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Analysis of Groundwater Quality from Coastal Aquifers around Agbara Industrial Estate, Lagos, Southwest Nigeria

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Abstract:- The quality of water is measured in terms of its physical, chemical and bacteriological characteristics. Groundwater in most coastal aquifers has deteriorated owing heavy anthropogenic interference with the hydrological cycle. The study revealed that the pH in the area is low and enhanced the high rate of microbial activity typified by elevated concentration of BOD. COD, total coliform and E.coli. They human and microbial activities affected the colour. The high concentration of manganese may be due to effluent from the industries within the estate which are discharge into the environment without proper treatment. The Piper diagram shows that the water type in the area in Na-Cl type indicating a possible marine source. Good sanitary habit and proper treatment of industrial effluent before discharge into the surrounding is advocated.

Keywords:- Groundwater Quality, Coastal Aquifers, Agbara Industrial Estate, Lagos, Southwest Nigeria

I. INTRODUCTION

Globally, increasing industrialization is taking place along coastlines and causing increased use of groundwater which has impacted on the quality of shallow coastal aquifer water (Amadi, 2011). Increasing contamination of surface water bodies in the last few decades has shifted attention to groundwater resources development (Amadi *et al*., 2012). Groundwater quality appraisal is an essential tool in effective water management and control of water borne diseases such as cholera, typhoid fever, diarrhea and meningitis (Egharevba, *et al*., 2010). The need of the hour is to make clean water available for people to use as it is the most important element to sustain life. The quality of water we consume is function of the quality of our health, as it aid digestion, regulate body temperature, restore body fluids and removes impurities from our internal system. It is nature's best beverages as it quenches ones thirst better than any other drink (Amadi, 2012).

Agbara industrial estate like most industrial estates in the world has a very high demand for water. The estate hosts many industries ranging from glass, plastic, pharmaceutical to food processing and manufacturing as well as hotels. The estate derives its water mainly through borehole, surface water and hand-dug wells for its daily water need. The tendency of effluents from these industries leaching through the highly porous and permeability formation and contaminating the shallow water table cannot be ignored completely, hence the need for the present study. The study is aimed at assess the quality of groundwater from the shallow aquifer within the vicinity of Agbara industrial estate with respect to domestic, agricultural and industrial application. This is necessitated because the manner in which industrial effluent are discharged in the estate are worrisome (Plates 1 and 2).

Plate 1: Effluent discharge point at Phama Deko Factory

Plate 2: Effluent discharge point at Beta Glass Industry

Study Location, Extent and Accessibility

The study area, Agbara Industrial Estate is located at Agbara, the southwestern part of Lagos State, Nigeria (Figure 1). The estate holds the following industries: Beta Glass, Pharma Deko, Lotus Plastic, Nestle Foods, Vita Malts, Homes and Komex Hotel, covering an area of about 54 Km^2. It is accessible in the north through Aton-Lusida road, in the east by Orile-Badagry road and in the west through Badagry-Cotonu road and has contact with the Atlantic Ocean in the south (Figure 2).

