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Assessment of Physico-Chemical Properties of Soils Around Quarry Sites of Different Agricultural zones of Ebonyi State, Nigeria

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***Abstract*—*Quarrying is an immemorial activity that physically disturbs soil and impacts soil quality chemically. This study assessed the physico-chemical properties of soils around quarry sites of various agricultural zones of Ebonyi state, southeastern Nigeria. Using transect method, triplicate auger soil samples (0-10 and 10-20cm depth) were collected from four equal distances (0, 50, 100 and 150m) away from two mining sites in each of Ebonyi central (Nigercem and CNCC) and Ebonyi north agricultural zone (CDC and Ngbo). A total of ninety six (96) samples were used for the study and standard laboratory techniques employed in soil physico-chemical determination. Data were subjected to analysis of variance (ANOVA), correlation and Principal component analysis. From the results, significantly ($p<0.05$) higher concentrations of silt(18.15-31.90%), clay(7.85-10.86%), silt clay ratio (SCR) (2.85-4.29) and bulk density(1.43-1.75gcm-3)were in Ebonyi central while higher sand(54.15-72.00%), moisture content (MC) (15.11-23.17%) and total porosity(TP) (31.54-44.19%) were in Ebonyi north agricultural zone.Apart from SCR,MC, and BD, physical properties also varied significantly along the sampling distances with most of them including clay(10.35%), SCR(4.13) and MC(20.62%)occurring in 100m. Across the soil depths, significant variation was only found in sand, BD and TP with higher values of all the physical properties except BD obtained in 0-10cm. All the soil chemical properties varied significantly except pH and %BS. Higher contents of pH(5.86-5.73), AvP(2.95-2.99 mgkg-1), Ca(26.65-46.32), Mg(7.73-18.37), K(5.95-8.46), Na(7.03-12.84), TEA(0.23-0.31), ECEC(47.59-86.29) and %BS(99.47-99.63) were in Ebonyi north while OC(0.43-0.86%) and TN(0.10-0.13%) were in Ebonyi central. Along the distances, chemical properties varied significantly apart from pH, Ca, Mg and %BS. Higher content of most of them including TN(0.14), AvP(3.35), K(9.75), Na(13.55), ECEC(72.57) and %BS(99.67) were in 150m. Within the soil depths, significant variation was only found in the concentrations of OC and TN with greater contents of all of them except pH, Mg and %BS obtained in 0-10cm. Physico-chemical properties especially MC,BD and pH exhibited obvious significant associations.PCA demonstrated that except SCR and pH, all the physico-chemcial parameters studied was significantly increased with intensity of quarry in the studied areas.*

***Keywords*—** *Agricultural zone, basic cations, physico-chemical, quarry, soil.*

I. Introduction

Population growth and industrial developments greatly increased the need for raw materials, today. This has also led to an increase in mining activities to be able to meet this need for raw materials. Part of raw materials is supplied from stone quarries. Quarrying, a form of surface mining, is undertaken as open-pit mining (Sarıand Özcan, 2018). Quarrying is an immemorial activity explored for different deposited minerals such as limestone and granite for construction and related purposes. Despite the benefits of generating significant cash and revenue for the economy, quarrying activities have not been adequately regulated by the government agency (Ogunmade *et al*., 2023), thus, quarryingcould potentially be a destructive developmental activity as its socio-economic benefits hardly compensates for the overall detrimental effects on natural ecological systems (Melodi, 2017) particularly in the context of soil degradation which have emerged as a critical and pressing environmental concern (Mir *et al*., 2020). Mining physically disturbs topsoil and impacts soil and water quality chemically (Martonas, 2017). Surface mining, the most common mining practice, removes topsoil and depletes soil nutrients, rendering land infertile and useless for agricultural purposes (Emmanuel *et al*., 2018; Norgate and Haque, 2012). Therefore, rock and rock mineral exploitation activities result to change in the physical and chemical composition of the soils (Hassan, 2022).

