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EVALUATION OF SURFACE AND GROUNDWATER QUALITY IN OWERRI METROPOLIS, SOUTHEASTERN NIGERIA

Amadi, A. N.
Department of Geology, Federal University of Technology,
P. M. B. 65, Minna, Niger State.
Corresponding author email: akoamadi @ yahoo.com.
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Abstract

Physio-chemical and microbial analyses were carried out on surface and groundwater samples within Owerri metropolis to determine their quality. The physio-chemical parameters analyzed were temperature, pH, electrical conductivity (EC), total dissolved solid (TDS), suspended solid (SS), total solid (TS), HCO_3^-, CO_3^-, Cl^-, SO_4^{2-}, NO_3^-, Ca^{2+}, Mg^{2+}, Na^+, K^+, Fe^{3+} and Mn while the bacteriological parameters includes salmonella-typhii and total coliform. The water can be classified as acidic to slightly alkaline and fresh water based on the pH and TDS. The HCO_3^- was the highest among the anions with concentrations that ranged from 16.0mg/l to 45.0 mg/L while Ca^{2+} had the highest concentrations that varied from 3.2 mg/L to 49.0 mg/L. The Piper trilinear diagram was used to classify the water in the area as Ca-HCO_3^- water. The concentrations of the physical and chemical parameters were below the recommended maximum allowable limit for safe drinking water by World Health Organization and Nigerian Standard for Drinking Water Quality except Mn in locations 3 and 7 which concentrations were slightly above the permissible limit by the two standards. Salmonella-typhii and E.coli were not detected in all the locations while concentration of total coliform was above the maximum permissible value recommended by the two standards that indicated faecal contamination of the water resources.

***Keywords**: Evaluation, Water Quality, Owerri Metropolis and Southeastern Nigeria.*

INTRODUCTION

Water is one of our most basic and important resources. Ensuring that we maintain an adequate safe supply of water is one of our most important environmental objectives. Groundwater is exposed to active pollution in the major cities in Nigeria especially in southeastern Nigeria due to the increase of urbanization, indiscriminate waste disposal and poorly managed municipal landfill system (Amadi, 2009). Polluted water contains hazardous substances that affect the health of man, animals and plants when consumed, or deteriorates the environment when spilled out on the surface. Owerri and its environs have undergone a great industrial and population growth during the past three decades. The main region of growth is in the Owerri metropolis which now has a population of about two hundred and thirty-one thousand, seven hundred and eighty-nine (231,789) (Wikipedia, 2006). This tremendous growth has led to the large accumulation of wastes, turning riverbanks, erosion sites, abandoned pit in the area into dumpsites (Amadi, 2008). The study is aimed at assessing the groundwater and the behaviour of constituent that have the potential to leach from dumpsites and other similar sites through the porous and permeable overburden to the shallow water table in the area. Good drinking water quality is essential for the well being of all people.

The need to ascertain the quality of water used by humans cannot be underestimated as the quality of groundwater, not quantity determines its usability (Amadi, 2008). Water intended for drinking and household purposes must not contain water-borne pathogens and the most specific bacterial indicator of faecal pollution from humans and animals is Escherichia coli (Olasehinde and Amadi, 2009).

MATERIALS AND METHODS

Location and Physiography of the Study Area

Owerri, the capital city of Imo state, the 'Eastern Heartland' lies between latitudes 5°15'N to 5°35'N and longitudes 6°55'E to 7°15'E (Fig. 1), covering a total area of about 1014km^2. It has a good road network and can be easily accessed through Aba, Port-Harcourt, Orlu, Okigwe and Onitsha routes (Fig.1)

The prevalent climatic condition is marked by two main regimes: the rainy and the dry seasons. The rainy season is from April to October during which the temperature varies from 23°C to 26°C, and this season is associated with the prevalent moisture-laden south-west trade wind from the Atlantic Ocean. The wet season is also characterized by double maximum rainfall during which the first peak occur in July and the second occurs in September with a mean annual rainfall of 2152 mm (Ezeigbo, 1989). The dry season starts in November, when the dry continental north-eastern wind blows from the Mediterranean Sea across the Sahara desert and Samarian desert and down to the southern part of Nigeria. Due to vagaries of weather, the August break sometimes occurs in July or early September. Humidity is usually low and clouds are absent, during the dry season. The effect of the harsh north easterly wind, also called Harmattan, is felt within the period. The average monthly temperatures are high throughout the year. A mean annual temperature of 32°C is typical of the area (Ezeigbo, 1989).The area lies within the tropical rain forest belt of Nigeria. The natural vegetation in greater part of the area had been replaced by derived savanna grassland interspersed with oil palm trees.

