Quality and Shelf Life of Major Brands of Bottled Water Marketed In Port Harcourt

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Abstract— Water is life and every living thing depends on it for existence. The quality and shelf life of major brands of bottled water in Port Harcourt was analysed for potability. Bottled water were purchased after 9 days from production and exposed to sunlight for periods of 28 days. Standard methods were used to determine the physicochemical and microbiological parameters. The results showed mean values of pH in brand BWJ which ranged from (5.7 – 6.0) during the study period and was not within the prescribed recommended WHO, NAFDAC & SON limits. The mean values for lead in brands BWE (0.03 ± 0.05mg/l) and BWA (0.03 ± 0.04mg/l) were above the prescribed recommended limits, antimony in brands BWE (0.15 ± 0.15mg/l); BWJ (0.09 ± 0.07mg/l); BWC (0.19 ± 0.22mg/l); BWL (0.22 ± 0.22mg/l) and BWA (0.51 ± 0.81) also exceeded the WHO permissible limits. The mean values of faecal coliform bacteria were below the permissible limits in BWE (0.0 ± 0.0MPN/100ml); BWL (0.0 ± 0.0MPN/100ml) and BWA (0.0 ± 0.0MPN/100ml) except for brands BWJ (23.2 ± 39.0MPN/100ml) and BWC (20.2 ± 38.0MPN/100ml) which exceeded the permissible limits. The mean values for Total Coliform Bacteria in bands BWE (0.0 ± 0.0MPN/100ml); BWL (2.0 ± 4.0MPN/100ml) and BWA (0.5 ± 1.0MPN/100ml) were below permissible limits except in brands BWJ (45.5 ± 55.0MPN/100ml) and BWC (36.5 ± 43.2MPN/100ml) which also exceeded the permissible limits. The mean values for Total Heterotrophic Bacteria for the study period were below permissible limits in brands BWA (35.7 ± 57.2 cfu/ml) and BWL (581.5 ± 1080.0 cfu/ml) except for brands BWJ (1875.0 ± 2054.0 cfu/ml); BWE (1042.5 ± 2038.0cfu/ml) and BWC (1205.2 ± 1382.0 cfu/ml) which were above the permissible limits. High levels of pH, lead, antimony, faecal and total coliform bacteria and total heterotrophic bacterial levels render the bottled water unsatisfactory for human consumption and portend heath concern. Bottled water stored at temperatures of 28°C or sunlight for a period of 28 days after 9 days from production, renders the bottled water quality unacceptable. It was recommended for the inclusion of an advisory best before label on the bottled water since the water deteriorates over time and all the water should be properly stored in cool and dry place.

Index Terms— Bottled water, health concern, shelf life, water quality, chemical quality, microbiological quality, physical quality

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I. INTRODUCTION

The availability of good quality drinking water is vital for the well-being of all people and water it is absolutely essential to sustain life [1] because of its role in proper functioning of cells and general metabolism [2]. Water for bodily functions is largely obtained by drinking therefore, when potable water is contaminated (chemically or biologically) severe health issues results [3].

Most people living in major cities of Nigeria do not have access to pipe borne water, probably due to unavailability or inadequacy of public water supply. This has made people resort to purchasing sachet or bottled water from vendors, as this has predominantly become a major source of drinking water [4]. Water bottled, distributed and sold for public consumption can be referred to as bottled water [5].

Port Harcourt is the capital and largest city of Rivers State and is a major industrial centre with rapid rural-urban migration due largely to the number of multinational firms as well as other industrial concerns, particularly business related to the petroleum industry. It is a centre for many brands of bottled water in Nigeria especially for the middle and high income social classes due to its relative high cost [6]. Bottled water like any drinking water used for human consumption should be safe and healthy to ensure adequate public health protection. However, there is always anxiety about the quality of bottled water because it is stored for longer periods and not always preserved under the recommended conditions or because containers and bottles are reused without adequate cleaning and disinfection [7]. In spite of the number of regulatory bodies, publications on bottled water and assumptions on its public health significance, many questions remain to be answered. One of the questions is if the changes in quality of bottled water on exposure to sunlight are of concern?
This stimulated a comparison among major brands of bottled water sold in Port Harcourt metropolis with the prescribed stand-

ards of World Health Organization (WHO), National Agency for Food and Drug Administration Agency Control (NAFDAC) and Standard Organization of Nigeria (SON) for drinking water quality in order to determine the shelf life and changes in quality of major brands of bottled water on exposure to sunlight.

II. THE PROBLEM

Bottled water in Port Harcourt are produced by different companies using different water sources, therefore, produces an uncertainty in the water quality being sold and providing a loop hole for fake products [6]. Hazard Analysis and Critical Control Point (HACCP) which is an important system in the production of bottled may fail, leading to microbial contamination by cysts which are known to be more persistent in the environment and more resistant to chemicals used for water treatment processes [8].

Improper and /or prolonged storage conditions of bottled water can lead to the growth of microorganisms to levels that may be harmful to human health and can affect immune-compromised individuals such as the infirm, elderly, young infants, people living with HIV/AIDS, people on immunosuppressive chemotherapy, and transplant patients [9]. Polyethylene terephtalate (PET) is the usual material from which bottles for water are made. Interactions between PET bottles and sunlight or elevated temperatures may lead to possible migration of PET degradation products such as Antimony causing an increase in the aldehyde content in the bottled water. Some of these elements at elevated concentrations in bottled waters can be harmful to human health and can cause morphological abnormalities, mutagenic effects, reduced growth, and increased mortality in humans.

However, there is need to determine the quality and shelf life of major brands of bottled water marketed in Port Harcourt.

III. STUDY OBJECTIVES

a) Determine the initial physico-chemical and microbiological quality of water from five brands of commercial bottled water.
b) Evaluate changes in physico-chemical and microbiological quality over a period of 28 days study.
c) Compare the results of the study with the standards prescribed for bottled water over a period of 28 days study.
d) Make recommendations on storage and shelf life of bottled water in Port Harcourt.

