Asian Journal of Environment & Ecology

Volume 22, Issue 3, Page 176-186, 2023; Article no.AJEE.106770
ISSN: 2456-690X

Quantitative Status of Indicator Bacterial and Heavy Metal of Groundwater in Some Coastal Areas of Akwa Ibom State, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJEE/2023/v22i3501

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/106770

Original Research Article

Received: 20/07/2023
Accepted: 25/09/2023
Published: 18/10/2023

ABSTRACT

This study evaluates the quality potential of groundwater in coastal areas of Akwa Ibom State, Nigeria. Thirty boreholes were sampled, and analyzed for heavy metals and biological parameters using routine techniques of groundwater studies. The study revealed bacterial contamination of groundwater in the area. Iron ranged from 0.0mg/l to 0.90mg/l; magnesium ranged from <0.01mg/l to 9.88mg/l; calcium ranged from <0.01mg/l to 20.78mg/l; *total coliform* bacteria ranged from 0.27MPN/100ml to 2400.01MPN/100ml; biochemical oxygen demand ranged from 0.1mg/l to 10.02mg/l. Mean BOD and COD were 0.76mg/l and 1.03mg/l respectively; mean *total coliform*,

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fecal coliform and *E-coli* bacteria were 530.65MPN/100ml, 557.24MPN/100ml and 113.17MPN/100ml respectively. The presence of bacterial coliform in the borehole water was attributed to poor waste disposal, surface run-off and perennial flooding in the area. The study showed that groundwater in the area is of poor quality and not suitable for drinking. Therefore, groundwater in the area should be treated to improve its quality before drinking.

Keywords: Boreholes; perennial flooding; anthropogenic activities; contamination; hazards; human consumption; public health.

1. INTRODUCTION

Water is the most abundant natural resource on earth that sustains all forms of life including human existence and development [1,2]. Water resources are also important resources agriculture and to virtually all production processes essential for human development. The demand for good quality water is on the increase all over the world as human population continues to increase with increasing advancement in human activities [1]. Global water budget has it that seawater accounts for 97%; while freshwater is 3% and of these only 1.3% is accessible for man's usage [1]. Today water resources are indeed under major stress around the world mainly due to anthropogenic activities.

Groundwater is the principal source of fresh water supply in both developed and developing countries, and it has been discovered that it is usually exposed to pollution due to anthropogenic activities and sea level rise [3,4]. Groundwater is polluted when harmful substances are released into aquifers to changes its physical, chemical and biological quality [1,3,4,5]. Therefore, groundwater should be carefully analyzed, as undiscovered harmful substances in the water could pose dangers to human health. The deleterious health effects associated with prolonged consumption of highly contaminated groundwater are well documented and include kidney and gastric disorder, typhoid, diarrhoeas, dysentery, hepatitis, cholera [6]. Water related diseases are the most critical health problems among the rural people of the Niger Delta of Nigeria and represents 80% of all illness in rural communities [1,2,3,6]. Increased human activities due to ppopulation growth in Akwa Ibom State may pose potential threats to safe and clean water supply, particularly in the coastal areas.Therefore, this study attempted to evaluate the quality potential of groundwater resources in some coastal areas of Akwa Ibom State, Nigeria for domestic and other purposes.

2. METHODOLOGY

2.1 Study area Description

The study area (Fig. 1.) comprises of the coastal areas located in the southern part of Akwa Ibom State, Niger Delta, Nigeria. It lies between latitudes $4^0$32' North and $5^0$33' North, and longitudes $7^0$25' East and $8^0$25' East. The area consists of ten local government areas (Fig. 1). The study area is a typical rainforest belt dominated by mangrove ecosystem, fresh water swamps and secondary vegetation, which has been considered to be among the most delicate in the world [7,8].