Hydrogeological Mapping of the Area

Detailed geological and hydrogeological investigation of the area was undertaken. The study area is outcropped by the Benin Formation which is known as the 'coastal plain-sands' (Fig.1). It consists mainly of sands, sandstone and gravel with clays occurring in lenses. The sands and sandstones are coarse to fine partly unconsolidated with thickness ranging from 0-2100 m (Avbovbo, 1978). The sediments represent upper deltaic plain deposits. The shales are few and they may represent upper deltaic plain deposit. However, the formation lacks faunal content and this makes it difficult to date, though an Oligocene-Recent age is generally accepted. The Benin Formation is composed mainly of high resistant fresh water-bearing continental sands and gravels with clay and shale intercalations (Onyeagocha, 1980).The environment of deposition is partly lagoonal and fluvio-lacustrine/deltaic (Reyment, 1965). The formation which dips south westward starts as a thin edge layer at its contact with the Ogwashi-Asaba Formation in the northern part of the area, and thickens southwards to about 100 m in Owerri area (Ibe, et al., 1992). The sandy unit which constitutes about 95% of the rock in the area is composed of over 96% of quartz (Onyeagocha, 1980). A marked banding of coarse and fine layers with a large scale cross bedding constitute the major sedimentary structures in the area (Ofoegbu, 1998).

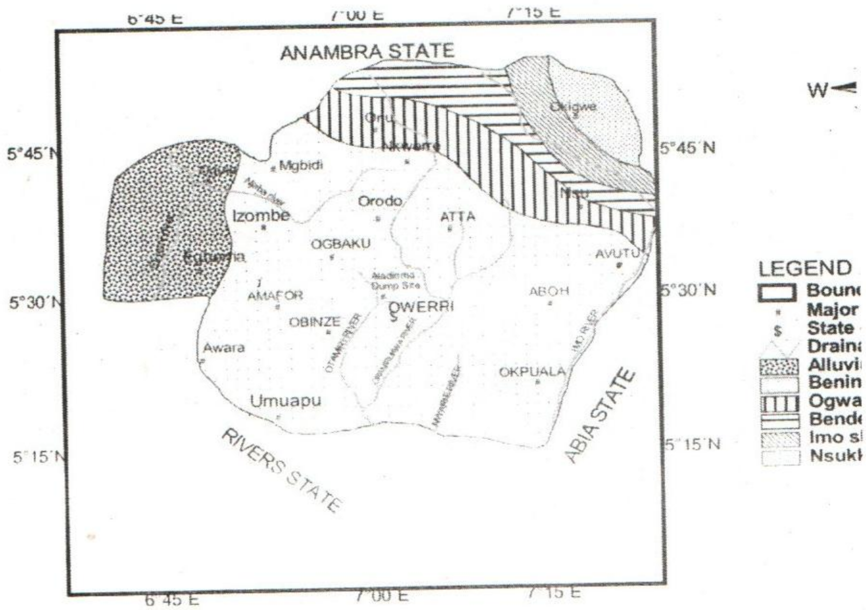

Fig. 1: Geological Map of Imo State showing the Study Area (Modified after Short and Stauble, 1967)

Stratigraphy of the Area

The stratigraphy of southeastern Nigeria has been studied in details by Uma and Egboka (1985). The Stratigraphic succession of rocks in the study area consists of Nsukka Formation, being the oldest formation and followed by Imo-Shale, Ameki Formation, Ogwashi-Asaba Formation while the youngest is the Benin Formation (Uma and Egboka, 1985). The coastal plain sand belonging to the Benin Formation extends to a considerable depth in the area and with good hydraulic properties for groundwater development. The formation consists predominantly of very thick coastal sand, sandstone, clays and sandy clays occur in lenses. The Benin Formation is in part cross-stratified with the forset beds alternating between coarse and fine-grained sands. Petrographic study on several thin sections (Onyeagocha,1980) shows that quartz makes up more than 95% of all grains. Groundwater occurs abundantly in the coastal plain sands (Benin Formation) and the static water level (SWL) ranges from 8-65 meters depending on the location and the time of the year. The Benin Formation is a good aquifer with an average annual replenishment of about 2.5 billion cubic meters per year (Onyegocha, 1980). In most areas, the sandy components form more than 90% of the sequence of the layers therefore permeability, transmissivity and storage coefficient are very high.

