of water, which comes in sizes ranging from 60 mL to 2 L, due to its affordability. However, many citizens are oblivious of the health hazards that it portends. The citizens may not be blamed, since they need ways to douse their press for water. [3]

The failure to provide safe, pipe-borne water for human consummation by the successive governments, led to the production of sachet water in Nigeria. The governments' ineptitude geared the sale of such water by individuals, with many of the producers not having in-depth knowledge of producing quality water and storage. [4] This has led to the outbreak of water borne diseases in various parts of Owerri metropolis of Imo State.

This study was therefore carried out to examine the effects of storage on the physicochemical qualities of sachet water produced, sold and consumed in Owerri metropolis of Imo State.

MATERIALS AND METHODS
Study area

Owerri, the capital of Imo state is a metropolitan city. It is located in South East Nigeria between longitude 5.485^{o}N and latitude 7.035^{O}E. There are three Local Government Areas making up Owerri Zone; Owerri Municipal, Owerri West and Owerri North. It has a high population density of 401,873 (2006 census report) due to governmental presence and booming business activities. It is approximately 40 square miles ($100km^2$) in area (Ministry of Urban Development, 2004). Owerri was selected for this study because of scarcity of water and extensive use of the 'sachet water'. This has resulted in residents buying sachet water for drinking purposes and domestic uses. With the high demand for this water, small scale industries have sprung up producing it to meet the demands.

Sample Collection

Fifteen brands of sachet water with NAFDAC certification were randomly obtained from different parts of Owerri metropolis, in bags within 24 hours of production and stored in a room at ambient temperature. Sachet samples were collected for Physico-chemical analysis. These were done immediately after collection and subsequently on a monthly basis. The sachet water samples were also checked for leakages on a monthly interval. Sampling was done between November, 2016 and April, 2017.

Physicochemical analysis of water samples

This involved the assessment of the physicochemical parameters of the sachet waters such as pH, temperature, total hardness, carbonate, bicarbonates, total solids, total dissolved solids, dissolved oxygen, biochemical oxygen demand, and presence of minerals such as (magnesium, chlorine and calcium). This was determined by methods described according to APHA. [5]

pH

The Jenway 1910 multipurpose set was used. The instrument is an automated

digital one and hand held. The pointer (electrode) was dipped into 10ml of the water sample and held in place for 2 – 3 minutes to stabilize. The pH value was then read off the instrument while still in the water.

Temperature

Temperature was determined using mercury-in glass thermometer. The thermometer was dipped into the water samples and held in place for 2 - 3 minutes to stabilize before taking the reading.

Chloride determination (Agretometric Method)

Five drops of phenolphthalein indicator solution was added to 50ml of the sample and was neutralized with 0.1N sulfuric acid to the colorless side of phenolphthalein. One ml of potassium chromate indicator solution was added and titrated with standard silver nitrate ($AgNO_3$) solution to the pinkish-yellow endpoint. A reagent blank titration was carried out in parallel to the sample titration. Chloride quality was calculated as follows:

Chloride, mg/I = [(A-B) (N) (35.45)/V] x 100

Where A= Silver nitrate solution, in ml for sample titration

B= Silver nitrate solution, used for blank titration

N= Normality of the silver nitrate solution

V= Sample volume (in ml).

Determination of Total Solid (TS)

The total solids were determined gravimetrically. [7] A measured volume of each water sample was dispensed into a previously weighed evaporation dish. The sample in the dish was evaporated to dryness over a Gallenkamp water bath. The dish was further dried in the oven at 105^0C, cooled in desiccators and reweighed. The amount of solid was determined by the difference between the dried solid in the evaporation dish and the dried evaporation dish and expressed as a percentage of the water volume analyzed as shown,

$$\% \text{ total solids} = \frac{W_2 - W_1 \times 100}{\text{Vol .of sample}}$$

Where, W_1 = weight of empty dish

W_2 = weight of dish and solids

Total dissolved Solids (TDS)

The percentage dissolved solids were also determined gravimetrically. A measured volume of the water sample was filtered through Whatman N0. 42 grade filter paper. The filtrate was used for the determination as described above. The solid (dissolved in the water sample filtrate) was calculated by

$$\% \text{ dissolved solids } = \frac{(W_2 - W_1) \times 100}{\text{vol. of filtered water sample}}$$

Where, W_1= weight of empty dish

W_2 = weight of dish and sample evaporated

Total hardness (using EDTA Titrimetric method)

Determination of total hardness was carried out by measuring 50ml of the water sample into a 250 ml conical flask. About 4ml of the buffer solution and 6 drops of ferrochrome black T indicator solution were added prior to titration. The content in the conical flask was titrated against 0.0IM EDTA to the end point indicated by a distinct blue coloration. Titration was repeated for consistent titer values from which an average titer was calculated. [6] It was then calculated thus;

