The Physico-Chemical Characteristics of Groundwater Quality in Some Coastal Areas of Akwa Ibom State

Abstract

This study analyzedthe physico-chemical characteristics of groundwater qualityin some coastal areas of Akwa Ibom State, Nigeria.The study utilized primary data obtained from thirty boreholes in the area. The primary data consist of water quality parameters obtained from laboratory analysis of collected groundwater samples in the study area. Spatial distribution of groundwater constituents was carried out using ArcGIS 10.4 software. The result indicated that thegroundwater in the coastal areas id acidic (pH ranges from 3.9 to 6.4); chlorideranges from2.0mg/l to 52.0mg/l; total dissolved solidsranges from 4.8mg/l to 128.2mg/l; nitrate ranges from <0.01mg/l to 10.0mg/l; and turbidity ranges from 1.0NTU to 3.11NTU. The result also indicates that the groundwater is saline (salinity level range from 4.32mg/l to 85.8mg/l);turbidity at some locations also exceeds permissible standards.The study revealed that the quality of groundwater in the coastal areas ispoor and not suitable for human consumption acidic and saline. Therefore, the groundwater in the coastal areas should be treated for acidity and salinity before domestic use.

Keywords:Borehole, chloride, Salinity, turbidity,acidity, saltwater intrusion

1. Introduction

Good quality water is strongly associated with good health, comfort and social well-being of people. Because of this, one of the targets of Sustainable Development Goals (SDG) is to provide access to safe drinking water by the year 2030 [1]. It has been reported that approximately 80% of all sicknesses and deaths in rural communities in most developing countries is caused by drinking polluted water caused by human activities [2, 3, 4]. This is because many people in rural communities have no access to adequate potable water in many regions of the world, as most of their sources of water supply are polluted [1 4]. Pollutants can leak from landfills, damage underground tanks, septic tanks, cesspits and percolate through the soil into groundwater aquifer. Fertilizers, pesticides and other chemicals used in agriculture can permeate through the soil to pollute groundwater system. Polluted groundwater poses serious threat to public health, as poor quality of water tremendously increase the levels of contagious waterborne diseases [5]. It has also been reported that about 3.1% of people die globally as a result of drinking contaminated water[6]. In a study on physico-chemical properties of ground water quality Ahmad and Mishra[7] found that the groundwater in various locations of Kanpur City is of very poor quality and is not suitable for drinking.

The rise in sea level due to climate change may cause the movement of saline seawater inland leading the encroachment of the seawater into the groundwater aquifers in coastal areas. This may lead to the contamination of ground water supply sources in the areas[8]. The groundwater aquifers in the low-lying coastal areas of Akwa Ibom State in the Niger Delta Region may be vulnerable sea water intrusion as the areas border the banks of the Atlantic Ocean. This may most likely impacts on the quality of groundwater in the coastal areas. In many developing countries such as Nigeria, people dependhighly on groundwater as a source of water supply for domestic and other uses [9]. Most of the rural communities obtain their water supply from boreholes, hand pumps and dug wells [2, 10]. Many of these water supply wells are installed as standalone in communities, individual homes, schools, and other institutions.More recently, the problems of groundwater pollution have been on the increase in the Niger Delta Region [11, 9, 12]. Some parts Akwa Ibom State have been reported to have upper unconfined aquifer with high static water levels.Aquifers in the Niger Delta states, including Akwa Ibom State have been contaminated mostly due to human activities [13, 14, 15, 16].The objective of the study was to determine the physico-chemical characteristicsof groundwater quality in the coastal area of Akwa Ibom State to assess its suitability for domestic purposes.

