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Full Length Research Paper

Assessment of soils around quarry terrain in Akamkpa local government area, Cross River State-Nigeria

[1*]Abua Moses and [2]Eyo Edet

[1]Department of Geography and Environmental Science, University of Calabar, Calabar-Nigeria
[2]Department of Agric Econs and Extension, University of Calabar, Calabar-Nigeria

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Soils around the quarry sites in Akamkpa Local Government Area of Cross River State - Nigeria were studied for physico-chemical parameters and heavy metal status. Samples were collected using soil auger at designated transects at the depths of 0-15cm and 15-30cm compositely. The soils are derived from acid crystalline rocks which are made up of granites and gneisses. They are characterized by coarse texture (mostly sand and loamy sand), strong acidity (PH range, 4.9 - 6.8), weakly-structured, medium organic carbon contents (0.42 - 3.21%), and low contents of exchangeable bases and available p contents (I5mgkg^{-1}) in the proscribed transects the mean bulk density (1.49mgm^{-3}) and its corresponding pore space (43.8%) suggests that the area is impacted by dense human activities occasioned by the quarry operations. Heavy metal status of the soils was within the threshold limits established for mineral soil environment. The soils may lack adsorptive capacity for pollutants based on the results of analysis. The level of organic carbon and total nitrogen cannot sustain intensive crop husbandry in the prescribed area. Thus, productivity of the soils could be improved via liming and application of organic/inorganic nutrients for sustainable cropping system in the ecological zone.

Key words: Assessment of soil, Terrain, Quarry, Physical-chemical Parameters, Heavy metals, ecological zone

INTRODUCTION

Worldwide, quarry mining involves a variety of operations which can be environmentally disruptive if proper sitting design, construction, operation and follow-up monitoring are not provided (Environmental Guidelines, 1993). This is so because of the associated fine dust particles, disruptions of the earth's surface via use of explosives in the blasting process via-a-vis health hazards to site workers. Thus, it becomes imperative to assess the soil of such area in an attempt to quantify the environment for sustainability (Bayrami et al., 2008).

The soil is derived from acid crystalline rocks which consist of granites and gneisses. The surface texture may range from loamy sand to sandy loam. Being leached mineral soils, they are acidic in reaction, low-in contents of exchangeable bases, organic carbon, total and available phosphorous. They are moderate infertility status (Abua and Edet, 2007).

The soils of the area have been placed in Soil Taxonomy (Soil Survey Staff, 1998) order Inceptisols and Ultisols (Holland et al., 1989). Some food crops grown in the area include cassava, yam, cocoyam, vegetable,

*Corresponding Author E-mail:ask4mossabua@yahoo.com

plantain, banana, etc. Others are tree crops such as oil palm (*Elaeis guineensis*), cocoa (*Theobroma cocao*), ubber (*Havea brasiliensis*), and Raphia palm (*Raphia spp*). Some natives are involved in the logging of timbers cum hunting activities which are frowned at by the state's legislation. The overall objective of the paper therefore, is to assess the soils around the quarry area of Akamkpa Local Government Area with a view to evaluating its physico-chemical characteristics and heavy metal status. The organization of this paper is clear. The materials and methods are presented in section 2 with recourse to the description of the study area, field studies and laboratory analysis. Next are the analytical results, followed by the discussion. The last section concludes the paper.

MATERIALS AND METHODS

Study area

The study area is located in the southern senatorial district of Cross River State within latitudes 5°24"N and longitude 8°12"E (Fig. I), The topography of the area is strongly undulating while the vegetation is typical of rainforest which are gradually being disturbed via quarry activities. Albeit secondary forest re-growth abound in which *Elaeis guineensis* (oil palm), *Anthocleista vogelii* (cabbage tree), *Musanga cercropiodes* (umbrella tree), *Pyncnanthus angolensis* (false walnut) and *Ceiba pentandra* (silk cotton trees) occurred commonly. The rarity of wildlife within the quarry radius might be partly due to vegetation cover that has been tampered with, followed by vehicular movement, operation of machinery, use of explosive and night-time illumination. Mean annual temperature is between 21° and 29°C during the dry season with an average annual rain fall of 3000mm (NIMET, 2008; Bulktrade, 1989). The high yielding quarry operations and tourism potentials of the area has placed the state in vintage position of economic prosperity. Essentially, the area is blessed with plethora of mineral resources, forest products and has the state of the art tourism potentials in the country.

