Original Research Article

Hydrogeology and Water Quality Assessment of the Middle Aquiferous Horizon of Onitsha and Environs in Anambra Basin, Eastern Nigeria.

Abstract

Onitsha is a commercial, ecclesiastical and administrative city located on 6°49′30″E and 6°8′30″N in South-Eastern Nigeria with a high population density. The study area is close to a confluence and occupies a landmass of 300 km^2 and geologically belongs to the Ameki group in Anambra basin. The lithology of ten (10) wells labeled W_5, W_7, W_9, W_{12}, W_{16}, W_{20}, W_{21}, W_{22}, W_{23}, and W_{24} were obtained from which a fenced diagram was generated; four aquiferous horizons were detected which range from shallow (15-24m), upper (30-32m), middle (<90m) and the deep (>90m). The study revealed that the flow direction of the groundwater is multidirectional which was influenced by the piesometric heights; the study also revealed that there is a depression (sinkhole) at the middle aquifer occasioned by the massive extraction of groundwater from the aquifer; this is as result of the population density of the study area with several functional boreholes taping its water from the middle aquifer on an hourly basis. Biogeochemical analyses were carried out on the groundwater from these wells and the result obtained when compared to WHO standard shows that the water was severely polluted particularly with coli form count, for example the an average of 14.7 total coli form count was recorded against 0 recommended by WHO. The cations and the anions were analized using acceptable method such as American Public Health Association, Allem et al, 1974 and Adeleke and Abegunde 2011while the heavy metals were analized with AAS model PYE Unicam SP 2900. The pH value of the groundwater was found to range between (6.5–7.05); other parameters measured include total hardness (TH), total dissolve solid (TDS), Electrical Conductivity (EC) and alkalinity has the following range of values (64–120 mg/l), (10–40 mg/l), (71–109 s/cm) and (56–220 mg/l) respectively. The cations and anions were obtained as follows; Ca^{2+} (1.46–8.62 mg/l), Mg^{2+} (0.72–2.57 mg/l), Cl^- (153.8–449.7mg/l), PO_4^- (7.5-61.5 mg/l) and NO_3^- (6-21.6 mg/l). The heavy metals includes; Fe (0.27-0.65 mg/l), Zn (0.04-1.16 mg/l), Mn (0.03-0.52 mg/l) and Ba (0.02-0.26 mg/l). The Chemistry of the water was traced to anthropogenic activities due to high

chloride and heavy metals measured; this is influenced by the countless number of septic tanks, open dumpsite, battery manufacturing companies, and effluent from pharmaceuticals and textiles industries amongst others present in the area. The authors recommend that drillers and borehole contractors should therefore drill deep into the deeper aquifer that is capped with clay/shale body for potable water while the water from the middle aquiferous horizon should be well treated before consumption by applying Adsorption and Osmosis filter method etc

Keyword: Onitsha, Anambra Basin, Groundwater, WHO and Analysis

Introduction

The study area was found about 1680, has been a center of commercial activities, an ecclesiastical and administrative center [21]. Onitsha and its environs constitute one rapidly urbanizing region. The urbanization process was correctly anticipated by [22], while investigating and modeling the urban sprawl pattern of Onitsha. Onitsha and Environs lie within the Nkisi-Idemili water shed and covers an area of about 300 km^2 within coordinate points $6^o8'30''$N and $6^o49'30''$E as shown in (**Fig 1**). The elevation of the study area range between 32 m above sea level from the East to the Coastal portion of River-Niger to about 100 m above sea level from the central half to East extremity. The area is drained by Anambra, Nkisi and Idemili Rivers all of which discharge into the River Niger. The sediments originated from the Cameroon massif and Abakilike anticlinoria and range from Campanian to Recent, [1, 2]

According to [3], Onitsha falls within the tropics with mean annual temperature range of 22^oC – 27^oC and mean annual rainfall between 1,500 mm-2,500 mm characterize by two distinct seasons; wet and dry with average monthly rainfall of 2000 mm. The wet season range between the month of April to October while the dry season is between November and March. The area of study covers basically Onitsha North, Onitsha South, Nkpor, Obosi and Iyiowa Odekpe. The total population of the study area according to 1991 census was 428,272 (four hundred and twenty eight thousand two hundred and twenty seven), while 2006 census put it at 512,939 (five hundred and twelve thousand nine hundred and thirty nine) with 19.77% increase according to the “Official Gazatte of Nigeria government” [4, 20] Table 1.