Several studies were found that examined the environmental impacts of marble, limestone, and granite quarrying and processing (Chang *et al*., 2010; Khyaliya *et al*., 2017; Li *et al*., 2019; Souza *et al*., 2010; Tugrul, 2019; Tugrul and Esat, 2019; Yavuz and Sabah, 2008). However, very few studies have been published which specially focused on the effects of quarrying on soil physico-chemical properties. As soil is the main sink for most pollutants produced in mining and quarrying activities, it is imperative to study the impacts of quarrying activities on soil properties. Moreover, a good knowledge of the variations of soil physical and chemical properties and their interactions around is essential for good land evaluation which is a pre-requisite for sound land use planning (Lawal *et al*., 2013).

Elsewhere, Zwolak *et al.*, (2019) reported that soil pollution from quarrying activities reduced soil moisture and soil organic contents. It can also alter soil pH causing retention of undesirable metals thereby affecting soil quality (Julie *et* *al*., 2018). Compared with the background pH, (Etim and Adie, 2012) reported a sharp decrease in pH occurred in topsoil samples; 200 m far away from the exploration arena. In addition, soils close to quarries may contain significant amount of contaminant like dusts and chemicals that can inhibit microbial activities thereby reducing the available nitrogen content of soils (Olatunde *et al.*, 2021). This study therefore examines the physico-chemical properties of soils around quarry sites of different Agricultural zones and seasons in Ebonyi state.

II. Materials and Methods

2.1 Study Location

Ebonyi State was created on October 1, 1996; with Abakaliki as its capital. It is located in the southeast geopolitical zone of Nigeria. There are 13 Local Government Areas (LGA) in the State namely: Abakaliki, Ebonyi, Izzi, Ishielu, Ohaukwu, Ikwo, Ezza South, Ezza North, Afikpo South, Afikpo North, Ohaozara, Onicha and Ivo. The State shares a border with Benue State to the North, Enugu State to the west, Imo and Abia States to the south and Cross River State to the east. The area is drained by the tributaries of the Ebonyi river and has a land area of approximately 5,935 square kilometers lying between latitude 7^0 30'E to 8^0 30'E and Longitude 5^0 40'N to 6^0 45' N (Awoke and Okorji 2004, Ota *et al*., 2021). The area is located within the partially modified low rain forest and wooded/ grassland derived savannah region of Southeastern Nigeria, characterized by period of dry and rainy seasons. The climate of Ebonyi State is of a humid tropical climatic region. The mean annual temperature stands at 28^o with an average rainfall of 1200mm - 2500mm (Ebonyi Agricultural Development Programme (EBADP), 2019). Shale parent materials are predominantly present in the soils (Ogbodo 2013b). The dominant vegetation is characterized by tree shrubs, with abundant palm trees particularly in the southern and central zones of the State. The area is comprised of three Agricultural Zones namely; Ebonyi North, Central and Ebonyi South Agricultural Zones (EBADP, 2019).

2.2 Field studies

Reconnaissance visit was carried out to identify the sampling sites namely Ebonyi Central Agricultural Zone (Nigercem and CNCC in Nkalagu, Ishielu L.G.A) and Ebonyi North Agricultural Zone (Ngbo site and CDC in Ohaukwu and Izzi L.G.A respectively). In each quarry site, triplicate soil samples (0-10 and 10-20cm depths) were collected from four distances viz; 0, 50, 100 and 150 m away from the quarry sites. A total of ninety-six (96) samples were utilized in the study. Undisturbed soil samples for determination of bulk density and moisture content were collected using core samplers. Soil samples collected were labeled, air-dried at room temperature, crushed and sieved using 2mm mesh sieve before being sent to laboratory for physico-chemical analysis.

2.3 Soil laboratory analyses

Particle Size Distribution was determined by hydrometer method according to the procedure of Gee and Or (2002) using water and sodium hexametaphosphate (calgon) as dispersant. Bulk density was measured using core method as Grossman and Reinsch (2002) recommended. Total porosity was computed from the bulk density as described by Vomocil (1965). Moisture content was determined using gravimetric method. Soil pH was determined in water and 0.1kCl using pH meter in soil/liquid suspension of 1:2.5 (Hendershot *et al.*, 1993). The method used to determine organic carbon was wet oxidation, as explained by Walkley and Black in 1934. Phosphorus availability was assessed through the Bray 2 solution technique as described by Olsen and Sommers (1982). Exchangeable K and Na were extracted using 1N Neutral Ammonium Acetate (NH_4OAC) and determined photometrically using flame photometer (Thomas, 1982). Exchangeable Magnesium and Calcium was determined using ethelene diaminetetraacetic acid (EDTA) (Thomas, 1982). Total Nitrogen was determined by kjehdahl digestion method using concentrated H_2SO_4 and a Sodium Copper Sulphate catalyst mixture (Bremner and Yeomans, 1988). Exchangeable Acidity was determined titrimetrically (Mclean, 1982). Effective Cation Exchange Capacity (ECEC) was calculated from the summation of all exchangeable bases and exchangeable acidity (IITA, 1982). Percentage Base Saturation (%BS) was determined by computation.

