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Physico-Chemical Properties and Bacteria Qualities of hand-dug wells in Ebukuma, Rivers State Nigeria

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Abstract: Physico-chemical and bacteria qualities assessments of groundwater in Ebukuma village Andoni-land, Rivers State, South-south Nigeria were investigated. A total of 84 fresh water samples from hand dug wells were collected between January-December, 2016. Physico-chemical and bacteria qualities of all samples were determined according to the standard methods for the examination of drinking water. The mean values of pH ranged from 6.80-7.32, temperature was $24.43^{0}C$ to $30.45^{0}C$ and salinity was 25.21mg/L to 34.79mg/L. The average values of physico-chemical parameters were generally higher in the months of January-March and lowest in the month of June and July. Total heterotrophic count for the duration 12 months of assessment ranged from 2.49-3.73. Generally, the values of total viable count, total coliform and faecal coliform were lower during the months of April-October while, November-March showed increased bacterial load. All the physico-chemical parameters and trace elements investigated were within the World Health Organisation (WHO) acceptable limits of tolerance, with the exceptions of turbidity (NTU) and iron (mg/L). The Pearson's correlation coefficient of indicator microorganisms showed high relationship in the distribution of total viable counts (TVC) and faecal coliform with 0.939 (P<0.01). Physico-chemical parameters like pH, temperature and salinity also showed high correlation with distribution of indicator microorganisms. The distribution of potentially pathogenic microorganisms in the 84 test samples showed 100% contamination of *Escherichia coli*. Installation of effective sustainable water treatment facilities will considerably improve availability of potable water and reduce the predisposition to pathogenic microorganisms.

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INTRODUCTION

Groundwater remains the largest source of fresh potable water in the world. It is estimated that groundwater provides potable water to around 1.5 billion people worldwide on a daily basis (Howard, 1997; Department of International Development (DFID), 2001) and undoubtedly the most convenient and reliable resource for meeting rural water demand in the tropical climes especially sub-Saharan Africa (MacDonald and Davies, 2002; Harvey, 2004).The concentration of developmental projects to urban centres in many sub-Saharan Africa has led to the inability of most governments of sub-Saharan African countries to provide infrastructure and meet basic needs of rural settlements. For the availability of potable water most people in rural areas resort to groundwater sources such as boreholes and wells as an alternative water resource.

The quality of groundwater varies from place to place, the factors associated with these variations could be the types of soils, surfaces through which it moves (Seth *et al*., 2014; Thivya*et al*., 2014) and seasonal changes (Trivede*et al*., 2010; Vaishali and Punita, 2013)**.** Naturally occurring contaminants are present in the sediments and rocks. As groundwater flows through the sediments, metals such as iron and manganese are dissolved and may later be found in high concentrations in the water (Moyo, 2013) while, heavy metals like lead, chromium and nickel could be predominant in oil polluted regions of South-south, Nigeria. Human activities can also alter the quality of groundwater through the disposal or dissemination of chemicals on the land surface which leaches into soils or direct disposal into groundwater. Furthermore, industrial discharges of improperly treated effluents, agriculture (Saliu and Ekpo 2008; Govindarajan and Senthilnathan, 2014) and indiscriminate disposal of waste and excreta can affect groundwater quality (Bello *et al.*, 2013; Aladese and Enabulele, 2014). Pesticides and fertilizers applied to lawns and crops can accumulate and migrate to the water tables thus affecting both the physical, chemical and microbial quality of water.

The South-south region of Nigeria is known for its abundance petroleum resources with the presence of major oil exploration companies within the major cities and some rural settlements. The activities of these oil exploration multinational outfits and the pipeline vandalism of some of the inhabitants for the purpose oil-theft has continually led to spillage of petroleum into the environment especially water bodies. These spillages affect the groundwater of these communities and due fact that there exists poor water treatment system in these rural settlements the inhabitants resulted into digging wells to access drinkable water.

Ebukuma is one the major villages situated in Andoni-land of Rivers State, South-south Nigeria. Most of the inhabitants of Ebukuma are fishermen and traders. Due to its semi-urban nature of the village their human waste disposal is mainly by hand-dug pits and direct disposal in the nearby surface water. This among others has been attributed to cause of possible epidemics in the regions. Ebukuma was epicentre of the localities affected with cholera epidemics of January-March 2015. It is therefore against this background that the physicochemical and bacterial water qualities of hand-dug wells in Ebukuma were assessed to ascertain whether the source of drinking water in this settlement was within the World Health Organisation acceptable standards for human consumption.

