Impacts of Contaminants on Groundwater Quality in Rukpokwu, Delta Region of Nigeria

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Abstract: This study investigated the characterization of borehole sediment and the impact of contaminants on groundwater quality in the Rukpokwu Community in the delta of Nigeria. The investigation supported by spatial data supported by GIS techniques provides a data baseline for the monitoring of organo-contaminants in groundwater quality in Rukpokwu. This low pH of the groundwater and irritation of the throat and mouth became a concern to the residents. This study is necessary because of the limited data on the level of organic contamination in groundwater in this section of the delta of Niger in Nigeria. So, there was a need to track the source of contamination in this part of the delta of Niger in Nigeria. These previous studies have suggested a highly permeable open aquifer in similar deltaic terrain. Ten (10) samples of borehole sediment and water collected at 30 m depth were being analyzed for textural and physicochemical characteristics. The parameters analyzed include Iron (Fe), Total Petroleum Hydrocarbon &Total Hydrocarbon Content (i.e., TPH and THC respectively) of borehole sediment in association with groundwater quality. Ten (10) sediment samples collected at a depth of 30m and were being analyzed for mean, sorting, skewness and kurtosis, using standard laboratory procedures. Coarse silt, poorly sorted and negatively skewed were the characteristics of the borehole silt. The Kurtosis suggested the leptokurtic and platykurtic nature of the sediment. The TPH and THC range from 0.58 to 0.85 mg/L and 1.26 to 2.84 mg/L respectively. The Fe and pH range in the sediment were 0.85 to 2.46 mg/L and 4.43 to 6.02 respectively. However, Fe in the groundwater ranges from 0.12 to 0.21 mg/L. The results were above the World Health Organization's acceptable contaminant level. Based on the piece of evidence provided by spatial data mapping and textural parameters, the characteristics of the borehole sediment significantly controlled the ingress of contaminants into the groundwater. The source of groundwater contamination is the abnormal concentrations of organic contaminants. These results significantly impact human health in the food chain. This study provides information to the environmental agency for a clean-up process.

Keywords: Spatial Data; GIS; Sediment-characteristics; Groundwater Quality; Contaminants; Borehole Sediment

DOI: 10.57237/j.res.2023.01.002

1 Introduction

The pathway for the migration of contaminants and pollutants alike from the source to the recipient is through the air, water and soil. Contaminants in soil exist in two forms, namely syngenetic (i.e., contaminants introduced during the formation of the soil or sediment) and post-genetic contaminants, i.e., contaminants introduced by extraneous sources after the formation of the sediment [1].

In both cases, the migration of the contaminant into an aquifer is a function of the mineralogical and textural characteristics of the sediment. Sediment and soil highly clayey impede the migration of contaminants and may act as a barrier system. The highly sandy porous and permeable sediment and soils enhance the migration of contaminants into the groundwater [2].

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Received: Received: December 1, 2022; Accepted: January 16, 2023; Published Online: February 3, 2023 http://www.resenvsci.org

Contaminants result from geological processes and anthropogenic activities, including the discharge of waste into water bodies. These contaminants are organic and inorganic [3, 4]. Iron is a recurring contaminant in delta groundwater. Hydrocarbon sources organic contaminants in groundwater in this region occur as total petroleum hydrocarbon and total hydrocarbon content [5, 6].

These contaminants, when above acceptable contaminant limits, are injurious to the ecosystem and human health. The presence of total hydrocarbon content and total petroleum hydrocarbon in drinking water causes a high fever and gastrointestinal disorders [7-11].

There is a need to track the correlation between groundwater quality and borehole sediment extracted at 3 m intervals to aquifer depth. An understanding of the chemical and physical characteristics of this sediment is a precursor to providing information about the potential for the migration of both inorganic and organic contaminants into the aquifer. It linked these textural characteristics to textural parameters, such as grain size distribution, orientation, and cementation. The parameters of interest include mean, sorting, skewness and kurtosis [12-14]. In this study, it has aligned the textural characteristics of the borehole sediment with the ingress of contaminants into watercourses, as supported by [15]. Spatial data mapping and GIS studies provide insight into the distribution of contaminants to the recipient bodies. Also, the data is useful to environmental regulators and water agencies in understanding the non-point source, point and real sources of contaminants within the area for comparative analysis [16–18].

