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THE INFLUENCE OF AQUIFER DEPTH ON MICROBIAL PARAMETERS OF BOREHOLE WATER IN CALABAR METROPOLIS, NIGERIA

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Abstract: Groundwater levels rises and falls in response to different phenomena such as seasonal fluctuations, and rainfall variability occasioned by global warming. These fluctuations are attributed to naturally occurring changes in climate and anthropogenic activities like changes in landscape, pumpage, induced infiltration, evapotranspiration, precipitation, temperature and pressure. The aim of this research was to assess the influence of aquifer depth on microbial parameters of borehole water. The aquifer depth was determined using seismic refraction method and the water samples were collected in a polyethylene container and preserved in an ice-packed box. It was immediately transferred to the laboratory for microbial analysis. It is believed that the deeper the depth of borehole the better the quality of water abstracted from it but this was not the case in the study area. Results show that even at the deepest depth of 50m, microbial parameters such as faecal and total coliform were still found because most of the boreholes were located close to pit latrines and soakaways. This scenario encourages the seepage of micro organisms through the soil strata from the pit latrines into the borehole. The multiple regression analysis shows that R^2 is 0.650. This implies that 65 percent of the variation in aquifer depth was explained by microbial parameter of borehole water in the study area. The researchers therefore recommended that boreholes should be sited far away from soakaways and pit latrine, furthermore a depth of atleast 70m is appropriate for sinking of boreholes within the study area.
Keywords: Microbial parameters, seasonal variations, boreholewater, total coliform, faecal coliform.

Introduction

The knowledge of groundwater depth is envitably required for planning, evaluation and management of groundwater resources. The problem of fresh water has raised agitation among scientist coupled with the over exploitation of groundwater resources due to increasing population growth, urbanization and changes in climate which result in hydrological imbalance. Calabar is underlined by Benin formation which consists of alternating sequences of gravel and sand of various sizes, silt, clay, lignite and alluvium. These alternating sequences build up a multi-aquifer system in the area (Eni, 2010).

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The depth of occurrence of groundwater in the formation varies from one location to another but becomes progressively shallower coastward. The quality of ground water reflects inputs from the atmosphere, soil and water-rocks reactions as well as pollutants sources such as mining land clearance, agriculture, acid precipitation, domestic and industrial wastes (Emoabino, and Alayande, 2006). The extreme seasonality of our climate, deep weathering process, varying lithology and alignment of rock determine the directional flow of groundwater (Igbokwe & Adindu 2011).

The most common aquifer materials in Calabar are unconsolidated sand and gravel, which occur in alluvial valley, coastal plain and dunes. Sandstone is the best aquifer material with high water yielding potentials. Other sedimentary rocks such as shale, clay and limestone's do not make good aquifier due to their low permeability.

Groundwater is structurally controlled and, therefore susceptible to investigations by a variety of techniques, including photogeology and geophyscis. The productivity of boreholes depends largely on how carefully the borehole is located and how lucky the driller is in hitting cracks and permeable layers with large openings (Eni, et al 2006). Groundwater has become a major subject of public concern the world over, despite the large volume of water that covers the surface of the earth, only 1% is fresh and easily available for human use.

In Calabar, groundwater is under threat from pollution especially from human life styles manifested by the low level of hygiene practiced in the study area. Within the aquifers, the groundwater is hosted by various minerals which influence its hydrochemistry and quality. Boreholes failures are also common and dry wells rampant in Calabar. Boreholes drilled at different points in the study area have low yields especially those located at low depths with an average of 10-20 litre/second daily. Some of the existing boreholes experiences high drawdown during the dry season (Eni, et al 2011).