MATERIAL AND METHODS

Study area description: Ebukuma (4.31^{O}N; 7.28^{O}E**)** is one of the creek settlements that make up the Andoni-land of Rivers State, South south Nigeria (Figure 1a). Andoni-land is made up of four islands with several rural settlements. Ebukuma (figure 1b) is one the villages located on Island III which has other settlements like Okoloile, Agbalama, AmaUbulom, AmaNgereNkpon, Otako, Okorobo-Ile, and several other smaller villages.Island III stands at the centre of Andoni-land as it is the link between Island I and II. The inhabitants of Ebukuma speaks the Obolo dialects which is the combination of Efik, Ibibio, Oron, and Ijaw dialects based on the original Ijaw intonation and Efik-Ibibio lexicon. The primary occupation of the inhabitants of Ebukuma is fishing and farming.

Figure 1a: Map of Nigeria

Figure 1b: Map of Andoni-land showing Ebukuma village

(Source Google maps)

Water sample collection: A total of 84 fresh water samples were collected between January-December 2016 from seven hand-dug wells in Ebukuma town. Samples were collected into closed sterilized 500 ml glass containers. They were collected by attaching a piece of string to the sampling bottle together with a clean heavy material that sink down the bottle into the well and unwinding the string slowly. They were placed on ice and transferred to the laboratory for immediate analysis.

Physico chemical analysis: All physico-chemical parameters of water samples in this study were determined according to methods described by American Public Health Association (APHA) (1992) and Ademoroti (1997). The parameters were all measured in mg/L except otherwise state. All the physico-chemical results obtained were compared with World Health Organisation (W.H.O) standards for acceptable limits. All the calculations of physico-chemical parameters from titres values were based according to methods described by Ademoroti (1997).

Trace element analysis: The concentration (mg/L or ppm) of the following trace elements were determined in all the water samples for the duration of 12 months. They were: zinc, copper, chromium, cadmium, lead, iron and manganese. Trace elements were determined using the atomic absorption spectrophotometer (Thermal elemental 969 series; flame used: acetylene gas).

Microbiological examination of water: Bacteriological analyses were performed as described in Standard Methods for the Examination of drinking water (APHA, 2005). Total heterotrophic count bacteria were determined by serial dilution up to 10^{-2}, which was followed by 1ml inoculation on Mueller-Hinton agar using pour plate method. Total and faecal coliforms were determined by the most probable number (MPN) per 100 ml sample using multiple tube fermentation. For samples with confirmatory results for coliforms test, further identification was done using an IMVIC test as described by APHA (2005). The presence of *Salmonella* sppand *Shigella*sppin water samples was investigated using pre-enrichment and enrichment techniques (APHA, 1992). Double enrichment in alkaline peptone water was used for isolation of *Vibrio cholerae* (CCDR, 1998). Isolated colonies were subjected to Gram's reactions, oxidase test, triple sugar iron agar, lactose fermentation and motility test.

Statistical analysis and data representation: All statistical calculations involving mean values, standard deviations, bar charts and pictorial representations were determined using the Microsoft excel version 2013 and SPSS (version 23.0). Pearson's correlation coefficients of environmental indices and microbial distribution were determined using SPSS (version 23.0).

RESULTS

The mean of pH of fresh water from wells in Ebukuma in Rivers State, South-south Nigeria ranged from 6.80-7.32 (figure 2). The average values of temperature for the duration 12 months sampling ranged 24.43^{0}C to 30.45^{0}C (figure 3). The mean values of temperature were higher in the months January-March while, lowest values were observed in July (24.43^{0}C) and June (24.58^{0}C). Similarly, the average values salinity was higher in the months of January-March and lowest mean values in the month of June and July. The values of salinity from different fresh water sources in Ebukuma ranged between 25.21mg/L to 34.79mg/L (figure 4). The monthly values of the physico-chemical parameters of fresh water from different wells in Ebukuma is shown in table 1. All the physico-chemical parameters investigated all fell within the World Health Organisation (WHO) acceptable limits of tolerance. With the exception of iron (mg/L) all other trace elements recorded values within environmental limits of tolerance (table 2).

The $\log_{10}$ of colony forming units of total heterotrophic count ranged from 2.49-3.73 (figure 5). Generally, the values of total viable count were lower during the months of April-October while, November-March showed increased total bacterial load. Similar trend occurred in the distribution of total coliform with November-March having higher mean values and April-October recorded lower values for total coliform count (figure 6). The monthly variation of faecal coliform (figure 7) showed the lowest recorded value in June (1.18) and highest was in December (7.45).