2 Materials and Methods

2.1 Sampling and Sampling Techniques

Ten (10) samples of borehole sediment and water were being collected at a depth of 30 m from Rukpokwu (Figure 1). In each sample, the water containing the sediment was being allowed to drain freely for twenty 24 hours into a container. It securely wrapped the drained sediment samples in a black polythene bag and it securely sealed the drained water into a sample bottle.

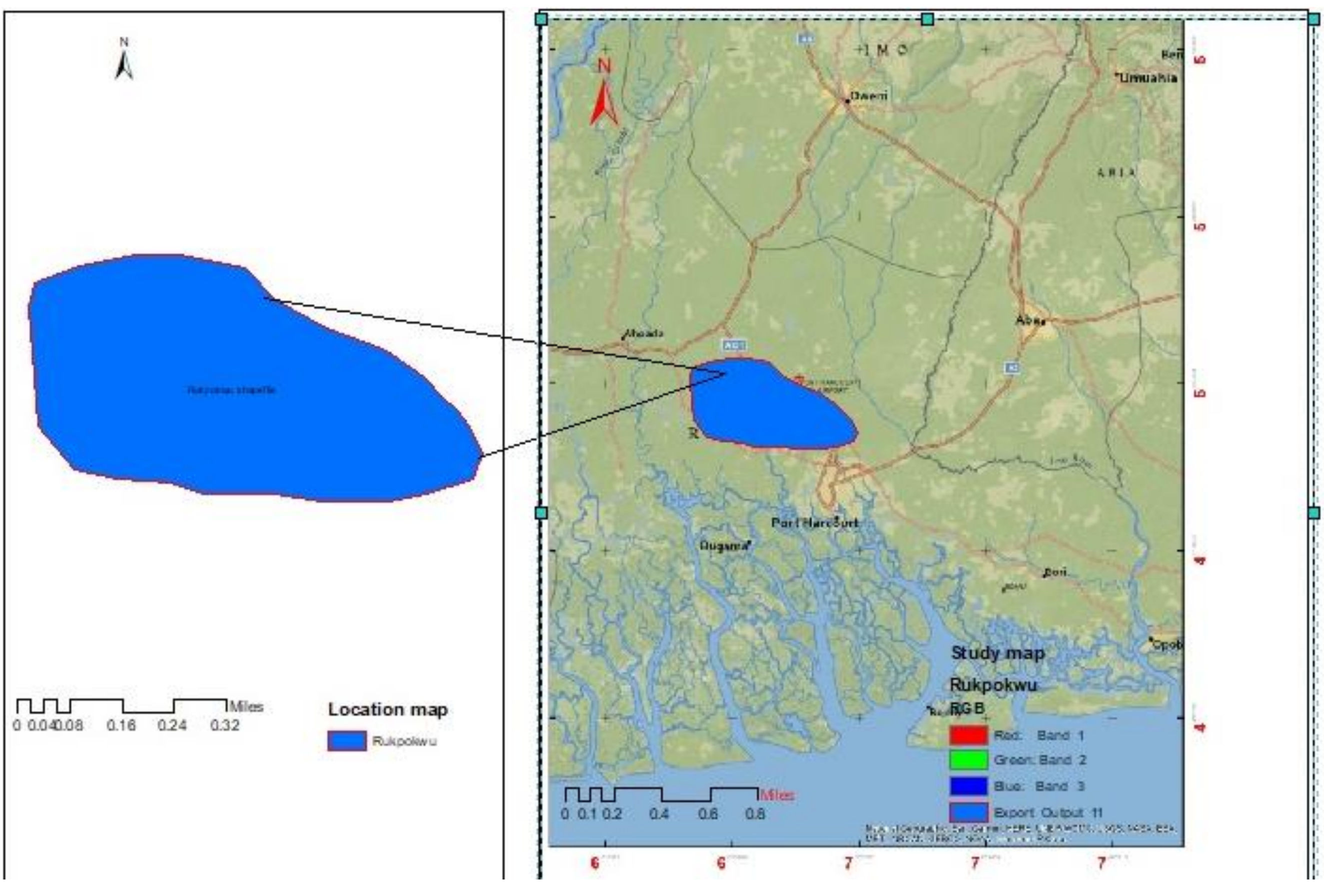

Figure 1 Location map of Rukpokwu

2.2 Particle Size and Experimental Studies

At the end of the draining exercise, the borehole sediment was air-dried and sieved for particle size analysis. In another development, it subjected the borehole sediment and drained water samples to Physico-chemical analysis, including analyzes for pH, total organic carbon (TOC), TPH, THC and iron (Fe). For the TOC, 10ml of 1.0M $K_2Cr_2O_7$ was being added to a flask containing 1gm of air-dried soil sample and then swirled gently to disperse the clusters of soil. It added 100 mL of distilled water to 20 ml of 1M H_2SO_4 in a burette. 3 drops of Ferroin indicator (0.025M solution) were being added and titrated with 0.5M $FeSO_4$. The amount of organic carbon [TOC] was calculated from the titre values.

For TPH determination, filtered sample waters in a 1L flask were transferred into a 500 mL funnel of separation. 50 mL of dichloromethane extracting solvent was being added. The funnel of separation was vigorously shaken for 5 mins and allowed to stand on a retort stand to separate the organic layer. This layer was mixed with 5 g of anhydrous sodium sulfate in a 250-mL beaker to remove water. The extraction was being done 3 times and added to the beaker. At room temperature, the extract evaporated in a hood. It transferred the concentrated extract to a pre-weighed bottle and evaporated to dryness. The total petroleum hydrocarbon (TPH) was being computed.

