EVALUATION OF WATER QUALITY INDEX AND SALT WATER INTRUSION OF DRINKING WATER SOURCES IN EKEDE COMMUNITY, ANDONI, NIGERIA.

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Abstract

The study examined the Water Quality Index (WQI) and Saltwater intrusion of the drinking water sources in Ekede Community, Andoni. The parameters were measured at the various water sources – with standard analytical methods. The calculated values of WQI ranged from 92.15 to 151.28. These values indicated that the water quality status is very poor as well as unsuitable for drinking. The saltwater water intrusion indices such as Simpson ratio (1.86, 1.31 and 1.29); TA/TH ratio (1.04, 1.53 and 1.28); BEX values which are negative and the low values of Na/Cl ratio (0.30, 0.17 and 0.39) all indicated salt water contamination of the water sources in the study area. The very poor, unsuitable and saltwater contaminated water bodies of the study area are not suggestible for use of regular human activities. Therefore, this study recommends that government should come to the aid of the community by providing portable drinking water in order to reduce the over dependence on lake water drinking source.

Keywords: Water Quality Index, Salt Water Intrusion, Ekede Community, Drinking Water Sources, Water Quality Status.

Introduction

Water of good drinking quality is of basic importance to human physiology and man's continued existence on earth. This accounts for why water is regarded as one of the most indispensable substances in life and it is most abundant (Etim *et al.,* 2013). Increase in human population has exerted an enormous pressure on the provision of safe drinking water especially in developing countries. Unsafe water is a global public health threat, placing humans at risk for a host of water borne diseases as well as chemical intoxication. Most of the fresh water bodies all over the world are getting polluted, thus decreasing the portability of water (Chandra *et al.,* 2012).

Due to increasing industrialization on one hand and exploding population on the other, the demands of water supply have been increased tremendously. Moreover considerable part of this limited quality of water is polluted by sewage, industrial wastes, and a wide range of pollutants generated due to anthropogenic activities (Vatkar, *et al.,* 2013). The status of quality of water that is supplied today in most areas worries the people. The quality of water depends on the location of the sources and the state of environment. Fresh water which is a precious and limited vital resource needs to be protected, conserved and used widely by man. But unfortunately such has not been the case, as the lakes, rivers and streams are polluted (Rajkumar and Gori, 2005).

Drinking water has always been a major issue in many developing countries. In Nigeria many of the rural populace do not have access to adequate water and therefore depend on other alternatives like wells and surface water sources for domestic use. There is no substitute for water in any of its uses. However, as much as water is important in life, where and when it is available, it must be kept safe and free of contamination and pollution for the survival of mankind (Ibeneme *et al.,* 2014).

Pollution of the aquatic environment is a serious and growing problem which leads to various deleterious effects on humans and aquatic organisms. It therefore becomes imperative to regularly monitor the quality of different water bodies in Ekede Community with the use of Water Quality Index (WQI) and Salt Water Intrusion (SWI) in order to assess the quality of different water bodies.

Water quality index is one of the most effective tools to communication information on the quality of water to the concerned citizens and policy makers. Water quality index provides a single number that expresses overall water quality at a certain location and time based on several water quality parameters. The objective of water quality index is to turn complex water quality data into information that is understandable and usable by the public. In a general note, water quality indices incorporate data from multiple water quality parameters into a mathematical equation that rates the health of a water body with number (Nyodee, 2016, Visa and Jomoh, 2010).

Many studies have been done on water quality index and salt water intrusion to evaluate water quality of different locations, by Yisa and Jimoh (2010), Rao and Nageswararao (2013), Yisa *et al.,* (2012), Damo and Icka (2013) and Olufemi *et al.,* (2010) but none of these studies has evaluated the water quality of different water bodies in Ekede community using water quality index and salt water intrusion. Therefore, the present study is to provide information on the physic-chemical parameters of the water bodies in order to appreciate the effect of unregulated anthropogenic activities on the quality of Ekede water bodies with use of Water Quality Index (WQI) and Salt Water Index (SWI) indices.

Materials and Methods of Analysis

Study Area

Ekede community is a riverine community in Andoni Nigeria. It is located at 4.48114 latitude and 7.43177 longitude with an estimated elevation terrain of six meters above sea level.

