Qualitative Assessment of Sachet and Bottled Water Marketed in Bauchi Metropolis, Nigeria

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Abstract

This study present the result of quality assessment of bottled and sachet water sold in Bauchi metropolis. Twenty-three (23) water brands consisting of fifteen (15) sachet water and eight (8) bottled water were collected, physically examined and assessed for their physiochemical and microbiological parameters using standard analytical procedures to ascertain the level of compliance with World Health Organization (WHO) and Standard Organization of Nigeria (SON) specification for drinking water. The results from the physical examinations reveals that none of the water brands indicated the mineral composition and batch number, while 20 % of the water brands had no manufacturing and expiry date. An expression was developed that established the relationship between TDS and EC having a multiplying factor of ***0.5*** *compared to* ***0.67*** *stipulated by standard. The findings revealed that the physical and chemical characteristics of the water brands do not wholly meet the recommended standards while the microbiological evaluation revealed that only 26.67% and 75.00% of the sachet and bottled water respectively had total bacteria coli form within the recommended standards. The result shows that 73.30 % and 25.00 % of Sachet and bottled water considered in this study are not fit for Human consumption at the time of the studies.*

Keywords: *Bottled water, Quality, Assessment, chemical, microbiological, physical, sachet water.*

1. Introduction

Water is one of the most essential commodities needed for the survival of eco-system (Saleh *et al*., 2001). It is very abundant in nature as its occupies about 70 % of the earth's crust. Despite its relative abundance, good quality drinking water is not readily available to man (Onweluzo and Akuagbazie, 2010). According to Ajewole (2010) about 1.2 billion people lack access to portable water worldwide and while only about 30 % of the Nigerian populace have access to clean drinking water. Access to safe drinking water is key to sustainable development, food production, poverty reduction and quality health (Adekunle *et al*., 2004). The non availability of good quality drinking water has resulted into a number of health challenges as water is known to be a primary causative agent of many contagious diseases. In developing countries of the world, 80 % of all diseases and over 30 % of deaths are related to drinking water (Onweluzo and Akuagbazie, 2010; Olaoye and Onilude, 2009). Research have shown that when clean water and needed hygiene condition are provided, the chances of occurrence of diarrhea, sleeping sickness and guinea worm infestation can be eliminated or prevented by 50, 80 and 100 % respectively (Alhassan and Ujoh, 2012).

Nigerian government neglect or insufficient investment in water infrastructure development has lead to unsafe epileptic public water supply (Dada, 2009). This insufficiency of water supply has given rise to the involvement of private individuals in the production of packaged drinking water (pure water) (Dada, 2009). The advent of sachet water has significantly help in tackling the insecurity associated with household drinking water supply with the renewed global commitments towards the achievement of millennium development goals (MDGs) by 2015 (Ndinwa *et al*., 2012). Commonly sachet water is known to be a safe and instant means of quenching public thirst. This water is now common in Nigeria, Ghana and other bordering West Africa countries (Cheabu and Ephraim, 2014). Sachet water is usually consumed without further processing especially during the dry and hot seasons in Nigeria. In addition to the prevalence of sachet water, bottled water are also widely consumed in many parts of the world by huge number of urban populace due to its pleasant taste, absence of odour and the believe that it is mostly free of germs. Bottled water are also consumed due to water scarcity resulting from natural disaster such as earthquake, tsunami, flood, drought and hurricane or other form of societal disasters like terrorist attack, war outbreak, sabotage and blockage that are capable of obstructing public and private water supplies for extended period of time (Guler, 2007; Guler and Alpaslan,2009). The hygiene of the environment and conditions under which majority of brands of packaged water are produced and stored are faced with a number of uncertainties (Ndinwa *et al.*, 2012).

Constant and periodic assessment of packaged drinking water is needed to satisfactorily enlighten the consumers about quality (Alhassan and Ujoh, 2012; Cheabu and Ephraim, 2014). National and international organizations standards have been explicitly developed for safe drinking water quality. Virtually all the available standards have upper limits for physical, chemical and microbiological properties which when exceeded are dangerous and have the potential of been harmful to the end users.

