Physicochemical and bacteriological assessment of surface waters from Southern-Ijaw, Bayelsa State, Nigeria

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Abstract

Physicochemical, trace elements and bacteriological assessments of surface waters from Southern-Ijaw, Bayelsa State, Nigeria were determined in this study. A total 240 water samples were collected from January to December, 2019. Water samples were subjected to physicochemical and heavy metals analyses for water quality assessment. Furthermore, bacteriological water quality was also investigated. Isolated strains were subjected to biochemical test to ascertain distribution of species. The results of the physicochemical parameters showed the average pH values were lower in the wet months where rainfalls are more frequent. Similar trend was observed in the monthly mean values of salinity and temperature. Many of the physicochemical parameters for water quality assessment exceeded the World Health Organisation (WHO) tolerance limits. The microbiological examination of water quality showed higher mean values in total bacteria and coliform counts in the months of the tropical dry season. *Escherichia coli* and *Salmonella* spp were most prevalent among isolated strains. The Pearson's correlation coefficient analysis showed high relationship between the mean values of physicochemical parameters like turbidity, nitrate, dissolved solids and pH with bacteriological indicators of assessment. Indiscriminate disposal of human excreta into rivers and creeks should be discouraged in order to prevent the possibility of an outbreak of epidemic.

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Introduction

The Niger-Delta region of Nigeria is largely made up of rivers, creeks and tributaries. Many of the inhabitants rely on these surface waters for drinking, fishing, agricultural purposes, manufacturing, transportation and recreational purposes. The indiscriminate discharge of human and industrial wastes into water bodies affect the water quality, human well-being, economic development and the ecosystem of the aquatic environment. Water quality is the measurement of the physicochemical, heavy metals and microbiological parameters of a water body.

Physicochemical parameters are pH, salinity, dissolved oxygen, biochemical oxygen demand, turbidity, conductivity, dissolved solids and total alkalinity. In addition, the assessment of ions nitrates, phosphates and sulphates are also part of the physicochemical indices of water quality assessment. Trace elements and heavy metals are also part of the parameters of assessing water quality. Pollution of an aquatic environment with trace elements and heavy metals are usually as an effect of industrial and municipal waste disposal (Diersong *et al*., 2009). Examples of these trace elements and metals are calcium, magnesium, zinc, lead, cadmium, chromium, vanadium, nickel and copper (Arokoya and Ukpere, 2014).

Microbiological examination of water quality entails investigation of the possibilities of the presence of potentially pathogenic microorganisms using the presence of group of microorganisms collectively referred to as indicator microorganisms (Cheesbrough, 2006; Jay *et* al., 2007). The microbiological assessment of water quality is an indication of the level of the discharge of human wastes into water bodies. In many rural settlements of the Niger-Delta there has been cases of disease outbreaks as a result of the local population being exposed to contaminated drinking water (Nkamare *et al*., 2012). These pockets of outbreaks are the resultant effects of the absence of basic amenities which includes an adequate sewage disposal system in many of these suburban settlements (Aladese and Ariyo, 2017).

This study was conducted in the creek villages of Southern-ijaw region of Bayelsa State, South-south of Nigeria. This region is notably characterised by inhabitants practicing open defaecation into surface waters due to unavailability of appropriate sewage disposal systems. The aim of this study is to ascertain the level of pollution on surface waters of Southern-ijaw in Bayelsa State. This will be achieved through physicochemical, trace elements and bacteriological assessment of qualities of these surface waters. The presence of potentially pathogenic microorganisms will be determined to ascertain the epidemic potentials of exposure to these water bodies.

Materials and Methods

Study area

Southern-Ijaw is geographically located on 4^0 48'N and 6^0 04'E in Bayelsa State, South-south of Nigeria. The region is predominantly coastline area (Appendix 1a and 1b) comprising mostly of creek settlements. Prominent localities in Southern-ijaw are Oporoma (political headquarter), Ogboinbiri, Peremabiri, Igbomotoru II and Amassama (sometimes refer to as Amassoma) the locality where the Niger Delta University is situated. The primary dialect of communication among the natives of Southern-Ijaw is the izon dialect and their primary occupation is mainly fishing activities.

Collection of Water Samples

A total of two hundred and forty (240) water samples were collected for the duration of 12 months spanning from January to December 2019. Samples were collected into sterile plastic containers. Samples were kept on ice and transported for further analysis within 24 hrs. An opaque specialised 300ml bottles were used to collect samples for the purpose of dissolve oxygen analysis. This was followed by the addition 1ml each of dissolve oxygen fixing compounds (Manganous sulphate and Sodium iodide-azide)

Physicochemical and Heavy Metals Analysis

The procedures described by American Public Health Association (APHA, 2005) were used to determine the physicochemical properties of water samples. Trace elements and heavy metals analyses were determined based on the methods described by Ademoroti (1997) using the atomic absorption spectrophotometer thermal elemental 969 series. The data of all analysed parameters were compared with World Health Organisation (WHO) standards for environmentally acceptable limits of tolerance.

