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ASSESSMENT OF WATER QUALITY OF BOSSO WATER-BOARD USING WEIGHTED ARITHMETIC INDEX METHOD

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ABSTRACT

Information on a method that can be used to ascertain status of potable water consumed by the public is very important. Water from Bosso Water-board was assessed at the Water Board and at the consumer end using Weighted Arithmetic Index Method. Water samples collected were analyzed for twelve parameters (pH, Electrical conductivity, Chloride, Total dissolve solids, Iron, Alkalinity, Nitrite, Nitrate, Zinc, Phosphate and *E.coli)*. The results of the analysis were used in computing Water Quality Index. The index for Water-board, Location A, B, and C were 5.96, 119.13, 60.71 and 57.66, respectively. These results showed that water sample from Bosso Water-board is fit for drinking, but samples from the consumer end were unfit. The implication is that pipe borne water supply from the Board can pose threat to the health of public when consumed.

Keywords: Drinking Water Quality, Weighted Arithmetic Index, Water Quality Status, Bosso

INTRODUCTION

The dynamics of water and economic growth are very complex, and depend principally on some physicochemical parameters of water on one hand and on management practice on the other hand (Grey and Claudia, 2006). Water is an important factor for sustainable growth in virtually all aspect of human endeavour such as agriculture and industry- small, medium or large-. It is a vital resource that helps create healthy atmosphere giving room for environment with healthy people (Animashaun, 2014).

It is noted that a strong correlation exist between access to safe drinking water and economic growth. High accessibility to safe drinking water is liable to attracting increase in the rate of economic growth as costs of unsafe drinking water will be minimised (Fogden and Wood, 2009).

The economic costs incurred from lack of access to safe drinking water ranges from costs associated with treatment of water-related disease to costs related to time lost in search of potable water. The resultant effect of these lost is felt through low productivity resulting from ill-health of affected individuals or prematurely deceased of skilled man power (Paul Jagals 2015; Duffy, 2015). This often place a heavy burden on individuals and on the nation at large especially the developing ones (Fogden and Wood, 2009; Yongabi, 2010). Hence, there is a need to ensure good quality status of drinking water source in order to protect public health (Chang *et al*., 1999)

The issue of water supply is a function of the infrastructure costs involved in sourcing, cleaning and transporting drinking water (Fogden and Wood, 2009). The rise in these costs is mainly due to high pollution loading of pollutants entering the freshwater resources and the quantity of water needed to be supplied to the increasing households (Yongabi, 2010). Water usage per person per day varies with countries; while average person in developed countries uses approximately 200–800 liters per day, in developing nations 60–150 liters per day is reported (Fogden and Wood, 2009). Aside the quantity of water needed, there is a need to monitor the water source with a tool that would provide valuable information regarding source water health risks (Hurley *et al*., 2012).

Determination of Water Quality Index (WQI) for drinking source water is gaining popularity recently (Ahaneku and Animashaun, 2013). This is however not surprising, as index gives results that can be easily understood by both the experts in water resources and the public (Otache *et al*., 2015). WQI is a numeric expression used to transform large quantities of water parameters data into a single number that gives a reflection of the state of water (Sanchez *et al.*, 2007; Bordalo *et al.*, 2006). It assesses the appropriateness of the quality of the water for a variety of uses such as habitat for aquatic life, recreation and drinking water (Cude, 2001).

To this end, this study aimed at assessing drinking water quality of water supply from Bosso Water Board, Minna, Niger state and the water received at the consumer end using Weighted Arithmetic Index (WAI) method.

MATERIALS AND METHODS

Study Area

The location under study is Bosso Area of Bosso Local Government, Niger State. It has an area of 1,592km ^{2} and a populace of 147,359 as at 2006 (NSG, 2007). The area under consideration is within the water-board as the water supply from the board as a small coverage. The water-board was established around 1970 and has a storage capacity of 4200m^3 (Ogunjimi, 2014).

Bosso like other local government in Niger is characterised with dry and rainy season. The dry season usually occurs 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^{0}C to 35^{0}C with an annual mean of about 30^{0}C while average rainfall is about 250mm (NSG, 2007).