Sampling.

A total of 13 borehole samples and two surface water samples (Fig.2) were collected in pairs using a glass and plastic container. Two drops of concentrated trioxonitrate (v) acid was added to the each of the water samples in the plastic container to prevent adsorption of trace element to the walls of the plastic container (Schroll, 1975). The water samples in the plastic container is for cation and trace element determination while the glass containers in which no acid was added is for anion analysis. The surface water was collected from Oramiriukwa and Otamiri rivers, respectively. The longitude, latitude and elevation of sampled location were measured with the aid of global positioning system (GPS), which lead to the construction of a 3-D terrain model (Fig.3) and groundwater flow direction (Fig.4) of the area using RockWork-2006 software. These maps generated will aid in the delineation of area of groundwater recharge and discharge as well as determination of migration pathway for contaminants.

Sample Preparation and Analysis

The physical parameters (pH, conductivity, temperature and turbidity) were determined on the field using a calibrated pH meter, conductivity meter, thermometer and turbidometer respectively. The chemical parameters (cations, anions and trace elements) were analyzed using Atomic Absorption Spectrometer (AAS) while microbial analyses of salmonella typhii and total coliform were carried out using presumptive count.

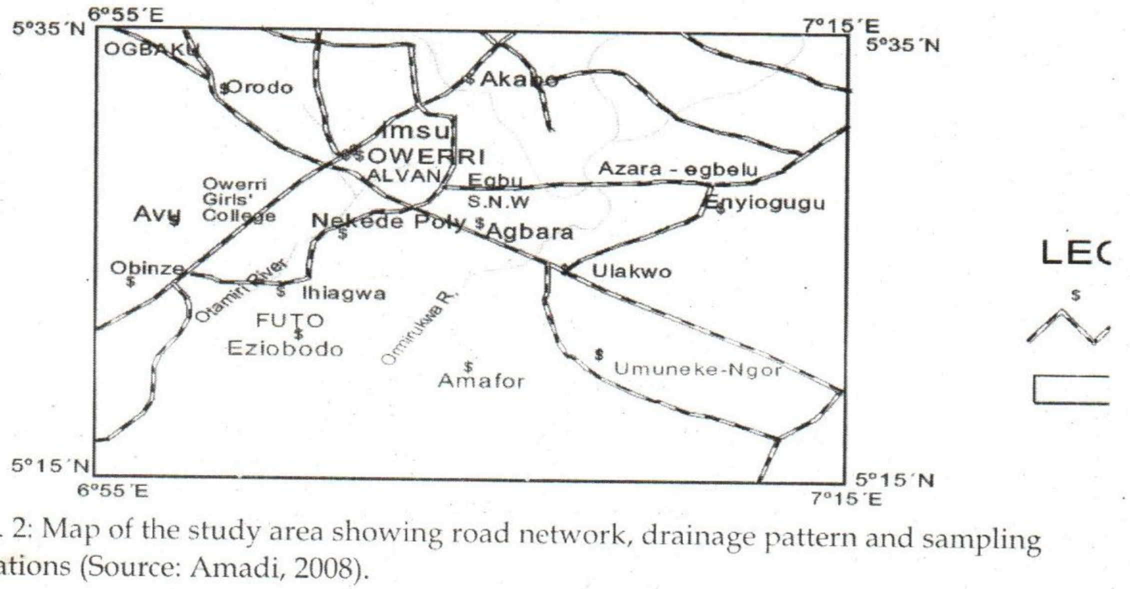

Fig. 2: Map of the study area showing road network, drainage pattern and sampling locations (Source: Amadi, 2008).

