INVESTIGATION OF QUALITY ATTRIBUTES OF SOIL AND GROUNDWATER IN BUNDU-AMA AND ENVIRONS,PORTHARCOURT SOUTHERN NIGERIA

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Abstract
Anthropogenic activities (poor sanitary conditions, commercial and domestic wastes disposal) and saline water intrusion have become a major environmental problem which exposes the soil and groundwater within the environment to heavy metals and other contaminants. Geology and hydraulic conductivity of the soil collected from the study area were studied. Physico-chemical characteristics of groundwater collected from boreholes and hand dug wells were also determined. The hydraulic conductivity of the area was determined by making four pits at varying depths of 0.0 m,0.5 m,1.0 m,and 1.5 m,at four locations. Also,heavy metals in the soil at five different locations of the study area were determined at depths of 0.4 m and 0.8 m. Results of hydraulic conductivity shows a range of 1.50*10>-4 - 2.75 * 10>-4 m/s indicating high permeability which could aid the infiltration of harmful wastes to the groundwater and soil. Heavy metals (Cu,Cd,Pb,Zn) were detected in the soil at various depths. However,Chromium, Cr,was generally less than detectable limits. The pH of the borehole water analyzed are acidic while that of the hand dug well water analyzed fell within the WHO recommended standards. Electrical conductivity of the analyzed hand dug water fell above WHO recommended standards. This could be as result of saline water intrusion which is also a contaminant. From the analysis in the analyzed groundwater, cations (Mg^{2+}, Na^{+},K^{+}) fell within WHO recommended standards. Also, the anions (Cl^{-},HCO^{-3}, CO_3^{2-}, SO_4^{2-}, NO^{2-}, PO_4^{3+}) fell within WHO recommended standards. All the heavy metals in the analyzed groundwater samples fell within WHO and NSDWQ recommended standards, except lead (Pb) and cadmium (Cd) which fell above WHO and NSDWQ standards which is also an indication of contamination.Good sanitary condition, continuous monitoring of groundwater quality from time to time as well as improving the waste disposal method are recommended.

Keywords: *Geology, Contamination, Groundwater, Hydraulic conductivity, World Health Organization.*

I. INTRODUCTION

Municipal Solid Waste (MSW) disposal, in most of the developing countries has been a chronic problem, particularly in areas with high population density and high production of waste. This has led to the pollution of groundwater causing a good percentage of the world population no access to safe drinking water. The creeks have become regions of indiscriminate waste disposal for commercial activities as well as effluents from industries within and around Bundu-Ama and environs. Moreover, poor sanitary conditions pose danger to the environment. There is little or no awareness by the inhabitants of the area of the danger that this indiscriminate dumping of refuse would pose to the groundwater resources.Soil's physicochemical aspect are indicators of possible pollution of groundwater. Therefore, the knowledge of dynamics of soil physio- chemical characteristics is imperative even in decisions regarding waste management. This is because variability in soil characteristics influences surface- and- groundwater resources that it supports including solid waste. A study in Abakaliki region of Nigeria, confirmed that soil physicochemical characteristics influence leachate contamination to groundwater through

the introduction of hazardous wastes in aquifer zones. (Obasi et al,2012). Particle size distribution of soil samples from solid waste dump sites have been studied in some selected dumpsites in PortHarcourt by some researchers. (Obianefo et al,2016).
This study investigates the quality attribute of soil and groundwater in Bundu-Ama and its environs, PortHarcourt, Southern Nigeria.

II. STUDY AREA, GEOLOGY AND HYDROGEOLOGY OF THE AREA

❖ Study Area

The study area is Bundu-Ama and environs in PortHarcourt, Southern Nigeria (Figure 1) and situated approximately on latitudes 4^0 45'N – 4^0 47'N and between longitude $7^0$01'E – $7^0$03'E.
The study area displays climatic characteristics that could be classified as humid, semi – hot equatorial type (Papadaki, 1996: Gobo, 1990). The area experiences heavy rainfall from March to October and even the dry months of November, December, January and February are not free from occasional rainfall (Gobo, 1988). The mean annual rainfall is about 2,500mm (Akintola, 1986).
The study area is characterized by a nucleated and linear settlement inhabited by people from many tribes of Nigeria while the original owners of the land are the Okirika and Ikwere tribes. There are supply of some essential public facilities such as electricity and roads which are not adequate, however. The inhabitants are majorly low income earners engaged in different small business activities such as trading and transportation. Other commercial and industrial companies operating in the area include Ibeto Cement, Union Dicon industry. Macoban Shipyard, and a Jetty for loading of petroleum products.