Methods

Water samples were collected from four sampling stations in Bosso Area which include the Bosso Water-board (Figure 1). The samples were collected using sterilized bottles and analysed for twelve physicochemical parameters (Table 1) using standard procedure of American Public Health Association, APHA (1995). The results of the analysis were compared with the established standard for drinking water quality by world health organization (WHO, 2004) and Nigeria standard for drinking water quality (NSDWQ, 2004). The results of the analysis of the parameters considered (except *E.coli*) were used in computing water quality index.

Determination of Water Quality Index

The relative importance of various parameters for Water Quality Index (WQI) for a water source depends on intended use of the water. In this study, WQI is computed from the point of view of its suitability for human consumption. The index was established using Weighted Arithmetic Index (WAI) method.

This index classified water quality according to the degree of purity by using the most commonly measured water quality variables. The considered variables are compared with their respective regulatory standards (Table 1) to give a single value used for the classification (Table 2) (Abbasi, 2002; Khan *et al.*, 2003).

Though, there are a number of methods, WAI was preferred because of its suitability for assessing a water source for human consumption (Shweta *et al*., 2013). The method has been widely adopted by various personnel in water resources. The index was computed using the following equations (Chauhan and Singh; 2010):

Water quality index

$$(WQI) = \sum Qi\mathrm{Wi} / \sum Wi \quad (1)$$

Qi is the quality rating scale for each parameter, which is calculated using the equation below

$$Qi = 100(Vi - Vo|Si - Vo) \quad (2)$$

Where;

V_i is the estimated concentration of the parameter in the analysed water

V_o is the ideal value of this parameter in pure water and it assumed a value of zero for all the parameters (except pH =7.0 and DO = 14.6mg/l)

S_i is the recommended standard value of parameter

Wi is the unit weight for each water quality parameter and it is calculated using the equation below

$$Wi = K/Si \quad (3)$$

Where,

K = proportionality constant and was calculated using the equation below

$$K = 1/\sum(\frac{1}{Si}) \quad (4)$$

RESULT AND DISCUSSION

The water samples were analysed for twelve physicochemical parameters and the results were compared with the established standards for drinking water by NSDWQ and WHO. pH value is a vital parameter when establishing the suitability of water for domestic use (Ahaneku and Animashaun, 2013). It was observed in the present study that water from Bosso Water Board has an average mean value of 7.49± 0.15and at the consumer end the samples have average mean values of 6.55± 0.10, 6.60± 0.52 and 6.58±0.17 for location A, B and C respectively (Table 3). Though, the variations in pH value is statistically significant at 5% , all the samples were within the permissible standard by World Health Organisation (WHO) and Nigeria standard for drinking water quality (NSDWQ).

Conductivity is a measure of current carrying capacity, as a function of concentration of available salt in water sample, thus as concentration of dissolve salt increases conductivity also increases. In this study, the average mean value of conductivity ranges from 76µs/cm to 124µs/cm (at water-board and consumers end). The result implies that the water is good as all the observed values falls within the prescribed limits by World Health Organization (WHO) and Nigeria Standard for Drinking Water Quality (NSDWQ).

Though, existence of chloride is expected in potable water, high concentration of the element is considered to be an indicator of pollution by sewage waste of animal origin as well as industrial waste. The average mean values for the Water Board and locations A, B and C are 75.84 mg/L, 20.68mg/L, 48.26mg/L and 45.26mg/L. The values were all within the permissible standard by WHO and NSDWQ

Total hardness above 300mg/L may cause deposition of scale in the distribution system and also result in excessive soap consumption and subsequent scam formation. The average mean of 28mg/L, 52mg/L, 40mg/L and 36mg/L were observed for Water-board, Location A, B, and C respectively which means they were all within the permissible standard of 300mg/L by WHO and NSDWQ.

Alkalinity is mostly formed due to dissolution of carbon dioxide in water (Venkatesharaju *et al.*, 2010). The average mean value for alkalinity of the water samples were observed to be 6.0 mg/L, 15.0 mg/L, 10.5m g/L. and 12.0mg/L for the Water Board, locations A, B, C respectively. The values were within the permissible limits by WHO and (NSDWQ).