The greater part of its boundary is marked with Atlantic Ocean and to the west is bounded by Ngo town the headquarters of Andoni L.G.A. The main occupation of the people is fishing and about 20% of the people are farmers. The farming activities in Ekede community are regulated by the swampy nature of the land because about 70% the total land mass is swampy. The oil and gas production activities go on in this area. The main source of water supply in this community is the lake water body surrounded by sea water with few hand dug wells and boreholes individually owned.

Sample Collection and Analysis

The water samples were collected from the lake, hand dug well and borehole water sources in sterilized bottles using the standard procedure for sample collection in accordance with standard methods of (APHA, 2005). The samples were analyzed as per standard methods for seventeen physic-chemical parameters in accordance with standard methods (APHA, 2005).

Calculation of Water Quality Index (WQI)

Fifteen parameters were used for the calculation of water quality index. Values used for each parameter were the mean values. The WQI has been calculated by the standards of drinking water quality recommended by the World Health Organization (WHO, 2006). The weighted arithmetic index method (Pathak *et al.,* 2015) has been used for the calculation of water quality index of the water bodies.

Calculation of sub index of quality rating (qn): The value of Qn is calculated by the expression

$$Qn = 100[(Vn - Vo)]/[(Sn - Vo)] \quad \text{.....................} \quad (i)$$

Where:

Qn = Quality rating for the nth water quality parameter.
Vn = Estimated value of the nth parameter.
Sn = Standard permissible value of the nth parameter.
Vo = Ideal value of the nth parameter in pure water. All the ideal values (Vo) are taken as zero for drinking water except for pH = 7.0 and DO ≈ 14.6 mg/L (Rao and Nageswararao, 2013).

Calculation of unit weight (Wn): Calculation of unit weight (Wn) for various water quality parameters inversely proportional to the recommended standards for the corresponding parameters. Wn K/Sn ....(ii)

Where:

Wn = Unit weight for the nth parameter.
Sn = Standard value for the nth parameter.
K = Proportionality constant.

The overall Water Quality Index (WQI) is calculated by aggregating the quality rating with the unit weight:

$$WOI = \sum \frac{Qn \ \ Wn}{Wn} \ldots\ldots\ldots\ldots\ldots\ldots\ldots.(iii)$$

The water quality index level showing the status of water quality is indicated in table 1.

Table 1: Water Quality Index (WQI) and status of water quality.

Water Quality Index Level	**Water Quality Status**
0 – 25	Excellent water quality
26 – 50	Good water quality
51 – 75	Poor water quality
76 – 100	Very poor water quality
> - 100	Unsuitable for drinking

Source: (Srinivas *et al.*, 2013)

Assessment of Salt Water Intrusion (SWI)

The assessment of salt water intrusion or contamination is identified by these indices:

- The Simpson ratio, by Korfali and Jurdi (2010) is

$$\frac{Cl}{HCO_3 + CO_3} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. (iv)$$

Five classes of this ratio are created to evaluate the level of contamination shown in table 2.

Table 2: The Level of Contamination of Simpson Ratio.

Level of Contamination	Class of the Level
< 0.5	Good quality
0.5 – 1.3	Slightly contaminated
1.3 – 2.8	Moderately contaminated
2.8 – 6.6	Injuriously contaminated
6.6 – 15.5	Highly contaminated

Source: (Korfali and Jurdi, 2010)

- An enrichment of Ca based on the ratios used by Rao and Nageswararao (2013) are:

$$\frac{Ca^{2+}}{Mq^{2+}}\ ratio \ldots\ldots\ldots\ldots\ldots\ldots (v)$$

$$\frac{Ca^{2+}}{HCO_3^- + SO_4^2} \ldots\ldots\ldots\ldots\ldots\ldots (vi)$$

The value of this ratio less than 1 indicates the salt water intrusion or contamination.

- Base Exchange Indices (BEX) is also used for SWI indicator. BEX according to Stuytzand (2008) could be calculated thus:

  BEX = Na + K + Mg – 1.0716 Cl (Meq/L)..............(vii)

  A positive value of BEX indicates none contamination while negative value of BEX represents contamination.

- **Na/Cl Ratio:** Na/Cl ratio as used by Babu *et al.,* (2013) with the formula.

$$\frac{Na}{Cl} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (viii)$$

Indicates SWI depending on the value of the ratio. The value of the ratio below 1 foretells the salt water contamination.

- Total Alkalin/Total hardness ratio TA/TH ratio as used by Rao and Nageswararo (2013) is for identification of salt water contamination. And the formula is $\frac{TA}{TH} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (ix)$

Where;

TA = Total Alkalinity, TH = Total Hardness if TA/TH ratio is less than or equal to unity then there is no sea water contamination. If TA/TH ratio is greater than 1, then there is sea water contamination.

