ZIBELINE INTERNATIONAL™ PUBLISHING
ISSN: 2521-0912 (Print)
e-ISSN: 2521-0912 (Online)
CODEN: JCOLBF

Journal Clean WAS (JCleanWAS)

DOI: http://doi.org/10.26480/jcleanwas.02.2024.56.61

CrossMark

RESEARCH ARTICLE

QUALITY ASSESSMENT OF SACHET AND GROUNDWATER FOR DRINKING PURPOSE IN OKERENKOKO, GBARAMATU KINGDOM, NIGERIA

O.M Omorogieva[a*], B.C Adebayo[a], O.O Falowo[b], J.A Tonjoh[a]

[a]Department of Marine Geology, Nigeria Maritime University, Delta State, Nigeria
[b]Department of Civil Engineering Technology, Faculty of Engineering Technology, Rufus Giwa Polytechnic, Owo, Ondo State, Nigeria
[*]Corresponding Author Email: osakpolor.omorogieva@nmu.edu.ng; osakpolor.omorogieva@physci.uniben.edu

ARTICLE DETAILS

Article History:

Received 02 January 2024
Revised 05 February 2024
Accepted 08 March 2024
Available online 26 March 2024

ABSTRACT

The aim of the study was to determine the quality of available drinking water sources in Okerenkoko, Gbaramatu Kingdom, Nigeria. The parameters assessed include pH, EC, TDS, Pb, Fe, Mn, bacterial and fungal counts using appropriate methods. The results was recorded in triplicate and presented in mean values; the pH values ranged from 6.0 – 7.33; Pb (0.04 – 0.60 mg/L); Fe (0.33 – 5.84 mg/L) and Mn (0.18 – 2.60 mg/L). Conversely, the bacteriological results showed a range of total bacteria counts of 2×10^3 - 18.3×10^3 (cfu/ml) and a total fungi counts of 2×10^3 - 20.3×10^3 (cfu/ml) respectively. On isolation, *Escherichia, Staphylococus Epidermis, Streptococus Spp* and *Staphylococcus Aureus* were recovered as bacteria isolates while *Trichoderma Spp, Agergillus Flavus, Ahergillus Niger, Penicillium Spp* and *Mucor* were recovered as fungi isolates in some of the water samples collected. Correlation analysis at $P < 0.01$ revealed a similar source for Pb, Fe and Mn which is attributed to the anthropogenic activities in the area. Juxtaposing correlation analysis with regression analysis using Pb as an independent variable, the result showed an increasing trend of the metals against the natural background which further confirms anthropogenic input. Groundwater in the study area cannot be consumed unless thorough treatment is administered in view of the health implication.

KEYWORDS

Shallow aquifer; coastal environment; health impact and microorganism

1. INTRODUCTION

Water is one of the natural resources that support the existence of human beings, plants and other living organisms. It occurs in different zones in the earth subsurface layers, as groundwater and on the surface of the earth as rivers, streams, lakes, seas and oceans (Yusuf et al. 2018). Water is very essential for the health of living organisms; it is mainly use in different areas of human endeavor (Omorogieva et al. 2022b; Ogundana and Talabi, 2014). Groundwater is the most dependable source of fresh water, particularly for drinking purpose (Omorogieva et al. 2022a; Falowo et al. 2015; Plummer et al. 2008). This is because other sources of water are not readily accessible for human consumption or were its available; the water quality may be very poor for the health of the biota in the terrestrial and aquatic ecosystems. For example, seawater contains dissolve ions and other contaminants; in addition, a vast amount of fresh water is locked up as ice and is inaccessible. Due to increase in global population and technological growth, the demand for freshwater have increase radically; as a result, it become necessary to constantly monitor the quality of groundwater as the main source of freshwater either for domestic, agricultural or industrial purposes (Singh et al. 2020; Ugwuja, 2022). Water laden with deleterious contaminants and microbial load is detrimental to human health and the ecosystem (Adimalla et al. 2020; Omorogieva and Tonjoh 2020). According to previous study, consumption of water contaminated with heavy metal may lead to increase in disease and mortality rate as well as vital organs dysfunction (WHO, 2017; Khalid et al., 2020).

