



Impacts of Quarrying Activities on Human Health in Boki Area Cross River State Nigeria

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Author's contribution

The sole author designed, analyzed, interpreted and prepared the manuscript.

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ABSTRACT

Field investigation, trace elements geochemistry, borehole and groundwater data were employed to determine the level of contamination or pollution of heavy and trace elements in abandoned quarrying, agricultural sites and its adjoining communities which are leads and other parts of Boki Local Government Area which have massive basement rocks as prospects for quarry establishment. This preliminary study on geosphere-biosphere becomes useful in medical geology as rock-soil-water-human interactions, and relationships are important and obvious. The mining pits depths range from 30.5 m to 50.0 m, while the boreholes depths is 41.0 m to 45.0 m and the thickness of regolith soil weathered Feralsols soil and less weathered Acrisols soil, varies from 22.0 m to 35.0 m in places. The Geochemical data obtained indicates Ba, Th, Ce, Zn, Zr are high in all rocks while Cr and Ni are generally low. In the water samples, some borehole values for the faecal pollution are high and indicates the water is contaminated, CaCO₃, Mg are high, while NO₂, F are low, when compared with established data from WHO standards, they indicates anomalies. The high Ba contents in a previous laboratory animals study shows it can cause nephropathy, but not carcinogenic or genotoxic. The identified boreholes water that are contaminated should be disinfected before use. For a sustainable quarry development in the area, there should be an Environmental Impact Assessment (EIA) with a clear baseline data, reclamation, remedial and rehabilitation procedures before abandonment at the end of the life of the quarries.

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1. INTRODUCTION

Boki Local Government Area (LGA) is in the northern part of Cross River State, about 100 km from the famous Obudu Plateau cattle ranch in Obalinku LGA. The area is in the southeast of the Nigerian Basement Complex terrain. It contains sheets 304 Bansara and 305 Mukuru and it is one of the largest LGA in the state, it has recently started receiving attention. This is to put the geology of the area in proper context with the Nigeria/Cameroon boundary area geology. The details of the geology of the rocks; granitoids, migmatites, granulites and other rocks in the area can be obtained from [1,2,3,4] and also in [5,6] while lineament features can be found in [7,8]. Some of the rocks which are being quarried are granulites at Kanyang quarry, migmatites of granodioritic composition at Katchuan and Charnockites at Buanchor area. It has been established that igneous rocks intrusions have impacts on the orogenic and folded belts because the heat supplied from these intrusions results in remobilization, redistribution and recrystallization of the rocks in these belts [9]. One of such intrusions which have been identified in the area is granitoids, and their magmas are frequently contaminated during stopping processes. The contamination by continental crust materials plays a major role in the genesis of igneous rocks, the chemical compositions are usually affected by these processes [2]. There are large deposits of biotite granites at Boje the LGA headquarters, adamellites at Ebok and enderbites (charnockitic rocks) at Bakum, Buanchor, Katabang and Ashuben hills, which can also be used to establish a quarry operation in the area. The Water Supply & Sanitation Sector Reform Programme (WSSSRP) which have been jointly funded by Government of Nigeria, The European Union, UNICEF and the host communities in the study area, have through their programmes which are aimed at preventing the spread of excreta related diseases like diarrhoea, typhoid and nitrogenous matter in stomach and oesophageal cancer, provided some water boreholes. They also advised on boiling water before drinking and also to drink only water from safe sources to prevent diseases and report cases of dead poultry or sick birds to the nearest authority. In addition, to always wash hands with soap or ashes at critical times like before eating, after using latrine or toilet, before handling food, after handling children's faeces and after handling Poultry and other animals.

The quality of the water from these boreholes needs regular analysis. Weathering in this humid sub-tropical rainforest region is high and the soil profile ranges from 22.0 m at Ubong to 35.0 m at Katchuan area. The soils identified are weathered Ferralsols and less weathered Acrisols and the mountainous parts in the area do not have any soil profile. This paper is an attempt by the authors to show that an associated understanding of geochemistry of the rock, soil and water, with human interactions can lead to a clear understanding of the origin and evolution of any rock based tropical disease in the area.