A number of studies have been carried out on the quality assessment of sachet and bottled drinking water across different Nigerian towns/cities and some part of the world. Nearly in all these studies reported across the country and some part of the world, the quality of approximately 50 % drinking water available to the populace seems to be unfit for consumption. It is however not out of place to assume that similar situation can be obtainable in other Nigerian cities or towns (Musa *et al.*, 2014a). There are however limited or no documented expository literature on the quality assessment of portable drinking water in Bauchi in recent time. One of the attempts to report the quality assessment of drinking water in Bauchi was by Isikwue and Chikezie (2014). However their work was limited to the analysis of five sachet water samples. Secondly the authors' only take account of sachet water and the entire manuscript did not report the level of compliance of physical examination with the relevant standards. These are significant aspects of water quality study such as metal compositions that needs to be explored. The main aim of this study is to give explicit account of the quality assessment of sachet and bottled drinking water in Bauchi metropolis.

2. Materials and Methods

2.1 Study Area

The study area is Bauchi the capital of Bauchi state. Bauchi is located on latitude 10^{o}17 N and Longitude 9^{o}49 E. The town has a mean annual rainfall of 1099 millimeters (mm) and mean water temperature of 27.4 ^oC. The city covers an area of 3,687 km^2 and had a population of 493 810 according to 2006 census data. Bauchi is located on the northern edge of Jos Plateau, at an elevation of 616 m. The main source of the water in Bauchi is Gubi dam. Gubi dam is an earth fill dam with clay core. It has a total storage capacity of 3.84 x 106 m^3. The maximum height of the dam is 27 m, length of the embankment 3.8 km, freeboard 3 m and spill way 70 m. The dam supplies 12.5 million gallon of water daily to the city, (Rome, Food and Agricultural Organization, 1988).

2.2 Sampling

To ensure adequate representative sampling, a preliminary survey was conducted before selection of the water to be analyzed. Enquiries identify popular brand names mostly patronized in the study area. A total of twenty three samples consisting of fifteen (15) brands of sachet water and eight (8) brands of bottled/table water were identified. The samples were collected from the sellers as packaged by the manufacturers and put in sterile polypropylene sample containers with leak proof lids. These were labelled appropriately and immediately transferred to Public Health Engineering Laboratory in the Department of Civil Engineering, Abubakar Tafawa Balewa University (ATBU) for subsequent analyses

2.3 Physical Examination

Physical examination of labeling information according to the method described by Oyeku *et al*, (2001).

2.4 Analyses

2.4.1 Physical and Chemical Characteristics:

Appearance, taste, and odour of the samples were evaluated subjectively using the standard operating procedure (SOP) on water analysis as specified by NAFDAC laboratory manual. Physical and chemical analysis as described by APHA (1998).

2.4.3 Microbiological Characteristics;

The microbiological quality of the water sample was determined using total bacteria count and faecal coliform indices.

3. Results and Discussion

3.1 *Physical examination*

Tables 3.1 and 3.2 showed the results of the Physical examination of sachet and bottled water

Table 3.1: Physical Examination for label compliance of Sachet Water

S/N	Parameter	Product Name	Manufacturer Address	Manufacturing Date	Batch Number	Expiry Date	NAFDAC Number	Mineral composition
1	SW1	+	+	-	-	-	+	-
2	SW2	+	+	-	-	-	+	-
3	SW3	+	+	-	-	-	+	-
4	SW4	+	+	+	-	+	+	-
5	SW5	+	+	-	-	-	+	-
6	SW6	+	+	+	-	+	+	-
7	SW7	+	+	-	-	-	+	-
8	SW8	+	+	-	-	-	+	-
9	SW9	+	+	-	-	-	+	-
10	SW10	+	+	-	-	-	+	-
11	SW11	+	+	-	-	-	+	-
12	SW12	+	+	-	-	-	+	-
13	SW13	+	+	-	-	-	+	-
14	SW14	+	+	-	-	-	+	-
15	SW15	+	+	+	-	+	+	-
Ref.	WHO guideline*	+	+	+	+	+	+	+
Ref.	SON guideline**	+	+	+	+	+	+	+

Table 3.2: Physical examination of bottled water

S/N	Parameter	Product Name	Manufacturer Address	Manufacturing Date	Batch Number	Expiry Date	NAFDAC Number	Mineral composition
1	BW1	+	+	+	+	+	+	-
2	BW2	+	+	+	+	+	+	-
3	BW3	+	+	+	+	+	+	-
4	BW4	+	+	+	+	+	+	-
5	BW5	+	+	+	+	+	+	-
6	BW6	+	+	+	+	+	+	-
7	BW7	+	+	+	+	+	+	-
8	BW8	+	+	+	+	+	+	-
Ref.	WHO guideline*	+	+	+	+	+	+	+
Ref.	SON guideline**	+	+	+	+	+	+	+