Statistical Analysis

That data are statistically analyzed using ANOVA to detect any significant difference between the sample means. Omega squared (W^2) by Huck (2012) is used to determine whether the various factors interest significantly with each other, with the equation as

$$W^2 = \frac{SS_{effect}}{SS_{effect} + SS_{effect}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (x)$$

Where;

Ss effect is the sum of the squares between means (Ms_b)

Ss error is the sum of squares within means (MS_w) Huck (2012) described the level of interaction based on the calculated value of W^2 shown in Table 3.

Table 3: Different Levels of Interactive Effect.

Value of Omega Squared (W^2)	**Level of Interactive Effect**
.01 – 0.5	Small effect
.06 - .13	Medium effect
$\geq$ .14	Large effect

Source: Huck (2012)

Results and Discussions

Descriptive Statistics of the Results

Descriptive statistics of the results from the analysis of the parameters in the study area water samples are presented in Table 4.

Table 4: Results of Descriptive Statistics of the Parameters in Water Samples with WHO Standard Values.

Parameter	Min.	Max.	Mean	SD	CV	(2006 WHO)
pH	4.78	7.20	5.99	1.21	0.20	8.50
DO	4.00	9.60	4.80	2.8	0.41	6.00
BOD	7.04	13.76	10.40	3.36	0.32	10.00
EC	14.10	301.00	157.55	143.45	0.91	250.00
TDS	20.00	160.00	90.00	70.00	0.78	500.00
Alkaline	2.00	108.00	55.00	53.00	0.96	500.00
Total Hardness	4.004	488.49	146.25	242.24	0.98	500.00
Cl^-	8.00	22.00	15.00	7.00	0.47	250.00
NO_3^-	0.88	2.65	1.77	0.89	0.50	50.00
SO_4^{2-}	1.38	7.58	4.48	3.10	0.69	200.00
PO_4^{2-}	0.035	0.035	0.035	0.00	0.00	5.00
K^+	0.107	4.502	2.30	2.20	0.96	10.00
Na^+	0.557	9.36	4.96	4.40	0.89	200.00
Ca^{2+}	22.02	35.05	28.54	6.52	0.23	75.00
Mg^{2+}	3.179	5.17	4.17	1.00	0.24	150.00

The result of the Descriptive statistics of the parameters showed that all of the mean values were lower than their WHO values except the mean values of DO and BOD which were greater than their WHO values. The mean values of DO (6.80mg/l) and BOD (10.40mg/l) were greater than 6.00mg/l and 10.40mg/l of WHO values respectively. Due to lack of an official guideline for healthy concentrations of the parameters in the study area, the concentrations of the parameters were compared with WHO water quality guideline. This observation agrees with that made by Zaveri and Patel (2016) in their study of groundwater Salinisation.

The Water Quality Index (WQI)

The calculated WQI values are shown in Table 5.

Table 5: Calculated Water Quality Index (WQI) values.

Sampling Location	WQI Value	WQI Level	Water Quality Status
Hand Dug Well Water (HWW)	92.15	76-100	Very poor water quality

Borehole Water (BHW)	111.92	>100	Unsuitable for drinking
Lake Water (LW)	151.28	>100	Unsuitable for drinking

The variation of the WQI values ranges from 92.15 to 151.28. The calculated WQI values for hand dug well water, borehole water and lake water samples are 92.15, 111.92 and 151.28 respectively. The WQI value of 92.15 for hand dug well water indicated very poor water quality status. The WQI values of 111.92 for borehole water and 151.28 for lake water indicated unsuitable water quality for drinking. The very poor and unsuitable water quality status indicated in high WQI values, observed in this study is due to high values in the Electrical Conductivity (EC), Total Dissolved Solids (TDS), Total Alkaline (AH) and Total Hardness (TH) parameters. The finding in the study of RaO and Nageswarara (2013) in agreement with this observation. The very poor and unsuitable water bodies are not suggestible for use of regular human activities.

Evaluation of Salt Water Intrusion

The calculated values of saltwater intrusion indices are displayed in Table 6.

The calculated values of these indices are for the assessment of saltwater contamination in the study area water sources.

Table 6: Hydrogeochemical Ratios of Ekede Community Water Sources.