For THC determination, it transferred 250-mL of the water sample into a 500ml separating funnel. The water acidified with 5-mL of sulfuric acid interacted with 25-mL of n-hexane and shaken for 3 mins. The organic layer being allowed to separate from the aqueous layer was being transferred into a 250 mL timed distillation flask. The aqueous layer extraction preceded the addition of the organic layer into the distillation flask. A reflux condenser fixed to the distillation flask is used to reflux the organic layer until 10 ml of the sample remains. The solvent evaporated to dryness, the pre-weighed flask being weighed was computed for THC. All analyzes were being done in triplicates using standard laboratory procedures as provided [19].

2.3 Spatial Data and GIS Analysis

A shapefile was prepared using Google Map Pro to prepare the location map of the study area. The fieldwork generated the GPS coordinates used for GIS tables. The base map [20] was The National Geographic World Map. An Excel data sheet converted to GIS tables was used to prepare the spatial distribution maps. The inverse distance weighted interpolation in 3D was deployed for raster analysis to produce spatial data maps [20].

3 Results

3.1 Textural Characteristics of Borehole Sediment

Borehole sediment assessed for the mean, median, sorting coefficient, skewness and kurtosis, provided a range of results, The Median (Md) (4.7-5.6), mean (3.0-5.1), sorting coefficient (0.99-2.85), skewness (0.6-0.8), and kurtosis (0.5- 2.58). The borehole characteristics is from coarse silt and very fine sand (Table 1).

Sample four (4) possesses the highest textural parametric values and is the coarse silt section of the borehole. Samples 3 (three) and five (5) comprise low textural parameters and represent a very fine sand fraction of the borehole sediments.

3.2 Statistical Validation Using T-Test Statistic

The descriptive statistics deployed to analyze particle size control of contaminants displayed 0.75 mg/L of TPH in the coarse silt fraction, with a deviation of 0.094 mg/L from the standard. There were 5 samples affected by this group. In the very fine sand fraction, the mean TPH concentration was 0.63 mg/L with a deviation of .094 mg/L from the standard. There were also 5 samples affected by this group. Therefore, there was a mean difference of 0.12 mg/L between the coarse silt and very fine sand group, with TPH concentration being 0.12 mg/L higher in the coarse silt fraction of the Rukpokwu borehole sediment.