The distribution of potentially pathogenic indicator microorganisms in the 84 test samples showed 100% contamination of *Escherichia coli* while *Salmonella* spp 63(75.0%) and *Shigella*spp 52(61.9%) were also observed with other from test water samples (table 3).

The Pearson's correlation coefficient of indicator microorganisms and physico-chemical parameters (table 3a; table 3b) showed high relationship in the distribution of total viable counts (TVC) and faecal coliform was 0.939 with statistical significance of $P<0.01$. The correlation coefficient of total heterotrophic count and *Enterococcus faecalis* was 0.835 with statistical significance ($P<0.01$) in their distribution relationship. The mean values of pH also showed statistical significance ($P<0.01$) in the correlation with faecal coliform (0.732). In the same vein the average values of temperature (^{0}C) also played an important elemental factor in the distribution of total bacterial count (Pearson's correlation coefficient: 0.580), total coliform (Pearson's correlation coefficient: 0.696) and *E. faecalis* (Pearson's correlation coefficient: 0.588) with statistical significance in correlation of $P<0.05$ (table 4a). The correlation of indicator microorganisms and heavy metals was investigated (table 4b). There was negative correlation in the values of cadmium and total bacterial load with correlation coefficient of -0.688 with statistical significance ($P<0.05$) while cadmium also had correlation of -0.811 with statistical significance of $P<0.01$ (table 4b).