It is apparent that the seasonal variations of water table level largely reflect the general climatic balance between rainfall and evaporation, and that the short term influences of these two factors tend to be smoothened out. The extent of occurrence depends mainly on the depth of the water table below the ground surface. The inhabitants of the study area do not acknowledge the fact that decomposers such as bacteria and fungi break down nitrogen containing molecules into ammonia gas and water soluble salts in waste dumps sewage and in dead organisms. These harmful chemicals percolate into the groundwater through the soil and containment it, groundwater is therefore rendered unsuitable for consumption. The use of pit toilets in Calabar South, and the use of fertilizers in urban agriculture are all potential sources of polluting groundwater in this area and with heavy rians and recharge, cum the topography makes the study area vulnerable to contamination.

A better understanding of the effect of aquifer characteristics on groundwater distribution within the study area would help private owners of boreholes to site one after a proper investigation has been carried out by a geophysicist and an hydrologist, instead of just sitting a borehole anywhere out of intuition without consulting an expert in the filed (Eni, et al 2011). Regional planners and policy makers will find the study valuable for effective regional strategies that will enhance sustainable exploitation of groundwater, without a total collapse of the aquifer. Groundwater level monitoring of boreholes will be required to develop an improved understanding of the water table fluctuations, the regional and local impacts of groundwater abstraction and dewatering related to groundwater yield will be investigated by the hydrologist. The research is expected to make a significant contribution to a further understanding of how best to harness groundwater taking aquifer depth into consideration.

Method of data collection

The research was carried out within forty five productive boreholes; to enable the researcher determined the relationship between boreholes depth and microbial parameters in the dry and wet seasons respectively. The co-ordinates of each borehole was measured with a Global Positioning System (GPS).

Depth to water table was measured using the seismic refraction method. The seismic refraction method is based on the fact that elastic waves passes through different earth materials at different velocities. The denser the material, the higher the wave velocity is. When elastic waves cross a geological boundary between two formations with different elastic properties, the velocity of wave propagation changes and the wave paths are refracted according to Snell’s law. The static water level will also be measured with a graduated bamboo in meters. This method is less expensive and reliable when properly applied and care taken during the measurement.

Water samples for microbial parameters were collected in a 100cm^3 polyethylene bottles and transported to the laboratory in an ice-packed cooler kit and analyzed within 24 hours. Random sampling was used for this study. Samplings of water from boreholes were undertaken twice in the year during the wet and dry season respectively.

RESULTS AND DISCUSSION OF FINDINGS

TABLE 1

S/N	Borehole sample location	Depth of Aquifer (m)	GPS READING		FC (Cfu/100Ml)		TC (Cfu/100ml)	
			Long	Lat	W/S	D/S	W/S	D/S
1.	Mary Slessor	25	8320126	4960044	2	6	1	3
2.	Etta Agbor Street	20	8317712	4961843	1	2	1	2
3.	Ndidem Usang Iso street	23	8318939	4962794	1	4	1	3
4.	Ediba Road	15	8315577	4962169	2	5	2	5
5.	M. C. C. Road	20	8313445	4960766	3	8	2	9
6.	Parliamentary Road	25	8316582	4963174	1	3	1	3
7.	Ikot Effa street	18	8317936	4960109	1	4	1	6
8.	Egerton street	30	8316444	4958456	1	2	2	5
9.	Marina Street	10	8318793	4956401	1	2	1	4
10.	Akai Effa street	40	8313081	4958837	1	2	1	4
11.	Chamley street	25	8314489	4953307	2	3	1	6
12.	Palm street	20	8316669	4956896	1	3	1	4
13.	Ikot Ansa	26	8312478	4952867	2	5	1	3
14.	Ikot Ishie	29	8324282	4953297	2	5	1	2
15.	Murray street	15	8329321	4953832	1	2	1	3
16.	Diamon Hill	29	8321659	4955943	1	3	1	4
17.	Asari Eso street	37	8321659	4955498	2	6	1	4
18.	Big Qua street	26	8324392	4954367	3	7	1	5
19.	Henshaw Ewa Street	19	8319594	4951345	1	3	2	8
20.	Atekong street	45	8312935	4949014	1	2	1	6
21.	White house street	42	8334843	4947927	1	4	2	4
22.	Azikiwe street	31	8310118	4946591	1	3	1	3
23.	State housing	41	8315076	4945404	1	2	1	4
24.	Mayne Avenue lane	18	8317136	4945935	1	4	2	6
25.	Abasi Obori street	49	8314098	4944899	1	5	1	7
26.	Etim Effiom street	33	8315646	4942604	1	3	1	5
27.	Akparika street	36	8321094	4950651	1	5	2	6