2. STUDY LOCATION

The study area, Boki LGA is in the Basement Complex of southeast Nigeria. The co-ordinates are within Northings 5° 10' N to 6° 30' N and Eastings 8° 45' to 9° 15' [5]. It has a rugged topography, thick rainforest vegetation, except the highlands and mountainous zones which indicate grassland vegetation, with Afi and Bembe rivers which are tributaries of Cross River, draining the area. The rivers have a dendritic drainage pattern at its youthful stage development, showing rapid downcuts, high gradients, steep-sided valleys, irregular courses, waterfalls and few well developed tributaries (Fig. 1a and b). The Mbe and Afi mountains have grassland vegetation similar to Obudu Plateau and it is cloudy mostly in the day due to water evaporating from the rocks. The area is within the tropical rainfall forest region and on the basis of agro-ecological zones, the Food and Agricultural Organization [10] characterized the area as in the humid tropics and sub-tropics. This agriculture-based classification becomes useful in medical geology as rock-soil-water-plant-human interactions and relationships are apparent in the area [11,12].

3. MATERIALS AND METHODS

The materials acquired are Shuttle Radar Topographic Mission (SRTM) 30 m x 30 m, Landsat 8 Pixel size: 1–7.9:30 m and in Nigerian shape files were employed to extract lineaments, highlands and lowlands for the preliminary studies [8], the detailed studies includes, field investigations which were carried out for groundtruthing, trace element geochemistry of the rocks obtained from the field were made, borehole rock samples were also obtained every one metre as shown in Table 1.

