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SEASONAL VARIATIONS IN HYDROCHEMICAL PARAMETERS OF GROUNDWATER IN CALABAR SOUTH, CROSS RIVER STATE, NIGERIA

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Abstract

The availability of potable water throughout the year has become a major problem of water resource management in many parts of the world, and especially in Calabar South of Cross River State, Nigeria. This study was therefore carried out to examine the seasonal variations in hydrochemical parameters in groundwater within Calabar South in order to ascertain its suitability for human consumption. Water from forty-five (45) producing boreholes were sampled during the wet and dry seasons in 2010. The results revealed significant variations in the concentrations of all the measured physical parameters between the wet and dry seasons at the 0.05 confidence level. Similarly, there were significant variations in the concentrations of bacteriological parameters (feacal and total coliform) between the wet and dry seasons at the 0.05 confidence level. The result posits that seasonality had tremendous impact on water quality parameters of borehole water in the area under investigation. It is recommended that water from the boreholes should be treated against bacterial infestation, particularly during the wet season.

Keywords: Seasonal variations, Hydrochemical parameters, groundwater, Calabar South, Cross River State

Introduction

The availability of potable water through out the year has become a major problem of water resource management in many parts of the world. Groundwater, being a major source of water for human consumption is very important in this regard. Changes in its quality can have serious consequences on the inhabitants of such areas. Groundwater supports habitat and maintains the quality of base flow to rivers. The chemical composition of groundwater is a measure of its suitability as a source of water for human and animal consumption, irrigation and for industrial and other purposes (Ikem and Sobande, 2006).

The quality of water is determined by its chemical composition and therefore its ultimate variability. Its assessment depends on the envisaged usage. Potable water for household consumption must be free of pathogenic bacteria, suspended sediments, harmful minerals and aesthetically acceptable to users (Kari Kari and Asarre, 2006). Water, whether at the surface or underground is never really chemically pure, because as surface water flows over rocks, dissolve minerals and carries debris deposited as a result of human activities. Within the aquifers, groundwater is hosted by various minerals which influenced its hydro chemistry and ultimate quality. The quality of water resources vary naturally and widely depending on climate, seasons and the geology of the bedrock as well as anthropogenic activities (Badmus, 2005).

Groundwater is under threat from pollution especially from human life style manifested by the low level of hygiene practiced in the study area. A number of potential sources of groundwater pollution are characteristically associated with urban environments. In some places, boreholes are located on dumpsites, cemeteries, and defunct sewage due to urban expansion. Borehole owners fail to acknowledge the fact that decomposers such as bacteria and fungi break down nitrogen containing molecules into ammonia gas and water soluble salt in waste dumps, sewage and dead organisms (Glynn and Plummer, 2005). These harmful chemicals percolate into the groundwater through the soil and contaminate it, thereby rendering groundwater unsuitable for consumption.

Nigeria is a well drained country with a close network of rivers and streams. Available data show that ground water resource though ample in the sum total are unevenly distributed all over Nigeria and are subjected to large seasonal variations (Shridha, 2009). The storage and circulation of groundwater at any place depends on two properties of rock, namely, porosity and permeability. Groundwater in Calabar is drawn from the interstices of the underlying sedimentary formation overlying the basement complex and soil sections of boreholes record show that it is predominantly clayey sands (Ugbaja, 2004). Groundwater resources naturally are continually collected, purified and distributed in the hydrologic cycle, a process that works when water is not polluted faster than it is replenished or chemical added that cannot be broken down by microbial action. Esu and Amah (2005), stated that a number of potential sources of ground water pollution is characteristically associated with urban environments. This confirms that groundwater pollution in urban environment is not restricted to shallow alluvial aquifer but can also penetrate bedrock aquifers Imoke et al (2006) further revealed that in developing nations many groundwater exploitation schemes are developed without due regard for quality issues.

Natural geochemical and biochemical, as well as, anthropogenic impact on ground water do not only threaten the quality of human health but also pose a threat to sustainable development and management of groundwater resources (Obasi and Balogun, 2009). The frequent use of fertilizers and pesticides to obtain high crop yield is a source pf ground water contamination in this area. Some of the chemicals applied on farmland move down with the deep percolation water from root zone and contaminates underlying water. Groundwater in areas characterized by high rainfall cum high water table, like the Calabar South, is most vulnerable to this type of contamination.