28.	Yellow Duke street	50	8319656	4946846	2	6	1	4
29.	Afokang street	30	8318211	4947592	1	4	1	4
30.	Ekorinim	34	8322438	4950644	2	7	1	3
31.	Ibesikpo street	39	8324312	4949178	1	3	1	5
32.	Oyo Ita street	27	8324557	4951124	1	2	1	4
33.	Goldie street	14	8326661	4949522	1	5	1	6
34.	Ekong street	29	8330089	4950378	2	4	2	8
35.	Musaha street	46	8328984	4950651	1	4	1	7
36.	Oyo street	32	8319903	4935409	1	5	5	10
37.	Uwanse street	37	8327567	4952753	2	6	1	7
38.	Akpanim street	36	8316063	4917028	1	5	2	6
39.	Ekpo Eyo street	39	8314856	4933275	1	4	1	5
40.	Essien Town street	40	8311256	4941628	1	3	1	4
41.	Umoh Orok street	43	8324979	4937656	1	5	1	3
42.	Garden street	33	8334757	4944687	1	6	1	6
43.	Edem Ekpo street	38	8336958	4942848	2	7	1	5
44.	Target street	27	8339567	4943645	1	5	4	7
45.	Edebom street	35	8335088	4936304	1	5	1	6

Relationship between depth of aquifer and microbial parameters of borehole water

The table above reveals that the values for faecal and total coliform at the deepest, depth of 50m still showed a value of 6cfu/100ml and 4cfu/100ml for faecal coliform and total coliform in the dry season.

It is believed that the deeper you sink a borehole the better the water quality, but this was not the case for microbial parameters analysed in the study area. This might be attributed to the high level of urban growth which has caused the inhabitants to locate boreholes near dump sites, pit latrines, cemeteries and defunct sewage.

Borehole water users in some parts of the study area such as Marina and Garden Street have complained of bad odour and algae in water. Researches conducted by Mather & Foster, (2003) and Miller, (2007) have shown that high coliforms in sewage water can percolate through the soil layers up to about 100 metres in sand and gravel aquifer. Existence of coliform in deep aquifer are usually associated with large pore sizes of soils, as observed in uniform gravels and sand structured clays and fractured rocks within areas of high rainfall (Marsh & Grossa, 2009).

People believed that the soil layers above an aquifer act as a natural filter that prevents many pollutants from infiltrating down to the ground water. But, findings reveal that those soil layers often do not adequately protect aquifers from contamination since they allow some microbes to penetrate groundwater even at great depths (Caroll, 2005).

High coliform population in some water samples are an indication of poor sanitary conditions in the area of study. Human wastes contaminant in water causes water-borne diseases such as diarrhea, typhoid and hepatitis. Inadequate and unhygienic handling of faeces and solid waste due to urban growth could have generated high concentration of microbial organisms in ground water.

High concentration of faecal and total coliform in groundwater may also be as a result of surface water infiltration which would be expected to occur on a regular basis due to the high rainfall within the study area.

Surface-water infiltration can also be expected during flooding. Indeed,
several recent studies such as Dunlap & McNabb (2005), Long & Saleem , (2006), Gerba & Melnick (2007) and Alien & Geldreich (2008) have indicated that groundwater contamination by bacteria is as common as previously suspected. The data from the study area support this conclusion and demonstrate that microbial contamination of groundwater is possible in areas where the boreholes are located below the depth of 50m.

