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Hydrogeological Characteristics and Groundwater Quality Analysis for Selected Boreholes in Ogbaru Local Government Area, Anambra State, Nigeria.

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Abstract

The extent and distribution hydrogeological and groundwater resources in parts of Anambra State, Nigeria was investigated. The hydrogeophysical and hydrochemical analysis of the shallow wells around Ogbaru in Anambra state was carried out to delineate the geologic layer constituting the aquifer, its suitability or otherwise as source of potable / drinking water and the tendency of the overburden to naturally protect the aquifer. The results show that the study area is majorly underlain by the Alluvial Plain Sands formation. Four different lithologic layers exist in the formation; laterite sandstone, clayey sand, sandstone and saturated sandstone, with varying water storage and yielding capacities. Boreholes depths within the Alluvial Plain Sands are shallow (10-50m) yet the sands are excellent aquifers with high yields (53.8-136.6m^3/d) especially along the Ogbaru L.G.A. axis. The result of the analysis showed that most of the physio-chemical and microbiological parameters are within the Nigeria standard for drinking water quality (NSDWQ) permissible limits.

Keywords: hydrogeological; lithologic layer; physiochemical; microbiological; permissible limits.

1. Introduction

The excessive demand on water resources by the increasing population of most developing economies like southeastern Nigeria exacerbated by the impact of climate change results in the drying up of surface water and depletion of groundwater. Groundwater resources account for the greater percentage of domestic and industrial water requirements especially in developing countries [22].

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The quality of groundwater is a function of natural processes as well as anthropogenic activities [8]. Quality of water is principally affected by pollution from diverse sources [26]. Inorganic chemicals and micro- organisms are common in human environments. Thus, the presence of contaminants above World Health Organization (WHO) standards can cause different kinds of diseases: typhoid fever, paratyphoid fever, dysenteries, gastroenterities, infectious hepatitis, schistosomiasis, asiatic cholera, back pains, pneumonia, nasal congestion [21].

Water is no doubt one of the most essential needs of human beings, for drinking and other domestic purposes. Its presence or lack of it determines to a great extent the nature of the natural environment in which our life and majority of our economic activities depend on [15]. Groundwater is a natural resource that is of immense importance to life. Its characteristics are greatly determined by the properties of the immediate geologic formations [7,3]. Groundwater constitutes over 90% of the world's readily available freshwater resources with the remaining 10% in lakes, reservoirs, rivers and wetlands [10,6].

Groundwater is often contained in aquifers. An aquifer is an underground water saturated stratum of formation that can yield usable amount of water to a well. There are two different types of aquifers based on physical characteristics. If the saturated zone is sandwiched between layers of impermeable materials, it is called a confined aquifer; if there is no impermeable layer immediately above the saturated zone, it is called an unconfined aquifer. Usually, an aquifer can produce an economically feasible quantity of water to a well or spring [14,23]. Aquifer characteristics are greatly influenced by formation strata and terrain type [4]. Hence, the acquisition of viable deep water wells is mainly dependent on adequate and reliable empirical knowledge.

This work aims at studying the hydrogeologic setting of the area and the hydrochemical nature of water from the various sampled borewells. This will ascertain the suitability of boreholes for water supply and the public health implications of water quality analysis results. The objective of the study is to determine the geologic layers constituting the aquifer, its viability as source of potable / drinking water and also to compare the hydrochemical and bacteriological properties of sampled borewells with the Nigeria standard for drinking water quality (NSDWQ).

1.1 Constraints/Limitations.

The challenges of the study included the capacity for sourcing of adequate funds for the hydrogeological investigations and the drilling of boreholes. However with the financial provision made for the study it was possible to complete the project with resounding sources.

2. The Study Area

2.1 Geology and Hydrogeology

The entire Ogbaru Local Government Area which constitutes a large wetland zone is located in the south western part of Anambra State, and lies between latitudes 5°42' and 6°08'N and Longitudes 6°,42' and 6°50E.

It is bound in the north by Onitsha South Local Government Area, in the east by Idemili South, Ekwusigo and Ihiala Local Government Areas, in the west by Delta State and in the south by Rivers and Imo States.