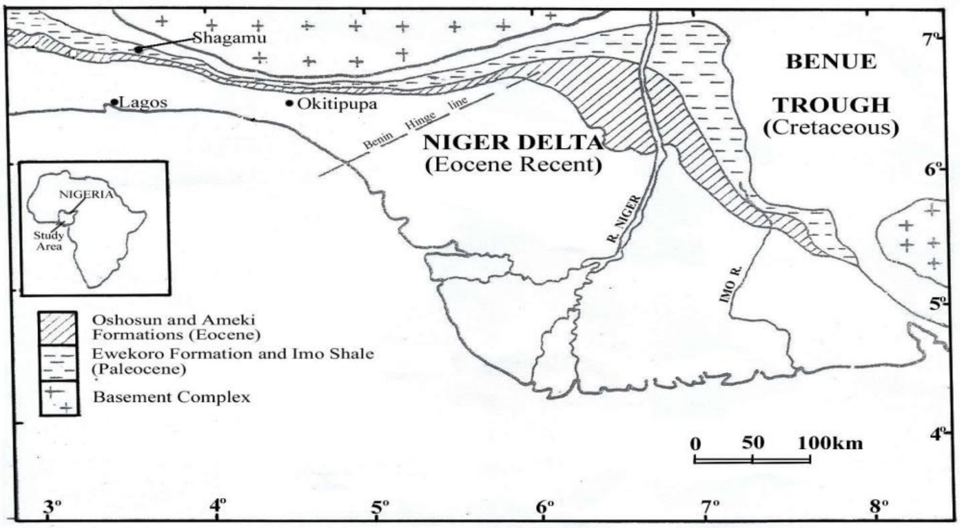

Fig. 1: Geological map of the Southern Nigeria showing the study area

Topography and Drainage System

The study area lies within the coastal plain of the Dahomey Basin, Southwestern Nigeria, where the relief is generally low with an average elevation of about 150 m to 350 m above sea level (Ajibade and Wright, 1988). The drainage pattern in the area is dendritic with tributaries having wide course. The area is drained by River Ijuri which flows in NE-SW direction where it joins the Atlantic Ocean.

Climate and Physiography of the Area

The study area is characterized by wet and dry seasons. The onset of the rainy season is usually March to November while the dry season takes the remaining part of the year. The study area falls within the tropical rainforest climate while the annual temperature is moderate with a value of about 28^{O}C. Humidity is high in the rainy season and drop to its lowest level during December due to harmattan.

Geology of the area

The survey area consists partly of Basement Complex rocks and partly of sedimentary rocks of Cretaceous and Tertiary age of the Dahomey Basin. The Basement Complex consists of three principal rock types, the ancient Meta-Sediments, the Migmatites-Gneiss complex and the Older Granites. The ancient meta-sediments consist of schist, granulites and calc-silicates. They represent the oldest rocks. The gneisses appear to have been largely derived from these meta-sediments by migmatization, involving essentially the introduction of microcline and quartz interstitially into the schist and granulites. The igneous and metamorphic rocks cover over half of the surface of Southwestern Nigeria and are collectively known as the Basement Complex. A contact-zone between the Basement Complex and the Sedimentary terrain was discovered along the Oru-Ijebuode area

(Figure 2). The Dahomey Basin is an extensive sedimentary basin on the continental margin of the Gulf of Guinea. It runs parallel to the coastal margins of Ghana, Togo, Benin Republic and Southwestern Nigeria (Figure 2). It is separated from the Niger Delta basin by the Benin hinge line and the Okitipupa ridge (Adegoke, 1972, Bankole et.al., 2006). The basin is a marginal pull-part (Reyment, 1965) or marginal sag basin (Whiteman, 1982) while developed in the Mesozoic era when the African and South American plates separated and the continental margin was founded (Jones, 2002). The Benin hinge line is part of the chain oceanic fractures while the Okitipupa ridge is a submarine basement ridge (Adegoke, 1972). The sedimentary rocks were studied along Lagos-Abeokuta road (Fayose, 1970). The sediments are generally poorly exposed except at the escarpment. The stratigraphic succession of rocks in the area is contained in Table 1.

Fig. 2: Geological and Stratigraphic map of Dahomey Basin, Southwestern Nigeria

Table1: Stratigraphic Correlation of Dahomey Basin

Age	Jones and Hockey (1964)	Adegoke and Omatsola (1981)
Recent	Alluvial Littoral	Lagoonal Deposit
Miocene Oligocene	Coastal Plain Sand	Coastal Plain Sand
Upper Euocene-Oligocene	Baro Formation	IIaro Formation
Lower Euocene-Middle Eocene	Oshosun Formation	Oshosun Formation
Lower Eocene-Upper Paleocene	Akimbo Formation	Akimbo Formation
Paleocene	Ewekoro Formation	Ewekoro Formation
Mastrician	Araromi Formation	Araromi Formation
Turonian	Afowo Formation	Afowo Formation
Neocomian Albian	Ise Formation	Ise Formation
Precambrian	Basement Complex	Basement Complex