The aquifer of the study area is formed mainly by this hydrologic formation [9,10]. The aquifer in the area is recharge by the high annual rainfall of the area and has been classified into the upper, middle and lower aquifer system. Most of the aquifers are made up of silt and clay sand. Unconfined fresh water aquifer is dominant in the area and as such, most of the groundwater boreholes in the area are shallow wells [9,10], many of which are hand dug wells [10]. The aquifer is recharged through direct infiltration water from streams and rivers, and rain water that percolation through the soil during the rainy season. The aquifer system of the area is discharged through evaporation and water abstraction and pumping from drilled boreholes and dug wells [10].

2.2 Sampling and Analytical Methods

The sampling points and their codes are presented in Table 1. Thirty samples were collected from boreholes within the study area in accordance with stipulated guidelines and standards [11]. The groundwater samples were collected using suitable water samplers. The samples were collected as true representative of the actual groundwater supply source. The samples for heavy metal analysis were collected in sterilized plastic bottles with preservatives to avoid contamination.

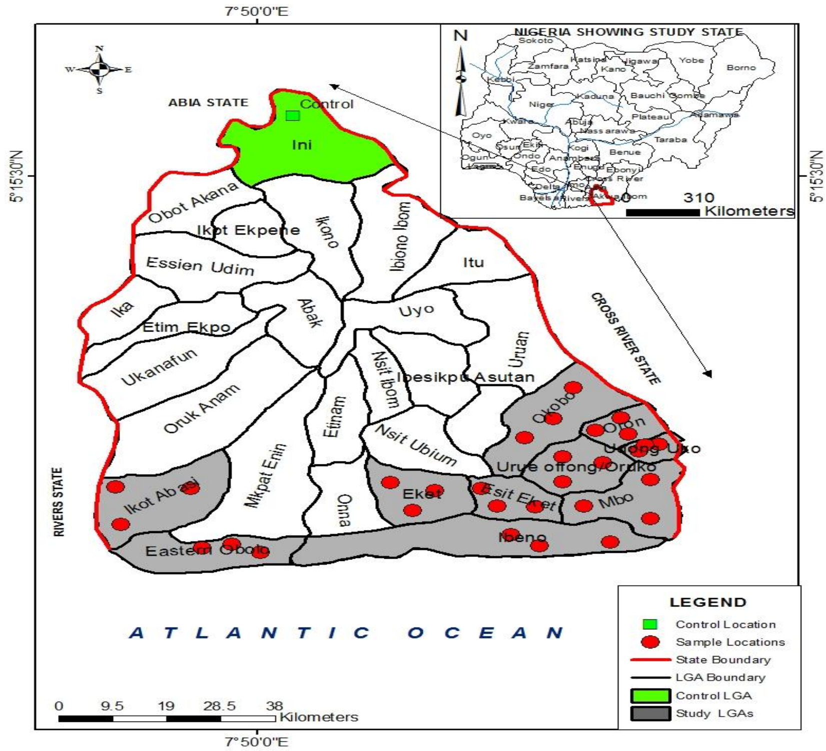

Fig. 1. Map of Akwa Ibom State showing study area

Biochemical oxygen demand (BOD) samples were collected in 250ml brown reagent (amber) bottles, sealed to exclude air bubble were fixed immediately with Winkler's I and II reagents. All samples were labelled, preserved in ice-parked cooler containers and transported to the laboratory for analyses. For bacteria analysis, about 200 to 500 centiliter hard glass bottles mounted with stoppers and thoroughly cleaned and sterilized were used.

Laboratory analysis of all the collected water samples were performed in accordance with standard acceptable methods and best practices [11]. Heavy metals and microbial parameters in the water samples were determined in an accredited laboratory. Heavy metals were determined using flame Atomic Absorption Spectrophotometer (AAS) duly calibrated with authentic standards. Microbial parameters were determined using analytical methods [12,13]. Known portion of the water samples collected is diluted with oxygenated water and incubated at 20°C for five days. At the end of the incubation period the samples were analyzed for bio-chemical oxygen demand (BOD).

All the data were aggregated, processed and statistically analyzed. The data were statistically analyzed using XLSTAT-2022 premium version software developed by [14]. The distribution of some heavy and biological parameters in the groundwater were performed using ArcGIS version 10.4. The values of the parameters obtained in the groundwater samples were compared with Nigerian Standard for Drinking Water Quality [15] and World Health Organization Guidelines for Drinking-water Quality [1].