+ = Indicated - = Not Indicated *=WHO Standard guidelines (2011) **=SON Standard guidelines (2007)

The National Agency for Food, Drug Administration and Control (NAFDAC agency requires that all the labeling of food and drugs must be informative and accurate. This information required on labeling include Producers name, Contact information, Batch number, Nutritional information, Expiration date (Best before date), Manufacturing date and NAFDAC registration number (Dada, 2009; Musa *et al*., 2014a). The results of the physical examination of the bottled water samples is presented in Table 3.1 which shows that all the bottled water samples exhibit 100 % compliance as regard the product names, manufacturers addresses, manufacturing and expiry dates, batch number and NAFDAC registration number as these information was clearly shown on their labeling. However, none of the bottled water brand studied indicates the mineral compositions. Table 3.2 revealed that all the sachet water investigated had 100 % compliance in term of the product names, manufacturing addresses, and NAFDAC number, while only 20 % (3 brands) of sachet water brand had no manufacturing and expiry date. These information are however essential as its tell the consumer whether the water sample is still within it shelf life or not. Furthermore, all the sachet water was observed to be without batch number and mineral composition on their labeling. Batch number is essential for any product especially when there is need to recall a product from the market in the event of discovery of any abnormality with the product. The act of non compliance by the water production factories as rightly observed in this present study is a source of great concern as the packaged water sold to the entire populace are likely to pose health risk when consumed. It has been reported that substantial number of packaged water vendor that resist compliance to best practices laid down by the authorities do not have the license to operate (Olaoye and Onilude, 2009; Ndinwu *et al*., 2008). It is however very worrisome that this is not the case with this present study as all the water vendor were duly certified to operate as evident in the NAFDAC registration provided.

3.2 Physical Properties of Packaged Water

Tables 3.3 and 3.4 showed the results of the physical characteristics of sachet and bottled water sold in Bauchi metropolis respectively.

3.2 Physical characteristics

Table 3.3: Result of Physical Analyses of Sachet Water

S/N	Parameter	Appearance	Odour	Taste	Turbidity (NTU)	pH	Conductivity (μscm^{-1})	Temperature (°C)	TDS (mg/L)	TSS (mg/L)
1	SW1	CCL	IO	UTS	0	6.72	5.46	26.5	2.73	ND
2	SW2	CCL	IO	UTS	0	6.81	4.67	26.1	2.335	ND
3	SW3	CCL	IO	UTS	1	6.97	8.56	26.5	4.28	ND
4	SW4	CCL	IO	UTS	0	7.69	2.78	26.5	1.39	ND
5	SW5	CCL	IO	UTS	0	6.95	3.86	26.2	1.93	ND
6	SW6	CCL	IO	UTS	0	7.67	8.9	27.1	4.45	ND
7	SW7	CCL	IO	UTS	0	7.36	5.7	26.3	2.85	ND
8	SW8	CCL	IO	UTS	0	6.85	8.84	26.5	4.42	ND
9	SW9	CCL	IO	UTS	0	7.43	9.42	26.2	4.71	ND
10	SW10	CCL	IO	UTS	0	6.93	10.68	26.3	5.34	ND
11	SW11	CCL	IO	UTS	0	7.75	8.44	26.6	4.22	ND
12	SW12	CCL	IO	UTS	0	6.90	5.68	26.5	2.84	ND
13	SW13	CCL	IO	UTS	0	7.72	6.96	26.1	3.48	ND
14	SW14	CCL	IO	UTS	0	7.65	2.46	26.4	1.23	ND
15	SW15	CCL	IO	UTS	0	6.98	2.94	26.7	1.47	ND
Ref.	WHO guideline*	CCL	IO	UTS	5	6.5-8.5	1000	-	500	0
Ref.	SON guideline**	CCL	IO	UTS	-	6.5-8.5	-	-	500	-