Large percent of Nigerian depends on groundwater as source of freshwater for domestic, industrial, agricultural and economic uses (Omorogieva and Ogieriakhi, 2021). The inhabitants' of Okerenkoko community including Nigeria Maritime University (NMU) staff and students are constantly experience health challenge similar to that of water borne diseases The main cause of this is yet unknown, hence we were motivated by the gap in knowledge to undertake this study. In addition, the area is characterized with high anthropogenic activities ranging from open defecation, crude oil spillage, ocean vessel leakages, and illegal crude oil theft amongst others (Tonjoh and Omorogieva, 2020). Okerenkoko is the biggest community in Gbaramatu Kingdom in the Niger Delta Sedimentary Basin (NDSB); it is situated along Escravos River which is under tidal influence of the Atlantic Ocean. According to other studies, a tidal environment is that part of a marine shore which is regularly submerged and exposed in the course of the rise and fall of the tide; such environments exhibit peculiar physicochemical and biological characteristics which, among others, play an important role in coastal dynamics, ecology, protection and engineering works as well as integrated coastal zone management practice (Flemming, 2005). Our specific objectives in this study are to measure the bacteriological and the physicochemical characteristics of the available and accessible drinking water in the study area in order to foster the doctrine of sustainable water management in the study area as well as to create awareness and provide baseline information of scientific based evidence for further study. This will eventually facilitate adequate and appropriate management of water sources in the study area and similar deltaic environment as well as contributing significantly to the Sustainable Development Goal (SDGs) particularly goal number six of the United Nations.

1.1 Hydrogeology of the Study Area

A study evaluated the hydrogeological condition of Okerenkoko groundwater (Ugwuja, 2022; Omorogieva et al., 2022c). Two aquiferous horizons (confined and unconfined) were identified; the unconfined horizon extends from the surface to about the depth of 375 m while the

Quick Response Code	Access this article online	
	Website: www.jcleanwas.com.my	**DOI:** 10.26480/jcleanwas.02.2024.56.61

Cite The Article: O.M Omorogieva, B.C Adebayo, O.O Falowo, J.A Tonjoh (2024). Quality Assessment of Sachet and Groundwater for Drinking Purpose in Okerenkoko, Gbaramatu Kingdom, Nigeria. *Journal CleanWAS (JCleanWAS), 8(2):* 56-61

confined horizon occurs below a thick clay layer. The aquifers found within the unconfined horizon have interference of saltwater from Escravos River Basin (ERB) as the main source of recharge beside rain water. In addition, anthropogenic flux was another main factor that contributes to the poor water quality. The area under study is a Mangrove Swamp Formation (MSF), this formation is underlain by the Warri Sombreiro/Coastal Plain Sand and overlain by the Beach Sands Formation (Edegbai et al. 2019; Akpoborie et al. 2015; Efobo et al. 2020). On the other hand, the confined horizon has some traces of iron but diminishes with greater depth. The measurement of available hydraulic head in the study area revealed that the groundwater flow from West to East towards ERB and finally empty into the Atlantic Ocean southward (Omorogieva et al., 2022c).

2. Materials and Methods

2.1 Site Description

Okerenkoko is one of the largest communities in Gbaramatu Kingdom within Nigeria coastal water ways. It is located along ERB between the coordinate of 5.386111N, 5.620556E and 5.393611N, 5.633889E respectively (Fig.1). The area is an estuary and a transitional environment between the continent and the deep marine with a dimension of 2.1 km by 2.4 km (5.04 km^2) land mass (Ugwuja, 2022). The main occupations of the indigenous people include fishing, farming, hunting and lumbering activities. The area can only be accessed through air and water ways.

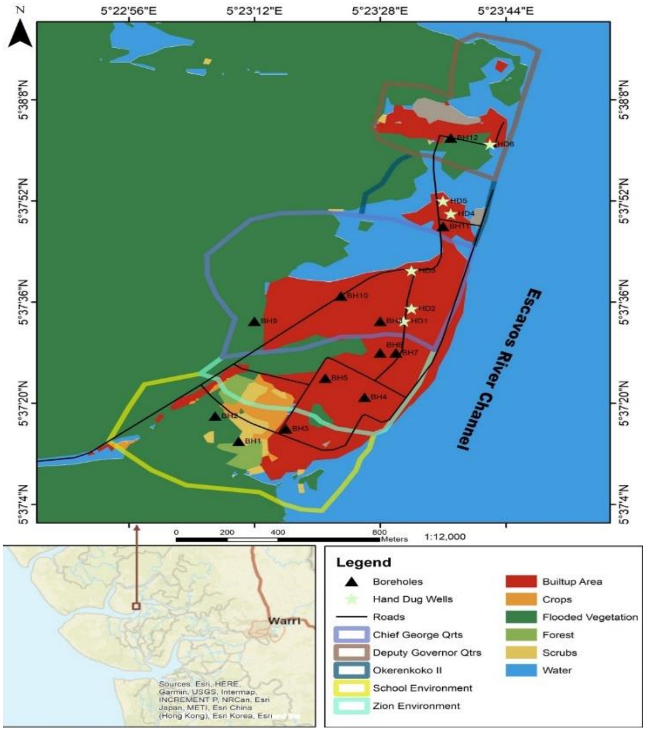

Figure 1: Map of Okerenkoko indicating sampling points and land use (Ugwuja, 2022)