2.4 Data analysis

Data generated were subjected to mean, analysis of variance (ANOVA) and correlation analyses using Genstat Statistical Package Version 18. Using SPSS Version 21. The factorial ANOVA were subjected to LSD test at $P<0.05$ to know the significant difference. ANOVA and Pearson’s correlation analysis were used to assess the relationship between heavy metal concentration and soil properties principal component analysis (PCA) was done to reduce the set of soil variables as well as pick out the most significant soil properties that substantially increased across the quarry sites.

III. Results and Discussion

3.1 Effects of quarry sites on soil physical properties studied

From Table 1, it was shown that at the various locations, sand, silt and clay particles significantly ($p<0.05$) varied from 54.2-74.9 (mean=63.08%), 17.22- 35.46 (mean=25.02%) and 5.7- 14.49 (mean=9.36%) decreasing as

Sand>silt >clay. Greater sand (74.9%), silt(35.46%) and clay(14.49%) were obtained in Ngbo, Nigercem and CNCC respectively. Sand particles dominated the mineral fraction in the soils probably because the soils were formed from decomposition of granitic parent materials rich in quartz and feldspars (Kumar *et al*., 2016; *et al*., 2019).

Considering the distances, significantly ($p<0.05$) highest (66.6, 26.58 and 10.35%) sand, silt and clay were obtained in 0, 50 and 100m respectively whereas lowest (61, 21.88 and 8.34%) sand, silt and clay sizes were obtained in 150, 0 and 0m respectively, implying that unlike silt and clay, sand fractions decreased progressively with increasing distance from the quarry sites. The quarry soils' high silt and sand contents suggest that the substrates' ability to bind nutrients and form aggregates is low (Brady and Weil, 2004).

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Consequently, soils of Ebonyi Central Agricultural Zone were sandy loam whereas Ebonyi North Agricultural Zone was loamy sand. In similar study, Belay *et al*. (2020) reported 16.7% silt loam for soil texture of the quarry in northern Ethiopia. Within the soil depths, higher sand (64.7%), silt(26.22%) and clay(9.7%) were at the topsoil (0-10cm).This generally decrease of sand down the soils due to sorting of fine materials, silt and clay, from surface horizon through action of erosion or eluviation and illuviation processes (Akinbola *et al*., 2009).

TABLE 1: Soil physical properties studied

	Sand	Silt (%)	Clay	TC	SCR	MC (%)	BD (gcm^{-3})	TP (%)
Location								
Nigercem	54.2	35.46	7.23	SL	6.45	14.84	1.77	30.96
CNCC	54.1	28.33	14.49	SL	2.12	15.37	1.74	32.11
CDC	69.1	17.22	10	LS	2.46	28.58	1.36	46.73
Ngbo	74.9	19.07	5.7	LS	3.24	17.76	1.49	41.65
LSD$_{(0.05)}$ Fa	**3.63**	**3.96**	**1.48**		**0.70**	**2.4**	**0.18**	**4.71**
Distance(m)								
0	66.6	21.88	8.34	SL	2.73	18.3	1.69	33.92
50	62.7	26.58	9.1	SL	3.88	19.35	1.59	37.75
100	61.9	25.23	10.35	SL	4.13	20.62	1.55	39.29
150	61	26.4	9.62	SL	3.53	18.28	1.52	40.49
LSD$_{(0.05)}$ Fb	**3.63**	**3.96**	**1.48**		**0.70**	**2.4**	**0.18**	**4.71**
Depth (cm)								
0-10	64.7	26.22	9.7	SL	3.62	19.44	1.51	41.09
10--20	61.4	23.83	9.01	SL	3.52	18.83	1.67	34.63
LSD$_{(0.05)}$Fc	**2.57**	**2.80**	**1.05**		**1.97**	**1.70**	**0.13**	**3.33**
LSD$_{(0.05)}$Fa X Fb	*	*	*		*	*	*	*
LSD$_{(0.05)}$Fa X Fc	*	*	*		*	*	**NS**	*
LSD$_{(0.05)}$Fb XFc	**NS**	*	*		*	*	*	*
LSD$_{(0.05)}$Fa X Fb X Fc	*	*	*		*	*	*	*