Microbiological Examination of Samples

Microbiological analyses were performed by the standard protocol for sanitary analysis of water samples described by APHA, 2005. Enumeration of total bacterial load were carried out using serial dilution up to 10^{-6} pour plating method. The most probable number (MPN) was used for determination of all coliform counts. The presence specific indicator species like *Salmonella* spp, *Shigella* spp, *Escherichia coli* and *Enterococcus faecalis* were investigated using methods described by APHA (2005). The presence of *Vibrio* spp was investigated based on the methodologies described by Canada Communicable Disease Report (1998)

Data Representation and Statistical Analysis

Data obtained from this study were represented in the forms of means and standard deviations and all charts and graphical representations were done using Microsoft excel version 2016. The statistical comparisons of means were also determined using Microsoft excel version 2016. Pearson's correlation coefficients to ascertain relationship between some physicochemical parameters and indictor microorganisms were calculated using IBM SPSS (version 23.0).

Results

The monthly mean values of pH of surface waters in Southern-ijaw showed lower average values the months of April to September with the lowest average value of 7.54 in the month of June and the highest value for pH was observed in the month of December with 7.71 (Figure 1). The monthly average figures for salinity (mg/L) revealed lower mean values from the months of May to October with the lowest mean value recorded at 96.56mg/L in September. The values of concentration of salinity in this study were observed to be higher from November to March (Figure 2). In the same vein, the values of temperature (^{0}C) was highest in March (31^{0}C) and lowest in the month of June at 24.3^{0}C (figure 3).

The monthly distribution of mean values and their corresponding standard deviations showed majority of the physicochemical indices exceeding the WHO acceptable standards of tolerance (table 1). The monthly mean distribution for trace elements (table 2) showed average values were within the WHO environmental acceptable limits with the exception of calcium, magnesium and iron.

The monthly mean values ($\log_{10}$) of the total heterotrophic count (cfu/ml) of brackish water from Southern-ijaw revealed higher values from October to March while, lower bacterial loads were observed from June-August (Figure 4). Similarly, figure 5 shows the monthly average values of total coliforms of brackish water from Southern-ijaw with lower values recorded in the months of June-August. For faecal coliforms the mean values begin to rise from October to March with peak value of 22.43cfu/ml in the month of December (Figure 6).

The distribution of indicator microorganisms from the samples showed *Escherichia coli* and *Salmonella* spp with the highest prevalence (table 3). *Vibrio* spp and *Shigella* spp were also prominent. The statistical analysis using Pearson's correlation coefficients (table 4) showed high relationship in the distribution of total viable count (TVC) and total faecal count (TFC) with 0.973 and 0.946 at $P<0.01$ (table 4). Physicochemical parameters like dissolved solids showed high correlation ($P<0.01$) with TVC (0.850), TCC (0.885) and TFC (0.887). The values

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of pH also had high correlation with TVC (0.823), TCC (0.863) and TFC (0.877). Another physicochemical parameter with relatively high correlation was turbidity (NTU) with correlation coefficients of 0.885 (TVC), 0.901 (TCC) and 0.899 (TFC).