2.2 Sampling Procedures

The study was focused on the understanding of the quality of drinking water in the study area with a view to ascertaining its contribution to the incessant health challenge often witness among the people living in the community including staff and students of NMU. The study becomes necessary in order to adopt management strategies that will provide long term management scheme of water sources accessible in the area for drinking purpose. Systematic sampling procedure was adopted by gridding the study area into five grids (School Environment (SE); Zion Environment (ZE); Okerenkoko II (OK2); Chief George Quarter (CGH) and the Deputy Governor Quarter (DGQ) respectively. Composite representative boreholes samples derived from shallow aquifer, dug wells, sachet and boiled water were collected for the study. Table 1 indicates the sample coordinates, Static Water Level (SWL), sources of sampled water, elevation, corrected water level and the description of each grid.

Table 1: Sampling Points Parameters

S/N	Lat.	Long.	SWL	Source	Code	Elevation	CWL	Description
1	5.386111	5.620556	0.14	BH1	SE	25.58	25.44	Staff Extension
2	5.387778	5.621111	1.67	BH3	SEO	15.86	14.19	Main Staff Quarter
3	5.390556	5.6225	0.44	BH4	ZE	8.68	8.24	Zion Main Quarter
4	5.391111	5.624444	0.9	BH6	ZC	9.17	8.27	Zion Church
5	5.391667	5.624444	0.7	BH7	ZEO	6.99	6.29	Behind Zion Church
6	5.391111	5.625833	1.1	BH8	GHO	14.43	13.33	General Hospital
7	5.391944	5.625833	0.63	HD1	OK	7.20	6.56	Okerenkoko II
8	5.392222	5.626389	0.69	HD2	OKO	10.16	9.47	Okerenkoko II
9	5.389722	5.626944	0.3	BH10	OK2	17.40	17.10	Okerenkoko II
10	5.386667	5.625833	0.31	BH9	OK2	20.00	19.69	NMU Main Campus Rd
11	5.393333	5.631111	0.4	BH11	CGH	7.93	7.53	Chief George House
12	5.393611	5.633889	0.76	BH12	DGH	11.46	10.69	Deputy Governors' House
13	5.389167	5.623333	1.2	BH5	ZE	15.09	13.89	Zion Main Quarter (BW)

Note: SE (School Environment), ZE (Zion Environment), OK2 (Okerenkoko II), CGH (Chief George House) and DGH (Deputy Governors' House)

During the field exercise, a total number of thirteen (13) water samples were collected from a typical coastal aquifer of recently deposited sediments belonging to Mangrove Swamp Formation (MSF), in a single survey during the month of September, 2021. The samples collected incudes nine (9) borehole water, two (2) hand dug wells, one (1) boiled groundwater water, and one (1) sachet water. The samples were collected from existing boreholes and dug wells in each grid through direct pumping from the aquifer after ten minutes in the case of borehole while deep sampler was used in collecting water at a depth of 0.3 m in the open dug wells (Rajmohan and Elango, 2005; Omorogieva et al. 2022c); the samples were stored in a well labeled pre-rinsed 200ml plastic bottles. Samples were transported to the labouratory for physical and hydrochemical analysis of pH, Electrical Conductivity (EC), Total Dissolved Solid (TDS), Pb, Fe and Mn using AAS after (APHA, 2005; Manivaskam, 2011).

2.3 Microbial Determination

Total Bacteria and Fungi Counts (cfu/ml) were determined by the most probable number (MPN) techniques according to the methods specified in America Public Health Association (APHA, 1995; Djaouda et al., 2018) manual. In a similar manner the bacteria isolates were further experimented in order to attain pure cultures. The pure cultures were then characterized and identified to determine the bacteria and fungi species using the standard microbial method. Furthermore, morphological tests were equally performed to enable the confirmation of each of the isolates recovered. The experiment was to test the ability the isolate to ferment a given sugar with the production of acid and gas or acid only as the case may be. The morphological test was necessary because most bacteria, especially gram-negative bacteria utilize different sugars as source of carbon and energy with the production of both acid and gas or acid only; the test is used as an aid in their differentiation.

