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Assessment of groundwater quality in Eti-Osa LGA, Lagos-Nigeria

Akoteyon[1], I. S., [1] Soladoye[1], O. and Mbata[2], U. A.

[1]Department of Geography and Planning, Lagos State University, Ojo, Lagos-Nigeria
[2]Department of Mathematics, University of Lagos, Akoka, Lagos-Nigeria
E-mails:sewwyco@yahoo.com; soladoyeo@yahoo.com;mbataugochukwu@yahoo.com
*Corresponding author

Abstract

The rapid population growth and the accelerated pace of industrialization have effect on groundwater quality as a result of its overexploitation and improper waste disposal, especially in urban catchment. Water Quality Index (WQI) is one of the most effective tools to communicate information on the quality of water to concerned citizens and policy makers. In this study, 18 locations were selected within the urban catchment using random sampling technique. The water samples were collected and analyzed for physico-chemical parameters including pH, Total Hardness, Calcium, Magnesium, Chloride, Nitrate, Sulphate, Total Dissolved Solids and Iron using standard procedure. The sampling locations were determined with GPS and interpolated on digitized topographical map of the study area. The 9 parameters were used for calculating Water Quality Index within the study area. The result show that, the groundwater quality ranges between 0.86 and 1,228.0mg/L. Total Dissolve Solid has the highest mean (607.44mg/L), followed by Cl (222.22mg/L) while Fe has the least value of (0.66mg/L).Further analysis revealed that, all the parameters examined except (pH, Ca, Cl and Fe) show high variation. Statistically significant positive correlations was observed between Total Hardness and Chloride (r =0.51) while negative correlation was observed between pH and Calcium (r = - 0.49) at p < 0.05.The computed WQI for the samples ranges from 26.62 to 24,345.0. The high value of WQI has been found to be mainly from the higher values of pH, Magnesium, Chloride, Total Dissolved Solids and Iron. About 98.77% of water samples in the study area are unsuitable for drinking while 0.17%, 0.28% and 0.77% are excellent, good and very poor respectively. The study recommended thorough treatment of the groundwater before consumption in the study area.

Keywords: Assessment; Groundwater; Nigeria; Water Quality; Water Quality Index

Introduction

Water is the most abundant molecular substance of the Earth crust. Of the entire earth surface, 70% is covered with oceans which contain 97.5% of the total water supply on Earth. Only 2.5% of the water supply on Earth is fresh water taking the form of rivers, lakes, permafrost of the polar caps or glaciers, groundwater among others. About 69.4% of this amount is permafrost, ice, etc., and only 30.6% is liquid water, of which 98.7% is found as groundwater (PAP/RAC,1997). Water is the most exploited of natural resources and is renewable.

In Nigeria the major sources of water include, surface water (springs/stream/rivers), groundwater (hand dug wells and boreholes), rain harvesting, pipe borne water and water vendors. Access to safe drinking water in Nigeria shows that 35% of urban population do not have access to safe drinking water while 70% of rural population depends mainly on unsafe sources of water such as open wells, rivers and streams for drinking (Eludoyin et al; 2007).

According to Federal Government of Nigeria (2007) it is estimated that 48% (about 67 million Nigerians) depend on surface water for domestic use, 57% (79 million) use hand dug wells, 20% (27.8 million) harvest rain, 14% (19.5 million) have access to pipe borne water, and 14% have access to borehole water sources.

Globally it is an inexhaustible natural resource, but regionally and locally it is exhaustible. At a global scale, there is apparent disappearance and deterioration of water quality both surface and groundwater due to anthropogenic pollution. In many parts of the world, the demand for water has been on the increase due to increase in population, urbanization and industrialization which invariably affect water resources quality. The importance of water to man cannot be over emphasized. Water is the most basic needs of human being used for drinking, agricultural and industrial production, hygiene and sanitation. The global demand for fresh water doubles every 20 years (Foster, 1999). This growing demand is putting enormous pressure on water resources. Increasing water pollution causes not only the deterioration of water quality but also threatens human health and the balance of aquatic ecosystems, economic development and social prosperity (Milovanovic, 2007).