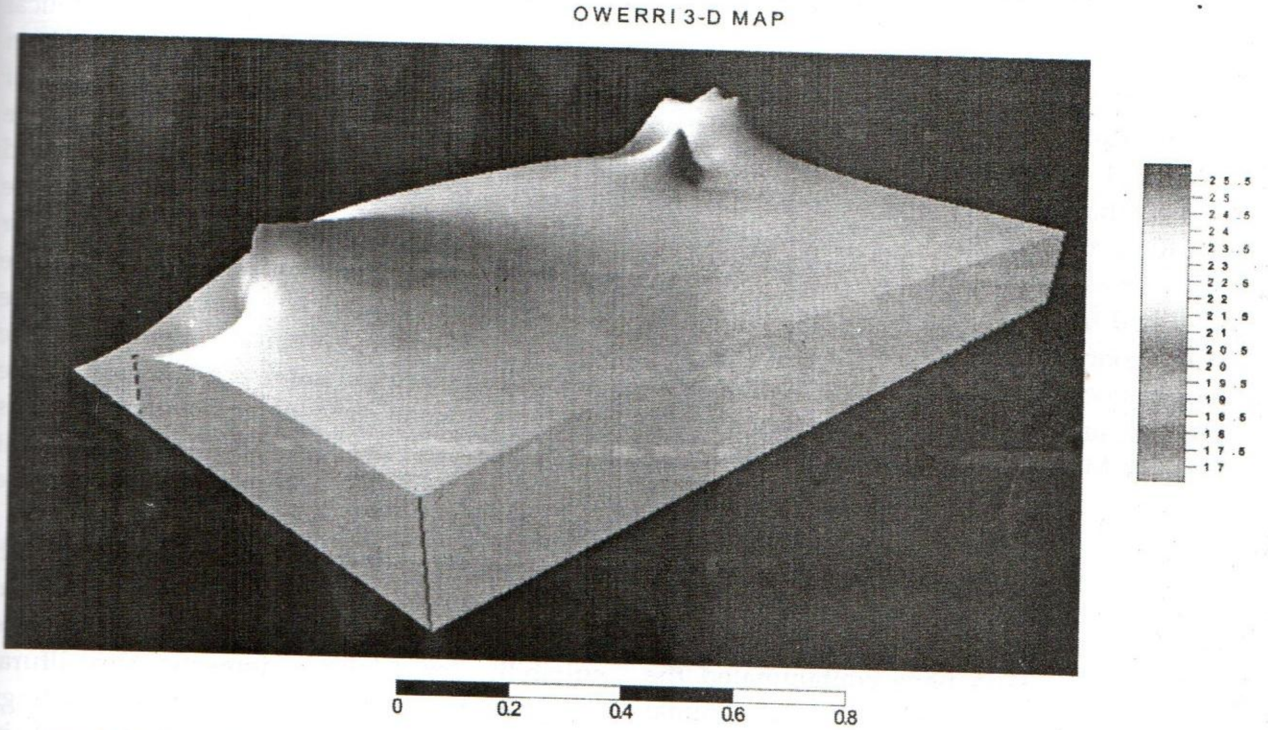

Fig.3: A digital terrain model (3-D map) of the area (Source: Amadi, 2008)