3. Results and Discussion

Table 2: Physicochemical and heavy metal results in mean value (n=13)

Sample Code	pH	EC µS/cm	TDS (mg/L)	Fe (mg/L)	Mn (mg/L)	Pb (mg/L)
BW	7.34	2422.67	1210.33	4.70	1.80	0.48
CGH	13.43	836.00	416.33	3.87	1.29	0.32
DGH	6.63	145.67	73.00	0.72	0.41	0.12
GHO	6.90	1383.55	1032.00	4.45	1.43	0.37
HD	6.63	145.67	73.00	0.72	0.41	0.11
OK	6.57	2480.33	1243.66	4.83	2.09	0.55
OK0	6.63	145.67	73.00	0.72	0.41	0.12
SE	6.90	375.33	187.33	0.89	0.34	0.09
SEO	6.10	939.00	469.00	1.77	0.65	0.17
SWO	7.27	93.33	46.33	0.45	0.18	0.05
ZE	5.23	87.00	43.67	0.34	0.18	0.05
ZC	6.13	2592.67	1286.67	5.84	2.41	0.61
ZEO	6.00	1517.33	758.67	3.458	1.42	0.38
WHO (2017)	**6.5–8.5**	1200.00	250.00	0.3	0.40	0.02
SON (2015)	6.5-8.5	1000.00	250.00	0.3	N/A	0.01

Table 1 represents the results recorded during the laboratory analysis of the physicochemical parameters in evaluating the suitability of drinking water in the study area. The pH showed a range of 5.23 at ZE borehole in the ZE grid to 13.43 at CGH. The values indicated that borehole water from CGH is highly basic whereas those derived from grids in the study area including the boiled (BW) and sachet water (SWO) respectively were within the acceptable range specified by the World Health Organization (WHO, 2017) and the Standard Organization of Nigeria (SON, 2015). Although pH value in water has no fundamental role to play with regards to the suitability of the water but can influence the occurrence of other dissolve chemicals that are injurious to human health. The high value of pH recorded in CGH may be attributed to the introduction of chemicals during treatment since the geology of the environment does not reflect that soil in the study area is rich in carbonate or bicarbonate materials capable of increasing the water alkalinity. At low pH, more substances are dissolved in water whereas at high pH ions exchanges are facilitated; this could lead to soil low permeability and porosity (Li et al., 2021; Singh et al., 2020). It was found that 46.15% of the wells sampled were acidic to slightly acidic while others are within the acceptable range of 6.5 – 8.5 respectively. It was also noted that 46.15% of the wells in the study area were also in the range of alkalinity whereas 7.69% represents extremely basic pH in groundwater.

Electrical Conductivity (EC) measured in µS/cm in the study ranged from 87.00 – 2592.67 (µS/cm). The lowest value of 87.00 µS/cm was recorded in ZE borehole within the ZE grid while the highest value of 2592.67 (µS/cm) was recorded in borehole tagged ZC in ZE grid. The increase in the dissolved substances in area could be attributed to high anthropogenic activities like the direct discharge of crude oil and various chemicals on the surface water; this can infiltrate directly to the shallow aquifer from which the borehole water was sourced. This was justified by the similar results recorded in boreholes sited within OKII grid as showed in Table 2. The high value of EC recorded in boiled water (BW) may be due to heating of the water because boiling increases the rate of evaporation vis a vise the concentration of dissolved substances. This observation was further justified by the high value of TDS recorded because TDS is directly proportional to EC.

On the other hand, the heavy metals assessed in the study area include Iron (Fe), Lead (Pb) and Manganese (Mn). In the study, the value of Fe recorded ranged from 0.34 mg/L at ZE to 5.84 mg/L at ZC. The specification for drinking purpose by international and national regulatory agencies without health concern is 0.3 mg/L. In the study area, 100% of the boreholes sampled exceeded the permissible limit (WHO, 2017; SON, 2015). The presence of high amount of Fe concentration in the groundwater may be due to the oxidizing nature of the environment and iron rich bottom sediments. Iron (II) Fe^{2+} is unstable and easily oxidized to Fe^{3+} to give brownish colouration to water. Excess of Fe in human system can lead to medical condition termed hemochromatosis that could severely damage the liver (Omorogieva et al., 2022; Selinus et al., 2013). Furthermore, Fe promotes the growth of “iron bacteria” which derive its energy from the oxidation of Fe^{2+} to Fe^{3+} and in the process deposit a coating materials on pipe through which water is supplied.