In view of the above, understanding the seasonal variations in the water quality parameters are of paramount importance to water resource managers. It is therefore imperative to undertake an extensive hydrochemical assessment of ground water in Calabar South to ascertain the seasonal variation in the hydrochemical parameters.

Study area

Calabar South in located within longitudes 8°15´E and 8°25´E, and latitudes 4°54´N and 4°58´N. It is one of the 18 Local Government Areas in Cross River State of Nigeria. The area is characterised by double maxima rainfall that climaxes in the months of July and September. Calabar South records an average annual rainfall amount of 3000mm and relative humidity of above 85% (NAA weather report, 2006).

In terms of lithology, the area is overlain with Tertiary sands of Benin Formation. The sands are mostly medium to coarse-grain, pebbly moderately-sorted, with local lenses of fine-grained, poorly cemented sand and silty clay. The nature of this formation makes it good aquifer.

Method of study

The authors identified a total of one hundred and fifty (150) productive boreholes in the study during the reconnaissance survey in December, 2009. From these 150 productive boreholes, a sample of 45 (30 per cent of 150) was selected (Figure 1 & Table 1) for study through a simple random sampling technique.

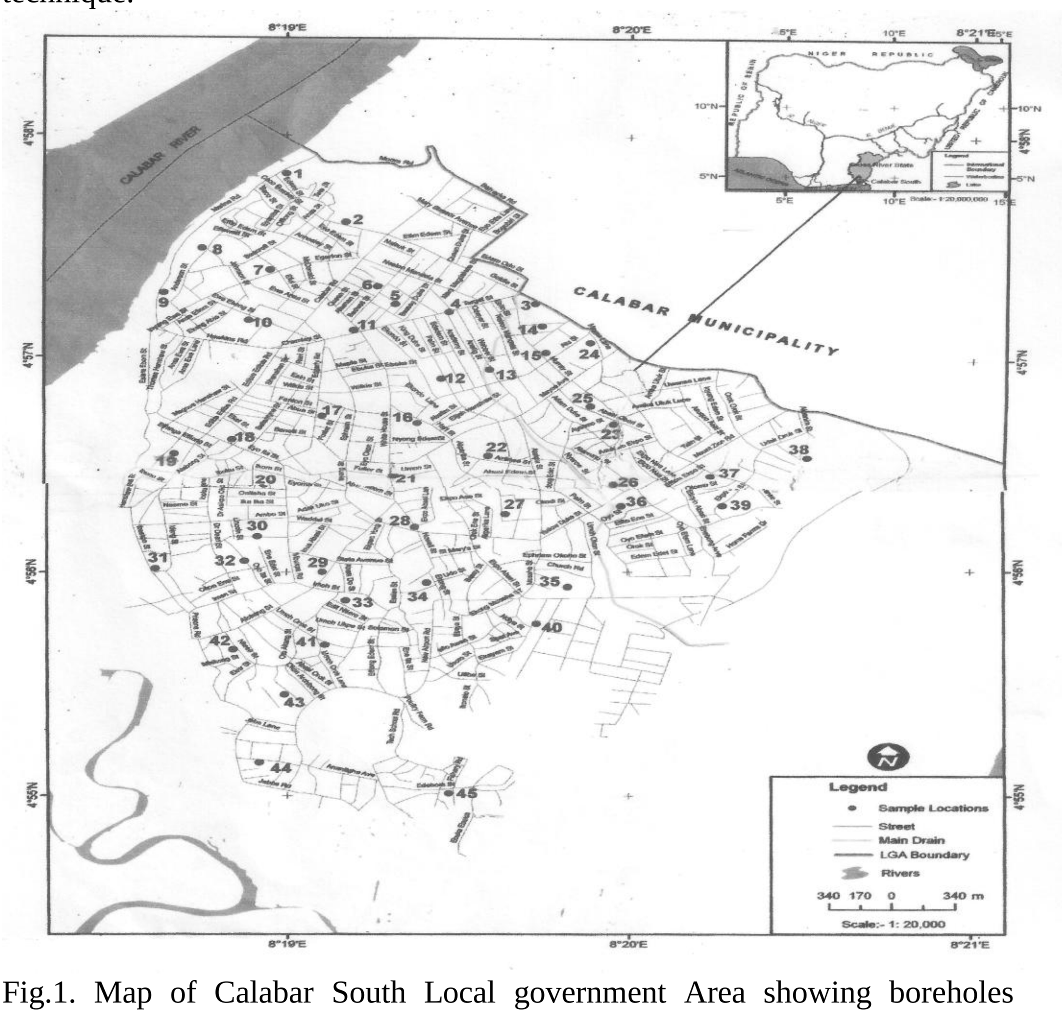

Fig.1. Map of Calabar South Local government Area showing boreholes sampling locations