The relief is a plain land of heights ranging from 0 – 50m and characterized by swampy conditions as a result of its alluvial mud content. Its geology is mainly alluvium while the river Niger, and Ulasi river which is its major tributary constitute the two major rivers in the area. However, there are local creeks and ponds all over its landscape [12]. Figure 2.1 shows map of Ogbaru and sample locations.

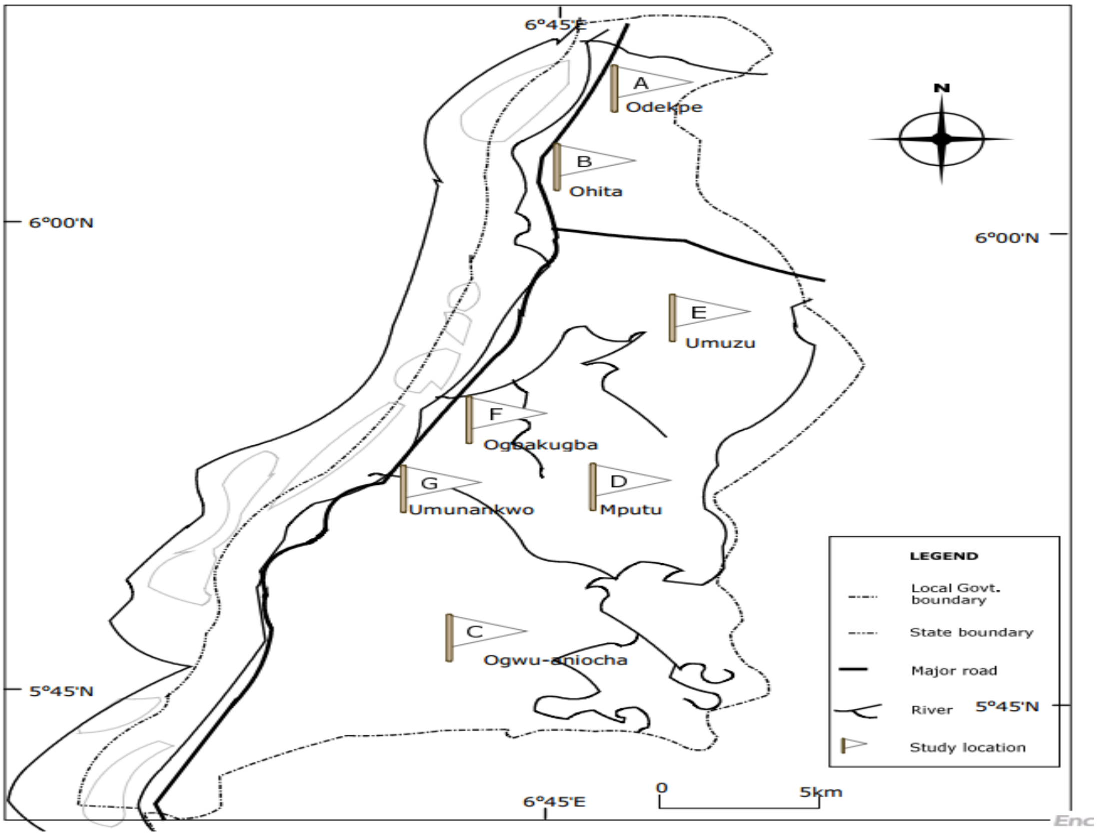

Figure 2.1: Map showing Ogbaru showing study locations

The escarpment areas of southeastern Nigeria form part of the humid tropical rainforest of Nigeria. Over 80% of the thick rainforest belt has been deforested, exposing the pedologic and hydrologic environment to the inclement weather. Two main climatic periods prevail in the area, the dry season (October to March) and the rainy season (April to September). The dry season is characterized by extreme aridity, dusty atmosphere, lowering of shallow groundwater levels and surface water due to excessive temperature that encourages evapo-transpiration. The implications of climate change have shown appositive trend in Africa as annual incidents of disaster events are on the increase. The annual rainfall in the area is about 2000mm. The rainfall occurs as violent downpours accompanied by thunderstorms, high runoff and heavy flooding, soil leaching and extensive sheet outwash. Over 60% of the precipitation in the area is lost to evapotranspiration with less than 40% left for infiltration.

Analysis of the pattern of water level fluctuation in different physiographic regions, the depth to water level and saturated thickness in different seasons, hydrogeological properties of the rocks etc are essential for the evaluation of groundwater development potentials.