The crucial role of water as the trigger and sustainer of civilizations has been witnessed throughout the human history. Groundwater is used for domestic and industrial water supply and irrigation all over the world. In the last few decades, there has been a tremendous increase in the demand for fresh water due to rapid population growth and the accelerated pace of urbanization, industrialization among others. The rapid rate of urbanization, especially in developing countries like Nigeria, has affected the availability of groundwater quality due to its overexploitation and improper waste disposal, especially in urban areas. According to WHO (1993) about 80% of all the diseases in human beings are caused by water. Globally, about 80% of all diseases and death in developing country are water-related as a result of polluted water (Ayeni et al; 2011, Aderibigbe et al; 2008).

Once the groundwater is contaminated, its quality cannot be restored by stopping the pollutants from the source. These resources are under threat from pollution either from human activities, land use and life style manifested by the low level of hygiene practiced in most developing nations among others (Ikem et al; 2002). It is therefore imperative to regularly monitor groundwater quality and device means to protect it. Water quality index is one of the most effective tools (Mishra and Patel, 2001; Naik and Purohit, 2001; Tiwari and Mishra, 1985; Ramakrishnaiah, Ranganna, and Sadashivaiah, 2009) to communicate information on the quality of water to the concerned citizens and policy makers. It, thus, becomes an important parameter for the assessment and management of groundwater.

WQI is defined as a rating reflecting the composite influence of different water quality parameters. WQI is calculated from the point of view of the suitability of groundwater for human consumption. In the study area, groundwater is heavily relied upon as source of water supply for both public and private use and at the rate at which development is springing up, this source of water supply might not be available or useable due to urbanization and pollution that results from anthropogenic activities. Hence, there is need to achieve safe drinking water friendly environment in order to overcome water related diseases within a growing urban area such as Lagos. The objective of this study is to assess the suitability of groundwater for human consumption based on computed water quality index values in the study area.

The Study Area

Eti-Osa Local Government Area is located between latitude 6^0 15' and 16^0 17'N and longitude $3^0$3' E and 3^0 35' east. It is bounded in the south by Atlantic Ocean, in the east by Ojo local government, north by Lagos lagoon and part of Mainland and Island local government and in the west by Ibeju- Lekki local government (Odumosu et al., 1999)(see fig.1).

The study area occupies an area of about 192.3km^2.The population is about 287,785 with density of 1,496 person per km^2 (NPC, 2006). The study area houses the Lagos lagoon and the beaches, which stretch to the Atlantic Ocean. It comprises of nine wards namely; Victoria Island, Ward H_1 and H_2, Ikoyi West, Ward L_1, Ikoyi East, Ward L_2, Obalende, Ward $_M$, Eti-Osa N. E, Ward K_3, Eti-Osa, S. E, Ward K_2, Eti – Osa N.W, Ward K_1, and Eti – Osa S.W, Ward $_J$.

The climate is tropical type with an average rainfall of 2500mm and temperature of 30^0C. The vegetation pattern reflects its coastal location with mangrove swamp trees such as Rhizophora mangle, Rhizophora racemosa and Avicennia Africana among others (Odumosu et al., 1999). The topography is between 3-15m above sea level.

The geology consists of quaternary alluvial deposits such as red-yellow, red-brown, grey and sandy- clays, silt, sand, gravels, and other detrital material. The major source of water provision in the study area includes pipe-borne water and boreholes.