Table 1. Borehole sampling location with geographical positioning systems

S/N	Borehole sampling location	GPS reading	
		Longitude	Latitude
1	Edem Street	8.32012	4.960044
2	Garden Street	8.317712	4.961843
3	Goldie Street	8.318939	4.962794
4	Target Street	8.315577	4.962169
5	Punch Street	8.318793	4.956401
6	Clifford Street	8.316582	4.963174
7	Egerton Street	8.317936	4.960109
8	Anderson Street	8.316444	4.958456
9	Marina Street	8.313445	4.960766
10	Ewa Ekeng Street	8.313081	4.95883
11	Chamley Street	8.314489	4.953307
12	Palm Street	8.316669	4.956896
13	Webber Street	8.312478	4.952867
14	Esita Street	8.324282	4.953297
15	Murray Street	8.329321	4.953832
16	Hart Street	8.321659	4.955943
17	Abua Street	8.324392	4.955498
18	Eyo Ita Street	8.31956	4.954362
19	Henshaw Ewa Str	8.31959	4.951845
20	Itam Street	8.32129	4.949014
21	White House Street	8.334843	4.947927
22	Azikiwe Street	8.310118	4.946591
23	Ayatmo Street	8.315076	4.945404
24	Mayne Avenue Lane	8.317136	4.945935
25	Abasi Obori Street	8.31409	4.944899
26	Etim Effiom Street	8.315646	4.942604
27	Akparika Street	8.321094	4.950651
28	Yellow Duke Street	8.319656	4.94684
29	Afokang Street	8.318211	4.947592
30	Ikono Street	8.322438	4.950644
31	Ibesikpo Street	8.324312	4.949178
32	Oyo Ita Street	8.324557	4.951124
33	Imoh Street	8.326661	4.949522
34	Ekong Street	8.330089	4.950378
35	Musaha Street	8.328984	4.950651
36	Oyo Street	8.319903	4.935409
37	Uwanse Street	8.327567	4.952753
38	Akpanim Street	8.316063	4.917028
39	Ekpo Eyo Street	8.314856	4.933275
40	Dr. Okon Street	8.311256	4.941628
41	Umoh Orok Street	8.324979	4.937656
42	Nkese Street	8.334737	4.944687
43	Edem Ekpo Street	8.336958	4.942848
44	Okon Ekpo Street	8.33956	4.94364
45	Edebom Street	8.335088	4.936304

Sixteen (16) hydrochemical parameters were also selected for study. These was made of five (5) physical parameters (pH, temperature, turbidity, electrical conductivity and biochemical oxygen demand), two (2) bacteriological parameters (feacal coliform and total coliform) and nine (9) major ions and heavy metals (Na^+, Fe^{2+}, Mn^{2+}, PO_4^{2-}, SO_4^{2-}, Cl^-, NO^{3-}, Ni^{2+} and Cr^{2+}).

Sampling of water was undertaken twice a year in order to have a representative samples at the peak of the wet season (July - August) and dry season (January – February) . Sampling was done once every week during these periods, covering a total of 8 weeks in each period.

Water samples were collected in $100cm^3$ polyethylene bottles apart from samples of BOD which was collected in a specialized glass ware maintained at a temperature between 20-25^oC. The samples were immediately transported to the laboratory in an ice-packed cooler kit for analysis within 24 hours. Samples meant for cation analysis were acidified to pH < 2, to keep the ion in solution. Temperature, pH and turbidity were measured insitu using WTW-Multline P_4 universal meter. Chemical analysis of the water samples were carried out using appropriate certified and acceptable procedures outlined in the standard methods of the examination of water described by APHA, (1988). Iron (Fe^{2+}) was primed with 0.5m solution of nitric acid to keep it in solution. Manganese and nickel were determined by EDTA titration and heavy metals were analyzed using UNICAM 959 atomic absorption spectrometer BOD was determined by titration using Winklens method.