3. Materials and Methods

The qualities of water resources in the study area were tested for physico-chemical and microbiological pollution. The samples were drawn from surface and underground water resources. Five (5) samples from each of the ground and surface water sources were collected for analysis. The sampling locations are depicted thus:

A - Odekpe
B - Ohita
C - Ogwu aniocha
D - Mputu
E - Umuzu
F - Ogbakuba
G - Umunankwo

3.1 Hydrogeological analysis

A thorough desk study and reconnaissance survey was implemented and appropriate target sites for geophysical measurements were identified based on favorable geomorphic/hydrogeological indications. This took into consideration mapping of available groundwater sources, location of possible areas of groundwater recharge, general appraisal of geology, soils and hydrological characteristics of the area. Detailed fieldwork involved geophysical measurements, borehole drilling and pumping tests. Pre-drilling geophysical surveys were conducted at each site with a Geoprobe Model 500 earth receptivity equipment and its accessories, using the Schlumberger configuration. The main objective of the surveys was to determine the depths to potable water, hydrogeological and hydrogeochemical properties of the boreholes. Hydrogeological/geological surveys were undertaken with the aim of determining the static water level, drilled depths, casing and screen positions etc.

During drilling, return cuttings were collected at 1meter-drilled depth interval and used to study grain-size, colour and associated interstitial materials useful in the determination of screen slot and gravel pack specification.

3.2 Hydrogeochemical analysis

Random sampling technique was employed in choosing the borehole water samples. Water samples collected in a properly washed bottle and analysed for physicochemical parameters, a few heavy metals, viz, temperature, turbidity, taste and odour, pH, total hardness, sodium (Na^+), calcium (Ca^{+2}), iron (Fe^{+2}), copper (Cu^{+2}), lead (Pb^{+2}), chloride (Cl^-), nitrate (NO_3^-), sulphate ($S0_4^{2-}$), carbonate ($C0_3^-$), bi-carbonate ($HC0_3^-$ using standard methods [5]. Bacteriological analysis was carried out to determine the fecal coliform count. The membrane filter technique was employed in this analysis [13].

4. Results and discussion

4.1 Aquifer Delineation and Characteristics

The aquiferous formations within Anambra State include the Alluvial Plain Sands, the Ogwashi-Asaba Formation and the Ameki/Nanka Sands [19]. The Alluvial Plain Sands were encountered in the different sampled areas. Results of borehole drilled-depths, water levels, static water levels and aquifer intervals of some of the boreholes are presented in Table 4.1.

Table 4.1: Aquifer Parameters of Boreholes in Ogbaru, Anambra State.

Town	Static Water Level of Borehole (m)	Drawdown at Equilibrium Level (m)	Yield of Borehole (m^3/d)	Specific Capacity (m^3/hr)	Transmissivity (m^2/d)
A	23.14	1.55	101.20	2.72	21.79
B	11.28	12.86	114.50	0.37	91.10
C	4.24	0.52	127.50	10.22	274.50
D	6.64	0.89	136.60	6.40	45.50
E	1.89	4.74	122.90	1.08	7.62
F	8.00	2.01	127.80	2.65	33.41
G	6.83	3.35	53.80	0.67	4.80

The occurrence of groundwater, depth to water table, depth to static water level in the studied water boreholes depicts a fairly consistent lithologic units, but varies only with differences in elevation. Within the Alluvial plain sediments (encountered within Ogbaru LGAs), borehole-drilled depths are shallow and vary from 10 to 50m. A very productive multi-aquiferous system at depths of 10-50m was identified. Water levels and static water levels (SWLs) within this geologic unit vary from 1.89-23.14m in sampled Local Government Area.

Figure 4.1 shows a four layered lithologic deduction of the various sampled locations. The first layer in Odekpe has a resistivity value of 21.0 Ωm and thickness of 4.0 m. The second layer has a resistivity value of 99.0 Ωm and a thickness of 3.0 m. The third layer has a resistivity value of 1571.0 Ωm and a thickness of 3.0 m while the fourth layer has a resistivity value of 301.0 Ωm and a thickness of 3.0 m. It can be seen that the first layer with resistivity 21.0 Ωm is laterite sandstone. The second layer is clayey sand. Third layer is sandstone and the fourth saturated sandstone. The second sampled borehole (Ohita) has four layers.