The observed Total Dissolved Solid (TDS) values ranged between 27.10 - 44.50 mg/L for all the samples which were far below 500mg/L permissible limits by WHO and NSDWQ. The entry of organic matter into water is often reflected in high values of nitrate (Chauhan and Singh, 2010). Though, samples from Bosso Water Board has no traces of nitrate (0.00 mg/L), Locations A, B and C respectively had an average mean values of 0.03mg/L, 0.015mg/L and 0.30mg/L, respectively. However, the values were within the permissible limit of 1.0 mg/L by WHO and NSDWQ.

Presence of zinc in drinking water in a considerable quantity pose no threat, as its deficiency in young children may retard growth and cause decrease in body resistance to disease. The observed values for Water Board and the three locations under (A, B and C) range between 0.17mg/L and 0.59mg/L. The use of metal tank for storage could be a source of zinc in water as well as galvanized coatings of piping (USEPA, 2001). However, the observed values were within established limits (5.0 mg/L) by WHO and NSDWQ.

The presence of iron can promote growth of certain kinds of bacteria that clog pipes. The average mean values of iron observed in at Water Board and locations A, B and C were 0.08mg/L, 1.55mg/L, 3.03mg/L and 1.45mg/L respectively and were within the established standards (1.0mg/L) by WHO and NSDWQ.

Water sample from Bosso Water Board was free of pathogenic bacteria (*Escherichia coli*.) indicating suitability of the source for drinking. Nevertheless, mean values of 4 CFU/100ml, 2 CFU/100ml and 2 CFU/100ml were recorded at locations A, B, and C, respectively, indicating that the water is no longer save for drinking at the respective household as no tolerance is given for the presence of the pathogenic bacteria (Ojodu, 2014).

The Water Quality Index for each of the water sampling location was determined with weighted arithmetic index using eleven of the physiochemical parameters (pH, Electrical Conductivity, Chlorides, Total Hardness, Alkalinity, Total Dissolved Solid, Nitrite, Nitrate, Phosphate, zinc, and Iron) considered. The values for Q_i, V_i, S_i, W_i, and (Q_iW_i) with their respective WQI were presented in Table 4-7.

Samples from Bosso water-board with observed pH mean value (V_i) of 7.49 have Q_i, W_i, and (Q_iW_i) values of 32.66, 0.0459 and 1.499 respectively (Table 4). The overall index for the sample from the water-board was 5.957 which showed that the water can be ranked as excellent at the water-board water and thus fit for drinking.

Samples from location A with observed chloride mean value (V_i) of 20.68 mg/L have Q_i, W_i, and (Q_iW_i) values of 8.272, 0.0016 and 0.0132 respectively (Table 5). The overall index for the sample was 119.13 indicating that the water can be ranked as unfit for drinking purpose at the location.

The Samples from the consumer end (location B) with observed chloride mean value (V_i) of 48.26 mg/L have Q_i, W_i, and Q_iW_i values of 19.304, 0.0016 and 0.0309 respectively (Table 6). The overall index for the sample from location B was 60.72 indicating that the water can be ranked as poor water quality at the location.

Samples from location C with observed pH mean value (V_i) of 6.58 have Q_i, W_i, and (Q_iW_i) values of -28, 0.0459 and -1.285 respectively (Table 7). The overall water quality index for the sample from this location was 57.66 showing that the water can be ranked as poor water quality at the location.

The results of the water quality index for the sample showed that with exception of the water-board where the water was considered fit for drinking; all other sampling locations failed WQI for drinking purpose (Figure 2). The water quality ranking observed for the locations gave a reflection of the total sum of the analytical results of the parameters used for the computation

CONCLUSION

Twelve physicochemical properties of Bosso Water Supply were assessed and the water quality status was evaluated using weighted arithmetic water quality Index. The result of study showed that the Bosso Water Supply is not suitable for drinking except at the Board where the water is treated. There is need for replacement of the aging infrastructure and extension of the Board to accommodate the ever increasing demand of the consumers. There should be caution in the consumption of the water from any other location which receives its water from the same Board to avoid exposure to diarrhea. More so, the study showed that Water Quality Index is a useful management tool in presenting the status of a water source to the populace to avoid economic lost.

