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Characterization of Bottled Water Quality Using Water Quality Index in Minna Metropolis of Niger State, Nigeria

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ABSTRACT
Random samples of bottled drinking water in Minna metropolis were collected and analyzed using water quality index. This study was carried out to characterize the bottled drinking water using water quality index so as to assess the suitability of bottled drinking water from different sources with the study area. Ten samples were purchased at the sources of production for four consecutive months of April, May, June and July 2019 and analyzed for pH, Calcium, Total Hardness, Total Alkalinity, Chlorides, Magnesium, Sulphate, Nitrate, Iron, and Manganese. The results show that all the parameters analysed were all within the permissible limits of World Health Organization. The results obtained for the WQI from the different bottled water products were found to be varied from 4.96 to 21.65. These results indicate that the all the bottled water samples analyzed are safe for human consumption and for other domestic purposes. Effort should, however, be made to ensure the sustainability of the current method of bottled water production within the metropolis.

Keywords: *Water quality index, bottled water, physiochemical properties, Minna.*

1 INTRODUCTION

Water is an essential natural resource for sustainability of life on earth. Humans may survive for several weeks without food, but barely few days without water because constant supply of water is needed to replenish the fluids lost through normal physiological activities, such as respiration, perspiration, urination, (Murray *et al.*, 2003). Though the hydrosphere is estimated to contain about 1.36 billion Km^3, only about 0.3% of the water, existing as fresh water in rivers, streams springs and aquifers, is available for human use; the remaining 99.7% is locked up in seas and oceans (Adekalu *et al.*, 2002). The world health organization (WHO) defines domestic water as 'water used for all usual domestic purposes including drinking, cooking, bathing and washing' (WHO, 2000). Quality of drinking water indicates the suitability of water for human consumption. The quality of drinking water is dependent upon its composition which is determined by natural processes and human activities in the environment where any water can be accessed. This quality is assessed through three basic water characteristics. They are the physical, chemical and microbial characteristics of water which must be maintained within certain limits for a sustained human health.

The majority of the Nigerian populace, particularly in the northern part of Nigeria does not have access to potable water and therefore, depend on raw water from wells, streams and rivers for drinking and other domestic uses (Shittu et al. 2009; Owamah et al. 2013; Babagana et al., 2018). But the related diseases to this naturally occurring sources of water has forced many of the populace to seek refuge in bottled and packaged water which are majorly believed to be of good quality. In many developing countries, numerous brands of bottled water and the relatively cheaper counterpart, sachet water, can be found in all cities, towns, and even villages.

The development of water quality index (WQI) for drinking water characterization has been described in several studies (Kumar et al., 2015; Saleem et al., 2016; Sulaiman et al., 2018; Mgbenu and Egbueri 2019).The WQI to represent gradation in water quality was first proposed by Horten (1965). Water quality index gives an indication of a single number that expresses the overall water quality at a certain area and time based on several water quality parameters (Roy and Gupta, 2012). WQI reflects a composite influence of contributing factors on the quality of water for any water system. Ramakrishnaiah et al (2009) described WQI as one of the most effective tools to communicate information on the quality of water to the concerned citizens and policy makers. WQI is thus computed to reduce the large amount of water quality data to a simple numerical value that articulates the whole water quality based on different water quality parameters. The aim, therefore, is to turn complex water quality data in to information that is easily understandable and useable by the public.

In this study, drinking water quality of Minna metropolis of Niger State were analyzed to determine current status of access to safe drinking water and required measures to be taken to meet demand. The quality of water available from some randomly selected Pure Water and Bottled Water factories in both metropolis were monitored by the physical, chemical and biological parameters of the water samples collected. Results obtained were used to determine the safety levels of the available water sources and parameters that need to be addressed towards achieving a safe and sustainable drinking water sources were identified.

2 METHODOLOGY

Minna is the capital city of Niger State, Nigeria. It has a population of 321,687 as at 2007. The straight distance between Minna and Abuja is 118 kilometers (74 miles). Minna is located at latitude 9.6152°N and longitude 6.5478°E, in the northern hemisphere. It consists of two major ethnic groups; the Nupe and the Gbagyi (11). The average weather situation is thus; Temperature 26°C, Wind (W) at 11 km/h, with 80% humidity.

2.1 SAMPLING AND EXPERIMENTAL METHOD

Random samples of bottled drinking water in Minna metropolis were collected and analysed using water quality index. Ten samples were purchased at the sources of production for four consecutive months of April, May, June and July 2019. The average of the results for these months was used in the WQI analysis. The analyses of various physical and chemical parameters such as pH, Calcium, Total Hardness, Total Alkalinity, Chlorides, Sulphate, Nitrate, Potassium, Sodium, Turbidity, COD, Dissolved Oxygen, Iron, Manganese and Electrical Conductivity were carried out according to descriptions by APHA (1992).

