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Assessment of Physicochemical and Microbiological Qualities of Potable Water Sources in Okorenkoko, Delta State Nigeria

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Abstract

Accessibility of Potable water in rural and riverine communities have reduced drastically in recent times. A total of six borehole water samples and a freshwater sample were obtained from Okerenkoko community in Delta State, Nigeria. The water samples were analyzed for physicochemical and microbiological parameters using standard procedures. Pearson correlational analysis was employed to evaluate the level of association of the data using Statistical Package for Social Sciences version 23. Our results showed that pH concentration values ranged from 5.62 to 7.81, electrical conductivity had 10.03 to 490.01 µS/cm, dissolved oxygen varied from 3.90 to 7.91 mg/L, COD had 10.01 to 50.03 mg/L. The fecal coliform count ranged from 4- 2400 MPN/ml, while the surface water had a fecal coliform count 2400 MPN/ml; fungal count 3.1 Log_{10}CFU/ml and 3.6 Log_{10}CFU/ml respectively, Total aerobic count had a maximal concentration value of 5.8 Log10CFU/ml and 5.4 Log_{10}CFU/ml; Total *Salmonella Shigella* Count it had a concentration of 4.0 Log_{10}CFU/ml. Microbes associated with the water samples were *Bacillus* sp., *Escherichia* sp., *Staphylococcus* sp., *Streptococcus* sp., *Shigella* sp., *Proteus* sp., *Pseudomonas* sp., *Klebsiella* sp., *Vibrio sp.* and *Micrococcus* sp. There is an urgent need to source-track the trajectory of pollutants from both from domestic and industrial activities. There is need that the government at all levels should improve the available potable water resources in Okerenkoko community.

Keywords: *Potable, Riverine, Fecal, Pollutant, Pearson, Industrial, Domestic, Physicochemical, Microbiological.*

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I. INTRODUCTION

Water is considered an elixir macromolecule employed in life and living activities. It accounts for the cellular function and contributes up to 70% of Body Mass Index. It is also considered a universal solvent and an indispensable natural resource (Ovonramwen *et al*. 2020). Potable water is one considered to be a wholesome and fit for consumption (Sojobi, 2016). This water may be used for agricultural, domestic, industrial and environmental purposes because they are not contaminated with exogenous, biological or chemical agents. The sources of this category of water can be categorized into ground and surface water. The ground water has been identified by Owamah (2019) as being the safest and most abundant source of potable water globally and also posited a number of empirical figures to delimit and buttress the existing qualities for water. Furthermore, WHO (2000) sufficiently asserted that proximity to wholesome water must be free from toxins and pathogens. In the Niger Delta Region of Nigeria, water from streams and lakes are also used for a number of domestic and industrial purposes in rural communities (Abdulsalam and Sule 2022). A few of these rural communities receive adequate access to potable water supply from both governmental and non-governmental manned -projects. Traditional, religious and other industrial activities have also impacted greatly on the quality of the surface water in low-income areas. Recent reports have identified the high cost of transporting packaged water from urban to riverine areas to have really contributed to the inability to access potable water. Rural populace in the Niger Delta is continually be-wildered by the inadequate sources of potable water which has been worsened by a number of challenges such as crude oil blowouts, artisanal pollution, floods and other natural disaster. Population explosion, industrialization and exploration activities in these areas have both directly and indirectly impacted on the quality of water. The physicochemical proxies of potable water in the rural communities have posed a wide array of challenges; many of these have been attributed to a number of factors especially from Anthropogenic. They may also serve as critical indicators of the quality of water. The failure of Government and Non-governmental organizations to provide quality drinking water for rural dwellers have also affected their lives and livelihood. There has been a surge in the incidence of water related diseases in both classes of the socio-economic ladder. According to

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Abdulsalam and Sule (2020) improving the available resources must correlate significantly to the improvement in sanitary activities within rural communities. This is the surest approach to limiting the the prevalence of these diseases associated with water. The proximity of the rural and riverine communities to oil installations and federal government establishments. Activities like the incessant artisanal refineries and cottage sales of crude oil products have been linked to a number of pollutions of available freshwater sources The objective of this study is to assess and correlate the physicochemical and microbiological indices of potable water sources in Okerenkoko community, Gbaramatu Kingdom in Delta State, Nigeria.

Okerenkoko community in Gbaramatu kingdom is located in Warri South-West Local Government Area, of Delta State, Nigeria. It is one of the popular settlements is the Okerenkoko community. Okerenkoko community seats close to the Escravos facility, operated by NNPC/Chevron Joint Venture. It may be interesting to quickly observe here that Okerenkoko community in Gbaramatu kingdom by its unique location opens into the Atlantic Ocean, through the Escravos River is a major path for vessels engaged by both Local and International oil companies which has been the mainstay of the Nigerian economy.