SCR=silt clay ratio, SL=sandy loam, LS= loamy sand, MC=moisture content, BD=bulk density, TP=total porosity.

Along the sampling distances, silt clay ratio (SCR) ranged from 2.73-4.13 and was irregular in its distribution from the quarry site and also differed insignificantly. However, the values of the SCR differed significantly amongst the locations and were 6.45,2.12, 2.46 and 3.24 in Nigercem, CNCC, CDC and Ngbo respectively. Within the soil depths, SCR was insignificantly greater (3.62) at the top soil compared to subsoil (3.52). Moreover, it was indistinctly distributed along the sampling distances where the highest (4.13) and lowest (2.73) were obtained in 100m and 0m respectively. Igwe *et al*. (1995) documented that the higher the silt clay ratio the younger the soils and that higher SCR are associated with landscape devastated by erosion. It follows that of Nigercem were younger than others.

Moisture is one of the most important properties of soil. Absorption of the nutrient by soil is largely depends on moisture content of the soil, moisture of soil also shows its effect on the texture of soil (Kekane *et al*., 2015). Moisture content (MC) in this study was shown to only vary significantly among the locations, it varied from 14.84-15.37% and 17.76-28.58% with mean value of 15.11 and 23.17% in Ebonyi central and Ebonyi north agricultural zone respectively. Also, it was irregular across the distances with insignificantly highest (20.62%) and lowest (18.28%) obtained at 100 and 150m respectively whereas depth-wise, it was insignificantly higher at the topsoil (19.44%) compared to subsoil (18.83%). Increased aggregation and total pore space (Vengadaramana and Jashothan, 2012), as well as dense vegetation cover and gradual organic matter supplements (Singh *et al*., 2004), may be the causes of higher MC in overburden soils located far from mining activities as opposed to those closer to the quarry.

Soil bulk density (BD) decreased with increasing distance away from the mining site with a range of 1.52-1.69 gcm^{-3}. It also varied significantly amongst the locations and depths with a range of 1.74-1.77(mean=1.75gcm^{-3}) and 1.36-1.49(mean=1.43 gcm^{-3}) in Ebonyi central and Ebonyi north agricultural zone respectively. In line with the present study Shrestha and Lal (2008) found higher bulk density in mining areas. The higher soil bulk density value of quarry area could be attributed to overload of soil, stone fragments, and boulders produced during the mining from the quarry pits, and due to track load movement. Similar results was also showed in Spain by Jordan *et al*. (2012). Gabarrón *et al*. (2019) also revealed that mining altered important soil properties such as increasing bulk density. The change in bulk density affects soil hydraulic properties and hydrological stability which in turn influences soil remediation. Furthermore, compacted mine soils prevent seed germination and the establishment of native vegetation. Moreover, it decreased with soil depth such that higher value was at the subsoil (1.67 gcm^{-3}) compared to topsoil (1.51 gcm^{-3}). This is in conformation with the work of Santra *et al.*, (2008). Increase of bulk density down the layers could be attributed to overburden effect on deeper layers as well as declining organic matter content with depth.

Inverse to BD, total porosity increased with increasing distance with the highest (40.49%) and lowest (33.92%) recorded at 150m and 0m respectively. In similar study, According to Gülser and Candemir (2014), increases in the proportion of macro porosity to total porosity may result from increases in the amount of sand and silt in the soil texture as

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measured at distances near the mine site. Within the locations, highest(46.73%) TP occurred in CDC followed by Ngbo(41.65%), CNCC(32.11%) and Nigercem(30.96%). Similar to SCR and MC, greater TP (41.09%) was at the topsoil, than subsoil. Soils with a porosity of 45–50% of volume are suitable for agriculture, according to Fetter (1998) and Riue and Sposito (1991). Thus, soils 150 meters away from the sites may be considered suitable for agriculture.