Several researchers have worked on the quality of the ground water in the shallow, upper and deep aquiferous horizons in the study area but little or nothing have been said about the hydrogeology and hydrogeochemistry of the middle aquifer. For example, [5] worked on the biophysiochemical characteristics of the deep aquifer at Onitsha and its environs. A wide spread of contaminates associated with groundwater at Onitsha was dealt with by [6] while [7,8] worked on the unconfined shallow aquifer in the study area. Groundwater resources are dynamic in nature and are noted to be the largest source of fresh water as a result, monitoring and conserving it becomes imperative [9]. In the last decade or more, the government of Nigeria has partially realized the significance of water resources and the need to develop it [10]. Hydrological models have been employ as a tool to explain the interrelation of the various hydrological phenomena and in the process solve hydrological and water resource problem. Nigeria depends largely on groundwater supply but yet not attracting attention it deserve [11]

Geologically, Onitsha metropolis is majorly underlain by the Ameki group which consists of Nanka sands, Nsugbe Sandstone and Ameki Formaiton FM [12].

The present study is focused on the hydrogeology and Chemistry of the middle aquiferous horizon using the fenced diagram as a model to reveal the stratigraphy and hydrogeology while the biophysicochemical analysis is to characterize the water quality of Onitsha and its environs. This became imperative due to the high demand in groundwater exploitation and water quality monitoring; this will help researchers, government, borehole contractors and other stakeholder to understand the hydrogeochemistry of the study area consequently contribute to sustainable development.

Table 1: Population Figures of the Study Area (After Ezemeodo and Igbokwe, 2013)

S/N	Names of areas	1991 Population	2006 Population
1.	Onitsha North	121,157	124,942
2.	Onitsha South	135,290	136,662
3.	Nkpor	64,732	94,697
4.	Obosi	85,249	124,699
5.	Iyiowa Odekpe	21,844	31,939

Source: Official Gazatte of Nigerian government (FGP71/52007/2,500(OL24)

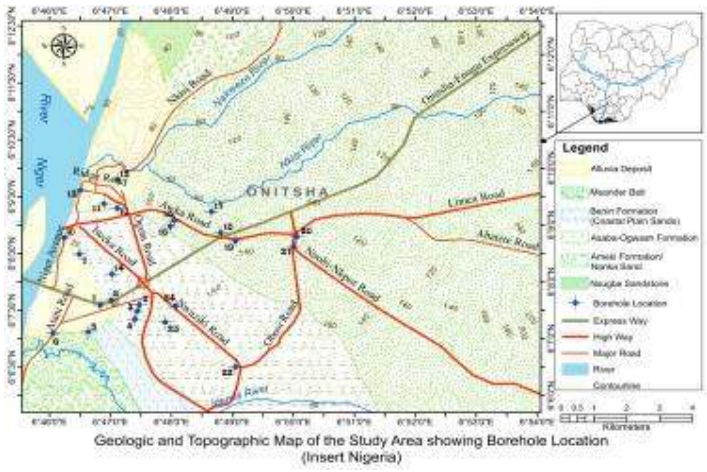

Fig 1: Location and Geologic Map of Onitsha and Environs.

Materials and Method

The study area falls within 6°49′30″E and 6°8′30″N and geologically belong to the Ameki group (Nwanjide, 1979 and 2014), (Fig 1) shows the location and geological map of the study area. Field survey was carried out using global positioning system (GPS). Litho log, from ten(10) wells (Fig.1) constructed by experienced hydrogeologist with distance apart as presented in (Fig.1), the wells were labeled W_5, W_7, W_9, W_{12}, W_{16}, W_{20}, W_{21}, W_{22}, W_{23}, and W_{24} from which geologic fenced diagram (3D diagram) showing the subsurface stratigraphy was drawn (Fig 3). Water samples from the ten (10) wells were collected and tested for coli form count, cations, anions and heavy metals. Acceptable methods according to [13, 14 & 15] were used to determine the coli form count, cations and anions while the heavy metals was determine with atomic absorption spectrometer (AAS) model PYE unicam SP 2900.

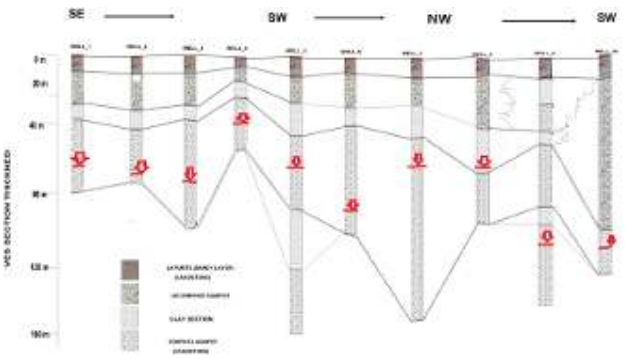

Fig 2: Litho Log of the wells and their Piesometric Heights.

