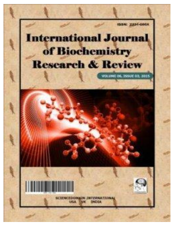

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Assessment of Physical Properties and Heavy Metals in Borehole Water from Ogale, Eleme Local Government Area of Rivers State

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Authors' contributions

This work was carried out in collaboration between all authors. Author JA designed the study while author NOO did sampling and laboratory analysis under the supervision of author JA. Author NOO wrote the first draft while author NB managed the literature. Author TO performed the statistical analysis. All authors read and approved the final manuscript.

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ABSTRACT

Aim: To assess the physical properties and some heavy metal levels of borehole water in Ogale, Eleme local government area of Rivers State.

Study Design: Water samples were collected from boreholes of twelve (12) communities in Ogale, Eleme and analyzed for physical parameters and heavy metal concentrations.

Place and Duration of Study: The samples collected from various sites were analyzed in the Laboratory of the Department of Chemistry, Rivers State University from November, 2016 to January, 2017.

Methodology: The physical properties were analyzed via standard methods while the heavy metals were assessed using a flame atomic absorption spectrophotometry.

Results: The pH varied from 4.6 – 6.1 which is below the standard recommended by the Standards Organization of Nigeria. Other physical parameters were below the maximum permitted limit. However, the total suspended solids and turbidity in Nsisioken, Ekirinde and Oken-eta were above

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the maximum permitted level. The concentration of Pb in all samples was above the maximum permitted limit of 0.01 mg/L. The concentration of Ni was above the permitted limit (0.02 mg/L) in boreholes at Ekpangbala, Ejii, Agbi and Nsisioken while the concentration of Cd is above the maximum permitted limit of 0.003 mg/L in boreholes in all the communities apart from Okori (0.002 ± 0.001 mg/L). The concentrations of other heavy metals (i.e. Zn, Cr and Mn) were below the permitted limit in all samples. The spatial distribution of the commulative heavy metals in the area suggests that Pb, Cd and Ni may have originated from the same source due to their positive correlations.

Conclusion: The low pH and relative high concentrations of Pb, Cd and Ni suggest that water from the boreholes in the area were of low quality for domestic use thus requires treatment and monitoring.

Keywords: Turbidity; heavy metals; physical properties; Ogale; boreholes.

1. INTRODUCTION

Water is an important part of rural and urban environment and the management of this resource is essential to ensuring a better and quality environment. However in developing countries, industrialization has resulted in the generation and accumulation of different wastes that contain heavy metals which eventually leach and cause havoc to the ecosystem. Various sources of heavy metals include soil erosion, natural weathering of the earth's crust, mining, industrial effluents, urban runoff, sewage discharge, insect or disease control agents applied to crops, and many others [1]. Heavy metals are natural components of the earth's crust and many of them have no known biological role in humans rather they persist and affect various metabolic activities thereby causing significant harm to the body [1,2]. In Ogoniland, most underground water is heavily polluted due to oil exploration [3]. Since heavy metals and metalloids are found in appreciable amounts in crude oil, oil exploration could be a major source of metal pollution in the vicinity of the companies [4]. Some of these metals such as mercury and arsenic could be deleterious even at low concentrations while others such as cadmium are complexed to ligands for excretion. However, they are bioaccumulated in the food chain and their concentration in tissues could be high upon continuous exposure since they are not chemically and biologically degraded [5].

Through rivers and streams, the metals are transported as either dissolved species in water or as an integral part of suspended substances causing the most detrimental effects on aquatic life [6]. Though, some heavy metals (e.g. copper, selenium, zinc) are essential to maintain the metabolism of the human body, their concentration above the desirable levels can be poisonous [6,7]. Heavy metal poisoning could be from drinking-water contamination (e.g. lead pipes), high ambient air concentrations near emission sources, or intake via the food chain. The impact of these pollutants is mostly confined to densely populated and urban areas with consumer-oriented industries [8].

Ogale in Eleme Local government Area of Rivers State is a semi-urban centre with rapid development, commercial and oil activities as well as service industries. The absence of potable water to every household has led to the proliferation of boreholes as a result of its high demand. As such, in some areas, boreholes are located close to downstream of soak away pits or waste dump sites.

Despite several studies in the literature on heavy metals in water, there seem to be no study of such in borehole water in Ogale. This study therefore assesses the heavy metal status of borehole water Ogale, Eleme and the long term health implications.