The mean concentration of each of the measured parameters was determined both for the wet (WS) and dry(DS) season and the values taken as the representative value for that borehole for the particular season. The results from the analyses were presented in tables and the

Results and discussions

The results of this study are presented in tables 2, 3 and 4. Table 2 shows the concentrations of some physical and bacteriological parameters while table 3 contains the concentrations of major ions while table 4 shows heavy metal parameters of borehole water quality in the study area. The summary of the descriptive statistics is presented in table 5.

Table 2. Physical and bacteriological parameters of borehole water

S/N	pH		Turbidity (NTU)		Electrical conductivity (µS/cm)		Temperature (^oC)		BOD (mg/l)		Feacal coliform (/100ml)		Total coliform (/100ml)	
	WS	DS	WS	DS	WS	DS	WS	DS	WS	DS	WS	DS	WS	DS
1	6.9	7. 5	4	2	250	150	27.5	29.0	29.0	1.60	2	6	1	3
2	6.4	7.1	8	6	200	120	28.6	29.5	29.5	1.80	1	2	1	2
3	5.9	6.9	14	10	150	110	29.0	30.0	30.0	3.03	1	4	1	3
4	5.7	6.8	14	9	150	100	29.0	30.5	30.5	3.08	2	5	2	5
5	6.7	6.9	7	5	190	100	28.0	29.0	29.0	2.09	3	8	2	9
6	5.5	6.8	10	8	130	70	29.0	29.6	29.6	2.09	1	3	1	3
7	6.8	7.3	6	4	240	130	28.0	29.0	29.0	3.06	1	4	1	6
8	6.6	7.5	5	3	200	120	28.5	29.5	29.5	1.75	1	2	2	5
9	5.0	6.7	12	10	120	60	30.0	30.9	30.9	5.05	1	2	1	4
10	6.8	7.3	3	1	290	170	27.0	28.5	28.5	0.09	1	2	1	4
11	6.2	6.9	9	5	160	130	29.0	29.7	29.7	2.80	2	3	1	6
12	6.4	7.1	11	6	150	110	29.2	29.9	29.9	2.50	1	3	1	4
13	6.8	7.2	15	9	120	80	29.4	30.0	30.0	2.05	2	5	1	3
14	6.0	6.8	13	7	110	60	29.6	30.1	30.1	2.60	2	5	1	2
15	6.5	6.9	12	6	130	90	29.0	29.7	29.7	2.80	1	2	1	3
16	7.0	7.3	15	8	140	105	29.5	29.9	29.9	1.85	1	3	1	4
17	5.5	6.5	17	11	100	65	29.9	30.3	30.3	1.01	2	6	1	4
18	6.4	5.2	1.4	7	125	55	29.7	30.2	30.2	2.07	3	7	1	5
19	6.3	6.8	13	6	130	60	29.2	29.8	29.8	4.05	1	3	2	8
20	6.9	7.2	10	5	145	70	29.0	29.5	29.5	3.01	1	2	1	6
21	6.7	7.1	8	4	180	95	28.9	29.6	29.6	1.25	1	4	2	4
22	7.1	7.4	18	4	240	120	28.7	29.5	29.5	1.50	1	3	1	3
23	7.2	7.6	13	7	200	90	28.5	29.8	29.8	1.60	1	2	1	4
24	6.9	7.1	14	5	190	80	28.9	29.5	29.5	1.40	1	4	2	6
25	6.8	7.0	16	7	220	120	28.5	29.0	29.0	1.50	1	5	1	7
26	6.4	6.9	10	3	110	80	29.8	30.0	30.0	3.08	1	3	1	5
27	6.8	7.0	17	9	250	120	27.2	28.9	28.9	1.10	1	5	2	6
28	7.0	7.2	20	11	300	160	26.9	28.5	28.5	1.15	2	6	1	4
29	7.1	7.4	19	8	260	120	27.1	28.7	28.7	1.00	1	4	1	4
30	6.7	7.1	14	8	240	110	27.8	28.9	28.9	1.25	2	7	1	5
31	6.8	7.2	12	6	200	90	28.5	29.6	29.6	1.40	1	3	1	5
32	6.4	6.9	11	5	180	105	29.0	29.7	29.7	2.05	1	2	1	4
33	6.6	6.8	10	4	170	115	29.5	30.1	30.1	2.15	1	5	1	6
34	6.1	6.7	12	6	190	100	29.3	29.8	29.8	2.40	2	4	2	8
35	6.2	6.9	8	3	150	90	29.8	30.1	30.1	3.06	1	4	1	7
36	6.5	6.8	9	4	160	80	29.6	29.9	29.9	3.00	1	5	5	10
37	7.1	6.8	11	5	180	95	29.2	30.1	30.1	2.45	2	6	1	7
38	7.3	7.9	19	11	260	110	27.5	28.9	28.9	1.15	1	5	2	6
39	6.3	6.7	11	6	150	70	29.0	29.8	29.8	2.85	1	4	1	5
40	6.8	7.0	21	6	180	110	29.7	30.0	30.0	2.01	1	3	1	4
41	6.9	7.2	10	7	200	140	29.5	30.2	30.2	1.85	1	5	1	3
42	6.0	6.8	15	8	130	80	29.9	30.1	30.1	2.80	1	6	1	6
43	5.9	6.6	18	11	120	70	30.0	30.5	30.5	3.70	2	7	1	5
44	6.1	6.7	12	6	160	90	29.8	30.3	30.3	2.50	1	5	4	7
45	6.2	6.9	10	4	180	105	29.5	30.0	30.0	2.15	1	5	1	6