2. Materials and Methodology

2.1 Description of the Study Area

The map of Akwa Ibom State showing the coastal areasis shown in Figure 1. It lies between latitudes $4^0$32' and $5^0$33'north, and longitudes $7^0$25' and $8^0$25' east. It is bounded to the north by Abia State, to the south by the Atlantic Ocean, to the east by Cross River State and to the west by Rivers State. The area is located in the tropical rainforest of the Niger Delta region and the area experiences a tropical climate that consists a rainy season that lasts from May to October and a dry season that lasts from November to April [17, 18]. There are creeks, and swamps due to the influence of the Atlantic Ocean. The humid tropical climate of the area is characterized by moderate temperature and high humidity. The climatic condition of the area favours teeming populations of fauna, flora and high terrestrial and aquatic biomass.

2.2 Geology and Hydrogeology of the Study Area

The coastal areas belong to the Benin Formation, with a total thickness of 1892 meters, which is overlain by elevated alluvial deposits, beach ridges and coastal plain sand and as such much of the terrace is cultivated. Due to the fact that, the underlying geology of the state is predominantly coastal plain sediments, its landscape is mostly flat terrain. According to Ajayi and Umoh[19], the area has four physiographic units namely: - escarpment (tertiary sand/sandstones), coastal plain (tertiary sand), coastal and alluvial swamps and bead, ridge complex. Edet[20] and Esuet al. [21] stated that the area is underlain by sedimentary formation of late tertiary and Holocene ages. The layer of recent alluvium and beach ridge sands occur along the coast and the estuaries of the area and also, along the floodplains of creeks. Inland, a greater part of the state consists of coastal plain sand, now weathered into lateritic layers, especially, in Ikono, Etinan, IkotEkpene, Ibeno and Itu LGAs.

2.3 Sampling and Analytical Methods

The names of the sampling points and their codes are shown in Table 1. Thirty waters samples were collected from groundwater boreholes within the study area. Sampling was carried out using appropriate water samplers in accordance with stipulated guidelines and standards [22]. True representatives of the real groundwater supply source in the area were collected using sterilized plastic bottles with preservatives to avoid contamination. For physico-chemical analysis, the samples were collected using thoroughly cleaned 1-litre plastic bottles fitted with stoppers. The bottles were first sterilized with sulphuric acid and then thoroughly rinsed with distilled water. All the samples were labelled, preserved in ice-parked cooler containers and transported to an accredited laboratory for analyses.

The data were analyzed statistically using XLSTAT-2022 premium version software developed by Addinsoft[23]. Descriptive statistic was used to determine the minimum, maximum, mean, and standard deviation of the data. The mean values of the data were compared with Nigerian Standards for Drinking Water Quality [24]and World Health Organization Guidelines for Drinking- water Quality[1]. The distribution of some physic-chemical parameters in the groundwater were performed using ArcGIS version 10.4.