II. METHODOLOGY

A total of 30 samples comprising of 10 effluents, 15 boreholes and 5 hand-dug wells were collected in the vicinity of Agbara Industrial Estate and analyzed using standard analylitical procedures (Clesceri, 1989). Each samples was analyzed for pH, colour, temperature, conductivity, calcium, calcium hardness, total hardness, potassium, chlorine, sodium, biochemical oxygen demand (BOD), chemical oxygen demand (COD), Escherichia coli (E.coli), total coliform (TC), total dissolved solid (TDS), total suspended solid (TSS), total solid (TS) ,bicarbonate, carbonate, chloride, manganese, iron, sulphate, nitrate and magnesium using procedures outlined in the Polintest Photometer Method (Polintest Photometer 5000) for examination of water and wastewater.

III. RESULTS AND DISCUSSION

The result of the physico-chemical and microbial analysis carried out are summarized in Table 2. A closer look at Table 2 shows that a total of seven parameters have their mean concentration exceeding the maximum permissible limit recommended by World Health Organization (WHO, 2006) and Nigerian Standard for Drinking Water Quality (NSDWQ, 2007) for a potable water. The parameters includes pH, colour, BOD, COD, total coliform, E.coli and manganese (Figure 3). Colour in water may be attributed to the presence of organic matter such as humic substances, metals such as iron or highly coloured industrial wastes (WHO, 2006; Amadi *et al*., 2012). The value of colour ranged between 5.0-180.0 TCU with a mean value of 68.4 TCU (Table 2). The colour values in some exceed the maximum permissible of 15.0 TCU (WHO, 2006). The pH values varied from 5.50-6.95 with an average value of 6.30. The low pH values may be due to the effect of direct discharge of industries wastes on the soil, surface and groundwater. The electrical conductivity value ranged from 34.0-702.0 µs/cm with an average value of 240.1 µs/cm and these values falls below the maximum permissible limit of 1000.0 µs/cm (WHO, 2006). The presence of ions in water makes it conductive. The value of total dissolved solid ranged between 22.1-500.0 mg/l with a mean value of 187.2 mg/l. The amount of TDS in water is a function of dissolved ions in water may be natural via bedrock dissolution or anthropogenic through industrial effluent. The value of suspected solid varied from 5.0-80.0 mg/l with a mean value of 36.78 mg/l. It refers to those solid that are not dissolved (soluble) in water.

The concentration of bicarbonate ranged between 13.0-100.0 mg/l with an average concentration of 49.45 mg/l while carbonate values ranged from 0.0-200.0 mg/l with a mean value of 18.18 mg/l. Chloride had concentration ranging from 3.5-150.0 mg/l with a mean concentration of 28.97 mg/l while sulphate values varied from 6.7-100.0 mg/l and an average value of 20.97 mg/l. Nitrate concentration ranged between 7.8-44.0 mg/l with a mean value of 16.59 mg/l (Table 2). The concentration of the major anion falls within the acceptable limits set by the World Health Organization except carbonate whose concentration in some locations was slightly higher in some locations and its enrichment may be attributed to the dissolution of the host rock. The mean concentration of calcium and magnesium are 17.01 mg/l and 18.51 mg/l respectively while the average values of sodium and potassium are 15.26 mg/l and 8.38 mg/l respectively (Table 2).