3. RESULTS

The summary of the results showing the minimum, maximum, mean, and standard deviation of heavy metals and biological parameter in groundwater of the coastal are shown in Tables 2 and 3 respectively. Table 2 also shows the comparison of some heavy metals (calcium, sodium, magnesium, potassium, iron and zinc) in the groundwater with Nigeria Standard for Drinking Water Quality [15] and World Health Organization permissible standards [1].

The distribution of iron magnesium, calcium and sodium in groundwater of the study area are shown in Figs. 2 to 5; while the distribution of *total coliform* bacteria and biochemical oxygen demand in groundwater of the study area are shown in Figs. 6 and 7.

Table 1. Groundwater sampling points in study area

Sampling Point Code	Description of Sampling Points	Coordinates
WSP 1	Green Star Hotel (Ikot Abasi)	N04^{0} 34’. 160” E007^{0} 32’. 749”
WSP 2	Uta Ewa Village Waterside (Ikot Abasi)	N04^{0} 32’. 844” E007^{0} 32’. 904”
WSP 3	Market Square (Ikot Abasi)	N04^{0} 34’. 779” E007^{0} 33’. 102”
WSP 4	Iko Waterside Tap (Eastern Obolo)	N04^{0} 31’. 319” E007^{0} 45’. 273”
WSP 5	New Layout Okoroete (Eastern Obolo)	N04^{0} 32’. 587” E007^{0} 44’. 972”
WSP 6	Ayama Waterside (Eastern Obolo)	N04^{0} 32’. 189” E007^{0} 44’. 636”
WSP 7	Terminal Road (Ibeno)	N04^{0} 32’. 626” E008^{0} 00’. 062”
WSP 8	Catholic Road Creek (Ibeno)	N04^{0} 33’. 181” E007^{0} 59’. 964”
WSP 9	Upenekang Park Beach (Ibeno)	N04^{0} 34’. 109” E007^{0} 56’. 599”
WSP 10	Ibaka Waterside (Mbo)	N04^{0} 39’. 142” E008^{0} 18’. 809”
WSP 11	Isong Inyang Udesi (Mbo)	N04^{0} 42’. 033” E008^{0} 13’. 703”
WSP 12	Akai Egbughu Community Water (Mbo)	N04^{0} 41’. 387” E008^{0} 15’. 662”
WSP 13	Odighi Ilie Udung Uko Eyoatai (Udung Uko)	N04^{0} 45’. 932” E008^{0} 15’. 195”
WSP 14	Ediko Road by Bridge Eyo-oko (Udung Uko)	N04^{0} 44’. 628” E008^{0} 13’. 555”
WSP 15	Uboro Isong Inyang Oron-Udung Uko Road (Udung Uko)	N04^{0} 46’. 365” E008^{0} 14’. 207”
WSP 16	Oron Beach Bakibom (Oron)	N04^{0} 49’. 613” E008^{0} 13’. 916”
WSP 17	Customs Barrack Jetty (Oron)	N04^{0} 49’. 053” E008^{0} 14’. 892”
WSP 18	Uya-Oro Junction (Oron)	N04^{0} 47’. 761” E008^{0} 12’. 474”
WSP 19	Ataobong Waterside (Okobo)	N04^{0} 51’. 270” E008^{0} 10’. 640”
WSP 20	Odobo Road School Okopodi (Okobo)	N04^{0} 50’. 614” E008^{0} 07’. 709”
WSP 21	Odobo Road Atipa Odobo (Okobo)	N04^{0} 49’. 590” E008^{0} 06’. 524”
WSP 22	Edok Oruko-Eket Road (Urue Offong/ Oruko)	N04^{0} 42’. 800” E008^{0} 10’. 482”
WSP 23	Uboro Oro (Urue Offong/ Oruko)	N04^{0} 44’. 662” E008^{0} 10’. 784”
WSP 24	Secretariat Road Urue Offong Village (Urue Offong/ Oruko)	N04^{0} 45’. 152” E008^{0} 09’. 272”
WSP 25	Adiaha Uko Close Qua Ibo Church (Eket)	N04^{0} 40’. 663” E007^{0} 58’. 988”
WSP 26	First Baptist Church Grace Bill Road (Eket)	N04^{0} 38’. 526” E007^{0} 55’. 702”
WSP 27	Carwash Plaza Liverpool Road (Eket)	N04^{0} 38’. 247” E007^{0} 55’. 132”
WSP 28	James Town Road Ekpeneobo (Esit Eket)	N04^{0} 39’. 911” E008^{0} 01’. 480”
WSP 29	Assang Uquo by Security Estate (Esit Eket)	N04^{0} 39’. 987” E008^{0} 03’. 141”
WSP 30	Uruaokok Junction (Esit Eket)	N04^{0} 39’. 744” E008^{0} 06’.0422”