Field studies

Composite soil samples were taken at two depth 0-15cm and 15-30cm at established reference point, positioned along North-South and East-West transects at different topographical locations of landscape using the soil auger at intervals of 500m, 1km, and 3km. The coordinates of the sampling stations were Geo-referenced using a Magellan Spot Track Map GPS at the prescribed transects and distance intervals. The samples were put in labelled polyethylene bags and transported to the laboratory for processing prior to laboratory analysis.

Laboratory analysis

The samples were air-dried, grinded with wooden roller and sieved via 2mm mesh. Particle size distribution (sand, silt and clay fractions) was carried out by Bouyoucos (1951) hydrometer method as outlined by Gee and Bauder (1986). The bulk density was determined by the core method (Tel and Hagarty, 1984) using a core sampler. The percent total pore space was computed from the bulk density assuming a particle density of 2.68cm^{-3}. Soil pH was determined in 1:2 soil/water ratio. The electrical conductivity (EC) was measured in 1:2 soil water extract using an electrical conductivity meter. The available phosphorous was determined by Bray and Kurtz (1945) No. 1 method. Exchangeable acidity was extracted with 1MKCL solution and the acidity in the extract measured by titration with 0.01MnaOH. The exchangeable bases were extracted with neutral 1MNH$_4$Ac, pH7; the potassium and sodium in the extract were determined by flame photometry while calcium and magnesium by versenate EDTA titration (Jackson, 1962).

Total Nitrogen was determined by the Macro-Kjeidahl digestion method. Heavy metal contents were extracted from the soils by digestion of the soil samples with a mixture of nitric and perchloric acid (Barnhisel and Bertsch, 1982). The metal concentrations in the extracts were read on Atomic Absorption Spectrophotometer (AAS).

RESULTS

Soil physico-chemical properties

The physical and chemical properties of the soil-surface (0-15cm) and subsurface (15-30cm) are summarized in Tables 1 and 2 in relation to the sampling locations.

The texture of the soil samples along the transects (NT, ET, WT, and ST) is mostly sand and loamy sand. Sand fraction ranged from 68.2 to 91.4% with a mean of 82.4%; silt fraction varied between 4.6 and 16.4% with a mean bulk density and its corresponding pore space were 1.49mgm3 and 43.8% in surface soil.

The PH varies from 4.9 to 6.8 with a mean value of 5.4 except the control station. Electrical conductivity value ranged from 0.01 to 0.071dsm^{-1} with a main value of 0.39dsm^{-1} for surface and subsurface soil.

Organic carbon content ranged from 0.43 to 21% with a mean of 2.01%. The total nitrogen level varied from 0.04 to 0.96% with a mean of 0.34%. Available P varied between 3 and 9mgkg^{1} with mean of 6mgkg^{1} for surface and subsurface soil.

Mean values of exchangeable bases were as follow: Ca (2.90cmolkg^{-1}), Mg (l.70molkg^{-1}), k (0.110molkg^{-1}). The effective cation exchange capacity (ECEC) ranged from 3.26 to 7.40cmolkg^{-1} for surface and subsurface

Table 1. Physico-chemical characteristics of soils from Quarry Sites in Akamkpa Local Government Area, Cross River State

Soil sample	GPS Coordinates	Depth	pH	EC	Org . C	Tot al	Bray p-1	Exchangeable bases (cmolkg)				EA	ECEC	B S	Sand	Silt	Clay	Texture	Bulk density	Pore space
		(cm)		DSm^{-1}	%	N %	Mgkg^{-1}	Ca	Mg	K	Na	Cmolkg^{-1}	Cmolkg^{-1}	%	%	%	%		Mgm^{-3}	%
Ref. Pt.	N05^{0}21'082"	0-5	5.3	0.046	1.41	0.10	5	3.51	1.96	0.09	0.03	1.81	7.40	75	91.4	4.6	4.0	S		
	E008^{0}24'10.6"	15.30	5.2	0.041	1.22	0.5	4	2.22	0.98	0.07	0.03	1.83	5.13	64	90.4	5.6	4.0	S		
NT$_1$	N05^{0}21'12.0"	0-5	4.9	0.032	3.21	0.14	6	2.82	1.26	0.08	0.04	2.72	6.92	61	80.4	7.6	13.0	1s		
1km	E008^{0}24'22.4"	15-30	4.9	0.030	1.31	0.08	3	1.36	0.87	0.06	0.03	2.81	5.13	45	70.4	12.6	14.0	S1		
W$_1$	N05^{0}21'04.5"	0-5	5.0	0.051	2.24	0.09	7	2.52	1.31	0.08	0.05	1.84	5.80	68	72.4	14.6	13.0	1s		
500m	E008^{0}24'28.2"	15-30	5.0	0.050	1.41	0.08	5	1.10	0.81	0.07	0.04	1.86	3.88	52	71.4	20.6	9.0	S1		
ET$_1$	N05^{0}21'22.8"	0-5	5.1	0.021	2.91	0.92	9	2.42	1.42	0.10	0.03	1.77	5.74	69	85.4	5.6	9.0	1s	1.49	43.8
1.5km	E008^{0}24'09.5"	15-30	5.1	0.023	1.53	0.80	7	1.82	0.97	0.08	0.03	1.78	4.68	62	75.4	10.6	15.0	S1		
EF$_2$	N05^{0}21'02.5"	0-5	5.4	0.041	2.21	0.96	8	2.80	1.45	0.08	0.04	1.69	6.06	72	83.4	5.6	11.0	1s		
2.5km	E008^{0}24'10.8"	15-30	5.2	0.039	1.10	0.71	6	1.36	0.88	0.06	0.03	1.70	4.03	58	74.4	11.6	14.0	S1		
ST	N05^{0}21'27.1"	0-5	6.8	0.01	0.71	0.04	3	4.10	2.10	0.16	0.04	0.87	7.21	89	90.4	4.6	5.0	S		
3km	E008^{0}19'27.1"	15-30	5.0	0.02	1.67	0.16	3	2.10	2.42	0.21	0.21	1.3	6.24	79	73.2	16.4	10.4	1s		

