Utilization of Water Quality Index (WQI) in Water Quality Assessment of Groundwater in Agbor Metropolis, Delta State Nigeria

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Abstract

A water quality index provides a single number that expresses the overall quality at a certain location and time based on several water parameters. The objective of the study was to calculate the Water Quality Index (WQI) of groundwater in Agbor metropolis, Delta State Nigeria in order to assess its suitability for drinking and domestic purposes. WQI was determined on the basis of various physico-chemical parameters namely pH, Electrical conductivity (EC), Turbidity, Total suspended Solids (TSS), Total Dissolved Solids (TDS), Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Sulphate, Nitrate, Phosphate, Chloride, Copper, Lead, Iron, Zinc and Cadmium. The calculation of the WQI was done using weighted arithmetic index method. The WQI was found to be 45.46 indicating that the groundwater in the study area is of good quality in its untreated state quality and therefore safe for human consumption and domestic purposes.

Keywords: Water Quality Index, Physico - Chemical Parameters, Weighted Arithmetic Index Method, Groundwater, Agbor metropolis

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1 Introduction

Water is vital for all known forms of life, and the access to safe water is a fundamental need and basic human (WHO, 2000). Globally, groundwater is the largest available and most important source of fresh water, which caters for an estimated 1.5 billion people worldwide daily and especially for meeting rural water demand in the sub-Saharan Africa (DFID, 2001; Harvey, 2004). Also, in Nigeria, groundwater plays a vital role as an important source of potable water in both rural and urban areas, and thus plays a vital role in the water supply chain (Adeyemi et al. 2003). The quality of water within a geographical location and source can be assessed using physical, chemical and biological parameters, whose values when found to exceed defined limits are harmful to human and environmental health (WHO, 2012).

Water quality index (WQI) provides a single number that expresses the overall water quality at a certain location and time based on several water quality parameters. WQI is basically a mathematical means of calculating a single value from multiple test results, as It has been realized that the use of individual water quality variable in order to describe the water quality for common public is not easily understandable (Bharti and Katyal, 2011. Akoteyon et al. 2011). The objective of WQI is to turn complex water quality data into information that is understandable and usable by the public. Also, WQI can be used as a tool in comparing the water quality of different sources and it gives the public a general idea of the possible problems with water in a particular region (Jagadeeswari and Ramesh, 2012).

Agbor town is situated in Delta State, Nigeria. It lies within longitudes 6° 05'E and 6° 20'E; and latitudes 6° 07'N and 6° 25'N, and covers an area of about 650 km^2 (Figure 1). The area lies within the equatorial climate with two distinct seasons; the wet (April to September) and dry (October to March) seasons; high humidity and atmospheric temperature of between 24° C - 27°C which supports the rainforest vegetation (Olobaniyi et al. 2007; Odjugo, 2008). The subsurface geology of the area indicates that it lies within the Benin formation, with a soil profile consisting of lateritic soil, fine grained sand, a sequence of medium to coarse grained sand with several horizons of intercalated discontinuous lenses of clay which constitute the main aquifer. Groundwater occurs at a depth generally greater than 60 metres, predominantly under unconfined conditions (Olobaniyi et al. 2007; Akpoborie et al. 2011). The objective of this study is to investigate the water quality and determine the Water Quality Index (WQI) of the groundwater in order to assess its suitability for human consumption and other domestic purposes.