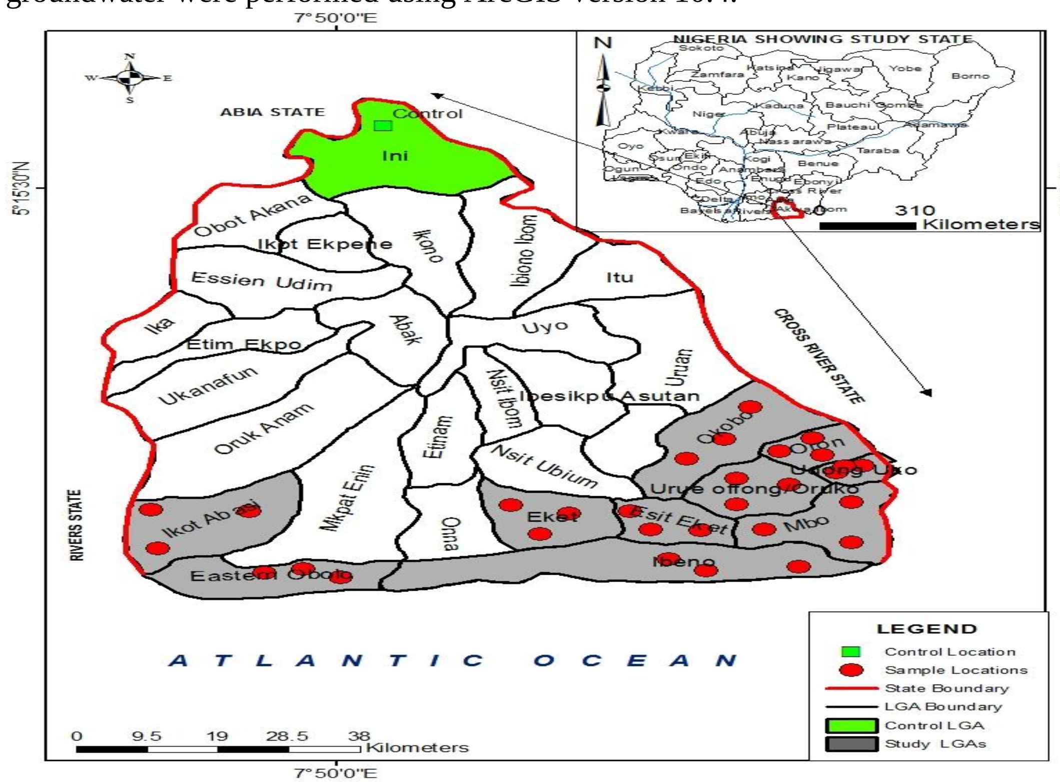

Figure 1: Map of Akwa Ibom State showing Study Area

Table 1: Groundwater Sampling Points in Study Area

Sampling Point Code	Description of Sampling Points	Coordinates
WSP 1	Green Star Hotel (IkotAbasi)	N04^{0} 34’. 160” E007^{0} 32’. 749”
WSP 2	UtaEwa Village Waterside (IkotAbasi)	N04^{0} 32’. 844” E007^{0} 32’. 904”
WSP 3	Market Square (IkotAbasi)	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	IsongInyangUdesi (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	OdighiIlieUdungUkoEyoatai (UdungUko)	N04^{0} 45’. 932” E008^{0} 15’. 195”
WSP 14	Ediko Road by Bridge Eyo-oko (UdungUko)	N04^{0} 44’. 628” E008^{0} 13’. 555”
WSP 15	UboroIsongInyangOron-UdungUko Road (UdungUko)	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 AtipaOdobo (Okobo)	N04^0 49'. 590" E008^0 06'. 524"
WSP 22	EdokOruko-Eket Road (UrueOffong/ Oruko)	N04^0 42'. 800" E008^0 10'. 482"
WSP 23	UboroOro (UrueOffong/ Oruko)	N04^0 44'. 662" E008^0 10'. 784"
WSP 24	Secretariat Road UrueOffong Village (UrueOffong/ Oruko)	N04^0 45'. 152" E008^0 09'. 272"
WSP 25	AdiahaUko 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 (EsitEket)	N04^0 39'. 911" E008^0 01'. 480"
WSP 29	AssangUquo by Security Estate (EsitEket)	N04^0 39'. 987" E008^0 03'. 141"
WSP 30	Uruaokok Junction (EsitEket)	N04^0 39'. 744" E008^0 06'.0422"
CWSP	Ini LGA	N5^0 24' 00" E 7^0 44'0 0"

WSP = water sampling point, CWSP = control water sampling point

3. Results and Discussion

The summary result showing the minimum, maximum, mean, and standard deviation of analysis of the physic-chemical parameters in groundwater of the coastal area is shown Table 2. A plot of borehole depths in the study area is shown in Figure 2; while the water tables are shown in Figure 3. Borehole depths obtained in the study area (Figure 2) ranged from 72m to 120.8m with an average of 104.2m. Similarly, the static water levels in the area (Figure 3) ranged between 2.5m and 11.7m with an average of 7.8m. Groundwater in the study area were obtained from shallow wells, medium to deep wells, while, the water tables were high. Wells WSP2, WSP7, WSP22, WSP23 and WSP24 have water levels less than 5m, while others range between 6m and 15m. Groundwater around UtaEwa in IkotAbasi, Mkpanak,inIbeno, EdokOruko in UrueOffong/Oruko, Uboro Oro in UrueOffong/Oruko and UrueOffong in UrueOffong/Oruko are more susceptible to bacteria contamination.