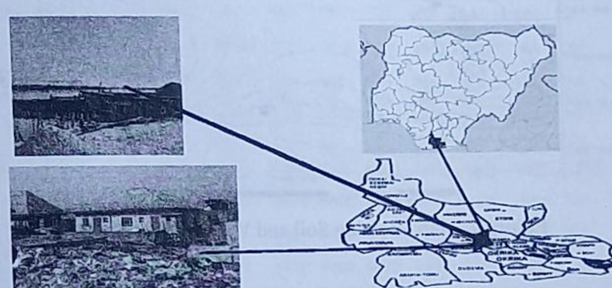

Figure 1. Map of Nigeria and Rivers State

❖ GEOLOGY

The area lies within the Niger Delta sedimentary basin, and the surface is classified as part of the Benin Formation (Simpson, 1954). The elevation of the study area varies between 3m and over 15m above mean sea level. The stratigraphy of the Delta consists of three major units: the Akata, the Agbada and the Benin Formations from base to top.
The Benin Formation is an extensive stratigraphic unit in the Southern Nigeria sedimentary basin. It is predominantly sandy with a few clay and shale intercalation (Short and Stauble, 1967).
The materials are believed to be deposited in a continental fluviatile to deltaic environment (Onyeagocha, 1980). The Benin Formation is overlain by the coastal plain sands, deltaic plain sands, abandoned beach ridges, mangrove and freshwater swamps and range in ages from Miocene to Recent

❖ HYDROGEOLOGY

Fresh water from Benin formation has been identified as highly porous sand and unconsolidated. All the aquifers in the Niger Delta are allocated within this lithostratigraphic unit. In the Niger Delta, the regional groundwater cause in four major aquifers delineated from lithologic and geophysical log within a depth bracket of 0-300 meters. The first aquifer occurs between 0-45m under phreatic conditions and is the most extensively exploited.

The second (50-30m) and the third (136 – 212m) are semi-confined, while the fourth (219 – 300) is perfectly confined and is the thickest. The aquifers are predominantly very fine to coarse grained sand beds with minor clays and conglomerate intercalations (Tse and Eshiemomo, 2016).

I. METHODOLOGY

3.1 SAMPLE COLLECTION AND DETERMINATION OF PHYSICO-CHEMICAL PARAMETERS

Three different methods were employed in this study, and they include:

Desk Study

Data acquisition through fieldwork and samples

Hydrogeochemical study

1. Desk Study
2. Data Acquisition

✓ Field Work

- Pitting: four (4) pits were dug to the depth of 1.5m for sieve analysis. Also, soil samples from five (5) points within the study area at depth of 0.4m and 0.8m per point were collected for heavy metals analysis.

Sampling: Sampling of soil for sieve analysis at depths of 0.0m, 0.5m, 1.0m and 1.5 respectively for sieve analysis (particle size determinant and hydraulic conductivity, and ten (10) groundwater samples were taken from hand-dug wells and boreholes for physiochemical analysis.

All samples (water and soil) were taken to the laboratory for analysis according to APHA, 1999.