The concentrations of the major cations fall below their recommended standards by both the World Health Organization and Nigerian Standard for Drinking Water Quality. Total solid (TS) is the summation of the total dissolved solids and total suspended solids. Its values ranged between 54.0-420.0 mg/l with a mean value of 166.8 mg/l (Table 1). Water containing high solids can cause laxative and constipation effect (Water *et al.,* 2010). The concentration of chemical oxygen demand (COD) ranged from 43.0-175.0 mg/l with a mean concentration of 96.4 mg/l as against the maximum permissible limit of 10.0 mg/l (NSDWQ, 2007). The determination of COD provides a measure of the oxygen equivalent of the portion of organic matter in water that is vulnerable to oxidation by a strong chemical oxidant. It accounts for the quantity of oxygen required for oxidation of organic and inorganic matter in water. The very high concentration of COD in the water implies that industrial effluent and other solid waste discharge into the surrounding contains oxidizable organic and inorganic pollutants (Otukune and Biukwu, 2005; Amadi, 2011). The biochemical oxygen demand (BOD) accounts for the oxygen required in the decomposition of organic matter. The concentration of BOD varied from 24.0-528.0 mg/l with an average value of 198.8 mg/l and these values by far exceeds the permissible limit of 6.5 mg/l (NSDWQ, 2007). The elevated concentration may as a result of microbial activity occurring during decomposition of organic matter in water. The concentration of total coliform ranged between 10.0-322.0 cfu/100ml with a mean concentration of 163.0 cfu/100ml as against the maximum permissible limit of 10.0 cfu/100ml (NSDWQ, 2007). The value of Escherichia coli (E.coli) varied between 0.0-8.0 cfu/ml with an average value of 2.45 cfu/ml and these values are slightly higher than the recommended value of 0.0 cfu/ml (WHO, 2006; NSDWQ, 2007). Poor sanitary condition arising from water contamination with human and animal faeces may be responsible for the observed high total coliform and Escherichia coli in the water. Studies have ascertained the presence of bacteria counts (total coliform and Escherichia coli) on both human and animal faeces (Amadi, 2009; Egharevba et al., 2010).

The concentration of manganese ranged between 0.03-1.50 mg/l with a mean value of 0.47 mg/l while iron concentration varied from 0.1-0.41 mg/l with an average value of 0.25 mg/l. The maximum permissible limit for manganese and iron are 0.2 mg/l and 0.3 mg/l respectively (WHO, 2006; NSDWQ, 2007). High manganese in water causes neurological disorder in human and its presence in the water from the area may be due to effluent discharge from the industries within the estate.

Table 2: Summary of physical, chemical and microbial analysis of groundwater and effluents from Agbara Industrial Estate, Lagos

Parameters (mg/l)	Minimum	Maximum	Mean	Standard Deviation	Variance
Temperature	26.00	26.00	26.00	8.22	67.60
Colour	5.00	180.00	68.36	55.58	389.07
pH	5.50	6.95	6.30	2.04	4.16
Conductivity	34.00	702.00	240.10	235.50	5460.10
TDS	22.10	500.00	187.21	177.26	3421.37
Suspended solid	5.00	80.00	36.78	22.16	491.09
Bicarbonate	13.00	100.00	49.45	29.71	882.71
Carbonate	0.00	200.00	18.18	63.25	4000.00
Chloride	3.50	150.00	28.97	43.65	1905.71
Manganese	0.03	1.50	0.47	0.47	0.22
Iron	0.10	0.41	0.25	0.09	0.01
Sulphate	6.70	100.00	20.97	28.00	783.82
Nitrate	7.80	44.00	16.94	11.25	126.67
CH	12.80	75.00	38.04	19.59	383.80
Total Solid	54.00	420.00	166.80	118.72	4094.93
Magnesium	1.80	150.00	18.51	45.71	2089.35
Calcium	3.90	75.00	17.01	20.89	436.58
Total Hardness	44.00	100.00	67.64	17.75	314.94
Potassium	0.40	75.00	8.38	23.07	532.42
Chlorine	0.10	0.61	0.24	0.24	0.06
Sodium	0.00	150.00	15.26	47.36	2242.78
BOD	24.00	528.00	198.80	170.36	2020.89
COD	43.00	175.00	96.40	68.34	4670.84
E.Coli (cfu/ml)	0.00	8.00	2.45	2.67	7.16
TC (cfu/100ml)	10.00	322.00	163.36	1230.86	9719.57

TDS- total dissolved solid; BOD- biochemical oxygen demand; CH- Calcium Hardness;
COD- chemical oxygen demand; TC- total coliform; E.coli- Escherichia coli