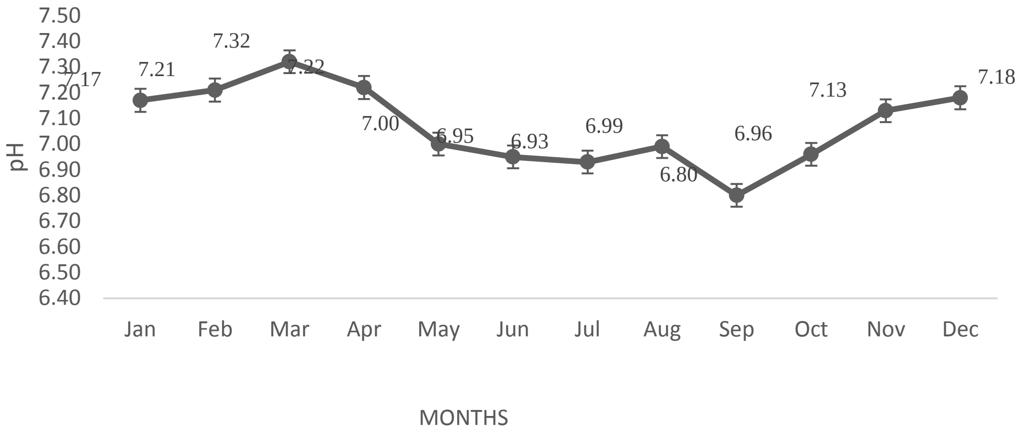

Figure 2. Monthly mean values of pH of fresh water samples in Ebukuma

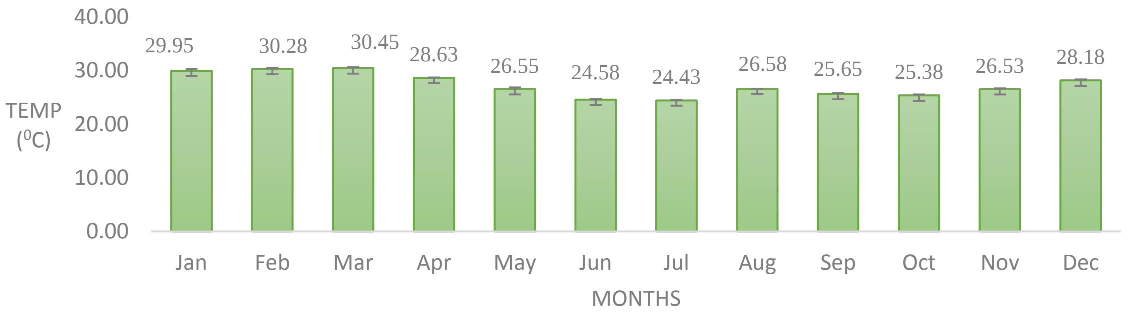

Figure 3. Monthly mean values of temperature of fresh water samples in Ebukuma

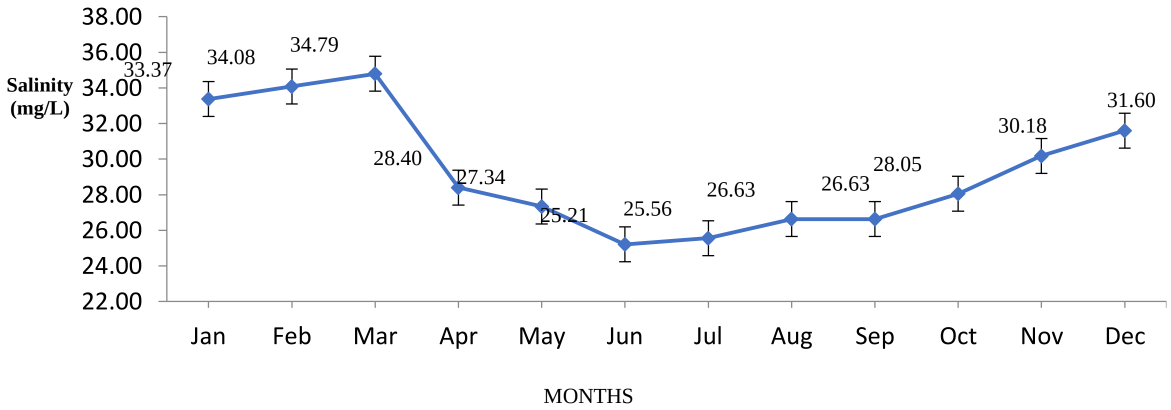

Figure 4. Monthly mean values of salinity of fresh water samples in Ebukuma

Table 1. Monthly variation of the physico-chemical parameters of fresh water from different wells in Ebukuma, Rivers State

Parameters	January	February	March	April	May	June	W.H.O limits
Conductivity µS/cm	8.26±0.036	8.33±0.030	8.35±0.046	8.64±0.046	8.46±0.060	8.39±0.060	1200 µs/cm
Dissolved solids	6.00 ±0.019	6.07 ±0.042	6.12 ±0.086	6.32 ±0.068	6.31 ±0.261	6.21 ±0.175	500mg/L
Alkalinity	69.13 ± 9.318	75.23 ±7.044	77.27 ±9.318	74.93 ±3.808	63.03 ±3.522	56.93 ±3.522	100mg/L
Dissolved oxygen	4.28±0.101	4.22 ±0.093	4.38 ±0.093	4.59 ±0.093	5.27 ± 0.093	6.62 ±0.176	Not specified
Turbidity	10.14 ±0.119	9.30 ±0.168	8.36 ±0.170	7.30 ±0.177	12.17 ±0.119	13.65 ±0.119	5.0 NTU
Sulphate	18.28 ±0.175	19.41 ±0.160	20.14 ±0.114	17.91 ±0.083	14.61 ±0.092	13.87 ±0.085	500mg/L
Total hardness	26.00 ±1.00	25.00 ±1.00	24.00 ±1.00	28.00 ±2.00	29.00 ±2.00	30.00 ±2.00	100mg/L
Calcium hardness	16.00 ±0.58	14.00 ±0.58	14.00 ±0.58	13.00 ±0.58	17.00 ±1.15	18.00 ±1.15	Not specified
Magnesium hardness	10.00 ±0.58	11.00 ±0.58	10.00 ±0.58	15.00 ±0.58	12.00 ±1.15	12.00 ±1.15	Not specified
Nitrate	1.80 ±0.065	1.87 ± 0.020	1.76 ±0.020	1.52 ±0.010	1.37 ±0.030	1.42 ±0.030	5mg/L
	July	August	September	October	November	December	
Conductivity µS/cm	8.39±0.045	8.32 ±0.095	8.29 ±0.050	8.31 ±0.035	8.31 ± 0.050	8.24 ±0.020	1200 µs/cm
Dissolved solids	6.23 ±0.239	6.05 ±0.044	6.05 ±0.106	6.07 ±0.102	6.11 ±0.109	6.06 ± 0.138	500mg/L
Alkalinity	52.87 ± 3.522	50.83 ±3.522	52.87 ±3.522	58.97 ±3.522	65.07 ±3.522	71.17 ±7.044	100mg/L
Dissolved oxygen	7.37 ±0.176	6.84 ±0.093	7.29 ±0.093	6.79 ±0.093	5.68 ±0.093	4.59 ±0.093	Not specified
Turbidity	10.61 ±0.115	15.98 ±0.116	18.58 ±0.119	16.24 ±0.117	10.92 ±0.119	13.13±0.119	5.0 NTU
Sulphate	12.20 ±0.082	13.30 ±0.083	12.16 ±0.080	13.10 ±0.081	14.95 ±0.099	15.89 ±0.082	500mg/L
Total hardness	31.00 ±2.00	31.00 ±2.00	32.00 ±2.00	31.00 ±2.00	29.00 ±1.00	27.00 ±1.00	100mg/L
Calcium hardness	20.00 ±1.15	20.00 ±1.15	22.00 ±1.15	21.00 ±0.58	19.00 ±0.58	16.00 ±0.58	Not specified
Magnesium hardness	11.00 ±1.15	11.00 ±1.15	10.00 ±1.15	10.00 ±0.58	10.00 ±0.58	11.00 ±0.58	Not specified
Nitrate	1.51 ±0.022	1.40 ±0.025	1.55 ±0.025	1.41 ±0.010	1.14 ±0.020	1.31 ±0.030	5mg/L