Table 3.4: Physical Analyses of Bottled Water

S/N	Parameter	Appearance	Odour	Taste	Turbidity (NTU)	pH	Conductivity (μscm^{-1})	Temperature (°C)	TDS (mg/L)	TSS (mg/L)
1	BW1	CCL	IO	UTS	0	6.93	2.54	26.3	1.27	ND
2	BW2	CCL	IO	UTS	0	6.95	1.94	26.8	0.97	ND
3	BW3	CCL	IO	UTS	0	6.82	1.06	26.3	0.53	ND
4	BW4	CCL	IO	UTS	0	6.84	2.68	26.3	1.34	ND
5	BW5	CCL	IO	UTS	0	6.45	4.58	26.1	2.29	ND
6	BW6	CCL	IO	UTS	0	7.40	8.26	27.0	4.13	ND
7	BW7	CCL	IO	UTS	0	6.97	3.44	26.2	1.72	ND
8	BW8	CCL	IO	UTS	0	6.80	2.18	26.5	1.09	ND
Ref	WHO guideline*	CCL	IO	UTS	5	6.5-8.5	1000	-	500	0
Ref	SON guideline**	CCL	IO	UTS	-	6.5-8.5	-	-	500	-

CCL= Clear Colourless, UTS= Unobjectionable Taste, OS= Objectionable Taste, ND= Not Detected, IO= Inoffensive.

Total dissolved solid (TDS) of the sachet samples showed higher levels of total dissolved solids (1.23 - 4.71

mg/L) than the bottled samples (0.53 – 4.13mg/L). However, TDS of all the water samples was observed to be within the World Health Organization (WHO) and Standard Organization of Nigeria (SON) standards of 500 mg/L. Total dissolved solids above the WHO upper limit of 500 mg/L affect the taste of drinking water negatively and not considered fit for drinking purpose. The results of this clearly shows that the salinity of the potable water analyzed is within the limit recommended for consumption.

Electrical conductivity (EC) of Bottled water sold in Bauchi metropolis ranges from 1.06 to 8.26 μscm^{-1}, while the sachet water showed conductivity value of 2.46 to 10.68 μscm^{-1}. The value of E.C is far too low compared to the maximum of 1000 μscm^{-1} recommended for drinking water by WHO standard. According to Ndinwa *et al.* (2012) low E.C value denotes the presence of minimal amount of dissolved salts (mineral elements such as calcium, magnesium and fluoride) in water. The long term drinking of packaged water with E.C value of less than 40 μscm^{-1} constitute a number of health risks such as higher probability of fracture in children, pregnancy disorder (preeclampsia), diuresis, premature or low baby weight at birth and increased tooth decay Guler and Alpalsan (2009).

Total suspended solids (TSS) analysis revealed that all the sachet and bottled water sold in Bauchi metropolis have zero total suspended solid (TSS) which is within the recommended Standard recommended by World Health Organization. This result clearly depicts that there are no particulate matter present in all packaged water under investigation.

The Turbidity of drinking water is purely dependent on the amount of particulate matter present in it. The turbidity of water interferes with disinfections (Musa *et al.*, 2014b). Turbidity is known to have effects on taste, odour and colour of water (Ndinwa *et al.*, 2011). It also serves as a transport medium of *Giardia* and *Cryptosporidium cysts* in drinking water system (Ando, 2005). The results of analysis shows that all the brands of sachet and bottled water sold in Bauchi metropolis was observed to have zero turbidity, with exception of SW3 which has turbidity value of 1 NTU. This value is however still within the recommended standard by World Health Organization (WHO). Turbidity in water results from the presence of suspended solids. Therefore, the observed zero turbidity is also a reflection of the zero TSS result earlier reported.

Temperature is a measure of the average thermal energy of a substance. The temperatures of the sachet water samples were within the range of 26.1 to 27.1 ^{o}C and that of bottled water samples were within the range of 26.1-27.0 ^{o}C. The value reported in this study is practically within ambient temperature. Although there was no recommended standard set by World Health Organization (WHO) and Standard Organization of Nigeria SON. According to Sunday *et al.,* 2011, temperatures within this range are favorable for maximum growth of mesophyll bacteria including human diseases causing agents. This phenomenon has the tendency to promote the development of undesirable taste and odour in water with time.

The sachet samples had a pH range of 6.81-7.75 while that of bottled water samples were within 6.8- 7.4. All the water samples analyzed were within the range 6.5 to 8.5 recommended by World Health Organization (WHO). It is very important to state that the packaged water samples with pH within the regulatory guideline values do not have any probability of posing health issues like as acidosis (Asamoah and Amorin, 2011). However, it was observed and deduce from the result from Table 3.3 and 3.4 that the TDS and the Electrical Conductivity had a distinctive relationship as shown on Figure 3.1 and 3.2.