In this study, three steps of water quality index were followed. In the first step each of the parameters (Calcium, Magnesium, Chloride, Sulphate, Total Hardnes, Nitrate, Total Dissolved Solids, Alkalinity) was assigned a weight (*wi*) according to its relative importance on the comprehensive quality of water which range from 1 to 5. The maximum weight of 5 were assigned to the parameter which influence more significantly the water quality and minimum weight of 1 is selected to the least regnant the water Quality.

2.4 CALCULATION OF WQI

The Water Quality Index (WQI) was calculated using the Weighted Arithmetic Index method. The quality rating scale for each parameter qi was calculated by using this expression in equation 1

$$qi = (Ci/Si)\times 100 \qquad [1]$$

A quality rating scale (qi) for each parameter is assigned by dividing its concentration (Ci) in each water sample by its respective standard (Si) and the result multiplied by 100. Relative weight (Wi) was calculated by a value inversely proportional to the recommended standard (Si) of the corresponding parameter in equation 2

$$Wi = 1/Si \qquad [2]$$

The overall Water Quality Index (WQI) was calculated by aggregating the quality rating (Qi) with unit weight (Wi) linearly as shown in equation 3

$$WQI = \left(\sum_{l=1}^{i=n} W_i q_i\right) \qquad [3]$$

The suitability of WQI values for human consumption is as presented in Table 1, according to Asuquo and Etim (2012).

TABLE 1: WATER QUALITY INDEX AND WATER QUALITY STATUS

WQI	STATUS
0-25	Excellent
26-50	Good
51-75	Poor
76-100	Very Poor
Above 100	Unsuitable for drinking

Source; Brown et al (1972), Chatterji and Raziuddin (2002).

3 RESULTS AND DISCUSSION

3.1 MINNA SAMPLING

Tables 2, 3 and 4 represent the estimated values of WQI for three of the ten sampled bottled water in Minna metropolis. The Tables also presented the parameters used in the analysis and the subsequent calculation of WQI. Table 5 presents the WQI values of all the sampled bottle water in the study area. From Table 2, the WQI for the EBW bottled water sample was recorded as 4.96, which according to Table 1, is observed to be excellent in terms of its status and water quality standard. Table 3 represents the WQI analysis of NBW bottled water sample where WQI was observed to be 21.76. According to Table 1, NBW was observed to be of good quality based on its status and it is very suitable for drinking. The same pattern was observed in Table 4 for SBW where the WQI was obtained as 7.79 which is also observed to be excellent as regards its status based on Table 1. The remaining bottled water samples were also analysed and their results summarized and presented in Table 5 which shows the overall WQI values for all the bottled water samples in Minna metropolis. From the estimated WQI values, all the values estimated range from 4.96 for EvBW sample to 21.76 for NBW sample. This shows that the bottled water products in Minna metropolis all fall within the acceptable water quality standard and therefore, portable and good for drinking purposes. Looking at the components of WQI, the pH of the aquatic systems is an important indicator of the water quality and the extent of pollution in the water samples. Results obtained for the average pH values in the sampled bottled water samples varied between 6.72 and 6.78 as shown in Tables 2 to 4. This shows that the average pH values fall within the permissible limit of 6.50-8.0 as stipulated by World Health Organization (ICMR 1975; WHO 2000). The level of pH values in water samples is attributed to the levels of concentration of calcium, magnesium and total alkalinity in the water. This, therefore, depicts that there is moderate level of these parameters in the samples obtained within the study area. With the WQI values for all the bottled water samples far below the permissible limit for drinking water, this suggests that the parameters analysed and used in the WQI analyses were all within the allowable minimum standards.

TABLE 2: COMPUTED WQI FOR BOTTLED WATER *EVBW*

M/N	PH	Cond (mg/L)	TA (mg/L)	TH (mg/L)	Cl^- (mg/L)	Ca (mg/L)	Mg (mg/L)	NO3 (mg/L)	SO_4^2 (mg/L)	Fe (mg/L)	Mn (mg/L)	
April	6.77	246	29	21	14	7.99	0.26	1.29	0.89	0.06	0.01	
May	7.33	80	13	44	43.49	3.36	5.69	0.86	5.37	0.01	ND	
June	6.88	88	18	42	41.22	3.8	1.55	0.64	6.21	0.03	ND	
July	7.21	84	18	44	41.6	4.1	1.64	0.58	6.28	0.01	ND	
Obs. V.	7.05	124.5	19.5	37.75	35.08	4.81	2.29	0.84	4.69	0.03	0.003	
St. V.	8.5	1000	120	150	250	200	20	50	100	0.3	0.2	
Wi	0.014	0.0001	1E-03	8E-04	5E-04	0.001	0.006	0.002	0.0012	0.39	0.58	0.996
Qi	3.33	12.45	16.25	25.17	14.03	2.41	11.45	1.68	4.69	10	1.5	
QiWi	0.047	0.0015	0.016	0.02	0.007	0.002	0.07	0.003	0.0056	3.9	0.87	4.938