The first layer is laterite sandstone (39.0 Ωm), second layer is clayey sand (86.0 Ωm), the third layey is silty sand (1372 Ωm) and the last is saturated sandstone (291 Ωm). Ogwu Aniocha has four layers, the first been laterite sandstone has a resistivity value of 38 Ωm, second layer has a resistivity value of 92.0 Ωm and a thickness, third layer has a resistivity value of 1382.0 Ωm and the last saturated sandstone has value of 351 Ωm. Mputu’s first layer has a resistivity value of 34.0 Ωm and a thickness of 5.0 m.

The second layer has a resistivity value of 81.0 Ωm and a thickness of 10.0 m, third has value of 1241.0 Ωm and the last has resistivity value of 696 Ωm with a thickness of 11.0m.

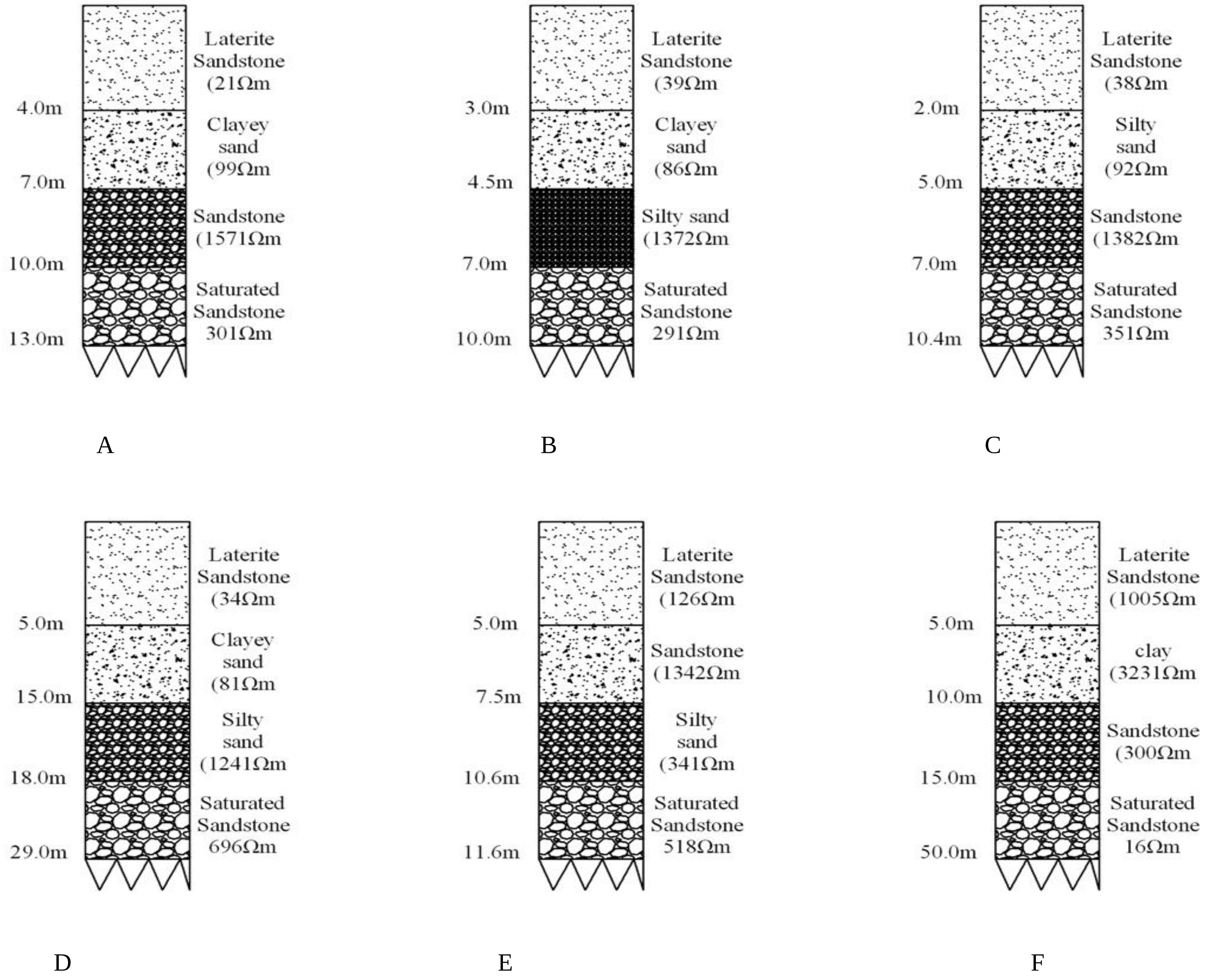

Figure 4.1: Geo-electric units for some boreholes in Ogbaru, Anambra state.

