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PHYSICOCHEMICAL AND BACTERIOLOGICAL PROPERTIES OF SURFACE WATERS FROM TWO LOCALITIES IN RIVERS STATE, NIGERIA

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ABSTRACT: *This study investigated the physicochemical and bacteriological properties of surface waters from Bori and Okoli'ile towns in Rivers State, Nigeria. A total of 360 brackish water samples were collected from January to December, 2019 from the two localities. Samples were subjected to physicochemical, trace elements and bacteriological examinations. Isolated colonies from microbiological examinations were subjected to further biochemical and physiological characterization. The result showed pH mean values were higher in the month of January to March, a period where rainfall is less frequent (dry months). Similar trend of occurrence was observed in the monthly mean values of temperature (^0C) and salinity (mg/L). Most of the physicochemical indices of water quality measurement recorded average values exceeding the stipulated acceptable environmental tolerance limits by the World Health Organisation (WHO). The microbiological examinations showed lower monthly mean values of total heterotrophic count, total coliforms and faecal coliforms counts during the wet months with statistically significant difference ($P<0.05$) when compared to the average values obtained in the dry months. The Pearson's correlation coefficient showed high relationship between total heterotrophic count and faecal coliforms, an indication of increase in human wastes into aquatic environments leading to higher bacterial population within the waterbody, which could be a predisposing factor for epidemic. It is recommended that local and regional governments should enforce appropriate measures to encourage personal and community practice of hygiene.*

KEYWORDS: Physicochemical Analysis, Bacteriological Properties, Surface Waters.

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INTRODUCTION

Water undoubtedly is the most essential substance for the maintenance of life (Oyinloye & Jegede, 2004). The component of a living cell is largely made up and maintained by water. About 71% of earth's surface area is made up of water (Okeola *et al*., 2010). Water exists in different forms which could be classified as groundwater and surface water. Groundwater includes hand-dug wells, boreholes and springs (NBS, 2012). Examples of surface water are streams, rivers, lakes, ponds, creeks, seas and oceans (Higler, 2012). Furthermore, water could be classified based on the salinity; these are fresh water (absence or minimal saline content), brackish water (moderate salinity) which are creeks, estuaries and lagoons, and marine water (considerably high amount of salinity content) with examples being seas and oceans.

Water quality is simply the assessment of the physical and chemical properties of a water body, both of which are collectively referred to as physicochemical indices of water quality assessment. Physicochemical properties of water entail physical examination, presence of ions, trace elements and heavy metals. Typical examples of physicochemical parameters are pH, salinity, electrical conductivity, dissolved solids, turbidity, total alkalinity and dissolved oxygen. Investigation of ions (nitrates, sulphates and phosphates) and trace elements like iron, zinc, manganese, cadmium, calcium, magnesium, nickel, copper, vanadium and chromium make up the complete physicochemical investigation of water quality (Diersong *et al*., 2009).

Additionally, water quality assessment involves microbiological examinations. This includes the investigation for total heterotrophic count, total coliform, faecal coliform, *Escherichia coli, Enterococcus faecalis* and fungi (Cheesbrough, 2006). The bacteria used in this water quality assessment are collectively referred to as indicator microorganisms (Jay *et al*., 2007).

Surface water is an integral part of life to the people of the Niger-Delta region. It serves as a source of drinking water, fishing activities, agricultural activities, manufacturing of local products, recreational activities and a means of transportation within the creek communities. The quality of these surface waters has a direct positive and detrimental effect on the aquatic ecosystem and human population residing in the vicinity.

This study was conducted in two settlements in Rivers State, South-South Nigeria with the aim to determine the physicochemical and bacteriological qualities of surface waters within these selected localities. The objective of this study is to ascertain the level of chemical and biological contamination of these water bodies, and possibly recommend ways to avert possible outbreaks of epidemics through changes in unhealthy practices.

MATERIALS AND METHODS

Study areas

Bori (4^0 40'N; $7^0$22' E) is the second largest town in Rivers State after Port Harcourt, South-South of Nigeria. Bori is the commercial centre of the Ogoni-land. The town is bordered by several creek communities like Gokana, Khana, Yeghe, Kor and Andoni communities. The people of Bori engage in farming and fishing as their primary sources of occupation.

Okoli'ile (4^0 31'N; $7^0$27'E) which could also be called Okolo'ile is one of the settlements in the heart of Andoni-land of Rivers State. Okoli'ile is a creek community with its inhabitants

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predominantly speaking the obolo dialect. Okoli'ile is bordered by numerous riverine communities like Ebukuma, Ngo, Uyeada and Ikuru town. The indigenous population are primarily involved in fishing and farming practices.

Sampling of water

A total of 360 brackish water samples were collected from the two study settlements. Fifteen (15) samples were collected from five (5) locations each in the two areas. Samples were collected for the duration of 12 months spanning from January to December 2019. Water samples were collected into sterile 5L plastic containers, placed on ice and transferred to the laboratory for analysis within 24hrs. Manganous sulphate solution (1ml) and sodium iodide-azide were added on 300ml opaque specifically designed to collect water samples for dissolved oxygen. These chemicals were added to fix oxygen when collected on site.

Analysis of physicochemical parameters

All physicochemical properties of collected samples from Bori and Okoli'ile were determined based on the procedure elucidated by American Public Health Association (APHA, 1992). All parameters, except otherwise stated, were measured in mg/L and data obtained were compared with World Health Organisation (WHO) standards for environmental acceptability.

Analysis of heavy metals

All heavy metals and trace elements were measured in mg/L. Heavy metals analyses were carried out using atomic absorption spectrophotometer (thermal elemental 969 series). The procedures for the analysis of heavy metals and trace elements used in this study were based on the methods described by Ademoroti, 1997. Data obtained were compared with WHO standards for environmentally acceptable limits of tolerance.

Bacteriological examination of water samples

Determination of bacterial profiling was performed based on the described methods of APHA, 2005. The total bacterial counts were determined with serial dilution up to 10^{-6}. The most probable number (MPN) in the procedure for sanitary analysis of water was employed to determine the total and faecal coliform enumeration. Further identification for specific species was done using IMVIC test as described by APHA (2005). Isolated colonies were subjected to various selective media and biochemical tests which are Gram's reactions, oxidase, triple sugar iron fermentation, sucrose utilization and motility test.

Statistical analysis

All data obtained were represented in the forms of means with their standard deviations and pictorial representation using Microsoft excel version 2016. The statistical comparisons of means were also determined using Microsoft excel version 2016. Pearson's correlation coefficients were calculated using IBM SPSS (version 23.0).

