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Quality Assessment of Popular Bottled Water Brands Sold in Owerri Municipal, Imo State, Nigeria

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Abstract

The analysis of the physical and chemical properties of popular bottled water brands sold in Owerri Municipal, Imo State, Nigeria for their level of compliance with World Health Organization (WHO) and Standard Organization of Nigeria (SON) specifications for drinking water quality was carried out. The pH of the samples was determined using a Checker Plus pH meter while the electrical conductivity (EC) and total dissolved solids (TDS) were measured using GroLine EC/TDS tester. The chemical parameters of the water samples were determined using a multiparameter photometer. Experimental results showed that the physicochemical parameters; pH, conductivity, total dissolved solids, copper, iron, zinc, chlorides and nitrates were found to comply with specifications for drinking water. The statistical analysis showed that though the sampled brands were fit for drinking, point contamination sources were responsible for the high coefficient of variation in some of the measured parameters in the samples.

Keywords: Bottled water, drinking water, WHO, copper, iron, zinc

1. Introduction

Water of good drinking quality is of basic importance to human physiology, and man's continued existence depends very much on its availability [1]. Good drinking water has remained a challenge, particularly in under-developed and developing countries [2]. In developing nations of the world, 80% of all diseases and over 30% of deaths are related to drinking water [1, 3, 4]. According to statistics from the Federal Ministry of Health, only about 30% of Nigerians have access to portable water while the United Nations estimated that about 1.2 billion people all over the world lack access to potable water [1, 5, 6]. The introduction of anthropogent chemicals, that have impact on health when present in trace amounts, has also become a problem [2, 7]. The need to define the quality of water has developed with the increasing demand of this resource. Water is said to be portable when its physical, chemical and microbiological qualities conform to specified standards [8]. Water quality guidelines form the basis for judgment of acceptability of public water supplies and the most preferred is the World Health Organization (WHO) regulations. The inadequacy in the supply of drinking water has given rise to the involvement of private individuals in the production of packaged drinking water [9]. Commonly, sachet water is known to be a safe and instant means of quenching public thirst. Bottled water is also widely consumed due to its pleasant taste, absence of odour and the presumption that it is mostly free from germs [10, 11]. However, 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 [12].

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A number of studies have been carried out on the quality assessment of sachet and bottled drinking water in different cities in Nigerian and other parts of the world. Most of these studies reported that approximately 50% drinking water available to the populace seems to be unfit for consumption. In the assessment of the quality of bottled and sachet water sold in Bauchi metropolis [10], results showed that 73.30% and 25.00% of sachet and bottled water considered in the study were not fit for human consumption at the time of the studies. The study of the quality of packaged drinking water brands marketed in Ibadan metropolis and Ile-Ife city in South Western Nigeria [13], showed that most of the sachet water brands fell below WHO drinking water standards and therefore are of doubtful quality. The quality assessment of packaged water in Uyo Metropolis South Eastern Nigeria [14] revealed that the conductivities of some of the samples were above the WHO standard for drinking water. In the study of the physicochemical characteristics of bottled water in Bolgatanga Municipality of Ghana [15], it was reported that two percent of the bottled water samples had pH levels below the minimum level of 6.5 recommended by WHO. The concentration of ions in selected bottled water brands sold in Malaysia [16] showed that the quality of the supplied bottled water samples was in accordance with standards set by WHO.

There are limited or no documented literature on the physicochemical quality of bottled drinking water in Owerri in recent time. The aim of this study, therefore, is to evaluate the physical and chemical characteristics of some popular bottled water brands sold in Owerri municipal and to ascertain their level of conformance with WHO and Standard Organization of Nigeria (SON) standards.

2. Materials and Methods

2.1. Sample Collection

Bottled water samples used for this study were collected in supermarkets within Owerri town. Four popular bottled water brands which include Eva, Nestle, Swan and Aqua Agad, were selected for this study and labeled A, B, C and D, respectively. The label information, manufacturing and expiring dates for each brand were noted.