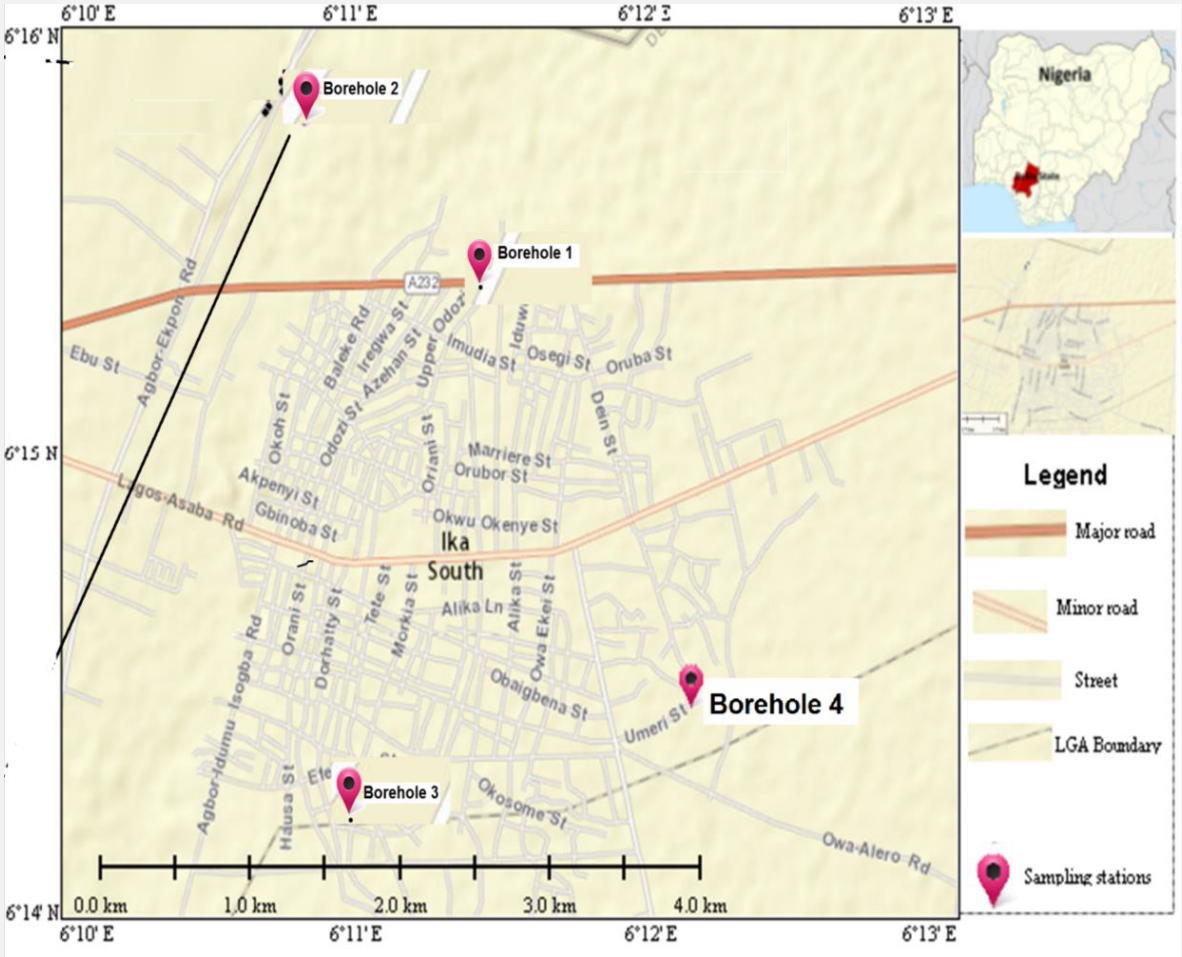

Figure 1: Map of study area showing borehole locations in Agbor, Delta State, Nigeria.

2 Materials and Methods

Groundwater samples were collected during the dry season between October 2016 and March 2017. Boreholes were selected taking into cognizance their location from potential sources of groundwater pollution such as dumpsites and industrial effluents. A total of 24 water samples were collected using pre–washed 1 litre plastic containers from selected boreholes. The sampling, preservation, transportation and analysis were carried out according to outlined procedures in the Standard Methods for the Examination of Water and Wastewater (APHA, 1998). The water samples were analysed for sixteen parameters namely pH, Electrical conductivity (EC), Turbidity, Total suspended Solids (TSS), Total Dissolved Solids (TDS), Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Sulphate, Nitrate,

Phosphate, Chloride, Copper, Lead, Iron, Zinc and Cadmium. Results were premised on both the Nigerian Standard for Drinking Water Quality (SON, 2007) and the World Health Organisation Standards (WHO, 2011). All sixteen parameters were considered in determining the Water Quality Index of the groundwater in the study area.