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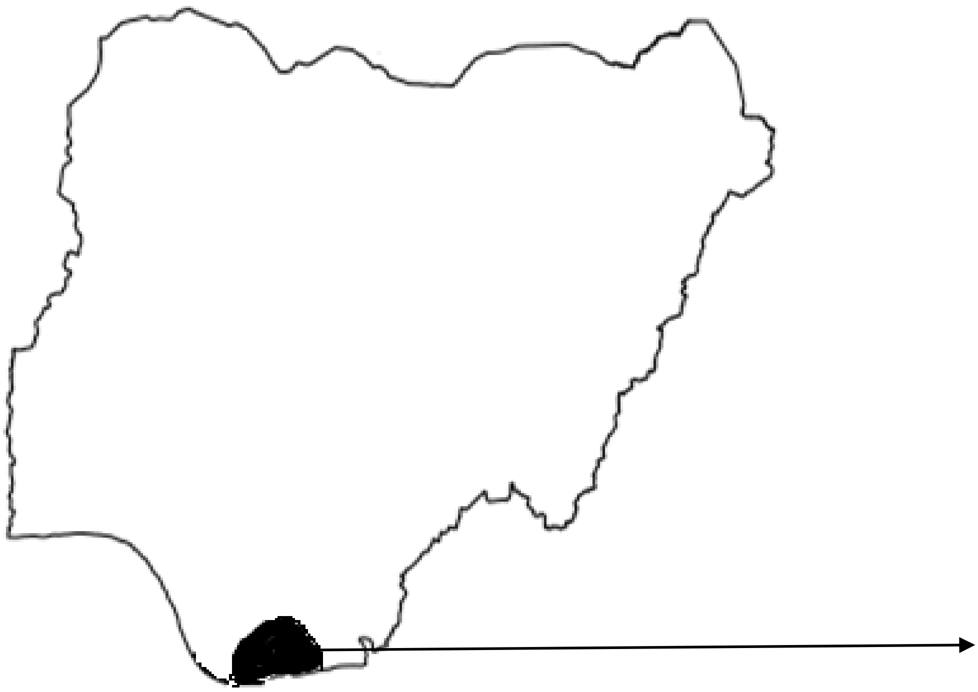

Figure 1a. Map of Nigeria showing the region where localities were situated.

Figure 1b. Map of sections of Rivers State showing the two settlements of study.

Source: Google maps inc.

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RESULT

The graphical representation of the obtained mean values of pH of brackish water samples in Bori and Okoli'ile showed higher average figures in the month of January to March while lower values were observed from May to October (figure 2). The statistical students' t-test comparison of mean values in the two localities show no significant difference (P>0.05). The pictorial representation of monthly mean values of temperature (^{0}C) showed lower temperature values in the month of May to October (figure 3). The statistical comparison of the mean values using statistical students' t-test revealed no statistically significant difference (P>0.05) in the values from the two localities. The evaluation of salinity content of the brackish water samples from the two areas showed reduced concentration of salinity (mg/L) from April to October in Okoli'ile, while there was slight reduction in the concentration from June to December in Bori (figure 4). The statistical comparison of means of salinity concentrations showed statistically significant differences (P<0.05).

The monthly mean values of the physicochemical parameters of brackish water revealed most of the environmental indices of quality assessment of water in Bori exceeded the WHO acceptable limits (table 1). Prominent are electrical conductivity (µS/cm), dissolved solids, turbidity and hardness of water which recorded values much higher than the acceptable limits of tolerance. The monthly average values of trace elements and heavy metals from Bori (table 2) showed elements like Ca^{2+}, Mg^{2+} and Fe^{2+} exceeded the limits. The similar trends of occurrence were noticed in the values of physicochemical parameters (table 3) and trace elements (table 4) in Okoli'ile.

The microbiological examination of brackish water samples from Bori and Okoli'ile entailed the investigation of the total heterotrophic count (figure 5). It was observed that in the month of April to September, there were lowered recorded mean values. Statistical comparisons of means showed Okoli'ile to be significantly higher at P<0.05 using the students' t-test. Similarly, lower monthly average values were observed in the month of April to September (figure 6). There is statistical significance in the distribution of the monthly mean values (P<0.05) with values from Okoli'ile having statistically higher values. In the same vein, the monthly mean values of faecal coliform counts from Bori and Okoli'ile (figure 7) showed lowered values from April to October. The monthly mean values obtained from Okoli'ile was statistically higher (P<0.05) when compared to the values of faecal coliform counts from Bori. Table 5 shows the monthly distribution of values of *Enterococcus faecalis* from the two settlements with statistical significance in the mean from Okoli'ile.

The result of the Pearson's correlations of indicator microorganisms and three (3) physicochemical parameters in Bori (table 3) was investigated. There was a high correlation in the distribution of total heterotrophic count with total and faecal coliforms. Similar trend was observed in table 7 which showed Pearson's correlation coefficient of indicator microorganisms with physicochemical parameters from Okoli'ile's brackish water.

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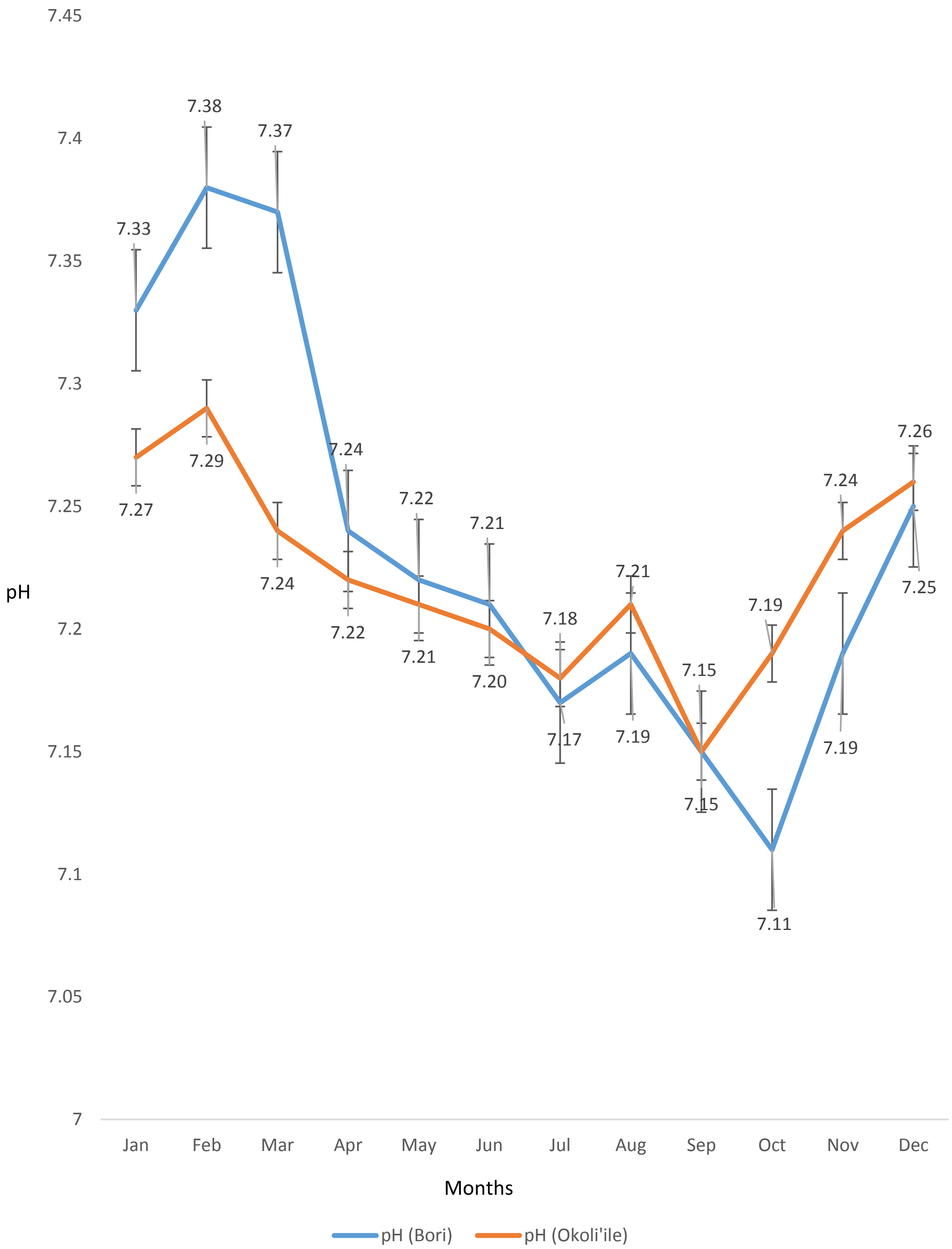

