Water quality assessment of selected bottled water brands in Gidan Kwano Area using Bottled Water Quality Index

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Abstract

The health implication of consuming packaged water of compromised quality necessitates a need for their assessment with a tool that can be understood by all. Thus, this study aims at determining the potability of selected brands of bottled water in Gidan Kwano Area using Bottled Water Quality Index (BWQI). Samples of six brands of bottled water were collected and analysed for six chemical parameters (pH, Conductivity at 24^{O}C, Nitrates, Nitrites, Chloride, Sulphates) and one microbiological parameter (E. coli). The results of the laboratory analysis were compared with Nigerian Standard for Drinking Water Quality (NSDWQ) and World Health Organisation (WHO). The results were also used for the computation of BWQI. The results of the physicochemical and microbiological parameters showed good quality status of the six brands as all the parameters were within the established limits of NSDWQ and WHO. The respective results (0.9, 0.88, 0.87. 0.84, 0.86 and 0.88) of the BWQI for the six brands assessed showed that while five brands representing 83.33 % can be ranked as excellent, the remaining one which represent 16.67 % had a rating of adequate/good quality. This implies that all the brands are suitable for drinking.

Keywords: Bottled water, Gidan Kwano, Physicochemical parameter, Water quality index

Introduction

Good quality of drinking water to be supplied to the ever increasing urban population is essential due to the negative consequences of the otherwise on the individual and public health (Onweluzo and Akuagbazie, 2010; Abdul Rasaq *et al.,* 2009; Mishra, *et al.,* 2009). Though, the quantity of fresh water system available in some developing nations such as Nigeria is such that can serve the existing population, access to safe drinking ones is still posing serious challenge. Provision of potable water for both the rural and urban populace is very paramount and thus was considered as part of millennium goal that ought to have been achieved by the developing nations. However, its accomplishment is still a mirage as the large rural dwellers are not captured in water supply schemes. The urban areas are though better they are also not free of challenges as they are confronted with either the problem of insufficient quantity or questionable quality of water supply (WSMP, 2008).

How much a water supply will be appreciated by the urban populace depends largely on the quality of the water. This implies that, aside the issue of quantity, bad quality of water supply is another reason why people in recent time try to source for alternative sources of drinking water. Though, problem of water quality seems to be an issue in virtually all the developing countries, it is more pronounced in some. While about 1.2 billion people lack access to potable water worldwide, about 130.2 million; representing 70% of the Nigerian populace lack access to clean drinking water (Mustapha *et al.,* 2015).

In Nigeria, the emergence of packaged water has greatly helped in reducing the insecurity associated with domestic drinking water supply which is one of the objectives millennium development goals (MDGs) aims to achieve (Mustapha *et al.,* 2015). However, due to high patronage of the packaged water by consumers which makes many producers aim at producing more than their capacity in an attempt to maximize profit, coupled with laxity on the side of the National Agency in charge of food control, the packaged water is becoming a threat to the health of man. Onweluzo and Akuagbazie (2010) agreed with the Institute of Public Health Analyst (IPAN) which mentioned that 50% of the "pure water" sold in the streets of Lagos may not be fit for human consumption and many other places in Nigeria are not also exempted. This has prompted a number of researches (such as Onweluzo, and Akuagbazie, [2010]; Maduka *et al.* [2014]; and Mustapha *et al.* [2015]) to assess the physicochemical and bacteriological parameters of packaged water. The results of their findings revealed that not all packaged water are fit for drinking.

Recently, Water Quality Index (WQI) has been proposed for the assessment of bottled water just as several indices had and are being developed for surface and groundwater. The first of its kind was developed by Toma *et al.* (2013), which prompted a more scientific one developed by Tsakiris (2016). WQI is based on comparison of the water quality parameters with respect to regulatory standards to give a single value to the water quality of a source which represent the overall water quality of the source (Ahaneku and Animashaun, 2013). They are intended to be used by both decision makers and stakeholders for quick and efficient decisions regarding water quality issues (Tsakiris, 2016). Tsakiri *et al.* (2017) claimed that no significant work has been documented in the developing world on bottled water quality indices as they are considered water of high quality. This study thus aims at assessing the drinking water quality of some bottled water consumed in Gidan Kwano, Niger State using Bottled Water Quality Index (BWQI) developed by Tsakiris (2016).