IV. STUDY AREA

Port Harcourt is the capital of Rivers State. It is located in the Niger Delta. It lies along the Bonny River (an eastern distributary of the Niger); 41 miles (661cm) upstream from the Gulf of Guinea and is located in the Delta region of the River Niger. The main city of Port Harcourt is the Port Harcourt Local Government Area. This large city also called the Garden City lies at latitude 05°21′N and longitude 06°57′E. It is an urban area bubbling with a plethora of economic and social [10], [11], [12]. The City has numerous business activities and is also an industrial centre particularly business related to petroleum. Port Harcourt features a tropical wet climate with lengthy and heavy rainy season and very short dry season. Water samples used in this study were obtained from Port Harcourt.

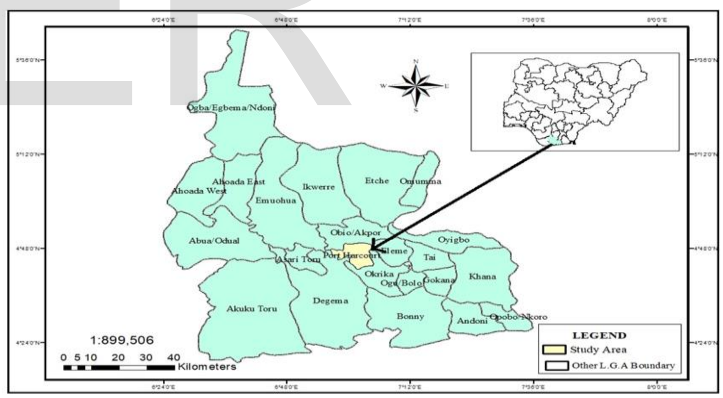

Figure 1: Map of Rivers State showing Port Harcourt, the study location

V. BRIEF REVIEW OF RELATED LITERATURE

[13], [14] conducted studies on total Antimony (Sb) content in drinking waters and concluded that the presence of Sb in bottled water was due to its migration from PET, as fresh water obtained directly from a spring, a well or stored in other types of plastic, such as polypropylene (PP) or low density polyethylene (LDPE), did not contain high Sb levels. According to [15], PET which is the basic material used in the production of bottle or container

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can also constitute a source of contamination which may lead to possible migration of PET degradation products when exposed to high temperatures like sunlight which increases the aldehyde content in the water. [16], observed that outbreaks traced to consumption of bottled water include cited incidents where in 1974 a cholera outbreak in Portugal occurred where *Vibrio cholera* was isolated from two springs that supplied water to a commercial bottling plant. Furthermore, [17] isolated *Psedomonas species, Flav.meningosepticum , Erwinia spp, Edwardsiella lictaluri, Staph epidermidis,* Total Coliform (TC), Faecal coliform (FC) from bottled water when stored at varying temperature between 4 and 45°C and discovered that contamination was highly aided by temperature, during handling and purification process and also in washing and filling phase of the bottles.

Studies conducted by [18], [19], [20] on bottled water brands revealed that some of the bottled brands tested failed to comply with the required microbiological standard limits.

VI. MATERIALS AND METHODOLOGY

A. ***Sample Type, Collection and Preparation***

Based on popularity and availability, eight bottles each of five commercial bottled water brands from the same batch was purchased from outdoor markets in Port Harcourt after 9 days of manufacture. To keep the brand names anonymous, the samples were labelled namely: BWA, BWC, BWE, BWJ and BWL. A total of forty water samples were taken to the laboratory for analyses. Analyses were conducted over a period of 28 days, thus, the first set of analyses was conducted on the first day of purchase and the remaining bottled water brands were randomly placed, stored and exposed to natural temperatures of sunlight subsequently.

B. ***Analytical Methods***

i. ***Physicochemical Parameters:*** Temperature was determined using Extech EC500 meter after calibrating the meter. Electrical conductivity was determined using Extech EC500 meter after calibrating the instrument with 1413 µS/cm standard solution. Turbidity was determined using Lamotte TC 3000wi, while Extech EC500 meter was used to determine Total Dissolved solids (TDS). The chemical analysis was done using standard laboratory methods suggested by the American Public Health Association [21]. Extech EC500 meter was used to determine pH and salinity, Nitrate was determined using the Brucine method, Sulphate was determined by Turbidimetric method, Phosphate was determined using stannous chloride method, Chloride was determined by Argentometric method and Total hardness was measured by EDTA Titration method. Heavy metals (Pb, Fe, Sb and Mn) were analyzed using Atomic Absorption Spectrophotometer by GBC Avanta Version 2.02.

ii. ***Microbiological Analysis:*** Heterotrophic plate count was performed using spread plate technique. Aliquots of 0.1ml of selected dilutions were inoculated separately on duplicate Nutrient Agar plates. The inoculated plates were incubated at 37°C for 24 hours and colony forming units counted thereafter; taking cognizance of the dilution factor. Unit of measurement was colony forming units (cfu) per millilitre of water. Membrane filter technique was used to isolate the presence of FC and TC using MacConkey Agar. Aliquots of 0.1ml of selected dilutions were inoculated separately on quadruplicate MacConkey Agar Plates. Duplicate of the inoculated plates were incubated at 45°C for 48 hours for Faecal Coliforms and 37°C for 48 hours for Total Coliforms. The dilution factor was considered in determining the most probable number after taking the counts. Unit of measurement was Most Probable Number/millilitre of water.

VII. RESULTS AND DISCUSSION

The results of mean levels of the parameters measured in the different brands of bottled water are presented in Tables 1 – 3 and Figs. 2 – 18. The correlation matrix showing the relationship between the parameters is presented in Table 4.