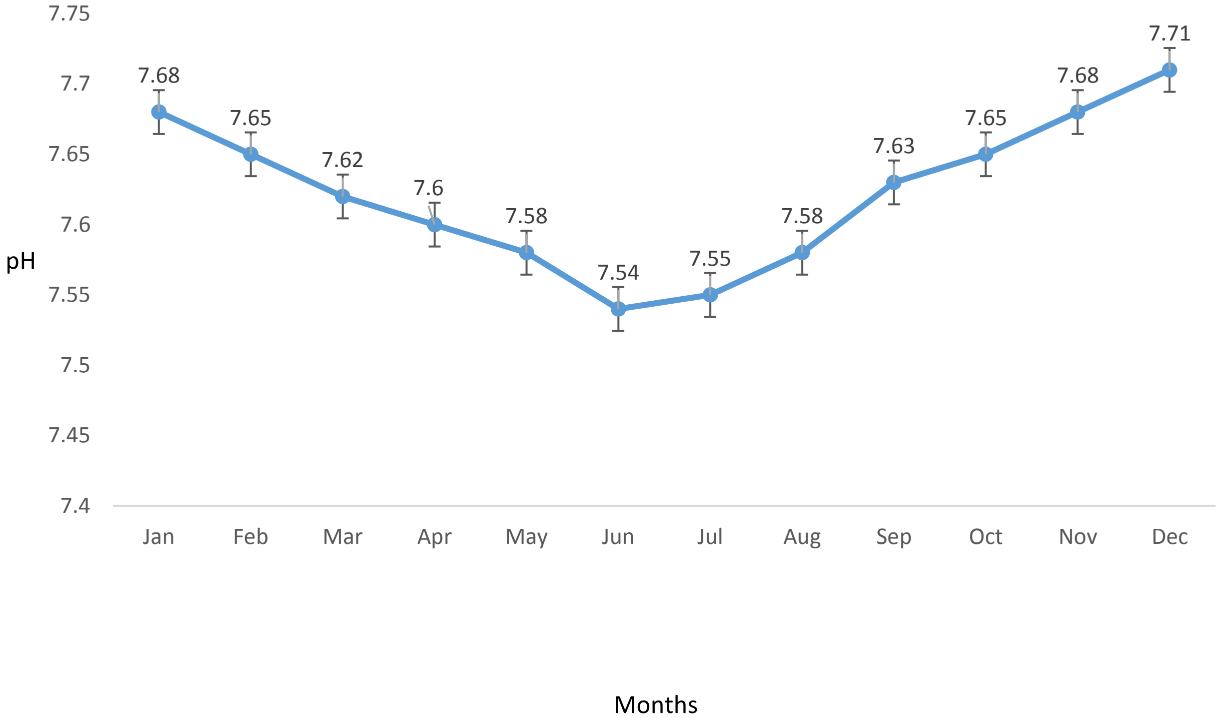

Figure1. Monthly mean values of pH of Brackish water samples in Southern Ijaw

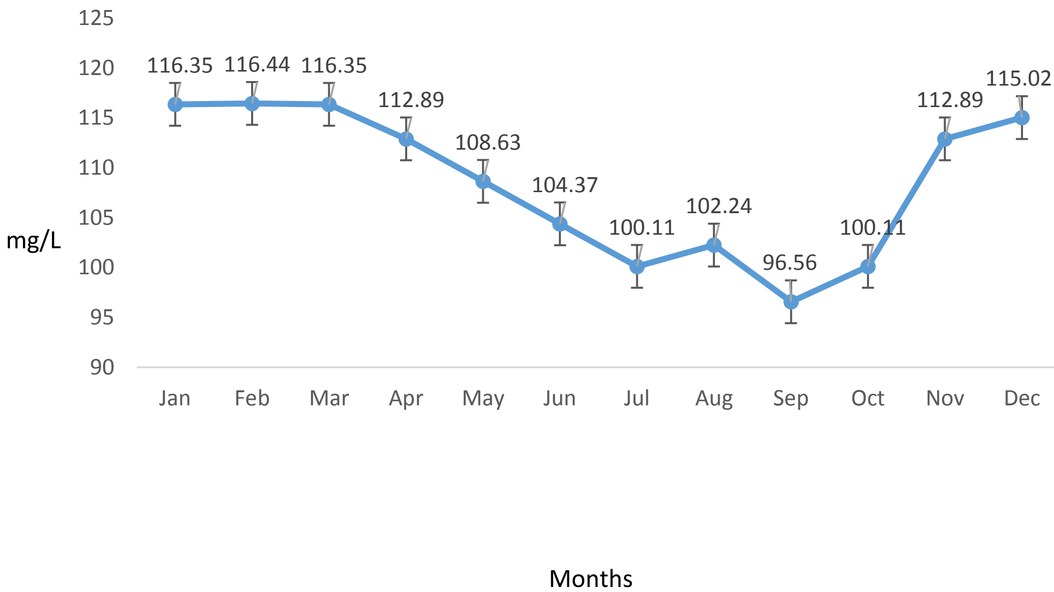

Figure 2. Monthly mean values of salinity of Brackish water samples in Southern Ijaw