2. Materials and Methods

2.1 Description of the Study Area

The study was conducted in Gidan Kwano, Minna Niger State Nigeria. The geographical coordinates of the area are between latitude 9^0 15' to 45^0 N and longitude 6^0 15' to 6^0 45'E covering about 13,930 km^2 (Enokela *et al.,* 2012). Gidan Kwano has a special savannah climate with distinct rainy and dry seasons. The dry season usually starts between October/November and ends at about march/April while the rainy season starts at about April/May through September/October. Temperature prevailing in the area is generally high with values ranging from 24^0C to $35^0$with an annual mean of about 30^0C. Gidan Kwano community where main campus of Federal University of Technology, Minna is situated in the area is located has an average rainfall of 250 mm (NSG, 2007). The sources of water in the area are bore-holes, wells and river. The drying up of the river in the dry season do aggravate seasonal water scarcity (Enokela *et al.,* 2012).

2.2 Sample Collection

Three samples were randomly selected from six brands of bottled water sold in Gidan Kwano area. The samples were taken to laboratory of the Department of Water Resources, Aquaculture and Fisheries Technology (WAFT), Federal University of Technology Minna, Nigeria for analysis. The brands of the bottled water collected are the most readily available and consumed within the area. Of the six brands, only two are produced within the state, the remaining four are brought from other states. All the samples considered were selected after ensuring compliance with the required information as highlighted by Mustapha *et al.* (2015) The information are Producer's name, contacts, batch number, nutritional information, manufacturing date, expiration date and NAFDAC registration number.

2.3 Determination of physicochemical parameters

Six chemical parameters were determined using standard methods recommended by the American Public Health Association, APHA (1995). The parameters were Electrical Conductivity, pH, Nitrates, Nitrites, Chlorides and Sulphates. The assessed parameters were compared with World Health Organization (WHO) and Nigeria Standard for Drinking Water Quality (NSDWQ). Three physical parameters (colour, taste and odour) were also observed but not used for BWQI computation.

2.4 Determination of Bottled Water Quality Index (BWQI)

BWQI is done from the point of view of its suitability for human consumption. The index consists of two stages. The first stage is an ON/OFF process which test the bottled water sample on two requirements fulfillment: (a) lack of population of the bacteria (*Escherichia coli)* and (b) having pH values with the range of 6.5 and 9.5. Upon the fulfillment of these two requirements, the evaluation procedure continues from the first stage to second stage, which is established on a multiplicative model using five sub-indices with their corresponding exponents. The five sub-indices (SI) denote the following five physicochemical parameters: nitrates (NO_3^-), nitrites (NO_2^-), chloride (Cl^-), sulphates (SO_4^{2-}) and electrical conductivity (EC) at a temperature of 20°C. This multiplicative process is expressed with the equation 1 below (Tsakiri *et al.,* 2017):

$$BWQI = \prod_{i=1}^{N} SI^{\lambda i} \quad (1)$$

Where the exponents (λi) denote sensitivity coefficients and represent the sensitivity of each sub-index (SI) in the final index, N stands for the total number of sub-indices partaking in the multiplicative procedure. It is worth mentioning that due to the multiplicative character of the index, the BWQI is very sensitive to each of the carefully chosen parameters. More so, each coefficient of sensitivity is increased by 20 percent, in an attempt to increase the impact of each sub-index on the final index. Hence, the coefficients of sensitivity for the multiplicative model of BWQI are $\lambda 1=\lambda 2=0.30$, $\lambda 3=\lambda 4=0.20$, $\lambda 5=0.20$ (Tsakiri *et al.,* 2017).