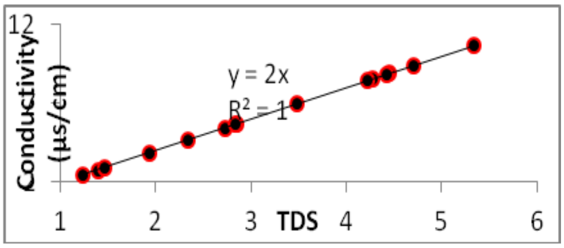

Figure 3.1: Conductivity (µs/cm) as a function TDS of Sachet Water

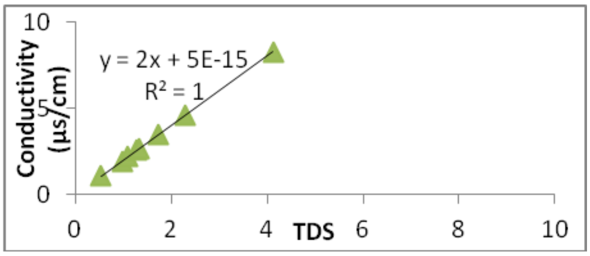

Figure 3.2: Conductivity (µs/cm) as a function of TDS of Bottled Water

Both plots gave One (1) as it regression and the E.C twice the TDS that gave an equation as:

TDS (mg/L or ppm) = EC (µS/cm) x 0.5 (3.1)

A very slight deviation from the expression adopted by the World Health Organization (2007) of the relationship between the Total Dissolved Solid and the Electrical conductivity

TDS (mg/L or ppm) = EC (µS/cm) x 0.67 (3.2)

Tables 3.5 and 3.6 showed the results of the Chemical characteristics of sachet and bottled water sold in Bauchi metropolis respectively.

3.3 Chemical Properties of Packaged Water

3.3 Chemical characteristics

Table 3.5: Results of Chemical analyses of sachet water

S/N	Parameter	Mn mg/L	Ca mg/L	Zn mg/L	Cr mg/L	Cu mg/L	Fe mg/L	K mg/L	Pb mg/L	Na mg/L	Cd mg/L	Cl mg/L
1	SW1	0.00	4.4	0.03	0.02	1.13	0.01	1.0	0.00	6.50	0.00	2.15
2	SW2	0.02	1.6	0.04	0.02	1.15	0.00	0.7	0.00	8.00	0.00	3.34
3	SW3	0.25	2.5	0.01	0.04	1.13	0.01	1.0	0.00	3.50	0.00	1.42
4	SW4	0.00	0.7	0.01	0.02	1.19	0.03	3.0	0.00	10.0	0.00	5.60
5	SW5	0.03	4.5	0.08	0.04	1.22	0.02	3.0	0.00	19.00	0.00	3.56
6	SW6	0.00	2.6	0.90	0.06	1.02	0.00	0.9	0.00	4.5	0.00	2.43
7	SW7	0.03	4.4	0.05	0.02	1.02	0.01	3.0	0.00	15.5	0.00	5.21
8	SW8	0.15	3.3	0.01	0.02	1.15	0.04	7.0	0.00	17.5	0.00	4.42
9	SW9	0.02	4.5	0.45	0.08	0.99	0.03	3.0	0.00	6.50	0.00	3.24
10	SW10	0.02	5.3	0.08	0.01	1.13	0.02	3.0	0.00	6.70	0.00	9.0
11	SW11	0.11	4.2	0.05	0.03	1.11	0.05	3.0	0.00	33.50	0.00	3.25
12	SW12	0.00	4.4	0.07	0.02	1.19	0.07	3.0	0.00	5.40	0.00	3.20
13	SW13	0.04	4.3	0.04	0.01	0.99	0.02	3.0	0.00	17.00	0.00	2.30
14	SW14	0.00	4.1	0.01	0.02	1.40	0.00	3.0	0.00	6.50	0.00	3.20
15	SW15	0.00	3.0	0.05	0.03	1.38	0.01	3.0	0.00	5.50	0.00	2.37
Ref.	WHO*	0.5	50	5	0.05	2	0.3	12	0.01	200	0.003	250
Ref.	SON**	0	0	3	0.05	1.5	0.3	0	0.01	200	0.003	200