WATER SOURCES	HYDROGEOCHEMICAL RATIOS				
	$CC/HCO_3 + CO_3$	Ca^{1+}/Mg^{1+}	TA/TH	BEX	Na/Cl
HWW	1.86	0.78	1.04	-0.58	0.30
BHW	1.31	0.59	1.53	-0.21	0.17
LW	1.29	0.47	1.28	-0.31	0.39

HWW = Handling Well Water

BHW = Bore Hole Water

LW = Lake Water

From the Table 6, the $Cl/CHCO_3 + CO_3$) ratio values of 1.86, 1.31 and 1.29 are observed at Hand dug Well Water, bore hole Water and Lake Water respectively. The ratio values of the water samples are between 1.30 to 2.80 as classified by Korfali and Jurdi (2010) to indicate moderately contaminated water sources. Based on this classification these water sources are moderately contaminated.

The Ca^{2+} /Mg^{2+} ratio is for identification of salt water contamination since magnesium is present in sea water in much greater concentration than calcium (Babu, et al, 2013). Ca^{2+}/Mg^{2+} value of seawater is 0.18. The ratio values of 0.78, 0.59 and 0.47 for Hand dug water, Borehole Water and Lake Water respectively are all greater than 0.18. The low value of Ca^{1+}/Mg^{1+} ratio (0.18) indicates the sea water contamination, but in the present study no water source is showing such a small value of less than or equal to 0.18.

The TA/TH ratio is also for the identification of salt water contamination (RaO and Nageswararao, 2013). From Table 6, the TA/TH ratio values are 1.04, 1.53 and 1.38 for Hand dug water, Borehole water and lake water respectively. These ratio values are more than unity which indicated that these water sources are contaminated with salt water (Chauhan, et al., 2010).

The base exchange indices (BEX) is for salt water intrusion indicator. Table 6 showed that the BEX values are –0.58, -0.21 and -0.31 for hand dug water, borehole water and lake water respectively. According to Stuyfzand (2008), a positive value of BEX indicates none contamination while negative value of BEX represents contamination. In this study as indicated in Table 6, the BEX values of water sources are all of negative values, indicating salt water contamination of the water sources.

The Na/Cl ratio from Table 6 ranges from 0.17 to 0.39. The hand dug water has the ratio of 0.30, the borehole water has 0.17 and the lake water has 0.39. The Na/Cl ratios of saltwater intrusion are usually lower than the marine values, i.e. < 0.86 (Babu, et al,. 2013). The calculated Na/Cl ratios of the water sources in the study area are lower than 0.86. The low Na/Cl ratios combined with other geological parameters could foretell the saltwater contamination.

Statistical Analysis

Statistical analysis of the parameters. The result of ANOVA is indicated in Table 7.

Table 7: Summary of ANOVA of Water Samples.

SOURCE OF VARIATION	SS	DF	MS	F	P
Between group means	46,096.89	2	23,048.45	3.43	
Within group means	282,191.49	42	6,718.85		
Total	**328,288.38**	**44**			

The result indicated the F-calculated value of 3.43 (at $p < 0.05$) is greater than F-critical of 3.23. The ANOVA result showed that there is significant difference between the sample mean values of the water sources. The significant difference, suggests that there are different local pollution sources containing different loads of pollutants in the study area.

To ascertain whether the various factors interact significantly with each other to bring about pollution of the water sources, is determined by the calculation of Omega Square. The calculated value of Omega Square which is 0.77 indicated large effects of the parameters on the water bodies thereby polluting the water bodies of the study area.

Conclusion

The study examined the water quality and saltwater intrusion of the drinking water sources of the study area. The calculated values of WQI ranged from 92.15 to 151.28. These values indicated that water quality status is very poor as well as unsuitable for human activities.

The saltwater intrusion indices such as Simpson ratio (1.86, 1.31 and 1.29); TA/TH ratio (1.04, 1.53 and 1.28); BEX values which are negative and the low values of Na/Cl ratio (0.30, 0.17 and 0.39) all indicated salt water contamination of the water sources in the study area.

The Omega Square calculated value of 0.77 equally indicated large effect of pollutants on the water sources.

The very poor unsuitable and saltwater contaminated water bodies of the study area are not suggestible for use of regular human activities.

Therefore, this study recommends that government should come to the aid of this community by providing portable drinking water in order to reduce the problem of lack of portable drinking water. The reason is that the local inhabitants are not rich enough to drill the right deep of borehole water or to treat the water already provided by shallow ones in the community.

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