Table 2. Summary of heavy metals in groundwater of the study area

Parameter	Min.	Max.	Mean	SD	NSDWQ limit (2015)	WHO limit (2017)
Calcium, Ca (mg/l)	<0.001	20.78	2.38	5.12	75.0	75–200
Sodium, Na (mg/l)	0.89	10.35	5.93	3.38	200.0	200
Magnesium, Mg (mg/l)	<0.001	9.11	5.99	4.42	20.0	50–150
Potassium, K (mg/l)	0.2	11.92	2.43	2.37		12.0
Iron, Fe (mg/l)	<0.001	0.75	0.36	0.37	0.3	0.1
Zinc, Zn (mg/l)	<0.001	0. 0.11	0.03	0.04	3.0	5.0
Lead, Pb (mg/l)	<0.001	<0.001	<0.001	<0.001	0.01	0.05
Nickel, Ni (mg/l)	<0.001	<0.001	<0.001	<0.001	0.02	
Copper, Cu (mg/l)	<0.001	<0.001	<0.001	<0.001	1.0	1.0
Chromium, Cr (mg/l)	<0.001	<0.001	<0.001	<0.001	0.05	

SD = standard deviation

Table 3. Summary of bacteria parameters in groundwater of the study area

Parameter	***Total Coliform*** **(MPN/100ml)**	***Fecal Coliform*** **(MPN/100ml)**	***E. Coli*** **(MPN/100ml)**	BOD (mg/l)	COD
Min	1.10	20.00	3.00	0.1	0.15
Max	≥2,400	≥2,400	460	10.0	12.0
Mean	530.65	557.24	113.17	0.76	1.03
SD	458.01	478.58	120.89	1.78	2.13
NSDWQ limit	10.00	0.00	0.00	0.0	0.0
WHO limit	0.00	0.00	0.00	0.0	0.0