Table 2: Summary of Physico-chemical Characteristics of the Coastal Groundwater

Parameter	Min	Max	Mean	Stdv	NSDWQ limit	WHO limit
pH	4.00	5.80	4.69	0.54	6.5-8.5	6.0-9.0
Cond. (µs/cm)	8.7	233	54.82	52.31		400
Temp.(^{o}C)	24.91	29.19	26.73	1.11		
Turbidity (NTU)	1.0	3.0	1.70	0.75	1	5
Chloride, Cl^- (mg/l)	2.0	52.0	11.9	9.8	250	250
Hardness (mg/l)	2.0	47.0	10.83	10.44	200	500
Res. Chlorine (mg/l)	0.01	0.09	0.03	0.03	0.4	0.5
Salinity (mg/l)	3.3	85.8	21.17	17.78		
Acidity as $CaCO_3$ (mg/l)	3.0	1.7	0.61	0.37		
Alkalinity as $CaCO_3$ (mg/l)	5.0	55.0	13.33	12.4		
Nitrite, NO_2^-(mg/l)	<0.001	<0.001	<0.001	<0.001		
Nitrate, NO_3^-(mg/l)	<0.001	10	1.08	2.25	10	11

Sulphate, SO_4^{2-} (mg/l)	0.0	4.0	0.47	0.94	500	400
Phosphate, PO_4^{2-} (mg/l)	0.001	0.68	0.23	0.22	5	
TSS (mg/l)	1.0	8.0	2.2	1.58	10	
TDS (mg/l)	5.0	128.15	30.18	28.74	500	600
Oil and Grease (mg/l)	<0.001	<0.001	<0.001	<0.001		