Figure 2. Monthly mean values of pH of Brackish water samples in Bori and Okoli'ile, Rivers State

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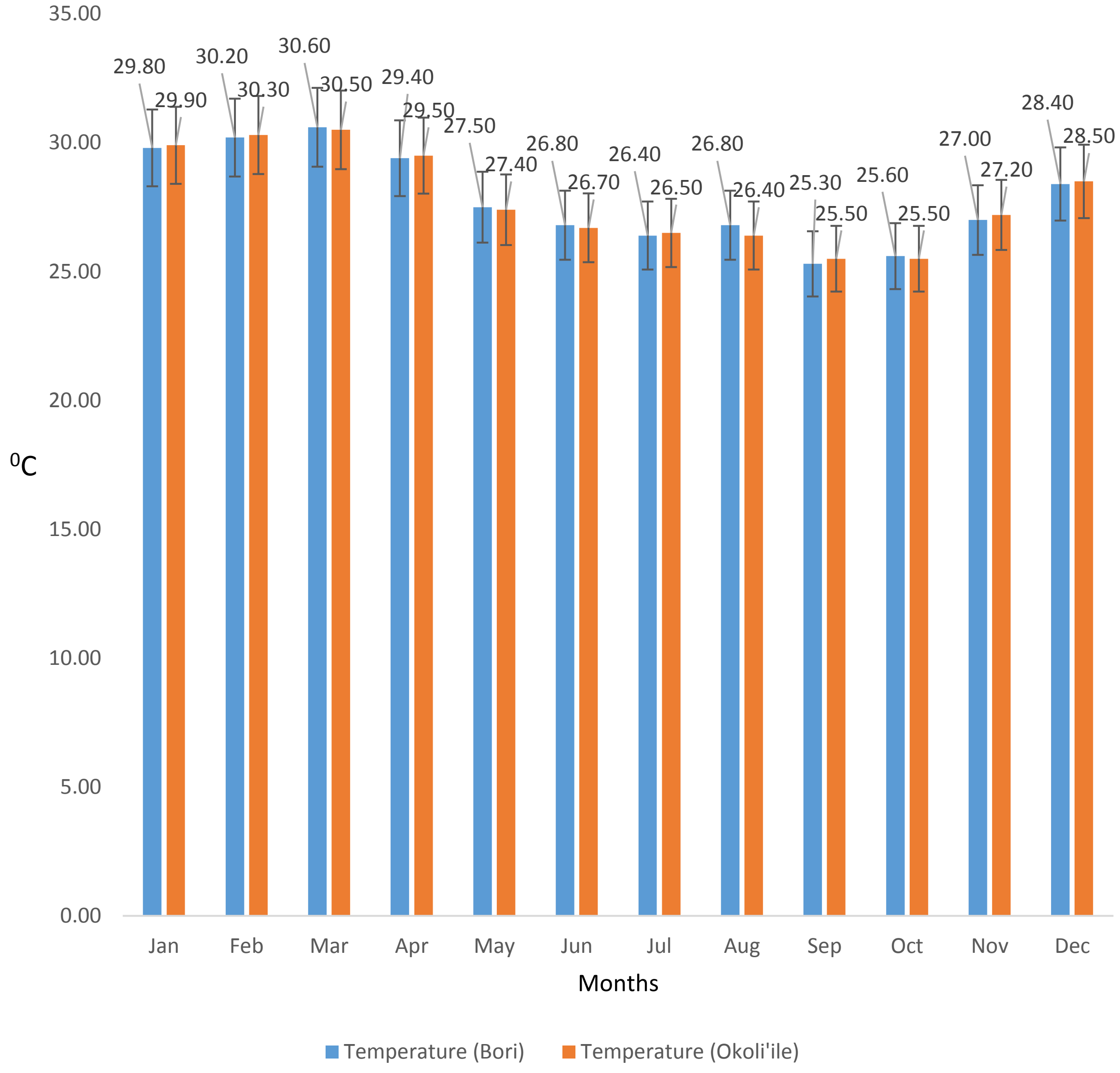

Figure 3. Monthly mean values of Temperature (^{0}C) of Brackish water samples in Bori and Okoli'ile, Rivers State

