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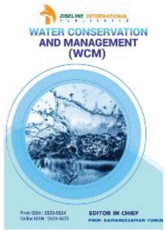

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RESEARCH ARTICLE

ASSESSING AQUIFER VULNERABILITY AND CONTAMINANT PLUME AT ARTISANAL REFINING SITES IN PARTS OF OKRIKA AND OGU-BOLO LOCAL GOVERNMENT AREAS, RIVERS STATE, NIGERIA

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ABSTRACT

This study aims at the assessment of aquifer vulnerability and contaminants plume where artisan refining of crude is taking place, which is a threat to availability of potable water. The ArcGIS version 10.3, ENVI version 4.7, Surfer 10, SPSS 22 and Microsoft Enterprise were used for the interpretation and the water and soil samples were analyzed in the laboratory using standard methods. A total number of sixteen (16) sampling points were selected using random sampling techniques for the water points and soil samples within Ogu Bolo and Okrika. The Digital Elevation Model was created from the elevation data obtained from SRTM (Short Radar Thematic Mapper) satellite image and contour extracted from the topographic map. The influence of the soil type, slope, flow accumulation, flow direction of the study area was used to delineate the level of contaminant plume. This was generated from the DEM using the ArcGIS 10.3 3-D analyst tool function. A water Quality index rating of 1 was measured in the study area which is an indication that the water is very bad. Also, the physiochemical analysis on soil and water revealed poor water and soil. Water analysis showed high concentration of Fe and Zn which made the water in the area unsuitable for drinking. Also, the soil samples recorded high levels of crude content from 1m, with concentration reducing with depth up to 3m. A general contamination map of Okrika/Ogu-bolo was modelled, indicating the contamination rating of the total land mass of the study area, with 23.59km (5.71%) rated very good, while 85.65km (20.71%) were rated good. Also, 140.37km (33.95%) had only showed moderate level of contamination while 112.56km (27.22%) recorded high level of contamination, with 51.29km (12.40%) of the total land mass having a very bad contamination record.

KEYWORDS

Aquifer vulnerability, plume, contaminant, water quality, artisanal refining, soil.

1. INTRODUCTION

Contamination of groundwater is on a steady rise particularly in our urban cities where so many industrial activities are carried out, increase in population, land that are used for commercial agriculture, poor sanitary system and other factors causing environmental degradation (Amangabara and Njoku, 2012). Also, to determine the concentration of these contaminants in the groundwater will depend on the quantity and nature of the elements that are found in it, which can be brought in naturally or through human actions and spread across the geological stratification of the area.

Water is vital to health, well-being, food security and socioeconomic development of mankind. Therefore, the presence of contaminants in natural freshwater continues to be one of the most important environmental issues in many areas of the world, where a significant part of population are far away from potable water supply. Low income communities, which rely on untreated surface water and groundwater supplies for domestic and agricultural uses are the most exposed to the impact of poor water quality. Availability of good quality water will ensure the sustainability of socio-economic development. In recent scenario the priority of the government has shifted to other sectors of the economy, rather than focusing on the combating outbreaks of water borne diseases due to consumption of contaminated groundwater.

Petroleum refining is responsible for the inputs of gaseous, solid and liquid wastes into the environment (Avwiri and Ononugbo, 2012). Some of these wastes are said to contain poisonous substances, and if brought into the environment, they will possibly cause damage to the environment, constantly staying deposits, found in living things could build-up in adipose tissues and also move up the trophic web or chain (Eluozo, 2013). In Nigeria, the Niger Delta region is believed to be the centre of natural and crude oil with numerous networks of product pipelines (both on and under the earth surface) completely across the entire region, and has

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resulted in the destruction of oil and gas pipelines, refining these products locally and the related environmental dangers which are obvious societal problems.

In the study area, some hand dug wells and deep wells (boreholes) were abandoned due to variations of the physico-chemical properties of groundwater (Nwankwoala and Nwagbogwu, 2012; Nwankwoala et al., 2017). Reports of oil spills and complaints associated with groundwater contamination have increased in Ogu Bolo and Okrika. This study therefore, evaluates the vulnerability of the groundwater within the study area.