2. MATERIALS AND METHODS

2.1 Study Area

The study was conducted in Ogale, the headquarters of Eleme Local Government Area of Rivers State, Nigeria between November, 2016 and January, 2017. Ogale consists of 9 communities which are Agbi, Alueken, Aluebo, Akara, Adama, Ejii, Ekpangbala, Mbuma- eta and Okori and 3 development areas which are Nsisioken, Oken-eta and Ekiride. The vegetation of Ogale is characterized by rainforest ecosystems which form part of the rich fauna and flora of Rivers State. The major economic activities in the area are farming and fishing. The major sources of water for drinking in the area are boreholes and the Ogale river.

2.2 Sample Collection and Analysis

The procedure for data collection started with a reconnaissance survey to the area. The study identified functional boreholes as those that are frequently in use with level of patronage greater than 100 persons per day. Through this approach, 5 functional boreholes (from each community) were randomly selected. Water samples were collected in 1 litre plastic bottles. Before the collection of water samples, the boreholes were allowed to pump for 15 min so that water with a constant temperature and pH can be collected. Water samples were collected at the borehole heads. Prior to sample collection, all plastic bottles were rinsed thrice with the sample water. After sampling, the containers were tightly covered, appropriately labeled and put in an ice-packed cooler and immediately taken to the laboratory for analysis for heavy metals using flame atomic absorption spectrophotometer, AAS (model AAanalyst 400 Perkin); 220GF. Preparation of samples was carried out using acid digestion before 2 mL of sample was injected into the machine by flow method. The heavy metals analysed were Mn, Cr, Zn, Pb, Cd and Zn. In addition, physical properties such as pH, total suspended solids (TSS), turbidity (TURB), total dissolved solids (TDS) and total hardness (TH) were determined using standard methods [9].

2.3 Statistical Analysis

Analysis of raw data including pearson correlation coefficients, principal component and clustal analysis were conducted using Minitab version 18 for Windows.

3. RESULTS AND DISCUSSION

The physical properties and heavy metal concentrations in borehole water samples are given in Tables 1 and 2. The pH of the water samples varies from 4.6 to 6.1 with an average of 5.2 ± 0.3 thus slightly acidic in all the stations. This is below the standard recommended by the Standards Organization of Nigeria (SON) for drinking water (pH 6.5 – 8.5) [10]. The acidic nature of the water samples is attributed to the presence of tiny shale intercalations in the aquiferous coastal plain sand [11]. However, other physical parameters are below SON maximum permissible limit apart from the total suspended solids and turbidities in Nsisioken, Ekiride and Oken-eta (which are above the maximum permissible limit). The pH does not exhibit any significant correlation (Table 3) with the heavy metal variations. This shows that pH is not a major contributing factor on heavy metal concentration in borehole water in the area. The concentrations of Pb in all the stations are above the SON maximum limit (0.01 mg/L) while the concentrations of Ni is above the permitted limit (0.02 mg/L) in Ekpangbala, Ejii, Agbi and Nsisioken. The concentrations of Cd are above the permitted limit (0.003 mg/L) in all the stations except Okori (0.002±0.001) (Table 2). Lead (Pb) is highly toxic and absorbed through ingestion by food, water and inhalation [12]. In humans, exposure to Pb can result in a wide range of biological effects depending on the level and duration of exposure. High levels of exposure could damage kidney, gastrointestinal tract, reproductive system, nervous system and also impairs synthesis of haemoglobin [6,13]. However the concentrations of Zn, Cr and Mn are below the maximum permitted limit in all stations. The low concentration of Mn confers good taste on water and would not promote the growth of algae in reservoirs or collection tanks [14]. Zinc is an essential mineral, but in excess can cause system dysfunctions that result in impairment of growth and reproduction of the contaminants. The clinical signs of zinc toxicity include vomiting, diarrhea, bloody urine, liver failure, kidney failure and anemia [6, 15]. Nickel is a trace element believed to play a role in physiological processes as a co-factor in the absorption of iron from the intestine but continuous exposure could concentrate the metal in the lung, heart, diaphragm, brain and spinal cord tissue where it causes systemic and organ damage [16,17].

The low pH and relatively high concentrations of Pb, Ni and Cd reveal the quality of borehole water in the area is quite low for domestic consumption and presents a potential health risk upon prolonged usage.

In order to reduce the dimensionality of the dataset (while preserving the relationship in the original data), the original heavy metal data was subjected to multivariate analysis. The Pearson's correlation coefficients of heavy metal are summarized in Table 3. Correlation analysis of the raw data reveal very strong correlation between Cd and Pb (r = 0.831), Cd and Ni (r = 0.94) and Ni and Pb (r = 0.829) at $p < 0.01$.