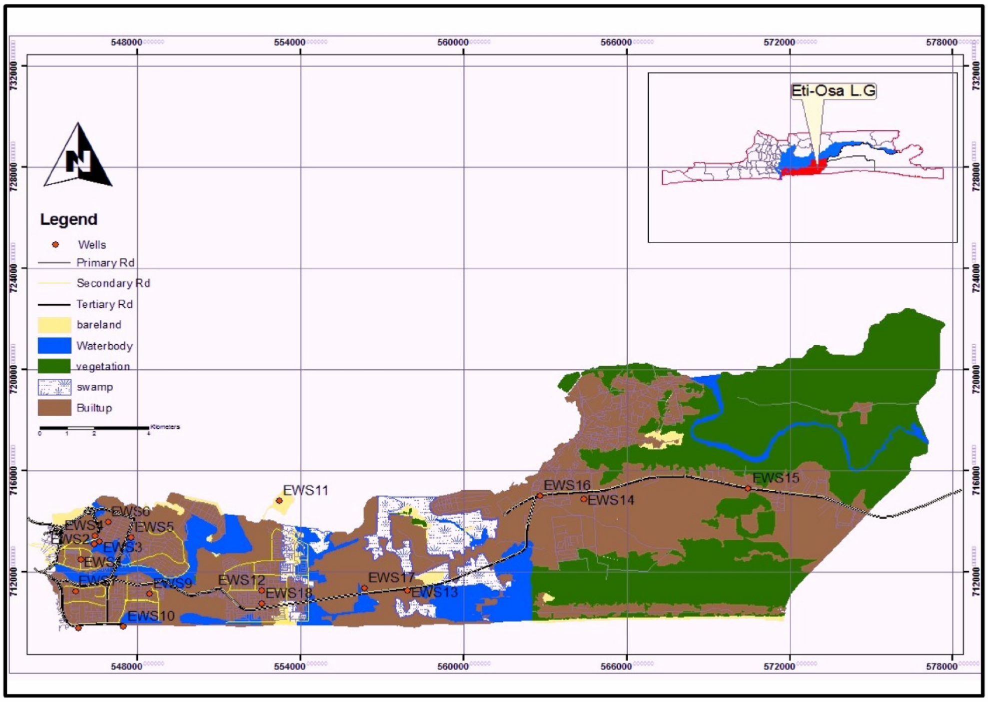

Figure 1: Study area

Material and Methods

Reconnaissance survey of the study area was carried out prior to the actual sample collection. The reconnaissance survey facilitated a better understanding of the spatial distribution of wells within the study area. Groundwater samples were collected during the month of June, 2009. The month was selected because it is the peak of the wet season in the area. It is expected that during this period, depth to the water table decreases. Therefore, contaminants are likely to reach the aquifer easily (Todd & Mays, 2005).

Eighteen (18) sampling points were selected using random sampling technique. Samples were analyzed for nine (9) physico-chemical parameters including pH, Total Hardness, Calcium, Magnesium, Chloride, Nitrate, Sulphate, Total Dissolved Solids and Iron using standard procedure. The parameters were selected because they are natural inorganic constituents commonly dissolve in water that are most likely to affect water use (Heath, 1964).

Co-ordinates of the sampling points were recorded using Global Positioning System (GPS) Garmin Channel 72 model. The sampling points were interpolated and digitized on a satellite imagery of the study area. The Water Quality Index (WQI) was used to determine the suitability of water quality in the study area based on the 9 parameters examined.

Water samples were collected in clean 1.5 litre plastic jar with screw caps, and packed in cooler containing ice and transported to the laboratory within 24hours from the time of sample collection. Samples were analyzed for physico-chemical analysis using standard methods for water samples examination of American public Health Association (1998). In situ analysis was carried out to determine pH and Total Dissolve Solids using potable digital meter,EXTECH pH-100 and HM digital EC/TDS/Temperature COM-100 respectively.

Total Hardness and Chloride were determined using titrimetry method. The concentrations of metals (Iron, Magnesium and Calcium) were determined by Atomic Absorption Spectrophotometer (AAS) while Sulphate and Nitrate was determined using HACH DR/2000 direct reading spectrophotometer which is internally calibrated.

In computing Water Quality Index (WQI), three steps were adopted. The first step, each of the parameters was assigned a weight (wi) according to its relative importance in the overall quality of water for drinking purposes (Table 3). In the second step, the relative weight (Wi) was computed from the following equation:

$$W_i = \frac{w_i}{\sum_{i=1}^{n} w_i} \qquad (1)$$

Where, W_i is the relative weight, wi is the weight of each parameter and n is the number of parameters.

In the third step, a quality rating scale (qi) for each parameter was assigned by dividing its concentration in each water sample by its respective standard according to the guidelines by (SON,2007) and the result was multiplied by 100:

$$q_i = (C_i / S_i) \times 100 \qquad (2)$$

where q_i is the quality rating, C_i is the concentration of each chemical parameter in each water sample in mg/L, and S_i is the Standard Organization of Nigeria Drinking Water Quality for each chemical parameter in mg/L according to the guidelines of the, 2007.

To compute the WQI, the SI was determined first, for each chemical parameter which was then used to determine the WQI as per the following equations:

$$SI_i = W_i \cdot q_i \qquad (3)$$

$$WQI = SI_i \qquad (4)$$

Where SI_i is the sub-index of ith parameter; q_i is the rating based on concentration of ith parameter and n is the number of parameters. The computed WQI values were classified into five types, “excellent water” to “water, unsuitable for drinking” (see Table 4).

Results and Discussion

Table 1 presents the descriptive statistics of groundwater parameters in the study area. It was observed that the pH in all the groundwater samples ranges from 6.79 to 7.22 with a mean of 7.01 mg/l, indicating slightly acidic to slightly alkaline environment. The pH values are within the prescribed limits of 6.5-8.5 for drinking water standards.