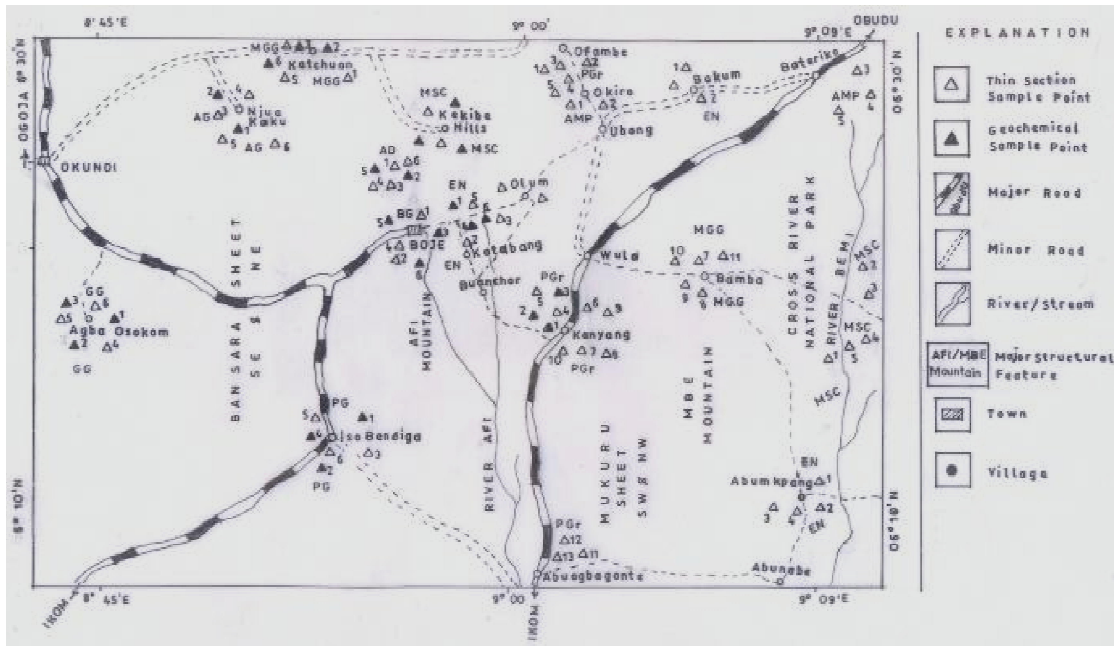


Fig. 1a. Sample location map of Bansara and Muku area

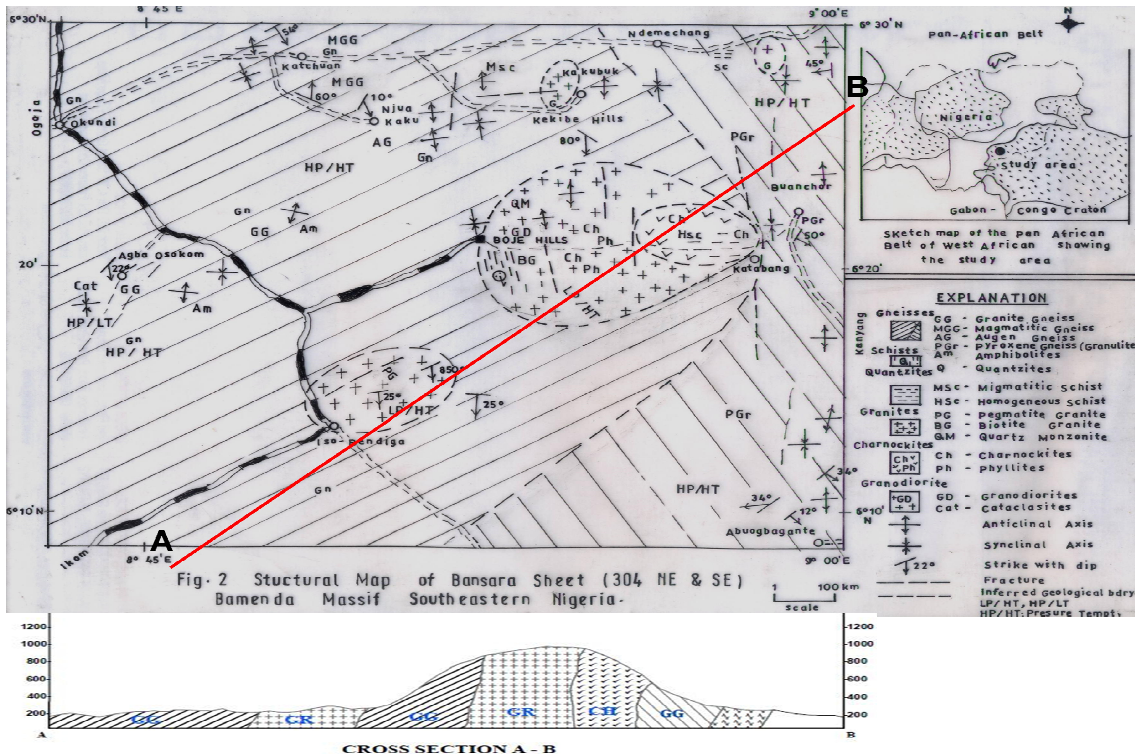


Fig. 1b. Geological map of the study area

The groundwater quality analysis and its impacts on human health for a sustainable quarrying activities and future resource development in Boki area were carried out in the laboratory of Cross River Rural Water and Sanitation Authority CR-RUWATSAN Calabar, Table 2. The rock samples were obtained from the mining pits and other areas representing a spatial and lithological variations were analysed for major, trace and rare earth elements, while water samples were obtained from boreholes drilled for the local communities through (WSSSRP) for the analysis of hydro-geochemistry and bacteriological composition in the area. These rocks which are fresh with good geographical spread were subjected to fusion dissolution methods of Inductively Coupled Plasma Mass Spectrometer (ICP-MS) technique to ensure complete release of the elements for analysis at the Activation Laboratory Ontario, Canada.

4. RESULTS

The blasting vibrations have created cracks in the rocks and residential homes closed to the quarries and the communities also complained of noise during blasting operations and also an asphalt plant is close to the residential homes and source of their drinking water. The field photographs of a borehole completed during one of the field surveys are shown in (Figs. 2 and 3), the average trace elements compositions are presented in Table 1, in parts per million (ppm), the water quality data is in Table 2, while the other data are plotted and method of interpretation relied on comparison of the test results with values established by World Health Organisation (WHO) and other standards and its

implications to health of the inhabitants living in the area. The report of the physical-chemical and bacteriological examination of twelve boreholes are presented in Table 2.

The basement hydrogeology is characterized by weathered overburden and/or fractured aquifers. The source of their drinking water is from existing boreholes and a few surface water from the highlands in the area, which drains out from fractures of the massive basement rocks. Below is a borehole completed at Ubong, Bansara area. Each of the tray represents 10.0 m and the borehole was terminated at 41.0 m due to reduced rate of drilling as fresh rocks were encountered.