2. THE STUDY AREA

The area study is located in the Okrika, and Ogu-Bolo Local Government Area of Rivers State (Figure 1). The area is readily accessible by a network of roads and footpaths and accessible to ships, boats, and canoes through the Bonny River and its tributaries. The study area is confined within the humid-hot equatorial climate, (Ojo, 1977). The average annual temperature is between 180 ^{0}C to 220 ^{0}C with annual range of about 200^{0}C. It is known for having two main seasons, the dry season and the wet season. The dry season begins from November and ends in March, while the wet stretches from mid-march to October. Fresh water is generally supplied by heavy precipitation estimated to have met annual rainfall above 2600mm (Ojo, 1977). The mean annual rainfalls within the past ten years, from 1997 to 2007, in Port Harcourt have shown notable variation. However, the maximum rainfall recorded within the years under review was in September 2006, with the mean annual rainfall within the periods (1997- 2007) estimate to be 4455mm.

The peaks of the rains occur in the months of June, July, September and October. The most significant factor that influences rainfall within this area is the tropical marine air mass, moisture. Laden air blows from the sea at least for ten months in a year that is, stretching from February to November. The counter air mass known as the tropical continental air mass blows from the Sahara desert with dry and dusty characteristics. It is usually experienced in the place of study between December and January. The relative humidity is very high all through the year, and it is greater than 80% (Offodile, 2002). Bonny River and its tributaries and the creeks are accountable for the drainage around the deltaic plain belt area. The dockyard creek in the south, Amadi and Okpoka creeks in the east the channel of Bonny River (Port Harcourt Harbour) by the west drain the area. These creeks flow in the N-S direction into the bonny river, which eventually flow to the west. Each of the creeks that border Port Harcourt area can be subdivided into three sections, the head water are usually fresh water streams, the down streams which are saline and the brackish water area in between them.

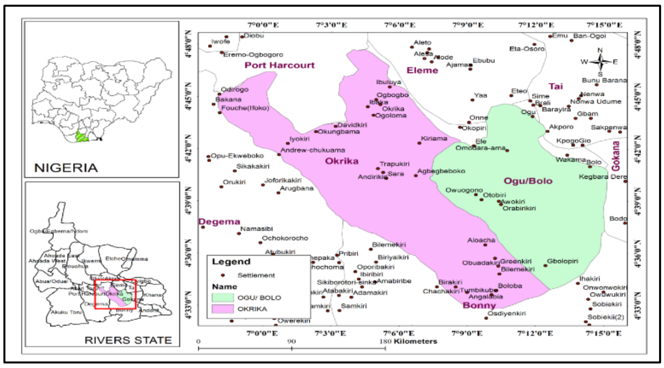

Figure 1: Generalized Map of Ogu-Bolo and Okrika

3. METHODS OF STUDY

To delineate the study area, the administrative map that covers the area of study was geo-coded with a minimum Root Mean Square (RMS) error of 0.00005. Subsequently, the subset output were digitized using on-screen method. The digitized products were overlain on each other, while a frame marking out the region of interest (ROI) i.e. Ogu-Bolo and Okrika political boundary which lies between latitude 4°48'21.885"N and 4°32'22.202"N and longitude 6°57'50.141"E and 7°15'19.895"E using ArcGIS 10.3. The area covers a land area of approximately 302.47km^2 (Ogu-Bolo 114.58km^2 and Okrika 187.8 km^2) this boundary was used to mark out the study area and subsequently, contour, drainage network, settlements, utilities and other spatial features relevant to achieving the set objectives.

A total number of sixteen (16) sampling points were selected using random sampling techniques used in selecting the water points (wells, boreholes) and soil samples within Ogu- Bolo and Okrika. The map required for this study was acquired with the use of Geographic Information System (GIS).