Table 3.6: Chemical Analyses of Bottled Water

S/N	Parameter	Mn mg/L	Ca mg/L	Zn mg/L	Cr mg/L	Cu mg/L	Fe mg/L	K mg/L	Pb mg/L	Na mg/L	Cd mg/L	Cl mg/L
1	BW1	0.12	0.20	0.50	0.03	0.01	0.05	1.5	0.00	3.50	0.00	3.34
2	BW2	0.04	0.72	0.64	0.01	0.03	0.01	2.3	0.00	4.20	0.00	5.83
3	BW3	0.01	0.65	0.70	0.01	0.01	0.00	0.6	0.00	9.05	0.00	2.75
4	BW4	0.45	0.17	0.15	0.01	0.07	0.00	4.5	0.00	3.65	0.00	5.82
5	BW5	0.56	2.65	0.07	0.01	0.03	0.01	0.3	0.00	3.80	0.00	3.12
6	BW6	0.21	1.56	0.12	0.02	0.05	0.01	3.2	0.00	5.50	0.00	5.42
7	BW7	0.97	0.30	0.15	0.00	0.01	0.00	0.7	0.00	6.30	0.00	3.15
8	BW8	1.48	4.20	0.67	0.00	0.02	0.00	1.6	0.00	3.70	0.00	1.87
Ref.	WHO*	0.5	50	5	0.05	2	0.3	12	0.01	200	0.003	250
Ref.	SON **	0	0	3	0.05	1.5	0.3	0	0.01	200	0.003	200

***WHO Standard guidelines (2011) **SON Standard guidelines (2007)**

Manganese is present in water. Among all the sachet water analyzed; 6 brands (40 %) shows the absence of manganese while the remaining 60 % had a manganese concentration ranging between 0.02- 0.24 mg/L. SW3 brand had the highest manganese level of 0.25 mg/L. Results of bottled water analysis revealed that 3 brands (BW5, BW7 and BW8) representing 37.5 % contains significantly high amount of manganese (0.56, 0.97 and 1.48). These values are higher than the guideline value of 0.50 mg/L set by WHO. Large quantity of manganese influences taste in water and encourage the growth of bacteria; though not hazardous but are very unpleasant.. Large doses of manganese have also been reported to cause lethargy, irritability, headache, sleeplessness, and leg weakness. This might lead to development of psychological symptoms such as aggressiveness, unaccountable laughter, impulsive acts and absent-mindedness (Saleh *et al.*, 2001). These in the long run usually result into a Parkinson like disease. These 3 brands could be detrimental to human health when consumed excessively over an extended period of time.

Iron as a trace element was not detected in about 50 % of bottled water while in the remaining 50 % the concentration was observed to vary from 0.01 – 0.05 mg/L. Among the sachet water, 77 % of the studied samples were observed to contain iron at a concentration varying between 0.01 – 0.07 mg/L while 13 % of the sachet water sold in the metropolis does not contain any trace of iron. These observed values are lower than the upper limit of 0.3 mg/L stipulated by World Health Organization (WHO) for drinking water. High concentrations of iron can affect the acceptability of drinking water, and should be given adequate priority during drinking water processing (WHO, 2006).

Copper occur naturally in water in only minute quantity (few micrograms per liter) in drinking water (Saleh *et al.*, 2001). The WHO guideline value for copper in drinking water is set at a maximum of 2 mg/L. In all the sachet and bottled water samples investigated none of the samples analyzed was observed to contain this trace element higher than the stipulated maximum concentration. While the sachet water was observed to be within 0.99- 1.40 mg/L the bottled water was found to have a copper level that varies from 0.01 -0.07 mg/L. One obvious fact with these results is that the sachet water tends to contain more copper than the bottled water. Higher level of copper is not desirable in drinking water as it could causes gastrointestinal disorder (SON, 2007).

Zinc is another example of trace element in water. The results of this study show that all the sachet and bottled water samples investigated were observed to contain appreciable quantity of this trace element. The sachet water was observed to have a zinc concentration that ranges from 0.01- 0.90 mg/L while the bottled water was observed to vary from 0.07 -0.67 mg/L. Analysis of these results clearly depicts that the values obtained were within the permissible level of 3 mg/L and 5 mg/L recommended by SON and WHO respectively. Higher concentrations of zinc in water are responsible for stringent tastes in water which are essentially not desirable.