2.4 Quality Parameters and Sub-Indices

The selection of the parameters and the transformation process of the absolute values of the quality parameters into sub-indices is evidently the most critical issue in the development of the BWQI (Tsakiris, 2016). When selecting the parameters to be included in any proposed index for water quality index development, hardly can the issue of subjectivity be avoided. To decide which parameters to include and their severity of impact, experts based knowledge approach was adopted along with a thorough bibliographic analysis on the subject (Tsakiris, 2016). In regard to the transformation of the absolute values of the parameters to standardized values in the same scale 0-1, the membership function method, used in fuzzy set theory was employed. According to this method, the absolute values covering a range within the permissible boundaries are transformed by the membership function to values between 0 and 1. Triangular or trapezoidal types of membership functions are used for the parameters of *E. Coli*, pH, nitrates, nitrites, chloride, sulphates and electrical conductivity (20 °C), respectively. It can be observed that if the absolute value is out of the allowable interval, the standardised value becomes zero. Due to the ON/OFF process (first stage) or the multiplicative model (second stage). This implies that the final BWQI will become zero since one of the sub-index is zero. The basic assumptions for the development of the BWQI are:

(a) The bottled water is generally of good or excellent quality and there is no need to test it towards indicators which represent severe pollutants (such as DO, BOD, turbidity). However, for security reasons one microbiological parameter (concentration of bacteria *E. coli*) was included in the first stage process of the BWQI. The same applies to *pH*, for which the bottled water has to fulfil the criteria 6.5≤pH≤9.5.

b) The bottled water is consumed continuously for long time by different people irrespective of their age, gender, health status. Based on these assumptions the proposed index has to be relatively general and fulfil the requirements of potable water (such as European Parliament and of the Council directives (EC), World Health Organisation (WHO) standards). These legislative documents were used for determining the boundaries of values above which the water is not appropriate for human consumption. Based on these thoughts the maximum allowable concentrations for the selected parameters of the BWQI are given in Table 1.

Table 1. Maximum allowable limits of drinking and BWQI parameters of EC (98/83) WHO (2011) and NSDWQ (2004)

Parameter	Stage	EC	WHO	NSDQW
Escherichia Coli	1	0.0 Number/250ML	0.0 CFU/100ml	
pH	1	6.5-9.5	6.5 – 8.5	6.5 – 8.5
Nitrates	2	50 mg/L	45 mg/L	50 mg/L
Nitrites	2	5 mg/L	1.0 mg/L	0.2 mg/L
Chloride	2	250 mg/L	250 mg/L	250 mg/L
Sulphates	2	250 mg/L	250 mg/L	250 mg/L
Electrical Conductivity at 20^oC	2	2500 µS/cm	250 µS/cm	1000 µS/cm

Sources Tsakiris, 2016; Ahaneku and Animashaun, 2013

c) The selected parameters involved in the multiplicative model belong to three categories with respect to their severity (Table 2). It is assumed that the nitrates and nitrites the belong to the first severity class (3). In the second class of severity (2) are chloride and sulphates and in the third class of severity (1) several salts (e.g. Ca^{++}, Na^+, K^+ etc.) represented by the electrical conductivity. It is also assumed that the first (highest) severity class has a triple impact on the final index in comparison to the third (lowest) severity class. Also, the second (medium) severity class has a double impact on the final index in comparison to the third (lowest) severity class. Finally, it is assumed that the sub-indices of the same severity class have the same coefficient of sensitivity (Tsakiris, 2016; Tsakiri *et al.* 2017).