Total hardness (mg $CaCo_3$/L) = ml titrant x 100/ml sample

Carbonate and Bicarbonate

Carbonate and bicarbonate in water were determined by titrating a known volume of water against standard sulfuric acid using phenolphthalein and methyl orange indicators respectively. 10ml of sample was transferred to 100ml conical flask and 2 drops of phenolphthalein indicator was added. Pink color showed the presence of carbonate which was titrated against 0.01N H_2SO_4 until the sample was colorless. The volume was denoted as A. 2 drops of methyl orange indicator was subsequently added and yellow color appeared. After titrating against 0.01N H_2SO_4, the yellow color changed to red and was denoted as B. Carbonate and bicarbonate were calculated thus:

CO_3^{2-} me/l = 2 x N x A/ml of sample x 1000

HCO_3 me/l = N x (B - A)/ml of sample x 1000

Where N = Normality of acid

2= Valency of carbonate

A= volume of titrant against phenolphthalein indicator

B= volume of titrant against methyl orange indicator

m) Determination of calcium and magnesium (Ca^{2+} & Mg^{2+}):

The versenate titration method was used in which EDTA-disodium salt solution was used to chelate them (Ca^{2+} & Mg^{2+}). Calcium was separately estimated by versenate method using ammonium purpurate (Murexide) indicator and thus magnesium can be obtained by deduction of Ca from Ca+Mg content. Both the cations can also be estimated by AAS. It was calculated thus:

$Ca^{2+} + Mg^{2+}$ me/l = N x V/ ml of sample x 1000

Ca^{2+} me/l = N x V/ ml of sample x 1000

Mg^{2+} me/l = ($Ca^{2+} + Mg^{2+}$) – Ca^{2+}.

Electrical Conductivity

The electrode was wetted thoroughly and then plugged into the conductivity meter (CyberScan CON510) before it was inserted into a 250ml beaker containing distilled water. The conductivity meter was then switched on, and zero error was corrected. The distilled water was replaced with sachet water samples and the electrode was inserted in each case. The system was allowed to stabilize and the reading was recorded.

Alkalinity Determination

Alkalinity was determined by measuring 50ml sample into conical flask. About 2 drops of phenolphthalein indicator was added and the resulting mixture titrated against a standard 0.10N H_2SO_4 solution until the pink colour disappeared. The burette reading was recorded and five drops of methyl orange indicator was added to the solution and titrated against the standard 0.10N H_2SO_4 solution to the first permanent pink color at pH 4.5. [6] Calculation was done using;

Total Alkalinity = ml titrant x Normality of acid x 50,000/ml sample

Dissolved oxygen (DO) (Modified Winkler method)

300ml BOD bottle was filled with the sachet water sample and closed with a stopper (special care was taken to avoid adding air to the liquid being collected). The stopper was removed and 1 ml of manganous sulphate solution was added at the top of the liquid. The stopper was closed and the bottle was shaken vigorously and the floc was allowed to settle half way. Then, 1 ml of concentrated sulphuric acid was added by allowing the acid to run down the neck of the bottle above the surface of the liquid and the stopper was applied and the bottle shaken vigorously until the precipitate dissolved. 201 ml of the sample was poured into an Erlenmeyer flask from the BOD bottle and the solution (reddish-brown color) was titrated against 0.0250 N sodium thiosulphate until the solution turned pale yellow color. The amount of titrant used was recorded, small quantity of starch indication was added with blue color developing and titration proceeded until the blue color disappeared. The total number of ml of sodium thiosulphate was recorded. Calculation was done using the formula:

Mg/L DO = ml titrant x normality of titrant x 8000/volume of sample.

Biochemical Oxygen Demand (BOD) using Winkler titration method:

The dissolved oxygen (DO) was measured at the beginning and recorded. After five days, the DO was again determined. The BOD was then calculated on the basis of reduction of DO and the size of the sample. Measurement of DO was made by using the Winkler titration method.

Statistical analysis

The statistical analysis employed were percentage, range, mean, standard error of mean and Analysis of variance (ANOVA). [8] The parameters were also correlated against the organisms to determine their relationship with each other. This was done using (MS Excel and SPSS software).

RESULTS

Physicochemical Analysis

The parameters assessed in the physicochemical analysis of the sachet water samples are as follows:

pH

The pH value of the sachet water samples are presented in Table 1. The pH values varied from 6.50 to 7.60 averaging 7.08 (Table 6) throughout the investigation period. 40% of the pH values were outside WHO limits of 7.0 to 8.0 in all the 15 samples analyzed while 60% were within WHO limits. An increase in pH was observed in all the samples up to week 8 followed by a decline between Week 8 and Week 16 (Table 1). The pH shows slightly alkaline trend.

Temperature

The temperature readings of the sachet water samples before, during and after storage are as presented in Table 1. The temperature values ranged from 25.1 to 40.1^{o}C. There was a gradual increase in temperature throughout the storage period. Meanwhile, the temperature values obtained throughout the investigation period fell within ranged by the World Health Organization.