Source: Authors' research, 2010

Table 3. Concentrations of major ions in borehole water

S/N	Na+ (mg/l)		PO_4^{2-} (mg/l)		SO_4^{2} (mg/l)		Cl^- (mg/l)		NO_3^{2-} (mg/l)	
	WS	DS	WS	DS	WS	DS	WS	DS	WS	DS
1	0.3	0.8	0.11	0.25	1.7	3.5	0.13	0.25	2.1	3.3
2	0.6	**1.2**	0.20	0.32	2.1	3.6	0.15	0.36	2.6	3.5
3	1.1	**1.9**	0.17	0.30	2.6	4.0	0.21	0.45	3.2	4.0
4	1.4	**2.2**	0.24	0.45	2.8	4.2	0.23	0.40	3.0	4.2
5	6.7	**6.9**	7	5	190	100	28.0	29.0	1.95	2.09
6	2.4	3.6	0.18	0.46	2.3	4.9	0.21	0.43	2.9	4.5
7	0.5	1.0	0.12	0.23	1.5	3.3	0.12	0.20	2.4	3.6
8	0.6	1.3	0.16	0.28	1.3	3.6	0.16	0.29	1.9	3.3
9	2.2	4.5	0.26	0.55	3.1	5.2	0.57	0.68	3.5	4.9
10	0.1	0.4	0.04	0.15	0.7	1.5	0.06	0.10	0.9	2.5
11	0.9	1.6	0.50	0.40	1.9	3.7	0.17	0.33	2.1	3.6
12	1.3	3.4	0.17	0.44	1.7	3.9	0.23	0.54	2.4	4.3
13	1.1	2.3	0.29	0.60	2.40	4.0	0.26	0.44	2.6	3.9
14	1.5	3.1	0.34	0.62	2.1	4.8	0.21	0.35	2.3	4.6
15	1.5	3.3	0.20	0.48	1.5	3.6	0.25	0.60	1.2	3.6
16	2.00	4.5	0.12	0.40	2.3	4.8	0.37	0.80	1.4	2.5
17	3.05	5.0	0.27	0.59	1.0	2.0	0.20	1.0	2.6	4.1
18	2.70	5..2	0.32	0.52	2.1	3.9	0.32	0.70	1.7	3.5
19	2.85	5.5	0.29	0.58	2.7	4.12	0.16	0.50	2.3	3.9
20	2.90	5.1	0.18	0.39	1.6	3.4	0.09	0.7	1.9	2.7
21	0.7	1.6	0.14	0.33	2.4	4.3	0.21	0.40	2.2	4.5
22	0.4	1.0	0.12	0.28	2.8	5.1	0.03	0.10	2.3	4.2
23	0.5	1.2	0.17	0.32	1.7	4.7	0.05	0.15	1.1	3.6
24	0.6	4.4	0.28	0.35	2.9	5.8	0.07	0.18	1.4	2.8
25	0.5	1.1	0.16	0.23	1.3	3.6	0.05	1.05	2.0	4.3
26	2.50	4.9	0.26	0.47	2.4	4.5	0.10	0.20	2.1	4.7
27	0.4	0.9	0.12	0.25	1.4	3.8	0.14	0.32	1.3	2.8
28	0.3	0.6	0.09	1.10	2.2	4.6	0.12	0.16	1.7	3.4
29	0.2	0.8	0.11	0.21	2.0	3.2	0.11	0.20	2.2	4.3
30	0.5	0.9	0.15	0.34	2.5	4.5	0.13	0.25	1.3	2.6
31	0.4	1.3	0.25	0.40	1.6	0.5	0.12	0.45	2.1	3.7
32	2.5	4.8	0.31	0-.48	2.3	4.6	0.26	0.50	1.6	4.3
33	3.0	5.2	0.20	0.41	2.1	3.7	0.31	0.65	0.09	2.6
34	2.3	3.8	0.15	0.36	2.7	4.8	0.15	0.38	1.7	2.9
35	0.7	1.9	0.33	0.54	1.1	2.8	0.29	0.70	1.6	3.8
36	2.7	5.6	0.24	0.49	1.5	3.6	0.21	0.50	2.3	4.3
37	0.9	1.6	0.22	0.33	1.9	4.3	0.16	0.33	2.1	3.2
38	0.2	0.7	0.19	0.24	0.9	2.5	0.09	1.15	2.7	4.6
39	1.6	3.6	0.22	0.40	1.6	3.8	0.21	0.40	1.4	2.7
40	0.5	1.8	0.23	1.38	1.3	2.5	0.17	0.50	2.1	3.8
41	0.8	1.5	0.17	0.25	2.1	3.9	0.22	0.41	2.5	4.9
42	1.6	3.8	0.14	0.32	2.7	4.6	0.17	0.38	1.6	3.7
43	2.5	5.7	0.18	0.34	1.4	3.9	0.19	1.50	2.8	4.0
44	1.7	3.5	0.26	0.45	2.5	4.8	0.70	1.80	1.3	3.6
45	1.1	2.0	0.31	0.55	1.3	3.7	0.04	0.90	2.2	4.5