3.2 Effects of quarry sites on soil chemical properties studied

Results of soil chemical properties studied (Table 2) showed that the soils were generally acidic irrespective of location, distance and depths. Moreover, variation of soil pH was insignificant among the location, distance and depths and their various combinations. To a large extent, the distribution characteristic of pH reflects the influence of the soil-forming parent material and human activities (Yu *et al*., 2022). However, in the present study, soil pH was slightly acidic with 5.82, 5.89, 5.79 and 5.66 recorded in Nigercem, CNCC, CDC and Ngbo respectively, indicating that on a mean basis, soil pH of Ebonyi central agricultural zone(5.86) was greater than Ebonyi north agricultural zone(5.73). In addition, soil pH was observed to decrease steadily with increasing distance from the sites and with highest and lowest values of 5.99 and 5.56 obtained in 0 and 150m respectively. Other workers (Yu *et al*., 2022), established that soils to the north of the quarrying area are acidic to weakly acidic, whereas those in the central area (in the vicinity of the building stone quarrying area) and southern (Laiyang County and its south) area tend to be neutral. Within the depths, it was also higher at the top(5.86) than sub soil (5.72). This was in congruent with the findings of Wilberforce *et al*. (2012) in Soils of Enyigba Pb-Zn Mine, Ebonyi State.

Unlike pH, organic carbon (OC) content of the soils differed significantly ($p<0.05$) among locations, distance and depths and their different interactions. Along the sampling distances, it was 0.68, 0.73, 0.41 and 0.77%at 0, 50, 100 and 150m respectively whereas it was 1.23, 0.50, 0.34 and 0.53% in Nigercem, CNCC, CDC and Ngbo respectively. These values (0.34-1.23%) were rated very low to moderate. Lower values recorded within the quarry sites could be due to high contamination of the soil with metal could elicit deleterious effects on microbial activities (Dai *et al*., 2004), provoking a low organic matter mineralization needed for plant growth. while higher OC at the last distance away from the mining area may be due to vegetation and topsoil removal around the mining area and the immediate surrounding (Salami *et al.* 2002). Equally, OC was shown to be higher at the topsoil(0.72) than subsoil (0.58). This result was in disagreement with that of Ojo*et al.* (2018) that recorded approximately the same at both soil depths (0.0 – 5.0 cm and 5.0 – 10.0 cm) of soils from farms in the vicinity of Durumi quarry site in Mpape, Abuja Nigeria. Differences could be due to varying sampling depths.

TABLE 2: Soil chemical properties studied

	pH (H_20)	OC (gkg^{-1})	TN (gkg^{-1})	AvP ($mgkg^{-1}$)	Ca	Mg	K ($cmolkg^{-1}$)	Na	TEA	ECEC	BS (%)
Location											
Nigercem	5.82	1.23	0.17	3.02	21.16	8.20	1.40	3.44	0.18	34.38	99.46
CNCC	5.89	0.50	0.09	2.89	32.14	7.25	10.50	10.61	0.29	60.80	99.47
CDC	5.79	0.34	0.10	2.61	51.47	20.35	8.37	19.76	0.28	100.23	99.72
Ngbo	5.66	0.53	0.11	3.38	41.16	16.39	8.54	5.92	0.33	72.35	99.53
$LSD_{(0.05)}$Fa	**0.68**	**0.13**	**0.02**	**0.35**	**3.95**	**1.64**	**1.19**	**1.87**	**0.04**	**7.56**	**0.93**
Distance(m)											
0	5.99	0.68	0.13	2.83	36.77	12.94	6.23	7.95	0.21	64.11	99.60
50	5.84	0.73	0.11	3.07	37.36	13.31	6.86	11.20	0.33	69.06	99.43
100	5.77	0.41	0.09	2.64	35.98	12.73	5.97	7.02	0.32	62.02	99.49
150	5.56	0.77	0.14	3.35	35.83	13.21	9.75	13.55	0.22	72.57	99.67
$LSD_{(0.05)}$Fb	**0.68**	**0.13**	**0.02**	**0.35**	**3.95**	**1.64**	**1.19**	**1.87**	**0.04**	**7.56**	**0.93**
Depth (cm)											
0-10	5.86	0.72	0.13	3.00	36.55	12.91	7.51	10.42	0.28	67.66	99.53
10--20	5.72	0.58	0.11	2.95	36.42	13.19	6.89	9.45	0.26	66.21	99.56
$LSD_{(0.05)}$Fc	**0.48**	**0.09**	**0.01**	**0.25**	**2.79**	**1.16**	**0.84**	**1.32**	**0.03**	**5.34**	**1.08**
$LSD_{(0.05)}$Fa X Fb	**NS**	*	*	*	*	*	*	*	*	*	**NS**
$LSD_{(0.05)}$Fa X Fc	**NS**	*	*	*	*	*	*	*	*	*	**NS**
$LSD_{(0.05)}$Fb XFc	**NS**	*	*	*	*	**NS**	*	*	*	*	**NS**
$LSD_{(0.05)}$Fa X Fb X Fc	**NS**	*	*	*	*	*	*	*	*	*	**NS**

