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Assessment of drinking water quality from shallow aquifers in host communities of FEDPONEK and FUTO in Imo State, Southeastern Nigeria

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Abstract

Nekede, Ihiagwa and Eziobodo communities has witnessed an upsurge in its population since the establishment of Federal Polytechnic Nekede (FEDPONEK) and Federal University of Technology Owerri (FUTO). A total of 45 groundwater samples were collected from boreholes tapping from the shallow aquifers system in the area and analyzed for relevant physical, chemical and bacteriological parameters using standard analytical methods. The essence of the study is to compare the quality/potability of the groundwater with the World Health Organization (WHO) and the Nigerian Standard for Drinking Water Quality (NSDWQ). The pH of the water ranges from 4.5 to 7.1 with an average value of 5.7. The total coliform counts vary from 32 cfu/cm to 425 cfu/cm with an average value of 115.0 cfu/cm. The concentration of manganese varies from 0.0mg/l to 1.5mg/l and a mean value of 0.3mg/l. The results of the physio-chemical parameters compare favourably with the World Health Organization and Nigerian Standard for Drinking Water Quality except Mn and pH in some locations. The low pH indicates that the water is slightly acidic and should be treated for pH before consumption. The bacteriological result shows high level of Total coliform and Escherichia coli in the groundwater which is an indication of faecal contamination. The water in the area is predominantly soft to moderately hard. In view of the high bacteria coliform count, boiling of water before drinking is important. It is also recommended that proper sanitary toilets be constructed in the area. The water in the area is Calcium-Bicarbonate type.
Keywords: Evaluation, water quality, shallow aquifer, Southeastern Nigeria.

Introduction

Groundwater is one of Nigeria's precious natural resources, providing reliable water supplies for millions of people. The ability of groundwater to provide a buffer against climatic variability and its fairly constant composition encourages its usability over surface water. Due to the ephemeral nature of surface water, groundwater still remains the only realistic and affordable means of providing potable water supply for poverty reduction and economic development. Groundwater occurs almost everywhere beneath the land surface and is largely controlled by the geology and geomorphology of the area. The widespread occurrence of potable groundwater and the natural processes that tend to provide barriers to some types of contamination are some of the reasons why it is preferred by most Nigerians as their source of water supply (Amadi and Olasehinde, 2008).

One of the objectives of the Millennium Development Goals (MDGs) is the reduction by half the number of people without access to potable water by the year 2015. Since Water is the elixir of life, developing and monitoring the quality of groundwater resources is a sure way of attaining the Millennium Development Goals (MDGs) and realization of part of the seven point agenda of the Federal Government.

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Location of the study area

Nekede community hosts Federal Polytechnic Nekede (FEDPONEK) while Ihiagwa and Eziobodo communities host Federal University of Technology Owerri (FUTO). The presence of these two tertiary institutions has increased the economic base of their host communities. The study area are situated between longitudes 6°55'E to 7°15'E and latitudes 5°15'N to 5°35'N covering an area of about 1340 km^2 (Fig.1). The area is a low lying terrain with good road network. It is drained mainly by Oramiriukwa and Otamiri Rivers, which are tributaries to Imo River (Fig.1).