S/N	Quality criteria	Range		Mean		Control site mean		WHO
		WS	DS	WS	DS	WET		
1	**PHYSICAL PARAMETERS**							
	PH	5-7.3	5.2-79	6.15	6.55	6.90	710	6 5-8.5
	TURBUDUTY (NTU)	3-21	2-11	12.00	6.50	5.40	4.10	50
	Elect cond (us/cm)	110-300	60-170	205.0	115.0	105	101	150.75
	Temperature (^oC)	270-305	285-305	28.5	29.50	25.0	26.0	25.0 ^0C
	Total dissolve solid (TDS)(Mg/l)	20-200	7.00-250	11.00	16.00	3.50	4.30	1000
	Total solid (Ts)(Mg/l)	10.5-40.0	22.0-590	25.25	40.50	2.10	2.30	1000
	Biochemical oxygen Demand (BOSs) (Mg/l)	0.06-4.09	0.09-5.05	2.07	2.50	1.01	1.15	0
	Chemical oxygen demand(CCD) Mg/l	2.40-10.0	6.56-16.00	6.20	11.24	2.02	2.25	0
	Dissolve oxygen (DO) mg/l	0.02-0.10	0.80-40.5	5.05	2.24	1.70	1.90	5.0
2	**MAJOR IONS/NUTRIENTS**							
	Sodium (Na+) (Mg/l)	0.1-3.05	0.457	1.57	3.05	1.00	1.45	200
	Phosphate (Po_4^2) (Mg/l)	0.04-0.50	021-1.38	0.27	0.76	0.01	0.05	5.0
	Chloride (CH) (Mg/l)	0.03-0.70	0.20-180	0.36	1.00	0.05	0.09	250
	Nitrite (No_3) (Mg/l)	0.09-3.50	2.60-4.90	1.79	3.75	0.01	0.02	10
	Sulphate (So_4^2) (Mg/l)	0.70-310	0.50-5.80	1.95	3.15	1.02	1.06	400
3	**HEAVY METALS**							
	Iron (Fe) (Mg/l)	0.01-1.10	0.04-250	0.55	1.27	0.02	0.30	1.0
	Manganese (Mn) (Mg/l)	0.001-0.07	0.01-0.10	0.04	0.05	0.01	0.02	0.05
	Nickel (Ni) (Mg/l)	0.02-0.07	0.04-1.00	0.05	0.52	0.01	0.03	0.05
	Chromium (Cr) (Mg/l)	0.02-0.70	0.06-1.00	0.36	0.53	0.10	0.15	-
4	**MICROBIAL**							
	Feacal Coliform (Fx) (cfu/100m/)	1-3	1-8	2.0	4.5	0	1	0
	Total Coliform (TC) (cfu/100m/)	1-5	2-10	3.0	6.0	0	1	0

Migration of city dwellers to suburbs and urban areas, have produced an almost explosive increase in the number of homes served by septic tanks, which now are the largest single contributor of sewage to groundwater in Calabar. Indiscriminate dumping of refuse cum landfill sites has also increased the contamination rate of ground water. Septic tank produces a poor quality of effluent, because sludge accumulates and digests in the septic tank thereby increasing the concentration of nitrogen and pathogens. The effluents of septic tank are infiltrated into the soil with a drain field.

The most readily detectable effects of septic tanks drainage on underlying groundwater are increases in nitrate, chloride and bacteria. Faecal-coliform contamination of water from large diameter boreholes was attributed to high water tables or flooding which caused septic tanks to overflow, permitting effluent to flow into the borehole.

The result shows clearly that sewage enters ground water through septic tanks and landfills. Disease causing bacteria in sewage include *Salmonella vibrio, shigella* and *mycobacicrium* which cause diseases such as typhoid, cholera, dysentery and tuberculosis. Pathogenic viruses include *entero viruses, reoviruses, rotaviruses, adino viruses,* and *hepatitis* viruses.