Table 1: pH and Temperature (^{o}C) Values of Sachet Water in 16 Weeks Period

SAMPLE CODES	Ph					TEMPERATURE (^{0}C)				
	WK 1	WK 4	WK 8	WK 12	Wk 16	WK 1	WK 4	WK 8	WK 12	Wk 16
S1	6.8	6.9	7.6	7.4	6.9	25.1	29.1	30.0	34.4	35.1
S2	6.6	7.1	7.3	7.1	6.7	25.5	30.5	32.2	35.5	35.8
S3	6.5	6.9	7.2	7.0	6.8	26.4	30.4	32.7	33.6	34.8
S4	7.0	7.0	7.1	7.0	6.5	26.8	28.8	30.6	32.7	34.9
S5	7.3	7.0	7.3	7.0	6.7	28.1	31.1	32.4	33.9	35.2
S6	6.8	6.9	7.4	7.3	7.0	27.2	34.2	35.7	35.9	40.1
S7	7.0	7.1	7.3	7.1	6.8	25.5	29.5	30.1	31.9	35.3
S8	6.7	7.0	7.2	7.0	6.7	26.4	30.4	31.6	32.4	34.8
S9	6.8	7.0	7.1	6.9	6.6	27.0	35.0	35.2	36.3	38.3
S10	7.2	6.9	7.2	7.0	6.8	25.2	31.2	31.7	32.3	34.6
S11	6.6	7.2	7.4	7.2	7.0	26.7	31.7	32.2	34.2	35.2
S12	6.7	6.9	6.9	6.7	6.5	26.2	31.2	32.4	34.6	35.9
S13	7.1	7.1	7.2	7.0	6.8	27.1	31.1	32.2	33.3	34.3
S14	6.6	6.9	7.4	7.1	6.7	28.2	29.2	30.2	31.2	33.4
S15	6.9	7.1	7.2	7.0	6.7	29.0	29.0	30.3	32.1	34.5

KEY: S1=Crystal, S2=Ricano, S3=Iroko, S4=Marlyn, S5=Emma, S6=Agad, S7=Clets, S8=Chipa, S9=Talent, S10=Izzy, S11=Anabebs, S12=Zipoue, S13=Enodoz, S14=Cosyran, S15=Elevated

Total Hardness, Calcium and Magnesium

The total hardness, calcium and magnesium values fluctuated between 0.04-0.24mg/l, 0.01-0.14mg/l and 0.01-0.09, respectively (Table 2). There was a gradual increase in the total hardness, calcium and magnesium values throughout the investigation period up to week 16 but the values were all within the WHO limits of 100mg/l, 75 and 30, respectively for drinking water standards (Table 7).

Chlorine

The WHO permissible limit of chloride in drinking water is 250 mg/L. The values of chloride obtained in the sachet water samples were very low, between 0.09 and 19.53mg/L (Table 3) averaging 8.58mg/l (Table 7), also within the WHO permissible limit. There was a decrease in chlorine values from week 1 up to week 16 (table 3).

Table 2: Total Hardness, Calcium and Magnesium Values in 16 Weeks Period

SAMPLE CODES	TOTAL HARDNESS (Mg/L)					CALCIUM (Mg)					MAGNESIUM (Mg)				
	WK 1	WK 4	WK 8	WK 12	WK 16	WK 1	WK 4	WK 8	WK 12	WK 16	WK 1	WK 4	WK 8	WK12	WK 16
S1	0.09	0.09	0.12	0.18	0.20	0.05	0.05	0.07	0.10	0.11	0.04	0.04	0.05	0.08	0.09
S2	0.10	0.14	0.16	0.20	0.24	0.06	0.08	0.09	0.10	O.12	0.04	0.06	0.07	0.10	0.12
S3	0.06	0.08	0.10	0.14	0.16	0.04	0.06	0.07	0.08	0.12	0.02	0.02	0.03	0.06	0.08
S4	0.08	0.10	0.14	0.20	0.24	0.05	0.06	0.08	0.12	0.14	0.03	0.04	0.06	0.08	0.10
S5	0.04	0.08	0.12	0.16	0.20	0.03	0.05	0.07	0.10	0.12	0.01	0.03	0.05	0.06	0.08
S6	0.06	0.10	0.14	0.18	0.22	0.04	0.06	0.08	0.10	0.12	0.02	0.04	0.06	0.08	0.10
S7	0.04	0.08	0.12	0.16	0.18	0.03	0.05	0.07	0.09	0.10	0.01	0.03	0.05	0.07	0.08
S8	0.08	0.10	0.14	0.18	0.21	0.05	0.06	0.08	0.10	0.11	0.03	0.04	0.06	0.08	0.10
S9	0.03	0.05	0.07	0.09	0.12	0.02	0.03	0.05	0.07	0.08	0.01	0.02	0.02	0.02	0.04
S10	0.07	0.09	0.11	0.15	0.18	0.04	0.05	0.06	0.07	0.09	0.03	0.04	0.04	0.08	0.09
S11	0.04	0.07	0.10	0.14	0.18	0.02	0.04	0.06	0.08	0.10	0.02	0.03	0.04	0.06	0.08
S12	0.06	0.09	0.12	0.16	0.18	0.04	0.05	0.07	0.09	0.10	0.02	0.04	0.05	0.07	0.08
S13	0.08	0.10	0.14	0.20	0.24	0.05	0.07	0.08	0.12	0.14	0.03	0.03	0.06	0.08	0.10
S14	0.02	0.04	0.06	0.08	0.12	0.01	0.03	0.04	0.06	0.08	0.01	0.01	0.03	0.03	0.04
S15	0.04	0.07	0.09	0.12	0.14	0.01	0.03	0.05	0.07	0.08	0.03	0.04	0.04	0.05	0.06