OC=organic carbon, TN=total nitrogen, AvP=available phosphorus, TEA=total exchangeable acidity, ECEC=Effective Cation Exchange Capacity, %BS=base

Similar to OC, total nitrogen (TN) also varied significantly ($p<0.05$) among locations, distance and depths and their different interactions. Soil nitrogen is mainly derived from the decomposition and mineralization of soil organic matter, and the increase of soil organic matter is beneficial to the decomposition of animal and plant residues and humus by soil enzymes, thereby releasing nitrogen (Six *et al*., 2002). Concentration of TN in this study was also higher at the topsoil (0.13%) than subsoil (0.11%). Amongst the locations, TN was higher (0.17%) in soils collected from Nigercem followed by Ngbo (0.11%), CDC (0.10%) and CNCC(0.09%). On average basis however, greater (0.13%) concentrations of TN occurred in Ebonyi Central agricultural zone compared to Ebonyi North agricultural zone (0.10%). In accordance with Landon's (1991) classification of total N status as >1% as very high, 0.5 to 1% high, 0.2 to 0.5% medium, 0.1 to 0.2% low, and < 0.1% as very low, TN of the soils in the different agricultural zones was rated low. Across the distances, it was

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highest (0.14%) at 150m followed by 0m(0.13%), 50m(0.11%) and 100m(0.09%). In similar study, the values were lowest in built-up areas and soils around quarry mines (Uquetan *et al.,* 2017). This result is also consistent with the findings as reported by (Wright *et al.,* 2000). A plausible reason for this scenario is due to high quality litterfall, root exudating by some plants and greater input of liable C into the soil.

Along the sampling distances, available phosphorus (Avp) varied significantly($p<0.05$) as 2.83, 3.07, 2.64 and 3.35mgkg^{-1} in 0, 50, 100 and 150m respectively, indicating that it was irregularly higher in its distribution from the quarry site. Similarly, Assel (2006) found a lower and reduced content of soil P inmine soils when compared to the natural forest, which was due to ecosystem disruption, removal of vegetation and loss of litter layer during mineral mining. Besides, Hilson (2001) argued that regardless of the overburden type used, plant available P tend to be low in mined soils, which may limit plant growth. Moreover, Avp was significantly highest (3.38 mgkg^{-1}) in Ngbo compared to 3.02, 2.89 and 2.61 mgkg^{-1} obtained in Nigercem, CNCC and CDC respectively. Within the soil depths, variation of Avp was insignificantly higher (3.00 mgkg^{-1}) at the top soil compared to subsoil (2.95 mgkg^{-1}). Nevertheless, available phosphorus were generally low relative to the critical limit of 8-12 mg kg^{-1} for tropical soils(Enwezor *et al*., 1990).The low values of available phosphorus may be a result of fixation in the acidic soil medium (Afu *et al*., 2019).