Table 1: Soil Sample location

S/N	Easting	Northing	LGA	Location	Sample type
1	7.119892	4.702188	OKRIKA	OK1	Soil
2	7.119892	4.702108	OKRIKA	OK2	Soil
3	7.11932	4.700406	OKRIKA	OK3	Soil
4	7.11891	4.700482	OKRIKA	OK4	Soil
5	7.20369	4.67842	OGU-BOLO	OB1	Soil
6	7.215291	4.691593	OGU-BOLO	OB2	Soil
7	7.11932	4.700406	OGU-BOLO	OB3	Soil
8	7.219415	4.76656	OGU-BOLO	OB4	Soil

Table 2: Water Sample locations

S/N	Eastings	Northings	LGA	Location	Sample type
1	7.0713611	4.7536111	OKRIKA	OR1	GWATER
2	7.07136	4.7537111	OKRIKA	OR2	GWATER
3	7.0713	4.7419167	OKRIKA	OR3	GWATER
4	7.0770556	4.7418167	OKRIKA	OR4	GWATER
5	7.203478	4.678651	OGU-BOLO	OG1	GWATER
6	7.215175	4.691741	OGU-BOLO	OG2	GWATER
7	7.275823	4.681742	OGU-BOLO	OG3	GWATER
8	7.275823	4.67005	OGU-BOLO	OG4	GWATER

3.1 Data Collection and Analysis

The Digital Elevation Model was created from the elevation data obtained from SRTM (Short Radar Thematic Mapper) satellite image and contour extracted from the topographic map. This was achieved by turning on hill shading in the layer properties dialog box by choosing the Stretched renderer and checking use hill shade effect (color ramp) to represent various elevation ranges. Triangulated Irregular Network (TIN) were generated from contour (with Z attribute value) and used to generate digital elevation model (DEM). Slope, Flow accumulation, flow direction was produced from the DEM using the Arc GIS 10.3 3-D analyst tool function of Arc GIS Version 10.3.

Watershed and other drainage morphometric analysis were generated from drainage map, while land use or land cover and its class statistics were generated from the Land sat image covering. The slope of the study area was derived and modelled by using digital elevation model data, data-set using create slope tool, and the percentage (%) units were included to display the slope. Figure 2 shows Ogu/Bolo Sample Locations while figure 3 shows Okrika Sample locations.

The spatial resolution of the Digital Elevation Model (DEM) used for this work was 15m, and it was gotten out of SRTM data. The ArcGIS 10.1 3-D surface analysis was used to generate the TIN and slope of the area in percentage while the three 3-D Analyst in ArcScene was used to generate the 3-D visualization of the Groundwater area. From the 3-D visualization, the elevation profile graphs were generated while the elevation profile graphs cross sectional chart with elevation plotted against distance gives terrain explanation of a selected line of sight over a set distance.