2.2. Analysis of Bottled Water Samples

Bottled water packs for each brand were collected fortnightly for a period of six weeks. The samples were analyzed immediately after collection. Bottled water was selected randomly in threes from a pack of each brand. For each set, 50 mL of water was measured from each of the three bottles and mixed to give 150 mL of the final study sample. All parameter determinations were done using this mixed volume. The selection, mixing and analysis were repeated two more times and the mean value of the triplicate runs for each parameter was obtained.

2.3. Instrumentation

The pH of the samples was determined using Checker® Plus pH meter. The conductivity and total dissolved solids (TDS) were determined using GroLine EC/TDS tester. Copper, iron, zinc, nitrates, and chlorides were determined using Multiparameter Bench Photometer model HI83200 by HANNA instruments.

3. Results and Discussion

3.1. Labels and Nutritional Information

The labeling requirements specified in the Nigerian Industrial Standard, NIS 345:2008 for packaged water by the SON includes the production batch number, nutritional information, production date and best use before/expiry date. The National Agency for Food and Drug Administration and Control (NAFDAC) also requires that the NAFDAC registration number, name and address of producers are to be displayed on all bottles of the samples. All the bottled water brands sampled fulfilled the NAFDAC requirements. All the bottles had the production batch number, production date and best use before/expiry date. However, these details were not legible enough to be recorded for Brand D. Only Brand B provided nutritional information while other requirements specified by NIS were met by all the brands. This information is essential as it tells the consumer whether the water sample is still within shelf life. The 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.

3.2. Physicochemical Analysis of Samples

Various studies carried out by Baba *et al*. [17], Semerjian [18], and Miranzadeh *et al*. [19] have shown that the qualities of bottled water in different countries were within acceptable range. However, the influx of a large number of local brands and administrative ignorance, the physical and chemical quality parameters of packaged water sources have not been found to be in the acceptable limits [15, 20]. In the present study, results of the physical and chemical analysis of the sampled brands of bottled water are shown in Table 1.

Table 1. Physicochemical Characteristics of Selected Bottled Water Brands

Parameters	Brand A				Brand B				Brand C				Brand D				SON
	Wk1	Wk2	Wk3	Mean	Wk1	Wk2	Wk3	Mean	Wk1	Wk2	Wk 3	Mean	Wk1	Wk2	Wk3	Mean	
pH	7.29	7.24	7.53	7.35	7.16	7.27	7.40	7.28	7.25	7.35	7.41	7.34	6.65	6.74	6.90	6.76	6.5-8.5
Conductivity (µS/cm)	130	130	120	127	270	270	270	270	200	200	200	200	10	10	10	10	1000
TDS (mg/L)	65	65	60	63	135	135	135	135	100	100	100	100	5	5	5	5	500
Zinc (mg/L)	0.18	0.27	0.23	0.23	0.16	0.10	0.22	0.16	0.14	0.15	0.23	0.17	0.21	0.31	0.29	0.27	3.00
Copper (mg/L)	0.02	0.04	0.07	0.04	0.02	ND	0.01	0.01	0.05	0.05	0.01	0.04	0.03	0.01	ND	0.01	1.00
Iron (mg/L)	0.02	ND	0.01	0.01	ND	ND	0.02	0.01	ND	ND	0.01	0.01	ND	0.02	0.01	0.01	0.30
Nitrates (mg/L)	1.70	7.90	5.40	5.00	1.40	7.40	8.30	5.70	1.70	ND	2.40	1.37	ND	3.10	5.40	2.83	50
Chlorides (mg/L)	0.02	0.12	0.04	0.06	ND	0.01	0.02	0.01	0.01	ND	0.02	0.01	ND	0.13	ND	0.04	250

Wk - week; A - Eva; B - Nestle; C - Swan; D - Aqua Agad; SON - Standards Organization of Nigeria maximum permitted limit (2007)

The study of the quality of bottled drinking water brands marketed in Tanzania [21] showed that the pH and TDS of the samples ranged from 7.3-7.6 and 126-7.8 mg/L, respectively. In this study, the pH of all the brands ranged from 6.6-7.6 and were within SON specification. Water with pH < 6.5 is acidic, soft and corrosive. Acidic water could contain metal ions such as iron, manganese, copper, lead and zinc which can give a metallic taste to water. In other words, acidic water contains elevated levels of toxic metals.