A. ***Temperature***

The mean temperature range was 28.35 ±0.30°C in BWL to 28.45 ±0.19°C in BWA. However, this was as a result of the difference in exposure of the brands of bottled water to varying sunlight over a period of 28 days study and this reflected the ambient temperature. This result concurs with the findings of [22], [23] that observed that ambient temperature (surrounding air temperature) influences the temperature of water samples during the period of analysis. Temperature can lead to a major influence on biological activity and growth, cool drinking water is preferable to warm; a temperature of 10°C is usually satisfactory [24]. The temperature range of the bottled water brands were above room temperature of 20-22°C and this is not satisfactory with respect to temperature as it cannot be enjoyed fresh upon consumption. This finding is in line with [25] that stated that although when the temperature of bottled water is above room temperature, it is not a general concern for public health; however, there is need to enjoy the freshest, cleanest water possible, and storing water in a cool place out of direct sunlight helps assure that. Temperature showed significant positive correlation with NO_3^- (r = 0.567) over the period of study

Table 1

Mean Physical Characteristics of Five Brands of Bottled Water over a Period of 28 days study

Sample Code	EC (µS/cm)	Turb. (NTU)	TDS (mg/l)	Temp. (°C)
BWE	150.25 ± 0.50	0.20 ± 0.14	105.25 ± 0.50	28.40 ± 0.40
BWJ	40.25 ± 0.50	0.18 ± 0.05	28.25 ± 0.50	28.38 ± 0.34
BWC	10.0 ± 0.0	0.13 ± 0.03	7.0 ± 0.0	28.40 ± 0.33
BWL	15.0 ± 0.0	0.10 ± 0.00	11.0 ± 0.0	28.35 ±0.30
BWA	64.25 ± 1.26	0.15 ± 0.05	45.5 ± 1.0	28.45 ± 0.19
WHO	**1200**	**5.0**	**1000**	**-**
SON	**1000**	**5.0**	**500**	**-**
NAFDAC	**1000**	**5.0**	**500**	**-**

n=number of samples (5)

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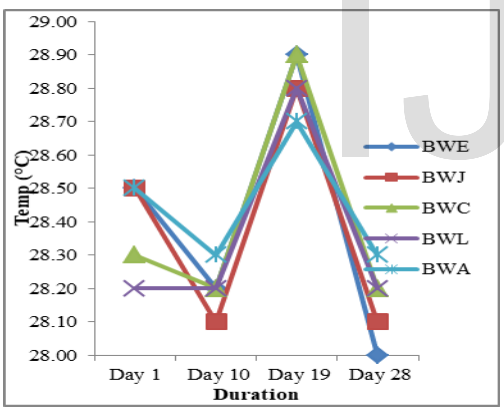

Fig. 2: Temperature of Brands of Bottled Water during the study period of 28 days

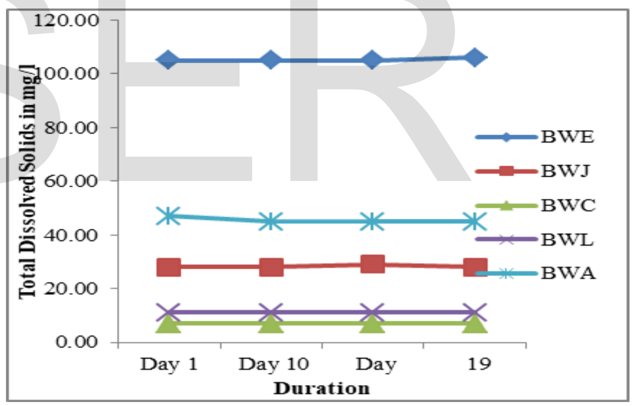

Fig. 4: TDS of Brands of Bottled during the study period of 28 days

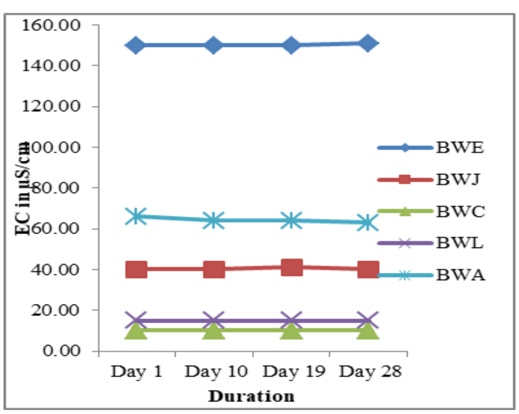

Fig. 3: Electrical Conductivity of Brands of Bottled Water during the study period of 28 days

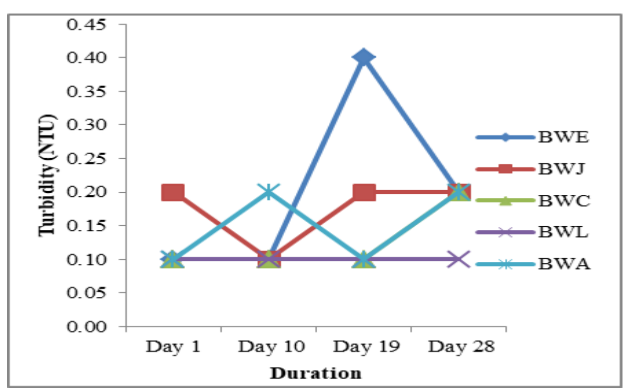

Fig. 5: Turbidity of Brands of Bottled Water during the period of 28 days

B. *Electrical Conductivity*

The mean electrical conductivity ranged from 10.0 ± 0.0µS/cm in BWC to 150.25 ± 0.50µS/cm and were below the prescribed permissible limit set by [26], [27], [28] during the period of study. The increased conductivity in BWE from 150 µS/cm - 151 µS/cm could be as a result of increase in the amount of dissolved materials in the water during the period of storage. This study is in line with [29] that conducted a study on sixteen brands of bottled water sold in Kurdistan region-Iraq after exposure to sunlight which revealed that the electrical conductivity results of bottled water samples showed short variation, which ranged from 309 - 361 µS/cm and that all samples were within the International Bottled Water Association limit for bottled water. EC showed significant positive correlation with pH (r = 0.548), Salinity (r = 0.998), Turbidity (r = 0.555), TDS (r = 1.000), Cl^- (r = 0.923), NO_3^- (r = 0.551), Hardness (r = 0.745).