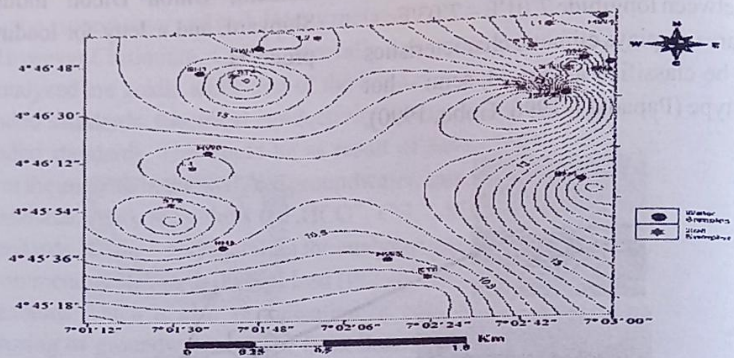

Figure 2. Map Showing Soil and Water Sampling Points

IV. RESULTS AND DISCUSSIONS

Table 1 - Hydraulic Conductivity (K) from the Sieve Analysis

Location	Depth (m)	Hydraulic Conductivity (K) m/s	m/s
L1	0.0	2.30E-04	2.30 x 10^{-4}
	0.5	1.64E-04	1.64 x 10^{-4}
	1.0	1.50E-04	1.50 x 10^{-4}
	1.5	1.50E-04	1.50 x 10^{-4}
L2	0.0	2.14E-04	2.14 x 10^{-4}
	0.5	1.77E-04	1.77 x 10^{-4}
	1.0	1.52E-04	1.52 x10^{-4}
	1.5	2.39E-04	1.47 x 10^{-4}
L3	0.0	2.46E-04	2.39 x 10^{-4}
	0.5	2.46E-04	2.46 x 10^{-4}
	1.0	1.89E-04	1.89 x 10^{-4}
	1.5	1.83E-04	1.83 x 10^{-4}
L4	0.0	2.32E-04	2.32 x 10^{-4}
	0.5	2.50E-04	2.50 x 10^{-4}
	1.0	2.75E-04	2.75 x 10^{-4}
	1.5	2.10E-04	2.10 x 10^{-4}

From the computed Hydraulic Conductivity (K), the values range between 1.50×10^{-4}–2.75×10^{-4} According to Macaulay (2008), these values are high which shows that the soil is permeable allowing for contaminant movement through the interconnected pore spaces of the soil underlying the study area.

Table 2 - Physiochemical and Heavy Metal Parameters analyzed in the Water Samples from the Study Area

Parameters (mg/l)	HW1	HW2	BH1	HW3	BH2	HW4	HW5	BH3	HW6	BH4	NSDWQ (2007)	WHO (2010)
pH	7.01	7.03	5.64	7.18	5.51	7.1	6.98	5.54	7.03	6.1	6.5 -7.5	6.5 - 7.5
Temperature (°C)	28.4	28.2	28.3	28.7	28.6	28.1	27.8	28.0	28.4	28.2	NA	NA
Turbidity (NTU)	0.9	0.87	0.3	0.89	0.31	0.84	0.92	0.35	0.86	0.34	5.0	5.0
Alkalinity	26	28	4.0	24	5.0	27	26	4.0	29	4.0	NA	NA
Electrical Conductivity	953	1240	197	1360	1450	1470	1520	295	1480	284	1000	1000
TDS	452	490	124	484	120	495	458	119	475	130	500	500
Total Hardness	44.7	51.1	3.5	47.7	4.0	49.2	48.3	4.1	45.9	5.1	NA	500
Sulphate	35.5	37.4	15.1	36.0	14.9	38.4	36.6	20.4	42.3	26.8	100	200
Chloride	49.4	47.8	8.9	48.1	8.7	49.7	48.7	10.1	47.2	9.92	250	250
Carbonate	0.83	0.80	0.01	0.82	0.02	0.88	0.86	0.02	0.81	0.01	NA	NA
Nitrate	2.44	2.21	1.45	2.98	1.60	3.4	3.83	1.57	4.16	1.55	NA	NA
Phosphate	0.14	·0.12	0.15	0.18	0.16	0.19	0.11	0.12	0.18	0.15	NA	NA
Bicarbonate	26.0	25.1	4.0	27.1	4.2	26.5	27.3	4.4	25.8	5.5	250	250
Calcium	13.83	14.2	0.159	14.4	0.17	14.11	13.92	0.17	14.5	0.16	NA	75
Magnesium	2.47	2.52	0.7	2.62	0.82	2.49	2.49	0.97	2.33	0.92	20	50
Sodium	101.45	104.25	22.78	100.60	23.21	103.6	102.5	22.53	110.18	24.9	200	200
Potassium	49.80	53.8	1.68	52.1	1.69	50.3	54.9	1.64	49.6	1.74	NA	200
Chromium	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	0.05	0.05
Zinc	0.155	0.162	0.125	0.134	0.122	0.139	0.181	0.131	0.163	0.137	3.0	5.0
Iron	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	0. 3	0. 3
Cadmium	0.025	0.028	0.046	0.030	0.043	0.031	0.027	0.048	0.029	0.035	0.003	0.003
Lead	0.302	0.317	0.039	0.337	0.036	0.308	0.312	0.023	0.324	0.028	0.01	0.01
Manganese	0.011	0.025	0.066	0.026	0.064	0.032	0.036	0.078	0.014	0.061	0.2	0.2
Copper	0.065	0.073	0.078	0.068	0.071	0.069	0.072	0.082	0.071	0.055	1.0	2.0