Conductivity provides a measure of common salts (usually salts of calcium, sodium, magnesium, chlorides and fluorides) dissolved in water. A higher conductivity value indicates that there are more chemicals dissolved in the water. Because dissolved salts and other inorganic chemicals conduct electrical current, conductivity increases as salinity increases. Elevated dissolved solids can cause "mineral tastes" in drinking water. The conductivity of samples from this study ranged from 10 µS/cm (Brand D) to 270 µS/cm (Brand B). This is an indication that brands A, B and C contain mineral additives. The very low conductivity values obtained for sample D showed that the source of water for the production did not undergo any further modification before bottling.

TDS above the WHO upper limit of 500 mg/L affect the taste of drinking water negatively and not considered fit for drinking purpose. TDS in the studied samples range from a very low 5 mg/L (Brand D) to 135 mg/L (Brand B) which are much lower than SON specified standard. The conductance and TDS of brand D is a pointer to the fact that demineralization was carried out to more than the desirable limit. Consumption of water low in mineral content can lead to excretion of huge amount of calcium, magnesium and other trace minerals in urine. The more the mineral loss, the greater the risk of high blood pressure, coronary artery disease, hypothyroidism, osteoporosis, etc. [22].

Copper is an essential element for living organisms, including humans, and in small amounts necessary in our diet to ensure good health. However, too much copper can cause adverse health effects, including vomiting, diarrhea, stomach cramps and nausea. It has also been associated with liver damage and kidney disease. The human body has a natural mechanism for maintaining the proper level of copper in it. However, children under one year old have not yet developed this mechanism and, as a result, are more vulnerable to the toxic effects of copper. People with Wilson's disease also have a problem with maintaining proper copper balance and should exercise particular care in limiting exposure to copper [2].

Iron is not hazardous to health but is considered a secondary or aesthetic contaminant. Zinc is an essential element and has a dietary value as a trace element. It is generally considered non-toxic. Zinc concentrations in water above 5.0 mg/L tend to be opalescent, develops a greasy film when boiled, and has an undesirable astringent taste [9]. In all the analyzed bottled water samples, the concentrations of these heavy metals were well below the stipulated maximum concentration.

Chloride ions concentration in the samples was determined to vary from 0.00 to 0.13 mg/L for all bottled water samples with the higher values occurring in the second week in Brands A and D. These results are well below the maximum permissible concentration of 250 mg/L desirable for drinking water. This limit was been laid down primarily based on taste considerations.

High nitrate concentration in drinking water usually indicates possible microbial contamination. Results from the analysis of nine bottled water brands collected from retail and food shops around University of Dhaka showed high nitrate concentrations of 72.93 mg/L and 110.66 mg/L in two of the studied brands [23]. This indicated high levels of microbial contamination in the two bottled water brands. Nitrate ion concentration in all the brands in this study ranged between 0.00 to 8.30 mg/L which are below SON maximum permissible concentration of 50 mg/L for drinking water. The lowest nitrate concentration was found in brand C while brand B had the highest concentration. This is an indication of a general fair level of hygiene in the production areas.

The physicochemical data on the quality of the bottle water brands in Table 1 were statistically analyzed to evaluate the consistency in quality over a six-week period. The results obtained are shown in Tables 2 and 3.