Umuzu shows a four layered lithologic units; first layer is laterite sandstone with a resistivity value of 126.0 Ωm, second is sandstone (1342.0 Ωm), third is silty sand (341 Ωm) and last is saturated sandstone (518 Ωm). Ogbakuba shows fours layers. The first layer is laterite sandstone with a resistivity value of 1005.0 Ωm and a thickness of 5.0 m; the second layer is clay with a resistivity value of 3231.0 Ωm and a thickness of 5.0 m.

The third layer is sandstone with a resistivity value of 300.0 Ωm and a thickness of 5.0 m, while the fourth layer is saturated sandstone sand with a resistivity value of 16.0 Ωm. There is a noticeable variation in the values of resistivity ranging from 16.0 to 3231.0 Ωm. Previously, geophysical methods have been utilized in delineating quality of groundwater. Authors in reference [27] combined gravity, magnetic and resistivity methods to study groundwater of Sinai in Egypt. Electrical resistivity method is the most commonly applied geophysical method for measuring apparent resistivity of subsurface materials [16].

4.2 Hydrochemical analysis of Boreholes

Contaminants in drinking water that have an adverse health impact are grouped into five categories: inorganic chemical contaminants, organic chemical contaminants, microbiological contaminants, radiological contaminants and turbidity [24]. In this study, the focus on the assessment of the level of contamination of the groundwater has been on the chemical and microbial contaminants because of the major concern of the impact on the health of the inhabitants.

The pH value is an important index of acidity or alkalinity and the concentration of hydrogen ion in groundwater (GW) [17]. The pH values of almost all of the water samples were found to be below the permissible range of 6.5-8.5 according to [20]. The survival of aquatic organisms is also greatly influenced by the pH of water bodies because most of their metabolic activities are pH dependent [11].

Electrical conductivity (EC) reflects the total concentration of soluble salts in water. It is used to measure the salinity hazard to crops. Throughout the study period, the maximum EC was 300 µS/cm and found in sampled location D. 100% of sampled water were within the permissible permissible limits (1000) µS/cm. Higher value of EC obtained in some of boreholes may be attributed to long residence time and existing lithology of the study area [9]. Five (5) of the seven (7) sampled locations had their EC values in the excellent (<250 µS/cm) class of water category. None of samples fell within the unsuitable (>3000 µS/cm). The maximum and minimum chloride concentrations in sampled water were 10 mg/l and 47 mg/l (Table 2). High chloride concentration values are mostly due to saline water intrusion problem; the study area is not prone to such problem. Salinity level tends to increase in area facing drought/ high temperature. The salinity value gotten from analysis agrees with the climate of the area. Ogbaru is known for very high amount of rainfall, hence recharge to groundwater will impact on this. Chloride in GW mostly comes from evaporation, salty connate water and seawater [18]. Authors in reference [1] noted that GW containing significant amount of Chloride also tend to have high amount Na ions indicating the possibility of contacts with water of marine origin. However, Chloride values in all samples of GW analyzed were satisfactory. High chloride content in inland water distribution system usually indicates sewage pollution. At concentrations above 250 mg/l, chloride rich water gives a salty test and causes various diseases such as high blood pressure [1].

The TDS value ranged between 28.3mg/l (location C) and 149.0mg/l (location D). Seawater intrusion is the main factor for the increased amount of TDS in GW, which was supported by a high value of sodium and chloride. Probable causes of increased value of TDS in GW may be due to dissolution, the weathering of sediment, and the solubility of lime and gypsum, all of which considerably increases TDS in GW. All analyzed samples were within the permissible limits (500 mg/l).