3.3 Spatial Distribution and GIS Data Analysis

In referencing location geography, concentrations of dominant THC water-bound contaminant occur in the South-Eastern end of Rukpokwu and range from 2.62 mg/L-2.80 mg/L. However, there is an isolated dominant case in the South-Western section. The Northern and North Eastern sections of Rukpokwu displayed a low concentration of 1.11 mg/L to 1.29 mg/L (Figure 2). The least to say that THC sediment-bound contaminant which dominates at the North-South axis of the area of study ranges from 2.67 mg/L-2.84 mg/L. In addition, the lowest concentration range of 1.26 mg/L-1.44 mg/L occurs in the North West and North-Eastern portions of the area of study (Figure 3). Also, the TPH bound to water recorded its dominant concentration in the North Western axis of the area of study with a range of 0.84 mg/L-0.87 mg/L (Figure 4). However, the lowest concentration is being cited North East of the study area, with a concentration range of 0.47 mg/L to 0.51 mg/L. Finally, TPH sediment-bound concentration is lowest in the Western section of the area of study with a range of 0.58 mg/L-0.51 mg/L (Figure 5).

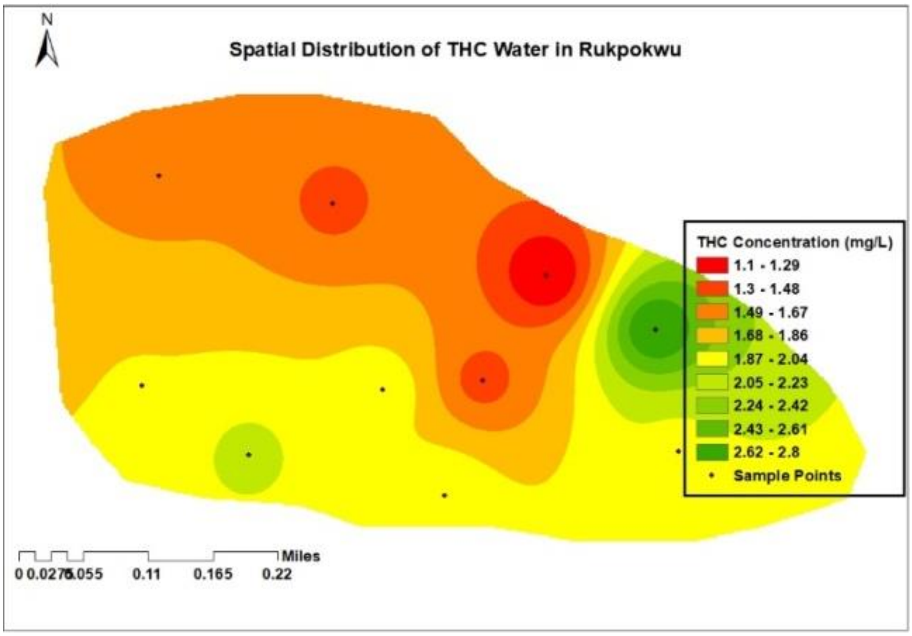

Figure 2 Spatial distribution map of THC water in Rukpokwu

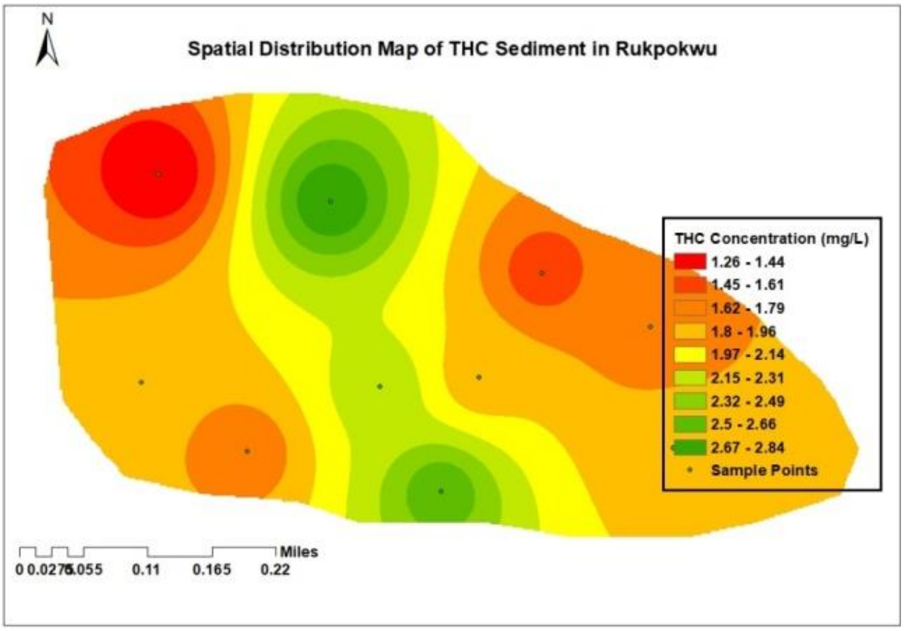

Figure 3 Spatial distribution map of THC sediment in Rukpokwu