Manganese (Mn) was also measured in the wells in the study area, a range of 0.1 mg/L at the ZE and SWO respectively to 2.41 mg/L in ZE and ZC which are both in ZE grid (Figure 1). Conversely, SWO represents the regular sachet water consumed by the public in the study area. The manganese (Mn) value recorded in the study exceeding the permissible limit in the drinking water available in the area. Excess Mn in water can result to odor in water; ideally, drinking water should be devoid of odor, otherwise it should not be consumed. It was observed that 100% of the sampled groundwater exceeded the permissible limit of 0.1 mg/L; the excess Mn in the groundwater in the study area is traceable to the chemical introduced into the groundwater system by anthropogenic activities ongoing in the study area, and may contribute significantly to the odor of the groundwater in the area (Omorogieva and Igberase, 2021; Li et al., 2021). Lead (Pb) concentration in borehole water was evaluated. This element is of public health concern because of its known health impact on human. Due to the health impact of Pb in human body, experts have recommended a permissible limit of 0.01 mg/L in drinking water. Lead has been widely reported to be responsible for a number of health challenges (WHO-UNICEF, 2000; WHO, 2017; Omorogieva et al., 2022b). The mean value of Pb in the drinking water assessed in this study area ranged from 0.05 – 0.6 mg/L. The lowest value of 0.05 mg/L was recorded in the popular sachet water (SWO) available in the community while the highest value of 0.6 mg/L was recorded in ZC borehole water within ZE grid. The values recorded in the study indicated that 100% of the wells assessed for drinking water sources were unsuitable for drinking purpose with regard to Pb concentration. The presence of Pb in the drinking water source may be is traceable to anthropogenic flux rather than geogenic inputs because of the level of Pb concentration above background value which can be facilitated by the incessant gas flaring, oil spill, direct and incidental discharge of chemical contaminants in the water system. A number of the health challenges have been identified with Pb concentration in water; these include low intelligent quotient (IQ), reproductive dysfunction, cancer and mental retardation (Taylor et al., 2010; WHO, 2017).

3.1 Statistical Treatment

Statistical analysis of regression and correlation at $p < 0.01$ was performed on the metal species (Fe, Mn and Pb). The result obtained (Table 3) showed a strong positive correlation which indicates that the leached metals into the groundwater system had a similar source. Juxtaposing correlation with regression analyses using Pb as an independent variable (Fig. 2 and 3), the result showed an increasing trend of the metals against the natural background which further confirms anthropogenic input.

Table 3: Correlation of Metal Specie in The Study

	Fe	Mn	Pb
Fe	**1**		
Mn	**.979****	**1**	
Pb	**.981****	**.999****	**1**

Bold values with **= Highly Significant (P < 0.01)