Table 2. Monthly variation of the trace elements of fresh water from different wells in Ebukuma, Rivers State

Parameters	January	February	March	April	May	June	W.H.O limits
Calcium	6.41±0.23	5.61 ± 0.23	5.61 ±0.23	5.21 ±0.46	6.81 ±0.46	7.21 ±0.46	75mg/L
Magnesium	2.43 ±0.14	2.67 ±0.14	2.43 ±0.14	3.65 ±0.28	2.92 ±0.28	2.92 ±0.28	20mg/L
Copper	0.0020 ±0.0003	0.0020 ±0.0004	0.0020 ±0.0005	0.0010 ±0.0003	0.0010 ±0.0002	0.0010 ±0.0003	2.0mg/L
Chromium	0.0020 ±0.0002	0.0010 ±0.0002	0.0030 ±0.0003	0.0020 ±0.0003	0.0010 ±0.0002	0.0010 ±0.0001	0.05mg/L
Cadmium	0.0007± 0.0001	0.0008 ±0.0002	0.0010 ±0.0002	0.0010 ±0.0001	0.0010 ±0.0002	0.0020 ±0.0003	0.003mg/L
Lead	0.0010 ±0.0002	0.0018 ±0.0003	0.0030 ±0.0004	0.0035 ±0.0003	0.0028 ±0.0003	0.0020 ±0.0002	0.01mg/L
Iron	3.14±0.119	3.54±0.115	2.73 ±0.215	3.70 ±0.116	5.00 ±0.119	5.67 ±0.115	3mg/L
Manganese	0.0050 ±0.0004	0.0065 ±0.0005	0.0080 ±0.0010	0.0060 ±0.0008	0.0050 ±0.0005	0.0050 ±0.0007	0.4mg/L
	July	August	September	October	November	December	
Calcium	8.02 ±0.46	8.02 ±0.46	8.82 ±0.46	8.42 ±0.23	7.62 ±0.23	6.41 ±0.23	75mg/L
Magnesium	2.67 ±0.28	2.67 ±0.28	2.43 ±0.28	2.43 ±0.14	2.43 ±0.14	2.67 ±0.14	20mg/L
Copper	0.0010 ±0.0002	0.0020 ±0.0005	0.0020 ±0.0005	0.0020 ±0.0005	0.0020 ±0.0003	0.0020 ±0.0004	2.0mg/L
Chromium	0.0010 ±0.0001	0.0010 ±0.0001	0.0010 ±0.0002	0.0020 ±0.0002	0.0020 ±0.0001	0.0030 ±0.0002	0.05mg/L
Cadmium	0.0030 ±0.0003	0.0030 ±0.0003	0.0010 ±0.0001	0.0020 ±0.0003	0.0016±0.0002	0.0007 ±0.0002	0.003mg/L
Lead	0.0020 ±0.0002	0.0018 ±0.0001	0.0017 ±0.0002	0.0020 ±0.0002	0.0022 ±0.0002	0.0015±0.0001	0.01mg/L
Iron	6.67 ±0.142	7.56 ±0.118	7.68 ±0.118	7.58 ±0.118	6.26 ±0.276	4.22 ±0.149	3mg/L
Manganese	0.0050 ±0.0004	0.0065 ±0.0005	0.0060 ±0.0005	0.0060 ±0.0004	0.0055 ±0.0004	0.0060 ±0.0004	0.4mg/L