Table 1. Physical properties of borehole water in Ogale area

Community	pH	COND (μS/cm)	TURB (NTU)	TDS (mg/L)	TH* (mg/L)	TSS (mg/L)
Aluebo	5.4±0.5	14.6±2.1	1.4±0.6	10.4±0.4	3.4±0.5	2.3±0.2
Ekpangbala	5.5±0.7	14.5±3.4	1.6±0.4	9.7±0.9	4.2±0.3	4.2±0.5
Ejii	4.6±0.3	19.4±1.8	2.5±1.2	15.2±0.8	2.9±0.2	3.4±0.2
Mbumata	4.7±0.2	20.0±0.9	2.7±0.9	12.8±1.2	2.7±0.1	1.6±0.6
Okori	4.6±0.4	19.7±1.2	1.9±0.8	19.6±0.7	1.6±0.4	2.5±0.3
Adama	5.3±0.1	20.0±0.8	3.4±0.7	20.5±0.9	4.3±0.4	4.4±0.4
Akara	5.3±0.3	20.4±1.6	2.2±1.1	18.4±0.5	2.5±0.2	2.8±0.6
Alueken	5.3±0.4	20.2±1.4	3.6±0.8	15.6±0.4	3.2±0.3	3.6±0.6
Agbi	4.8±0.3	24.0±2.6	2.9±1.6	11.8±0.6	5.4±0.2	5.8±0.3
Nsisioken	6.1±0.8	52.2±6.4	10.8±2.4	56.4±0.3	26.2±0.5	49.4±0.9
Ekiride	5.1±0.2	47.8±4.8	9.2±2.8	51.8±0.4	21.2±0.4	30.6±0.6
Oken-eta	5.4±0.5	42.2±3.1	8.8±2.7	39.2±0.3	10.1±0.4	36.4±0.5
SON limits	6.5-8.5	1000	5	500	150	30

*Values are presented as mean±SD from 5 samples per community. SON, Standards organization of Nigeria. * as $CaCO_3$; NTU, Nephelometric turbidity units.*

Table 2. Heavy metal concentrations of borehole water in Ogale area

Community	Pb	Zn	Ni	Cr	Cd	Mn
Aluebo	0.032±0.001	0.092±0.003	0.007±0.002	0.002±0.001	0.045±0.007	0.003±0.001
Ekpangbala	0.114±0.001	0.022±0.003	0.252±0.010	0.005±0.002	0.143±0.006	0.005±0.001
Ejii	0.023±0.001	0.114±0.004	0.022±0.002	0.002±0.001	0.023±0.002	0.004±0.001
Mbumata	0.021±0.002	0.004±0.002	0.007±0.002	0.009±0.001	0.004±0.001	0.007±0.001
Okori	0.043±0.001	0.061±0.003	0.009±0.002	0.007±0.002	0.002±0.001	0.004±0.001
Adama	0.012±0.001	0.001±0.001	0.001±0.001	0.004±0.002	0.009±0.001	0.006±0.002
Akara	0.033±0.001	0.257±0.006	0.005±0.002	0.008±0.001	0.004±0.001	0.004±0.002
Alueken	0.014±0.001	0.184±0.003	0.002±0.001	0.005±0.001	0.072±0.005	0.003±0.002
Agbi	0.262±0.007	0.116±0.002	0.381±0.039	0.004±0.001	0.242±0.009	0.003±0.001
Nsisioken	0.473±0.013	0.097±0.004	0.297±0.054	0.003±0.001	0.201±0.003	0.021±0.003
Ekiride	0.051±0.003	0.052±0.004	0.007±0.002	0.003±0.001	0.026±0.002	0.017±0.002
Oken-eta	0.042±0.001	0.211±0.007	0.003±0.001	0.007±0.003	0.073±0.003	0.022±0.002
SON limits	0.01	3	0.02	0.05	0.003	0.2

Values are presented as mean±SD from 5 samples per community. SON, Standards organization of Nigeria. All values are in mg/L

Table 3. Pearson correlation matrix for the metal concentrations and pH in borehole water

	Pb	Zn	Ni	Cr	Cd	Mn	pH
Pb	1						
Zn	-0.027	1					
Ni	**0.829**	-0.122	1				
Cr	-0.252	0.171	-0.204	1			
Cd	**0.831**	0.049	**0.94**	-0.247	1		
Mn	0.408	0.101	0.065	-0.114	0.191	1	
pH	0.51912	0.17738	0.28749	-0.2298	0.40358	0.50892	1

Correlation coefficients in bold are significant at $p < 0.01$

Following principal component analysis of the heavy metal data, 68% of the total variance is attributed to the first two components (Table 4). The PC loading i.e. a plot of PC2 vs PC1 groups the metals into clusters. Lead (Pb), Ni and Cd constitute a firmly related group (i.e. a cluster) while each of Cr, Zn and Mn belong to a group (Fig. 1). This trend is clearly evident following clustal analysis of the heavy metal data (Fig. 2). These findings are in agreement with the correlation data.