KEY: S1=Crystal, S2=Ricano, S3=Iroko, S4=Marlyn, S5=Emma, S6=Agad, S7=Clets, S8=Chipa, S9=Talent, S10=Izzy, S11=Anabebs, S12=Zipoue, S13=Enodoz, S14=Cosyran, S15=Elevated

Table 3: Chlorine, Carbonate and Bicarbonate Values in 16 Weeks Period

SAMPLE CODES	CHLORINE (Mg/L)					CARBONATE (CO₃)					BICARBONATE (HCO₃)				
	WK 1	WK 4	WK 8	WK 12	WK 16	WK 1	WK 4	WK 8	WK 12	WK 16	WK 1	WK 4	WK 8	WK 12	WK 16
S1	17.04	9.3	2.83	0.18	0.11	0.00	0.00	0.00	0.00	0.00	6.10	6.21	6.10	6.12	6.26
S2	19.53	12.34	6.75	3.58	2.44	0.00	0.00	0.00	0.00	0.00	3.66	3.65	3.66	3.65	3.64
S3	16.69	11.24	1.83	0.15	0.10	0.00	0.00	0.00	0.00	0.00	3.66	3.65	3.65	3.66	3.69
S4	18.52	14.28	10.11	5.34	4.34	0.00	0.00	0.00	0.00	0.00	2.44	2.43	2.41	2.43	2.56
S5	17.41	12.34	6.67	4.43	3.98	0.00	0.00	0.00	0.00	0.00	2.45	2.42	2.34	2.32	2.44
S6	11.91	8.23	4.23	0.19	0.09	0.00	0.00	0.00	0.00	0.00	6.10	6.10	6.01	6.01	6.00
S7	18.01	10.01	3.21	0.16	0.04	0.00	0.00	0.00	0.00	0.00	6.85	6.82	6.81	6.85	6.24
S8	18.41	10.23	5.89	3.34	2.57	0.00	0.00	0.00	0.00	0.00	5.41	5.40	5.39	5.38	5.41
S9	18.64	9.23	2.76	0.14	0.02	0.00	0.00	0.00	0.00	0.00	3.71	3.70	3.71	3.69	3.52
S10	18.72	12.34	9.34	3.45	2.18	0.00	0.00	0.00	0.00	0.00	3.43	3.42	3.41	3.40	3.23
S11	17.56	10.23	7.34	3.73	2.23	0.00	0.00	0.00	0.00	0.00	6.46	6.45	6.42	6.41	6.76
S12	16.08	6.56	4.59	2.93	1.88	0.00	0.00	0.00	0.00	0.00	2.54	2.52	2.54	2.51	2.11
S13	16.86	8.87	3.43	1.48	1.11	0.00	0.00	0.00	0.00	0.00	3.72	3.71	3.70	3.71	3.22
S14	19.23	9.57	6.66	4.77	3.33	0.00	0.00	0.00	0.00	0.00	6.81	6.82	6.79	6.80	6.12
S15	17.89	7.01	4.48	2.12	1.67	0.00	0.00	0.00	0.00	0.00	4.02	4.03	4.01	4.03	4.01

KEY: S1=Crystal, S2=Ricano, S3=Iroko, S4=Marlyn, S5=Emma, S6=Agad, S7=Clets, S8=Chipa, S9=Talent, S10=Izzy, S11=Anabebs, S12=Zipoue, S13=Enodoz, S14=Cosyran, S15=Elevated

Carbonate and Bicarbonate

Carbonate was absent in all the water samples before, during and after storage while bicarbonate was found in all brands, at the concentrations between 2.42 to 6.85 (Table 3) averaging 5.24 (Table 7). The bicarbonate concentration detected in all sachet water samples were less than the WHO minimum permissible limits of 244. There was no significance increase or decrease in the bicarbonate values throughout the investigative period.