II. Materials And Methods

The water samples were obtained from the actively used points in the Okerenkoko community. The water samples were collected using aseptical and standard conditions and labelled accordingly. The water samples were used to rinse the containers, while specific amber bottles were used in the collection of water samples meant for BOD, COD, Heavy metals and microbiological analysis. A total of seven (7) samples were obtained for the study. The water samples meant for chemical analysis were preserved in an ice-cold chest. The chain of custody were used to label the flask containing the samples.

A. Physicochemical Analysis

1. Determination of ph, conductivity and total dissolved solids: The pH and conductivity variables were measured using a digital Oakton pH meter (model PCD 650) and HANNA Conductivity/TDS meter (HI 9835) respectively. The pH and Conductivity/TDS meters were standardized with buffer solutions (pH4.0 and pH7.0) and conductivity standard solution respectively. The device was used to make contact with the water samples, rinsed and re-calibrated after use (Agbabiaka and Sule, 2010).
2. Determination of nitrate (APHA 4500-NO3-B): About Ten milliliter (10ml) of the sample and the already prepared Nitrate solution were mixed and left for a five minutes. A second sample lot was filled with the blank sample used to retun the reading of the equipment to zero. The water sample digested was placed carefully placed in the cuvettes and result was measured in mg/l nitrate nitrogen (NO_3^--N). The equipment, DR 5000^{TM} UV spectrophotometer was used.
3. Determination of phosphate: The water sample and the phosphate reagent-powder pillow were mixed in their right proportions. The standard/Analyte sample (the blank) used in zeroing the equipment. The water sample was then placed in cuvettes and loaded, then the phosphate (PO_4^{3-}) results were reported in mg/l. The equipment DR 5000^{TM} UV spectrophotometer was used.
4. Determination of calcium: The level of calcium in the water samples was measured on the basis of ASTM (D511) method at a precision detection concentration of not less than 0.05mg/l. The calibration was developed using known analytes. The calcium content was evaluated and the values converted to mg/L from concentration of calcium was ascertained from the data generated by the AAS and expressed in mg/l.
5. Determination of potassium: The samples were evaluated for the level of potassium using an analytical grade Atomic Absorption Spectrophotometry (ASTM D4192) method. The precision of the detection was 0.05mg/l. The AAS was calibrated and adjusted for the analysis before the sample was injected. The eluant concentration value of the eluant was presented in mg/L.
6. Determination of magnesium: The level of Magnesium (Mg) in the water sample was also evaluated using the Atomic Absorption Spectrophotometry (ASTM D511) method. With a similar detection and accuracy as mentioned at 0.05mg/l. prior to the analysis, calibration was done with standard of known concentrations. Dissolved Magnesium (Mg) was determined by aspirating a portion of the filtered sample (without pre-treatment) directly in AAS. Concentration of Magnesium was ascertained from the data generated by the AAS.
7. Determination of Total Organic Carbon (TOC): Total organic carbon content was determined using the rapid oxidation method, about fifty milliliter of the potable water was heated to dryness in a conical flask and allowed to cool. Then 5ml of potassium dichromate ($K_2Cr_2O_7$) and 7.5 ml conc. H_2SO_4 were heated for 10 minutes. The colour of the potassium dichromate changed to dark brown after heating, then it was made up to 100mL including the blank. About 20mL was measured out from the 100mL of the both sample and 2 drops of ferrroin solution was added to each flask which was then titrated to each flask with ammonium sulphate (NH_4SO_4) until a red coloration formation. The titre values of both the blank and the sample was recorded
8. Determination of Salinity (APHA 2520B): The salinity of the sample was evaluated using the refractometric approach (HRN-2N ATAGO Japan). This was done by taking two drops of the sample and water and the readings were documented.
9. Determination of Biochemical Oxygen Demand (APHA 5210D): The method of APHA (2012) was adopted.

About 50ml of the of the samples of the water was measured into a 200ml BOD bottle using the standard techniques as decribed by APHA (2012). The test was carried out under the condition of elimination of residual oxygen by filling the bottle to the brim and using the cork of the bottle to cork; this was after the sample was used to rinse the bottles used the analysis to prevent extraneous water from altering the value of the BOD. DO1 was measured within the 15mins duration at room temperature and a blank dilution water and the water samples were in their respective BOD bottles were incubated for 5 days. After 5 days, DO_5 measured by adopting similar procedures. The BOD_5 was mathematically determined as follows:

$BOD5 = \frac{D.O_0 - D.O_5}{P}$ where $D.O_0$ = initial dissolved oxygen; DO_5 = Dissolved oxygen on the 5^{th} day.

10. Determination of Chemical Oxygen Demand (COD): One hundred milliliter (100ml) of the sample was added into 500ml conical flask and 10ml Potassium permanganate and 10ml sulphuric acid was added was reacted with the water sample. The solution of the water samples and reagents were incubated for 4 hours. The mixture was evaluated for COD at intervals and an additional 10ml of potassium permanganate was added to stable its indicator precipitation which was countered by the permanganate tried to disappear. A blank was constituted using the reagent solution while water samples were treated to the similar condition employed for the measurement of BOD, the final result was presented in mg/L just that the difference was the introduction of KI-solution final sample prior to measurement.