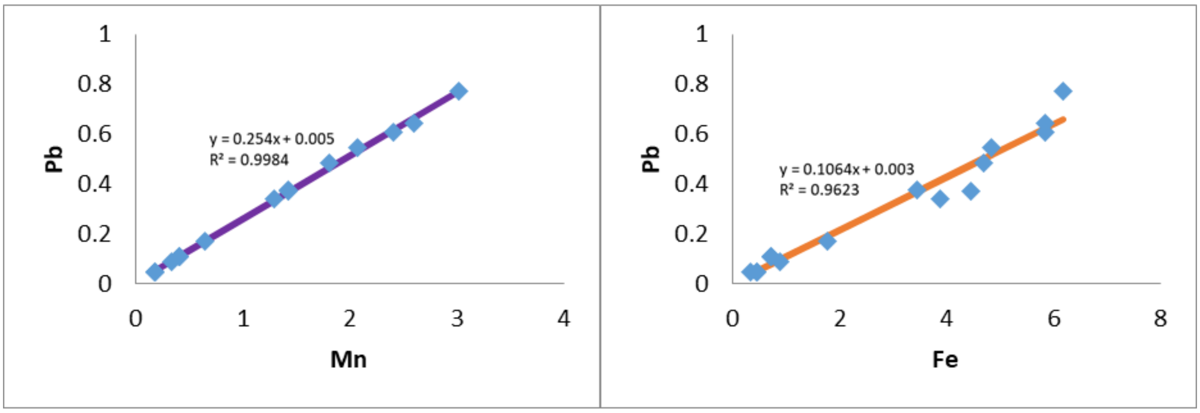

Figure 2a and b: regression analysis using Pb an independent variable

3.2 Biological Characteristics

Table 4 represents the results of the biological characteristics of Okerenkoko drinking water. The results indicates that all drinking water sources including the sachet water (SWO) and the rudimentary approach of boiling as a means of improvising for water treatment were impacted by bacteria and fungi species. The presence of bacteria and fungi in water indicates that the water is contaminated and may not be fit for consumption; ideally, drinking water should be free of biological contamination (Li et al. 2021; WHO; 2017; Isikhuemen and Omorogieva, 2015). The values of microorganisms recorded in the drinking water in the study area are worrisome and calls for urgent concern. For example, the lowest value of 2033 cfu/ml and 2000 cfu/ml for bacteria and fungi counts respectively were recorded in ZC in ZE grid (Fig. 1) against 0 cfu/ml specified by regulatory agencies (Table 4). The sources of microorganisms in water are mainly due to human and animal faecal; this was traced to the infiltration of septic tanks into the shallow aquifer and the frequent open defecation on soil and in the water bodies by the inhabitants of the community. The practice of open defecation in the study area and other communities in Gbaramatu coastal water ways is seen as norm because over 85% of houses build are without toilet facilities and about 50% of the houses with toilet facilities have no running water for flushing, hence the regular practice of open defecation the water bodies. Furthermore, the residents with standard toilet facility evacuate the contents of their respective septic tank directly into the creeks which eventually flow into the river and infiltrate through soil media into the shallow aquifer thereby contaminating the groundwater.

Table 4: Mean value of Bacteria and Fungi Counts

Sample Code	Bacteria Counts (cfu/ml)	Fungi Counts (cfu/ml)	SON (2015)	**WHO (2017)**
BW	4367	12567	0	**0**
SWO	2133	2100	0	**0**
GHO	18300	7000	0	**0**
SEO	11000	17600	0	**0**
OK0	7333	10950	0	**0**
HD	5467	6213	0	**0**
ZE	5600	5037	0	**0**
ZEO	5400	11067	0	**0**
CGH	5033	7967	0	**0**
DGH	3433	3133	0	**0**
OK	3067	6333	0	**0**
SE	2300	3033	0	**0**
ZC	2033	2000	0	**0**

Table 5: Bacteria and fungi isolates recovered from drinking water sources in Okerenkoko.

Bacterial Isolate	GHO	SEO	OK0	HD	ZE	ZEO	BW	CGH	DGH	OK	SE	SWO	ZC
Escherichia	+	+	-	+	+	+	-	-	-	-	-	-	+
Staphylococus epidermis	+	+	-	+	-	+	+	-	-	-	+	+	-
Streptococus Spp	+	-	+	+	+	-	-	-	-	+	-	+	-
Staphylococcus aureus	-	-	+	+	+	-	+	_	+	-	+	+	-
Fungi Isolate	**GHO**	**SEO**	**OK0**	**HD**	**ZE**	**ZEO**	**BW**	**CGH**	**DGH**	**OK**	**SE**	**SWO**	**ZC**
Trichoderma spp	-	+	+	-	+	+	+	-	-	-	-	+	-
Agergillus flavus	-	+	-	+	-	-	+	+	+	-	+	-	+
Ahergillus Niger	-	+	-	-	-	-	+	-	-	+	-	-	-
Penicillium Spp	+	+	-	+	+	+	-	+	-	+	+	+	+
Mucor	-	-	-	+	-	+	-	+	-	+	-	+	-

On isolation, the following species of bacteria; *Escherichia, Staphylococus epidermis, Streptococus Spp and Staphylococcus aureus* were recovered while *Trichoderma spp, Agergillus Flavus, Ahergillus Niger, Penicillium Spp* and *Mucor species* of fungi were recovered from the sampled drinking water sources in the study area (Table 5).

In the study area, *Escherichia coli* was absent in the following water sources*;* OK0, BW, CGH, DGH, OK, SE and SWO but present in GHO, SEO, HD, ZE, ZEO and ZC. On the other hand, *Staphylococcus aureus* was absent in GHO, SEO, ZEO, CGH, OK and ZC water sources but present in OK0, HD, ZE, BW, DGH, SE and SWO. In the Okerenkoko, the locals depend largely on water sourced from CGH, SE, ZE, and ZC as well as routinely boiled water (BW) and sachet water (SWO) imported from the nearest urban center (Warri) for drinking purpose. The presence of bacteria and fungi species couple with high level of heavy metal concentration in the drinking water may be responsible for the incessant complaints of stomach disorder, headache and fever by the inhabitants of the community. For example, *Escherichia coli* occur in abundance in the human and animals' intestinal wall but do not harm the host. However, *Escherichia coli* and *Staphylococcus aureus* can cause significant health challenge outside their original place of abode (WHO, 2017). The presence of *E. coli* in water can cause severe disease, like the meningitis, urinary tract infections and bacteraemia; while some strain like the enteropathogenic can cause acute diarrhoea. Symptoms may include; abdominal cramps, headache, mild watery diarrhea and nausea, as well as vomiting and fever in toddlers. Although humans factor is the only obvious sources of *E. Coli* in the drinking water but the high population of the community couple with the practice of open defecation, poor sanitation and hygienic environment, interaction of surface water with the shallow groundwater is a possibility (Omorogieva and Ogieriakhi, 2021; Nataro and Kaper, 1998 in WHO, 2017). The organism can be transmitted from infected person or animal to its victim as well as through the consumption of contaminated food and water. Like *E. Coli, Staphylococcus aureus* is either aerobic or anaerobic; they are non-motile and non-spore-forming, catalase, and are relatively widespread in the environment but are found mainly on the skin and mucous membranes of animals rather than the faecal and intestinal wall. Occasionally, it can be found in the gastrointestinal tract and in sewage. It can get into water bodies through swimming pools, surface water, and other recreational waters. The consumption of foods containing *S. aureus* toxins can lead to enterotoxin food poisoning within a few hours (Antai, 1987; LeChevallier and Seidler, 1980).