All the basic cations (Ca, Mg, K and Na) differed significantly ($p<0.05$) across the locations and sampling distance except Ca and Mg that was insignificant along sampling distance. Concentrations of Ca, Mg, K and Na varied as 26.65 and 46.32, 7.73 and 18.37 cmolkg^{-1}, 5.95 and 8.46 cmolkg^{-1} and 7.03 and 12.84 cmolkg^{-1} in Ebonyi central agricultural zone and Ebonyi north agricultural zone respectively, indicating that basic cations of both soils followed decreasing trend of Ca> Mg> Na > K. According to reports, Ca typically predominates at the exchange sites of the majority of soils, while Mg, K, and Na have lower concentrations (Enloe *et al*., 2006). This could be because monovalent cations (K and Na) may have significantly leached from the system while divalent cations (Ca and Mg) are strongly adsorbed to soil particles at increasing soil moisture content (Chileshe *et al*., 2020). Furthermore, the mining company's addition of lime to the effluent would explain the high calcium content of mine waste substrates (Chileshe *et al*., 2020) with resultant higher soil concentrations (10-20 cmolkg^{-1}) (FAO, 2004). Also, basic cations were not significantly affected by soil depths. However, higher concentrations of Ca (36.55 cmolkg^{-1}), K(7.51 cmolkg^{-1}) and Na(10.42 cmolkg^{-1}) were obtained at topsoil whereas higher Mg(13.19) was at the subsoil. It was also observed that all the basic cations followed irregular pattern across the sampling distances with higher concentrations of Ca(37.36 cmolkg^{-1}), Mg(13.31 cmolkg^{-1}) and Na(11.20 cmolkg^{-1}) were obtained in 50m distance while higher K(9.75 cmolkg^{-1}) was at 150m.

Total exchangeable acidity (TEA) was shown to only vary significantly among the locations and sampling distances. It ranged from 0.18-0.29 and 0.28-0.33 cmolkg^{-1} with mean value of 0.23 and 0.31 cmolkg^{-1} in Ebonyi central and Ebonyi north agricultural zone respectively. Also, like basic cations, it was irregular across the distances with significantly highest(0.33 cmolkg^{-1}) and lowest(0.21 cmolkg^{-1}) obtained at 50 and 0m respectively. This result was in contrast with the findings of (Ramahlo**,** 2013) who reported that values of exchangeable acidity farmlands around three mining sites in phalaborwa, Limpopo Province increase with increasing distance from the pollution source. Higher concentrations of TEA within 50 and 100m from the quarry sites supports the finding of Oelofse *et al*. (2008) that continuous exploitation of solid minerals on a particular site causes increased soil acidity. Moreover, according to Adamu *et al*. (2015a) mining activities are often times associated with the generation of vast quantities of mines rock and mine tailings, and these may eventually elevate levels of sulphates and acidity in soils. Depth-wise, TEA was insignificantly higher at the topsoil (0.28 cmolkg^{-1}) compared to subsoil(0.26 cmolkg^{-1}) and this could probably be as result of higher OC at the topsoils which can as well contribute to soil acidity (Brady and Weil, 2004).

Effective cation exchange capacity as well was indistinct in its distribution along the distances sampled. It was highest (72.57 cmolkg^{-1}) at 150m followed by 50m (69.06 cmolkg^{-1}), 0m (64.11 cmolkg^{-1}) and 100m (62.02 cmolkg^{-1}). High ECEC in far distance from mining could be attributed to clay particles and manure applications by farmers (particularly in humic form) that contributed to soil colloids with charges which can hold cations (Syafrimen and Yulnafatmawita 2018). ECEC in this present study also varied significantly amongst the locations with a range of 34.38-60.80 (mean=47.59 cmolkg^{-1}) and 100.23-72.35 (mean=86.29 cmolkg^{-1}) in Ebonyi Central and Ebonyi North agricultural zone respectively. According to the rating of ECEC given by Landon (1991) (i.e. in cmolkg^{-1}), > 40 very high, 25 – 40 high, 15 – 25 medium, 5 – 15 low. Effective cation exchange capacity is generally very high (Landon, 1996). Moreover, ECEC decreased insignificantly with soil depth such that higher value was at the topsoil (67.66 cmolkg^{-1}) compared to subsoil (66.21 cmolkg^{-1}). The observed slight increased in ECEC levels for soil samples at the surface, when compares to subsoil, is an indication that heavy metal mobility may be slightly impaired at that depth. This will reduce the leaching and availability of heavy metals for plant uptake (Katharine and Jeremy, 2018; Cornell University Cooperative Extension (CUCE), 2007). Amongst the location, percent base saturation (BS) was insignificantly influenced by location, distance and depth. However, within the locations, highest (99.72%) %BS occurred in CDC followed by Ngbo (99.53%), CNCC(99.47%) and Nigercem(99.46%). Similar to Mg greater %BS was at the topsoil(99.56%) than subsoil (99.53%). Along the distances, higher %BS was obtained at 150m (99.67) followed by 0m(99.60%), 100m(99.49%) and 50m(99.43%). The high base saturation of the studied soil samples was also reported by Odoh *et al*. (2014) which could be as a result of increase of Ca, Mg, K, and Na by dust