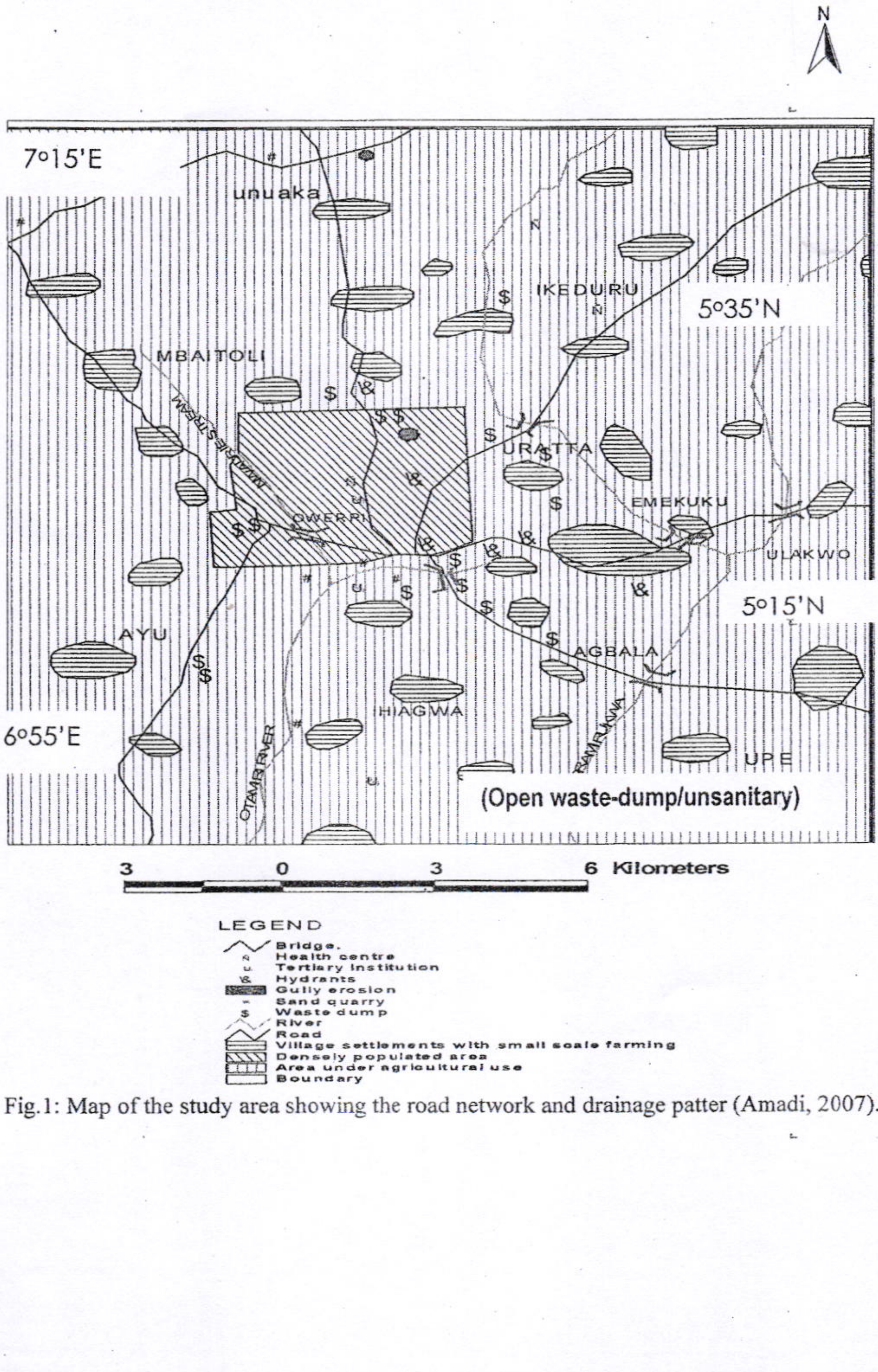

Fig.1: Map of the study area showing the road network and drainage patter (Amadi, 2007).

Clin. ıte and physiography of the area

The prevalent climatic condition is marked by two main regimes: the rainy and the dry seasons. The rainy seasons are from (April to October) during which the temperature varies from 23 □C to 26 □C and these seasons are 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 (Monanu and Iyang, 1975). 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 (Monanu and Iyang, 1975). 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 savannah grassland interspersed with oil palm trees.

Land-use Characteristics

The area is characterized by large scale urbanization and poor land use pattern. It is occupied mainly by residential buildings, commercial areas comprising of both private and government offices. Open spaces are occupied by motor mechanics workshops, block molding units, farming and urban gardening. The land use pattern is prone to groundwater pollution and hence the need for the present study.

Geology and hydrogeology of the area

The major outcrop in the study area is the Benin Formation which is known as the coastal plain-sands (Fig. 2). It consists mainly of sands, sandstone and gravel with clays occurring in lenses. The sandstones are coarse to fine grained, partly unconsolidated and 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. The formation lacks faunal content and this makes it difficult to date, though an Oligocene-Recent age is generally accepted (Avbovbo, 1978). The Benin Formation is composed mainly of fresh water-bearing continental sands and gravels which form very high prolific aquiferous formations (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 100m in Owerri area (Reyment, 1965; Etu-Efeotor and Odigi, 1983). The sandy unit which constitutes about 95% of the rock in the area is composed of over 96 % of quartz (Onyeagocha, 1980). Large scale cross beddings constitute the major sedimentary structures in the area (Amadi and Amadi, 1990; Ngah, 2002).