Table 4. Principal component loading of heavy metal concentrations

Variable	PC1 (48.5 %)	PC2 (19.6 %)	PC3 (16.6 %)	PC4 (12.6 %)
Pb	0.551	0.1	0.028	-0.131
Zn	-0.037	0.777	-0.163	0.593
Ni	0.545	-0.11	-0.31	-0.035
Cr	-0.218	0.398	-0.572	-0.682
Cd	0.556	0.048	-0.218	0.082
Mn	0.203	0.462	0.709	-0.399

The percentage (in brackets) is the explained contribution of principal components to the total variance

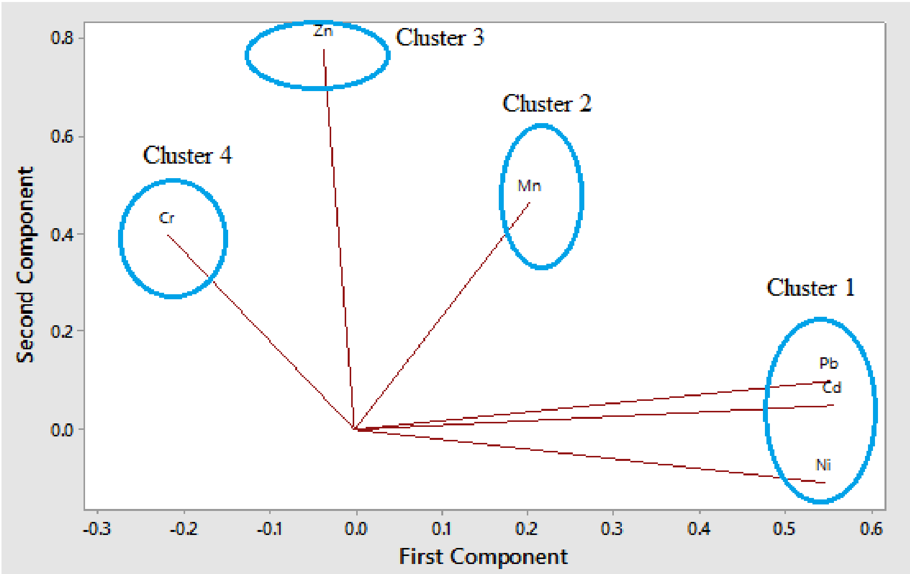

Fig. 1. Loading plot for the components in rotated space

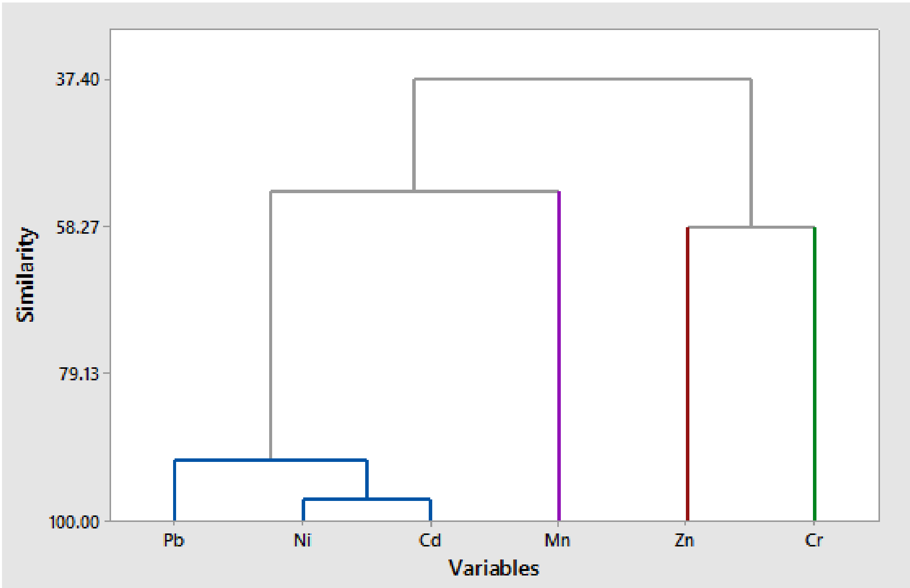

Fig. 2. Dendogram following clustering analysis of raw data using the complete linkage agglomeration strategy. The clusters are distinguishable by the colours.

4. CONCLUSION

The water from the boreholes in the area requires pH adjustments and treatment for the removal of Pb, Ni and Cd to be safe for domestic purposes. The strong association of Pb, Ni and Cd (after multivariate analysis of data) coupled with their relative high concentration reveal that they could be from the same source. However, routine monitoring and assessment of boreholes are required to prevent the indiscriminate sinking of these facilities to meet the ever increasing demands of people in the area by sanitary inspection officers is recommended.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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