2.1 Determination of Water Quality Index

In this study, Water Quality Index (WQI) was calculated by using the Weighted Arithmetic Mean method, which classifies water quality according to the degree of purity by using the most commonly measured water quality variables (Bangalore and Latha, 2008; Chauhan et al. 2010, Balan et al. 2012; Chowdhury et al. 2012 and Shweta et al. 2013). The weighted arithmetic water quality index (WQI_A) was originally proposed by Horton (1965) and developed by Brown et al. (1972). The calculation of WQI was made by using the following equations:

$$WQI_A = \frac{\sum Q_i W_i}{\sum W_i}$$

The quality rating scale (Qi) for each parameter is calculated by using the expression:

$$Q_i = 100 \left[\frac{V_i - V_o}{S_i - V_o} \right]$$

where,
V_i = Estimated Concentration of the i th parameter of interest in the analysed water.
V_o = The ideal value of the i th parameter in pure water. $V_o = 0$ (except pH = 7.0; and DO = 14.6 mg/l)
S_i = Recommended Standard value of the ith parameter.
The unit weight (W_i) for each water quality parameter is calculated by using the following formula:

$$W_i = \frac{K}{S_i}, \quad K = \frac{1}{\sum \left(\frac{1}{S_i} \right)}$$

where K = proportionality constant and can also be calculated by using the above simultaneous equation.

The rating of water quality according to this WQI is given in Table 1.

Table 1: Classification of Water Quality based on Weighted Arithmetic Water Quality Index Method‡

WQI Value	Water Quality Status	Grade
0 – 25	Excellent	A
26 – 50	Good	B
51 – 75	Poor	C
76 – 100	Very Poor	D
Above 100	Unsuitable for drinking purpose	E

‡Source: Brown et al (1972), Chatterji and Razuiddin (2002), Shweta et al. (2013)

3 Results and Discussions

The physico - chemical analyses of groundwater samples and comparison with the Standard Organization of Nigeria (SON, 2002) and WHO (2011) standards are summarized in Table 2. Results showed that all the physico – chemical parameters considered were within the National Standard for Drinking Water (SON, 2007) and WHO (2011) permissible limits for drinking water quality, except values for pH (acidic) and lead which can be attributed to the geology of the area and the mineral salts dissolved in the groundwater (USGS, 2015).

Table 2: Summary of the Physical and Chemical Parameters of Selected Borehole water in Agbor, Delta State.

Parameter	Test Result (Min - Max)	Mean ± SD	SON, 2007	WHO, 2011
pH	5.0 - 6.50	5.75 ± 0.36	6.5 - 8.5	6.5 - 8.5
EC	10. 00 - 50.00	30.00 ± 6.55	1000	1000
Turbidity	0.00 - 4.00	2.00 ± 0.94	5	3
TSS (mg/l)	0.00 - 4.00	2.00 ± 1.47	0	N/A
TDS (mg/l)	12.60 - 35.90	48.50 ± 4.66	500	500
DO (mg/l)	5.40 - 6.20	5.80 ± 0.19	7.5	5.0
BOD (mg/l)	0.38 - 1.20	0.44 ± 0.31	0.05	0.05
Sulphate (mg/l)	0.07 - 2.00	1.04 ± 0.16	100	100
Nitrate (mg/l)	0.06 - 0.23	0.15 ± 0.04	50	50
Phosphate (mg/l)	0.09 - 0.46	0.28 ± 0.08	5	10
Chloride (mg/l)	6.50 - 15.60	11.05 ± 1.32	250	250
Copper (mg/l)	0.022 - 0.069	0.046 ± 0.01	1.0	2.0
Lead (mg/l)	0.000 - 0.015	0.005 ± 0.01	0.01	0.01
Iron (mg/l)	0.080 - 0.29	0.173 ± 0.05	0.3	0.1
Zinc(mg/l)	0.005 - 0.05	0.025 ± 0.01	3.0	1.5
Cadmium (mg/l)	0.00 - 0.00	0.00 ± 0.00	0.003	0.003