We identified a large vein deposits of barite $BaSO_4$ in (Fig. 4), which are yellowish to brown in colour at Kekibe hills and a white coloured type at Olum area. The (Fig. 5), is the site of the asphalt plant of the company that owns the quarry at Kanyang. The trace elements data, plots of spider diagrams indicates high contents of Ba, Th, Ce, Zn and Zr and low contents of Cr and Ni as shown in (Figs. 6 and 7). This principal ore of barium can be used in drilling mud, paint manufacture, filler for paper and textiles. These trace element Lead, Zinc, and Arsenic, which are present in the rocks analysis were not identified in the water samples probably due to the sampling locations which are mostly different from the boreholes samples. Low concentration of Zinc affects human subjects and farm livestock generally, serious concentration of Lead can cause body poison while Arsenic toxicity causes skin diseases, circulatory problems and risk of cancer [13].



Fig. 2. Field photograph showing the sample tray of the borehole completed at Ubong



Fig. 3. Field photograph showing the author identifying the rock samples and the borehole



Fig. 4. Field photograph of Barite vein at Kekibe-Kakubuk, Bansara area



Fig. 5. Asphalt plant of ANFO construction at Kanyang

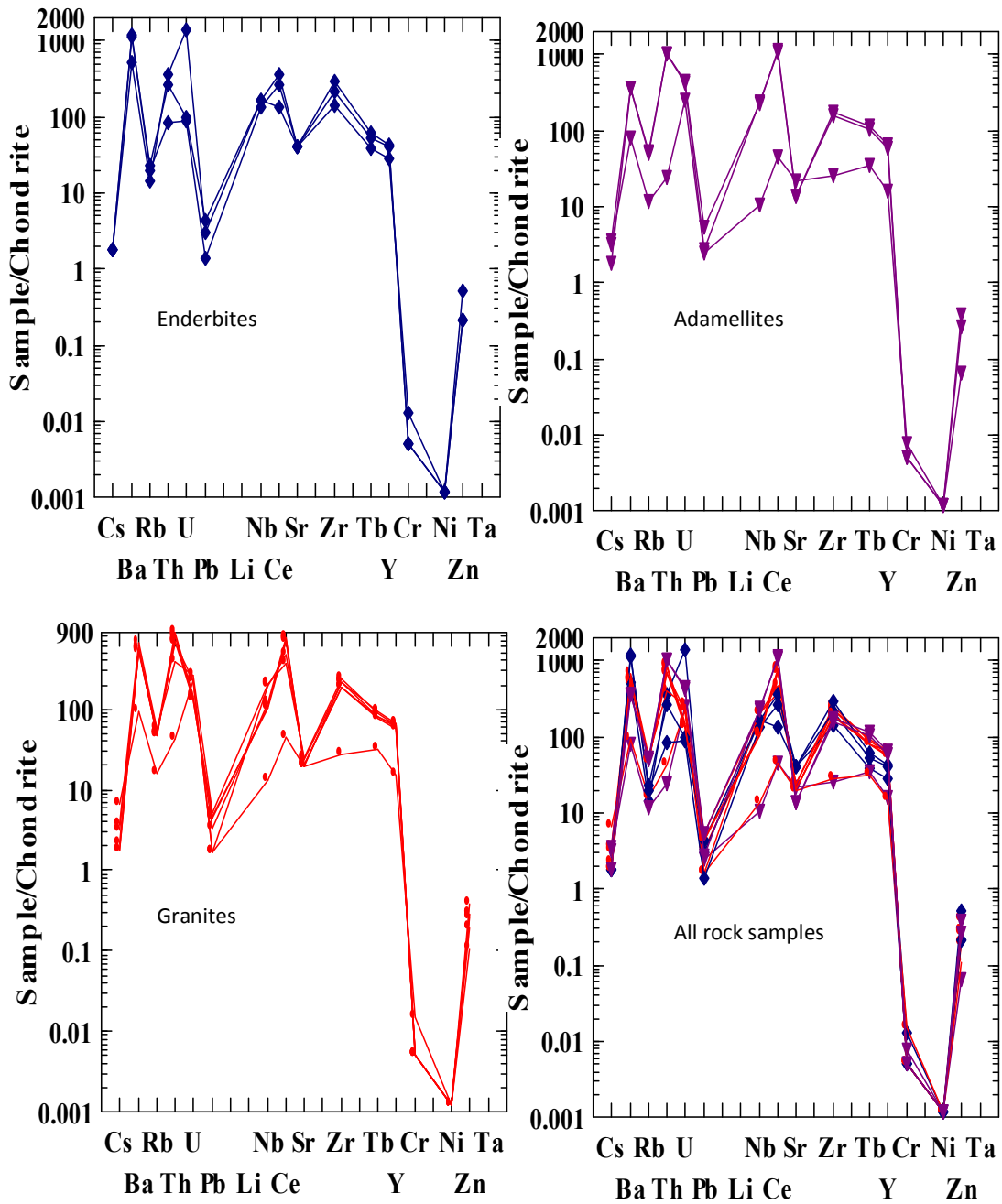


Fig. 6. Enderbites, Adamellites, Granites and all rocks Chondrite-normalized spider diagrams of the rocks, showing high contents of Ba, Ce, Zn and Zr, and low contents of Cr and Ni in all the igneous rock samples