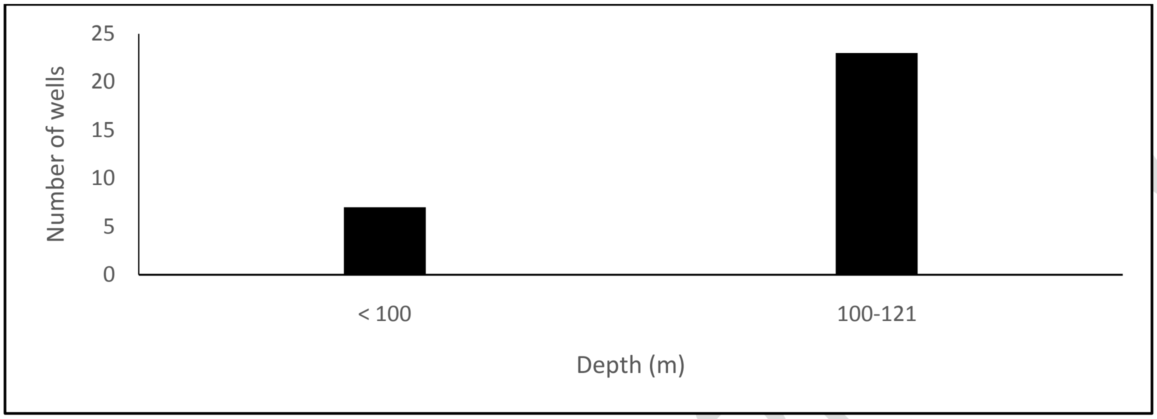

Figure 2: Groundwater Borehole Depths in the Study Area

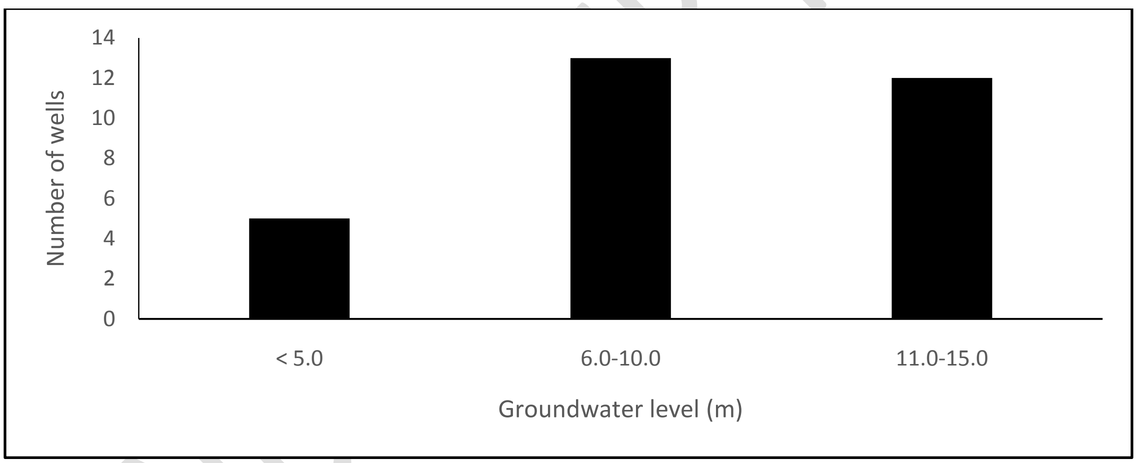

Figure 3: Groundwater Borehole Water Levels in the Study Area

pHdistribution of in groundwater of the Study of Area

The range of pH in groundwater resources of the area in comparison with permissible limits is shown in Table 2; while the distribution of pH inthe groundwater is shown in Figure 4. Thevalues of pH in the waterranged from 4.0 to 5.8 with mean deviation of 4.69±0.54.Figure 4 shows low values of pH around Eket and EsitEket and UdungUko areas; while higher values are observed around IkotAbasi, Urue-Offong/Oruko, Oron, Mbo and Okobo areas. The highest values are observed around the border areas (Ibeno and Eastern Obolo) closer to the Atlantic Ocean (Figure 4). There is a gradual decreasing pattern of pH values in the water from the coast towards the hinterland, suggesting likely saline incursion at the coast, which makes groundwater there less acidic.The groundwater in the coastal area is dominantly acidic, with pH values less than 6.0, which are below the minimum acceptable levels by NSDWQ[23] and WHO[25].The pH values in this study are in agreement with similar by Adedejiet al. [13], Beka et al.[11] and Edet[9].

Figure 4: pH Concentration Distribution Map of Study Area

Chloride in groundwater of the Study Area

The range of chloride in groundwater of the area in comparison with permissible limits is shown in Table 2. The chloride values in the water ranged from 2.0mg/l to 52.0mg/l with a mean deviation of 11.9±9.8mg/l. The distribution of chloride in the water is shown in Figure 5. Minimum values of chloride are observed around EsitEket, Urue-Offong/Oruku, Okobo and parts of Oron, while the maximum value of 52.0mg/l was obtained in well WSP16, which is at the border area to the Atlantic Ocean. This shows migration of chloride contaminants from seawater of the Atlantic Ocean towards the coastal groundwater system. Adedejiet al. [13] reported chloride concentrations of 5.0 mg/l to 9.4mg/l in groundwater in Akwa Ibom State; also, studies by Bekaet al. [11] and Edet[9]showed mean chloride concentrations of 40.0mg/l and 26.1mg/l respectively in groundwater in the State. Usually, the chloride concentration in groundwater is less than 30mg/l [26],except where there is saltwater intrusion [11, 27]. The saltwater incursion may be as a result of rising sea level due to climate change as the study area is located along the coastline [11, 26].