Table 3 gives the mean observed values (V_i) of the sixteen selected physico-chemical parameters of water samples, standard drinking water values (S_i) according Nigerian Standard for Drinking Water Quality (SON, 2007), unit weights (W_i), Water Quality rating (Q_i) and

W_iQ_i.

Table 3: Calculation of Water Quality Index (WQI) of borehole water collected in Agbor, Delta State.

Parameter	Mean Test Result (V_i)	SON Limits (S_i)	K	Weightage (W_i)	Quality Rating (Q_i)	$[(W_i)\ (Q_i)]$
pH	5.75	6.5 – 8.5	0.0022	0.00026	250.00	0.065
EC	30.00	1000	0.0022	0.0000022	3.00	0.0000066
Turbidity	2.00	5	0.0022	0.00044	40.00	0.0176
TSS (mg/l)	2.00	0	0.0022	0.000	0.00	00.00
TDS (mg/l)	48.5	500	0.0022	0.0000044	9.70	0.00004268
DO (mg/l)	5.8	7.5	0.0022	0.00029	123.90	0.0359
BOD (mg/l)	0.44	0.05	0.0022	0.044	880.00	38.72
Sulphate (mg/l)	1.04	100	0.0022	0.000022	1.04	0.00002288
Nitrate (mg/l)	0.15	50	0.0022	0.000044	0.30	0.0000132
Phosphate (mg/l)	0.28	5	0.0022	0.00044	5.60	0.002464
Chloride (mg/l)	11.05	250	0.0022	0.0000088	4.42	0.0000389
Copper (mg/l)	0.046	1.0	0.0022	0.0022	4.60	0.01012
Lead (mg/l)	0.005	0.01	0.0022	0.22	50	6.60
Iron (mg/l)	0.173	0.3	0.0022	0.0073	57.66	0.421
Zinc(mg/l)	0.025	3.0	0.0022	0.00073	0.833	0.000608
Cadmium (mg/l)	00.00	0.003	0.0022	0.733	00.00	00.00
				$\sum W_i =$ 1.009		$\sum(Q_i)(W_i) =$ 45.87

The water quality index (WQI) of the study area was then calculated using the weighted arithmetic index formula as follows:

$$WQI_A = \frac{\sum Q_i W_i}{\sum W_i} = \frac{45.87}{1.009} = 45.46$$

The WQI calculated value (45.46) lies within the range 26 - 50 of the WQI_A classification scale (Table 1), an indication that the groundwater is of "Good" quality and therefore suitable for drinking and other domestic purposes. Similar WQI values of 38.52 to 48.67 for groundwater was reported by Etim et al. (2013) in their study on groundwater collected from boreholes in the Niger Delta region of Nigeria.

4 Conclusions and Recommendations

The assemblage of different physico-chemical parameter values into a single number creates an index tool for utilization in management and public health awareness. The objective of the study was to calculate the Water Quality Index (WQI) of groundwater in Agbor

metropolis in Delta State, Nigeria in order to determine its suitability for drinking purposes. The water quality index (WQI) of 45.46 obtained is a clear indication that the untreated groundwater in the study area is of good quality and therefore safe for human consumption and domestic purposes. Continuous monitoring of the groundwater and types of pollutants discharged into the aquifer especially within the areas of aquifer recharge is recommended in order to maintain the water quality.

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