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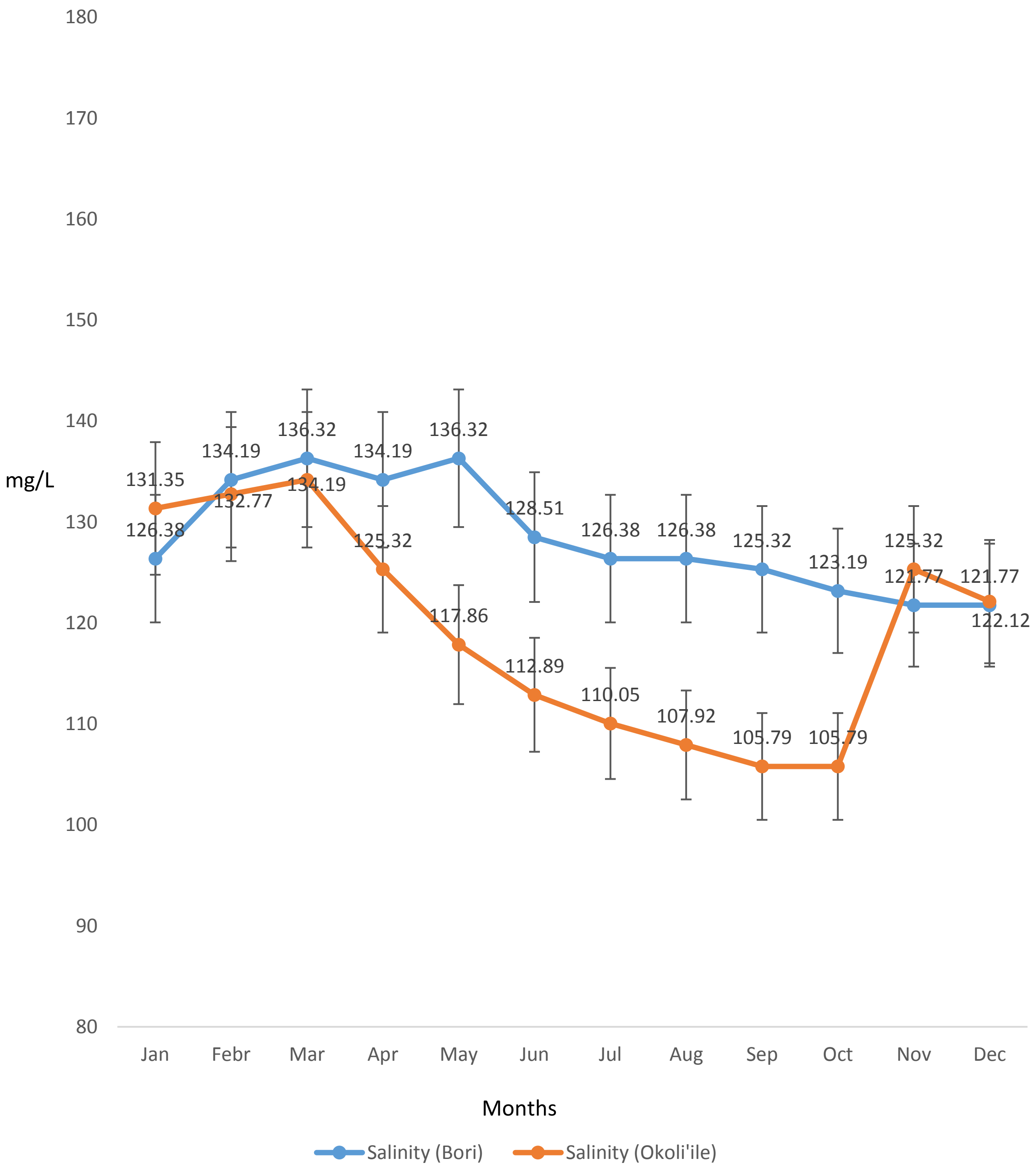

Figure 4. Monthly mean values of salinity (mg/l) of Brackish water samples in Bori and Okoli'ile, Rivers State

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Table 1: Monthly variation of the physico-chemical parameters of brackish water from Bori, Rivers State

Parameters	January	February	March	April	May	June	W.H.O limits
Conductivity µS/cm	2125.41±120.11	2137.55±64.24	2157.22±96.40	2479.80±100.10	3377.81±146.29	3842.56±164.00	1200 µs/cm
Dissolved solids	1540.92±87.08	1549.72±46.57	1563.95±69.83	1797.76±72.42	2442.14±97.05	2785.86±118.90	500mg/L
Alkalinity	211.47±7.044	215.53±3.522	211.47±7.044	225.70±7.044	219.60±7.044	205.37±3.522	100mg/L
Dissolved oxygen	3.10±0.200	3.13±0.115	3.17±0.153	3.33±0.252	4.07±0.153	4.57±0.473	Not specified
Turbidity	12.04±0.125	12.18±0.157	12.13±0.157	13.18±0.303	14.34±0.496	14.88±0.637	5.0 NTU
Sulphate	541.74±2.54	553.41±2.12	560.08±1.87	534.41±2.12	542.74±1.63	521.41±2.64	500mg/L
Total hardness	404.00±1.00	403.00±1.00	403.00±1.00	396.00±2.00	390.00±2.00	406.00±2.00	100mg/L
Calcium hardness	278.00±0.58	277.00±0.58	277.00±0.58	258.00±1.15	256.00±1.15	288.00±1.15	Not specified
Magnesium hardness	126.00±0.58	126.00±0.58	126.00±0.58	138.00±1.15	134.00±1.15	118.00±1.15	Not specified
Nitrate	2.62±0.050	2.63±0.050	2.85±0.161	2.70±0.105	3.06±0.128	2.82±0.030	5mg/L
	July	August	September	October	November	December	
Conductivity µS/cm	3600.44±220.96	3429.42±169.56	3444.76±119.60	3198.11±67.82	2720.90±120.78	2153.57±63.80	1200 µs/cm
Dissolved solids	2610.21±160.25	2486.22±122.78	2497.45±86.71	2318.63±49.17	1972.54±87.57	1561.34±46.26	500mg/L
Alkalinity	205.37±3.522	203.33±3.522	223.67±7.044	217.57±7.044	217.57±3.522	211.47±3.522	100mg/L
Dissolved oxygen	4.60±0.361	4.60±0.200	4.40±0.211	4.30±0.200	3.90±0.529	3.43±0.586	Not specified
Turbidity	16.11±0.865	15.38±0.808	14.78±0.980	14.06±0.201	13.10±0.512	12.33±0.384	5.0 NTU
Sulphate	515.28±2.86	516.08±3.12	521.41±2.12	523.41±2.12	534.74±1.63	534.74±1.62	500mg/L
Total hardness	406.00±2.00	409.00±2.00	408.00±2.00	408.00±1.00	407.00±1.00	407.00±1.00	100mg/L
Calcium hardness	287.00±1.15	280.00±1.15	289.00±1.15	290.00±0.58	287.00±0.58	288.00±0.58	Not specified
Magnesium hardness	119.00±1.15	129.00±1.15	119.00±1.15	118.00±0.58	120.00±0.58	119.00±0.58	Not specified
Nitrate	2.49±0.039	2.50±0.076	2.49±0.090	2.50±0.076	2.49±0.071	2.58±0.087	5mg/L

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Table 2: Monthly variation of the trace element parameters of brackish water from Bori, Rivers State