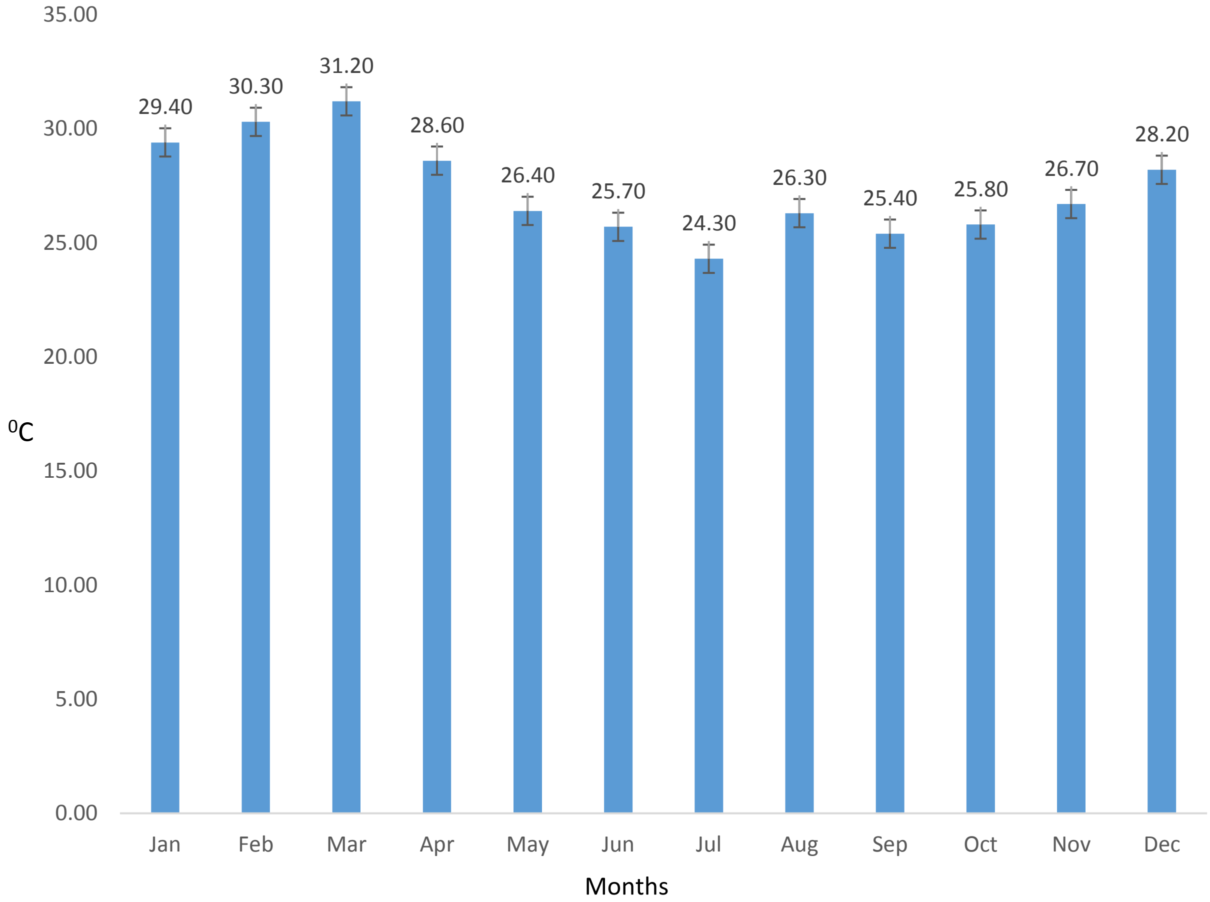

Figure 3. Monthly mean values of temperature of Brackish water samples in Southern-Ijaw

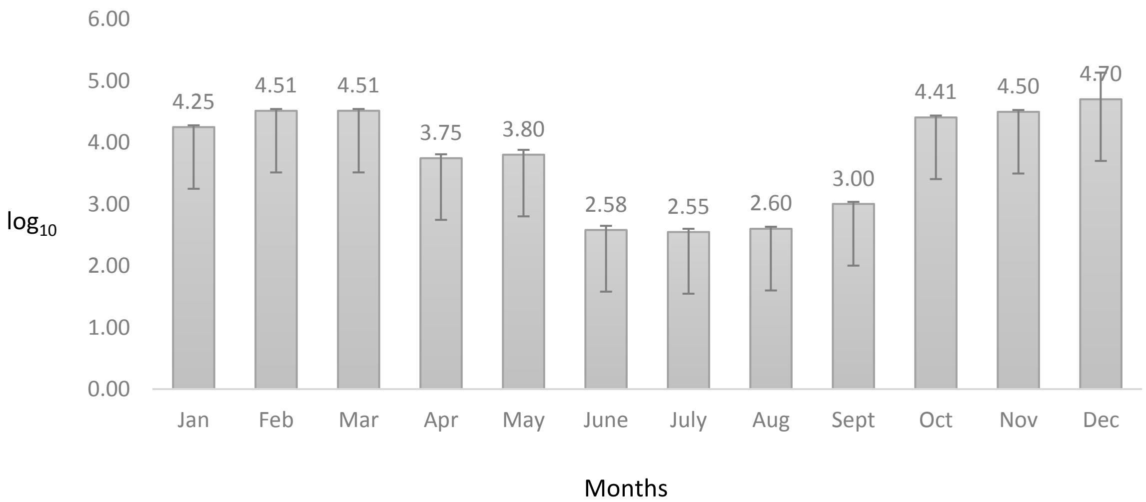

Figure 4. Monthly mean values (log_{10}) of total heterotrophic count (cfu/ml) of brackish water from Southern-Ijaw, Bayelsa.

Table 1. Monthly variation of the physico-chemical parameters of brackish water from Southern-Ijaw, Bayelsa State