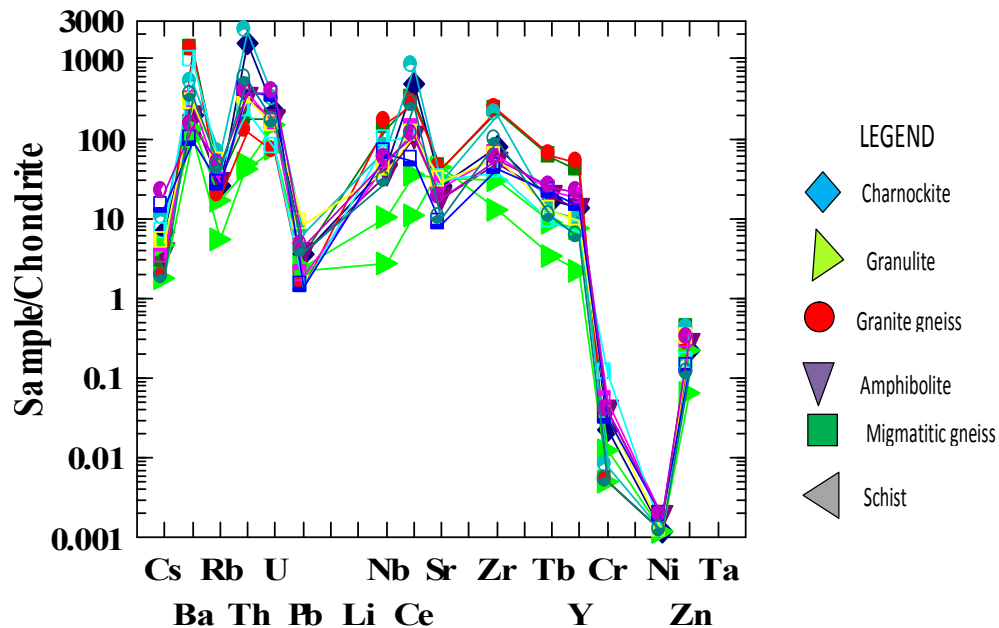


Fig. 7. Chondrite-normalized spider diagram for all rocks showing high contents of Ba, Th, Ce, Zr, and low content for Cr and Ni all the metamorphic rocks

5. DISCUSSION

Barium, in Table 1, has very high concentration in all the rocks in the study area and this is consistent with the values obtained elsewhere in the Basement Complex of Nigeria, while Indium has the lowest concentration in all the rocks [2]. Barium compounds occur naturally in igneous and metamorphic rocks in the area. In a previous laboratory animals studied, there is evidence high barium can cause nephropathy, but no evidence of carcinogenic or genotoxic [14]. Using trace elements geochemistry and geostatistical studies, of some igneous rocks, water and edible vegetables in Ishiagu area southeast Nigeria [15], observed that high trace elements concentrations in the environment could pose great risk to human health and well being, while [16] observed that heavy metal bioaccumulation are indicators of pollution and health risks. They added that these elements are transferred by natural processes to humans. Some trace elements present in the rocks were not identified in the water boreholes samples, while some located in densely populated areas like Bansan Isobendege; Nkanya, Kakwagom, Irruan and Okundi are characterized by iron concentration above the desirable limit, very bitter sweet to a stringent taste and contaminated with pathogenic