Parameters	January	February	March	April	May	June	W.H.O limits
Calcium	111.42±0.23	111.02±0.23	111.02±0.23	103.41±0.46	102.60±0.46	115.43±0.46	75mg/L
Magnesium	30.62±0.14	30.62±0.14	30.62±0.14	33.53±0.28	32.56±0.28	28.67±0.28	20mg/L
Copper	0.0200±0.0017	0.0300±0.0015	0.0200±0.0016	0.0400±0.0020	0.0400±0.0021	0.0400±0.0021	2.0mg/L
Chromium	0.0036±0.0003	0.0038±0.0003	0.0035±0.0005	0.0036±0.0005	0.0039±0.0006	0.0039±0.0006	0.05mg/L
Cadmium	0.0020±0.0004	0.0025±0.0002	0.0030±0.0002	0.0035±0.0002	0.0045±0.0002	0.0050±0.0001	0.003mg/L
Lead	0.0040±0.0007	0.0038±0.0009	0.0039±0.0008	0.0033±0.0010	0.0033±0.0011	0.0031±0.0012	0.01mg/L
Iron	2.80±0.113	2.82±0.121	2.75±0.090	2.66±0.438	2.64±0.654	3.23±0.592	3mg/L
Manganese	0.0055±0.0005	0.0055±0.0005	0.0060±0.0006	0.0063±0.0006	0.0061±0.0007	0.0063±0.0006	0.4mg/L
	July	August	September	October	November	December	
Calcium	115.03±0.46	112.22±0.46	115.83±0.46	116.23±0.23	115.03±0.23	115.43±0.23	75mg/L
Magnesium	28.92±0.28	31.35±0.28	28.92±0.28	28.67±0.14	29.16±0.14	28.92±0.14	20mg/L
Copper	0.0500±0.0022	0.0500±0.0024	0.0400±0.0018	0.0400±0.0020	0.0300±0.0021	0.0300±0.0020	2.0mg/L
Chromium	0.0040±0.0005	0.0035±0.0005	0.0038±0.0005	0.0036±0.0004	0.0035±0.0004	0.0034±0.0003	0.05mg/L
Cadmium	0.0060±0.0001	0.0050±0.0002	0.0050±0.0001	0.0030±0.0003	0.0028±0.0004	0.0026±0.0001	0.003mg/L
Lead	0.0033±0.0008	0.0028±0.0011	0.0030±0.0009	0.0033±0.0009	0.0036±0.0008	0.0038±0.0007	0.01mg/L
Iron	3.15±0.666	3.75±0.433	3.85±0.306	3.94±0.510	3.64±0.395	2.95±0.324	3mg/L
Manganese	0.0065±0.0005	0.0063±0.0005	0.0064±0.0007	0.0063±0.0007	0.0060±0.0009	0.0055±0.0007	0.4mg/L

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Table 3. Monthly variation of the physico-chemical parameters of brackish water from Okoli'ile, Rivers State

Parameters	January	February	March	April	May	June	W.H.O limits
Conductivity µS/cm	2032.63±34.47	2093.28±78.37	2062.82±72.90	2438.79±50.09	3124.75±228.82	3588.94±163.50	1200 µs/cm
Dissolved solids	1473.65±24.99	1517.58±56.81	1495.54±52.86	1768.13±36.32	2265.44±165.89	2601.98±118.54	500mg/L
Alkalinity	164.70±6.100	172.83±3.522	183.00±6.100	178.93±3.522	187.07±3.522	162.67±3.522	100mg/L
Dissolved oxygen	3.42±0.104	3.28±0.076	3.22±0.0.257	3.78±0.749	4.25±0.203	5.02±0.257	Not specified
Turbidity	11.24±0.210	11.23±0.0.259	11.99±0.069	12.65±0.203	13.71±0.246	13.04±360	5.0 NTU
Sulphate	373.58±3.71	377.89±2.15	396.30±1,79	400.18±1.87	394.56±1.68	385.60±2.5	500mg/L
Total hardness	400.00±1.00	399.00±1.00	398.00±1.00	392.00±2.00	391.00±2.00	403.00±2.00	100mg/L
Calcium hardness	272.00±0.58	270.00±0.58	271.00±0.58	265.00±1.15	264.00±1.15	274.00±1.15	Not specified
Magnesium hardness	128.00±0.58	129.00±0.58	127.00±0.58	127.00±1.15	127.00±1.15	129.00±1.15	Not specified
Nitrate	3.61±0.060	3.72±0.062	3.61±0.068	3.69±0.072	3.81±0.091	3.70±0.136	5mg/L
	July	August	September	October	November	December	
Conductivity µS/cm	3816.23±117.67	3296.01±45.70	3426.24±125.78	3166.28±49.34	2860.13±46.66	2179.99±60.41	1200 µs/cm
Dissolved solids	2766.77±85.31	2389.64±33.08	2484.02±91.20	2295.55±35.77	2073.59±33.83	1580.44±43.88	500mg/L
Alkalinity	154.53±9.318	162.67±3.522	156.57±3.522	166.73±7.044	162.67±3.522	156.67±3.522	100mg/L
Dissolved oxygen	5.02±0.257	4.58±0.369	4.78±0.076	4.82±0.104	4.65±0.087	4.02±0.126	Not specified
Turbidity	12.75±0.169	12.55±0.176	12.23±0.210	11.77±0.263	11.58±0.165	11.42±0.188	5.0 NTU
Sulphate	378.23±1.84	383.25±1.95	376.44±1.72	372.85±2.64	366.23±3.01	363.56±2.55	500mg/L
Total hardness	404.00±2.00	410.00±1.00	409.00±2.00	409.00±2.00	400.00±1.00	399.00±1.00	100mg/L
Calcium hardness	275.00±1.15	280.00±0.58	278.00±1.15	280.00±1.15	273.00±0.58	271.00±0.58	Not specified
Magnesium hardness	129.00±1.15	130.00±0.58	131.00±1.15	129.00±1.15	127.00±0.58	128.00±0.58	Not specified
Nitrate	3.60±0.126	3.65±0.151	3.59±0.250	3.75±0.2000	3.66±0.070	3.50±0.145	5mg/L

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Table 4. Monthly variation of the trace element parameters of brackish water from Okoli'ile, Rivers State

Parameters	January	February	March	April	May	June	W.H.O limits
Calcium	109.02±0.23	108.22±0.23	108.62±0.23	106.21±0.46	105.81±0.46	109.82±0.46	75mg/L
Magnesium	31.10±0.14	31.35±0.14	30.86±0.14	30.86±0.28	30.86±0.28	31.35±0.28	20mg/L
Zinc	0.0041±0.0008	0.0440±0.0008	0.0480±0.0008	0.0510±0.0007	0.0550±0.0008	0.0066±0.0009	3.0mg/L
Copper	0.0200±0.0038	0.0300±0.0035	0.0300±0.0036	0.0400±0.0036	0.0400±0.0037	0.0500±0.0030	2.0mg/L
Chromium	0.0038±0.0001	0.0039±0.0001	0.0036±0.0003	0.0035±0.0004	0.0039±0.0003	0.0040±0.0003	0.05mg/L
Cadmium	0.0030±0.0002	0.0030±0.0002	0.0040±0.0001	0.0048±0.0002	0.0050±0.0002	0.0060±0.0003	0.003mg/L
Lead	0.0040±0.0005	0.0038±0.0005	0.0040±0.0005	0.0035±0.0006	0.0035±0.0005	0.0031±0.0007	0.01mg/L
Iron	3.31±0.269	3.54±0.194	3.64±0.196	3.76±0.215	4.79±0.883	5.06±1.178	3mg/L
Manganese	0.0056±0.0006	0.0055±0.0006	0.0060±0.0006	0.0065±0.0008	0.0066±0.0008	0.0069±0.0009	0.4mg/L
	July	August	September	October	November	December	
Calcium	110.22±0.46	112.22±0.46	111.42±0.46	112.22±0.46	109.42±0.23	108.62±0.23	75mg/L
Magnesium	31.35±0.28	30.86±0.28	31.83±0.28	31.35±0.28	30.86±0.14	31.10±0.14	20mg/L
Zinc	0.0620±0.0011	0.0590±0.0014	0.0600±0.0018	0.0560±0.0016	0.0550±0.0010	0.0480±0.0008	3.0mg/L
Copper	0.0600±0.0032	0.0500±0.0033	0.0400±0.0030	0.0400±0.0031	0.0300±0.0033	0.0300±0.0031	2.0mg/L
Chromium	0.0043±0.0002	0.0044±0.0001	0.0039±0.0003	0.0038±0.0004	0.0035±0.0003	0.0037±0.0004	0.05mg/L
Cadmium	0.0060±0.0002	0.0060±0.0002	0.0050±0.0003	0.0040±0.0002	0.0038±0.0002	0.0029±0.0003	0.003mg/L
Lead	0.0033±0.0005	0.0027±0.0006	0.0030±0.0005	0.0034±0.0005	0.0036±0.0005	0.0036±0.0004	0.01mg/L
Iron	4.99±1.218	5.01±1.173	4.80±0.990	4.66±0.763	3.78±0.218	3.49±0.171	3mg/L
Manganese	0.0065±0.0008	0.0063±0.0009	0.0066±0.0007	0.0063±0.0006	0.0060±0.0005	0.0057±0.0006	0.4mg/L