Total solid and Total Dissolved Solid

The Total Solids (TS) and Total Dissolved Solids (TDS) values of samples varied between 50mg/l and 85 mg/l (Table 4) averaging 61.64mg/L (Table 7). These values were within the WHO standards of 500mg/l for drinking water quality. As denoted in Table 4, there was a remarkable increase in the values of TS and TDS from week 1 to week 16.

Table 4: Total Solid and Total Dissolved Solids Values in 16 Weeks Period

SAMPLE CODES	TOTAL SOLID (Mg/L)					TOTAL DISSOLVED SOLID (Mg/L)				
	WK 1	WK 4	WK 8	WK 12	WK 16	WK 1	WK 4	WK 8	WK 12	WK 16
S1	50	55	60	65	70	50	55	60	65	70
S2	60	65	68	72	75	60	65	68	72	75
S3	50	53	55	58	60	50	53	55	58	60
S4	58	61	64	68	72	58	61	64	68	72
S5	67	70	72	75	78	67	70	72	75	78
S6	62	65	68	71	75	62	65	68	71	75
S7	73	76	79	82	85	73	76	79	82	85
S8	58	62	66	69	73	58	62	66	69	73
S9	67	69	72	75	78	67	69	72	75	78
S10	61	64	67	69	72	61	64	67	69	72
S11	58	62	66	70	74	58	62	66	70	74
S12	60	65	68	71	75	60	65	68	71	75
S13	59	62	66	68	73	59	62	66	68	73
S14	60	63	66	68	71	60	63	66	68	71
S15	71	74	77	79	85	71	74	77	79	85

KEY: S1=Crystal, S2=Ricano, S3=Iroko, S4=Marlyn, S5=Emma, S6=Agad, S7=Clets, S8=Chipa, S9=Talent, S10=Izzy, S11=Anabebs, S12=Zipoue, S13=Enodoz, S14=Cosyran, S15=Elevated

Electrical Conductivity (EC)

The electrical conductivity results of sachet water samples showed short variation, which ranged from 126.35 to 144.44 $\mu\Omega$/L (Table 5), averaging 135.86 $\mu\Omega$/L (Table 11). There was a gradual increase in the EC values throughout the investigative period but all samples were still within the WHO limit of 750-1200 $\mu\Omega$/L for drinking water.

Total Alkalinity (TA)

The values of total alkalinity are also presented in Table 5. The values ranged from 3.71mg/l to 9.02mg/l averaging 7.24mg/l within the period under investigation. This value also indicated that the water is soft. There was a gradual decrease in values within this period but the values were still within the WHO limit of 150mg/l for drinking water.

Table 5: Electrical Conductivity and Alkalinity Values in 16 Weeks Period

SAMPLE CODES	ELECTRICAL CONDUCTIVITY (µΩ/L)					TOTAL ALKALINITY (Mg/L)				
	WK 1	WK 4	WK 8	WK 12	WK 16	WK 1	WK 4	WK 8	WK 12	WK 16
S1	136.99	137.89	138.23	139.31	141.34	6.10	6.00	5.89	4.99	3.84
S2	126.35	127.11	128.23	129.65	132.22	5.01	4.99	4.37	3.48	2.72
S3	139.87	140.02	141.34	143.34	144.44	8.39	7.98	7.11	6.67	5.87
S4	132.03	133.25	134.88	135.01	136.33	8.01	7.71	6.74	5.88	5.02
S5	129.34	130.02	131.22	132.42	134.34	9.02	8.98	7.76	6.03	5.77
S6	137.12	138.83	139.34	140.00	141.33	8.48	8.00	7.78	6.98	6.00
S7	128.98	129.99	130.11	131.33	133.12	6.89	6.11	5.34	4.91	3.78
S8	139.81	140.03	141.37	142.00	143.22	9.10	8.34	7.46	6.67	6.08
S9	137.78	138.34	139.88	140.21	143.23	8.34	7.78	6.47	5.77	4.53
S10	127.37	128.01	129.89	130.32	132.57	7.45	6.99	5.67	4.09	3.31
S11	134.34	135.33	136.23	137.12	138.23	8.98	7.09	6.09	5.69	5.22
S12	128.88	129.89	130.02	131.24	132.24	6.88	6.11	5.78	4.79	3.90
S13	138.67	139.05	140.56	141.52	144.44	7.75	7.00	6.74	5.33	4.88
S14	136.38	137.34	138.21	139.00	142.03	6.22	5.09	5.00	4.29	3.71
S15	127.77	128.78	129.23	131.01	133.11	9.01	8.23	7.98	6.78	5.44

KEY: S1=Crystal,   S2=Ricano,   S3=Iroko,   S4=Marlyn,   S5=Emma, S6=Agad, S7=Clets, S8=Chipa,   S9=Talent,   S10=Izzy, S11=Anabebs, S12=Zipoue, S13=Enodoz, S14=Cosyran, S15=Elevated