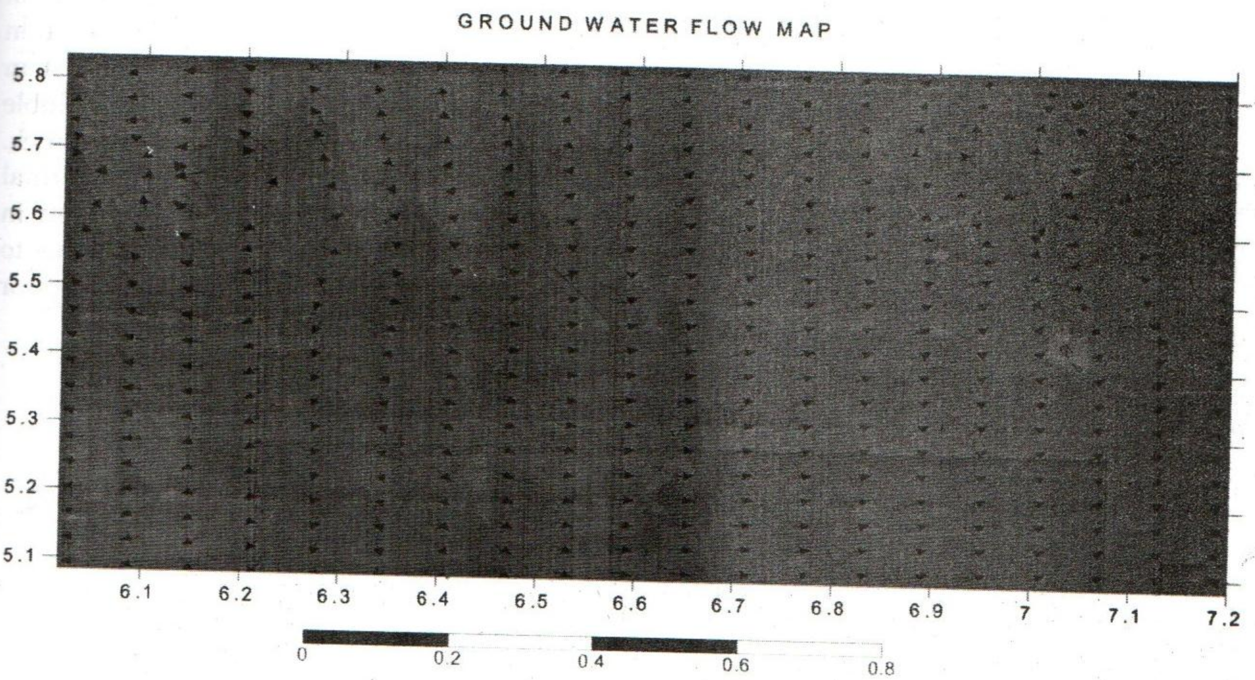

Fig.4: Groundwater flow direction in the area (Source; Amadi, 2008)

RESULTS AND DISCUSSIONS

The results of the physio-chemical and microbial analyses are contained in Table 1. The mean, standard deviation, minimum to maximum values of each parameter analyzed are also indicated in Table 1. The univariate statistical overview of surface and groundwater chemistry in the area showed no contamination by majority of the parameters when compared with the WHO (2003) and NSDWQ (2007) guideline value for drinking water quality. Mn in locations 3 and 7 had higher values while total coliform had its concentration high throughout the locations. Locations 3 and 7 host the Federal Polytechnic and Agbala mortuary, respectively and excess Mn content in the body can cause neurological disorder. The heavy human activities in the area may have contributed to the Mn concentration while the presence of total coliform in all the locations is a clear indication of faecal contamination in the area. This implies that coliform bacteria have contaminated the water resources in the area through animal wastes. The use of boreholes in location 3 and 7 should be discontinued. The aquifer system in the area is highly porous and permeable which is reflected in high hydraulic conductivity and transmissivity. The tendency of leachate migrating from underlying soakaway and pit-latrine in the shallow water-table cannot be ruled-out. Most bacteria cannot withstand high temperatures, boiling of the water will render their effect harmless. Oramiriukwa and Otamiri rivers, the only two surface water samples had the highest coliform concentration and may be due to the dropping of animal and human wastes in both rivers.

Most cases of groundwater contamination are caused by poor well construction. Good sanitation is of great importance in combating water borne diseases. However, the choice of sanitation technology depends on economic, social, geological, hydrogeological and technical issues. The availability of water for a given purpose is not as important as the suitability of the water for the desired purpose. The upsurge in human population, industrialization and urbanization in Owerri metropolis and the consequent increase in demand for water for domestic, irrigational and industrial uses make it important to periodically examine the surface and groundwater system in the area. The chemistry of groundwater is a function of the products of the rate of infiltration and its interaction with the host rock through which it passes as well as anthropogenic influence (Amadi, 2008).

Understanding the quality of groundwater with its temporal and seasonal variation is important because it is the factor that determines the suitability for drinking, domestic, agricultural and industrial purposes. The present findings are in line with some previous work especially in the area of low pH, which according to Uma (1986) may be caused by gas flaring in the region, leading to the formation of acid-rain and subsequently acid-water through infiltration into the water-table. Also, the low concentration of cations and anions in the groundwater system may be attributed to the paucity of soluble material in the overlying soil and bed rock. However, the high concentration of total coliform and E. coli. Into groundwater system in the area is a recent development, and is due to faecal contamination resulting from poor sanitary condition in the area.