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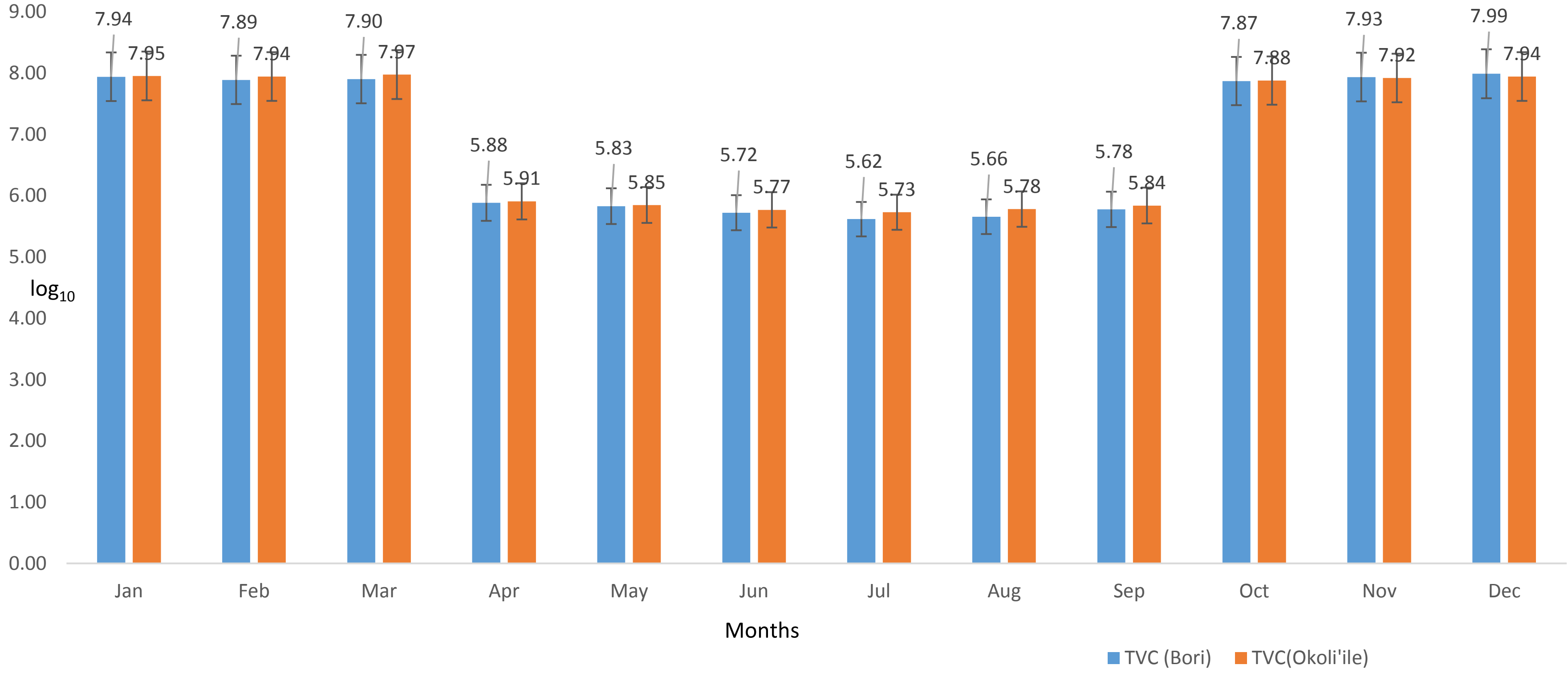

Figure 5. Monthly mean values ($\log_{10}$) of total heterotrophic count (cfu/ml) of brackish water from Okoli'ile, Rivers State

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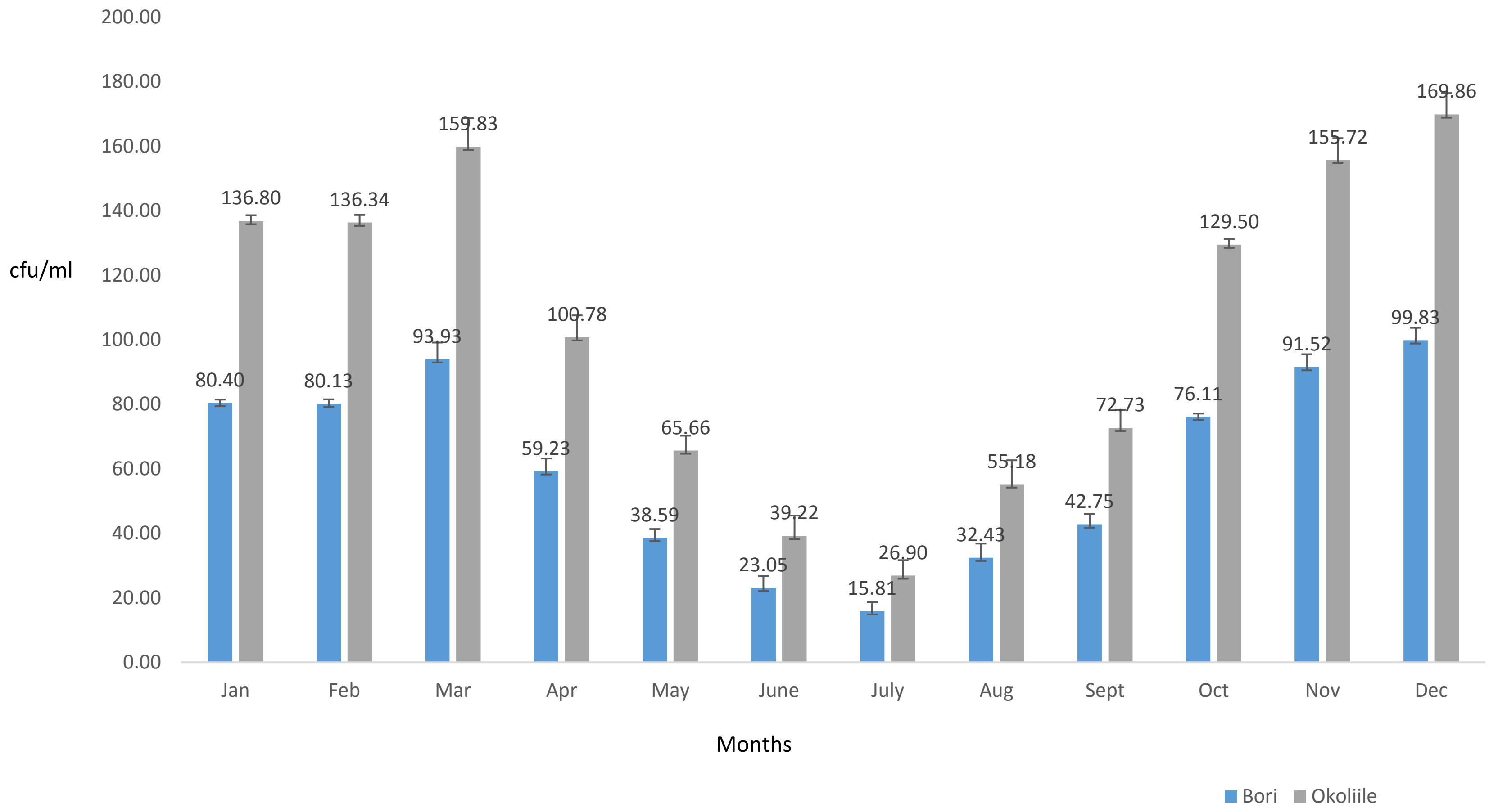