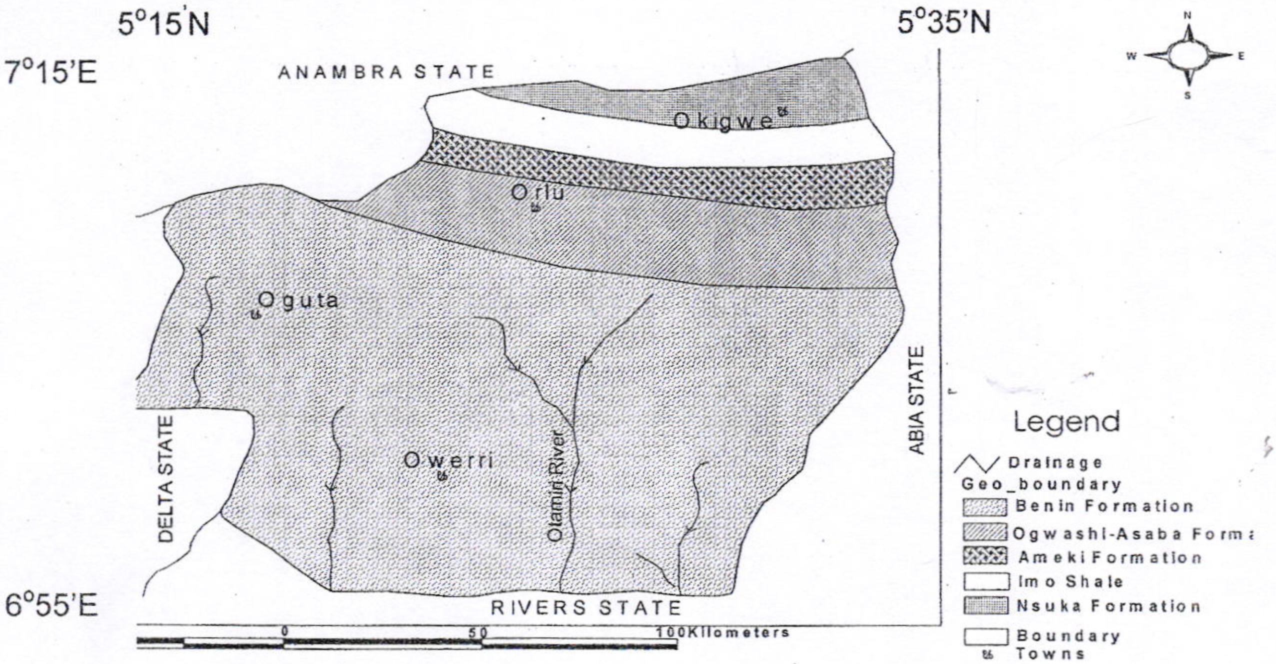

Fig. 2: Geological map of the Study Area (Modified from Short and Stauble, 1967)

Materials and methods

Water sampling was undertaken using standard procedures. A pair of 45 groundwater samples was collected in plastic bottles from water boreholes tapping from the shallow aquifers (between 10 to 45 meters) in the area and adjoining communities. Two drops of concentrated trioxonitrate (v) acid was added per bottle (one set of samples) for the homogenization and prevention of absorption of trace metals to the walls of the container (Schroll, 1975). These samples were used for the determination of cations (Na^+, K^+, Ca^{2+} and Mg^{2+}) as well as trace metals (Fe and Mn). The other set (45 samples) in which no acid was added were used for the determination of the anions (NO_3^-, SO_4^{2-}, HCO_3^- and Cl^-). Prior to the collection of the water samples, some physical parameters (pH, conductivity and temperature) were determined in the field using a calibrated pH metre, conductivity meter and thermometer respectively while the other parameters were determined in the laboratory.

After the collection, the water samples was stored in a cool box and latter taken to the regional water quality laboratory of Federal Ministry of Agriculture and Water Resources, Minna for the determination of ions and trace metals. Nitrate was measured using the method of Crumpton et al., (1992). Calcium, calcium hardness, sodium, potassium, magnesium, iron and copper concentrations were measured using standard method 3111B of APHA (APHA, 1980). Total dissolved solid, chloride, sulphate, bicarbonate and manganese were measured using the United States Environmental Protection Agency (USEPA) methods 160.1, 325.3, 375.4, 340.2 and 365.2 respectively (USEPA, 1983). The determination of Total coliform and Escherichia coli was carried out using presumptive count and differential count respectively.

The coordinates of the sampled location were determined using global positioning system (GPS). The values of the longitude, latitude, elevation and static water level (SWL) were used to generate the contour map (Fig. 3), digital terrain model (Fig. 4) and groundwater flow direction (Fig. 5) of the study area. A careful observation of these maps reveals the contour lines are very close at northwest and northeast (Figures 3 and 4) indicating the area of groundwater discharge (Fig. 5). This implies that groundwater discharge is topographically controlled. These maps will also aid in the study of the possible contaminant migration pathway in the area.