SD = standard deviation

Fig. 2. Iron concentration distribution map of study area

Fig. 3. Magnesium concentration distribution map of study area

Fig. 4. Calcium concentration distribution map of study area

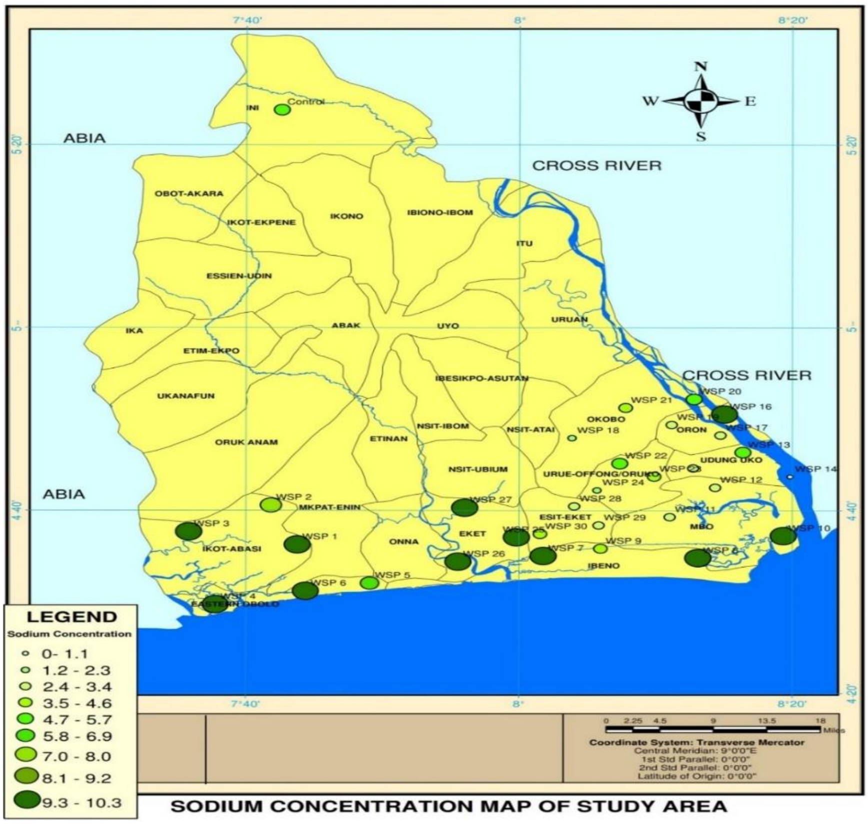

Fig. 5. Sodium concentration distribution map of study area

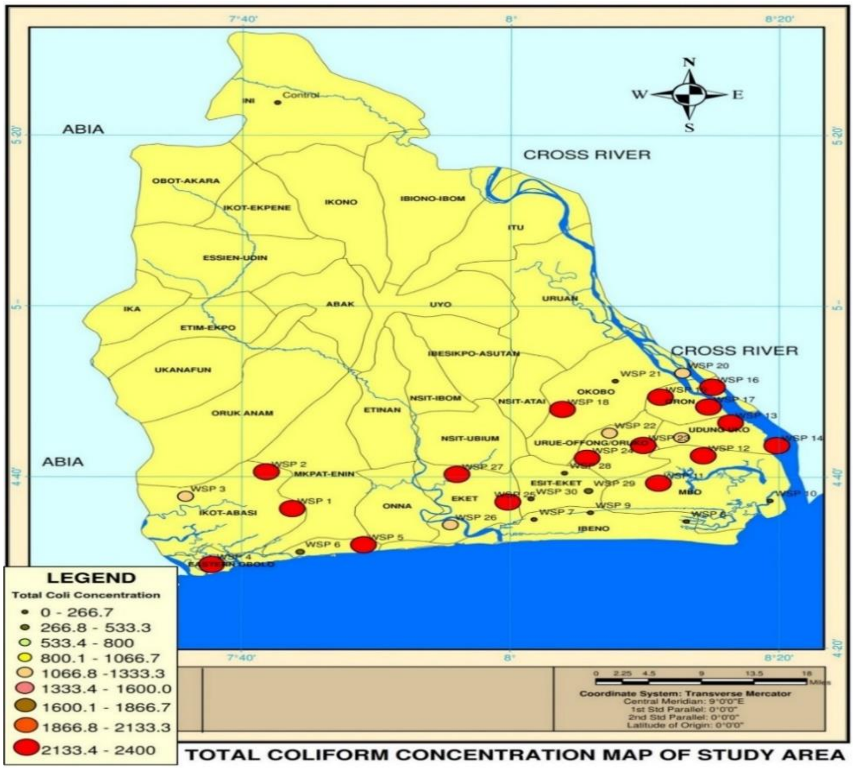

Fig. 6. Total coliform concentration distribution map of study area

Fig. 7. BOD concentration distribution map of study area

4. DISCUSSION

The spatial interpolated values of iron in the groundwater of the study area (shown in Fig. 2.) ranged from <0.01mg/l to 0.90mg/l. The highest interpolated value of iron was obtained in Eastern Obolo on the eastern part of the area. In a similar study, Beka et al. [9] reported iron concentrations ranging from 0.01mg/l to 8.5mg/l in groundwater in Akwa Ibom State; while [16] reported iron concentration as high as 0.38mg/l in groundwater in Port Harcourt. Again, in a similar study carried out by Nwankwo et al. [17] mean iron concentrations of 0.18 mg/l and 0.168 mg/l were obtained in groundwater in Ghana and Tanzania respectively. The spatial interpolated values of magnesium in groundwater of the study area (shown in Fig. 3.) ranged from <0.01mg/l to 9.88mg/l, which are below permissible limit. The maximum interpolated value (9.88mg/l) was found in well WSP 8 (Ibeno) on the eastern part of the area. These values agree with the studies by Edet [10] and Sokpuwu [18]. In another related study, Meride, and Ayenew [19] reported an average value of 13.67mg/l for magnesium in groundwater in Wondo Genet campus, Ethiopia.

The spatial interpolated values of calcium in the groundwater of the study area (shown in Fig. 4.) ranged from <0.01mg/l to 20.78mg/l, which are below permissible limit. The highest value was found around Oron Beach and Catholic Road Creek Ibeno. These values agree with the study by Edet (2017) who reported a calcium ranging from 0.1 to 26mg/l in groundwater in southern Akwa Ibom State. Also, Beka et al. [9] reported a calcium range of 33.4mg/l to 1.6mg/l in groundwater samples in Akwa Ibom State. In another similar study, Sokpuwu [18] reported an average Calcium value of 7.21mg/l in groundwater samples within Eleme, Rivers State; while Meride, and Ayenew [19] obtained calcium concentrations ranging from 2.2mg/l to 7.3 mg/l in groundwater in Wondo Genet campus, Ethiopia. The spatial interpolated