Table 1: Descriptive Statistics of groundwater sample parameters

Parameters	Mean	SD	LCL	UCL	CV (%)
pH	7.01	0.43	6.79	7.22	6.13
TH	37.11	19.92	27.21	47.02	53.68
Ca	16.11	6.82	12.72	19.50	42.33
Mg	2.71	2.54	1.44	3.97	93.73
Cl	222.22	87.82	178.55	265.89	39.52
TDS	607.44	341.88	437.43	777.46	56.28
NO3	0.77	0.50	0.52	1.02	64.94
Fe	0.66	0.19	0.56	0.76	28.79
SO4	1.80	0.99	1.31	2.29	55.00

All units except pH are in mg/l, SD-Standard deviation, LCL-Lower Confidence Limit, UCL-Upper Confidence Limit
CV-Coefficient variation.

The results show that Total Hardness varied between 27.21- 47.02, with a mean of 37.11mg/l, indicating the groundwater Quality of the study area is slightly hard. The TDS, which is an indicative parameter to assess the degree of water quality, varied between 437.43 - 777.46 with a mean of 607.44mg/l .The TDS values were above the prescribed limits of 500mg/l for drinking water purpose. TDS in groundwater are generally not harmful to human being but high concentration of these may affect persons, who are suffering from kidney and heart diseases (Gupta, 2004).

Water containing high solids may also cause laxative or constipation effects. The concentration (mg/L) of Calcium, Magnesium, Chloride, Sulfate and Nitrate are in the range of 12.72 -19.50, 1.44-3.97, 178.55 – 265.89, 1.31 -2.29 and 0.52-1.02 with a mean of 16.11, 2.71, 222.22, 1.80 and 0.77 respectively.

Compared to SON, the concentration of Ca, Cl, SO_4 and NO_3 are below the safe limit of 300, 250, 100 and 50 mg/L for drinking, respectively whereas, concentration of Mg (2.71mg/l) was above the permissible limits of 0.2mg/l for drinking purpose.

Since the chloride-rich minerals are not found in the study area, the higher concentrations of chloride in the groundwater could be caused by pollution sources **from** domestic wastewater and septic tanks. Iron content varies from 0.56-0.79 mg/l, with a mean of 0.66 mg/l. The concentration of Fe (0.66mg/l) is above the prescribed limits of 0.3mg/l for drinking water standards. On the pattern of relative variation, the result of the Coefficient of variation (C.V) shows that all the examined groundwater variables with the exception of pH, Ca, Cl and Fe are heterogeneous, hence there is need for routine monitoring of groundwater quality in the study area.

Table 2 presents the correlation among various parameters of groundwater in the study area. Statistically significant positive correlations was observed between Total Hardness and Chloride (r =0.51). Negative correlation was observed between pH and Calcium (r = - 0.49) at $p < 0.05$.

The computed WQI shows that the groundwater samples ranges from 26.62 to 24,345.0.The high value of WQI has been found to be mainly from the higher values of pH, Magnesium, Chloride, Total Dissolved Solids and Iron. About 98.77% of water samples in the study area are unsuitable for drinking while 0.17%, 0.28% and 0.77% are excellent, good and very poor respectively (see table 4).

In a similar study, (Ramakrishnaiah,et al.,2009) examined the groundwater quality of Tumkur Lake watershed in Indian and found that the high value of WQI are mainly from Fe, NO_3,TDS, hardness, Flouride, Bicarbonates, Magnesium and Manganese. The study further revealed that, about 54.54% of water samples in the study area are unsuitable for drinking while22.72% have very poor quality. Yusuf (2007) , investigated the quality of groundwater characteristics in Lagos-City and inferred that urban groundwater are characterized by high major ions concentration and its degradation could result from human activities as well as municipal waste disposal .

Yogendra and Puttaiah (2008) used WQI for the determination of the suitability of the urban waterbody.The study revealed that there is seasonal variation in pollution load of waterbody and is very high during summer compared to winter and rainy seasons. The WQI analysis shows that the water quality rating is eutrophic and unsuitable for human use. Ojo (1995) examined the health risk from surface and groundwater contamination in urban centers of Nigeria and inferred that the consequences of solid waste disposal, poor sewage, unsanitary conditions and the perennial problems of unsafe water supply are some of the most important causes of health risks in many urban centers of West Africa.