Figure 6. Monthly mean values of total coliform count (cfu/ml) of brackish water from Okoli'ile, Rivers State

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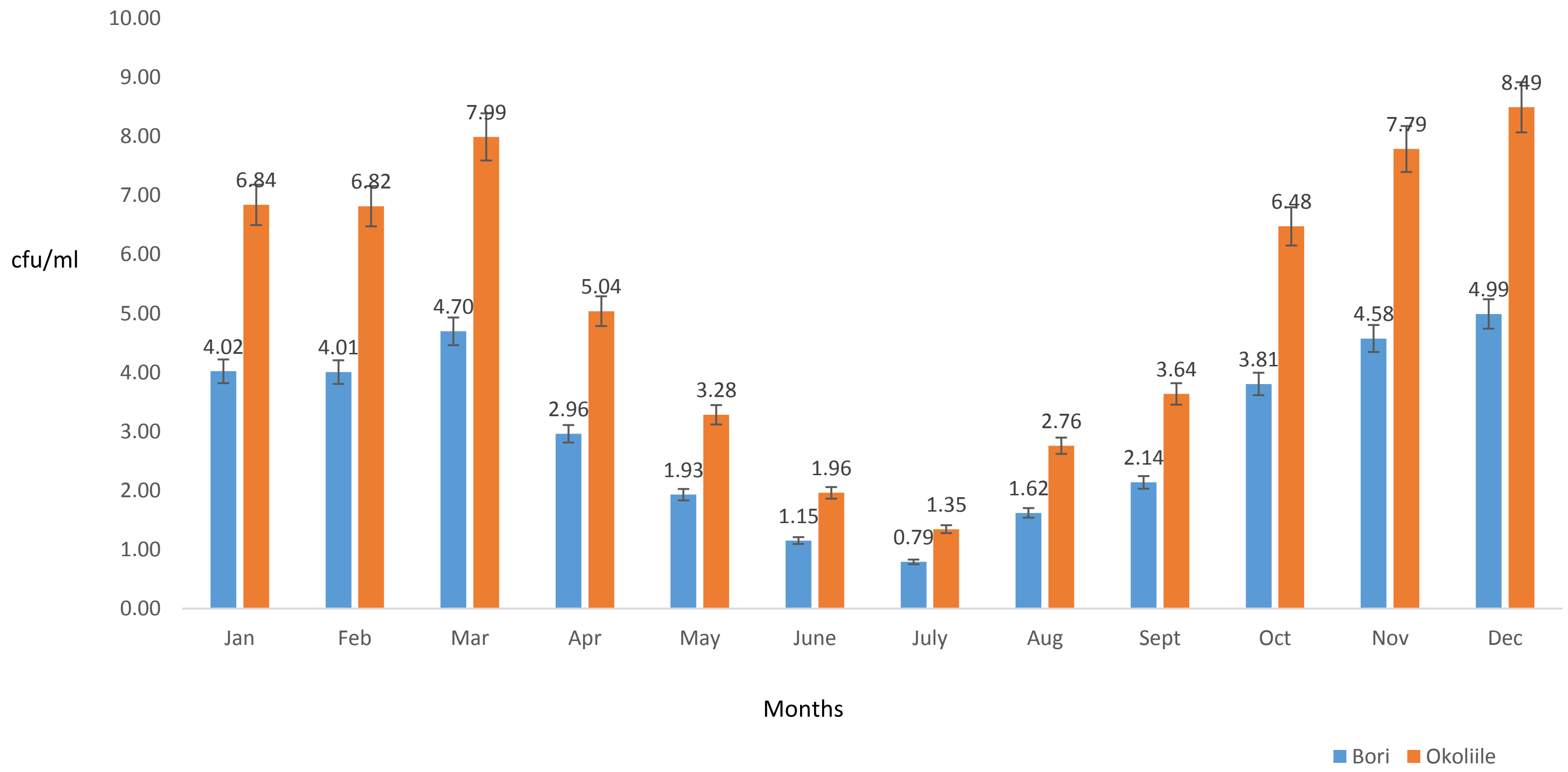

Figure 7. Monthly mean values of faecal coliform count (cfu/ml) of brackish water from Okoli'ile, Rivers State

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Table 5: Monthly mean values of *Enterococcus faecalis* (CFU/ml) count of brackish water from Bori and Okoli'ile, Rivers State.