Table 6: Dissolved Oxygen and Biochemical Oxygen Demand Values in 16 Weeks Period

SAMPLE CODES	DISSOLVED OXYGEN (DO) Mg/L					BIOCHEMICAL OXYGEN DEMAND (BOD) Mg/L				
	WK 1	WK 4	WK 8	WK 12	WK 16	WK 1	WK 4	WK 8	WK 12	WK 16
S1	4.98	4.00	3.89	2.76	1.88	2.98	2.90	2.89	2.76	1.21
S2	4.51	3.88	2.98	2.11	1.45	2.51	2.18	2.08	1.81	1.67
S3	4.72	4.10	3.84	2.68	2.04	3.72	3.10	2.84	2.68	2.11
S4	4.11	3.85	3.22	2.83	2.22	4.11	2.85	2.22	2.13	2.12
S5	4.46	3.79	2.74	2.01	1.98	3.46	2.79	2.74	2.01	1.87
S6	3.99	3.37	2.97	2.00	1.88	2.99	2.37	1.97	1.60	1.44
S7	3.76	3.02	2.45	2.33	1.76	2.02	2.00	1.33	1.11	1.02
S8	4.88	4.22	3.56	2.75	2.13	3.88	3.22	3.16	2.75	2.12
S9	3.59	3.17	2.55	2.24	1.22	2.59	2.17	1.55	1.24	1.13
S10	4.06	3.37	2.88	2.23	1.88	3.06	2.37	2.28	2.23	2.00
S11	3.57	2.88	1.03	1.99	1.10	2.57	2.88	1.03	1.00	0.96
S12	4.47	3.76	3.28	2.46	2.12	3.47	2.76	2.28	2.16	1.28
S13	4.82	4.24	3.08	2.68	2.14	3.82	3.24	3.08	2.68	1.89
S14	3.49	2.76	2.05	1.79	1.12	2.49	2.36	1.85	1.79	1.23
S15	4.84	3.33	2.90	2.25	2.12	3.84	2.33	2.20	1.25	1.19

KEY: S1=Crystal,   S2=Ricano,   S3=Iroko,   S4=Marlyn,   S5=Emma, S6=Agad, S7=Clets, S8=Chipa,   S9=Talent,   S10=Izzy, S11=Anabebs, S12=Zipoue, S13=Enodoz, S14=Cosyran, S15=Elevated

Table 7. Mean Values of Sachet Water in 16 Weeks Period

PARAMETERS	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	MEAN*	WHO STANDARDS
Ph	7.1 2	7.00	6.88	6.92	7.06	7.08	7.06	7.92	6.88	7.02	7.08	6.74	7.04	6.94	6.98	7.05±1.15	7.0-8.0
Temp(^{0}C)	30.74	31.90	31.58	30.76	32.14	34.62	30.64	31.12	34.36	31.00	40.00	32.06	31.60	30.44	30.98	32.26±1.44	-----
TH(Mg/L)	0.14	0.17	0.12	0.15	0.12	0.14	0.12	0.14	0.07	0.12	0.12	0.12	0.15	0.06	0.09	0.12±0.02	100
Ca	0.08	0.09	0.07	0.09	0.07	0.08	0.07	0.08	0.05	0.06	0.05	0.07	0.09	0.04	0.05	0.07±0.04	75
Mg	0.06	0.08	0.04	0.06	0.05	0.06	0.05	0.06	0.02	0.06	0.05	0.05	0.06	0.02	0.04	0.05±0.02	30
Cl	5.89	8.94	6.00	10.52	8.97	4.93	7.87	8.09	6.16	9.21	8.22	6.41	6.35	8.71	6.63	7.53±2.61	250
C0$_3$	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00±00	----
HC0$_3$	6.16	3.65	3.66	2.45	2.40	6.04	6.71	5.41	3.67	3.39	6.48	2.44	3.61	6.67	4.02	4.45±1.06	244-732
TS(Mg/L)	60.00	68.00	55.20	64.60	72.40	68.20	79.00	65.60	72.20	66.60	66.00	67.80	65.60	65.60	77.20	61.66±4.88	500
TDS(Mg/L)	60.00	68.00	55.20	64.60	72.40	68.20	79.00	65.60	72.20	66.60	66.00	67.80	65.60	65.60	77.20	67.60±4.88	500
EC(μΩ/L)	138.75	128.71	141.80	134.10	131.47	139.32	130.71	141.29	129.63	129.63	136.25	130.45	140.85	138.59	129.98	134.77±8.04	750-1200
TA(mg/L)	5.36	4.11	7.20	6.67	7.51	7.5	5.78	7.45	6.58	5.50	6.61	5.50	6.34	4.86	7.49	6.30±1.73	150
DO(Mg/L)	3.50	2.70	3.34	2.80	3.00	2.84	2.66	3.51	2.55	2.88	2.11	3.22	3.40	2.24	3.10	2.92±0.03	5-13
BOD(Mg/L)	2.55	2.05	2.89	2.69	2.57	2.07	1.50	2.03	1.74	2.39	1.69	2.39	2.94	1.94	2.16	2.24±0.01	1- 5