C. *Total Dissolved Solids (TDS)*

The total dissolved solid (TDS) indicates the general nature of salinity of water [30]. The mean TDS values ranged from 7.0 ± 0.0 mg/l in BWC to 105.25 ± 0.50 mg/l in BWE. There was no significant variation in TDS values during the period of study from in all bottled water brands with BWE having the highest TDS value (Fig. 4). The TDS values for the five brands of bottled water had levels below the permissible limit prescribed by [26], [27], [28] during the period of study and did not have any negative aesthetic effects. This finding is in line with the study of [29] that revealed that the TDS values of sixteen samples of bottled water on exposure to sunlight varied between 155 and 188 mg/l and were within the WHO and IBWA standards. TDS showed significant correlation with pH (r = 0.549), EC (r = 1.00), Salinity (r = 0.998), Turbidity (r = 0.555), Cl^- (r = 0.922), NO_3^- (r = 0.551), Hardness (r = 0.743).

D. Turbidity

Turbidity measures the relative clarity or cloudiness of water and is an indication of effectiveness of filtration of water supply [31]. The mean turbidity values ranged from 0.10 ± 0.00 NTU in BWL to 0.20 ± 0.14 NTU in BWE. However, turbidity values were below the prescribed 5.0 NTU permissible limit set [26], [27], [28]. This finding is in line with [6] that conducted study on changes in quality of seven major brands of bottled water marketed in Port Harcourt and discovered that the mean turbidity of all the bottled water varied between 0±0.0 NTU in most bottled water and 0.8±0.1NTU in BWP and were below 5.0 NTU permissible limit recommended by set [26], [27], [28]. Turbidity showed significant correlation with EC (r = 0.555), Salinity (r = 0.557), TDS (r = 0.555), Cl^- (r = 0.603), NO_3^- (r = 0.508), PO_4^{3-} (r = 0.658), Hardness (r = 0.517).

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Table 2

Mean Chemical Characteristics of Five Brands of Bottled Water over a Period of 28 day study

Sample Code	pH	Salinity (‰)	Cl^- (mg/l)	NO_3^- (mg/l)	PO_4^{3-} (mg/l)	Hardness (mg/l)	Fe^+ (mg/l)	Mn^{2+} (mg/l)	Pb (mg/l)	Sb (mg/l)
BWE	6.93 ± 0.09	0.07 ± 0.0	4.00 ± 0.36	1.46 ± 0.95	0.08 ± 0.07	7.7 ± 0.0	0.06 ± 0.07	0.01 ± 0.01	0.03 ± 0.05	0.15 ± 0.15
BWJ	5.8 ± 0.14	0.02 ± 0.0	1.10 ± 0.12	0.81 ± 0.57	0.10 ± 0.11	6.28 ± 0.95	0.05 ± 0.07	0.05 ± 0.01	<0.01	0.09 ± 0.07
BWC	6.53 ± 0.29	0.01 ± 0.0	1.0 ± 0.0	0.15 ± 0.20	0.13 ± 0.17	0.05 ± 0.0	0.07 ± 0.07	0.02 ± 0.02	<0.01	0.19 ± 0.22
BWL	6.55 ± 0.65	0.01 ± 0.0	1.0 ± 0.0	0.56 ± 0.58	0.12 ± 0.14	0.05 ± 0.0	0.07 ± 0.07	0.02 ± 0.02	<0.01	0.22 ± 0.22
BWA	6.98 ± 0.19	0.03 ± 0.0	1.0 ± 0.0	1.11 ± 0.76	0.10 ± 0.09	0.05 ± 0.0	0.03 ± 0.02	0.02 ± 0.02	0.03 ± 0.04	0.51 ± 0.81
WHO	6.5 – 8.5	1000	250	50	1.0	500	0.3	0.4	0.01	**0.006**
SON	6.5 – 8.5		100	50	1.0	500	0.3	2.0	0.01	
NAFDAC	6.5 – 8.5		100	50	1.0	500	0.3	2.0	0.01	

n=number of samples (5)

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E. *Nitrates (NO_3^-) (mg/l)*

Nitrate is the principal form of combined nitrogen found in natural waters. Nitrate values for the five brands of bottled water ranged from 0.15 ± 0.20 mg/l in BWC to 1.46 ± 0.95 mg/l and were below WHO permissible limits of 50 mg/l in drinking water [32]. The health concern related to nitrate is that microorganisms present in the water can change nitrate to nitrite. This is a health concern for the body because it causes haemoglobin in the blood to change to methaemoglobin. Methaemoglobin reduces the amount of oxygen that can be carried in the blood, resulting in cells throughout the body being deprived of sufficient oxygen to function properly. The condition called methaemoglobinemia can result [6]. High methaemoglobin levels may lead to anoxia, brain damage or death [33]. NO_3^- showed significant correlate with pH (r = 0.607), Temp (r = 0.567), EC (r = 0.551), Salinity (r = 0.545), Turbidity (r = 0.508), TDS (r = 0.551), Cl^- (r = 0.514), THB (r = -0.541).

F. *Phosphates (PO_4^{3-}) (mg/l)*

Phosphate values for the five brands of bottled water ranged from 0.08 ± 0.07 mg/l in BWE to 0.13 ± 0.17 mg/l in BWC and this were below the prescribed permissible limit of [26] of 1.0 mg/l for phosphate. However this shows the acceptability of the water for drinking with respect to phosphate. PO_4^{3-} showed significant correlation with only Turbidity (r = 0.658).