Results and Discussion

Fig. 4 shows the hydro-geological section across the study area while (**Fig 2**) shows strategraphic (Litho log) and piesometric water surfaces of the study area. A quick look at (**Fig. 4**) shows that the area of study is overlain by lateric soil with variable thickness which is then underlain with a thick coarse sandy horizon with lenses of medium shale to medium sand occurring with the coarse sand. The thickness of the coarse sand range between 8 – 27m. The figure also shows that the coarse sand horizon is underlain with clay with thickness of six (6) metres at Awada Plastic industrial area to twenty three (23) metres at Nkpor. Below the shale and sand horizon at about 102 metres is the top of a medium grained sand zone which is the main aquifer which varies in thickness from twenty three (23) metres at Obosi to more than ninety two (92) metres at Nkpor. The aquifer is prolific and extends from the main market-GRA- inland Town, - Akwa Road- Nkpor and Obosi. The geologic fenced diagram is shown in (Fig.3). The diagram shows the subsurface stratigraphy and the various aquiferous horizons from unconfined, semi-confined to confined in the region. At the base of the unconfined aquifer lie the semi-confined and the confined upper, middle and deep aquiferous horizons made up of sandstone within the Ameki Formation. The groundwater flow direction in the middle aquifer is presented in (Fig.5); it shows multidirectional flow that is superimposed on the regional southwest flow direction. The diagram revealed that there is a sinkhole or depression occasion by groundwater extraction within and around the densely populated area such as Okpoko, Fegge, Housing Estate and Main Market area. When groundwater is pumped from an aquifer, the rate at which water flows in from the surrounding rock to replace that which is extracted is generally slower than the rate at which water is taken out [23]. When this happen, a cone of depression can likewise develop in potentiomentric surfaces consequently lower the regional water table. Another consequence of lowering the water table is that the surrounding rocks can no longer hold water due to compaction by the weight of the overlying rocks; this decrease their porosity, permanently reducing their water holding capacity and may also decrease their permeability. At the same time, as the rocks below compact and settle, the ground surface itself may subside. It imperative to state that lowering of the water table or the potentiomentric surface also may contribute to sinkhole formation [23] which is the case of

the study area, this assertion is supported by [4, 16, 17, 23 & 24]. From the foregoing, there is a possibility of mass movement leading to land slide within a geological time frame due to soil instability and the lowering of water table.The values for the static water level and hydraulic head in metres with their coordinate in the area of study are shown in (Table 3).

Geochemical and bacteriological analysis of the water samples shows a high concentration of almost all the parameters that were analyzed for (Table 2). The mean values of the parameters were also shown in the table, most of the value exceeded World Health Organization [18] standard for drinking water. The mean values for the anion were 286mgl^{-1} for Cl^- against 250 mg l^{-1} recommended WHO; the presence of high amount of chloride indicates linkage from septic. PO_4^{2-} value was found to be 36.2 mg l^{-1}. Other anions such as NO_3^-, SO_4^{2-} where below the permissible limit. The major cations; Na^+, Ca^{2+} and Mg^{2+} were within the required standard. Electrical conductivity (EC) was found to below (WHO, 2006) standard of 1200 mg l^{-1}. The alkalinity recorded 1.51mg l^{-1} against 100 mg l^{-1}. The TDS, DO, BOD, COD, TSS mean values were; 20 mg l^{-1}, 64 mg l^{-1}, 4.26 mg l^{-1}, 25.9 mg l^{-1} and 20 mg l^{-1} respectively. Of the heavy metals assessed, the values were high in some areas while in other areas, the values were low as summarize in (Table 2). Most worrisome is the total coli form count measure in MPN/100M1. The values of all the total coli form count across the wells where above WHO value of value of 0 (Table 3) some of the wells recorded 38, 23,14,13,12 and 11 respectively, this is alarming. From the foregoing, the inhabitants of Onitsha and environs are seriously exposed to health risk. The geochemical result is similar to early researcher in study [4,8]

Table 2: Results of Physiochemical Parameters for the Study Area Compared with WHO (2006)