B. Microbiological analyses

1. Determination of Total Heterotrophic Bacteria Count (THBC): Total heterotrophic bacterial counts for the different water samples were determined using the spread plate method on nutrient agar (Oxoid, Basingtoke, United Kingdom) was used. The water samples were made to go through a 10-fold serial dilution by using 1ml of well mixed water and 9ml diluent. Then 0.1ml aliquots of diluent samples was plated on plate count agar in triplicates. The plates were incubated for period of 24-48 hours in the incubator at 37ºC. Characteristic colonies, with counts between 30-300 then these values were expressed as CFU/ml (Nwachukwu *et al*., 2010).
2. Determination of total coliform count using most probable number: The Most Probable Number (MPN) test was used to ascertain both fecal and total coliforms respectively. The method described by Harley and Prescott (2002) was employed in this analysis. The 5-test tube approach with the first set of test tubes receiving double strength and the two other tubes was made to contain 10ml of single strengths for the presumptive test by using 10 ml of water, 5 tubes received 1ml of water, 5 tubes received 0.1ml of water. Thereafter, incubation was done at 37ºC for 48hours. The presence of gas and fermentation was used to ascertain the responses (Uzoigwe and Agwa 2012).
3. Determination of fecal coliform using most probable number: The most probable number (MPN) test for water examination for the presence of fecal coliforms was performed according to the procedures described by Harley and Prescott (2002). Enumeration of responses obtained from the responses for the fecal coliform studies. The most probable number (MPN) of coliforms were presented in MPN per 100 ml of the water sample (Madigan and Martinko, 2006). This analysis was similar to the total coliform analysis but in the case of fecal eveluation incubation was done at 44.5ºC.

4. Determination of total Salmonella–Shigella counts in water: The *Salmonella–Shigella* counts present in the water samples depending on its location in Okerenkoko community was determined using the spread plate method on Salmonella Shigella agar (Oxoid, Basingtoke, United Kingdom) was used. Water samples were prepared by 10-fold serial dilutions with 1ml of water into 9mls Selenite F-broth (Oxoid) were purchased from a local vendor Jochem Limited in Choba, Rivers State as diluents. 0.1ml aliquots of appropriate dilutions was spread on selenite-f broth /Salmonella–shigella Agar. The petri dishes carrying the already spread inoculum from the enrichment were incubated at 370C for two days. Colonies of the test organisms that appeared on the medium after incubation was presented below

Mathematically represented

$$Titre = \frac{\text{Average Number of colonies xDilution factor}}{\text{volume plated}}$$

Values were expressed as CFU/ml.

Enumeration of total Salmonella–shigella counts were carried out using the stated procedures (Nwachukwu *et al*., 2010).

5. Determination of total vibrio counts in water: The methods of Nwachukwu *et al*. (2010) was employed in the enumeration of the vibrio-load. The salmonella-shigella counts present in the six different group of borehole water depending on location in community were determined using the spread plate method on Thiosulfate-citrate-bile salts-sucrose agar (Oxoid, Basingtoke, United Kingdom) method. The water samples were prepared by 10-fold serial dilutions with 1ml of water into 9mls peptone water as diluents. 0.1ml aliquots of appropriate dilutions were spread on heat sterile Thiosulfate-citrate-bile salts-sucrose agar. The plates were incubated for period of 48 hours in the incubator at 370C. Colonies that were observed during this incubation period were counted. Values were expressed as cfu/ml.

6. Isolation of fungi from water samples: The water samples were diluted using a 10-fold serial dilution system and plated using the spread plate method on the Potatoe dextrose agar and incubated at room temperature. The plates were incubated for 48hrs. The plate counts were represented in CFU/ml using the counts derived from the plate counts. The individual colonies were subcultured and examined using both wet-mount and cotton blue procedures and the micrographs were used for tentative identification of the fungal isolates.

III. RESULTS

A Physicochemical and Coliform Composition

The result presented in Table 1.0 shows the physicochemical composition of the water samples obtained from the study area. The pH of the water samples was presented in their mean concentration values. The pH of the water sample ranged from 5.62±0.01 to 7.92±0.11. The result showed there was a significant difference between the values obtained for the other samples as can be deduced from the superscripts. The pH of the water samples for the borehole were observed to be alkaline while the water samples from the community borehole was observed to be slightly acidic with a pH of 5.62. The Electrical conductivity (EC) of the water samples ranged from 10.03±0.71 to 490.01±0.03 and this was for S_3KR and S_5OK respectively. The sample obtained from Dennis borehole (S_5OK) had the maximum concentration value for the electrical conductivity. The level of electrical conductivity of the boreholes was lower than 500 (µS/cm) and the value recorded for the S_3KR which was Krutie community source was about 10.03±0.71 µS/cm. The total dissolved solids had a concentration range from 6.05±0.01 to 894.07±0.01(mg/L). The water samples obtained from Dennis compound which was a ground water source and a borehole had the maximum concentration value which was the 894.07±0.01(mg/L). Table 2 shows the fecal coliform composition of the water samples. The water sample obtained from the Okerenkoko community borehole had a concentration value of 2400 MPN/100 ml. The S_1OK sample had a total coliform count of 1200 MPN/100ml. The water samples S_2OK, S_1KR, S_4OK, S_5OK had a lower fecal contaminant compared to other water samples. Similar outcome was observed for the total coliform compositions as presented in Table 3.0. The confirmatory and completed test were used to underscore the presence of the indicator organisms in the water samples.