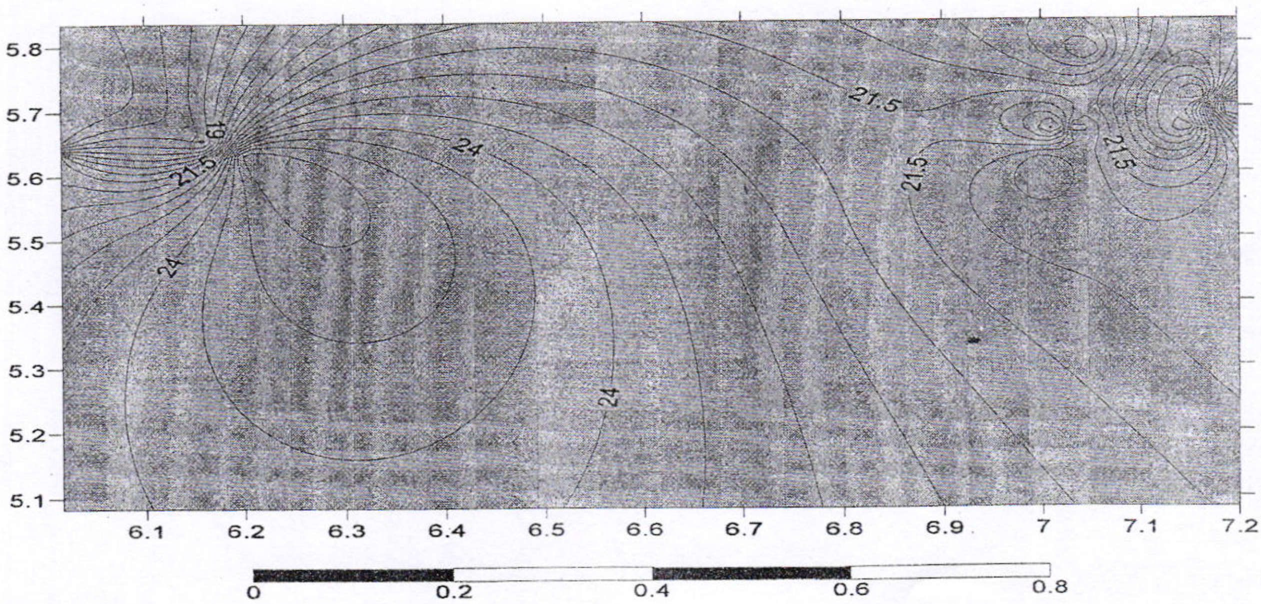

Fig. 3: Contour map of the study area (Source: Amadi, 2007)

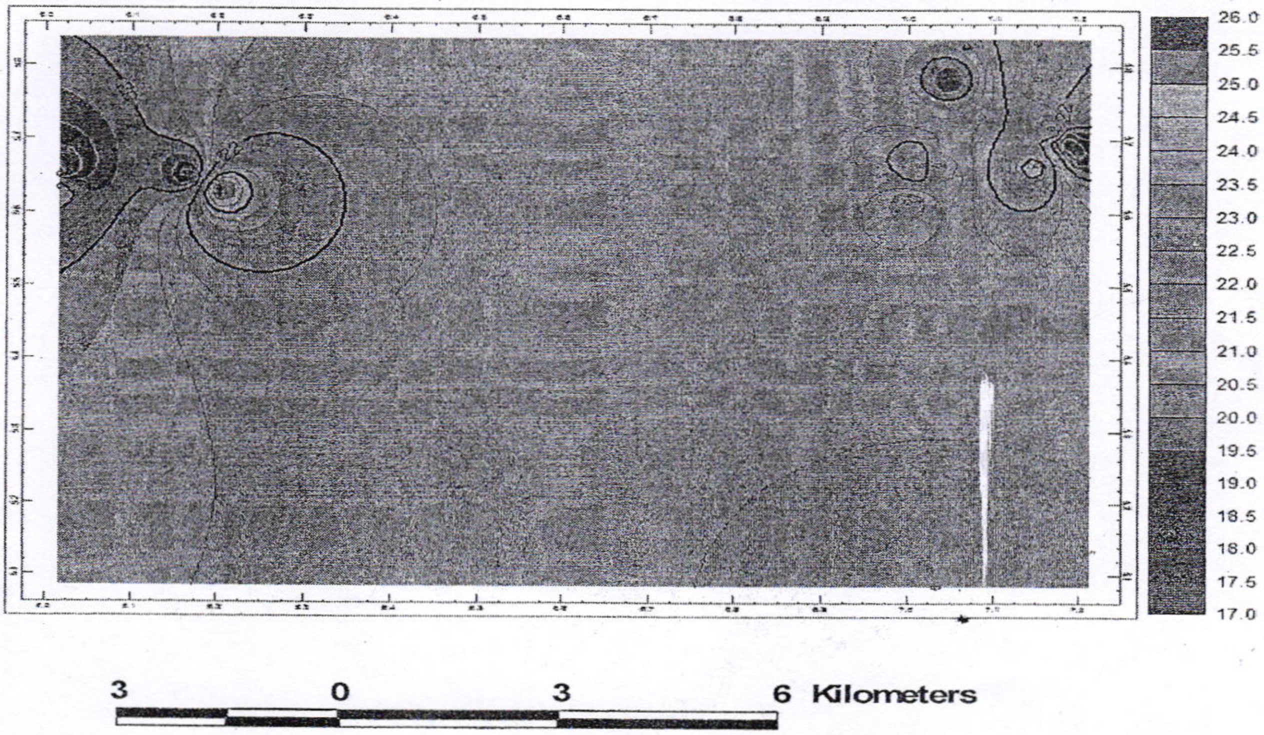

Fig. 4: Digital terrain model of the study area (Source: Amadi, 2007)