Parameters	**January**	**February**	**March**	**April**	**May**	**June**	**W.H.O limits**
Conductivity µS/cm	2229.98±109.08	2151.72±112.78	2208.81±189.03	2680.34±91.11	3302.48±460.68	3862.51±248.69	1200 µs/cm
Dissolved solids	1616.69±79.15	1559.85±82.02	1601.37±137.09	1943.19±65.99	2394.23±334.11	2800.28±180.36	500mg/L
Alkalinity	164.70±6.100	166.73±7.044	180.97±137.044	170.72±6.215	185.03±3.522	168.77±7.044	100mg/L
Dissolved oxygen	4.62±0.126	4.65±0.304	4.38±0.161	4.95±0.132	5.52±0.126	5.95±0.150	Not specified
Turbidity	12.08±0.166	12.21±0.182	12.16±0.182	13.21±0.300	14.38±0.482	14.91±0.620	5.0 NTU
Sulphate	214.44±1.162	219.64±1.101	231.44±1.716	236.04±1.055	255.70±2.588	255.84±2.150	500mg/L
Total hardness	360.00±1.00	364.00±1.00	361.00±1.00	354.00±2.00	366.00±2.00	370.00±2.00	100mg/L
Calcium hardness	242.00±0.58	245.00±0.58	240.00±0.58	237.00±1.15	246.00±1.15	246.00±1.15	Not specified
Magnesium hardness	118.00±0.58	119.00±0.58	121.00±0.58	117.00±1.15	120.00±1.15	124.00±1.15	Not specified
Nitrate	3.49±0.197	3.63±0.202	3.53±0.327	3.26±0.226	3.32±0.136	3.96±0.523	5mg/L
	July	August	September	October	November	December	
Conductivity µS/cm	3675.47±170.52	3533.69±80.02	3586.74±38.77	3359.18±180.45	2607.77±194.68	2196.11±148.08	1200 µs/cm
Dissolved solids	2664.67±123	2561.90±58.05	2600.30±27.97	2435.35±130.89	1890.61±141.17	1591.95±107.73	500mg/L
Alkalinity	158.60±6.98	160.56±0.076	160.56±3.389	162.67±3.522	168.77±3.522	164.70±3.522	100mg/L
Dissolved oxygen	6.28±0.029	6.17±0.076	6.23±0.029	6.20±0.173	5.70±0.100	5.10±0.173	Not specified
Turbidity	16.14±0.845	15.41±0.788	14.81±0.958	14.09±0.214	13.14±0.499	12.36±0.376	5.0 NTU
Sulphate	268.37±2.150	257.70±2.568	262.90±3.541	244.97±1.007	230.37±1.188	214.04±1.055	500mg/L
Total hardness	376.00±2.00	374.00±2.00	372.00±2.00	370.00±2.00	364.00±1.00	360.00±1.00	100mg/L
Calcium hardness	247.00±1.15	246.00±1.15	245.00±1.15	245.00±1.15	243.00±0.58	240.00±0.58	Not specified
Magnesium hardness	129.00±1.15	128.00±1.15	127.00±1.15	125.00±1.15	121.00±0.58	120.00±0.58	Not specified
Nitrate	4.33±0.567	4.42±0.683	3.70±1.074	2.90±0.879	2.86±0.844	2.82±0.619	5mg/L

Table 2. Monthly variation of the trace element parameters of brackish water from Southern-Ijaw, Bayelsa State

Parameters	**January**	**February**	**March**	**April**	**May**	**June**	**W.H.O limits**
Calcium	96.99±0.23	98.20±0.23	96.19±0.23	94.99±0.46	98.70±0.46	98.70±0.46	75mg/L
Magnesium	28.67±0.14	28.92±0.14	29.40±0.14	28.43±0.28	29.16±0.28	30.13±0.28	20mg/L
Zinc	0.0343±0.0012	0.0370±0.0020	0.0360±0.0023	0.0380±0.0020	0.0410±0.0024	0.0460±0.0025	3.0mg/L
Copper	0.0330±0.0014	0.0440±0.0022	0.0430±0.0025	0.0400±0.0024	0.0460±0.0023	0.0500±0.0023	2.0mg/L
Chromium	0.0036±0.0003	0.0041±0.0002	0.0038±0.0003	0.0044±0.0003	0.0044±0.0004	0.0049±0.0005	0.05mg/L
Cadmium	0.0036±0.0004	0.0040±0.0005	0.0040±0.0004	0.0050±0.0004	0.0060±0.0005	0.0050±0.0004	0.003mg/L
Lead	0.0044±0.0004	0.0040±0.0004	0.0050±0.0003	0.0055±0.0005	0.0058±0.0004	0.0063±0.0005	0.01mg/L
Iron	4.63±0.110	4.83±0.105	4.94±110	5.33±0.115	6.24±0.115	6.66±0.100	3mg/L
Manganese	0.0050±0.0003	0.0054±0.0003	0.0057±0.0002	0.0074±0.0005	0.0080±0.0004	0.0080±0.0005	0.4mg/L
	July	August	September	October	November	December	
Calcium	99.00±0.46	98.70±0.46	98.20±0.46	98.20±0.46	97.39±0.23	96.19±0.23	75mg/L
Magnesium	31.35±0.28	31.10±0.28	30.86±0.28	30.36±0.28	29.40±0.14	29.16±0.14	20mg/L
Zinc	0.0460±0.0025	0.0500±0.0027	0.0520±0.0025	0.0450±0.0035	0.0440±0.0024	0.0350±0.0025	3.0mg/L
Copper	0.0600±0.0031	0.0550±0.0030	0.0500±0.0026	0.0430±0.0028	0.0400±0.0024	0.0460±0.0023	2.0mg/L
Chromium	0.0053±0.0005	0.0044±0.0006	0.0042±0.0004	0.0044±0.0005	0.0037±0.0004	0.0038±0.0003	0.05mg/L
Cadmium	0.0070±0.0002	0.0070±0.0002	0.0064±0.0004	0.0054±0.0004	0.0049±0.0005	0.0039±0.0004	0.003mg/L
Lead	0.0068±0.0004	0.0080±0.0001	0.0073±0.0002	0.0064±0.0003	0.0058±0.0003	0.0049±0.0004	0.01mg/L
Iron	6.80±0.085	6.64±0.121	6.36±0.153	5.99±0.076	5.39±0.608	5.01±0.608	3mg/L
Manganese	0.0075±0.0005	0.0069±0.0006	0.0080±0.0005	0.0067±0.0003	0.0060±0.0004	0.0054±0.0005	0.4mg/L