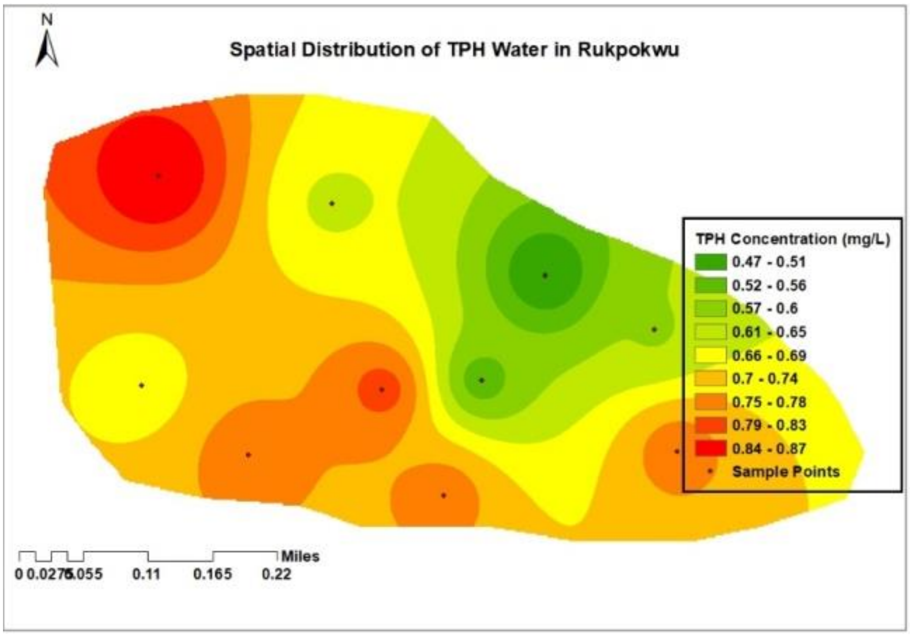

Figure 4 Spatial distribution map of TPH water in Rukpokwu

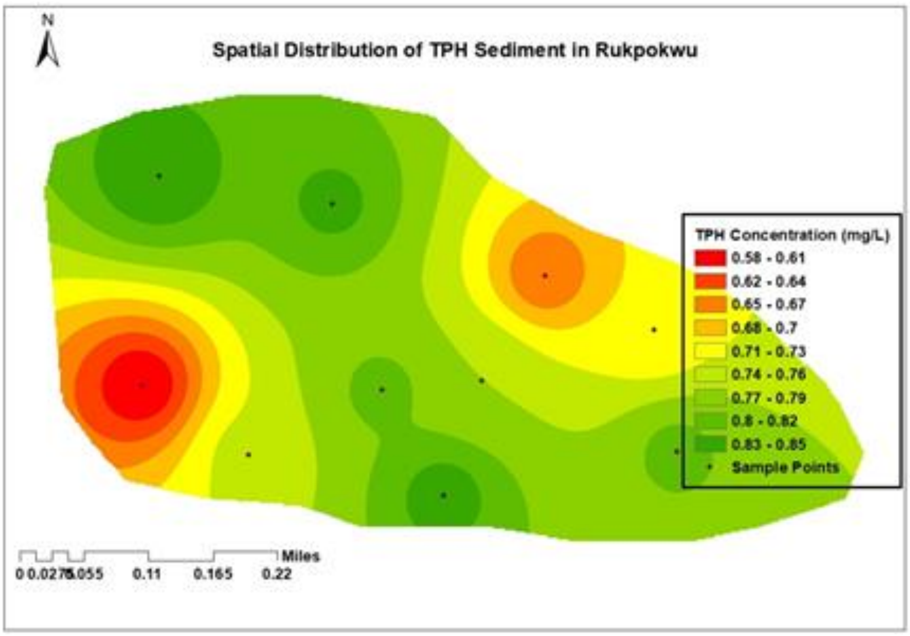

Figure 5 Spatial distribution map of TPH sediment in Rukpokwu

Table 1 Physicochemical characteristics of borehole sediment and groundwater

Borehole depth	Media	GPS Readings (Degrees Decimal)		Mean and Standard Deviation of Parameters			
Units (m)		Latitude	Longitude	pH Not Applicable	TPH mg/L	THC mg/L	Fe mg/L
3	Water	4.902426	7.001703	5.43 ±0.02	0.67 ±0.02	1.86 ±0.02	0.120 ±0.02
	Sediment			4.43 ±0.02	0.58 ±0.02	1.82 ±0.02	2.3 ±0.02
6	Water	4.90501	7.001917	5.60 ±0.02	0.87 ±0.02	1.60 ±0.02	0.184 ±0.02
	Sediment			4.04 ±0.02	0.85 ±0.02	1.26 ±0.02	1.87 ±0.02
9	Water	4.901563	7.003023	5.87 ±0.02	0.76 ±0.02	2.10 ±0.03	0.146 ±0.02
	Sediment			5.16 ±0.02	0.74 ±0.02	1.66 ±0.03	2.10 ±0.02
12	Water	4.904659	7.004058	5.78 ±0.02	0.64 ±0.03	1.43 ±0.02	0.143 ±0.01
	Sediment			4.97 ±0.02	0.83 ±0.03	2.84 ±0.02	2.46 ±0.01

Borehole depth	Media	GPS Readings (Degrees Decimal)		Mean and Standard Deviation of Parameters			
Units (m)		Latitude	Longitude	pH Not Applicable	TPH mg/L	THC mg/L	Fe mg/L
15	Water	4.902368	7.00467	5.65 ±0.02	0.80 ±0.02	1.96 ±0.01	0.215 ±0.02
	Sediment			4.78 ±0.02	0.80 ±0.02	2.27 ±0.01	1.4 ±0.02
18	Water	4.901069	7.005425	5.85 ±0.02	0.76 ±0.01	2.00 ±0.02	0.170 ±0.02