The WHO guidelines value stipulates a maximum concentration level of sodium in drinking water to be 200 mg/L. The Sodium concentration level in both bottled and sachet water brands sold in Bauchi metropolis was within this set guideline value. Analysis of the results shows that the sodium concentration of sachet water ranges between 3.5 – 33.50 mg/L in this present study while the bottled water brands varies from 3.5- 9.05 mg/L. The value observed in this study is low when compared to 7.79-15.43 mg/L and 11.55- 15.43 mg/L reported for sachet and bottled water in Bolgatanga municipality, Ghana (Oyelude and Ahenkorah, 2012). Sodium has the tendency of affecting the taste of water meant for consumption when its concentrations are above the threshold limit value.

Calcium plays a key role in bone formation and development. The concentration of calcium was determined to be within 0.7- 5.3 mg/L for sachet water and 0.17 – 4.20 mg/L for bottled water brands. These values were lower than upper limit of 50 mg/L stipulated by the WHO. Similarly, low level of calcium was reported for packaged water in Abraka and Warri, Nigeria (Ndinwa *et al.,* 2012). Adult within the age bracket of 19-50 years requires 1000 mg Ca^{2+} (Guler amd Alphasan, 2009). The result of this water analysis signifies that only approximately 0.3 % of calcium dietary reference can be fulfilled when 2 litres of this packaged water are consumed daily. Extensive consumption of these brands of water over some period might be associated with some health issues because of the minute presence of calcium. It is advisable that water with high quantity of calcium within the permissible limit should be consumed always (Guler amd Alpalsan, 2009). Although there are no established proof on adverse health effects attributed to excess calcium in drinking water but excess calcium ions is known to cause water hardness (Oyelude and Ahenkorah, 2012).

Potassium is a necessity for the sustenance of a biological system. It is an essential nutrient in intracellular fluid, acid-alkaline balance, osmotic pressure regulation, muscular contraction and nerve impulse conduction (Soetan *et al.,* 2010). This mineral element was detected in all the packaged water studied. The concentration of potassium varied from 0.7 – 7.0 mg/L and 0.3 – 4.5 mg/L for sachet and bottled water respectively. The observed value in this present study is satisfactorily within the guideline value by WHO.

Chloride ions concentration was determined to vary from 1.87 – 5.83 mg/L for bottled water while the chlorine level for sachet water ranges from 1.42 – 9.0 mg/L. The result is appreciably within the WHO guideline value of maximum permissible concentration of 250 mg/L desirable for drinking water. 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 (Ndinwa *et al.,* 2012). But higher concentration of chloride ions in drinking water can add its taste to the water. The value observed in this study was higher than 0.31- 3.03 mg/L reported for sachet water analysis in Warri and Abraka, Nigeria (Ndinwa *et al*., 2012) but very low when compared to the range of 5.05-18.97 mg/L and 8.95 -24.80 mg/L reported for sachet and bottled water in Ghana (Oyelude and Ahenkorah, 2012) and 2.94 – 19 mg/L for processed drinking water in Turkey (Guler, 2007).

The presence of heavy metals such as lead (Pb) and cadmium (Cd) were not detected in all the tested water samples. The results showed that the level of metals in all the brand of sampled water was within the recommended range set by World Health Organization (WHO) and Standard Organization of Nigeria (SON). The implication of this result is that the manufacturers of these brands of water obtain raw water from chemically good sources. Chromium was however detected to be within the range of 0.01 – 0.08 mg/L in the sachet water and 0.01 – 0.04 mg/L in the bottled water. Analysis of this result shows that all the bottled water exhibit 100 % compliance but two brands (SW6 and SW9) of the sachet water was observed to contain 0.06 an 0.08 mg/L of chromium, a concentration higher than 0.05 mg/L stipulated by WHO as the upper threshold limit of chromium considered to pose any significant health risk in drinking water.

3.4 Microbial Properties

The World Health Organization set the Maximum Contaminant Level (MCL) for total bacterial count in drinking water to be zero cfu/100 ml of water (WHO, 2011). The results of the Microbiological characteristics of sachet water sold in Bauchi metropolis depicted on Table 7 and 8 shows that 73.33 % (11 brands) of the sachet water had total bacterial counts between 1- 15 cfu/100 ml which is above the stipulated value by WHO with SW3 having the highest number (15 cfu/100 ml) of total bacterial coliform, while the remaining 26.67 % (4 brands) satisfactorily conform to the World Health Organization (WHO) set zero limit.

