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Qualitative Assessment of Bottled Water Sold in Benin City Nigeria Using Physico-Chemical Indicators

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ABSTRACT: Bottled water is water that is intended for human consumption and is sealed in bottles or other container with no added ingredients except that it may contain safe and suitable fluorides. The sale and consumption of bottled water continues to grow rapidly in most places in Nigeria and is of public health concern**.** This study was designed to assess the physical and chemical quality of bottled drinking water sold in retail outlets in Benin City. Twenty five (25) brands of bottled drinking water were collected, physically examined and assessed for their physiochemical parameters using standard analytical procedures to ascertain their level of compliance with World Health Organization (WHO) and Nigerian Standard for Drinking Water Quality (NSDWQ) specification for drinking water. The results revealed that the physical and chemical parameters of all the brands of bottled water analysed were below WHO (2011), NESREA (2007) and NSDWQ (2007) permissible limits. The findings therefore suggest that these bottled water were fit for human consumption. However, there is a need for strict and routine monitoring of the packaged drinking water with the view of raising their standards.

Keywords: Bottled water, Physical and chemical limits, Consumption, Monitoring

Introduction

Water of good drinking quality is of basic importance to human physiology and man's continued existence depends very much on its availability (Onweluzo and Akuagbazie, 2010). Accessibility and availability of fresh clean water is a key to sustainable development and an essential element in health, food production and poverty reduction (Adekunle *et al*., 2004). However, despite its relative abundance, good quality drinking water is not readily available especially in developing countries. Unavailability of good quality drinking water is widespread and this has numerous health effects (Anyanwu and Nwigwe 2015). In developing nations of the world, 80% of all diseases and over 30% of deaths are related to drinking water (Dada and Ntukekpo, 1997).

Nigerian government's neglect or insufficient investment in water infrastructure development has led 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). Bottled water are widely consumed in many parts of the world by huge number of urban populace due to its pleasant taste, absence of odour and the belief that it is mostly free from germs. They 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 bottled water are produced and stored are faced with a number of uncertainties (Ndinwa *et al.*, 2012).

The demand for bottled water has increased over the years due to the fact that non-availability of reliable safe municipal water has left the impression that most bottled water offers a healthy, safer and water with better quality (Gardner, 2004). Continuous increase in the sale and indiscriminate consumption of packaged water in

Nigeria is of public health significance (Ogundipe, 2008). High demand for packaged water for various occasions has led to springing up of small scale entrepreneurs who engage in production of packaged water without due regard to hygienic practices in the production processes. The implication of this is lack of guarantee that the product will meet set standards for drinking water.

Bottled or packaged water is any portable water that is manufactured, distributed or offered for sale which is sealed in food grade, bottle or other container and is intended for human consumption (Warburton and Austin, 1997). Bottled water is usually manufactured and marketed by standard companies, both local and multinational. These waters are either drawn from sources like natural springs or deep boreholes or treated according to the specifications set by regulatory agencies. The sources of water used are supposed to be well protected and of good hygiene with an in-house quality control laboratory and expert which check the water quality before they are sold out.

However, most bottled water manufacturers in Nigeria obtain their raw water mostly from local, municipal piped water or well water, hence adherence to production and analytical standards are doubtful as most of the factories are observed to lack appropriate technology for achieving these (Oyedeji *et al.,* 2010). Surveillance carried out by NAFDAC between 2004 and 2005 revealed that some producers of packaged water indulge in sharp practices such as packaging of untreated water, production under unhygienic conditions, illegal production of unregistered water in unapproved premises, use of non-food grade sachets and release of packaged water for distribution and sale without date marking (Edema and Atayese, 2010).

This study therefore aims to provide information as to the safety of bottled water marketed in some communities in Southern Edo State Nigeria by determining the physical and chemical parameters of several brands.

Materials and methods

Description of the study area: Benin City the capital of Edo State is located in the heart of the tropical rain forest. It lies within the geographical coordinates of longitude 5°04' East and 6°43' East and latitude 5°44' North and 7°34'. The climate of Benin City though comparatively stable is not uniform. A rhythm of rainfall occurs in conjunction with the movement of the South Westerly monsoon wind across the Atlantic Ocean and the timing of these movements varies from year to year. Typically, the regions have the characteristic features of the humid tropical wet and dry climate governed primarily by the rainfall. There are two distinct seasons, rainy season covers from March to October and the dry season begins in November and terminates in April (Imoobe and Koye 2011). The main source of water for bottled water production in the study area is groundwater.