values of sodium in the groundwater of the study area (shown in Fig. 5.) ranged from 1.1mg/l to 10.3mg/l. The maximum interpolated value of sodium (10.3mg/l) was found at well WSP 26. As indicated in Fig. 5., low sodium levels were observed around Esit Eket, Urue-Offong/Oruku, Okobo and parts of Oron and Mbo located within the eastern part of the coastal area. Maximum sodium levels were observed around the Eket and Oron located border areas to the Atlantic Ocean and its major tributaries as shown in the sodium spatial distribution in Fig. 5. This shows the possible migration of sodium contaminants from the Atlantic Ocean towards the coastal groundwater system. In similar studies, Edet [10] reported a sodium concentration ranging from 0.6 to 120mg/l in groundwater in southern Akwa Ibom State.

It is evident from Table 2 that calcium, sodium, magnesium, potassium concentrations in the groundwater are below permissible limits. The groundwater in the area is generally characterized by low concentrations of calcium with the exceptions of Oron Beach Area and Catholic Road Creek Ibeno. In related studies, Beka et al. [9]; Edet [10]; Sokpuwu [18] reported similar range of these chemical parameters in groundwater of the Niger Delta region including Akwa Ibom State. Magnesium is a natural constituent of groundwater [19]. Meride, and Ayenew [19]; Saha et al. [20] have identified other likely sources of magnesium in groundwater as dolomite decomposition, serpentine, magnetite, montmorillonite and ferromagnesian minerals among others. Also, Saha et al. [20] attributed the likely sources of sodium in groundwater to agricultural by-products and the weathering of silicate and halite minerals like feldspar. Potassium may be cause by chemical breakdown of silicates and clay minerals or enter groundwater through the use of fertilizer and the decomposition of animal waste [20]. Iron concentrations were high in many of the groundwater boreholes. The mean value of iron in the groundwater ((Table 2) exceeded Nigerian permissible limit by 150% and WHO limit by 650%. In related studies, Beka et al. [9]; Ukpaka and Ukpaka [16] reported high iron concentrations in groundwater in Akwa Ibom State and Port Harcourt City respectively. This implies that the groundwater in the Niger Delta region is generally high in iron. The concentrations of zinc in the groundwater samples were generally low below permissible limits (Table 2).