bacteria from the faecal coliforms analysis. The pH ranges from slightly acidic which affects taste to desirable limit. Magnesium hardness is within acceptable limits in only four boreholes while the rest are above permissible limits. It helps to activate enzyme systems and excess Mg concentration may cause kidney or bladder stone problems and irritation when passing urine, while deficiency can cause structural and functional changes. The total hardness of water for CaCO_3 mg/L indicates 300 desirable limit and 600 permissible limits. The total Calcium is high in four boreholes hardness is essential for nervous and muscular system, cardiac function and coagulation of blood, if higher it may cause rickets, urinary concretion, disease of the kidney, bladder and stomach disorder [13]. Fluoride is essential for teeth and bones, reduces dental cares in concentration range of 0.8 – 1.0 mg/L and at high levels teeth mottling, skeletal and crippling fluorosis occur. Manganese was identified in one borehole and it was high, this can cause unpleasant test. Some constituents like Zinc, Arsenic, Lead, Aluminium and Ammonium were not detected may be due to the analytical procedures or they were not present. The faecal coliform in three boreholes indicates they are contaminated and the water requires treatment before use.

Table 1. Trace elements chemical composition of some igneous rocks from Boki area in (ppm)

Elements	Enderbites			Adamellites			Granites		
	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg
Mo	5.00	2.00	3.67	4.00	1.90	3.15	3.00	1.90	2.27
Ag	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49
In	0.19	0.19	0.19	0.19	0.19	0.19	0.20	0.19	0.20
Sn	1.00	0.99	1.00	3.00	1.00	2.30	2.00	1.00	1.30
Sb	1.80	0.49	0.93	0.49	0.49	0.49	0.49	0.49	0.49
Cs	0.49	0.49	0.49	1.80	0.50	0.88	1.00	0.49	0.80
Hf	37.20	20.30	26.10	34.70	4.90	28.20	30.70	4.30	20.40
Ta	3.50	2.60	3.17	4.20	0.50	2.45	3.50	0.30	2.40
W	0.99	0.99	0.99	5.00	0.99	1.66	0.99	0.99	0.99
Ti	1.00	0.30	0.53	1.80	0.50	1.23	1.70	1.00	1.03
Pb	16.00	5.00	10.67	19.00	6.00	12.67	19.00	9.00	12.67
Bi	1.70	0.39	0.837	0.39	0.39	0.39	0.39	0.39	0.39
Th	14.90	3.50	9.93	37.20	1.80	24.97	47.70	1.00	30.87
U	16.70	1.10	6.33	3.20	1.60	2.27	5.40	3.00	4.47
Sc	26.00	21.00	23.67	18.00	10.00	16.00	23.00	6.00	16.00
Be	2.00	1.00	1.67	5.00	2.00	3.00	2.00	2.00	2.00
V	73.00	17.00	37.00	70.00	24.00	36.00	43.00	6.00	19.00
Ba	4,022.00	1,755.00	3,228.00	2,236.00	319.00	1,676.80	1,192.00	276.00	892.00
Sr	493.00	472.00	480.00	293.00	236.00	255.17	253.00	163.00	193.67
Y	94.00	62.00	82.30	148.00	34.00	119.30	142.00	36.00	102.00
Zr	1,584.00	777.00	1,180.00	1,347.00	152.00	999.17	977.00	140.00	655.30
Cr	50.00	19.99	29.99	60.00	19.99	26.66	30.00	19.99	23.33
Co	15.00	8.00	11.00	10.00	7.00	8.17	5.00	2.00	3.00
Ni	19.99	19.99	19.99	19.99	19.99	19.99	19.99	19.99	19.99
Cu	50.00	20.00	33.30	30.00	9.99	26.67	20.00	9.99	16.66
Zn	240.00	100.00	146.67	180	50.00	116.67	170.00	30.00	106.67
Ga	30.00	24.00	26.00	34.00	20.00	31.17	35.00	18.00	29.00
Ge	2.00	2.00	2.00	3.00	1.00	2.50	3.00	1.00	2.30
As	5.00	4.99	4.99	7.00	4.99	5.50	8.00	4.99	7.00
Rb	78.00	49.00	64.67	195.00	55.00	153.50	182.00	41.00	132.00
Nb	63.00	49.00	58.00	76.00	5.00	46.30	88.00	4.00	58.30

Table 2. Laboratory report of physiochemical/bacteriological examination of boreholes (CR-RUWATSAN, 2010-2019) location: Boki LGA, cross river state