Table 2. *Selected parameters of the BWQI and their severity class Table*

Parameters	Severity Class
Escherichia Coli	3
pH	2
Nitrates	3
Nitrites	3
Chlorides	2
Sulphates	2
Electrical Conductivity at 20^oC	1

Sources Tsakiris, 2016

The above theoretical background forms the basis upon which BWQI calculator was built to facilitate easy and quick computation (Tsakiris, 2016). The index for each of the brands under consideration was established using BWQI calculator which was built on the above mentioned assumption and equation. Water Quality Index is rated between 0 and 1(Table 3), with 1 being the highest rating of quality

Table 3. Bottled Water Quality Index Rating

BWQI	BQWI Rating
0.85 – 1.00	Excellent Quality
0.70 – 0.85	Adequate/good Quality
< *0.70*	Unacceptable Quality

Source: Tsakiris, 2016

3.0 Results and Discussion

3.1 Physicochemical Analysis

The mean value of the results of each of the brands was determined and compared with the standards of WHO and NSDWQ. All the samples were odourless, colourless and tasteless. pH is a measure of the hydrogen and hydroxyl ions in water. While acidic water has more hydrogen ions basic water is richer in hydroxyl ions. pH value of water is thus a function of the quantity of chemicals in water (Ahaneku and Animashaun, 2013). None of the bottled waters sampled was beyond the accepted standard range of between 6.5 and 8.5 by both WHO and NSDWQ. The samples have a pH value that ranges between 7.02 and 7.99. While sample six has the highest value (7.99), the lowest was recorded in sample 3. The pH value recorded in this study is higher than some of the values (5.52) reported by Taiwo *et al.* (2010), it is however in line with the values recorded by Onweluzo and Akuagbazie (2010) and Hussein *et al.* (2014). Electrical conductivity is a measure of the current flowing capacity of the water. The presence of dissolved chemical has influence on the rate of flow of electrical current. Therefore, the quality of water is reflected by its electrical conductivity value. Sample 5 has the highest electrical conductivity of 100 µS/cm while sample six has the lowest with 3µS/cm. However, all the values obtained were within the permissible value WHO and NSDWQ (Table 1).

Table 4. Chemical and Bacteriological parameters of the six bottled water samples

	pH	EC(µs/cm) @24ºC	NO_3^- (mg/L)	NO_2^- (mg/L)	Cl^- (mg/L)	SO_4^{2-} (mg/L)	*E. coli* (CFU /100ml)
Sample 1	7.64 ±0.03	21 ±5.13	3.10 ±0.03	0	9.64 ±0.10	77.2 ±5.55	0
Sample 2	7.50 ±0.26	24 ±5.89	1.30 ±0.02	0	12.5 ±1.01	106 ±8.45	0
Sample 3	7.02 ±0.1	69 ±12.01	3.10 ±0.1	0	12.22 ±0.83	98 ±2.35	0
Sample 4	7.09 ±0.08	66 ±7.78	1.4 ±0.11	0.5 ±0.02	11.54 ±0.56	115 ±10.57	0
Sample 5	7.06 ±0.15	100 ±20.09	1.85 ±0.05	0	19.29 ±1.05	111 ±15.40	0
Sample 6	7.99 ±0.02	3 ±0.11	0.5 0.021	0	17.36 ±1.02	106 ±6.67	0

The Chloride values recorded for samples one to six were 9.64 mg/L, 12.5 mg/L, 12.22 mg/L, 11.54 mg/L, 19.29mg/L and 17.36mg/L respectively. They are all within the permissible values of WHO and NSDWQ. The results agreed with the values obtained by Taiwo *et al.* (2010). Potability of water also depend on nitrate value. Higher nitrate values of water indicate pollution by organic matter (Chauhan and Singh, 2010). The Nitrate values for samples 1 to 6 were 3.1 mg/L, 1.3 mg/L, 3.1 mg/L, 1.4 mg/L, 1.85 mg/L, and 0.5 mg/L respectively. All the values were within WHO (45mg/L) and NSDWQ (50 mg/L). Nitrites is as important as nitrate as a water parameter, its excess in water is dangerous to health of man especially babies (USEPA, 2001). Virtually all the samples were free of Nitrite except for sample four which has a value of 0.05 mg/L. The value is nevertheless below the established limits of WHO (1.0mg/L) and NSDWQ (0.2 mg/L). Presence of Sulphate in water causes odour, diarrhea, and gastrointestinal problems. The minimum and maximum Sulphate values obtained were 77.2 mg/L and 115 mg/L respectively. The values were within the established limits (250mg/L) of WHO. These results agree with earlier reports which noted the presence of sulphate in bottled water (Onweluzo and Akuagbazie ,2010; Hussein *et al.,* 2014; Taiwo *et al.*, 2010). Each of the sampled bottled water was free of *E-coli*. This is an indication of good water quality status of all the bottled water. There is zero tolerance for E. coli in bottled as its presence suffice to render the water unsafe.