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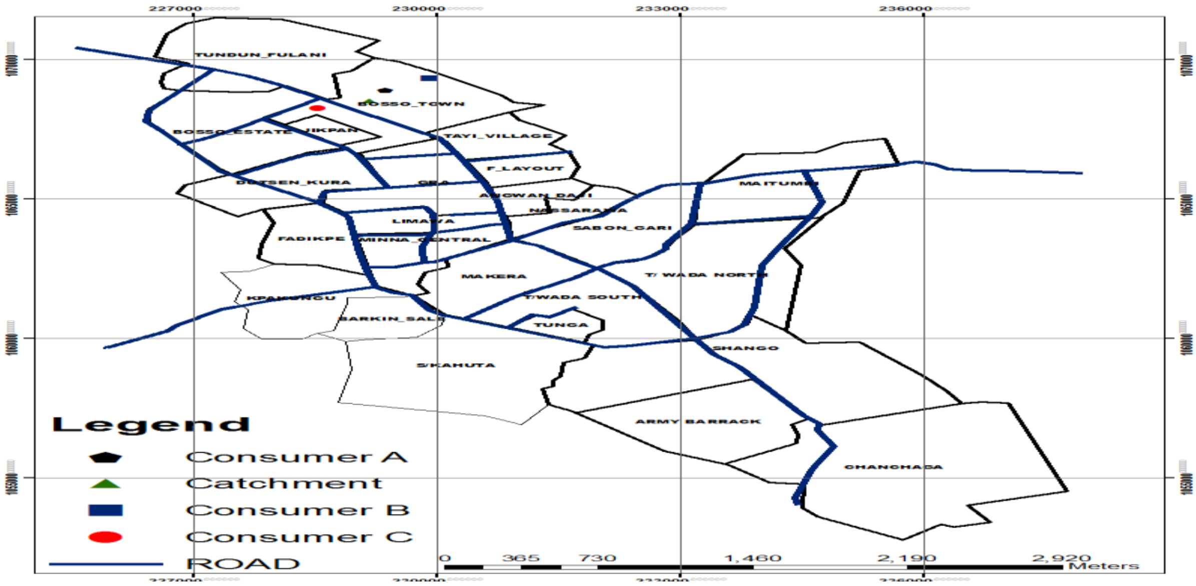

Figure 1: Map showing sample locations in Bosso area

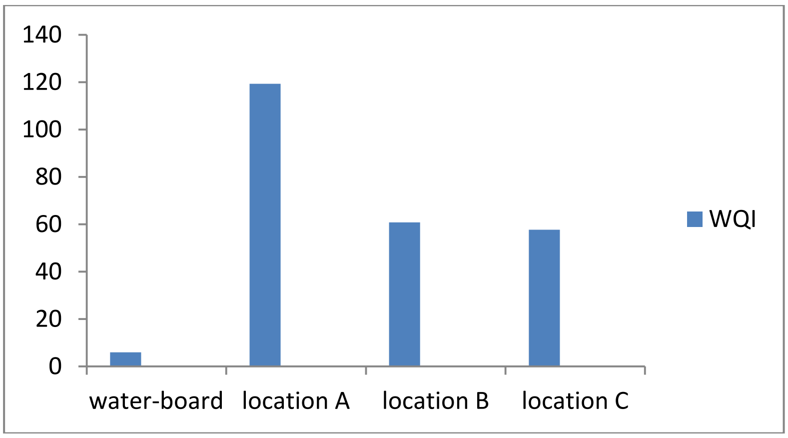

Figure 2: Water Quality Index Ranking of the Location

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Table1: Established Standard for Water Parameters

Parameters	**WHO**	**NSDWQ**
pH	6.5 – 8.5	6.5 – 8.5
Electrical Conductivity	250 (µS/cm)	1000 (µS/cm)
Chloride	250 (mg/L)	250 (mg/L)
Nitrate	45 (mg/L)	50 (mg/L)
Total Dissolve Solids	500 (mg/L)	500 (mg/L)
Iron	1.0 (mg/L)	1.0 (mg/L)
Phosphate	5.0 (mg/L)	
Total Hardness	300 (mg/L)	500 (mg/L)
Nitrite	1.0 (mg/L)	1.0 (mg/L)
Alkalinity	120 (mg/L)	200 (mg/L)
Zinc	5.0 (mg/L)	3 (mg/L)
E.coli	0.0 (cFu/100ml)	-