	Sediment			5.55 ±0.02	0.84 ±0.01	2.64 ±0.02	1.76 ±0.02
21	Water	4.902489	7.0059	5.64 ±0.01	0.54 ±0.01	1.40 ±0.01	0.126 ±0.02
	Sediment			6.02 ±0.01	0.76 ±0.01	1.84 ±0.01	1.25 ±0.02
24	Water	4.903781	7.006683	5.8 ±0.01	0.47 ±0.01	1.10 ±0.02	0.21 ±0.02
	Sediment			5.61 ±0.01	0.64 ±0.01	1.5 ±0.02	0.85 ±0.02
27	Water	4.903113	7.008024	5.76 ±0.02	0.60 ±0.02	2.80 ±0.02	0.18 ±0.02
	Sediment			5.44 ±0.02	0.70 ±0.02	1.66 ±0.02	1.26 ±0.02
30	Water	4.901612	7.008305	6.32 ±0.02	0.76 ±0.01	2.00 ±0.03	0.12 ±0.02
	Sediment			5.82 ±0.02	0.80 ±0.01	1.84 ±0.03	2.1 ±0.05
[11] acceptable limits for water and sediment				6.5-8.5	0.01-0.3 mg/L	0.01-0.3 mg/L	0.3 (water)-10 (sediment) mg/L

4. Discussion

The textural characteristics of the borehole sediments based on the median, mean, sorting coefficient and skewness displayed coarse silt to very fine sand. These sediments sorted poorly and negatively skewed grain sizes. The kurtosis displayed sediment grains are very leptokurtic to platykurtic. These characteristic features displayed deposition in a high-energy environment. There was not sufficient time for the sediment to sort out the grains. These characteristics dominate in all the borehole sediment as reported elsewhere for a similar deltaic environment [13]. [21]. However, a higher pH is being reported for water and sediment in a similar deltaic environment [22].