Table 3. Distribution indicator microorganisms from fresh waters from wells in Southern Ijaw, Bayelsa Nigeria

Indicator bacteria	**Number of test**	**Number positive**
Escherichia coli	240	240 (100)*
Enterococcus faecalis	240	32 (13.33)*
Salmonella spp	240	240 (100)*
Shigella spp	240	224 (93.33)*
Vibrio cholerae	240	224(93.33)*

*Numbers in parenthesis represent percentages

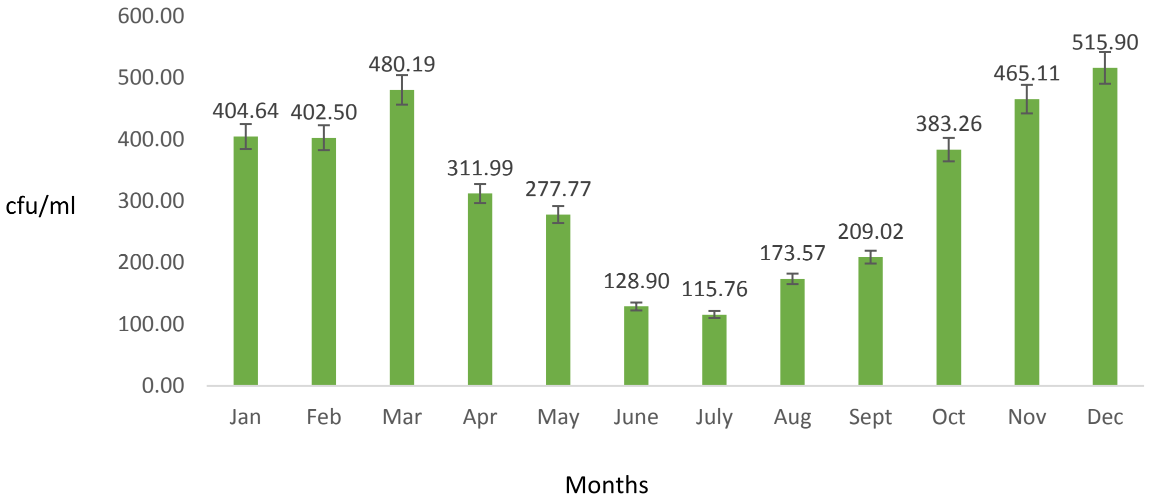

Figure 5. Monthly mean values of total coliform count (cfu/ml) of brackish water from Southern-Ijaw, Bayelsa State.

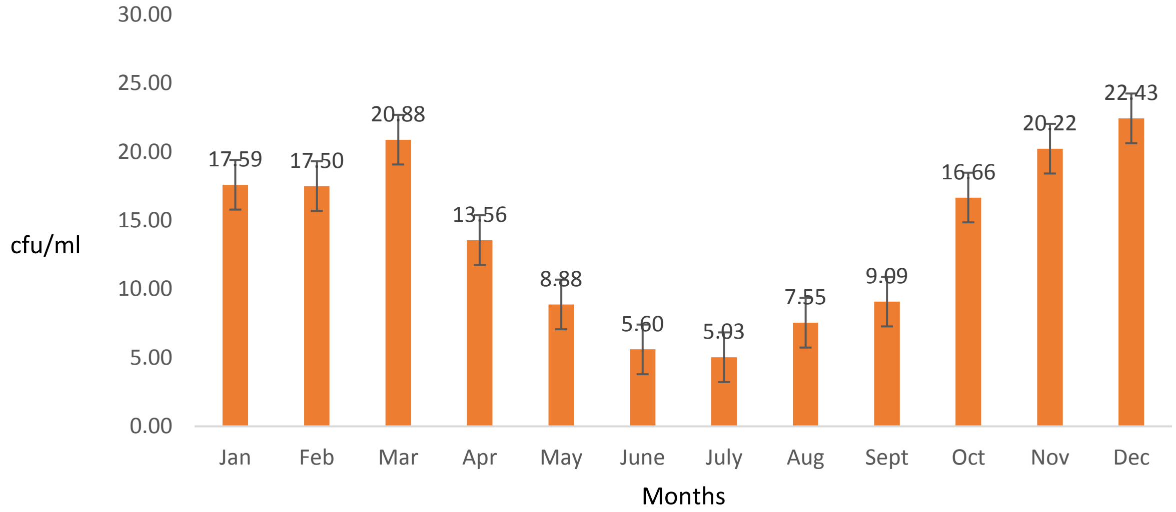

Figure 6. Monthly mean values of faecal coliform count (cfu/ml) of brackish water from Southern-Ijaw, Bayelsa State.