The spatial interpolated values of *total coliform* bacteria in the groundwater of the study area (shown in Fig. 6.) ranged from 0.27MPN/100ml to 2400.01MPN/100ml. These findings corroborate the study of Beka et al. [9] who obtained an average *coliform* level of 0.17cfu/ml in groundwater in Akwa Ibom State. This suggests the possible presence of *fecal coliform* and *E-coli* bacteria in groundwater of the coastal area [19]. High values of *coliform* bacteria were interpolated for groundwater boreholes around Esit Eket, Ibeno, Oron, Eastern Obolo, and Mbo on the Eastern part of the coastal area. The contamination of the groundwater in the area might have been caused by the perennial flooding of the area by the Atlantic Ocean tributaries (Water bodies), which may result in the seepage of bacteria in the groundwater [9]. The spatial interpolated values of BOD in groundwater of the study area (shown in Fig. 7.) ranged from 0.1mg/l to 10.02mg/l. Biochemical oxygen demand refers to the amount of dissolved oxygen used by microorganisms when decomposing organic matter [5]. It determines the amount of biodegradable organic matter present in the groundwater samples [5,21]. According to NSDWQ and WHO guidelines and standards, groundwater sources used for consumption should contain no BOD (i.e. BOD = 0mg/l). The high distribution of BOD in the groundwater of the area could be caused high human activities as some of the areas are densely populated. Specific possible causes of BOD in groundwater of the coastal area may be leachate from decomposed organic waste, perennial flooding, high precipitation and surface runoff penetration [22].

Bacterial coliform (*total coliform, fecal coliform* and *E-coli*) were detected in the groundwater (Table 3). This finding corroborated the study of Beka et al. [9] who also found bacterial *coliform* in groundwater in Akwa Ibom State. This may be caused by perennial flooding and surface runoff that conveys human faeces from upland area to the coastline causing the contamination of the groundwater. There is also the likelihood of the groundwater contamination due to the practice of poor waste disposal and the proximity of septic discharge pits to the groundwater sources in the area [9]. BOD and COD concentrations were detected in the groundwater samples (Table 3), which indicates the likelihood of the presence of microorganisms in the groundwater of the area [22]. Bacterial coliform, BOD and COD in the water samples can be attributed to perennial flooding and discriminating waste disposal resulting in bacterial contamination of the groundwater in the area [10]. The presence of BOD and COD in the groundwater of the coastal area may be an indication of organic pollution, the leaching and percolation of organic and inorganic matters into aquifers [5,22].

The low concentrations of calcium Sodium, calcium, magnesium, and potassium obtained in the groundwater boreholes in the area pose no immediate risk to human health. Sodium, calcium, magnesium, and potassium are vital for the proper functioning of the human body [19]. Potassium helps to regulate blood pressure, protect the heart and prevent the contraction of muscle, and its deficiency can cause muscle weakness, depression and high rate of heart beat. The levels of magnesium and calcium in the groundwater could serve as a good source of supplements requirement by people suffering from sleep related ailments [23]. The presence of coliform bacterial, BOD and COD indicates that the groundwater in the coastal area is contaminated and not safe for human consumption. The contamination of the groundwater by *fecal coliform* and *E. coli* bacteria portends serious health risks. People in the coastal areas may be at high risk of waterborne diseases such as gastroenteritis, dysentery, diarrhea, cholera, and typhoid fever, among others [19,24].

5. CONCLUSION

The study revealed high iron concentration in groundwater of the study area, which exceeded permissible limits and not suitable for human consumption without treatment.

The study further revealed that the groundwater in the coastal zone is contaminated with bacterial coliforms, resulting in BOD and COD levels. This is of serious health concern as drinking bacterial contaminated water sources may pose hazards to public health in the area. Thus, the inhabitants of this coastal area may be at health risks from waterborne diseases such as diarrhea, cholera and typhoid fever.

It is necessary to treat groundwater in the area to improve its quality as the dwellers depend on it for drinking-water. Hence, the need for intervention by both local and state government authorities. Government intervention measures should include the establishment of water treatment plants. Awareness should be created among the inhabitants of this area on the risk of continuous drinking of contaminated groundwater. They should be encouraged to boil their water before drinking and to practice good sanitation by disposing their wastes properly. Finally, it is recommended to continue conducting studies on groundwater resources in the coastal zone.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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