$$WQI = \frac{\sum Q_i w_i}{\sum w_i} = \frac{4.938}{0.996} = 4.96$$

TABLE 3: COMPUTED WQI FOR BOTTLED WATER ***NBW***

M/N	PH	Cond (mg/L)	TA (mg/L)	TH (mg/L)	Cl^- (mg/L)	Ca (mg/L)	Mg (mg/L)	NO3 (mg/L)	SO_4^{2} (mg/L)	Fe (mg/L)	Mn (mg/L)	
April	6.72	370	12	22	48.27	7.57	0.76	1.38	1.34	0.13	ND	
May	6.74	276	14	84	38.61	33.6	2.4	1.06	4.47	0.15	0.03	
June	6.64	259	10	80	34.18	30.25	6.3	0.88	3.88	0.07	0.03	
July	6.96	262	12	65	38	30.74	5.9	0.86	3.75	0.05	0.01	
Obs. V.	6.77	292	12	63	40	26	3.84	1.05	3.36	0.1	0.03	
St. V.	8.5	1000	120	150	250	200	20	50	100	0.3	0.2	
Wi	0.014	0.00012	0.001	0.0008	0.0005	0.0006	0.0058	0.002	0.0012	0.39	0.58	0.996
Qi	-15.33	29.2	10	42	16	13	19.2	2.1	3.36	33.33	15	
QiWi	-0.215	0.0035	0.0097	0.034	0.008	0.0078	0.1114	0.004	0.004	13	8.7	21.67

$$WQI = \frac{\sum Q_i w_i}{\sum w_i} = \frac{21.67}{0.996} = \mathbf{21.76}$$

TABLE 4: COMPUTED WQI FOR BOTTLED WATER ***SBW***

M/N	PH	Cond (mg/L)	TA (mg/L)	TH (mg/L)	Cl^- (mg/L)	Ca (mg/L)	Mg (mg/L)	NO3 (mg/L)	SO_4^{2} (mg/L)	Fe (mg/L)	Mn (mg/L)	$\sum^{N}$
April	6.78	350	9	22	13.03	5.05	2.29	1.29	2.24	0.07	ND	
May	7.04	78	20	34	13.03	10.09	2.15	1.22	3.58	0.03	0.01	
June	7.4	84	16	36	14.36	11.84	3.18	0.92	4.25	0.01	0.01	
July	7.24	88	14	36	16.3	12.6	4	0.84	4.2	0.03	0.01	
Obs. V.	7.12	150	14.75	32	14.18	39.58	2.91	1.07	3.57	0.04	0.008	
St. V.	8.5	1000	120	150	250	200	20	50	100	0.3	0.2	
Wi	0.014	0.0001	0.00097	0.0008	0.0005	0.0006	0.0058	0.002	0.0012	0.39	0.58	0.996
Qi	8	15	12.29	21.33	5.67	19.79	14.55	2.14	3.57	13.33	4	
QiWi	0.112	0.0018	0.012	0.017	0.0028	0.011	0.084	0.004	0.0043	5.199	2.32	7.768

$$WQI = \frac{\sum Q_i w_i}{\sum w_i} = \frac{7.768}{0.996} = 7.79$$

TABLE 5: WQI VALUES OF THE BOTTLED WATER SAMPLES

Bottled Water Sample	WQI
EvBW	4.96
NBW	21.76
SBW	7.8
YBW	11.59
LBW	9.58
VBW	6.82
HBW	8.24
FRBW	21.65
GBW	17.64
FBW	10.81

4.0 CONCLUSION

The 10 bottled water samples collected randomly within Minna metropolis were characterized using WQI for the purpose of determining their suitability for drinking purposes. The use of WQI in characterizing drinking water quality which involves assembling different parameters into one single number has proven to be an easy way interpreting and characterizing water samples and this has helped in providing an important tool for water management purposes. With the suitability of these sampled bottled water confirmed, efforts should be made by the relevant authorities in the stat to ensure the sustainability of this feat in keeping the consumers of these products safe.

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