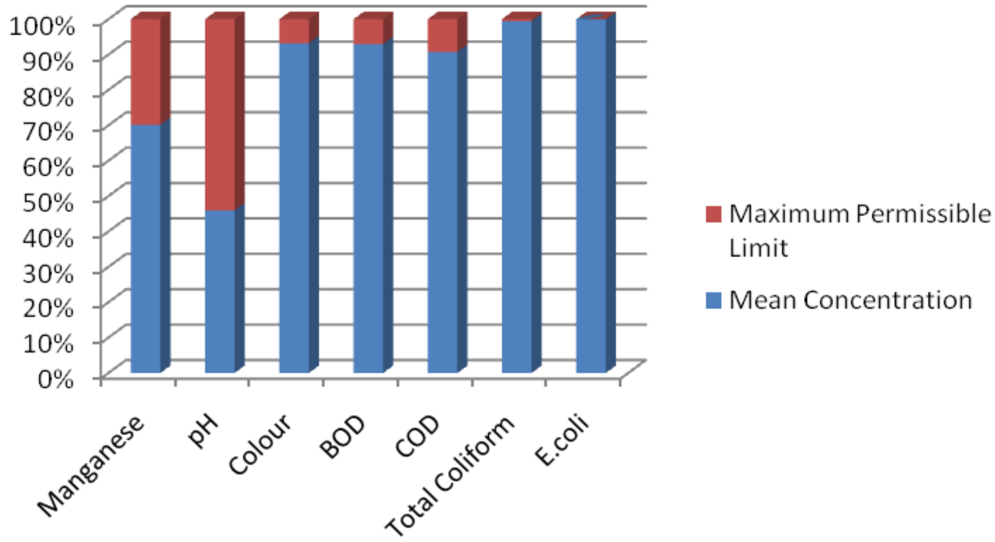

Figure 3: Correlation analysis between mean concentration and the recommended maximum permissible limits of (WHO, 2006; NSDWQ, 2007)

Piper Diagram

This method was devised by Piper in (1944) to outline certain fundamental principles in a graphic procedure which appears to be an effective tool in separating analytical data for critical study with respect to sources of the dissolved constituents in water. The ionic strength of the groundwater is generally dominated by major cations (sodium, potassium, calcium and magnesium) and anions (bicarbonate, chloride, carbonate and sulphate). Hydrochemistry of the groundwater in coastal aquifer in the Lagos region of Nigeria was summarized through the trilinear plots of the major anions and cations (Figure 4) generated using concentrations of the cationic and anionic species expressed in milli-equivalents per litre. The concentration of 8 major ions (Na^+ ,K^+, Mg^{2+}, Ca^{2+}, Cl^-, CO_3^{2-}, HCO^-_3 and SO_4^{2-}) are represented on a trilinear diagrams by grouping the (K^+ with Na^+) and the (CO_3^{2-} with HCO^-_3), thus reducing the number of parameters for plotting to 6. On the piper diagram, the relative percentages of the cations and anions are plotted in the lower triangles, and the resulting two points are extended into the central field to represent the total ion concentration. The water type in the area is Na-Cl type indicating a marine source. The study area is surrounded by the Atlantic Ocean and the possibility of saltwater intrusion cannot be overemphasised.

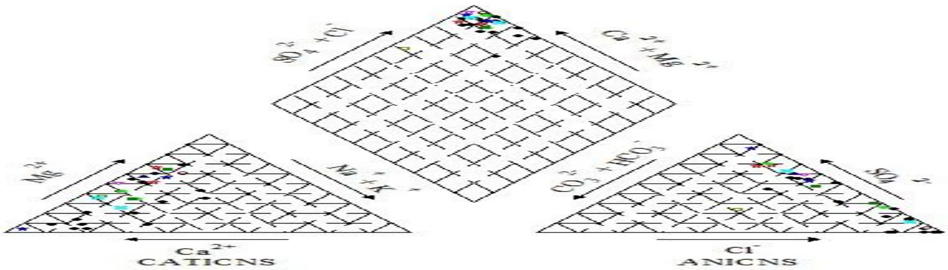

Figure 4: Piper diagram of groundwater from the study area

IV. CONCLUSION

The study revealed that the pH in the area is low and this may be responsible for the high rate of microbial activity typified by elevated concentration of BOD. COD, total coliform and E.coli. The high concentration of manganese may be due to effluent from the industries within the estate which are discharge into the environment without proper treatment.

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