Figure 5: Chloride Concentration Distribution Map of Study Area

Total dissolved solidsand Total suspended solids in groundwater of the Study Area

The levels of total dissolved solids (TDS) obtained in groundwater of the area (Table 2) ranged from 5.0mg/l to 128.15mg/l with a mean deviation of 30.18±28.74mg/l; while The concentrations of total suspended solids (TSS) in the groundwater (Table 2) ranged from 1.0mg/l to 8.0mg/l with a mean deviation of 2.2±1.58mg/l. These values are below both NSDWQ and WHO permissible limits. The distribution of TDS in the groundwater is shown in Figure 6. The maximum value of 128.15mg/l was obtained at well WSP 16. Lowest TDS values were observed around EsitEket, Urue-Offong/Oruku, Okobo, parts of Oron and Mbo located on the eastern part of the coastal area. High values were obtained around the border areas (Eastern Obolo, Ibeno) to the Atlantic Ocean and around Eket and Oron as shown in Figure 6. The levels of TDS in this study are in agreement with the work of Adedeji et al.[13], who obtained a TDS range of 4.72 to 86.75g/l in groundwater samples in Uyo, Akwa Ibom State; and Sokpuwu[12]who obtained an average TDS of 106.48mg/l in groundwater samples in a coast area of neighbouring Rivers State. The results are also in tandem with the works of Bekaet al. [11] who obtained 12.63 and 147.2mg/1. In a similar study, Edet[9] obtained an average TDS of 177.90mg/l in groundwater in southern Akwa Ibom State. It is also shown in Table 2 that TSS levels are within permissible limit. The highest value (8.0mg/l) of TSS was obtained at well WSP 4. The levels of TSS obtained in the groundwater agree with the works of Edet [9],Bekaet al.[11], and Sokpuwu [12]. Adedeji et al. [13].

Figure 6: TDS Concentration Distribution Map of Study Area

Salinity in groundwater of the Study Area

The concentration levels of salinity obtained in the groundwater of the area (Table 2) range from 3.3mg/l to 85.8mg/l with a mean deviation of 21.17±17.78mg/l. The distribution of salinity in the groundwater is shown in Figure 7. The highest value of 85.8mg/l was observed in well WSP 16 followed by well WSP 20 (83.62mg/l). The presence of salinity in the groundwater samples is an indication of sea water intrusions into the coastal groundwater aquifer due to rise in sea level caused by climate change[26 - 28]. As shown in Figure 7, low salinity levels are observed around EsitEket, Urue-Offong/Oruku, Okobo and parts of Oron and Mbo, while high levels were observed around the border areas to the Atlantic Ocean and around Eket and Oron. This shows a migration of seawater from the Atlantic Ocean towards the coast. Higher sea level results in increased seawater intrusion crossing the transition boundary [8, 27-31]causing salinity to continue its inland intrusion into the groundwater of coastal areas. Areas with shallow aquifers are more vulnerable to saltwater intrusion. Salinity in the groundwater is generally proportional to the levels of total dissolved solids and the conductivity of the water [8, 30]. The rising sea level due to climate change accounts for the level of salinity in the groundwater of the study area. Bjerklieet al.[28]have also linked rising salinity of groundwater in coastal areas with corrosion of materials and structures, such as metal conduit pipes, sewer, and electrical utilities. The level of salinity in the water samples around wells WSP3, WSP 8, WSP16 and WSP20 indicates that the groundwater in these areas is not fit for drinking.

Figure 7: Salinity Concentration Distribution Map of Study Area

Nitrate, sulphate and phosphate in groundwater of the Study Area

Nitrate, sulphate and phosphate levels are within permissible limits (Table 2). The groundwater is generally characterized by very low concentrations of Nitrate, Sulphate and phosphate. In a related study, Edet[9]reported range of nitrate, sulphate and phosphate in some groundwater samples in southern Akwa Ibom. The distribution of nitrate in the groundwater is shown in Figure 8. The highest nitrate value, which falls on the threshold of NSDWQ limit was obtained at well WSP 8 (Ibeno area). Sulphate was obtained in 8 (27%) out of the 30 sampled boreholes, the highest was obtained in well WSP 16 (Oron Beach Bakibom). Nitrate, sulphate and phosphate concentrations observed in groundwater of the area may be due to human activities, such as the use of chemical phosphorus fertilizer for agriculture, industrial and domestic effluents or human sewage [33]. According to Sahaet al. [26] the low concentrations of sulphate may be an indication of the presence of bacteria in the groundwater. Globally, nitrate pollution of groundwater is a major environmental concern as it is one of the most common chemical contaminants of groundwater [31 - 32].