Table 1: Summary of results of the physio-chemical and bacteriological analyses of surface and groundwater

Parameter	L-1	L-2	L-3	L-4	L-5	L-6	L-7	L-8	L-9	L-10	L-11	L-12	L-13	L-14	L-15	Min.	Max.	Mean	SD
Temperature (°C)	32	32	32	31	33	33	31	33	32	32	32	32	33	33	32	31	33	32.24	0.66
pH	4.8	6.8	6.8	7.1	6.5	6	6.5	4.8	6.6	5.6	4.6	4.7	5.8	4.5	4.6	4.5	7.1	5.72	1.01
	13.0	36.0	28.0	94.4	10.0	11.0	20.5	8.0	37.0	9.0	88.0	42.0	11.0	17.0	28.0	8.0	94.4	32.66	30.47
TDS (mg/L)	7.3	23.0	18.0	18.0	3.3	5.2	10.3	7.2	24.0	6.0	57.0	27.0	7.2	11.0	19.0	3.3	57.0	17.87	16.55
S. Solid (mg/L)	10.0	8.0	4.0	8.0	9.0	11.6	3.2	1.8	2.6	3.6	5.1	7.0	6.0	15.0	20.0	1.8	20.0	8.04	5.77
Bicarbonate(mg/L)	42.0	39.0	36.0	18.0	25.0	17.9	13.0	19.6	45.0	27.0	23.0	16.0	38.0	30.0	42.0	16.0	45.0	28.97	11.36
Carbonate (mg/L)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00
Chloride (mg/L)	3.6	4.0	2.4	0.45	2.9	1.3	1.0	5.3	3.1	2.3	1.8	2.6	4.3	1.6	1.7	0.45	5.3	2.63	1.47
Manganese(mg/L)	0.1	0.5	1.5	0.0	0.1	0.05	0.02	0.05	1.0	0.01	0.03	0.03	0.9	0.05	0.3	0.0	1.5	0.36	0.53
Iron (mg/L)	0.71	0.23	0.18	0.03	0.6	0.56	0.03	0.37	0.14	0.15	0.24	0.19	0.43	0.12	0.1	0.0	0.7	0.28	0.23
Sulphate (mg/L)	17.0	4.0	5.0	0.9	2.0	4.0	1.0	15	3.0	3.5	2.0	1.0	2.0	3.0	5.0	0.9	17.0	5.08	5.55
Nitrate (mg/L)	32.0	25.0	22.0	15.0	30.0	28.2	12.0	19.7	16.3	24.0	18.0	19.4	40.0	34.0	29.0	12.0	40.0	24.51	8.87
Ca^{2+} Hardness(mg/L)	62.6	45.0	37.1	43.0	39.8	29.3	51.0	104.0	84.2	44.0	65.0	55.0	57.9	31.4	28.9	29.0	104.0	53.59	24.11
Total Solid (mg/L)	17.0	32.0	25.0	15.0	15.0	18.0	13.0	10.0	29.0	9.0	35.0	29.0	51.0	25.0	49.0	9.0	51.0	25.41	14.36
Magnesium (mg/L)	7.9	4.8	3.7	2.62	3.8	5.1	1.2	1.6	8.8	7.5	7.2	7.7	8.5	9.8	3.3	1.2	9.8	5.56	3.02
Calcium (mg/L)	24.0	26.0	21.0	7.2	22.0	18.0	3.2	16.0	49.0	30.0	39.0	32.0	34.0	26.0	17.0	3.2	49.0	24.51	13.67
T. Hardness (mg/L)	87.0	60.0	53.0	51.8	56.0	45.0	48.0	156.0	122.0	75.0	96.0	81.0	84.0	64.0	43.0	43.0	156.0	77.69	36.50
Potassium (mg/L)	6.5	0.63	1.6	1.5	1.4	0.41	0.4	3.6	0.2	1.1	2.3	0.56	2.4	0.3	1.8	0.2	6.5	1.85	1.98
Chlorine (mg/L)	0.06	0.15	0.18	0.0	0.1	0.02	1.0	0.17	0.13	0.11	0.6	0.03	0.14	0.12	0.1	0.0	1.0	0.23	0.32
Sodium (mg/L)	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.06	0.17
T.coliform(cfu/i00mL)	129.0	52.0	48.0	87.0	68.0	72.0	56.0	81.0	38.0	61.0	53.0	92.0	68.0	359.0	462.0	38.0	462.0	130.94	144.81
S. typhii (cfu/100mL)	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil			

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 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 diagram 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 concentration 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 concentrations. The degree of mixing between waters can also be shown on the Piper diagram (Fig.9). The Piper diagram was used to classify the hydro-chemical facies of the water samples according to their dominant ions. The water in the area is Ca-HCO_3^- type.