Source: Authors' research, 2010

Table 4. Concentration of heavy metals

S/N	Fe^{2+} (mg/l)		Mn^{2+} (mg/l)		Ni^{2+} (mg/l)		Cr^{2+} (mg/l)	
	WS	DS	WS	DS	WS	DS	WS	DS
1	0.12	2.25	0.01	0.02	0.03	0.07	0.7	1.0
2	0.15	0.28	0.02	0.03	0.05	0.09	0.2	0.5
3	0.26	0.45	0.03	0.05	0.08	1.00	0.2	0.6
4	0.90	1.06	0.04	0.06	0.02	0.06	0.3	0.5
5	13.5	17.5	23.5	33.0	5.80	8.04	2.10	3.05
6	0.65	1.04	0.03	0.09	0.05	0.09	0.4	1.0
7	0.40	0.80	0.01	0.02	0.03	0.06	0.3	0.9
8	0.30	0.70	0.02	0.04	0.04	0.08	0.2	0.7
9	1.10	2.50	0.06	0.10	0.03	0.07	0.4	0.7
10	0.01	0.04	0.001	0.01	0.03	0.07	0.4	0.6
11	0.80	1.01	0.01	0.03	0.02	0.05	0.2	0.5
12	0.75	1.07	0.05	0.1	0.02	0.04	0.4	0.8
13	0.90	5.2	0.03	0.07	0.07	0.04	0.2	0.4
14	0.98	1.33	0.02	0.06	0.04	0.07	0.3	0.7
15	0.03	1.00	0.02	0.04	0.03	0.07	0.02	0.06
16	0.01	0.10	0.01	0.03	0.03	0.08	0.3	0.5
17	0.02	0.15	0.01	0.04	0.02	0.05	0.2	0.4
18	0.06	1.30	0.03	0.06	0.06	1.0	0.3	0.6
19	0.07	0.20	0.01	0.02	0.02	0.06	0.4	0.7
20	0.9	1.15	0.04	0.07	0.03	0.05	0.1	0.4
21	0.02	0.40	0.02	0.04	0.05	0.09	0.2	0.3
22	0.06	0.35	0.02	0.05	0.03	0.08	0.3	0.8
23	0.04	0.30	0.01	0.02	0.07	1.00	0.04	0.09
24	0.02	1.00	0.01	0.03	0.03	0.06	0.4	0.7
25	0.01	0.10	0.03	0.05	0.03	0.07	0.7	1.0
26	0.02	0.25	0.02	0.06	0.05	0.09	0.2	0.5
27	0.02	0.40	0.02	0.04	0.08	1.00	0.2	0.6
28	0.01	0.35	0.03	0.06	0.02	0.06	0.3	0.5
29	0.05	0.20	0.01	0.03	0.03	0.07	0.4	0.7
30	0.03	1.00	0.01	.005	0.05	0.09	0.4	1.0
31	0.02	0.20	0.07	0.05	0.03	0.06	0.3	0.9
32	0.04	0.35	0.01	0.03	0.04	0.08	0.2	0.7
33	0.06	1.40	0.04	0.07	0.02	0.06	0.8	1.0
34	0.02	0.25	0.01	0.04	0.03	0.07	0.4	0.6
35	0.03	0.30	0.001	0.02	0.02	0.05	0.2	0.5
36	0.04	0.10	0.03	0.07	0.02	0.04	0.4	0.3
37	0.01	0.15	0.01	0.04	0.07	0.04	0.2	0.4
38	0.04	0.30	0.02	0.03	0.04	0.07	0.3	0.7
39	0.01	0.45	0.01	0.02	0.03	0.07	0.5	0.6
40	0.05	1.00	0.04	0.07	0.02	0.06	0.2	0.5
41	0.02	0.35	0.02	0.06	0.03	0.05	0.4	0.9
42	0.01	0.20	0.01	0.02	0.02	0.05	0.3	0.5
43	0.06	1.45	0.01	0.03	0.02	0.04	0.4	0.9
44	0.02	0.40	0.03	0.06	0.03	0.06	0.3	0.7
45	0.07	1.50	0.02	0.05	0.03	0.07	0.3	0.6

Source: Authors' research, 2010

Table 5. Summary of descriptive statistics

	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