Figure 8: Nitrate in Concentration Distribution Map of Study Area

Turbidity in the groundwater of the Study Area

The levels of turbidity in groundwater of the area (Table 2) ranged from 1.0NTU to 3.0NTU with a mean value of 1.7±0.75NTU. The distribution of turbidity in the water is shown in Figure 9. The values of turbidity in the water exceededNSDWQ limit but below WHO permissible limit. The highest value was obtained at Eket, EsitEket and Mbo areas on the East of the coastal area. The level of turbidity in groundwater of the study area could be caused by impact of surface run-off into the coastal aquifers[28].

Conductivity level of groundwater in the Study Area

The conductivity levels of the groundwater ranged from 8.7µs/cm to 233µs/cm with a mean deviation of 54.82±52.31µs/cm. This result is in agreement with the studies by Edet[9], Beka et al. [11], and Adedeji et al.[13].Conductivity levels in groundwater are caused by high ions concentrations from dissolved solids [9, 11, 13]. The conductivity levels in the groundwater are within WHO limit for drinking water.

Temperature levels of groundwater in the Study Area

The temperature level of the groundwater (Table 2) ranged from 24.91^0C to 29.19^0C with a mean deviation of $26.73±1.11^0$C. The temperature levels of the groundwater samples were relatively homogeneous, this is consistent with study carried out by Edet[9], Beka et al. [11], and Adedejiet al. [13]on groundwater in AkwaIbom State. It is also consistent with study carried out by Sahaet al. [26] on groundwater in Tista, Bangladesh. The high temperature levels of the groundwater along the coastline may be due to perennial flooding and seawater incursion into the groundwater.

Figure 9: Turbidity Concentration Distribution Map of Study Area

Hardness levels of groundwater in the Study Area

The hardness levels of the groundwater are within permissible standards as indicated in Table 2. In related studies, Edet[9], Beka et al. [11], and Adedeji et al. [13]obtained similar range of hardness levels in groundwater boreholes in southern Akwa Ibom State. The level of hardness in the groundwater samples suggests that the water is soft or freshwater in nature [12, 26].

5. Summary and Conclusion

This work indicates that groundwater of the coastal areas studies is acidic, turbid and saline, thus, not suitable for human consumption without treatment. The pH values are less than 6.0., which are below the minimum acceptable levels. The water should be treated for these parameters to improve its quality. The pH can be improved to acceptable standard by liming method.

Chloride levels (2.0mg/l and 52.0mg/l and salinity levels (3.3mg/l to 85.8mg/l) are indication of seawater intrusions into the groundwater due to rise in sea level caused by climate change. The shallow aquifers of the area are more vulnerable to saltwater intrusion. High chloride concentrations in the groundwater can make it unpalatable and, thus, not fit for human consumption. Also, high concentration of chloride is capable of corroding metal pipes and structures as well as causing damage to agriculture crops. Total dissolved solids were high in some locations, which also contributed to the high levels of salinity and conductivity obtained in the groundwater. Salinity in the groundwater is generally proportional to the levels of total dissolved solids and the conductivity of the water. The levels of salinity of groundwater in the area is not suitable for drinking, and capable of corroding of materials and structures, such as metal conduit pipes, sewer, and electrical utilities.

Also, the levels of acidity, alkalinity and conductivity suggest that the groundwater may be corrosive to metals and capable of attacking metal conduits or pipes. The level of hardness in the groundwater samples suggests that the water is soft or freshwater in nature. The low levels of nitrate, sulphate and phosphate in the groundwater may not pose risk to human health.

Generally, the study shows that the groundwater in the area is contaminated mineral salts and not suitable for human consumption. Therefore, to safeguard public health, treatment is recommended. Regular monitoring of groundwater quality in the area is required.

Conflict of interest: the authors have declared that no competing interests exist.

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