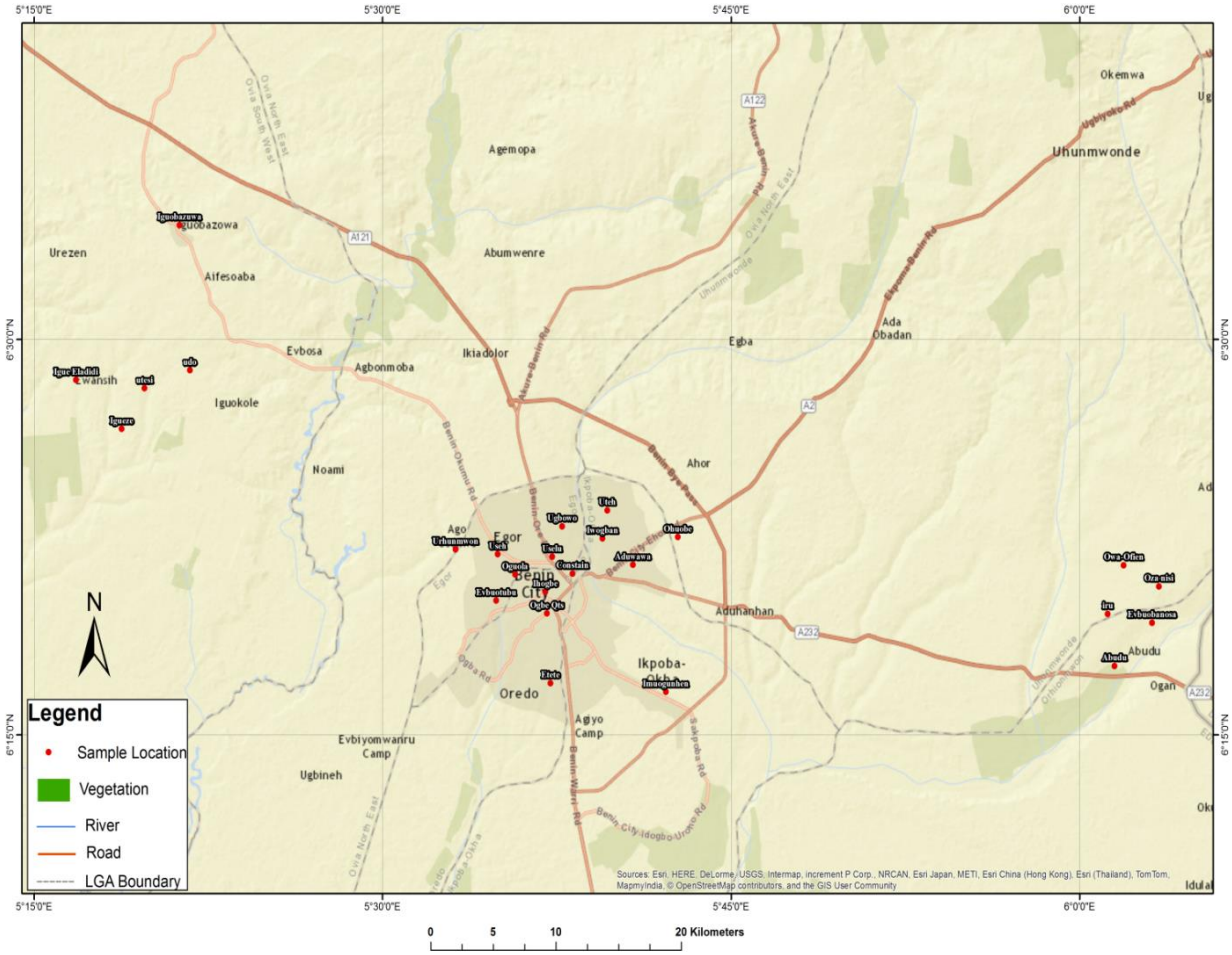

Figure 1: Map of the study area

Sample collection: A total of 25 samples of bottled water of different brands were randomly collected from commercial vendors at different parts of the study area. The samples were sealed and unopened until physical and chemical analysis were carried out on them.

Analysis of the water Samples: The physical and chemical parameters such as temperature was determined using thermometer calibrated in degree Celsius. pH was measured using Hanna pH metre (Hi-96107 model). Total dissolved solids (TDS) were measured using *Wagtech* Probe. Sulphates, nitrate, and total hardness were determined using standard methods of APHA (2002). Chloride was determined by Morh's method (Agbede *et al*, 2015).

Results and Discussion

The results of the physicochemical properties of bottled water obtained in some communities in Edo State are shown in Table 1.