Location	PH	EC	ALK.	COLOUR	TURB.	TSS	TDS	DO	BOD	COD	HCO_3^- mg/l	Na mg/l	K mg/l	Ca mg/l	Mg mg/l	TEMP	HARD	PO_4^{3-} mg/l	NO_3 mg/l	SO_4^{2-} mg/l	Cl^- mg/l	Ba mg/l	Cu mg/l	Mn mg/l	Fe mg/l	Zn mg/l
1	7	100	56	2.7	11	0	20	6.1	4.7	24.8	30.05	1.08	0.8	2.25	0.72	27.5	68	53.5	9.6	27	284	0.04	0.01	0.03	0.49	0.15
12	6.5	91	220	1.9	8	1.9	40	7.3	4	18.1	61	1.79	0.15	3.17	2.19	29.1	102	50	14.8	80	343	0.04	0.01	0.05	0.47	0.12
2	6.8	109	160	1.6	8	6.3	30	4.4	4	42.2	12.2	3.2	0.23	8.62	1.1	28.5	70	30.5	20.4	99	450	0.08	0.01	0.22	0.38	0.71
23	7.1	71	151	0.9	9	2.5	10	7.3	4.4	12.4	30.5	0.93	0.61	1.46	0.74	29	106	39.5	7.6	22	225	0.14	0.01	0.48	0.27	0.04
9	7	74	150	0.5	10	32	20	6.2	4	16.2	18.3	0.85	0.32	2.79	1.31	28.3	90	7.5	21.6	89	320	0.02	0.01	0.03	0.30	0.36

7	7	80	130	2.4	7	2.7	10	5.8	4.8	16	48.8	1.26	0.46	3.68	0.9	28.1	86	55.5	6	11	154	0.12	0.03	0.06	0.65	0.04
16	6.7	86	211	1.5	11	2.4	20	6.9	5.2	34.2	42.7	1.23	0.34	4.12	1.03	27.9	120	32.7	14.2	98	296	0.12	0.04	0.46	0.38	0.10
21	7.1	89	90	2.2	9	2.8	20	6.8	2.3	21.6	36.6	0.89	0.79	2.47	0.81	29	64	10.5	13.6	57	260	0.26	0.13	0.13	0.35	0.21
20	6.5	91	140	1.4	10	2.3	20	6.4	4.4	19	61	1.56	0.26	3.62	2.57	29.1	66	21	9.4	30	237	0.12	0.06	0.52	0.57	0.12
22	6.8	99	200	0	7	7.5	10	7.2	4.8	54.2	36.6	3.32	0.61	8.34	1.09	29.2	82	61.5	19.5	68	291	0.04	0.01	0.26	0.27	1.16
TOTAL	68	890	1508	15.1	90	60	200	64	42.6	259	377.8	16.11	4.57	40.5	12.5	286	854	362	137	576	2858	1	0.31	2.24	4.13	2.99
MIN	6.5	71	56	0	7	0	10	4.4	2.3	12.4	12.2	0.85	0.15	1.46	0.72	27.5	64	7.5	6	11	154	0	0.01	0.03	0.27	0.04
MAX	7.1	109	220	2.7	11	32	40	7.3	5.2	54.2	61	3.32	0.8	8.62	2.57	29.2	120	61.5	21.6	99	450	0.3	0.13	0.52	0.65	1.16
MEAN	6.8	89	151	1.51	9	6	20	6.4	4.26	25.9	37.78	1.611	0.457	4.05	1.25	28.6	85	36.2	13.7	58	286	0.1	0.03	0.22	0.41	0.3
S. D	0.2	11.87	51.8	0.85	1.5	9.4	9.428	0.9	0.8	13.5	16.24	0.919	0.234	2.46	0.63	0.6	19	19.1	5.52	33	78.6	0.1	0.04	0.2	0.13	0.36
WHO	6.5-8	1200	100	5	5	N/S	1500	N/S	N/S	500	200	200	0.2	75	50	25	500	10	50	500	250	0.05	0.5	0.1	0.3	0.01