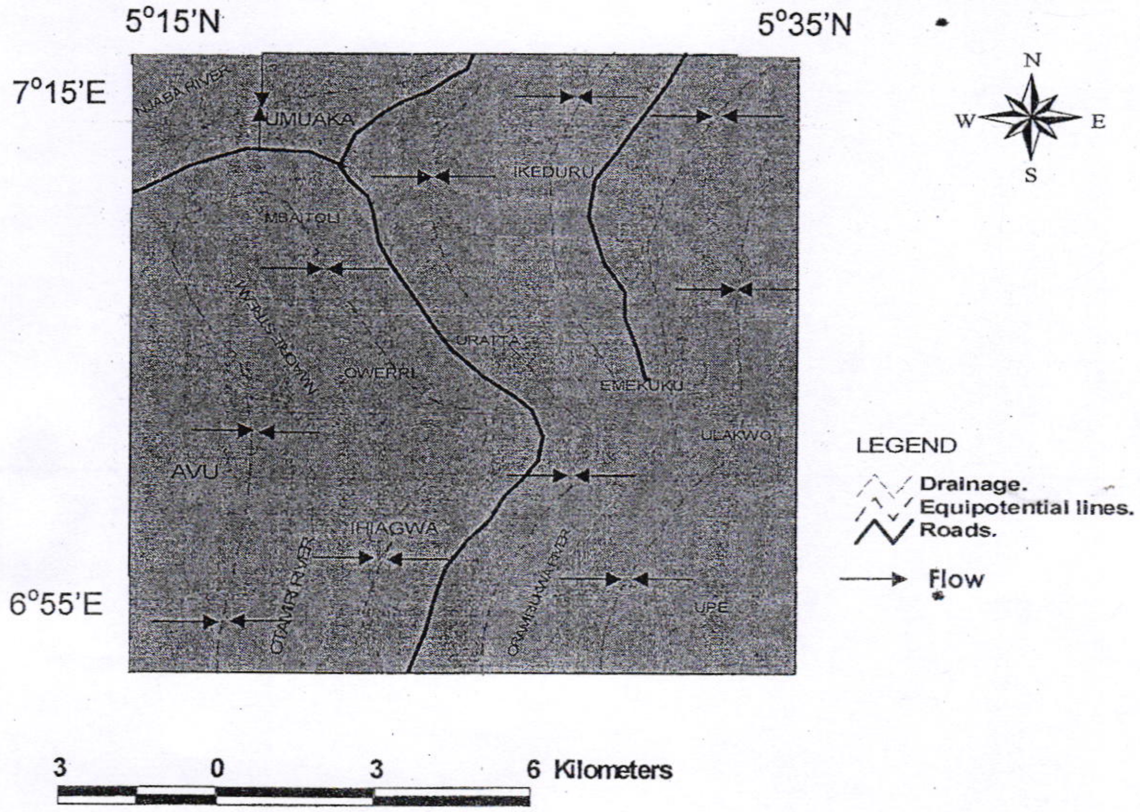

Fig. 5: Groundwater flow direction for the study area (Amadi, 2007).

Results and discussion

The statistical summary of the physico-chemical and bacteriological data are contained in Table 1. The result revealed that the groundwater is colourless, odourless and turbulent free. The temperature varies from 29.6°C to 33.0°C and a mean value of 32.04°C while the conductivity ranges from 8.0 µS/cm to 121.93 µS/cm with an average value of 35.93 µS/cm. Total dissolved solids (TDS) ranges from 3.3 mg/l to 76.27 mg/l and an average value of 19.99 mg/l while suspended solid varies from 1.8 mg/l to 38.92 mg/l with a mean value of 9.61 mg/l. Total hardness (TH) is of the order of 8.0 mg/l to 156.0 mg/l and an average value of 71.3 mg/l. Hardness causes scale precipitation in boilers, but can also protect pipes against corrosion (Ibe and Sowa, 2002). The values of these parameters are lower than the maximum permissible limits of World Health Organization (WHO, 2003) and Nigerian Standard for Drinking Water Quality (NSDWQ, 2007) thus indicating good water quality. TDS is a quantitative measure of the sum total of organic and inorganic solutes in water and should not exceed 500mg/l. The pH is of the order of 4.5 to 7.1 with a mean value of 5.71 as against a pH range of 6.5 to 8.5 recommended by WHO (2003) and NSDWQ (2007). This implies that the groundwater in the area is slightly acidic. The low pH could be as a result of the breakdown of the organic matter derived from vegetation cover and humus buried in sediments, and subsequent infiltration of rain water (acid rain) through the highly porous and permeable overburden into th. hallow water table. The low pH values in the area may be due to the decomposition of organic matter and gas flaring which gives rise to acid rain (Etu-Efeotor and Akpokodje, 1990; Amadi and Olasehinde, 2008). This is in agreement with the pH concentrations obtained in the present study. Most groundwater in Nigeria have pH ranging from 4.5 to 6.5, however, pH values of up to 7.0 or more may be obtained (Egboka, 1986). Carbondioxide emitted into the air via gas flaring and water in the air react together to form carbonic acid, a weak acid according to the equation below: H_2O (l) + CO_2 (g) → H_2CO_3 (aq).