I. Salinity (‰)

The salinity values were less than 1000 mg/l set by the [26]. This indicates that all the five brands of bottled water tested in this study which ranged from 0.01 ± 0.0 ‰ in BWL and BWC to 0.07 ± 0.0 ‰ in BWE were below the limit. Salinity showed significant positive correlation with pH (r = 0.561), Turbidity (r = 0.557), TDS (r = 0.998), Cl^- (r = 0.939), NO_3^- (r = 0.545), Hardness (r = 0.741) and a significant negative correlation with EC (r = -0.998).

J. Hardness (mg/l)

The hardness in drinking water varies depending on the rocks and soils of the area that the water comes from and the treatment process used. Hardness values for the five brands of bottled water ranged from 0.05 ± 0.0 mg/l to 7.7 ± 0.0 mg/l and were below the maximum permissible level of 500 mg/l according to [26] guidelines. Hardness showed significant positive correlation with EC (r = 0.745), Salinity (r = 0.741), Turbidity (r = 0.517), TDS (r = 0.743) and Cl^- (r = 0.770).

G. *Iron (Fe) (mg/l)*

Iron is a metallic element found in the earth's crust. Water seeping through the soil and rock can dissolve minerals containing iron and hold it in solution. Occasionally, iron pipes also may be a source of iron in water. Iron is not considered hazardous to health. In fact, iron is essential for good health because it transports oxygen in the blood [33]. Iron values for the five brands of bottled water ranged from 0.03 ± 0.02 mg/l in BWA to 0.06 ± 0.07 mg/l in BWC and BWL and are presented in Fig. 4.12. The five brands fell below 0.3mg/l prescribed standard limit of [26], [27], [28]. However, as little as 0.3mg/l can cause water to turn a reddish-brown colour [34]. Fe showed significant positive correlation with FCB (r = 0.536).

H. *Manganese (Mn^{2+}) (mg/l)*

Manganese is one of the most abundant metals in the earth's crust, usually occurring with iron. Manganese is an essential element for humans and other animals and occurs naturally in many food sources. The five brands of bottled water were below the permissible limit of 0.4mg/l by [26] and 2.0 mg/l by [28]. This is an indication of acceptability with respect to manganese. A manganese deficiency may inhibit growth, disrupt the nervous system, and interfere with reproductive function. Mn^{2+} showed significant positive correlation with TCB (r = 0.576) and a significant negative correlation with pH (r = -0.695).

I. *Lead (Pb) (mg/l)*

The mean values for lead values in brands BWE (0.03 ± 0.05mg/l) and BWA (0.03 ± 0.04mg/l) were above the prescribed recommended limits. Brands BWJ, BWC and BWL had no detectable concentrations thus complying for these three brands with [26] limit of 0.01 mg/l. Lead concentration at 0.11mg/l and 0.10mg/l in BWE and BWA on day 1 and 28 on exposure to sunlight was present and above the [26] of 0.01mg/l (Fig. 4.14). This means that brands BWE and BWA were unsatisfactory with respect to lead concentration for human consumption on day 1 and day 28 after production on exposure to sunlight. This is in line with [23] that discovered little concentration of lead (Pb) in the

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bottled water samples within the first week of production and after three months of storage and concluded that attention must be paid to the little quantity of Pb presence in the bottled water. High concentrations of lead cause damage to target organs such as kidney and liver and cause adverse health effects [35]. Pb showed significant positive correlation with Sb (r = 0.690). This means that they are from the same source.

J. *Antimony (Sb)*

Antimony (Sb) is naturally present in water, rocks and soil. Antimony was considered as a possible replacement for lead in [33]. The mean values of antimony in brands BWE (0.15 ± 0.15mg/l); BWJ (0.09 ± 0.07mg/l); BWC (0.19 ± 0.22mg/l); BWL (0.22 ± 0.22mg/l) and BWA (0.51 ± 0.81) exceeded the WHO permissible limits (Table 2). The concentrations of Antimony in brand BWE on day 1 (0.31mg/l) and 28 (0.21mgl), brand BWJ on day 10 (0.19mg/l), 19 (0.03mg/l) and 28 (0.09mg/l), brand BWC on day 1 (0.48mg/l) and 10 (0.04mg/l), brand BWL on day 1 (0.38mg/l) and 28 (0.41mg/l) and lastly brand BWA on day 1 (1.72mg/l) and 28 (0.49mg/l) were above the permissible limit of (0.006 mg/l) set by [26] in all the brands during the period of study (Fig. 15) making them unacceptable for human consumption. This study is in line with [25], [26], [36], [37] that examined water samples stored from a few hours to 7 days at temperatures ranging from -20ºC to 80ºC and observed slight increase in Sb content in samples stored at 60ºC and rapid release of Sb into the matrix after 5–24 h of storage at 80ºC. [25], [26], [36], [37] concluded that the presence of Sb in bottled water was due to its migration from PET. Sb showed significant positive correlation with Pb (r = 0.690). This showed that as the concentration of lead increased, the concentration of antimony also increased.