B Microbial Quality Studies

Microbial composition of the water samples was presented in Fig. 1. The water samples were observed to contain fungal contaminants. The water samples obtained from the Okerenkoko community and George borehole were observed to contain a wide array of microbial contaminants. NMU/Krutie Community Borehole S_1KR was observed to have 5.4 Log_{10} CFU/ml while the fungal count was 3.5 Log_{10} CFU/ml. The S_3Ok the water samples obtained from the Okerenkoko community was observed to have total aerobic bacterial count of 4.7 Log_{10} CFU/ml, fungal count was 3.2 Log_{10} CFU/ml, total *Staphylococcal* count 4.3 Log_{10} CFU/ml, total *Escherichia coli* count was 4.7 Log_{10} CFU/ml.

C Microbial Characterization studies

The result presented at Table 4.0 shows the *Salmonella* and *Shigella* studies, the studies showed that the enrichment studies revealed that the selenite was observed to change colour from colourless to slightly pinkish-brown. The degree and pace for the change was observed to be highest for the samples S_3OK although the acetone wet mount was negative for the water samples. The wet mount study did not clearly identify any viable parasite or cyst that could be indicative of the wholesomeness of the water. Table 5.0A shows the characterization and identification of the bacterial contaminants of the water samples. The study identified the presence of *Bacillus*, *Salmonella*, *Klebsiella*, *Pseudomonas*, *Micrococcus*, *Staphylococcus* and *Escherichia* were observed during the study. The study also identified the fungal flora such as *Acemonium* sp., *Mucor* sp., and *Sclerotina* sp., as presented in Table 5.0 B.

Table 1. Physicochemical composition of portable water samples obtained from Okerenkoko

SAMPLES	S_1OK(B)	S_2OK(B)	S_4OK(B)	S_5OK(B)	S_1KR(B)	S_2KR(B)	S_3KR(S)
pH	6.91±0.01f	7.10±0.01d	5.62±0.01f	7.60±0.03g	7.81±0.00f	7.92±0.11g	7.42±0.02i
E.C (µS/cm)	190.02±1.68j	120.1±0.25h	60.06±1.10k	490.01±0.03k	140.05±0.14j	160.01±0.10k	10.03±0.71j
TDS (mg/L)	114.04±0.76i	72.08±0.01g	36.01±0.08j	894.07±0.01j	84.03±0.01i	98.02±0.04j	6.05±0.01h
TSS (mg/L)	111.01±0.01h	70.12±0.02f	33.0±0.01i	890.01±0.03i	83.01±0.02h	97.04±0.14i	4.01±0.02f
Phosphate(mg/L)	1.72±0.02c	1.80±0.03b	2.21±0.02d	1.63±0.01d	1.20±0.04c	1.91±0.17e	1.53±0.02d
Nitrate(mg/L)	0.51±0.01b	0.22±0.01a	0.30±0.00c	0.51±0.03c	0.05±0.07a	0.07±0.07b	0.08±0.18bc
Carbonate(mg/L)	0.11±0.10ab	0.13±0.01a	0.10±0.00b	0.14±0.01b	0.16±0.14b	0.19±0.13c	0.12±0.01c
D.O (mg/L)	3.970±0.07e	4.365±0.011c	7.911±0.01g	6.335±0.01f	4.759±1.03e	3.970±0.00f	4.758±0.01g
BOD (mg/L)	2.577±0.12d	1.788±0.00b	4.941±0.01e	2.182±0.12e	1.394±0.00d	1.789±0.00d	2.183±0.12e
COD (mg/L)	15.09±0.06g	25.14±0.01e	10.01±0.014h	30.03±0.03h	20.06±0.92g	25.12±0.04h	50.03±0.03k
Pb (mg/L)	0.034±0.02a	0.037±0.01a	0.037±0.00a	0.041±0.00a	0.038±0.05a	0.040±0.00ab	0.038±0.01ab
Cd (mg/L)	0.002±0.00a	0.005±0.01a	0.004±0.00a	0.006±0.00a	0.001±0.00a	0.001±0.00ab	0.001±0.00a
Hg (mg/L)	0.079±0.00ab	0.017±0.00a	0.028±0.01a	0.026±0.00a	0.034±0.00a	0.016±0.00a	0.026±0.00a

Data represents triplicate Mean± Standard Error; Superscripts reflect homogenous subsets, Columns with similar superscripts are significant at p<0.05 and otherwise are not significant at p>0.05. **Key**:S_1KR=NMU/Krutie community borehole, S_2KR=Sengemenge Hotel borehole, S_3kR=Krutie Community River , S_1OK= George's borehole, S_2OK=NMU Okerenkoko borehole, S_4OK=Okerenkoko Community borehole, S5OK=Dennis borehole , FL= Flourish Sachet water(Control), CO= Concept Sachet

Table 2. Fecal Coliform composition of water samples.