pH (wet season)	45	2.30	5.00	7.30	6.4933	.49882	.249
pH (dry season)	45	2.70	5.20	7.90	6.9867	.39635	.157
Turbidity (wet season)	45	18.00	3.00	21.00	12.2222	4.20437	17.677
Turbidity (dry season)	45	10.00	1.00	11.00	6.3556	2.50595	6.280
Electrical conductivity (wet season)	45	200.00	100.00	300.00	178.4444	50.52927	2553.207
Electrical conductivity (dry season)	45	115.00	55.00	170.00	100.0000	26.88359	722.727
Temperature (wet season)	45	3.10	26.90	30.00	28.8933	.86034	.740
Temperature (dry season)	45	2.40	28.50	30.90	29.6911	.55055	.303
Biochemical oxygen demand (wet season)	45	4.03	.06	4.09	1.2820	.81817	.669
Biochemical oxygen demand (dry season)	45	4.96	.09	5.05	2.1940	.91694	.841
Feacal coliform (wet season)	45	2.00	1.00	3.00	1.3333	.56408	.318
Feacal coliform (dry season)	45	6.00	2.00	8.00	4.2000	1.60397	2.573
Total coliform (wet season)	45	4.00	1.00	5.00	1.3556	.80214	.643
Total coliform (dry season)	45	8.00	2.00	10.00	5.0222	1.78998	3.204
Sodium ions (wet season)	45	6.60	.10	6.70	1.4402	1.22266	1.495
Sodium ions (dry season)	45	6.50	.40	6.90	2.8222	1.79834	3.234
Phosphate (wet season)	45	6.96	.04	7.00	.3591	1.01591	1.032
Phosphate (dry season)	45	4.85	.15	5.00	.5296	.71439	.510
Sulphate (wet season)	45	189.30	.70	190.00	6.1333	28.03836	786.150
Sulphate (dry season)	45	99.50	.50	100.00	6.0027	14.36414	206.329
Chloride (wet season)	45	27.97	.03	28.00	.8089	4.14741	17.201
Chloride (dry season)	45	28.90	.10	29.00	1.1484	4.26066	18.153
Nitrate (wet season)	45	3.41	.09	3.50	2.0364	.64298	.413
Nitrate (dry season)	45	2.81	2.09	4.90	3.6976	.72460	.525
IIron ions (wet season)	45	13.49	.01	13.50	.5042	2.00812	4.033
Iron ions (dry season)	45	17.46	.04	17.50	1.1529	2.64347	6.988
Manganese ions (wet season)	45	23.50	.00	23.50	.5436	3.49994	12.250
Manganese ions (dry season)	45	33.00	.00	33.00	.7774	4.91268	24.134
Nickel (wet season)	45	5.78	.02	5.80	.1642	.85939	.739
Nickel (dry season)	45	8.00	.04	8.04	.3249	1.20668	1.456
Chromium (wet season)	45	2.08	.02	2.10	.3547	.30717	.094
Chromium (dry season)	45	2.99	.06	3.05	.6800	.42710	.182
Valid N (listwise)	45						