Table 3 - Heavy Metals Concentration (mg/kg) in Soil

Heavy Metals	Cu		Cd		Pb		Zn		Cr	
Soil Depth (m)	0.4	0.8	0.4	0.8	0.4	0.8	0.4	0.8	0.4	0.8
Site 1	6.50	6.65	3.00	3.20	5.70	5.20	27.30	24.1	NIL	NIL
Site 2	6.70	6.50	2.8	2.7	5.9	5.65	29.1	28.5	NIL	NIL
Site 3	5.40	5.80	2.5	2.1	4.6	4.9	23.2	22.8	NIL	NIL
Site 4	6.70	6.10	3.1	2.9	6.12	6.0	30.1	29.6	NIL	NIL
Site 5	6.80	6.20	2.9	3.2	8.90	8.40	35.1	33.7	NIL	NIL
WHO (1996)	36		0.8		85		50		100	

❖ RESULTS

pH
pH values for sample ranged from 5.51 to 7.18 with a mean value of 6.51. The highest recorded occurred in HW3(7.18) while the lowest occurred in BH2 at 5.51

Temperature
Water temperature values for the water samples ranged from 27.8 Cto 28.7 C with the mean value of 28.27 C

Electrical Conductivity
Electrical Conductivity value for the water samples ranged from 197us/cm to 148us/cm

Total Dissolved Solids
The concentration values of Total Dissolved Solids (TDS) in the water samples ranged from 119 mg/l to 495 mg/l with a mean value of 91.7 mg/l. The highest value was recorded in HW4 with value of 495 mg/l while the lowest value was recorded in Bh3.

Turbidity
Turbidity values for the water samples ranged from 0.30NTU to 0.92 NTU with a mean value of 0.66 NTU. The highest value was recorded in HW5 with value of 0.92 NTU while the lowest value was recorded in BH1 with a mean value of 0.3 NTU

Alkalinity
Alkalinity concentration values in the water samples ranged from 4.0 mg/l to 29.0 mg/l with the mean value of 17.7 mg/l. The highest value was recorded in HW6 while the lowest value was recorded in BH1

Total Hardness
Total Hardness concentration values in the water samples ranged from 3.5 mg/l to 51.1 mg/l with the mean value of 30.6 mg/l

Sulphate

Sulphate concentration values in the water samples ranged from 14.9 mg/l to 42.3 mg/l with the mean value was recorded in HW6 while the lowest value of 14.9 mg/l was recorded in BH2.

Chloride
Chloride concentration values for the water samples ranged from 8.7 mg/l to 49.4 mg/l with the mean value of 32.85 mg/l. The highest value of 49.4 mg/l was recorded in HW1 while the lowest value of 8.7 mg/l was recorded in BH2.

Carbonate
Carbonate concentration values ranged from 0.01 mg/l to 0.88 mg/l with a mean value of 0.506 mg/l. The highest value of 0.8 mg/l was recorded in HW4 while the lowest value was recorded in BH4

Phosphate
Phosphate concentration values ranged from 0.11 mg/l to 0.19 mg/l with the mean value of 0.15 mg/l. The highest value of 0.19 mg/l was recorded in HW4 while the lowest value of 0.11 mg/l was recorded in HW5.

Bicarbonate
Bicarbonate concentration values for the water samples ranged from 4.0 mg/l to 27.3 mg/l with a mean value of 17.59 mg/l. The highest value of 27.3 mg/l was recorded in HW5 while the lowest value of 4.0 mg/l was recorded in BH1.

Calcium
Calcium concentration values in the water samples ranged from 0.159 mg/l to 14.5 mg/l with the mean value of 8.56 mg/l. Highest value of 14.5 mg/l was recorded in BH1.

Magnesium
Magnesium concentration values ranged from 0.745 mg/l to 2.521 mg/l with the mean value of 1.84 mg/l. Highest value of 2.521 mg/l was recorded in HW2 while the lowest value of 0.745 mg/l was recorded in BH1.

Sodium
Sodium concentration values ranged from 22.53 mg/l to 110.18 mg/l with a mean value of 71.56 mg/l. The highest value of 110.18 mg/l was recorded in HW6 while the lowest value of 22.53 mg/l was recorded in BH3.

Potassium
Potassium concentration values in the water samples ranged from 1.641 mg/l to 53.8 mg/l with the mean value of 31.73 mg/l. Highest value of 53.8 mg/l was recorded in HW2 while the lowest value of 1.641 mg/l was recorded in BH3

Chromium
Chromium concentration values in all the water samples were less than detectable limit.