4. Conclusion

In this study, it was noted that anthropogenic activities in the study area influence the quality of drinking water. Evidence now abounds that the basic physical, biological and chemical parameters use in accessing the quality of drinking water compromised the acceptable global standard. It was noted with dismay that ZE grid in Zion environment was the most impacted. This grid command the highest population of the locals with the visible anthropogenic activities like direct discharge of hydrocarbon fraction into the surface water, regular practice of open defecation and engine emissions. Furthermore, ZE grid also represents the commencement of the community many years back. This study has demonstrated with scientific evidences that the incessant health challenge faced by the inhabitants of the study area can be traced to the poor drinking water quality, sanitation and hygiene condition. Government, community opinion leaders and all stakeholders should join hands to provide standard treatment tank in the study area and the adjoining communities.

Acknowledgements

We acknowledge the Government of the Federal Republic of Nigeria for establishing the Nigeria Maritime University in the study area, the platform in which the study was carried out. We also acknowledge our field support staff in the person of Orobosa Ekponwen Praise, Onoja Bethel and Ukachukwu Decency.

References

Adimalla N, Qian H, Nandan MJ. 2020. Groundwater chemistry integrating the pollution index of groundwater and evaluation of human health risks: a case study of hard rock terrain of south India. Ecotoxicology and Human Safety,

Akpoborie IA, Aweto KE, Ohwoghere-Asuma O. 2015. Urbanization and major ion hydrogeochemistry of the shallow aquifer at the Effurun - Warri metropolis, Nigeria. Environment and Pollution l: 4-11

Antai SP. 1987. Incidence of *Staphylococcus aureus*, coliforms and antibiotic-resistant strains of *Escherichia coli* in rural water supplies in Port Harcourt. Journal of Applied Bacteriology, 62:371–375.

APHA. 1995. Standard methods for the examination of water and wastewater Public Health Association. 20th.Washington, DC, USA.

American Public Health Association. 2005. Standard method for the examination of water and wastewater (21st edn). *Washington, DC: APHA-AWWA-WEF*.

Djaouda M, Lecke A, Maine MK, Wadoube Z, Liang S, Nola M, Njine T. 2018. Assessment of bacteriological quality of groundwater from boreholes in Maroua (Far North Cameroon). International Journal of Biological and Chemical Sciences,12 (2): 958-974.

Edegbai AJ, Schwark L, Oboh-Ikuenobe FE. 2019. A review of the latest Cenomanian to Maastrichtian geological evolution of Nigeria and its stratigraphic and paleogeographic implications. Journal of African Earth Sciences, 150:823-837

Efobo O, Ugbe FE, Akpoborie IA. 2020. Groundwater condition and hydrogeochemistry of the Sombreiro-Warri Deltaic plain deposit (Shallow Benin Formation) in the vicinity of Agbarho, Nigeria. J. Sci. Res. 12 (4), 633-643.

Falowo OO, Daramola, AO, Ojo OO. 2015. Geophysical investigation for groundwater potential in Rufus Giwa Polytechnic Owo, Southwestern Nigeria. The International Journal of Engineering and Science, 4 (11): 29-39.

Flemming, BW. 2005. Tidal Environments. Encyclopedia of Coastal Science. https://doi.org/10.1007/1-4020-3880-1_315

Khalid S, Shahid MN, Shah AH, Saeed F, Saeed MA, Qaisrani A, Dumat C. 2020. Heavy metal contamination and exposure risk assessment via drinking groundwater in Vehari, Pakistan. Environmental Science and Pollution Research.

LeChevallier MW, Seidler RJ. 1980. *Staphylococcus aureus* in rural drinking-water. Applied and Environmental Microbiology, 39:739–742.

Li P, Karunanidhi D, Subramani T, Srinivasamoorthy K. 2021. Sources and consequences of groundwater contamination. Archive of Environmental Contamination and Toxicology. https://doi.org/10.1007/s00244-020-00805-z

Manivaskam N. 2011. Physicochemical examination of water sewage and industrial effluent. 6th. Meerut, India: Pragati Prakashan.