Viruses can cause a wide variety of diseases, including gastroenteritis, diarrhea, respiratory illness, heart diseases, liver disease and various infections and rashes. Other pathogens in sewage include protozoa like *endamoeaba histolytica,* and helmith parasites such as ascaris and tape worm. Faecal colifon tests normally indicate presence of pathogens. This may not always be reliable, since some pathogens may survive faecal coliform in the underground environment. Studies undertaken by Marsh & Grossa (2009), showed that applicable number of micro organisms were found after much longer distance of ground water movement including a distance of 830m in sand stone and gravelly soil.

Large underground survival distances for micro-organisms, however, are usually associated with large pore sizes as seen in uniform gravels and sands structured clays especially during periods of high rainfall. The best protection against bacterial and viral contamination of ground water by sewage is a relatively thick layer of medium to fine-textured soil without pronounced structural features between the sewage source and the ground water.

Potable water should be located as far as possible from the sewage source, and borehole water that may have the slightest chance of containing pathogenic organisms should be chlorinated or disinfected before use.

Table 3

Summary of the multiple regression analysis of the influence of aquifer depth on borehole microbial parameters

A - Model summary

Model	R	R-square	Adjusted R. square	Std error of the estimate
1	.806	650	.634	16.09130

a. Predictors: (Constant) Tc,Fc

b. Dependent Variable: Aquifer depth

B -

Model	Unstandardized Coefficient		Standardize	T	sig
	B	Standard error	Beta		
Constant	152.636	6.909		22.092	.000
Fc	-21.997	2.579	-.797	-8.529	.000
TC	25.675	2.143	.525	.411	.000

Dependent variables: Aquifer depth

FC = Faecal coliform

TC = Total coliform

Table 3A above indicates that R is 0.806, R^2 is 0.650 and the adjusted R^2 is 0.634. The standard error of the estimate associated with the model is 16.09130. The regression model for the relationship between aquifer depth and borehole microbial parameters is given as;

$$Y = 152.6 - 21.9FC + 25.7\ TC.$$

The model shows that there is a negative relationship between aquifer depth and faecal coliform while a positive relationship exist between total coliform and equifer depth.

This means that a given unit increase in depth of aquifer while holding microbial parameters of borehole waters, constant, faecal coliform will decrease by a magnitude of 21.9 and total coliform will increase by a magnitude of 25.7 respectively. With R^2 = 0.065, it means that 65 percent of the variations in aquifer depth was explained by microbial parameters of borehole water while 35 percent was unexplained.

Conclusion

Water is an essential element needed for metabolic activities and it is necessary for sanitation and chemical reactions. Aquifer characteristics should be properly measured and the water sample analyzed during the construction of boreholes in Calabar to reduce the risk of contaminations. High urbanization rate in Calabar has resulted in the degradation of groundwater within the study area. Proper water treatment is required for boreholes located in areas which are highly contaminated with microbial parameters.

The main aim of this research was to evaluate the influence of aquifer depth on microbial parameters of borehole water in Calabar metropolis. The data collected from the field were used to achieve the specific objectives. The result reveals that water quality parameters vary between wet and dry season.

Groundwater in Calabar South is enriched with iron oxide. This finding supports the suggestion by Long & Saleem (2006), that the principal products of urbanization which alter ground water chemistry is iron. The marked concentrations of these ions and the fact that several groundwater samples were also contaminated by faecal and total coliform suggest that groundwater is contaminated by infiltration of surface water polluted by municipal, agricultural and industrial waste through leakage from sewage. It is likely that surface water enters the aquifers at some locations during flooding. The results from this study suggest that the key parameters to monitor in groundwater in urban areas are faecal coliform and total coliform.

Effective methods of removing these microbial parameters include aeration and filtration. Human activities such as sewage disposal, and farming, within the study area, were seen to have great impact on the quality of ground water. Water samples at locations with pH less than 6.5 could be treated by allowing the water to pass through granules of dolomites.

Finally, there is seasonal and spatial variation in the concentration of microbial borehole water parameters in Calabar and most of the observed characteristics and trends are thought to be related to the climate regimes and geology of the area. Boreholes that are highly polluted should be subjected to simple sand filtration and flocculation.

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