The TOC for water and sediment are within the acceptable contaminant level provided by the world health organization. The TPH and THC in both water and sediment are above the acceptable contaminant level provided by the World Health Organization. It is an observation that water treatment in the delta of Nigeria is based on the reduction of iron to acceptable contaminant levels. This attention is based on the brown colouration of groundwater in the presence of high iron content. There is little attention given to the effect of organic pollutants in the aquifer. Hydrocarbon contaminants are being reported in sachet water from the boreholes in this region and are the major cause of high fever and gastrointestinal disorders in humans [23]. This study has sourced THP and THC as the major groundwater water hydrocarbon contaminants and pollutants in the region. At 95% CI, there is strong statistical evidence that the behaviour of the TPH and THC in this region is linked with the presence of coarse silt and very fine sand, which creates a permeable porous aquifer. This aquifer allows the migration of organic pollutants into the groundwater.

Iron in the water and sediment remain lower than the acceptable contaminant level provided by the World Health Organization (WHO). However, these values are lower than the Fe content reported in some parts of the delta of Niger in Nigeria [17]. In novelty, spatial data distribution study using GIS techniques is not readily available in the delta region of Nigeria. However, non-3D studies reveal similar patterns of differences and erratic occurrence of organo-contaminant and iron distribution between sampling locations. The organo-contaminant and iron point sources are not detectable using GIS techniques. However, previous studies of surface water and sediments revealed the occurrence of organo-contaminants above acceptable limits. The total iron in the surface water and surface sediment is usually below acceptable limits based on the oxidation of ferrous iron to the ferric state. Therefore, in comparison with similar articles provided [24, 25], uncontrollable disposal of hydrocarbon products and crude oil discharge into the watersheds in the delta region of Nigeria account for the infiltration of organo-contaminants into the groundwater.

5. Conclusions

This study investigated the characterization of borehole sediment and the impact of contaminants on groundwater quality in the Rukpokwu Community in the delta of Niger in Nigeria. The low pH of the groundwater and irritation of the throat and mouth became a source of concern to the residents. Therefore, this scenario made the tracking of contaminant ingress into the groundwater necessary. The borehole sediments were being analyzed for textural and physicochemical parameters. These parameters include median, mean, sorting coefficient and skewness. The water samples were being investigated for iron (Fe), and organic contaminants (i.e. Total Petroleum Hydrocarbon and Total Hydrocarbon Content). In this study, the textural characteristics of the borehole sediment revealed two major environmental scenarios namely, poorly sorted and negatively skewed coarse grain sizes and very fine silt sizes.

These characteristics are the causes of ingress of hydrocarbon contaminants into the groundwater. The TPH and THC are above the acceptable contaminant level provided by the World Health Organization. Therefore, spatial data and GIS analysis were used to provide baseline data and information on characterized borehole water and sediments impacted by Fe and organo-contaminants. Spatial data and GIS studies support that vulnerable textural characteristic of the associated segregated sediments provide linkages for the transport of these contaminants into the groundwater in Aluu. It has provided an insight into the danger of misunderstanding the critical state of groundwater in oil exploration sections of the delta in this study. This study has provided insight into the danger of locating boreholes for water extraction in proximity to hydrocarbon spills and other sources. A quick fix of damaged oil pipelines and an immediate clean-up process will mitigate the problem of groundwater contamination in this region.

Acknowledgements

The authors are indebted to the Niger Delta University Central Laboratory and the Bayelsa State Medical University for the use of laboratory facilities. Mr. Suoye Diete-Spiff made this support possible.

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