With respect to TDS, GW can be grouped as excellent, good, fair, poor and unacceptable [2]. All samples fell within the excellent class (0-300mg/l). Highest value of total hardness was (108mg/l) in location D while minimum value is at location F (24mg/l). Reduced rainfall causes lesser amount of dilution of hard water. According to [20], the allowable limit of hardness is about 500 mg/l. Test result demonstrates that all water samples were within permissible limit.

Total coliform count used as indicator to measure the degree of pollution and sanitary quality of well water was tested for. Total coliform bacteria are not likely to cause illness, but their presence indicates that the water in the area may be vulnerable to contamination by more harmful microorganisms. The results of microbial analysis (Table 4.1) show that the total coliform number count per 100 ml varied. However, all results analyzed conformed to the guidelines for drinking water quality, which are 10 in 100ml. Fecal coliform was absent in all samples. This means samples are free from fecal contamination. All other parameters analyzed were within the permissible limit defined.

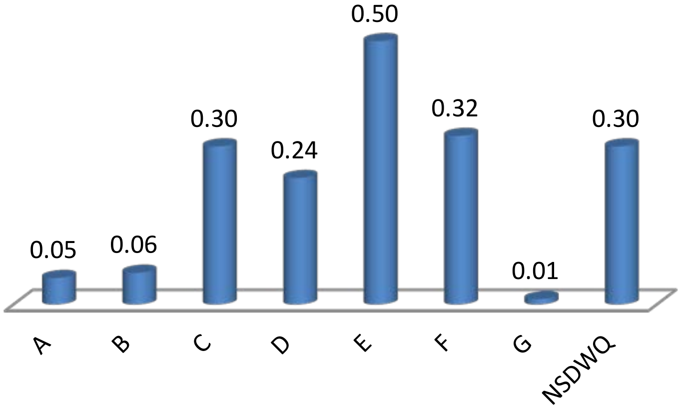

Figure 4.2: Concentration of Iron (Fe^{2+}) in the boreholes of Ogbaru, Anambra state

The main problem militating against water quality here is the high iron content which alters the colour of the water to reddish brown on exposure to free air and hence undesirable. The shallow nature of the aquifer may indicate a possible linkage/ pathway through a deep lateritic soil, from where iron is being readily contributed to the groundwater. Iron (Fe^{+2}) concentrations in the ground water samples ranged from 0.01-0.5 mg/l. Almost 50% of sampled wells exceeded the MPL (Fig. 4.2), low pH favours oxidation of ferrous iron to ferric iron, giving an objectionable reddish-brown color to the water. Iron also promotes the growth of "iron bacteria" which derive their energy from the oxidation of ferrous iron to ferric iron and in the process deposit a slimy coating on the piping [28].

4.3 Interaction between physicochemical, heavy metals and microbiological parameters

Hypothesis propounded was subjected to the Pearson correlation (r) test to investigate the possibility of a relationship between the parameters (microbial and physicochemical parameters). Tests as shown in Table 4.2 reveal that significant interactions exist among some physicochemical parameters and heavy metals. Fecal coliform were non-detectable hence no relationship could be established. While at $P<0.05$, Ca^{+2} correlated with Mg^{2+} (r=1.00), NO_2^- (r=0.49), NO_3^{2-} (r=-0.49), Fe^{2+} (-0.12), Mn^{2+} (r=-0.39) and TC (r=-0.86), pH correlated positively with Fe^{2+} (r = 0.07), and also correlated with most of the parameters (Table 3). Most parameters correlated amongst self, thus indicator parameters influence presence of others. Ca^{+2} shows a perfect correlation (r=1.0) with total hardness (TH), this further confirms relationship betwixt duo.

Table 4.1: Physicochemical and bacteriological status of groundwater from Ogbaru, Anambra.