Table 2. Statistical Analysis of Bottled Water Brands A and B

Parameters	Brand A						Brand B						SON
	Min	Max	Range	Mean	SD	CV (%)	Min	Max	Range	Mean	SD	CV (%)	
pH	7.24	7.53	0.29	7.35	0.16	2	7.16	7.40	0.24	7.28	7.28	2	6.5-8.5
Conductivity (µS/cm)	120	130	10	127	6	5	270	270	0	270	0	0	1000
TDS (mg/L)	60	65	5	63	3	5	135	135	0	135	0	0	500
Zinc (mg/L)	0.18	0.27	0.09	0.23	0.05	20	0.1	0.22	0.12	0.16	0.06	38	3.00
Copper (mg/L)	0.02	0.07	0.05	0.04	0.03	58	0.00	0.02	0.02	0.01	0.01	100	1.00
Iron (mg/L)	0.00	0.02	0.02	0.01	0.01	100	0.00	0.02	0.02	0.01	0.01	120	0.30
Nitrates (mg/L)	1.70	7.90	6.20	5.00	3.12	62	1.40	8.30	6.90	5.70	3.75	66	50
Chlorides (mg/L)	0.02	0.12	0.10	0.06	0.05	89	0.00	0.02	0.02	0.01	0.01	100	250

Min – Minimum; Max – Maximum; SD - Standard deviation; CV - Coefficient of Variation

Table 3. Statistical Analysis of Bottled Water Brands C and D

Parameters	Brand C						Brand D						SON
	Min	Max	Range	Mean	SD	CV (%)	Min	Max	Range	Mean	SD	CV (%)	
pH	7.25	7.41	0.16	7.34	0.08	1	6.65	6.90	0.25	6.76	0.13	2	6.5-8.5
Conductivity (µS/cm)	200	200	0	200	0	0	10	10	0	10	0	0	1000
TDS (mg/L)	100	100	0	100	0	0	5	5	0	5	0	0	500
Zinc (mg/L)	0.14	0.23	0.09	0.17	0.05	29	0.21	0.31	0.1	0.27	0.05	20	3.00
Copper (mg/L)	0.01	0.05	0.04	0.04	0.02	58	0.00	0.03	0.03	0.01	0.02	115	1.00
Iron (mg/L)	0.00	0.01	0.01	0.00	0.01	0	0.00	0.02	0.02	0.01	0.01	100	0.30
Nitrates (mg/L)	0.00	2.40	2.40	1.37	1.23	90	0.00	5.40	5.40	2.83	2.71	96	50
Chlorides (mg/L)	0.00	0.02	0.02	0.01	0.01	100	0.00	0.13	0.13	0.04	0.08	173	250

Min - Minimum; Max - Maximum; SD - Standard deviation; CV - Coefficient of Variation

In brand A, the pH, conductivity and TDS had a low coefficient of variation (< 5.0 %). This indicated that these values were fairly constant throughout the period of study. Nitrate, chloride and copper concentrations had a high coefficient of variation, indicating obvious changes in their concentrations during the period of study. Iron concentration had a coefficient of variation of 100%. In the second week, iron was not detected in Brand A but was present in the first and third weeks. This showed that the iron found in the samples was not from the water table but could have been introduced during the production process. The high variation in chloride concentration indicated that the chloride used in the water purification or mineral additive sources needs to be properly regulated.

The pH and TDS of brand B and brand C were constant throughout the period of study. Copper and iron were not detected in brand B in some of the weeks suggesting that they were introduced into the products from point sources during the packaging process. Brand C showed a possible point source contamination for iron. The presence of copper in this brand, however, was detected in all the weeks, giving an indication that the pollution might have come from the groundwater. pH and TDS for Brand D were constant over the weeks. The variation in copper and iron concentrations over the weeks in this brand suggested that they were introduced from point sources.

Nitrate concentrations in all the studied brands were well below the specified SON standards. However, the concentration ranges in all the brands were wide, giving an indication that there is inconsistency in the maintenance of sanitary conditions in the packaging areas.

4. Conclusion

The study showed that the analyzed bottled water brands collected from major supermarkets in Owerri Municipal were of good quality and met the SON's drinking water quality specifications for the tested parameters. Quality control units in some of these companies should include concentrations of mineral elements in their labeling to effectively monitor the courses of unexpected changes in ion concentrations or appearance of fugitive ions during packaging in the finished products.

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