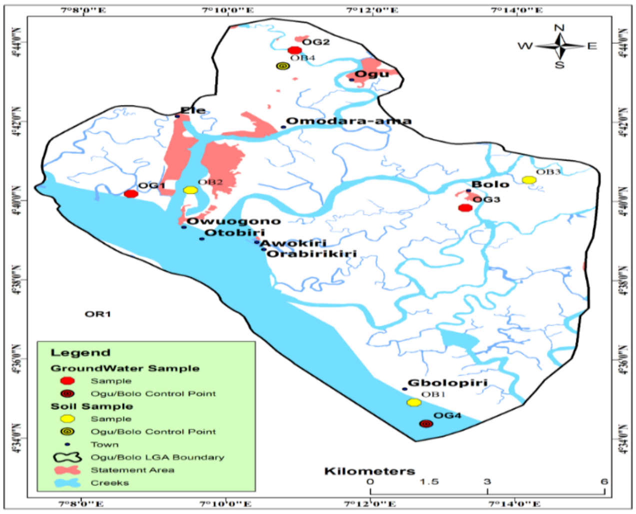

Figure 2: Ogu/Bolo Sample Locations

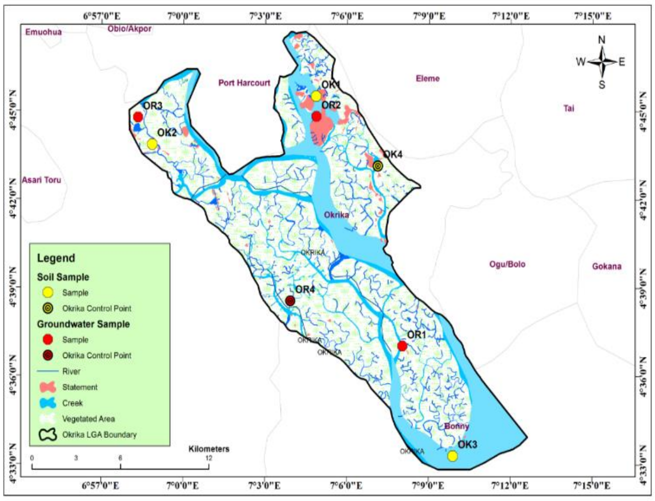

Figure 3: Okrika Sample location

Figure 4: Spilled site due to Artisan refining activities

4. Results and Discussion

Table 3: Descriptive Statistics

Parameter	Min	Max	Mean	Standard Deviation	Variance	NESREA Limit	WHO (2011)
pH	0.10	0.02	0.15	0.01	0.01	0.01	-
Cu	-	-	-			1.00	5.00
Fe	0.81	0.21	0.38	0.32	0.10	0.50	0.30
Zn	0.09	0.20	0.14	0.06	0.00	0.05	-
Temp	28.70	30.10	29.93	0.98	0.96	-	-
BTEX	-	-	-			-	-
Cl	57.39	85.36	70.99	26.14	683.08	-	200-300
DO	1.90	2.30	3.0	0.76	0.57	40.00	-
Turbidity	15.70	18.20	17.1	9.29	65.60	-	4.00
COD	2.10	2.30	2.2	0.67	0.45	30.00	-

4.1 Water Quality Index Model

Water Quality Index (WQI) is a technique of rating that provides the composite influence of individual water quality parameters on the overall quality of water for human consumption (Tiwari, 1985; WHO, 1993). Water quality indices are tools to determine conditions of water quality and, like any other tool require knowledge about principles and basic concepts of water and related issues (Nikbakht, 2004). WQI is one of the most effective tools to communicate information on the quality of water to the concerned citizens and policy makers (Ramakrishnaiah et al., 2009).

WQI is a dimensionless number that combines multiple water quality factors into a single number by normalizing values to subjective rating curves (Miller et al., 1986). WQI a well- known method as well as one of the most effective tools to express water quality that offers a simple, stable, reproducible unit of measure and communicate information of water quality to the policy makers and concerned citizens. It thus, becomes an important parameter for the assessment and management of ground water (Venkata and Reddy, 1995; Chauhan et al., 2010).WQI summarizes large amounts of water quality data into simple terms (e.g., excellent, good, bad, etc.) for reporting to management and the public in a consistent manner.

Water quality index is a 100 point scale that summarizes results from a total of different measurements when complete. It is a dimensionless number that combines multiple water-quality factors into a single number by normalizing values to subjective rating curves (Miller et al., 1986). Factors to be included in WQI model could vary depending upon the designated water uses and local preferences. Some of these factors based on this study includes Polycyclic Aromatic Hydrocarbon (PAH), Total Petroleum Hydrocarbon (TPH), Benzene Toluene Ethyl benzene Xylene (BTEX), Iron (Fe), Zinc (Zn), Copper (Cu), Lead (Pb), Hydrocarbon Utilizing Bacteria (HUB), Chloride (Cl), Nitrate (Ni), Sulphate (SO_4), pH, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Turbidity, Dissolved Oxygen (DO), Temperature etc. These parameters occur in different ranges and expressed in different units.

The WQI takes the complex scientific information of these variables and synthesizes into a single number (Cude, 2001). Graphs are used to convert field data to a Q or Quality Value. The Q value is then multiplied by Weighing Factor to get the Water Quality Index for that parameter. The results are then totalled to get the Overall Water Quality Index. The index equation generates a number from1 to 100, with 1 being the poorest and 100 indicating the best quality of water. Within this range, designations is set by CCME (2005) to classify the quality of water as poor, marginal, fair, good or excellent.

4.2 Water Quality Index (WQI) Interpretation

The index equation generates a number between 1 and 100 with 1 being the poorest and 100 indicating the best water quality. Within this range, designations have been set by CCME (2005) to classify water quality as poor, marginal, fair, good and excellent. The designations can be seen in Table 4 while Table 5 shows water quality rating.