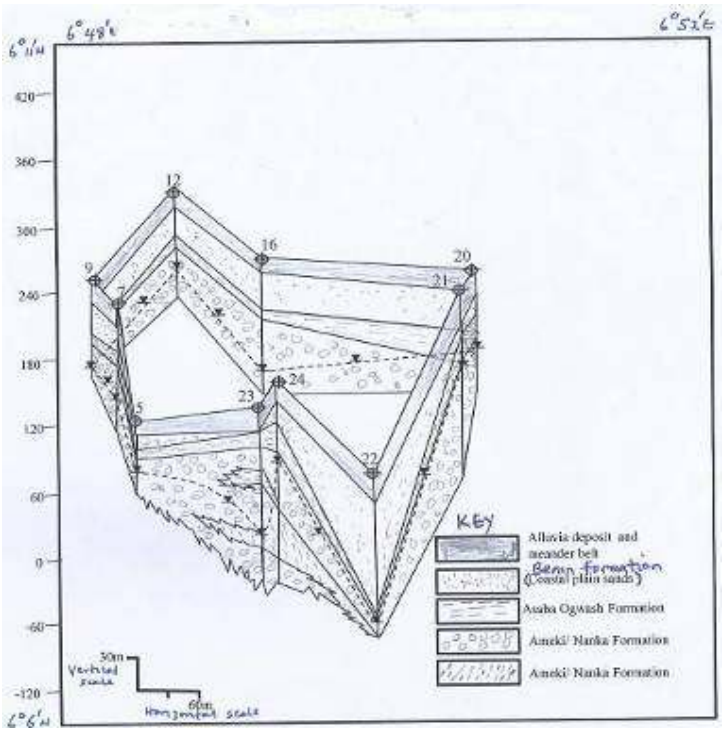

Fig. 3 Geologic Fence Diagram for Onitsha and Environs

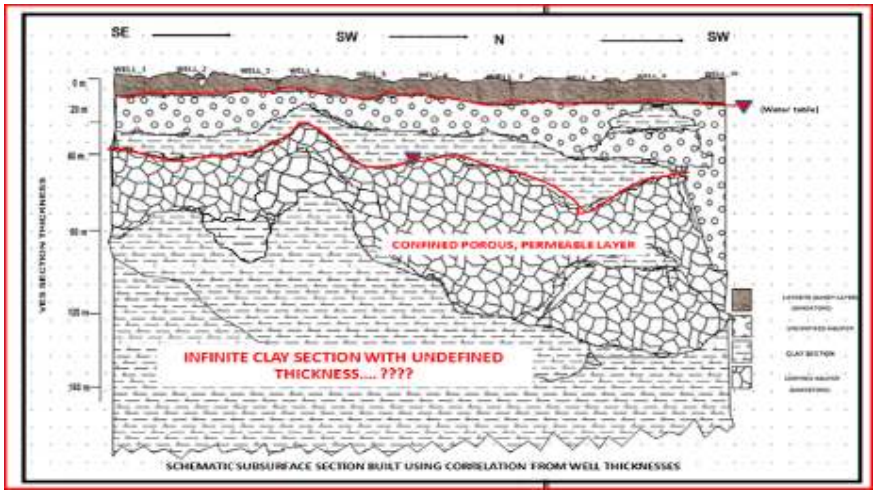

Fig 4: Sequence Stratigraphy of the study Area

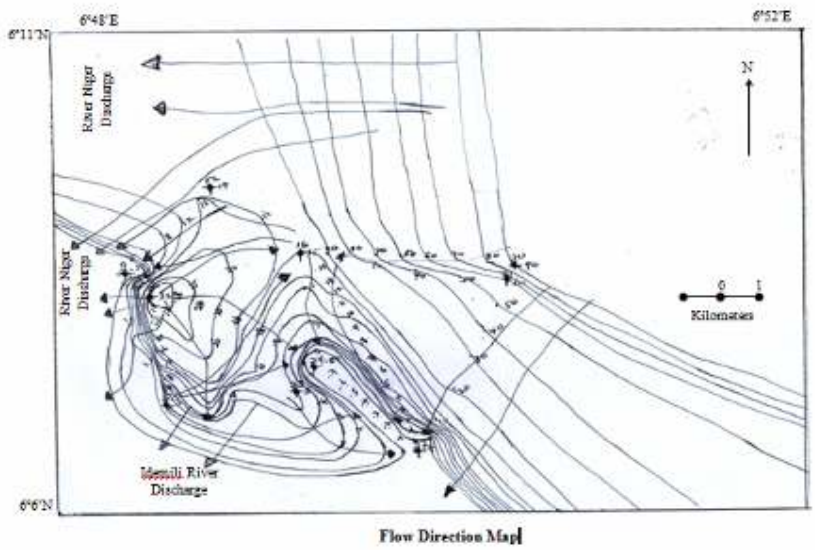

Fig 5: Groundwater Flow Direction

Table 3: Coordinate and Hydraulic Head Value Calculated for Boreholes around the Study Area