The pH of the water samples examined ranged from 6.7 - 7.6, temperature ranged from 27 °C - 30°C, TDS obtained in the water samples ranged from 8.4 - 28.4 mg/l while total hardness varied from 4 – 27 mg/l. The concentration of chloride (Cl^-) in the bottled water ranged from 6.8 - 19.3 mg/l. Nitrate concentration ranged from 0.36 - 4.2 mg/l. The concentrations of sulphate was found to range from 0.12 - 5.5 mg/l. The result showed that the parameters studied were below WHO (2011), NESREA (2007) and NSDWQ (2007) permissible limits.

Table 1: Concentrations of physical and chemical parameters in bottled water in some communities in Edo State

Brands of bottled water	pH	(TDS) (mg/l)	Total hardness (mg/l)	Chloride (mg/l)	Nitrate (mg/l)	Sulphate (mg/l)
BW1	7.4	17.6	26	11.6	2.45	1
BW2	6.8	15.3	22	19.32	1.75	2
BW3	7.2	16.8	19	15.42	2.5	3
BW4	7.4	17.2	17	19.1	4.2	5
BW5	7.5	9.6	6.0	7.1	0.36	0.12
BW6	6.9	16.2	26	18.6	4.2	2
BW 7	6.9	8.4	6	7.3	0.76	0.14
BW 8	7.4	17.1	12	14.1	2.3	4
BW 9	6.7	16.8	21	8.7	2.1	3
BW 10	7.6	9.8	8	7.3	3.10	0.18
BW 11	6.9	8.4	11	8.4	0.6	0.3
BW 12	6.7	28.4	27	12.3	1.8	1
BW 13	7.1	28.4	23	15.6	2.2	4
BW 14	7.5	11.4	16	12.6	1.6	3
BW 15	7.4	9.2	6	11.4	1.8	0.3
BW 16	7.3	10.6	8	11.7	1.1	0.17
BW 17	7.3	11.2	9	11.7	1.2	0.19
BW 18	7.3	11.2	23	13.4	3.6	4
BW 19	6.7	18.3	17	9.2	2.3	2
BW 20	7.3	15.4	15	15.4	2.1	3
BW 21	7.4	11.4	10	11.7	1.6	0.2
BW 22	7.5	17.3	18	18.2	1.8	2
BW 23	7.4	25.3	12	10.2	2.6	5
BW 24	7.5	10	4	6.8	2.4	0.3
BW 25	7.5	10.2	7	10.6	1.2	0.2
WHO (2011) mg/l	6.5-8.5	1000	200	250	50	250
NSDWQ (2007) mg/l	6.5-8.5	500	150	250	50	100
NESREA (2007) mg/l	6.5-8.5	2000	100	600	20	500

The results implied that pH was high in all the bottled water which is consistent with 6.8- 7.4 gotten by Ibrahim *et al.*, (2015). High pH values can result from accidental spills, treatment breakdowns etc. (WHO, 2011). If pH value is higher than permissible limit, it will adversely affect the corrosion rate of metals (Shaikh and Mandre, 2009). However, metal corrosion or solubility problem occur when pH of the water happens to be more acidic (Onwughara *et al.*, 2013; Agbede *et al*., 2015). Even though pH has no direct effect on human health, its indirect action on physiological process cannot be over emphasized (Adekunle *et al*., 2004). It is very important to state that the bottled 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). In this study, pH was within permissible limit of 6.5 to 8.5 specified by WHO (2011), NESREA (2009) and NSDWQ (2007).

Temperature is a measure of the average thermal energy of a substance. Values obtained were within acceptable limits of 30^0C set by NESREA (2009) but were above 25^0C set by NSDWQ (2007). However, most were within permissible limit of 29°C set by WHO (1998). Higher values of 29.4°C was reported by Adekunle *et al.,* (2007) in Abeokuta, Nigeria and 29.0-32.4°C by Ajayi *et al.,* (2008). Temperature is one of the most important parameter in water because almost all its properties can be influenced by it (Imoisi *et al.*, 2012). According to Sunday *et al.,* (2011) cited in Ibrahim *et al*., (2015), high temperatures 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 Total Dissolved Solids (TDS) describes the presence of inorganic salt and organic matter in solution or water (Mustapha *et al.*, 2012**)**. In this study, the values of TDS were below permissible limit of 1000 mg/l set by WHO (2011), 2000mg/l set by NESREA (2009) and 500mg/l set by NSDWQ (2007). However, Ndinwa *et al* (2012) recorded values of between 2.47 and 62.3mg/l in bottled water samples in Delta State, Nigeria while Ajayi *et al.,* (2008) recorded high values, ranging from 78.0 to 180mg/l in Ibadan, Nigeria. TDS in water may

affect its taste (WHO, 1996). It has been reported that drinking water with extremely low levels of TDS may be unacceptable because of its flat and dull taste (WHO, 1996).