S/No	Parameters/Units	NDWQS/WHO Standards (2017)	Test result										Health impact
			Loc1	Loc2	Loc3	Loc4	Loc5	Loc6	Loc7	Loc8	Loc9	Loc10	
1.	Appearance	-	-	-	-	Sat.	-	-	-	Sat.	-	Sat.	
2.	Taste	Unobj	Unobj	Unobj	Unobj	Sat.	Sat.	Unobj	Unobj	Sat.	Unobj	Sat.	
3.	Odour	Unobj	Unobj	Unobj	Unobj	Sat.	Sat.	Unobj	Unobj	Sat.	Unobj	Sat.	
4.	pH	6.5-8.5 Desirable Limit	6.8	6.8	6.8	6.5	6.8	7.1	6.3	6.3	6.80- 6.85	6.1	Slightly acidic affects taste
5.	Temperature (°C)	Ambient	19.3	19.3	19.3	27.9	27.5	19.4	22.4	27.3	19.1- 19.4	27.2	
6.	Colour (Pt-Co) Scale	<5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0- 0.0	0.0	
7.	DO (mg/l)	<5	-	-	-	-	-	-	-	-	-	-	
8.	Turbidity (FTU)		0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.0- 0.0	0.0	
9.	Conductivity (ms/cm)	1000	0.45	0.45	0.45	79.2	79.5	0.46	0.12	79.20	0.2- 0.36	79.2	
10.	Ca ²⁺ (mg/L)	75	57.6	57.6	57.6	0.18	0.18	39.2	0.16	0.19	21.6- 41.6	0.18	
11.	Na ⁺ (mg/L)	200	-	-	-	-	-	-	-	-	-	-	
12.	K ⁺ (mg/L)	10-12	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.0- 0.0	0.0	
13.	SO ₄ ²⁻ (mg/L)	400	4.0	4.0	4.0	0.0	0.0	0.0	0.00	0.00	0.0- 0.0	0.0	
14.	Cl ⁻ (mg/L)	250	12.0	12.0	12.0	0.0	0.0	3.0	2.00	0.00	3.0- 3.5	-	
15.	Mg Hardness (mg/L)	< 30 -100	186	186	186	0.36	0.32	138	-	0.31	122- 254	0.33	High concentration of Mg may have laxative effects. Mg salts are diuretic and cathartic
16.	Total Alkalinity (mg/l)	100	-	-	-	-	-	-	-	-	-	-	

S/No	Parameters/Units	NDWQS/WHO Standards (2017)	Test result										Health impact
			Loc1	Loc2	Loc3	Loc4	Loc5	Loc6	Loc7	Loc8	Loc9	Loc10	
17.	Calcium Hardness (mg/l)	75	144	144	144	0.22	0.51	98.0	3.2	0.54	54-104	0.51	High
18.	NO ₂ ⁻ (mg/l)	0.2	0.02	0.02	0.02	0.0	0.0	0.0	0.0	0.00	0.05-0.0	0.0	
19.	NO ₃ ⁻ (mg/l)	50	10.3	10.3	10.3	0.0	0.0	9.3	0.15	0.00	11.1-14.0	0.0	
20.	NH ₃ (mg/l)	-	0.19	0.19	0.19	0.0	0.0	0.0	-	0.00	0.0-0.0	0.0	
21.	NH ₄ ⁺ (mg/l)	-	0.0	0	0	0.0	0.0	0.0	-	0.00	0.0-0.0	0.0	
22.	PO ₄ ³⁻ (mg/l)	3.5	0.0	0	0	0.42	0.50	3.6	1.97	0.51	0.43-0.70	0.56	High
23.	F ⁻ (mg/l)	1.5	0.07	0.07	0.07	0.0	-	0.07	0.43	-	0.0-0.0	-	
24.	Cl ₂ (mg/l)	0.5	0.3	0.3	0.3	0.32	0.30	0.0	0.18	0.34	0.0-0.0	0.31	
25.	Fe ²⁺ (mg/l)	0.3	0.61	0.61	0.61	0.0	0.0	0.0	0.00	0.00	0.02-0.0	0.0	High
26.	Mn ²⁺ (mg/l)	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.6-0.0	0.0	High
27.	Cu ²⁺ (mg/l)	1	0.9	0.9	0.9	0.0	0.0	0.0	0.76	0.00	0.0-0.0	0.0	
28.	As (µg/l)	10	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.0-0.0	0.0	
29.	Al ³⁺ (mg/l)	0.2	-	-	-	-	-	-	-	-	-	-	
30.	Pb ²⁺ (µg/l)	10	0.0	0.0	0.0	-	-	0.0	0.00	-	0.0-0.0	0.0	
31.	Zn ²⁺ (mg/l)		-	-	-	-	-	-	-	-	-	-	
32.	Total Hardness as CaCO ₃ (mg/l)	150	330.0	330.0	330.0	0.0	0.0	236	40.0	0.00	176-358	0.0	Hard - Very hard, may cause disease of kidney, bladder and stomach disorder