Table 4. Pearson's correlation coefficients of indicator microorganisms and physico-chemical parameters of surface water from Southern-Ijaw, Bayelsa State, Nigeria

		TVC	TCC	TFC	pH	Temp	Salinity	D.S	D.O	Turbidity	Sulphate	Nitrate	Iron
TVC	Pearson Correlation	1.000	.973**	.946**	.823**	.681*	.731**	-.850**	-.674*	-.885**	-.846**	-.832**	-.864**
	Sig. (2-tailed)		.000	.000	.001	.015	.007	.000	.016	.000	.001	.001	.000
	N	12	12	12	12	12	12	12	12	12	12	12	12
TCC	Pearson Correlation	.973**	1.000	.989**	.863**	.708*	.755**	-.885**	-.684*	-.901**	-.874**	-.796**	-.881**
	Sig. (2-tailed)	.000		.000	.000	.010	.005	.000	.014	.000	.000	.002	.000
	N	12	12	12	12	12	12	12	12	12	12	12	12
TFC	Pearson Correlation	.946**	.989**	1.000	.877**	.710**	.735**	-.887**	-.669*	-.899**	-.887**	-.758**	-.888**
	Sig. (2-tailed)	.000	.000		.000	.010	.006	.000	.017	.000	.000	.004	.000
	N	12	12	12	12	12	12	12	12	12	12	12	12
pH	Pearson Correlation	.823**	.863**	.877**	1.000	.458	.513	-.742**	-.429	-.753**	-.807**	-.735**	-.765**
	Sig. (2-tailed)	.001	.000	.000		.134	.088	.006	.164	.005	.002	.006	.004
	N	12	12	12	12	12	12	12	12	12	12	12	12
Temp	Pearson Correlation	.681*	.708*	.710**	.458	1.000	.873**	-.891**	-.964**	-.895**	-.803**	-.281	-.887**
	Sig. (2-tailed)	.015	.010	.010	.134		.000	.000	.000	.000	.002	.377	.000
	N	12	12	12	12	12	12	12	12	12	12	12	12
Salinity	Pearson Correlation	.731**	.755**	.735**	.513	.873**	1.000	-.919**	-.928**	-.893**	-.881**	-.439	-.891**
	Sig. (2-tailed)	.007	.005	.006	.088	.000		.000	.000	.000	.000	.153	.000
	N	12	12	12	12	12	12	12	12	12	12	12	12
	N	12	12	12	12	12	12	12	12	12	12	12	12
D.S	Pearson Correlation	-.850**	-.885**	-.887**	-.742**	-.891**	-.919**	1	.897**	.955**	.941**	.528	.978**
	Sig. (2-tailed)	.000	.000	.000	.006	.000	.000		.000	.000	.000	.078	.000
	N	12	12	12	12	12	12	12	12	12	12	12	12
D.O	Pearson Correlation	-.674*	-.684*	-.669*	-.429	-.964**	-.928**	.897**	1	.895**	.812**	.322	.896**
	Sig. (2-tailed)	.016	.014	.017	.164	.000	.000	.000		.000	.001	.307	.000
	N	12	12	12	12	12	12	12	12	12	12	12	12
Turbidity	Pearson Correlation	-.885**	-.901**	-.899**	-.753**	-.895**	-.893**	.955**	.895**	1	.952**	.628*	.983**
	Sig. (2-tailed)	.000	.000	.000	.005	.000	.000	.000	.000		.000	.029	.000
	N	12	12	12	12	12	12	12	12	12	12	12	12
Sulphate	Pearson Correlation	-.846**	-.874**	-.887**	-.807**	-.803**	-.881**	.941**	.812**	.952**	1	.601*	.957**
	Sig. (2-tailed)	.001	.000	.000	.002	.002	.000	.000	.001	.000		.039	.000
	N	12	12	12	12	12	12	12	12	12	12	12	12
Nitrate	Pearson Correlation	-.832**	-.796**	-.758**	-.735**	-.281	-.439	.528	.322	.628*	.601*	1	.578*
	Sig. (2-tailed)	.001	.002	.004	.006	.377	.153	.078	.307	.029	.039		.049
	N	12	12	12	12	12	12	12	12	12	12	12	12
Iron	Pearson Correlation	-.864**	-.881**	-.888**	-.765**	-.887**	-.891**	.978**	.896**	.983**	.957**	.578*	1
	Sig. (2-tailed)	.000	.000	.000	.004	.000	.000	.000	.000	.000	.000	.049	
	N	12	12	12	12	12	12	12	12	12	12	12	12