Table 1: Statistical Summary of the Groundwater data

S/No	Parameters	Min.	Max.	Mean	SD	WHO Standard	NSDWQ Standard
1	Temperature(^{0}C)	29.60	33.00	32.04	0.92	Ambient	Ambient
2	Colour (TCU)	2.00	24.00	11.63	7.17	Colourless	5.0
3	Ph	4.50	7.10	5.71	0.93	6.5-8.5	6.5-8.5
4	E.C (mm-hos/cm)	8.00	121.93	35.93	34.86	1000.00	1000.00
5	TDS (mg/l)	3.30	76.27	19.99	19.96	500.00	500.00
6	Suspended solid (mg/l)	1.80	38.92	9.61	9.18	500.00	500.00
7	Bicarbonate (mg/l)	0.00	45.00	27.52	12.46	150.00	200.00
8	Chloride (mg/l)	0.45	16.93	3.46	3.82	200.00	250.00
9	Manganese (mg/l)	0.00	1.50	0.30	0.45	0.10	0.20
10	Iron (mg/l)	0.03	0.71	0.27	0.21	0.30	0.30
11	Sulphate (mg/l)	0.90	17.00	4.64	4.7	150.00	100.00
12	Nitrate (mg/l)	12.00	40.00	23.81	7.84	45.00	50.00
13	Calcium hardness (mg/l)	28.90	104.00	51.11	20.41	200.00	150.00
14	Total solid (mg/l)	9.00	124.20	31.01	27.85	150.00	150.00
15	Magnesium (mg/l)	1.20	9.80	5.50	2.72	200.00	200.00
16	Calcium (mg/l)	3.20	49.00	23.76	11.55	200.00	250.00
17	Total hardness (mg/l)	8.00	156.00	71.27	34.32	500.00	500.00
18	Potassium (mg/l)	0.00	16.31	2.54	4.01	150.00	150.00
19	Copper (mg/l)	0.00	1.00	0.19	0.25	1.00	1.00
20	Sodium (mg/l)	0.00	0.50	0.05	0.15	150.00	200.00
21	Total coliform (cfu/cm)	32.00	425.00	115.00	3.42	10.00	10.00
22	Escherichia coli(cfu/100ml)	0.00	25.00	3.60	0.14	0.00	0.00

TDS-Total Dissolved Solids; WHO-STD-World Health Organization Standard; NSDWQ-Nigerian Standard for Drinking Water Quality, E.C-Electrical Conductivity,

Acid rain has the potential of causing severe corrosion of the metal casing used for the water well construction (Olarewaju, et.al., 1996). Medically, consumption of water with low pH over a long period of time may lead to the disorder of the acid-base balance in the body system, causing metabolic acidosis. The concentration of bicarbonate ranges from 0-45.0 mg/l and a mean value of 27.52 mg/l while chloride concentration varies from 0.45-16.9 mg/l with an average value of 3.46 mg/l. The concentration of sulphate ranges from 0.9-17.0 mg/l with a mean value of 4.64 mg/l while nitrate concentration is of the order of 12.0-40.0 mg/l and an average value of 23.81 mg/l. The concentrations of the anions fall below the maximum permissible limits of WHO (2003) and NSDWQ (2007) indicating good water quality. The concentration of calcium varies from 3.2 mg/l to 49.0 mg/l with an average value of 23.76 mg/l while magnesium concentration ranges from 1.2 mg/l to 9.8 mg/l and a mean value of 5.5 mg/l. Sodium has concentration ranging from 0-0.5 mg/l with an average value of 0.05 mg/l while potassium concentration is of the order of 0-16.6 mg/l and a mean value of 2.54 mg/l. The general low concentrations of the major ions in the groundwater are may be due to the paucity of soluble materials in the underlying formation and the o\ lying soils. Furthermore, the porous and permeable aquiferous formation in the area allow rapid inf. ration of water and thus little contact and solution time between the percolating water and the few soluble materials present. The iron concentration ranges from 0.03 mg/l to 0.71 mg/l with a mean value of 0.3 mg/l while manganese concentration varies from 0-1.5mg/l and an average value of 0.3 mg/l. The concentrations of the analyzed trace elements are within the allowable limits recommended by WHO (2003) and NSDWQ (2007) except Manganese in some locations. High concentration of manganese causes neurological and gastrointestinal disorder (NSDWQ, 2007). High iron content in water may cause staining of laundry, corrosion and scaling of metal pipes. The presence of iron, copper and manganese in water can give undesirable taste (Ezeigbo, 1988; Olarewaju, et.al., 1996; Ibe and Sowa, 2002). Copper concentration is of the order of 0-1.0 mg/l and a mean value of 0.19 mg/l.