Ref. Pt. - Soil samples at reference point
NT$_1$ - Soil samples at 1km north transect
ET$_1$ - Soil samples at 1.5km east transect
WT$_1$ - Soil samples at 500m west transect
ST - Soil samples at 1km south transect

soils. Base saturation varied from 45 to 89% with a mean of 73% in surface and subsurface soils (Table 2).

Heavy metal contents of the soils samples are presented in Table 3. Mean values for the soil samples collected from the area were as follows: 76.60mgkg-1 for Fe, 43.02mgkg-1 for Mn, 28.43mkg-1 for Cu, 37.44mgkg-1 for Zn, 1.32mgkg-1 for Cr, 2.20mgkg-1 for Ni, 0.22mgkg-1 for Co and 3.78mgkg-1 for V. Table 3 shows mean heavy metal concentrations.

DISCUSSION

Textural classes of the soil were mostly loamy sand in the surface while sandy loan dominated the subsurface soils.

The mean bulk density value of 1.49Mgm^{-3} and pore space of 43.8% reflects soil of high sand content. Thus, soils with high sand content exceeding 70% have weak surface aggregation (Donahue et al., 1990). Such soils are porous and have high rate of water infiltration and air circulation (Gbadegesin and Abua, 2011).

The soil reaction is acidic with a mean pH value of 6.8 for surface soils (Table 2). The acidity of the soils might have been due to washing away of basic cations from the soils by the high rainfall in the area. Such acid soil condition can cause phosphate fixation and reduce the ability of microbes to fix atmosphere nitrogen. Values of electrical conductivity are low (range, 0.01-0.071dSm^{-1}) as the values do not exceed the critical values of 2dSm^{-1} (FAO, 1974) for sensitive crops species and 4dSm^{-1} (Donahue et al., 1990) for identifying the soils as saline soils. Thus, the soils have no salinity problem.

The soils are rated medium in organic carbon contents of 2.01% in the surface soils. Correspondingly, total nitrogen is rated medium (mean, 0.34%) in the soils of the area (Holland et al, 1990). These levels of organic carbon and total nitrogen cannot sustain intensive crop production in the area and therefore need application of fertilizers.

Available P mean value of 6mgkg^{-1} for surface soils is an agricultural limitation as the value is

Table 2. Summary of physical and chemical properties of soil from quarry site, Akamkpa LGA, Cross River State – Nigeria