S/N	LATITUDE	LONGITUDE	ELEVATION ASL (M)	DEPTH TO SWL (M)	HYDRAULIC HEAD (M)	LOCATION
5	$6^{0}46^{1}38^{11}.3$	$6^{0}07^{1}07^{11}.5$	42.2	39.6	2.6	New Heaven Layout Okpoko
7	$6^{0}46^{1}29^{11}.4$	$6^{0}08^{1}29^{11}.4$	39.6	75	32.1	Fegge Obosi Street
9	$6^{0}46^{1}12^{11}.4$	$6^{0}08^{1}47^{11}.4$	23.6	72.248	-48.7	Niger Steel Road: Main Market
12	$6^{0}47^{1}07^{11}$	$6^{0}09^{1}48^{11}.3$	79.6	63	16.6	GRA Phase 1
16	$6^{0}48^{1}00^{11}$	$6^{0}09^{1}01^{11}$	103.1	88.392	14.7	Awka Road Emmanuel Ch Rd. Inland town
20	$6^{0}50^{1}00^{11}.6$	$6^{0}08^{11}48^{11}.9$	149.9	64.008	85.9	Nkpor

21	$6^{0}49^{1}59^{11}.6$	$6^{0}08^{1}41^{11}.3$	121.5	64.008	57.5	**Nkpor**
22	$6^{0}49^{1}03^{11}$	$6^{0}06^{1}30^{11}.4$	107.8	108	-0.2	**Near Federal Ministry of Works Obosi**
23	$6^{0}47^{1}540^{11}$	$6^{0}07^{1}17^{11}.6$	111.2	106.5	4.7	**Awada Plastic Industry**
24	**$6^{0}47^{1}64^{11}.3$**	**$6^{0}07^{1}35^{11}.0$**	**59.6**	**67.8**	**-8.2**	**Mgbemena St. Awada**

Table 4: Values of Coli Form Count

S/N	CODE	COLI FORM COUNT
1	BH1	11
2	BH 12	38
3	BH2	23
4	BH23	12
5	BH9	1
6	BH7	12
7	BH16	12
8	BH21	11
9	BH20	13
10	BH22	14
	WHO	0

Conclusion

The hydrogeology and groundwater quality assessment of the middle aquiferous horizon of Onitsha in Anambra Basin in Eastern Nigeria have been carefully studied. The aquifer based on 3D geologic fenced diagram belongs to Ameki group in Anambra basin, South Eastern Nigeria. The lithology and piesometric surfaces of the study area are shown in (Fig.2). The diagram revealed that the study areas are overlain with lateritic overburden with variable thickness (Fig.4). Below the lateritic overburden is sequence of coarse sandy horizon which is underlain by clay of about six (6) metres at Awada Plastic Industrial area to about twenty three (23) metres at the Nkpor. It also show that the clay is underlain with shale and sandy horizon at about 102 meters below the surface is the top of a medium grained sand zone which is the main aquifer that varies in thickness. The aquifer is prolific and flows in a multidirectional

local network occasion by the depression which occurs as a result of massive extraction of groundwater from the closely sunk boreholes in the middle aquifer couple with the ever increasing population of the inhabitants in the study area [21, 22 & 23].

The results obtained from the groundwater samples shows that coli form counts were very high in the all the well. The cations and anions were slightly higher than normal while others were below limits when compared with [18]. Other physicochemical parameters such as COD, BOD, BO, TSS, TDS, etc were also measure and the results were presented in (Table 2).

The ultimate results shows that the water quality is very poor; this is influenced by infiltration of leachate, linkages from the septic tanks couple with runoff from dumpsite and poor environmental management of the study area occasion by anthropogenic activities [5, 19]. In the nearest geological time frame, there may be a natural disaster such as landslide owning to mass movement as a result of soil instability due to extraction of water from closely sank boreholes in the study area.

Recommendation

- Drilling of wells into the middle aquiferous horizon should be discontinued in other to minimize the rate of water extraction the aquifer.
- Drillers and contractors should be encouraged to drill deeper into the deep aquiferous horizon so as to obtain clean and potable water, and decongest the number of wells being sunk in the middle aquiferous horizon.
- The water from the middle aquiferous horizon should be well treated before consumption by applying Adsorption and Osmosis filter method etc.
- Government should ensure compliance to existent environmental laws and stiff punishment given to defaulters.
- Health survey should be carried out to shows the extent of exposure and health impact on the receiving communities.

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