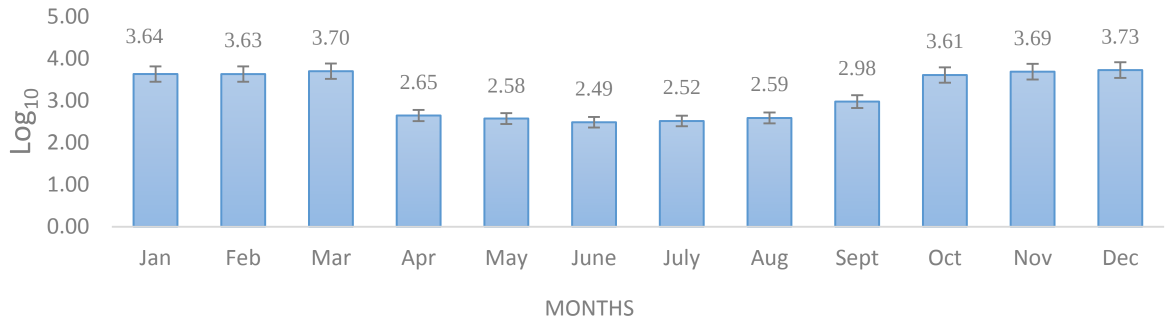

Figure 5. The monthly distribution of total heterotrophic count from fresh waters from Ebukuma

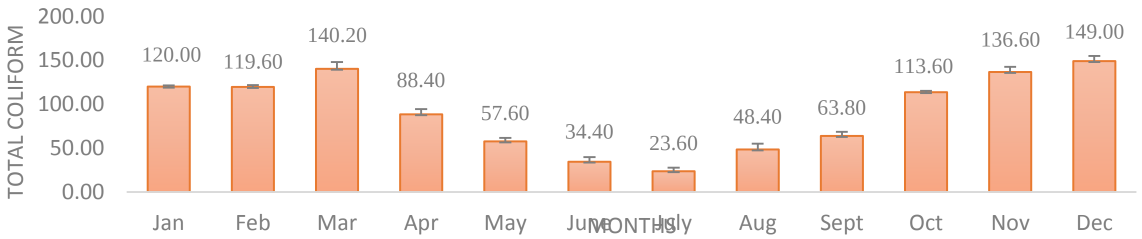

Figure 6. The monthly distribution of total coliform count from fresh waters from Ebukuma

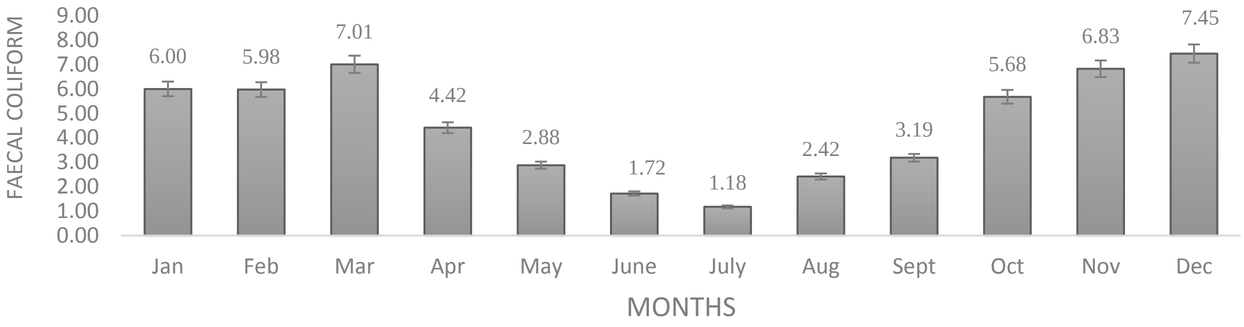

Figure 7. The monthly distribution of faecal coliform count from fresh waters from Ebukuma

Table 3. Distribution indicator microorganisms from fresh waters from wells in Ebukuma, Rivers State, Nigeria.