3.4 Microbiological characteristic

Table 3.7: Result of Microbiological Analyses of Sachet water against 0.1ml.

S/N	Parameter	Total Bacterial count at 37°C (colony)	Faecal coliform count at 44 °C (colony)
1	SW1	1	0
2	SW2	1	0
3	SW3	15	0
4	SW4	3	0
5	SW5	4	0
6	SW6	0	0
7	SW7	2	0
8	SW8	1	0
9	SW9	0	0
10	SW10	2	0
11	SW11	1	0
12	SW12	1	0
13	SW13	1	0
14	SW14	0	0
15	SW15	0	0
Ref	WHO*	0	0
Ref	SON**	0	0

Table 3.8: Results of Microbiological Analyses of Bottled water

S/N	Parameter	Total Bacerial count at 37°C (colony)	Faecal Coliform count at 44°C
1	BW1	0	0
2	BW2	0	0
3	BW3	0	0
4	BW4	0	0
5	BW5	0	0
6	BW6	1	0
7	BW7	0	0
8	BW8	1	0
Ref.	WHO*	0	0
Ref.	SON**	0	0

*WHO Standard guidelines (2011) **SON Standard guidelines(2007)

The high level of faecal bacteria contamination are strongly attributed to poor quality of water source, improper pipeline maintenance, insufficient or lack of personal hygiene (Obiri-Danso *et al.*, 2003; NAFDAC, 2009; Olaoye and Onilude, 2009). The act of testing for the presence of coliform is a measure of the efficiency of the treatment process employed and the integrity of the water distribution system (Da Silva *et al*., 2008). It would not be out of place to state that the treatment process and distribution system employed by most of the water vendors are doubtful as it does not comply with standard operating procedure. The poor microbial quality observed in this present study has also been reported in some part of Nigeria and other part of the world (Obiri-Danso *et al.*, 2003; Adekunle *et al* .,2004; Ajayi *et al.*, 2008; Dada, 2009; Cheabu and Ephraim, 2014). The result of bottled water analysis showed that 13.33 % (2 brands) of the bottled water brands had total bacterial counts of 1 cfu/100ml while 87.67 % (6 brands) analyzed do not show any trace of faecal coliform. The low plate of 0-1 cfu/100ml observed is very consistent with the result of water analysis in Saudi Arabia. The result obtained in this work is appreciably low when compared with report from Canadian bottled water >100 cfu/100ml, Al- Gassin region of Saudi Arabia >180 cfu/100 ml and 104 cfu/ml for some part of Britain, United Kingdom (Ajayi *et al.,* 2008). In this present study higher percentage of the bottled water were produced under good sanitary conditions. According to Da Silva *et al*., 2008, the singular fact that a number of this packaged water contains coliform, there is however the need for improved monitoring and supervision of the water processing industry to ensure 100% compliance as water meant for consumption must be free from any form of bacteria that might constitute health hazard.

Faecal Coliform is sub-division of total coliform bacteria. The presence of faecal coliform in drinking water represents a greater risk to infectious pathogens (Musa *et al*., 2014a). The result of this study revealed that all the bottled and sachet water investigated had a zero faecal coliform. This result shows quantitative agreement with global and national standard for drinking water.

4. Conclusion

The study revealed that none of the sachet and bottled water indicates the mineral composition and batch number while 20 % of the sachet water had no manufacturing and expiry dates. Higher proportion of both type of packaged water was significantly deficient in mineral element such as calcium, potassium and sodium. The experimental results also shows that the water samples analyzed were observed to have zero concentration of lead and cadmium; two brands (13.33 %) of sachet water contained chromium above the upper limit of the guideline value. The expression adopted by the World Health Organization (2007) for the relationship between TDS and EC has a multiplying factor of **0.67**, but from this analysis it gave a multiplying factor of **0.5**. Results of microbial evaluation revealed that 73.33 and 25.00 % of the sachet and bottled water respectively had total bacteria coliform count exceeding limit set by World Health Organization (WHO) and Standard Organization of Nigeria (SON). Although no faecal coliform was observed in the samples, the total bacteria count observed in most of the samples is an indication of the presence of bacteria and fungi in the water. However there is need to educate producers and retailers on the importance of maintaining good hygiene practices during production, handling, storage and sales. Packaged water sold in Bauchi metropolis at the time of the study partly met the recommended WHO standards in terms of physical and chemical properties but failed to meet the required standards for physical examination and microbiological quality.

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