Temp = Temperature, Ts = Total solid, TDS = Total Dissolved Solid, TH = Total Hardness, Ca = Calcium, Mg = Magnesium, Cl = chlorine, C0$_3$ = Carbonate, Hco$_3$ = Bicarbonate, EC = Electrical Conductivity, TA = Total Alkalinity, DO = Dissolved oxygen, BOD = Biochemical oxygen Demand. S1= Crystal,S2 = Ricano,S3 = Emma, S4 = Clets, S5 = Agad, S6 = Talent, S7 = Iroko, S8 = Izzy, S9 = Marlyn S10 = Chipa, S11 = Anabebs, S12 = Zopoue, S13 = Enodoz, S14 = Cosyran, S15 = Elevated   * = Mean values ± Standard Error of Mean

Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD)

The dissolved oxygen and biochemical oxygen values obtained for the sachet water samples are as presented in Table 6. The dissolved oxygen values ranged from 1.03-4.98 mg/l (table 6) averaging 3.86 mg/l. The value of the DO after 5days period gives the BOD whose average was 2.28mg/l(Table 6). Meanwhile, both the DO and BOD values were all within the WHO limit of 5-13mg/L and 1-5mg/L of drinking water, respectively.

Mean Values of Sachet Water in 16 Weeks Period

Table 7 shows the mean values of the sachet water in 16 weeks period and their standard i.e. World Health Organization (WHO) Standard.

DISCUSSION

The results of this investigation revealed that the stored water samples did not show physical signs of pollution until after 8 weeks of storage. pH is one of the parameters that addresses the aesthetic quality of water such as taste which has no serious health significance. [9] Generally pH of water is influenced by geology of catchments area and buffering capacity of water. Increase observed in pH, could also be attributed to the production of basic metabolic waste products by increasing bacterial population or could be attributed to increased primary productivity wherein carbonates, sulfate, nitrates and phosphates are converted to hydroxyl ions.

In their review [10] stated that microorganisms frequently change the pH of their own habitat by producing acidic or basic metabolic waste products. Earlier studies [11] on the quality of water brands sold in Egypt showed that the range of pH of most bottled water brands sold in Egypt falls within 6.4 to 6.9 but increased to 7.0 to 7.7 after 6 weeks storage. This was also in accordance with earlier reports [12] that reported that the value of pH of bottled water in Turkey ranges from 6.2 to 6.8 at production but increased to 7.1 to 7.8 after 12 weeks storage. A relatively high pH of sachet water was recorded in their study of

the effects of storage on the physiochemical parameters of bottled water in Abeokuta attributing high pH to increased primary-productivity. [3]

High temperature contributed to the low quality of water discovered in some of the sachet water samples. The reason for this could be due to greater solar radiation resulting in increased coliform count found in most of the water samples especially S2, S4, S8, S10, S11, S12 and S13. Prescott *et al.,* reported 20-45^{0}C as optimal growth temperature for mesophilic microorganisms. [10] The variations observed in temperature of the samples can be attributed to sampling locations and the time of the day reading was taken. According to WHO report, [9] 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 was enhanced by warm water conditions and could lead to the development of unpleasant tastes and odors.

In chlorine treated water intended for human consumption, certain levels of residual chlorine are left in the water after treatment to prevent the growth of any microorganism that may get in contact with the treated water after leaving the plant and before getting to the final consumer. This type of chlorine that is used to maintain the integrity of water is called Free chlorine residual (FCR). [13] Its availability in treated water influences greatly the quality of water at the end use. The mean FCR concentration of the 15 sachet water samples was 8.58mg/L. The free chlorine residual (FCR) decreased in the sachet waters during storage especially in S1, S3, S6, S7 and S9. This could have affected the physicochemical quality of the sachet water after storage. The results indicated that the FCR concentrations are not sufficient enough to hold back the recovery of bacteria in the sachet water samples. Though WHO recommended FCR concentration between 0.2mg/L and 0.5mg/L for chlorine treated drinking water, the occurrence of coliform

bacteria in water with FCR concentration greater than 0.5mg/l was reported. [14] A limit of 250 mg/l of chloride has been recommended as maximum permissible limit for drinking water. [15] This limit has been laid down primarily based on taste considerations. However, no adverse health effects on humans have been reported from intake of water containing even higher concentrations of chloride. [15]

Furthermore, in the chlorinated water samples, there were progressive decline in water quality during storage. This could be due to chlorine decay which was the major factor in deteriorating the water quality after storage. This agrees with the result of Dada who discovered that FCR less than 0.2mg/L leads to water deterioration. [16] Relatively high water temperature and the presence of higher organic/inorganic impurities are the main reasons that cause the large chlorine decay in the sachet water samples.