Indicator Microorganisms	Number of test samples	Number positive
Escherichia coli	84	84(100.0)
Salmonella spp	84	63(75.0)
*Shigella*spp	84	52(61.9)
Enterococcus faecalis	84	10(11.9)
Vibrio cholerae	84	9(10.7)

*Numbers in parenthesis represent percentages

Table 4a: Pearson's correlation coefficients of indicator microorganisms and physico-chemical parameters of fresh water in Ebukuma, Rivers State, Nigeria

	TVC	Total coliform	Faecal coliform	E.faecalis	pH	Conductivity µS/cm	Dissolved solids	Alkalinity	Chloride	Dissolved oxygen	Turbidity	Sulphate	Total hardness	Calcium hardness	Magnesium hardness
TVC		.939**	.939**	.835**					.829**				-.594*		-.581*
Total coliform	.939**		1.000**	.889**	.732**			.777**	.854**	-.682*		.651*	-.688*		
Faecal	.939**	1.000**		.889**	.732**			.777**	.854**	-.682*		.651*	-.688*		
E.faecalis	.835**	.889**	.889**		.696*			.697*	.758**	-.609*		.612*	-.656*		
pH		.732**	.732**	.696*				.876**	.842**	-.909**	-.809**	.931**	-.919**	-.883**	
Conductivity µS/cm							.580*								.803**
Dissolved solids						.580*									
Alkalinity		.777**	.777**	.697*	.876**				.732**	-.871**	-.727**	.814**	-.751**	-.798**	
Chloride	.829**	.854**	.854**	.758**	.842**			.732**		-.838**		.878**	-.921**	-.664*	
Dissolved oxygen		-.682*	-.682*	-.609*	-.909**			-.871**	-.838**		.762**	-.928**	.935**	.917**	
Turbidity					-.809**			-.727**		.762**		-.775**	.742**	.843**	
Sulphate		.651*	.651*	.612*	.931**			.814**	.878**	-.928**	-.775**		-.965**	-.915**	
Total hardness	-.594*	-.688*	-.688*	-.656*	-.919**			-.751**	-.921**	.935**	.742**	-.965**		.874**	
Calcium hardness					-.883**			-.798**	-.664*	.917**	.843**	-.915**	.874**		
Magnesium hardness	-.581*					.803**									

Nitrate									.615*			.679*	-.647*		
Temperature	.580*	.696*	.696*	.588*	.897**			.784**	.917**	-.896**	-.656*	.956**	-.928**	-.829**	
Calcium					-.883**			-.797**	-.663*	.917**	.843**	-.915**	.874**	1.000**	
Magnesium	-.582*					.805**									1.000**
Zinc															
Copper	.790**	.673*	.673*			-.663*	-.872**		.586*						-.725**
Chromium	.684*	.811**	.811**	.651*	.688*			.664*	.627*						
Cadmium	-.688*	-.768**	-.768**	-.662*				-.734**	-.726**	.756**		-.625*	.651*		
Lead						.598*	.610*								
Iron					-.874**			-.767**	-.777**	.947**	.817**	-.932**	.943**	.944**	
Manganese															

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Table 4b: Pearson's correlation coefficients of indicator microorganisms, some physico-chemical parameters and trace elements of fresh water in Ebukuma, Rivers State, Nigeria

	Nitrate	Temp	Calcium	Magnesium	Zinc	Copper	Chromium	Cadmium	Lead	Iron	Manganese
TVC		.580*		-.582*		.790**	.684*	-.688*			
Total coliform		.696*				.673*	.811**	-.768**			
Faecal		.696*				.673*	.811**	-.768**			
E.faecalis		.588*					.651*	-.662*			
pH		.897**	-.883**				.688*			-.874**	
Conductivity µS/cm				.805**		-.663*			.598*		
Dissolved solids						-.872**			.610*		
Alkalinity		.784**	-.797**				.664*	-.734**		-.767**	
Chloride	.615*	.917**	-.663*			.586*	.627*	-.726**		-.777**	
Dissolved oxygen		-.896**	.917**					.756**		.947**	
Turbidity		-.656*	.843**							.817**	
Sulphate	.679*	.956**	-.915**					-.625*		-.932**	
Total hardness	-.647*	-.928**	.874**					.651*		.943**	

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Calcium hardness		-.829**	1.000**							.944**	
Magnesium hardness				1.000**		-.725**					
Nitrate		.684*								-.623*	
Temperature	.684*		-.828**					-.642*		-.855**	
Calcium		-.828**								.945**	
Magnesium						-.726**					
Zinc											
Copper				-.726**							.581*
Chromium											
Cadmium		-.642*								.624*	
Lead											
Iron	-.623*	-.855**	.945**					.624*			
Manganese						.581*					