Zinc
Zinc concentration values in the water samples ranged from 0.122 mg/l to 0.181 mg/l with the mean value of 0.145 mg/l. Highest value of 0.181 mg/l was recorded in HW5 while the lowest value of 0.122 mg/l was recorded in BH2

Iron
Iron concentration values in all the water samples were less than detectable limit

Cadmium
The concentration values for cadmium in the water samples ranged from 0.025 mg/l to 0.048 mg/l with a mean value of 0.048 mg/l was recorded in BH3 while the lowest value of 0.025 mg/l was recorded in HW1.

Lead
Lead concentration values ranged from 0.023 mg/l to 0.337 mg/l with a mean value of 0.203 mg/l.The highest value of 0.337 mg/l was recorded in HW3 while the lowest value of). 023 mg/l was recorded in BH3.

Manganese
Manganese concentration values ranged from 0.011 mg/l to 0.078 mg/l with a mean value of 0.04 mg/l. Highest concentration values of 0.078 mg/l was recorded in BH3 while the lowest concentration value of 0.011 mg/l was recorded in Hw1

Copper
Copper concentration values in the water samples ranged from 0.055 mg/l to 0.082 mg/l with a mean value of 0.063 mg/l. The highest value of 0.055 mg/l was recorded in BH4

DISCUSSION

pH (Hydrogen ion concentration): The pH quantifies the concentration of hydrogen ion in water. Neutral pH has a value of 7 while above 7 indicates alkaline or basic. Also, below 7 indicates acidity. The pH of the water samples from the area of study is in the range of 5.51 to 7.18 with a mean of 6.51 compared to the permissible limit of 6.5 to 8.5 recommended by WHO (2010) and NSDWQ (2007). All the water samples in the Hand dig wells (HW1 to HW6) are within the permissible range of WHO (2010) and NSDWQ (2007),however, all the water samples in the Boreholes (BH1 to BH4) are acidic and below the range recommended by WHO (2010) and NSDWQ (2007). Acidic water can boast the rate of chemical weathering and dissolution of rocks.

Electrical Conductivity
Electrical Conductivity values ranged from 197us/cm to 1520us/cm. Compared to National Standard for Drinking Water Quality (NSDWQ,2007) and WHO (2010) permissible limits of 1000us/cm, the water samples in BH1, BH2, BH3,BH4,and HW1 were below permissible limits while the water samples in the HW2 to HW6 were above the limits. Electrical Conductivity (EC) is a measure of water capacity to convey electric current. Dissolved salts and other inorganic chemicals conduct electrical current. Conductivity is also affected by temperature. Warmer water has higher conductivity than cold water. Also, saltwater intrusion in groundwater can increase the electrical conduction of groundwater.

Cadmium
The measured concentration values of cadmium in the water samples shows that cadmium concentration is above the 0.003 mg/l permissible limit recommended by WHO (2010) and NSDWQ (2007), in BH1 to BH4,and HW3 to HW6,with the exception of HW1 and HW2 with values of 0.025 mg/l and 0.028 mg/l, respectively. Generally, the study area is contaminated with cadmium.
Pesticides from used pesticides cans, burning of fossil fuels such as coal or oil, and incineration of multiple waste such as plastics, and batteries, which can be deposited as solid waste. (Sahmoun et all,2000). Exposure to cadmium through water and soil leads to cancer and organ system toxicity such as skeletal, urinary, reproduction, cardiovascular, central and peripheral nervous and respiratory systems

Lead
Lead contamination is observed from the analysis of the water samples as all the measured concentration values are above the 0.01 mg/l permissible limit of WHO (2010) and NSDWQ (2007). Lead exposure leads to severe harm in the body systems and organs. Lead causes anemia, weakness, and kidney damage, and brain damage in infants as well as nervous system of unborn child. Sources of lead include burning of fuels and coals, paint industry, (lead-based paint), batteries disposed as waste.

I. CONCLUSION

The evaluation of the parameters that determined the level of contamination to groundwater has been carried out. The inference gotten from the study revealed that effluents and wastes from industrial activities as well as domestic activities have negative effects on the groundwater resource. The results from the study area (Bundu-Ama and environs) showed that groundwater within the study area is not suitable for drinking due to contamination of lead and cadmium. Also the groundwater from the boreholes are acidic. It is therefore necessary that Federal, State and Local Government Agencies should regularly monitor and actively regulate the activities of the industries around the city of Port Harcourt, especially, Bundu-Ama axis. The illegal and unsafe refining of crude oil in the area should be discouraged and brought under total control.

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