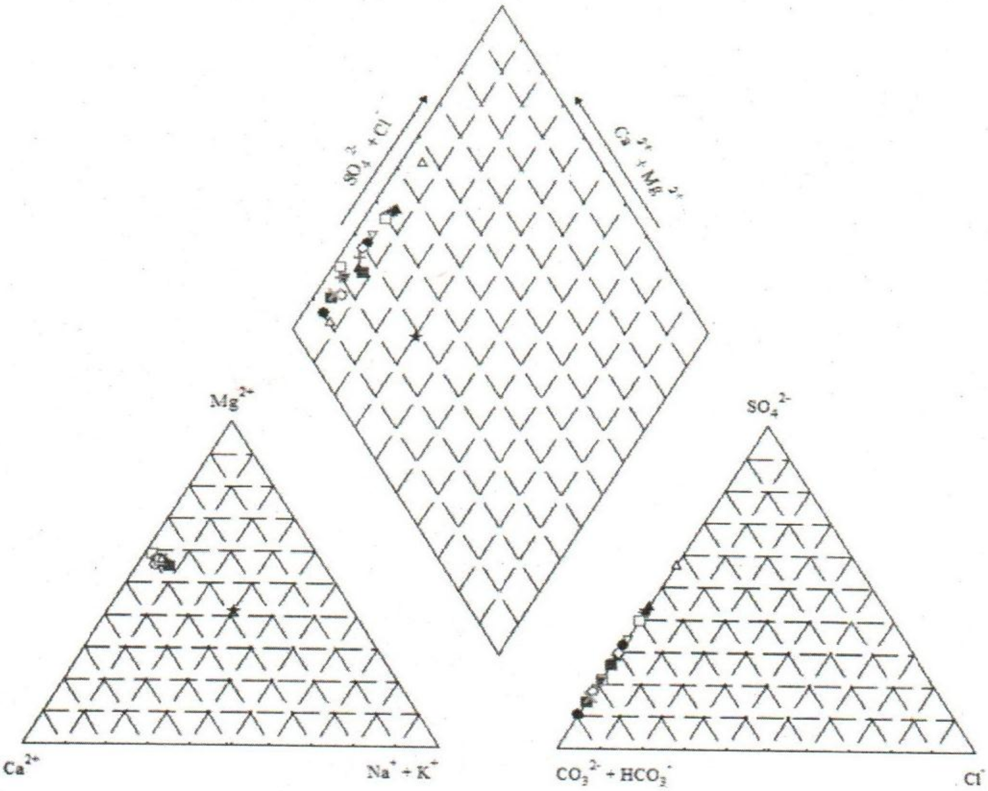

Fig. 9: Trilinear diagram for Groundwater in Owerri Metropolis.

CONCLUSION

The water sources in Owerri metropolis were investigated using geological, hydrogeological, physico-chemical and microbial parameters. The water in the area is classified as Ca-HCO_3^- type. All the analyzed physical and chemical parameters in the area are far below the NSDWQ (2007) and WHO (2003) maximum allowable limits except total coliform and Mn (locations 3 and 7) that shows high concentration. The observed anomalies are purely anthropogenic in origin. Coliform bacteria are transmitted to water from different waste products, broken drains, refuse dumps, etc and its presence signifies faecal contamination and possible contamination by pathogenic organisms. The hydrogeological mapping carried out revealed that the aquifer system in the area is largely unconfined, highly porous and permeable. Boiling of the water before drinking is recommended because of the high coliform content in the groundwater. Most bacteria do not withstand heat or high temperature. Periodic checks of the chemical and bacteriological quality of water sources in the area should carried out. Dumping of wastes on river banks should stop and offenders prosecuted.

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