Nataro JP, Kaper JB. 1998. Diarrheagenic *Escherichia coli*. Clinical Microbiology Reviews, 11:142–201.

Ogundana AK, Talabi A. 2014. Geoelectric characterization of aquiferous units and its implication on groundwater potential of Owo, South-western Nigeria. American Journal of Water Resources, 2 (2): 37- 40.

Omorogieva OM, Igberase VI. 2021. Comparative study of Leachate Characterization: Implication for Sustainable Environmental Management. International Journal of Earth Sciences Knowledge and Applications, 3: (3) 305-313.

Omorogieva OM, Imasuen O.I, Adanu EA, Tonjoh JA. 2022b. Hydrogeological and heavy metal assessment of abandoned borrow Pit and its impact on groundwater quality: Evidence from hydrogeology and geochemistry, Nigeria. Sustainable Water Resource Management, Sustainable Water Resources Management. https://doi.org/10.1007/s40899-022-00653-w

Omorogieva OM, Ogieriakhi OE. 2021. Assessment of Injection Wells (IWs) as a measure of flood control. Environmental Earth Sciences, 80: 495. https://doi.org/10.1007/s12665-021-09783-4

Omorogieva OM, Tonjoh AJ. 2020. Bioavailability of heavy metal load in soil, groundwater, and food crops Manihotesculenta and Carica papaya in dumpsite environment. Int. J. Environ. Sci. Technol. DOI 10.1007/s13762-020-02812-y

Omorogieva OM, Tonjoh JA, Brisibe, O. 2022a. Assessments of Heavy Metal Contamination in Groundwater Source from Benin Formation Aquifer in and around Dumpsite Environment, and its Impact on Human Health. J. Appl. Sci. Environ. Manage, 26: (2), 323-334.

Omorogieva OM, Ugwuja JC, Tonjoh JA, Ehinlaye AC. 2022c. Hydrogeochemical evaluation of the suitability of Coastal Groundwater under tidal influence for irrigation and drinking purposes. Journal of African Earth Sciences (Accepted for publication)

Plummer M, Best N, Cowles K, Vines K . 2008. Output Analysis and Diagnostics for MCMC in R, 2008. URL project.org/package= coda. R package version 0.13-3.

Rajmohan N, Elango L. 2005. Nutrient chemistry of groundwater in an intensively irrigated region of southern Indian. Environ. Geol, 47: 820-830.

Selinus O, Allowa B, Centeno JA, Finkelman RB, Fuge R, Lindh U, Smedley P. 2013 Essentials of medical geology (revised edition). Springer 805p

Singh KK, Tewari G, Kumar S. 2020. Evaluation of groundwater quality for suitability of irrigation purposes: A case study in the Udham Sing Nagar, Uttarakhand. Journal of Chemistry. https//doi.org/10.1155/2020/6924026

SON. 2015. Nigerian standard for drinking water quality. Nigeria Industrial Standard NIS-554-2015. https:// afric acheck. org/ wpcontent/ uploa ds/ 2018/ 06/ Niger ian- Stand ard- for- Drink ing- Water-Quali ty- NIS- 554- 2015. pdf.

Taylor MP, Schniering CA, Lanphear BL, John AL. 2010. Lessons learned on lead poisoning in children: one hundred years on from turners' declaration. Journal of Paediatrics and Child Health doi: io.lll/j.1440-1754.2010.01777.x

Tonjoh JA, Omorogieva OM. 2020. Assessment of Groundwater Quality and Saltwater intrusion in Benikrukru, Gbaramatu, Delta State, Nigeria. Nigeria Journal of Applied Science, 38:78-88

Ugwuja, Jennifer Chinwemma. 2022. Hydrogeochemical Evaluation of the suitability of Coastal Groundwater under Tidal Influence for Irrigation and drinking purposes in Okerenkoko Gbaramatu Kingdom, Delta State Nigeria. Unpublished Bachelors' thesis, Nigeria Maritime University, Nigeria, 49p

WHO. 2017. Guidelines for drinking-water quality. Fourth edition incorporating the first addendum, WHO, ISBN 978-92-4-154995-0.

WHO-UNICEF. 2000. Global water supply and sanitation assessment. Available online at www.who.int/water_sanitation_health/Globassessment/GlobalTOC.htm

Yusuf A, Olasehinde A, Mboringong MN, Tabale RP, Daniel EP. 2018. Evaluation of heavy metals concentration in groundwater around Kashere and its environs, upper Benue trough, Northeastern Nigeria. Global Journal of geological sciences, 16: 25-36.