Bacteriologically, the water is contaminated as shown by the high concentrations of total coliform and Escherichia coli. The concentration of total coliform varies from 32.0 cfu/ml to 425.0 cfu/ml with an average value of 115.0 cfu/mL as against a maximum permissible value of 10 cfu/mL by the WHO and NSDWQ, while Escherichia coli concentration ranges from 0-25 cfu/100mL and a mean value of 3.6 cfu/100ml as against 0 cfu/mL by WHO and NSDWQ. The faecal contamination is higher in surface water than groundwater and their enrichment in groundwater via infiltration cannot be ignored. Faecal indicator bacteria are universally present in high numbers in the faeces of humans and warm-blooded animals. The principal risk associated with water is that of infectious diseases and is related to faecal contamination. Majority of the water-borne diseases are caused by pathogenic bacteria, viruses and protozoa contained in the human and animal faeces. The mean concentration of calcium, bicarbonate and total coliform from the major towns in the area are shown in Figures 6, 7 and 8 respectively.

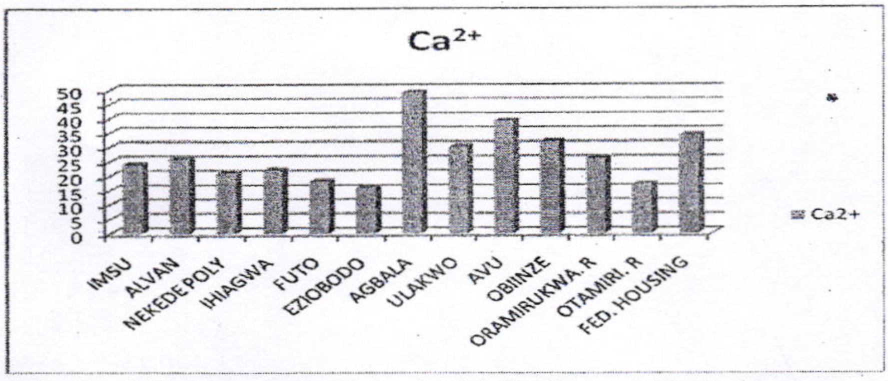

Fig. 6: Bar chart representation for Calcium Concentration in the area

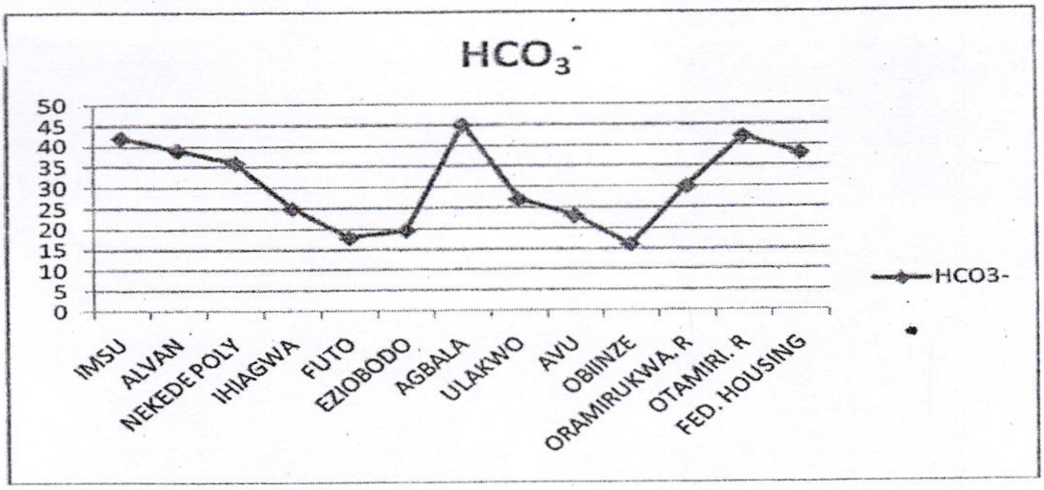

Fig.7: Bar chart representation for Bicarbonate Concentration in the area

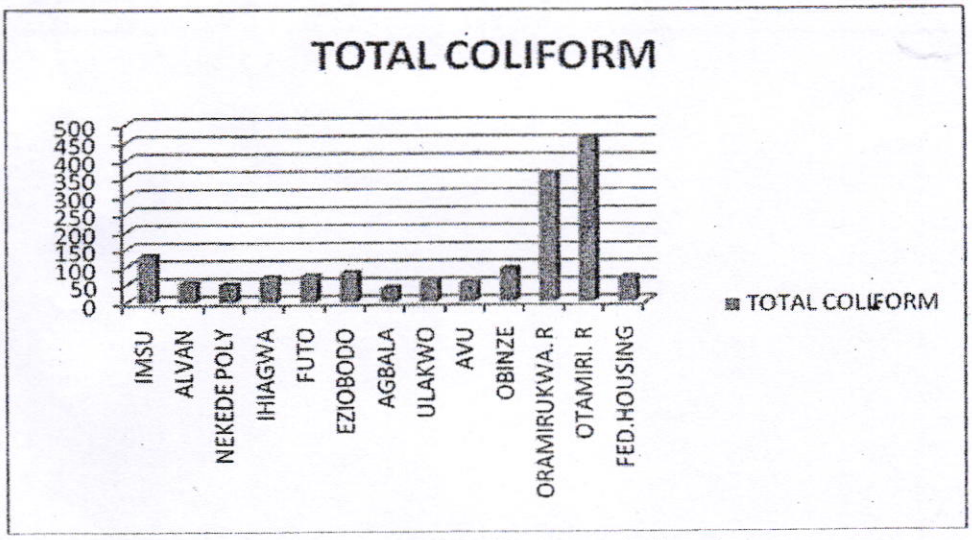

Fig. 8: Bar chart representation for Total Coliform count in the area

For the purpose of Piper diagram, the cations are grouped into three major divisions: sodium (Na^+) plus potassium (K^+), calcium (Ca^{2+}) and magnesium (Mg^{2+}). The anions are similarly grouped into three categories: bicarbonate (HCO_3^-) plus carbonate (CO_3^-), sulphate (SO_4^{2-}) and chloride (Cl^-). Each sample will be represented by a point in each trilinear diagram. Unique symbols may be selected for each sample and can be referenced in a symbol index at the