Samples	3-tubes	3-tubes	3-tubes	MPN/100mL-1	Confirmatory test	Completed test
S1k	0	1	0	3	+	+
S2k	3	3	2	1200	+	+
S3K	3	3	0	240	+	+
S1O	3	3	2	1200	+	+
S2O	2	0	0	4	+	+
S3O	3	2	1	150	+	+
S4O	3	0	0	23	-	-
S5O	1	0	0	6	-	-
FL	1	1	0	7	+	+
CO	1	0	0	7	+	+

Table 3. Total coliform composition of water samples obtained from Okerenkoko.

Samples	3-tubes	3-tubes	3-tubes	MPN/100mL-1	Confirmatory test	Completed test
S1k	3	0	0	23	+	+
S2k	3	3	2	1200	+	+
S3K	3	3	1	1000	+	+
S1O	3	3	1	1000	+	+
S2O	0	2	1	14	+	+
S3O	3	3	3	2400	+	+
S4O	3	0	0	23	-	-
S5O	0	2	0	8	-	-
FL	0	1	0	3	+	+
CO	1	1	0	7	+	+

Key:S_1KR=NMU/Krutie community borehole, S_2KR=Sengemenge Hotel borehole, S_3kR=Krutie Community borehole, S_1OK= George's borehole, S_2OK=NMU Okerenkoko borehole, S_4OK=Okerenkoko Community borehole, S5OK=Dennis borehole , FL= Flourish Sachet water(Control), CO= Concept Sachet. Water "+" = Positive/ Present; "-"= Negative/Absent

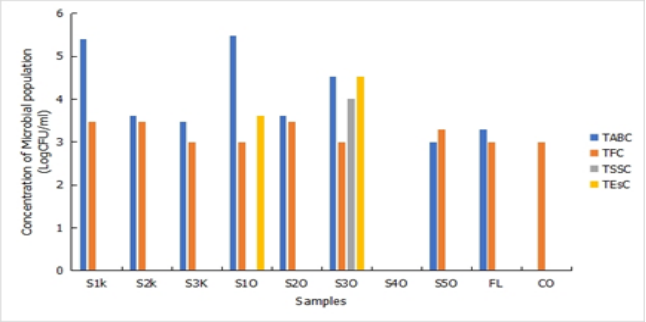

Fig 1: Microbial quality of water samples obtained from Okerenkoko

Key: TABC=Total Aerobic Bacterial Count, TFC=Total Fungal count, TSSC= Total *Salmonella* and *Shigella* Count and TEsC= Total *Eschericia coli* count. S_1KR=NMU/Krutie community borehole, S_2KR=Sengemenge Hotel borehole, S_3kR=Krutie Community borehole, S_1OK= George's borehole, S_2OK=NMU Okerenkoko borehole, S_4OK=Okerenkoko Community borehole, S5OK=Dennis borehole, FL= Flourish Sachet water (Control), CO= Concept Sachet

Table 4. Selenite Enrichment and Bacterial Assessment report.

Samples	*Salmonella* and *Shigella* sp.	Acetone-wet mount
S1k	+	-
S2k	+	-
S3K	+	-
S1O	+	-
S2O	+	-
S3O	+++	-
S4O	+	-
S5O	+	-
FL	+	-
CO	+	-

Key:S_1KR=NMU/Krutie community borehole, S_2KR=Sengemenge Hotel borehole, S_3kR=Krutie Community borehole, S_1OK= George's borehole, S_2OK=NMU Okerenkoko borehole, S_4OK=Okerenkoko Community borehole, S5OK=Dennis borehole , FL= Flourish Sachet water(Control), CO= Concept Sachet

Table 5. A. Colonial characteristics of bacterial isolates obtained from water samples in Okerenkoko, Delta State

Sample	Morphology on Plate count Agar	Code	Genus
S30-1	Milky colony, raised and regular edges with a colonize of 1.5 mm	1	*Proteus*
S30-2	Wide colony of about 5mm size, flat with regular edges	2	*Salmonella*
S30-3	Translucent colony, flat surface with a colony size of about 2.1mm and regular edges	3	*Klebsiella*
S30-4	Transparent, milky, flat surface, irregular edges and a size of 2.2mm	4	*Pseudomonas*
S30-5	Creamy, raised surface with an irregular edge and a size of 3.2 mm	5	*Micrococcus*
S20-1	Dull Milky colony, raised surface, irregular edges and 1.8 mm size	6	*Shigella*
	Morphology of isolates on EMB-media		
S3O -1	Dark on reverse side raised 1.6 mm	11	*Staphylococcus*
S3O -2	Colourless raised and size of 1.4 mm	12	*Bacillus*
S3O -3	Transparent and Flat	13	*Vibrio sp*
S3O -4	Creamy, raised and 1.3 mm	14	*Escherichia*