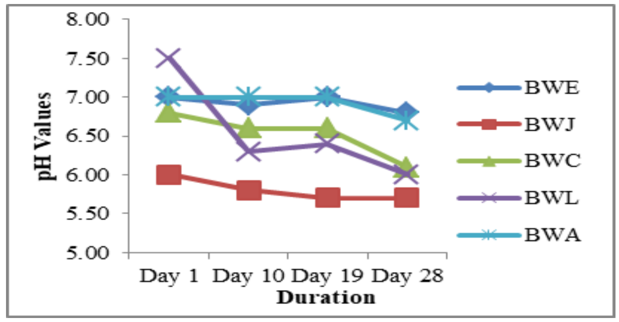

Fig. 6: pH of Brands of Bottled Water during the study period of 28 days

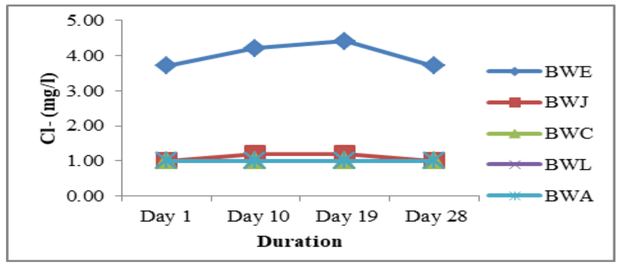

Fig. 7: Chlorides of Brands of Bottled Water during the study period of 28 days

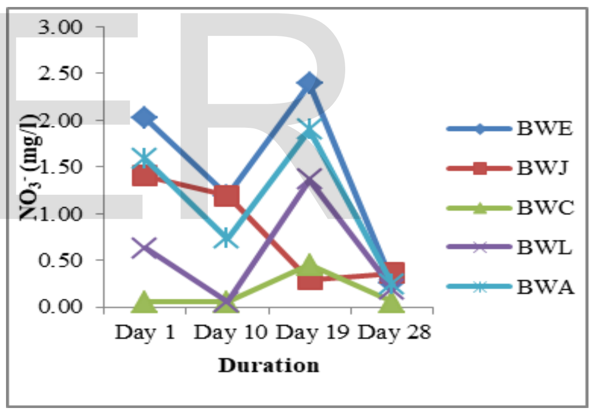

Fig. 8: Nitrates of Brands of Bottled Water during the study period of 28 Days

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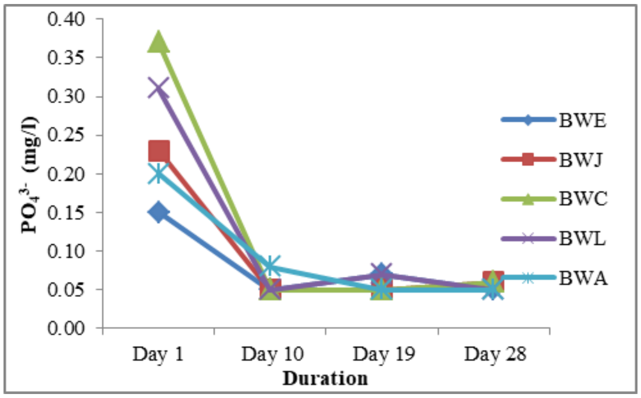