Table 4: Weighting Factors for Different Participating Parameter

Factor	Weight
Dissolved Oxygen (DO)	0.1
Fecal coli form	0.1
pH	0.09
Biological Oxygen Demand (BOD)	0.09
Turbidity	0.08
Total Petroleum Hydrocarbon (TPH)	0.07
Temperature	0.07
Polycyclic Aromatic Hydrocarbon (PAH)	0.05
Iron (Fe)	0.05
Chemical Oxygen Demand (COD)	0.05
Lead (Pb)	0.04
Chloride (Cl)	0.04
Benzene Toluene Ethylbenzene Xylene (BTEX)	0.03
Zinc (Zn)	0.03
Copper (Cu)	0.03
Hydrocarbon Utilizing Bacteria (HUB)	0.03
Nitrate	0.03
Sulphate (SO_4)	0.02
	1

Table 5: Water Quality Rating ((Brown *et al.*, 1970 & Ramakrishnaiah *et al.*, 2009)

Water Quality Index Range	Water Quality Rating
90-100	Excellent
70-89	Good
50-69	Medium
25-49	Bad
0-24	Very Bad

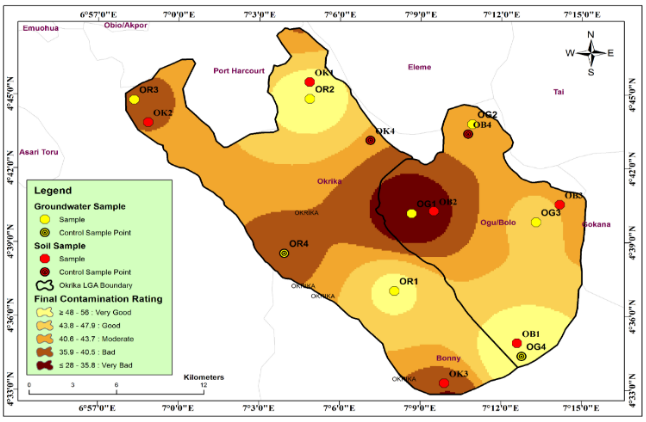

Figure 5: General contamination map rating of Okrika and Ogu/Bolo

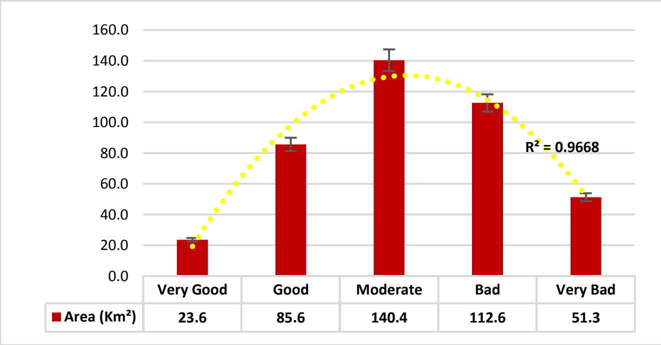

Figure 6: General contamination graph rating of Okrika and Ogu/Bolo

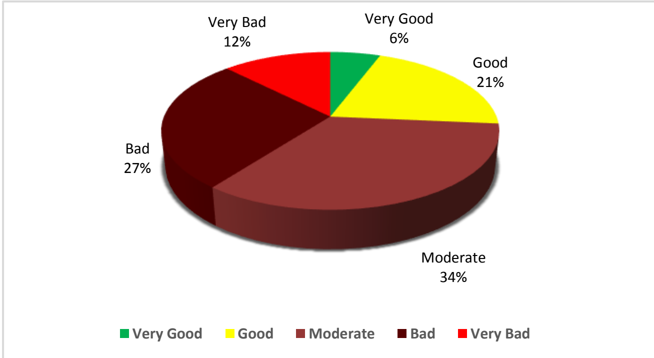

Figure 7: General Contamination of Okrika and Ogu/Bolo

5. Conclusion

Results from the area under study (Okrika and Ogu-Bolo) shows that the water within the study area is not suitable for drinking as well as for other domestic purposes. The study also revealed that there are negative effects of bunkering and artisan refining on the aquifer, and the contaminants are flowing at a very faster rate into the aquifer as a result of the elevation. The hydrochemistry of Okrika and Ogu-Bolo area studied showed that the water is not drinkable, and also not good for domestic activities as a result of the existence of high concentration of Fe and Zn. It is therefore recommended that geochemical analysis of water samples be carried out regularly to determine any future pollution of the water due to the activities in the area. More so, appropriate water treatment of borehole should be done while the artisanal refining activities should be discouraged in the area.

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