There was a remarkable increase in the values of TS and TDS from week 1 to week 16. The concentration was higher after storage, which was likely due to death of planktons as a result of depletion of nutrients and sedimentation of organic materials in water. Edema *et al.,* also made similar observations. [3] The amount of total solids and total dissolved solid are influenced by the activity of plankton and organic materials.

The total solid and total dissolved solid for the sachet water were also high. The main constituents of the total dissolved solid were calcium, magnesium, bicarbonates, chlorides and sulphates. Total dissolved solids affect the taste of drinking water if present at levels above the WHO recommended limit of 500mg/l. The TDS in the water samples were within WHO recommended limits.

The magnesium and calcium concentrations were also within WHO recommended limits of 30mg/l and 75mg/l, respectively. Calcium, which is essential for nervous system and for the formation of bones, is commonly present in all water

bodies where it usually comes from the leaching of rocks. [17] On the other, magnesium is usually less abundant in water than calcium, perhaps due to the fact that magnesium is found in the earth's crust in much lower amounts as compared to calcium. [17] High concentration of magnesium in drinking water gives unpleasant taste to the water. [9] Calcium and magnesium concentration in water have been linked to outcomes in heart diseases. [18] There is epidemiological evidence to suggest a lower incidence of heart disease in communities with hard water (high calcium and magnesium content). [19]

Hardness is frequently used as an assessment of the quality of water supplies. The hardness of a water is governed by the content of calcium and magnesium salts (temporary hardness), largely combined with bicarbonate and carbonate and with sulfates, chlorides, and other anions of mineral acids (permanent hardness). [19]

Conductivity of water depends upon the concentration of ions and its nutrient status and the variation in dissolved solid content. The result shows that conductivity increased with increasing temperature over a period of time, indicating the increase of ions. This was in agreement with the work, [20] who posited that temperature increase leads to increase in conductivity. Conductivity is a numeric measure of the capacity of an aqueous solution to pass electric current. Pure water has a conductivity of 1µs/cm and is not expected to conduct electricity. The high conductivity values of the sachet water samples imply that the dissolved salts were high. [20]

Alkalinity and pH are the factors responsible for determining the amenability of water to biological treatment. [21] There was a gradual decrease in alkalinity values within this period. The low alkalinity values observed may be due to dilution of water during storage. This value also indicated that the water is soft. Similar findings were in their study of effects of storage on the physicochemical parameters of bottled water in California. [22] The value of

alkalinity in water provides an idea of natural salts present in water. [22] The cause of alkalinity is the minerals which dissolve in water from soil. The various ionic species that contribute to alkalinity include bicarbonate, hydroxide, phosphate, borate and organic acids. These factors are characteristics of the source of water and natural processes taking place at any given time. [22]

A decrease in dissolved oxygen was generally observed in all sachet water samples throughout the investigation period, an indication of possible bacterial respiration of organic materials by the bacterial flora of the sachet water samples tested. [9] Reported that there is tendency for the level of dissolved oxygen to fall with time indicating possible microbial respiration of organic materials amongst other reasons. Concentration of dissolved oxygen indicates water quality and its relation to the distribution and abundance of various algal species. [9] Also, presence of dissolved oxygen in water may be due to direct diffusion from air and photosynthetic activity of autotrophs. Present observations are in agreement with similar ones made at a domestically polluted municipal water [23] and at the Dahikhura Resevoir in Pakistan. [24] A high value of free carbon dioxide and pH along with low dissolved oxygen in highly polluted municipal storage water at Naukuchiyatal situated in Kumaon, Himalayas was also discovered. [25]

The Biochemical Oxygen Demand obtained in this study was within the standard range of (1-5 Mg/L) for potable water. [15]

CONCLUSIONS

The results of this work revealed that prolonged storage caused an increase in pH up to week 8 followed by a decrease up to the end of the experiment in all pure water samples tested. Increase in temperature caused chlorine decay (i.e. FCR) resulting in rapid deterioration of the sachet waters. There was a remarkable increase in the values of TS and TDS from week 1 to week

16. The magnesium and calcium concentrations were also within WHO recommended limits of 30mg/l and 75mg/l, respectively. A decrease in dissolved oxygen was generally observed in all sachet water samples throughout the investigation period. Lastly, the Biochemical Oxygen Demand obtained in this study was within the WHO standard range of (1-5 Mg/L) for potable water. Therefore, it is recommended that expiry date of sachet water produced in Nigeria should not exceed eight weeks from the date of production. The public should be sensitized not to drink sachet water that has exceeded eight weeks from the date of manufacture as doing so will lead to a lot of health hazards associated with drinking unsafe water.

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