Fig. 9: Phosphates of Brands of Bottled Water during the study period of 28 days

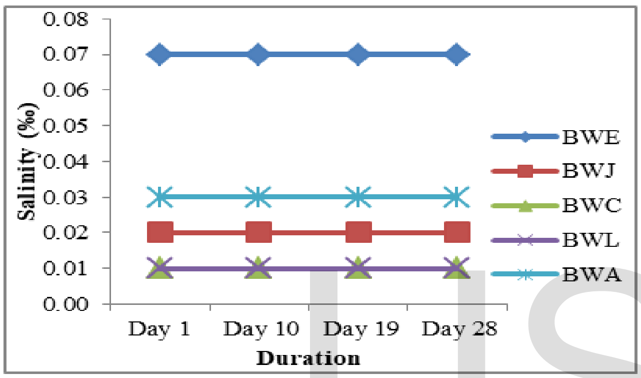

Fig. 10: Salinity of Brands of Bottled Water during the study period of 28 days

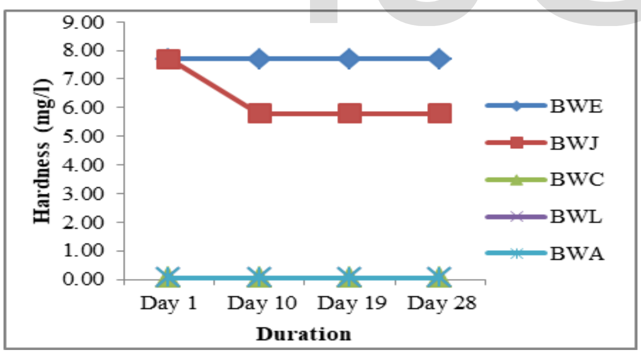

Fig. 11: Hardness of Brands of Bottled Water during the study period of 28 days

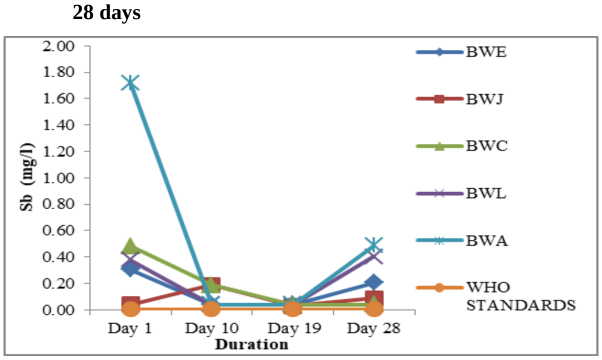

Fig. 15: Antimony of Brands of Bottled Water during the study period of 28 Days

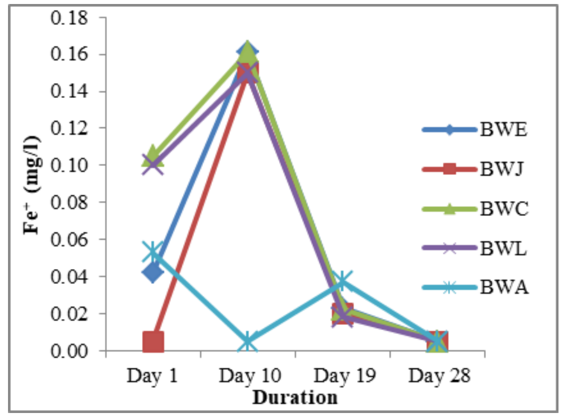

Fig. 12: Iron of Brands of Bottled Water during the study period of 28 days

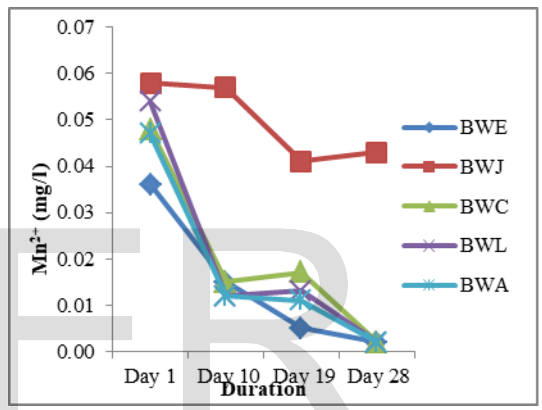

Fig. 13: Manganese of Brands of Bottled Water during the study period of 28 days

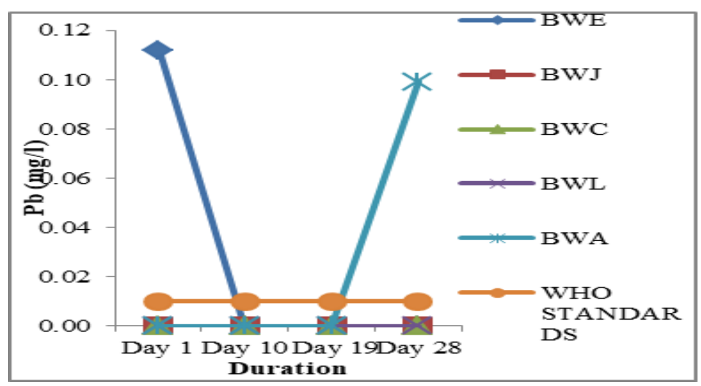

Fig. 14: Lead of Brands of Bottled Water during the study period of 28 Days

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Table 3

Mean Microbiological Characteristics of Five Brands of Bottled Water over a Period of 28 day study

Sample Code	FCB (MPN/100ml)	TCB (MPN/100ml)	THB (cfu/ml)
BWE	0.0 ± 0.0	0.0 ± 0.0	1042.5 ± 2038.0
BWJ	23.2 ± 39.0	45.5 ± 55.0	1875.0 ± 2054.0
BWC	20.2 ± 38.0	36.5 ± 43.2	1205.2 ± 1382.0
BWL	0.0 ± 0.0	2.0 ± 4.0	581.5 ± 1080.0
BWA	0.0 ± 0.0	0.5 ± 1.0	35.7 ± 57.2
WHO	0	0 - 10	<1000
SON	**0**		**<1000**
NAFDAC	**0**		**<1000**

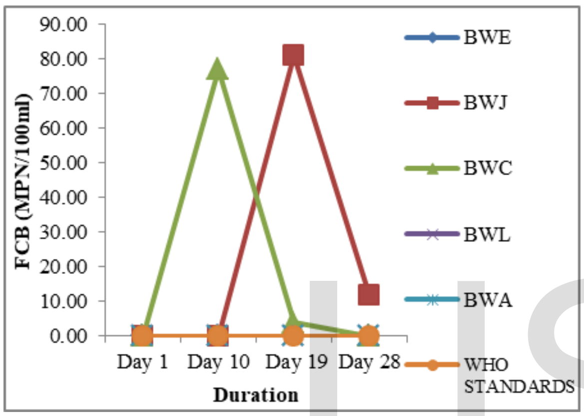

Fig. 16: FCB of Brands of Bottled Water during the study period of 28 days

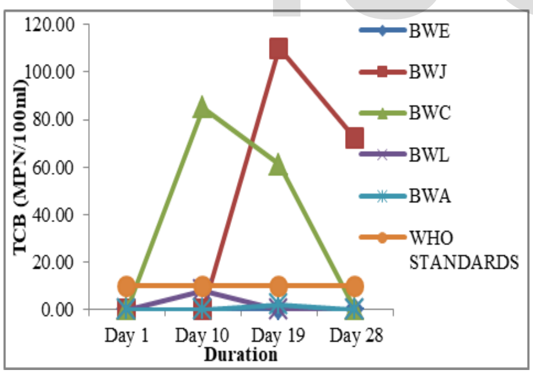

Fig. 17: TCB of Brands of Bottled Water during the study period of 28 days

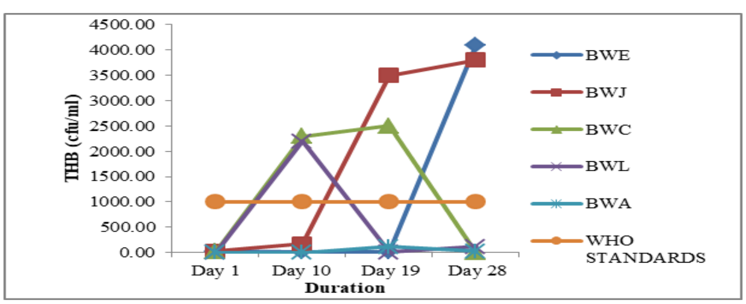

Fig. 18: THB of Brands of Bottled Water during the study period of 28 days

K. *Faecal Coliform Bacteria (FCB)*

Faecal Coliform Bacteria Count ranged from 0.0 ± 0.0 MPN/100ml in BWE, BWL and BWA to 23.25 ± 39.0 MPN/100ml in BWJ. Brands BWJ (on day 19 and 28) and BWC (36.5 ± 43.2MPN/100ml) were above the prescribed standard limit (0 MPN/100ml) of WHO, SON and NAFDAC for FCB in bottled water during the study period. This finding is in line with Stoler *et al.* (2012) that reported that the numbers of faecal coliforms, Enteroccocci, Salmonella in packaged water increased at storage temperature of 26°C. The presence of coliform may be an indication of poor treatment, handling or contact with surface water sources (Isikwue & Chikezie, 2014) and this may be of high health concern for consumers. In brands BWL, BWA and BWE there were no Faecal Coliform Bacteria detected during the period of the study. FCB showed significant correlation with only Fe (r = 0.536). The faecal pollution is associated with iron particles.