Table 5.B. Morphological characteristics of fungal isolates obtained from water samples in Okerenkoko, Delta State

Sample	Morphology on Plate count Agar	Microscopy	Presumptive Identity
S2k-1	Bright white mold with Fluffy edges and whitish-brown at the reverse	Non septate, straited with a conidiospore.	*Sclerotina* sp.
S5O-2	Whitish mold with four-(4) concentric inclusions on the surface; and brownish at the reverse side of the plate	Pseudsohyphae with a massive sporangiosphore	*Mucor* sp.
S3O-4	Whitish mold with a dull brown on the reverse side of the plate	Septate hyphae with an ariel conidophore	*Microsporium* sp.
S3O-5	White cotton like colony with colourless reverse	Unbranched septate hyphae with oblong conidia	*Acemonium* sp
S2O-1	White cottony aerial mycelium. Reverse grey	Septate hyphae with long or short conidoisphores	*Scedosporium boydii*

Table 6. Correlation matrix of the physicochemical parameters

	pH	Temp	EC	TDS	TSS	Phosphate	Nitrate	Carbonate	DO	BOD	COD	Pb	Cd	Hg	THC
pH	1														
Temp	.180	1													
EC	.270	.869**	1												
TDS	.289	.539	.727*	1											
TSS	.222	.113	.244	.840**	1										
Phosphate	-.394	-.599	-.669*	-.245	.199	1									
Nitrate	.143	.785*	.900**	.378	-.185	-.776*	1								
Carbonate	.280	-.594	-.674*	-.217	.260	.692*	-.834**	1							
DO	-.449	-.470	-.489	.004	.386	.865**	-.644	.535	1						
BOD	-.271	.317	.563	.164	-.261	-.369	.744*	-.777*	-.179	1					
COD	.340	-.313	-.328	.201	.570	.663	-.602	.804**	.600	-.520	1				
Pb	-.034	-.399	-.449	-.023	.347	.854**	-.623	.728*	.843**	-.293	.859**	1			
Cd	-.328	.105	.048	.499	.668*	.522	-.231	.145	.641	-.108	.540	.513	1		
Hg	-.214	-.077	-.267	-.110	.108	.473	-.373	.239	.406	-.174	.271	.518	.145	1	
TH	.231	.327	.612	.157	-.300	-.599	.797*	-.652	-.508	.851**	-.414	-.393	-.384	-.340	1
**. Correlation is significant at the 0.01 level (2-tailed). Correlation is significant at the 0.05 level (2-tailed).															

IV. DISCUSSION

The pH of water is an indicator parameter used to ascertain the state of wholesomeness of any water. The concentration values of pH obtained from the study ranged from pH 5.62 to pH7.81. The concentration values of pH obtained for the study were all within the WHO, SON, NAFDAC and USEPA permissible limits The sample S_4OK had a pH of 5.62 and also being the lowest concentration value obtained from the study. These findings were tandem with the earlier report by Nduka *et al*. (2008) as they observed a pH of 5.0 for the Udu River which incidentally is located in Delta State, Nigeria. Furthermore, the present study agrees strongly with the report of Igwe *et al*. (2021) whose investigation obtained a range of values between 6.8 to 6.9 while the control samples had a range from 6.0 to 7.1. In a related study, Ocheli *et al*. (2020) reported ranges between pH 6.2 and 8.5 for surface water, pH 6.6 and 8.3 for shallow well and pH 6.5 and 8.4 for borehole water while WHO permissible limit of 6.5–8.5. These concentration values agree with previously data in the Niger Delta Region (Bolaji and Tse, 2009). When the concentration values of pH of potable water is low then it could be categorized as being acidic which suggest that it may lower metabolic activities or impair fecundity rate of living things. It may also induce a number of biochemical reactions including corrosion of pipes, clogging of pipes, poor taste of water (Agbalagba *et al*., 2011). Osayande *et al*. (2015) observed the acidity of potable water and its potential to increase the risk of gastroenteritis especially *Helicobacter pylori*. Although USEPA (2019) recommends that the pH of status of potable water may not have any direct detrimental effect on humans although there are wide claims on the preference to alkaline water. Ovanramwen (2020) observed that the pH of the surface water could be correlated to the level of nitrates or total nitrogen present although, they reported a poor association between the electrical conductivity and the total dissolved solids of most potable water.