Total hardness in water consists mainly of dissolved calcium and magnesium salts. The total hardness varied from 4 to 27mg/l which is contrast to 8.0-121.0mg/l obtained by Ajayi *et al.,* (2008). Total hardness results in all the bottled water were low and could be described as soft water. Genarally, water supplies with hardness greater than 200mg/l is considered poor, those in excess of 500mg/l are unacceptable for most domestic purposes. In all the water samples, hardness was found below permissible limit of 200mg/l set by WHO (2011), 100mg/l set by NESREA (2009) and 150mg/l set by NSDWQ (2007). The low concentration of hardness in this study can be attributed to low concentration of calcium and magnesium ions in the various brands of bottled water. Hence, it can be said that water samples examined were not hard and can be used for drinking. Hardness in water is due to natural accumulation of salts when water dissolves ions due to contact with soil and geological formations or it may enter water from direct pollution by human activities (Awoyemi *et al.,* 2014).

The concentration of chloride (Cl^-) in the bottled water ranged from 6.8 to 19.3mg/l which was however in contrast to 1.87–5.83 mg/l obtained by Ibrahim *et al.,* (2015). The concentration of chloride obtained was relatively low and was below permissible limit of 250mg/l set by WHO (2011), NSDWQ (2007) and 600mg/l by NESREA (2009). Chloride concentration above permissible limit could cause corrosion of metals and impacts detestable taste in drinking water. Chloride usually occurs naturally as NaCl, $CaCl_2$ and $MgCl_2$ in widely different concentrations, in water. They enter water by solvent action of water on salts present in the soil or from polluting materials like sewage discharged (Shaikh and Mandre, 2009). This eventually find their way into sources of water used for bottled water. 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 packaged water analysis in Warri and Abraka, Nigeria (Ndinwa *et al*., 2012).

Nitrate was found to be within permissible limit of WHO (2011) and NSDWQ (2007) threshold of 50mg/l and NESREA (2009) permissible limit of 20mg/l. Interest is centered on excessive concentration of nitrate in drinking water as is known to cause infantile methemoglobinaemia when converted to highly toxic nitrite by certain bacteria found in the intestinal tract of infants (Ademoroti, 1996; Oyakhilome *et al*., 2012).

The concentrations of sulphate were found to range from 0.12 to 5.5mg/l which contrast with 6.9 and 12.1mg/l obtained by Anyanwu and Nwigwe (2015). In all the brands of bottled water samples, sulphate was found within permissible limit of 250 mg/l specified by WHO (2006), 500mg/l by NESREA (2009) and 100mg/l set by NSDWQ (2007). However, Taiwo *et al.,* (2010) recorded a higher value of 14.56mg/l while Ndinwa *et al*., (2012) reported very low values (0.00 – 1.11mg/) in bottled water samples. The presence of sulphate in drinking water can cause noticeable taste and very high levels might cause a laxative effect in unaccustomed consumers. Taste impairment varies with the nature of the associated cation; taste thresholds have been found to range from 250mg/litre for sodium sulphate to 1000 mg/l for calcium sulphate. It is generally considered that taste impairment is minimal at levels below 250 mg/litre (Radojevic and Bashkin, 1999, WHO, 2006).

The sources of sulphate in underground waters a major source to bottled water industries, may be due to water action on rocks and geological formation. Excess sulphate has a laxative effect, especially in combination with magnesium and/or sodium. Sulphates exist in nearly all natural waters, the amount vary depending on the nature of the terrain through which they flow. They are often derived from the sulphides of heavy metals like iron, nickel, copper and lead (Chindo *et al.,* 2013).

Conclusion

The results of this study revealed that the physical and chemical parameters of the brands of bottled water analysed were below WHO (2011), NESREA (2007) and NSDWQ (2007) threshold. However, close monitoring of the physical and chemical parameters of bottled water must be carried out by regulatory agency like NAFDAC in the study area in view of the possible risks to the health of consumers, particularly in the processing and packing stages of the water. Dissolution of rock minerals by the groundwater and seepage of contaminants into groundwater source are possible reasons for the contaminations that occur since bottled water manufacturer in the study area depend on groundwater source for their production.

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