S/No	Parameters/Units	NDWQS/WHO Standards (2017)	Test result										Health impact
			Loc1	Loc2	Loc3	Loc4	Loc5	Loc6	Loc7	Loc8	Loc9	Loc10	
33.	NaCl (mg/l)	100	19.8	19.8	19.8	-	0.0	4.95	0.66	0.00	4.95-5.78	0.0	
34.	TDS(mg/l)	500	0.23	0.23	0.23	35.7	39.0	0.23	0.06	39.10	0.1-0.18	39.8	
35.	TSS (mg/l)	0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.0-0.0	0.0	
36.	Faecal Coliforms/100ml of H ₂ O (CFU/100)	0	7.0	7.4	7.2	0.0	0.0	0.0	Uncont.	0.00	0.0-0.0	0.0	Contaminated/Not Safe - Safe
37.	Total Coliform/100ml of H ₂ O (CFU/100)	0	19.0	19.1	19.5	0.0	0.0	0.0	Uncont.	0.00	0.0-0.0	0.0	Contaminated/ Not Safe - Safe

Note: Unobj = Unobjectionable; Sat. = Satisfactory; Cont. = Contaminated; WHO = World Health Organisation; NDWQS = Nigerian Domesticated Water Quality Standards; Loc1 – Bansan Isobendege; Loc2 – Nkanya Kakwagom Irruan 2; Loc3 – Okundi; Loc4 – Boje Area; Loc5 – Obubra Ntemante; Loc6 – Katchuan Irruan; Loc7 – Kanyang 1 Primary School; Loc8 – Orunghe Bawop 2; Loc9 – Nkak1 and Nkak 2; Loc10 – Borum 1; Source: Cross River – Rural Water Sanitation Agency CR-RUWATSA

The agricultural potential of the area include, forest trees with canopy morphology, cassava, palm oil, palm wine, yam, pineapples, banana and cocoa. The canopy forest provides cover for large scale banana, cocoa production and some vegetables which are climbers. "According to [17]", the soil nutrients in the area were identified to be low to moderate in status, while organic carbon and cation exchange capacity are moderate in composition. The chemical and base saturations are higher compared with the physical properties. The topography in the area is high, this may be responsible for the variations. However, in the middle slope zones the soil quality indices, base saturation, cation exchange capacity and organic matter composition are high in Ogoja province. The areas are prone to rockfalls, rockslides, landslides, deforestation and bush burning as it was observed in Buanchor in 2012. These geohazard challenges can be mitigated by proper management of farm and forest lands in the area [8]. According to [18], vegetation and soil organic matter play essential role in the fractionation, distribution and storage of the chemical elements in the humid tropical environment in the southern parts of Cameroon. They used biogeohydrodynamics, which combined approaches in mineralogy, crystallography, biogeochemistry, microbiology, hydrology, geophysics and pedology to study parts of a humid environment. They observed that different groundwater zones, namely flooded areas, hill slope lateritic profiles, weathering interface between the saprolite, in the basement rocks and swampy areas have a strong geochemical contrast.

6. CONCLUSION AND RECOMMENDATIONS

Barium is very high in the rocks but absent in the water because of either the analytical procedures or below the detection limit. The borehole water samples analysis in some wells are hard, contaminated with faecal coliform, they need to be disinfected before use. The water analysis should be carried out two times every year. When we visited the areas some boreholes were not functional and they need services by the communities or local authorities. This probably points to the fact that the analysis must have been done at the time of borehole completion only. In this preliminary medical geology report, we were not able to analyse the soil, plant, animal and human beings due to cost of the analysis and lack of primary health facility

records for monitoring commonly reported health challenges and its association with rocks, soils, vegetation, human interactions and aetiology. However, we suggest funding for a more detailed biogeohydrodynamic study in this forested tropical environment of the Boki area for geochemical contrast determination and their health implications.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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