Electrical conductivity is also an indicator parameter which describes the presence of organics and salts. Water in its original form devoid of impurities is a conductor of electricity; this explains the difference in the concentration values of distilled water and ground water. The process of distillation removes the ions and radicals using a resin-exchange; presence of certain impurities may not correlate to the presence of ions including pollutants such as crude oil (Fondriest-Staff, 2010; Edema, 2012). The present study observed the E.C observed ranged from 10.03 to 490.01 µS/cm. The samples S_1KR and S_2KR had an electrical conductivity of 140 and 160 µS/cm while S_1OK and S_4OK had 6.91 and 5.62 µS/cm. The results of the findings agreed with the earlier report of Ocheli *et al*. (2020) whose study observed that ground water had a high level of electrical

conductivity than other sources. Suggestions that EC values higher than 400 µS/cm definitely contains a number of ions and radicals. Shashe and Magashi (2014) reported that the study conducted in Owerri metropolis had lower conductivity which was indicative of lesser presence of ions. Although they reported values between 18 to 88 µS/cm which was slightly higher than the values obtained for the present study; the implication suggest that the soil mineral composition could impact on the quality of the water in terms of the conductivity ratings. These may impact on the aesthetics of the water and their potential to impact negatively or interact on the exchangeable cations of health concern (Nwosu *et al*. 2004). The dissolved oxygen of the water samples varied from 3.90 to 7.91 mg/L. The concentration value obtained for the surface water was 4.7 mg/L which also indicate a relative level of biogenic activity in the water either as a result of a number of religious or sanitary practices. The values were in tandem with report of Ovoramwen (2020) although slightly higher they reported which was 5.21 mg/L. The concentration value of higher in ground water may indicate there is a substantial infiltration of organics. The concentration value for dissolved oxygen for S_4OK was 7.4 mg/L which is a community borehole which is prone to a number of biological activities.

The chemical oxygen demand for the water samples was observed to be between 10.01 to 50.03 mg/L for the water samples. The maximal concentration was observed for the surface water S_3KR was 50.03 mg/L which is the most accessible water for the community. The ground water or borehole water tagged George Borehole had 10.01 mg/L; these values were all within the WHO recommended limits. The concentration of lead (Pb) in the water samples obtained from S_1OK was 0.034mg/L while that of the S_3KR which was a surface water had 0.038 mg/L. Ugbomeh *et al*. (2012) reported the variation in the levels of heavy metals in aquatic sources may vary from one geophysical location to seasonal; they observed a sharp fluctuation in titre of heavy metals during the dry season along the Soku Oil field Area of Niger Delta In another study, Akporido and Onianwa (2015) reported 39 µg/L in the surface water of Esi River in Western Niger Delta, the concentration was higher than the recommended limits while Obire *et al*. (2003) reported higher levels of lead in the Benin River at Koko with a concentration value of 2270 µg/L. These findings also suggest that the impact of oil exploration could impact on the quality and quantity of concentration of oxygen in most water resources. These were attributed to seepages and run-offs from an impacted environment. These findings corroborate the report of Akankali *et al*. (2019) whose investigation identified the role of the industrial activities on the le vel of water pollution. Metals are naturally occurring substances in the soil; their presence have been attributed to physical and biological activities one of which is weathering and geochemical activities. These heavy metals have been reported in a number of peer reviewed articles as a leading cause of many health challenges including liver failure and cancer in every animal, this does not exclude the fact that they may be involved in corrosion of pipes and cause huge economic loss (Howard and Olulu, 2012). Exchangeable ions such as calcium and magnesium ions have been identified as principal causes of the harness of water, which makes it unable to form lather with soap. The work of Bolaji and Tse (2009) identified that the concentration of ions in most potable water consumed in Rivers State ranged from 0.35mg/L to 9.25mg/L for Calcium while the for Mg^{2+} was between 0.02 to 7.40 mg/L. They observed that the level of calcium was higher than the recommended limits for drinking water. Several reports have tried to correlate the level of calcium to that of the Carbonates in the water this is because calcium and magnesium exist as carbonates such as Calcium and Magnesium carbonates.

The fecal coliform for the water samples studied in the present work showed that the coliform concentration ranged from 4-2400 MPN/ml. The result obtained from our study showed that both the underground and surface water had variations in the coliform concentration for both fecal and total coliforms. The result also revealed that the surface water was impacted by fecal coliforms of up to 2400 MPN/ml for the water sample obtained from S_3KR.These findings corroborates the report of Onyango *et al*. (2018) whose findings observed a coliform count of about 27500 MPN/ml in drinking water sources in Isiolo, Kenya. This goes a long way to buttress that a number of the water sources accessed by many indigent communities may be impacted by biological contaminants. A similar study observed that a number of studies suggest that a number of groundwater sources may also be impervious to biological agents as was observed in some groundwater sources within the Nigerian Maritime University in Okerenkoko this may strongly agree with the report of Entry and Farmer (2001) which they suggested that nature of aquifer and desalting strategy may limit the presence of vegetative organisms. Nnadozie (2016) reported 177 CFU/ml in the coliform analysis of surface water obtained from the Abonema wharf in Port Harcourt. Although the surface water is a flowing one, the sample collection points and season when the sample was obtained may impact the result obtained for the study. Shashina *et al*. (2020) is of the opinion that the presence of coliform in potable water greater than a single concentration value could imply that a water sample in question could be regarded as being unwholesome for consumption

The water samples obtained from the study location were observed to contain a significant microbial concentration. The water samples obtained from S_2OK had a variety of microbes. Total aerobic bacterial count in the water samples S_1OK and S_1KR had the maximum microbial concentration of about 5.8 Log_{10}CFU/ml and 5.4 Log_{10}CFU/ml respectively while the total fungal count was 3.1 Log_{10}CFU/ml and 3.6 Log_{10}CFU/ml respectively. The aerobic bacterial count for the community borehole S_5OK and control (Flourish sachet water) samples had 3.0 Log_{10}CFU/ml and 3.3 Log_{10}CFU/ml. The borehole water (S_1OK) and surface water (S_3OK) had a high concentration of the Total *Escherichia coli* count of about 3.6 Log_{10}CFU/ml and 4.5 Log_{10}CFU/ml respectively.