Table 2: Water Quality Index rank

WQI Value	Rating of water Quality
0 – 25	Excellent Water Quality
26 – 50	Good Water Quality
51 – 75	Poor Water Quality
76 – 100	Very Poor Water Quality
Above 100	Unfit for Drinking Purpose

Source**:** Chauhan and Singh (2010)

Table 3: Descriptive statistic of water quality parameter of water sample

Station	Statistical Tools	pH	E.C	Cl	TH	ALK	TDS	NO_2	PO_4	NO_3	Zn	Fe	*E.Coli*
Waterboard	Mean	7.49	124	75.84	28	6.0	44.5	0.00	0.58	0.02	0.17	0.08	0.00
	Max	7.60	129	79.85	30	6.5	47.5	0.00	0.60	0.03	0.18	0.09	0.00
	Minimum	7.31	117	71.42	25	5.5	40.75	0.00	0.55	0.01	0.16	0.07	0.00
	SD	0.15	6.25	4.29	2.64	0.5	3.43	0.00	0.02	0.01	0.01	0.01	0.00
Location A	Mean	6.55	76.0	20.68	52	15	27.1	0.03	0.01	0.04	0.59	3.03	4.00
	Max	6.65	79.0	22.75	54	16	29.65	0.03	0.02	0.11	0.63	3.09	5.00
	Minimum	6.45	72.0	19.25	49	14	25.15	0.03	0.01	0.01	0.54	2.92	3.00
	SD	0.10	3.61	1.84	2.65	1.0	2.31	0.00	0.01	0.06	0.05	0.10	1.00
Location B	Mean	6.60	100	48.26	40	10.5	35.8	0.02	0.30	0.03	0.38	1.55	2.00
	Max	6.64	105	50.15	42	11.5	36.6	0.02	0.34	0.03	0.40	1.58	2.18
	Minimum	6.54	95.0	45.07	38	9.5	34.8	0.01	0.27	0.03	0.35	1.53	1.85
	SD	0.52	5.0	2.78	2.0	1.0	0.92	0.00	0.04	0.00	0.03	0.03	0.17
Location C	Mean	6.58	120	45.26	36	12.0	29.5	0.03	0.30	0.03	0.35	1.45	2.00
	Max	6.70	125	55.75	38	13.0	31.0	0.03	0.34	0.03	0.38	1.60	2.18
	Minimum	6.39	115	30.53	33	10.5	27.5	0.03	0.27	0.03	0.30	1.25	1.85
	SD	0.17	5.0	13.13	2.64	1.32	1.80	0.00	0.04	0.00	0.18	0.18	0.17

All parameters are in mg/L except for E.C (µs/cm), *E. Coli* (CFU/100ml) and pH which has no unit

Table 4: Computation of water quality index for the Bosso Water-board Sample

Parameters	**Observed values (V_i)**	**standard values (S_i)**	**Quality rating (Q_i)**	**Unit weight (W_i)**	**($Q_i W_i$)**
pH	7.49	6.5 – 8.5	32.66	0.0459	1.499
E.conductivity(µs/cm)	124	250	49.6	0.0016	0.0794
Chloride (mg/L)	75.84	250	30.3	0.0016	0.0485
T.hardness (mg/L)	28	300	9.33	0.0013	0.0121
Alkalinity (mg/L)	6.00	120	5.00	0.0033	0.0165
TDS (mg/L)	44.50	500	8.90	0.0008	0.0071
$N0_2$(mg/L)	0.00	1.00	0.00	0.3904	0.0000
$P0_4$ (mg/L)	0.58	5.00	11.60	0.0781	0.906
$N0_3$ (mg/L)	0.02	45.00	0.04	0.0087	0.0003
Zn (mg/L)	0.17	5.00	3.40	0.0781	0.2655
Fe (mg/L)	0.08	1.00	8.00	0.3904	3.1232
Total				**1.0002**	**5.958**
(WQI) =$\sum Q_iW_i / \sum W_i$= 5.958 / 1.0002 = 5.957					