From table 5, pH ranged from 5.00 to 7.30 with a mean value of 6.49 in the wet season while the dry season concentrations varied between 5.20 and 7.90 with a mean value of 6.99 in the dry season. Turbidity ranged from 3.00 to 21.00 with a mean value of 12.22 while the dry season concentrations ranged between 1.00 and 11.00 with a mean value of 6.36. Generally, the results show seasonal variations in means of all measured water quality parameters.

The results of the Student's t-test are presented in table 6.

Table 6. Results of student's t-test

Parameter	t-value	Df	Sig (2-tailed)
pH	-7.748	44	0.001
Turbidity	13.660	44	0.001
Electrical conductivity	16.171	44	0.001
Temperature	-13.130	44	0.001
BOD_5	-11.584	44	0.001
Feacal coliform	-13.213	44	0.001
Total coliform	-16.828	44	0.001
Na	-10.252	44	0.001
PO_3	-2.937	44	0.005
SO_4	0.064	44	0.949
Cl	-7.079	44	0.001
NO	-18.489	44	0.001
Fe	-4.844	44	0.001
Mn	-1.110	44	0.273
Ni	-2.637	44	0.012
Cr	-7.790	44	0.001

From table 6, over 87 per cent (14 out of 16) of the measured water quality parameters exhibit significant variations in their concentrations between the dry and wet seasons at the 0.05 confidence level. Only the variations in SO_4 and Mn were however, not significant at the tested level of significance. Negative t-values are indications that the mean of the dry season samples were higher than those of the wet season and vice versa.

For example, the mean concentration of feacal coliform was higher in the dry season (4.20c/100ml) than in the wet season (1.33c/100ml) (Table 5). Hence, seasonality has significant effect on the groundwater quality of Calabar South in Cross River State, Nigeria.

On comparing this results with the World Health Organisation (WHO, 2006) and Federal Ministry of Environment standards for water for domestic purposes, we found out that the mean pH values (6.49 and 6.99) for the dry and wet seasons respectively were within the WHO recommended range of 6.50 – 8.50 for water for domestic purposes. However, turbidity had wet and dry seasons' mean values of 6.36 NTU and 12.22 NTU respectively and were higher than WHO standards for drinking water. Similarly, feacal and total coliform counts were found to be higher than the WHO recommended standard of zero (0) during both seasons. These higher values of feacal and total coliform have polluted most of the borehole water and render them unfit for drinking purposes. Using such water for domestic purposes, like drinking, posses threat to human health.

The results of this study suggest that's that there is erratic variation in the concentration of water quality parameters which may be attributed the fact that boreholes in the area are producing at different depths. For instance, it was discovered that the shallower the depths of boreholes, the higher the concentrations of feacal and total coliforms in the water.

CONCLUSION

This study examined the seasonal variations in hydrochemical parameters of groundwater in Calabar South, Cross River State, Nigeria. Water samples were collected from 45 producing boreholes in the area. Standard field and laboratory techniques were adopted for the study. From the data obtained and the discussion that ensued revealed that the concentration of water quality parameters in Calabar South area is seasonally controlled. This seasonal variation affects the availability of potable in the area, all year round. These variations have more influence on the bacteriological parameters of water. It is therefore recommended that water from boreholes should be treated against bacterial infestation, particularly during the wet season.

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