top of the diagram. Concentrations entered in the source data-file in units of milligrams per litre (mg/l) are converted to milli-equivalent per litre (meq/l) for display on the diagram (Fig.9). The diamond field is designed to show both anion and cation groups. For each sample, a line is projected from its point in the cation and anion trilinear diagrams into the upper region where the lines intersect. Fifteen samples out of the 45 samples analyzed were used to construct the Piper diagram (Fig. 9).

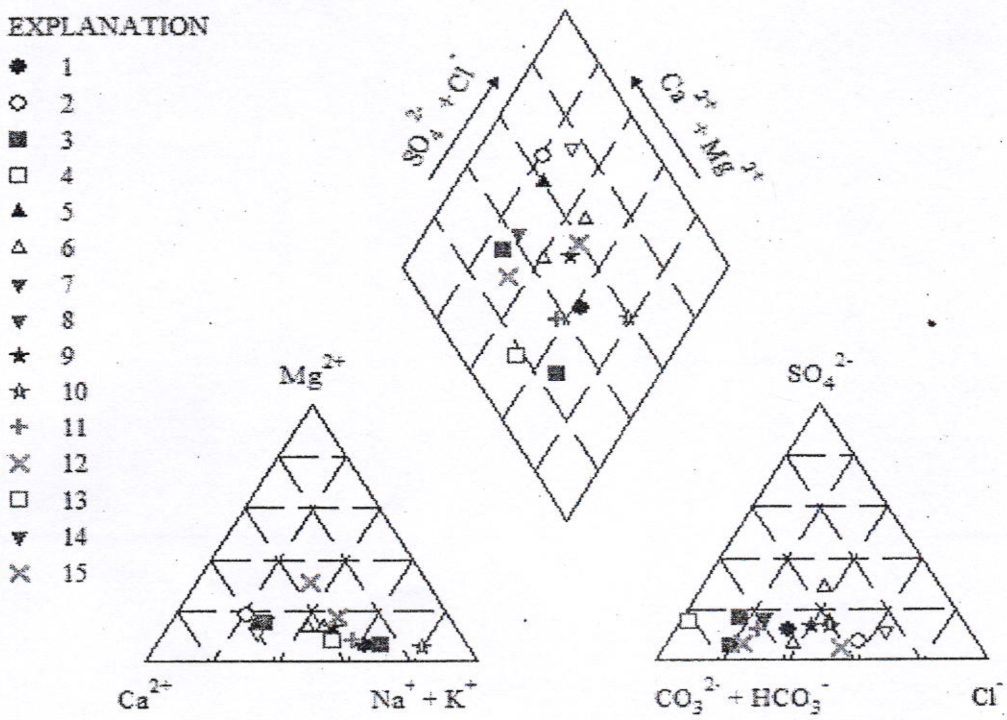

Fig. 9: Piper diagram of Groundwater samples in Ihiagwa and environs

Conclusion

The physical and chemical parameters evaluated falls within the WHO and NSDWQ permissible limits for safe drinking water, indicating good groundwater quality except Mn that showed high value in few locations and mean pH value of 5.7, which is an indication that the groundwater is slightly acidic. The water is however poor with respect to its high bacteriology, due to the high content of total coliform and Escherichia coli. The high population in the area due to students' concentration in the area is a major contributing factor. Boiling of the water before consumption is recommended as most bacteria cannot withstand high temperature.

Recommendation

The water should be treated for pH and boiled before consumption. It is also recommended that proper sanitary toilets be constructed in the area. Periodic examination of the water is advocated. Water intended for drinking and household purposes must not contain water-borne pathogens. Frequent examinations for faecal indicator organisms remain the most sensitive and specific way of assessing the hygienic quality of water, and should be carried out on the water regularly, especially as provided for in the Nigerian Standard for Drinking Water Quality (NIS 554:2007).

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