L. *Total Coliform Bacteria (TCB)*

Total Coliform Bacteria Count for the five brands of bottled water ranged from 0.0 ± 0.0 MPN/100ml in BWE to 45.50 ± 55.00 MPN/100ml in BWJ. TCB count in Brands BWJ (45.5 ± 55.0MPN/100ml) and BWC (36.5 ± 43.2MPN/100ml) were above the prescribed standard limit (0-10 MPN/100ml) set by WHO for TCB in bottled water making the water unacceptable for consumption. Brands BWL (2.0 ± 4.0MPN/100ml), BWE (0.0 ± 0.0MPN/100ml) and BWA (0.0 ± 0.0MPN/100ml) were below the prescribed standard limit. This finding is in line with Ojekunle & Adeleke (2017) that discovered slight growth of Coliform when bottled water samples were stored after the three months of storage. Total coliforms counts in water samples can however be affected by temperature and the nature of packaging material used (Paine, 2002). TCB showed significant positive correlation with Mn^{2+} (r = 0.576) and a significant negative correlation with pH (r = -0.525).

M. *Total Heterotrophic Bacteria (THB)*

Total Heterotrophic Bacteria Count for the five brands of bottled water ranged from 35.75 ± 57.2 cfu/ml to 1875.00 ± 2054.0 cfu/ml. The mean values of THB for brands BWA (35.7 ± 57.2MPN/100ml) and BWL (581.5 ± 1080.0MPN/100ml) maintained a low THB count during the study period and were below the permissible limit while that of brands BWE (1042.5 ± 2038.0MPN/100ml), BWC (1205.2 ± 1382.0MPN/100ml) and BWJ (1875.0 ± 2054.0MPN/100ml) were above the permissible limits. This result is in line with (Liee, 2011) who stated that contributing factors to these high THB counts observed could be due to prolonged storage, storage temperature and typical natural flora of the source water used for different brands. THB showed significant negative correlation with NO_3^- (r = -0.541).

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Table 4

Correlation Matrix Showing Physical, Microbiological and Chemical Parameters in Five Major Brands of Bottled Water over a period of 28 days

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	**pH**																	
2	**Temp. (°C)**	0.203																
3	**EC (µS/cm)**	.548*	-0.017															
4	**Salinity (‰)**	.561*	-0.014	.998**														
5	**Turb. (NTU)**	0.183	0.341	.555*	.557*													
6	**TDS (mg/l)**	.549*	-0.017	1.000**	.998**	.555*												
7	**Cl$^-$ (mg/l)**	.462*	0.054	.923**	.939**	.603**	.922**											
8	**NO^{3-} (mg/l)**	.607**	.567**	.551*	.545*	.508*	.551*	.514*										
9	**PO$_4^{3-}$ (mg/l)**	0.26	0.236	0.179	0.177	.658**	0.178	0.204	.466*									
10	**Hardness (mg/l)**	-0.094	-0.052	.745**	.741**	.517*	.743**	.770**	0.232	0.023								
11	**Fe$^+$ (mg/l)**	0.041	-0.283	0.107	0.118	-0.361	0.104	0.168	-0.009	-0.312	0.215							
12	**Mn^{2+} (mg/l)**	-.695**	-0.031	-0.251	-0.274	-0.193	-0.253	-0.277	-0.257	-0.22	0.342	0.33						
13	**Pb (mg/l)**	0.115	-0.139	0.032	0.021	0.065	0.036	-0.121	-0.172	-0.155	-0.184	-0.149	-0.22					
14	**Sb (mg/l)**	-0.092	-.490*	-0.042	-0.048	-0.149	-0.039	-0.121	-0.385	-0.327	-0.141	0.007	-0.204	.690**				
15	**FCB (MPN/100ml)**	-0.018	-0.166	-0.225	-0.206	-0.182	-0.226	-0.142	-0.265	-0.188	-0.139	.536*	0.055	-0.065	0.119			
16	**TCB (MPN/100ml)**	-.525*	0.226	-0.354	-0.353	-0.13	-0.356	-0.297	-0.43	-0.343	0.118	0.064	.576**	-0.149	-0.194	.457*		
17	**THB (cfu/ml)**	-0.43	-0.083	-0.127	-0.125	-0.135	-0.129	-0.103	-.541*	-0.415	0.271	-0.127	0.419	-0.181	-0.114	0.236	.763**	

Note: N= 5, *p<.05, **p<.01

VIII. CONCLUSION

The findings of this study revealed that the levels of chemical (pH, lead and antimony) and microbiological (Faecal Coliform Bacteria, Total Coliform Bacteria and Total Heterotrophic Bacteria) parameters increased above recommended standard limits on exposure to storage temperatures of 28°C or sunlight for a period of 28 days after 9 days from production, renders the bottled water quality unsatisfactory for human consumption.

Based on the findings of this study, the following recommendations were made:

1. Regulators should monitor pH of various brands of bottled water to keep it at a level suitable for human consumption.
2. There is need to specify information of the physicochemical properties on the label of the various brands of bottled water that will represent the real values of physicochemical properties as at when it is produced.
3. It is also advised that regulators enforce and ensure that bottled water producers include best before label on the bottled water since the quality deteriorates over time.
4. Sensitization of retailers and consumers through proper education and awareness programmes should be carried out by to ensure that bottled water purchased should be stored at cool temperatures to avoid microorganisms from multiplying when left at room temperature for prolonged periods.
5. A review of policies and procedures governing the bottling, storage and usage of bottled water produced in Nigeria is recommended to ensure adequate protection of local, national and international consumers.
6. Further study should be done using same brand of bottled water obtained directly from the production company and the open market.

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