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed

DISCUSSION

The physico-chemical parameters of the fresh water analysis in Ebukuma showed many of the parameters were within the World Health Organisation (W.H.O) acceptable limits, as shown tables 1 for physico-chemical properties and table 2 for trace elements. However, turbidity (NTU) and iron (mg/L) exceeded the tolerable limits. Similar study on some of the sections of the Lagos lagoon reported high values for these physico-chemical parameters (Saliu and Ekpo, 2006). It was opined that the high values observed from these environmental indices obtained could be as a result of uncontrolled waste disposal into the Lagos lagoon. In addition, the continual influx of industrial and domestic wastes into the lagoon considerably increase the presence of some ions which tends to lower the dissolved oxygen; thus, having some degree of adverse effect on the normal ecological framework of the water-bodies (Olayemi, 1994; Lawson, 2011). Onyema (2013) reported that the indiscriminate act of waste disposal into water bodies has been linked with the resultant effect of high microbial load and benthic organisms present in the aquatic ecosystem. This assertion was also in collaboration with earlier documented study (Aladese and Enabulele, 2014). All the findings of the physico-chemical analysis of fresh water in this study is in agreement with earlier reports (Edokayi*et al*., 2004; Nwankwo*et al*., 2008; Amangabara*et al*., 2012; Nwankwoala*et al*., 2013; Olorode *et al*., 2015).

The presence of faecal coliform and *E. coli* in all the water samples indicates the level of disposal of human wastes in the environment around these hand-dug wells in this locality. The isolation of *Vibrio cholerae* from well waters in this study signifies the potential health hazard of the absence of potable water in the community. These could be attributed to inadequate or lack of water treatment facilities in many of these rural settlements. The cross-contaminations of well water from sewages could be a major risk factor of contaminations (Ayeni, 2014). The report of Igbinosa*et al*., 2009 on the occurrence of *Vibrio* pathogens in the final effluents of rural wastewater treatment facilities demonstrated that *Vibrio* pathogens could easily survive treatment processes of the Eastern Cape province of South Africa either as free living micro-organism or when associated with planktons. Furthermore, Igbinosa and Okoh (2008) and Igbinosa*et al*. (2009) both studies affirmed that chlorine disinfection at the normal recommendations might be inadequate for *Vibrio*spp removal, thus posing public health importance to the rural communities. Unlike, these studies in South Africa where some form of treatment is carried out on wastewater in rural communities, the locality in this study has no form of water treatment facilities.

Although, few settlements like Khana, Gokana and Bori all in neighbouring Ogoni-land had boreholes with water treatment plants installed by the oil exploration and drilling companies' resident in those areas, whilemany villages in Andoni-land which includes Okoli'ile, Ikuru and Ebukuma do not have water treatment facilities. These communities lacking safe drinking water were the most affected by the January-March 2015 cholera outbreaks, these settlements lack many basic essential facilities and most of these communities resulted in drinking from wells and nearby rivers.

Another major challenge affecting the water quality of Ebukuma is that the inhabitants do not have any form of sewage disposal system; it was observed that all faecal materials are either deposited in near bushes or channeled in polyvinyl chloride (PVC) pipes directly from their homes into the nearest water-bodies or rivers. Ironically, these rivers and creeks are also used for other activities like fishing, agricultural and recreational purposes. This may constitute one of the major risk factors of cholera outbreaks in these localities. The inadequate or absence of an effective sewage treatment and has been linked to the higher distribution of pathogenic *Vibrio* species and other potentially pathogenic microbes in the past (Akoachere*et al.*,2008). Furthermore, the lack of safe drinking water through non-installation of water purification facilities in these coastal rural communities has made inhabitants of these areas to resort to consumption well waters. Due to the nature of the depth which is below the sea-level in Ebukuma and coupled with oil-spillage challenges, the resultant products obtained from thesehand dug wellsas source of drinking water at most times are usually chemically and microbiological unsafe for consumption (Amangabara*et al*., 2012; Angaye and Yougha, 2015). Some of these hand-dug wells in Ebukuma were usually constructed relatively close to these polluted rivers and possibility of soil leaching is highly probable.

Conclusively, proper installation of effective sustainable water treatment facilities by local and regional government will considerably improve availability of safe and potable water to many of these creek settlements along the South-south region of Nigeria. In addition, Non-governmental organisation and relevant governmental agencies should intensify their efforts geared towardspublic awareness on the dangers of indiscriminate disposal of human wastes in waterbodies.

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