These findings corroborate the report of Nnadozie (2016) that reported the presence of significant coliforms in the ground and surface water sources in Port Harcourt Metropolis especially in the surface water. The activities such as defecation, dumping of domestic waste and channeling of effluents including grey water have been identified as a remote challenge to surface water while with respect to ground water these can be traced to decades of seepages into the water bed (Sasakova *et al*. 2018). Total *Salmonella Shigella* Count was present in the S_3OK; it had a concentration of 4.0 $Log_{10}CFU/ml$. In a related study Megchún-García *et al*. (2018) reported coliforms ten times higher than observed in a community in Mexico and it attributed it to the seepages from septic tanks into the surface and ground water sources. Agricultural, industrial and environmental activities can greatly impact on the safety or quality of potable water.

Microbes associated with the potable water samples were *Bacillus* sp., *Escherichia* sp., *Staphylococcus* sp., *Streptococcus* sp., *Shigella* sp., *Proteus* sp., *Pseudomonas* sp., *Klebsiella* sp., *Vibrio* sp. and *Micrococcus* sp. *Escherichia coli* is an indicator of fecal pollution. *Shigella* and *Salmonella* are enteric organisms responsible for Shigellosis and Salmonellosis which may cause life threatening diseases. *Vibrio* species could lead to severe gastrointestinal conditions. One of the prevalent diseases in the region is Typhoid fever caused by *Salmonella* sp. The economic turnover of the infection on both socio-economic class resident in the study area has increased geometrically in recent years. A study by Eboh *et al*. (2017) reported the following organisms *Escherichia* sp., *Enterobacter* sp., *Alcaligenes* sp, *Klebsiella* sp., *Staphylococcus* sp, *Bacillus* sp., *Proteus* sp., *Micrococcus* sp., *Serratia* sp., *Acinetobacter* sp., *Alcaligenes* sp. and *Pseudomonas* sp. from ground water at Ukwuani LGA in Delta State. Furthermore, Onyango *et al*. (2018) reported isolates such as *Clostridium* species along with enteric organisms from his study on ground water supplies in Kenya. The soil is a natural reservoir of organisms. The study conducted by Ordinoha (2011) identified the sharp practices of most local and artisanal technicians involved in the "drawing of borehole" as a major reason for the proliferation of the microbial pathogens. They further indicated that the depth of the boreholes was shallow and that may be the reason seepages. According to Abubakar (2018) over 50% of the persons in the rural areas are infected by the quality of drinking water available to them; this has contributed to the enteric disease burden within the Niger region. The impact of industrial activities in some riverine communities in the Niger Delta have also been identified in recent investigations (Owamah *et al*. 2013; Ehiowemwenguan *et al*., 2014; Okereke *et al*., 2014; Adogo *et al*., 2015; Adebawore *et al*., 2016; Sojobi, 2016 and Owamah, 2020). The fungal flora isolated from the water sources during the investigation were *Sclerotina* sp., *Mucor* sp., *Microsporium* sp., *Acemium* sp., *Scedoporium* sp and *Penicillium* sp. These fungal florae have been identified in some of the studies conducted on water especially ones used in rural communities impacted by industrial, environmental and domestic activities in the Niger Delta. Similarly, Eboh *et al*. (2017) reported the presence of *Rhizopus* and *Penicillium* sp. were observed in their study and this corroborates our study that the ground and surface water had mycelia of vegetative fungi. The water available to the teaming populace in Riverine communities in Nigeria is fast depleting with the increasing challenges of crude oil theft and cottage refinery activities in the Niger Delta. The level of sanitary activities has been widely criticized as being very pod or crucial with a number open defecation and indiscriminate dumping of waste materials into receiving water and a number of religious activities conducted on the banks of the water bodies.

V. Conclusion

The study evaluated and identified that the potable water sources were tainted with both indicator chemical radicals and some microbiological agents. Some of which were higher than recommended limits. There was a positive association between the physicochemical values obtained from the study which further revealed the sources of the water were under some attack by anthropogenic sources. There is need for government at all levels to improve the available groundwater resources in Okerenkoko with the aim to routinely monitor the physicochemical and microbiological quality indicators for the purpose of sustaining limited sources. There is an urgent need to source-track the trajectory of pollutants from both from domestic and industrial activities for a robust corrective action.

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