Table 5: Computation of Water Quality Index for Location A Samples

Parameters	**Observed values (V_i)**	**standard values (S_i)**	**Quality rating (Q_i)**	**Unit weight (W_i)**	**($Q_i W_i$)**
pH	6.55	6.5 – 8.5	- 30	0.0459	- 1.377
E.conductivity(µs/cm)	76	250	30.4	0.0016	0.0486
Chloride (mg/L)	20.68	250	8.272	0.0016	0.0132
T.hardness (mg/L)	52	300	17.3	0.0013	0.0225
Alkalinity (mg/L)	15.00	120	12.5	0.0033	0.0413
TDS (mg/L)	27.10	500	5.42	0.0008	0.0043
$N0_2$ (mg/L)	0.03	1.0	3.0	0.3904	1.1712
$P0_4$ (mg/L)	0.01	5.0	0.2	0.0781	0.0156
$N0_3$ (mg/L)	0.04	45	0.08	0.0087	0.0007
Zn (mg/L)	0.59	5.0	11.8	0.0781	0.9216
Fe (mg/L)	3.03	1.0	303	0.3904	118.29
Total				**1.0002**	**119.152**
(WQI) =$\sum Qi\mathrm{Wi}/\sum Wi$ = 119.152 / 1.0002 = 119.13					

Table 6: Computation of the Water Quality Index for Location B Samples

Parameters	**Observed values (V_i)**	**standard values (S_i)**	**Quality rating (Q_i)**	**Unit weight (W_i)**	**($Q_i W_i$)**
pH	6.6	6.5 – 8.5	- 26.6	0.0459	- 1.2209
E.conductivity(µs/cm)	100	250	40	0.0016	0.064
Chloride (mg/L)	48.26	250	19.304	0.0016	0.0309
T.hardness (mg/L)	40	300	13.33	0.0013	0.0173
Alkalinity (mg/L)	10.5	120	8.75	0.0033	0.0289
TDS (mg/L)	35.8	500	7.16	0.0008	0.00573
$N0_2$ (mg/L)	0.015	1.0	1.5	0.3904	0.5856
$P0_4$ (mg/L)	0.30	5.0	6	0.0781	0.4686
$N0_3$ (mg/L)	0.03	45	0.06	0.0087	0.0005
Zn (mg/L)	0.38	5.0	7.6	0.0781	0.5936
Fe (mg/L)	1.55	1.0	155	0.3904	60.152
Total				**1.0002**	**60.73**
(WQI) =$\sum Qi\mathrm{Wi}/\sum Wi$ = 60.73 / 1.0002 = 60.72					

Table 7: Computation of Water Quality Index of Location C Samples **(suuuum)**

Parameters	**Observed values (V_i)**	**standard values (S_i)**	**Quality rating (Q_i)**	**Unit weight (W_i)**	**($Q_i W_i$)**
pH	6.58	6.5 – 8.5	- 28	0.0459	- 1.285
E.conductivity(µs/cm)	120	250	48.00	0.0016	0.077
Chloride (mg/L)	45.26	250	18.24	0.0016	0.029
T.hardness (mg/L)	36	300	12.00	0.0013	0.016
Alkalinity (mg/L)	12	120	10.00	0.0033	0.033
TDS (mg/L)	29.5	500	5.90	0.0008	0.005
$N0_2$ (mg/L)	0.03	1.0	3.00	0.3904	1.171
$P0_4$ (mg/L)	0.30	5.0	6.00	0.0781	0.469
$N0_3$ (mg/L)	0.03	45	0.07	0.0087	0.001
Zn (mg/L)	0.35	5.0	7.00	0.0781	0.547
Fe (mg/L)	1.45	1.0	145	0.3904	56.608
Total				**1.0002**	**57.67**
(WQI) =$\sum Qi\mathrm{Wi}/\sum Wi$= 57.67 / 1.0002 = 57.66					