Study carried out on the quality of possible contamination of groundwater around areas close to refuse dumps in the Lagos metropolitan area showed that several water supply wells in Lawanson residential area and the Ikeja industrial area have high concentrations of iron and mercury exceeding WHO standards (Ojo, 1995). He maintained that in general, Lagos metropolitan areas have similar natural concentrations of these metals hence; the results suggest that water quality differences may be the result of the large number of refuse dumps in the residential areas.

Conclusion

The result show that, the groundwater quality ranges between 0.86-1,228.0mg/L.Total Dissolve Solid has the highest mean (607.44mg/L), followed by Cl (222.22mg/L) while Fe has the least value of (0.66mg/L).Further analysis revealed that, all the parameters examined except (pH,Ca,Cl and Fe) show high variation. The computed WQI (table 2) shows that the groundwater samples ranges from 26.62 to 24,345.0.The high value of WQI has been found to be mainly from the higher values of pH, Magnesium, Chloride, Total Dissolved Solids and Iron. About 98.77% of water samples in the study area are unsuitable for drinking while 0.17%, 0.28% and 0.77% are excellent, good and very poor respectively.

The study concluded that, there is need to regularly monitor the quality of groundwater and device means to protect it. This study provides a preliminary assessment of the groundwater quality in the study area and will serve as a data base for future investigations and monitoring of the resource. The paper recommended thorough treatment of the groundwater before consumption in the study area.

Table 2: Inter-dependency between Parameters of Water Samples and their Significance

Parameter	Pearson's Co-efficient of Correlation	Co-efficient of Determination	Significance Level
pH vs TH	0.06	0.01	NS
pH vs Ca	-0.49	0.24	S
pH vs Mg	-0.27	0.07	NS
pH vs Cl	0.25	0.06	NS
pH vs TDS	-0.39	0.15	NS
pH vs NO3	-0.19	0.04	NS
pH vs Fe	-0.1	0.01	NS
pH vs SO4	0.42	0.18	NS
TH vs Ca	0.19	0.04	NS
TH vs Mg	0.04	0.01	NS
TH vs Cl	0.51	0.26	S
TH vs TDS	0.18	0.03	NS
TH vs NO3	-0.22	0.05	NS
TH vs Fe	-0.21	0.04	NS
TH vs SO4	0.13	0.02	NS
Ca vs Mg	0.29	0.08	NS
Ca vs Cl	0.09	0.01	NS
Ca vs TDS	0.65	0.42	NS
Ca vs NO3	-0.31	0.09	NS
Ca vs Fe	0.05	0.01	NS
Ca vs SO4	-0.26	0.06	NS
Mg vs Cl	0.03	0.01	NS
Mg vs TDS	0.36	0.13	NS
Mg vs NO3	0.45	0.2	NS
Mg vs Fe	-0.39	0.15	NS
Mg vs SO4	-0.08	0.01	NS
Cl vs TDS	0.23	0.05	NS
Cl vs NO3	0.18	0.03	NS
Cl vs Fe	-0.01	0.01	NS
Cl vs SO4	0.42	0.18	NS
TDS vs NO3	0.13	0.02	NS
TDS vs Fe	-0.16	0.03	NS
TDS vs SO4	-0.09	0.01	NS
NO3 vs Fe	0.12	0.01	NS
NO3 vs SO4	0.39	0.15	NS
Fe vs SO4	0.05	0.03	NS

NS-Not Significant, S-Significant

Table 3: Relative Weight of Chemical Parameters

Parameters	**SON**	**Weight (wi)**	**Relative weight (Wi)**
Ph	6.5-8.5	4	0.13333
Total Hardness(TH)	500	2	0.06666
Calcium	300	2	0.06666
Magnesium	0.2	2	0.06666
Chloride	250	3	0.10000
Total Dissolve Solids (TDS)	500	4	0.13333
Nitrate	50	5	0.16666
Iron	0.3	4	0.13333
Sulphate	100	4	0.13333
		$\sum$ wi= 30	$\sum$ Wi= 1.0000

SON-Standard Organization of Nigeria,2007

Table 4: Water quality Classification based on WQI value

WQI value	Water quality	Percentage of water samples
<50	Excellent	0.17
50-100	Good water	0.28
100-200	Poor water	0
200-300	Very poor water	0.77
> 300	Water unsuitable for Drinking	98.77

Source: Brown et al.,(1970)

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