BH	°C	pH	Cond. μS/cm	TDS (mg/l)	Salinity (mg/l)	Cl^- (mg/l)	HCO_3^- (mg/l)	TH (mg/l)	Ca^{2+} (mg/l)	Mg^{2+} (mg/l)	SO_4^{2-} (mg/l)	NO_2^- (mg/l)	NO_3^{2-} (mg/l)	Mn^{2+} (mg/l)	TC	FC
A	26	5.8	264.00	132.00	33.00	20.00	11.00	38.00	23.00	15.00	6.00	0.03	35.00	0.07	4	0
B	28	5.5	73.10	36.60	22.00	13.00	42.00	55.0	34.00	21.00	7.00	0.01	12.00	0.04	3	0
C	29	5.6	5.70	28.30	ND	ND	47.00	66.00	39.00	27.00	10.00	0.02	7.00	0.05	2	0
D	25	6.8	300.00	149.00	78.00	47.00	157.00	108.00	62.00	46.00	3.00	0.03	3.00	ND	1	0
E	29	6.2	71.40	53.70	ND	ND	38.00	48.00	29.00	19.00	ND	0.02	4.40	0.02	2	0
F	28	5.5	154.80	77.40	17.00	10.00	54.00	24.00	15.00	9.00	2.00	0.04	11.00	0.01	6	0
G	27	6.3	186.80	93.40	28.00	17.00	47.00	70.00	41.00	29.00	ND	0.01	12.00	ND	2	0
X	-	6.5-8.5	1000.00	500.00	500.00	250.00	500.00	500.00	200.00	250.00	100.00	0.20	50.00	0.20	10	0

ND – Not Detected X – NSDWQ, 2007 BH –Borehole TC – Total Coliform/ 100ml H_2O

FC - Fecal Coliform/ 100ml H_2O

Table 4.2: Correlation analysis of parameters for Boreholes in Ogbaru, Anambra State.

	°C	*pH*	*Cond.*	*TDS*	*Sal.*	*Cl^-*	*HCO_3^-*	*TH*	*Ca^{2+}*	*Mg^{2+}*	*SO_4^{2-}*	*NO^{2-}*	*NO_3^{2-}*	*Fe^{2+}*	*Mn^{2+}*	*TC*
°C	1.00															
pH	0.60	1.00														
Cond.	0.96	0.58	1.00													
TDS	0.94	0.64	0.99	1.00												
Sal.	0.94	0.67	0.86	0.84	1.00											
Cl^-	0.94	0.67	0.86	0.85	1.00	1.00										
HCO_3^-	0.54	0.69	0.45	0.47	0.77	0.77	1.00									
TH	0.50	0.76	0.31	0.35	0.67	0.67	0.81	1.00								
Ca^{2+}	0.48	0.75	0.29	0.33	0.65	0.66	0.80	1.00	1.00							
Mg^{2+}	0.52	0.78	0.33	0.38	0.68	0.68	0.82	1.00	1.00	1.00						
SO_4^{2-}	0.15	0.54	-0.35	-0.33	0.15	0.15	-0.17	0.01	0.03	0.00	1.00					
NO_2^-	0.51	0.52	0.41	0.51	0.44	0.45	0.27	0.50	0.49	0.51	0.24	1.00				
NO_3^{2-}	0.32	0.34	0.37	0.35	0.02	0.02	-0.59	-0.48	0.49	-0.48	0.23	0.22	1.00			
Fe^{2+}	0.50	0.07	-0.39	-0.30	0.36	0.36	0.16	-0.11	0.12	-0.10	-0.21	0.00	-0.58	1.00		
Mn^{2+}	0.16	0.59	-0.23	-0.20	0.34	0.34	-0.62	-0.40	0.39	-0.41	0.75	0.36	0.68	0.21	1.00	
TC	0.16	0.69	0.01	-0.06	0.28	0.28	-0.46	-0.85	0.86	-0.84	0.00	-0.56	0.47	0.04	0.21	1.00

Correlation is significant at the 0.05 level (2-tailed).

5. Conclusions and Recommendations

Most of the boreholes are located at very shallow depths. The depth ranges from 10.0 to 50.0m from the earth's surface. This means that sinking boreholes in sampled area is more economical than in other regions with deeply buried aquifers. From the analysis of the ground water samples, main parameters affecting quality of samples are pH and Fe^{2+}. Iron which has values in almost 50% of samples need be subjected to treatment before use. Presence of metal in water can be reduced via different processes. Methods have evolved and series of laboratory tests conducted to ascertain the efficiency of these treatment/ reduction methods. The removal of metals from polluted water can be achieved by ion exchange, chemical oxidation, chemical precipitation, activated carbon adsorption, and biological removal of heavy metal by bacteria [25, 29].

It is further recommended that efforts should be made to examine the quality of water in such a region because of the shallowness of aquifers in the region. Also, for sustainable water supply in sampled areas, wells can be drilled to deeper depths as this may control iron pollution of water.

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