Parameter	Transect samples		Maximum Tolerable limits
	Range	Mean (surface)	
No. of samples	1.3	-	-
pH	4.9 – 6.8	5.4	5.1-6.5
Ec (dSm^{-1})	0.01 – 0.71	0.039	2-4dSm^{-1} +
Org. C	0.42 – 3.21	2.01	2.0% ++
Total N (%)	0.4 – 0.96	0.34	0.20% ++
Avail P. $mgkg^{-1}$	3 – 9	6	20$mgkg^{-1}$ +++
Calcium (Ca) (cmolkg)	1.10 – 4.10	2.90	10 – 20$cmolkg^{-1}$ +++
Magnesium (Mg) (cmolkg)	0.81 – 2.42	1.70	3-8$cmolkg^{-1}$
Potassium (K) (cmolkg)	0.06 – 0.21	0.11	0.6-1.2$cmolkg^{-1}$ +++
Sodium (Na) (cmolkg)	0.03 – 0.21	0.06	0.7-1.2$cmolkg^{-1}$ +++
ECEC (cmolkg)	0.81 – 21.81	1.71	4.1 $cmolkg^{-1}$ +++
Base sat. (1%)	3.26 – 7.40	6.48	10 $cmolkg^{-1}$ +++
Sand (1%)	45 – 89	73	60-80% +++
Silt (%)	68.2 – 91.4	82.4	NL
Clay (%)	4.6 – 16.4	8.4	NL
Iron (Fe) ($mgkg^{-1}$)	4.0 – 19.4	9.3	NL
Manganese (Mn) ($mgkg^{-1}$)	69.43 – 88.24	76.60	10,000-100,000$mgkg^{-1}$*
Copper (Cu) ($mgkg^{-1}$)	37.45 – 43.02	40.23	200 - 2000 $mgkg^{-1}$**
Zinc (Zn) ($mgkg^{-1}$)	22.62 – 33.14	28.43	1-100 $mgkg^{-1}$**
Chromium (Cr) ($mgkg^{-1}$)	29.89 – 43.21	37.44	10-300 $mgkg^{-1}$**
Nickel (Ni) ($mgkg^{-1}$)	1.24 – 1.40	1.32	5-1000 $mgkg^{-1}$**
Cobalt (Co) ($mgkg^{-1}$)	1.92 – 2.36	2.20	10-1000 $mgkg^{-1}$**
Vanadium (V) ($mgkg^{-1}$)	0.18 – 0.29	0.22	1-70 $mgkg^{-1}$**
	3.26 – 4.21	3.78	20-500 $mgkg^{-1}$**

Notes * = Brady and Weil; + = Miller and Donahue, 1996; ** = Bohn et al., 1985; ++ = FPDD, 1990; +++ = Holland et al., 1989

Table 3. Heavy Metal Contents in Soils from Stemco Quality in Obong

Heavy metal ($mgkg^{-1}$)	North transect	West transect	South transect	Mean transect	Natural levels in mineral soil environment ($mgkg^{-1}$)
Iron (Fe)	88.24	72.12	69.43	76.60	10,000-100,000*
Manganese (MN)	37.45	40.23	43.02	20.23	200-2000**
Copper (Cu)	22.62	29.52	33.14	28.43	2-100**
Zinc (Zn)	39.23	43.21	29.89	37.44	10-300**
Chromium (Cr)	1.40	1.24	1.32	1.32	5-1000**
Nickel (Ni)	1.92	2.32	2.36	2.20	10-100**
Cobalt (Co)	0.18	0.20	0.29	0.22	1-70**
Vanadium (V)	3.86	3.26	4.21	3.78	20-500**

* Brady and Weil, 1991
** Bohn *et al*., 1985

below 15$Mgkg^{-1}$ (Holland et al., 1989).

Exchangeable bases are generally low in the soil. This is reflected by low values of effective cation exchange capacity of less than 10$cmolkg^{-1}$ established for productive soils (Enwezor et al., 1990).

About 77% of the samples collected from the area have high percentage bases saturation exceeding 60, indicating that the basic nutrients may be in available forms in the soils.

Taking into consideration, the sandy texture, medium organic carbon content and low effective cation exchange capacity (ECEC), the soils lack adsorptive capacity for pollutants. The values of heavy metals are within the tolerable limits established for mineral soil environment (Bohn et al., 1985). Despite these low concentrations of metals in the soils, their impacts as to the degree of contamination can be possible depending on the local edaphic factor (Jeandaude and Robert, 1982).

CONCLUSION

The soils of the prescribed area are formed from acid crystalline rocks. They are characterized by coarse texture in the surface while the subsurface have fine clay accumulation. They are acidic in reaction with a pH range between 5.4 to 6.8 within the ecological settings. The low organic contents of the soils cannot guarantee food security in terms of intensive crop production. The high sand contents (> 70%) are capable of exposing the soils to erosion hazards. Such soil may lack adsorptive capacity for nutrients and pollutants. The heavy metal status of the soils is within the permissible limits allowed by FEPA (1988) and WHO (1986). In spite of these, there should be periodic environmental auditing and monitoring of the project area to ensure environmental quality and sustainability. The soils could be put into productive use in terms of crop husbandry by the application of organic/inorganic fertilizers.

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