Discussion

The physicochemical analysis of brackish water from Southern-ijaw showed peak average values of pH in the months of November-December and January-March, these are months with relatively lower rainfalls a period of the year referred to as dry season or dry months in tropical sub-Saharan Africa. The lowest mean value of pH (figure 2) was observed in the month of June (7.54). Similarly, lower average values were observed in the months of June-October in the concentration of salinity (figure 3) while, January to March and November-December (dry months) had higher recorded mean values for salinity. The reasons attributable to this trend of events could be due to influx or discharge of fresh water mostly through rainfalls into these creeks and rivers. This assertion is in concordance with past reports (Abowei, 2010; Udoh *et al*., 2013).
The temperature is another key factor in the persistence and survival of microorganisms in the aquatic ecosystem. The dry months also had higher average values with peak figure in the month of March (31.2^{0}C). The values obtained in the mean values is in agreement with similar study by Olubanjo and Adeleke (2020).
With the exception of nitrates all the other indices of water quality examined in these brackish waters (table 1) exceeded the acceptable limits of tolerance. It is noteworthy to mention that the values of electrical conductivity (µS/cm), dissolved solids and turbidity (NTU) all exceeded the environmental limits for tolerance. The mean values for each month for trace elements (table 2) showed metals like zinc, manganese and lead having values within the acceptable limits. However, the monthly mean values obtained for iron exceeded the specified limits of acceptability. This high value of iron expected and could be attributed to the activities of oil exploration by the multinational companies operating in Southern-ijaw and the environs. Aladese and Ariyo (2017) reported similar high values of iron concentration from their studies in Ebukuma, a riverine community in Andoni-land of Rivers State, Nigeria.
The bacteriological assessment of brackish water in Southern-ijaw showed higher mean values in the dry months with higher statistically significant difference (P<0.05). The peak value was recorded for total heterotrophic count in the month of December (figure 5). Similar trend of events was observed in total coliform counts (figure 6) and faecal coliform counts (figure 7) with lower average counts in the wet months (April- September). The distribution of indicator microorganisms from surface showed all samples were contaminated with *E.coli* and *Salmonella* spp. This was followed by *Vibrio* spp and *Shigella* spp with 93.33% contamination of test samples (table 3). The presence of *E.coli* and *Salmonella* spp in all the water samples indicates the level of biological contamination through indiscriminate disposal of human excreta into water body.
The practice of uncontrolled dumping of wastes into creeks and lagoons has effect on the aesthetics and ecological balance of the aquatic environment. Lawson (2011) and Onyema (2013) both reported that there exists a high correlation of indiscriminate disposal of wastes into lagoons and increased population of benthic population and microbial load. The continual influx of industrial and domestic wastes into rivers and estuaries considerably increases the presence of some ions which tend to increase the biochemical oxygen demand and having effect on the entire ecological framework of the aquatic environment. This assertion and the results obtained in this study is in agreement with documented reports (Edokayi, 2004, Amangabara and Egenma, 2012; Aladese and Enabulele, 2014; Olorode *et al*., 2015).
One major challenge noteworthy of mention is the conspicuous absence of an effective sewage disposal system in many communities within Southern-ijaw. Human excreta from households are channelled directly through polyvinyl chloride (PVC) pipes into the nearest rivers. Aladese & Ariyo (2017) reported similar practice in Ebukuma, a creek settlement in the heart of Andoni-land of Rivers where influx of excreta into nearby rivers and the fact that this the below sea level of many of these settlements in the region affects the quality of their drinking water. The physicochemical, trace elements and bacteriological assessments of the water quality in that earlier study agrees with the assertion of other documented studies in the past (Amangabara *et al*., 2012; Angaye and Yougha, 2015; Onyegeme-Okerenta *et al*., 2016).

Conclusion

The local and regional government must discourage and enforce the prevention of incessant disposal of domestic and industrial wastes into these aquatic environment as this could be an epidemiological pre-disposing factor for disease outbreaks. Furthermore, provision of potable drinking water, effective waste disposal system and public enlightenment on the importance of personal and community hygiene should be encouraged.

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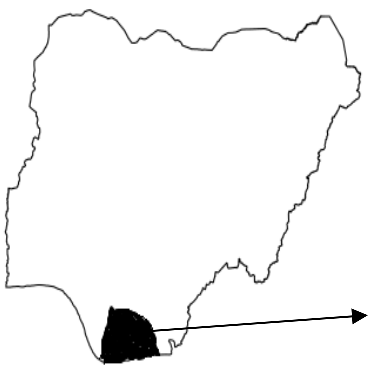
Appendix 1a. Map of Nigeria showing the location of Southern-Ijaw



Appendix 1b. Map of Southern-Ijaw showing major settlement (Source: Google map Inc.)