3.2 Bottled Water Quality Index

The results of the laboratory analysis of the water quality parameters were computed for BWQI using EU standard. Bottled Water Quality Index for each of the six brands available in the study area was established using the physicochemical and microbiological parameters. The water quality index scores of samples one to six were 0.9, 0.88, 0.87. 0.84, 0.86 and 0.88 respectively (Figure 1). Five out of the six samples representing 83.33 % are rated as excellent, while sample four which represent 16.67 % had a rating of adequate/good score. This result showed a slight variation with the findings of Tsakiri *et al.* (2017) having 75 % of the samples classified as excellent, 11 % as good and the remaining 14 % rated as unacceptable.

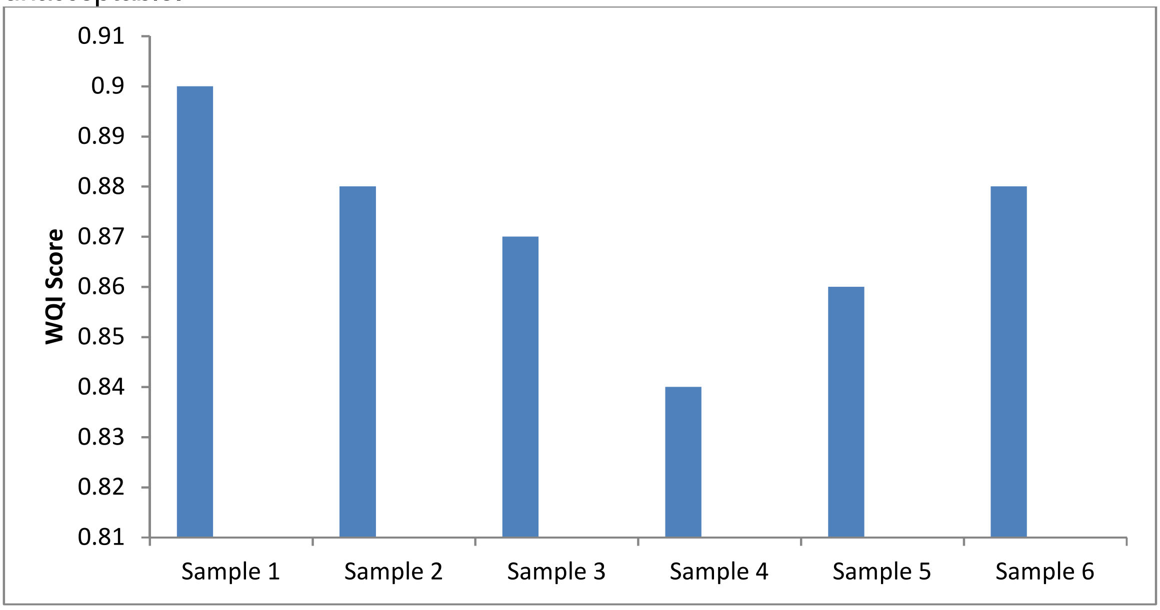

Figure 1: Bottled Water Quality Index rating for the six brands

4.0 Conclusion

Water quality parameters of bottled water consumed around the Gindan Kwano Area were assessed and the water quality index was established using bottled water quality index. The result of the findings showed that bottled water consumed around the area can be considered safe and healthy, as they all have water quality index rating of excellent except for sample four which falls below the excellent rating. It is however having an index rating within the range of adequate/good water quality and hence, they are all suitable for drinking.

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