	Bori	Okoli'ile
Jan	1.33 ± 0.58	1.90 ± 0.70
Feb	3.00 ± 1.00	3.60 ± 1.10
Mar	3.00 ± 1.00	3.60 ± 1.10
Apr	1.67 ± 0.58	2.20 ± 0.70
May	1.33 ± 0.58	1.90 ± 0.70
Jun	1.33 ± 0.58	1.60 ± 1.10
Jul	1.00 ± 0.58	1.20 ± 0.70
Aug	1.00 ± 0.58	1.20 ± 0.70
Sep	1.00 ± 0.58	1.60 ± 1.10
Oct	2.33 ± 0.58	2.90 ± 0.70
Nov	3.00 ± 1.00	3.60 ± 1.10
Dec	2.67 ± 0.58	3.20 ± 0.70

Table 6. Pearson's correlation coefficients of indicator microorganisms and physico-chemical parameters of surface water from Bori in Rivers State, Nigeria

		TVC	TCC	TFC	pH	Temp	Salinity
TVC	Pearson Correlation	1.000	.932**	.932**	.468	.470	-.198
	Sig. (2-tailed)		.000	.000	.125	.123	.538
	N	12	12	12	12	12	12
TCC	Pearson Correlation	.932**	1.000	1.000**	.483	.544	-.108
	Sig. (2-tailed)	.000		.000	.112	.067	.738
	N	12	12	12	12	12	12
TFC	Pearson Correlation	.932**	1.000**	1.000	.482	.544	-.108
	Sig. (2-tailed)	.000	.000		.112	.068	.738
	N	12	12	12	12	12	12
pH	Pearson Correlation	.468	.483	.482	1.000	.949**	.575
	Sig. (2-tailed)	.125	.112	.112		.000	.051
	N	12	12	12	12	12	12
Temp	Pearson Correlation	.470	.544	.544	.949**	1.000	.587*
	Sig. (2-tailed)	.123	.067	.068	.000		.045
	N	12	12	12	12	12	12
Salinity	Pearson Correlation	-.198	-.108	-.108	.575	.587*	1.000
	Sig. (2-tailed)	.538	.738	.738	.051	.045	
	N	12	12	12	12	12	12
**. Correlation is significant at the 0.01 level (2-tailed).							
*. Correlation is significant at the 0.05 level (2-tailed).							

TVC: Total heterotrophic count; TCC: Total coliform count; TFC: Total faecal count;

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Table 7. Pearson's correlation coefficients of indicator microorganisms and physico-chemical parameters of surface water from Okoli'ile in Rivers State, Nigeria.

		TVC	TCC	TFC	pH	Temp	Salinity
TVC	Pearson Correlation	1.000	.927**	.927**	.704*	.493	.608*
	Sig. (2-tailed)		.000	.000	.011	.103	.036
	N	12	12	12	12	12	12
TCC	Pearson Correlation	.927**	1.000	1.000**	.690*	.567	.670*
	Sig. (2-tailed)	.000		.000	.013	.054	.017
	N	12	12	12	12	12	12
TFC	Pearson Correlation	.927**	1.000**	1.000	.690*	.567	.669*
	Sig. (2-tailed)	.000	.000		.013	.055	.017
	N	12	12	12	12	12	12
pH	Pearson Correlation	.704*	.690*	.690*	1.000	.825**	.860**
	Sig. (2-tailed)	.011	.013	.013		.001	.000
	N	12	12	12	12	12	12
Temp	Pearson Correlation	.493	.567	.567	.825**	1.000	.951**
	Sig. (2-tailed)	.103	.054	.055	.001		.000
	N	12	12	12	12	12	12
Salinity	Pearson Correlation	.608*	.670*	.669*	.860**	.951**	1.000
	Sig. (2-tailed)	.036	.017	.017	.000	.000	
	N	12	12	12	12	12	12
**. Correlation is significant at the 0.01 level (2-tailed).							
*. Correlation is significant at the 0.05 level (2-tailed).							

TVC: Total heterotrophic count; TCC: Total coliform count; TFC: Total faecal count;

DISCUSSION

The result of the physicochemical analysis of surface waters in Bori and Okoli'ile showed similarities in the data obtained over the duration of 12 months. The pH values peaked at Bori (7.38) and Okoli'ile (7.29). It was observed that the values obtained from these two localities had figures for pH values within the acceptable level for environmental tolerance and drinking (6.5–8.5). The values of pH observed in this study showed a similar trend with reported studies in Calabar river (Akpan, 2000; Wetzel, 2001). It was observed that average pH values were considerably reduced in the month of April to October, a period where the rain is abundant and a period known as the rainy season or wet months in tropical sub-saharan Africa. The trend observed in the decline in the pH values in wet months is in agreement with the reports of Ajao and Fagade (2002) and Udoh *et al*. (2013). Similar occurrence of monthly distribution was observed in the values of temperature (^{0}C) where lower average values were also observed in wet months. Salinity is the measurement of salt concentration in mg/L. The result of salinity in this study showed higher values in Bori with statistically significant difference at $P<0.05$. In addition, the values of salt concentration were lower in the wet months. The likely reasons for these reductions of mean values for pH, temperature and salinity in the wet months could be attributed to higher discharge of fresh water during these months when rain is frequent (Abowei, 2010; Udoh *et al*., 2013).

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The result of physicochemical parameters of brackish water (table 1) and trace elements (table 2) from Bori showed similar trends of results with data from physicochemical parameters of brackish water (table 3) and trace elements (table 4) from Okoli'ile. With the exception of nitrates, all other physicochemical indices of water quality assessment exceeded the environmentally acceptable limits. Saliu and Ekpo (2006) asserted that the indiscriminate disposal of human and industrial wastes into creeks and lagoons is the major reason the quality of water and aesthetics is diminished. Their assertion was further confirmed in studies of Onyema, 2013. The high values of iron concentration exceeding limits—in some months in Bori and every month in Okoli'ile—could be due to the activities of oil-exploration companies in the area with attendant spills.

The microbiological examination of surface waters from both localities revealed lowered total heterotrophic counts in the wet months (April–September). There were significant differences ($P<0.05$) in the values of total viable counts in the dry months and in the wet months. This could be attributed to the fact that during these wet months, there was an increased influx of fresh water into the water body (Onyegeme-Okerenta *et al*., 2016). Similar occurrence was observed in total coliform (figure 6) and faecal coliform (figure 7) with statistically significant ($P<0.05$) higher mean values during the dry seasons when there were lesser rainfalls. In table 5, the monthly mean values of *E. faecalis* were higher in Okoli'ile with statistical difference ($P<0.05$) in the values recorded. The average monthly values of these indicator microorganisms, which had higher distribution in the dry months from the two localities with statistically significant differences, is in concordance with past reports (Aladese & Ariyo, 2017; Bello *et al*., 2013).

CONCLUSION

It was observed in this study that most of the households in these two settlements tend to channel most of their human excreta through polyvinyl chloride (PVC) pipes directly into the nearest creeks and rivers; a practice that is very prominent in many creek settlements of the Niger-Delta region. Akoachere *et al*. (2008) linked the inadequacy and absence of effective human waste disposal systems as the major reasons for high contamination of potentially pathogenic microorganisms into water bodies. Indiscriminate dumping of human and industrial wastes into these water bodies have a direct effect on the local population because these inhabitants have regular contacts with these surface water, mostly through drinking and recreational activities and these, in our opinion, could be a predisposing factor for epidemics associated with the region.

RECOMMENDATIONS

The local and regional governments in these areas are advised to make provision for effective waste treatment and disposal systems, so as to avoid uncontrolled disposal of wastes directly into the water body. In addition, industries operating in these areas should be monitored and encouraged to pre-treat their effluents before they are discharged into the aquatic environment.

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