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particles and other industrial decompose waste dump by the quarry company.

3.3 Correlations among soil physicochemcial parameters studied

Results of the interrelationship among soil physico-chemical properties indicated that strong positive correlation among the parameters measured (Table 3). According to Evans (1996), When r is 0.00 - 0.19 = very weak, r is0.20 - 0.39 = weak, r is 0.40 – 0.59 = moderate, r is0.60 - 0.79 = strong, r is 0.80 – 1.0 = very strong. Clay exhibited significantly positive association with MC (r=0.27), BD (r=0.41), pH (r=0.42), TEA (r=0.39), AvP (r=0.22), Ca (r=0.29), silt (r=0.38) and TP (r=0.23) as well as SCR (r=-0.40) that it correlated distinctly and negatively with, suggesting that increase in clay content will significantly increase MC, BD, pH, TEA, AvP, Ca, silt and TP whereas it will reduce SCR. Similarly, moisture content correlated distinctly and positively (r=0.313, r=0.56, r=0.71, r=0.26, r=0.41, r=0.35, r=0.47, r=0.25, r=0.78, r=0.75, r=0.58 and r=0.70) with BD, pH, ECEC, %BS, TEA, AvP, Na, K, Ca, Mg, Sand and TP respectively. Equally, bulk density (BD) exhibited strong association (r=0.47, r=0.86, r=0.25, r=0.34, r=0.80, r=0.22, r=0.31, r=0.55, r=0.54, r=0.68, r=0.46 and r=0.37) with OC**,** pH, ECEC, TEA, AvP, K, Ca, TN, sand, silt, SCR and TP respectively. Also, organic carbon had serious positive relationship with pH(r=0.38), AvP(r=0.54), TN(r=0.91), silt(r=0.61) and SCR(r=0.56), implying that OC increases in tandem with pH, AvP, TN, silt and SCR whereas its negatively significant (r= -0.20) association with ECEC, implied that it reduces with increase in ECEC. Similarly, from the findings of Maiti and Ghose (2005) in abandoned mine land, organic carbon positively correlated with available N and K. Soil pH as well had serious positive correlation (r=0.52, r=0.52, r=0.81, r=0.24, r=0.27, r=0.62, r=0.48, r=0.56, r=0.78, r=0.57, r=0.37 and r=0.75) with ECEC, TEA, AvP, Na, K, Ca, Mg, TN, sand, silt, SCR and TP respectively. In addition, Effective cation exchange capacity (ECEC) displayed (r=0.48, r=0.43, r=0.43, r=0.83, r=0.69, r=0.93, r=0.86, r=0.72 and r=0.77) with %BS, TEA, AvP, Na, K, Ca, Mg, sand and TP respectively. Besides, percent base saturation correlated distinctly and positively with Na(r=0.57), K(r=0.54), Ca(r=0.28), Mg(r=0.34) and sand(r=0.24), indicating that increase in %BS will cause significant increase in Na, K, Ca, Mg, sand whereas its increase will decrease TEA (r=-0.49), silt (r=-0.51) and SCR (r=-0.22) of the soils studied.

3.4 Principal Components Analysis (PCA)

Principal component analysis (PCA) is extensively utilized in assessing soil quality due to its remarkable ability to effectively integrate and streamline high-dimensional variable systems, accurately assign weights to each variable, and eliminate subjective biases. PCA is widely used to reduce data, extract a small number of latent factors, and discriminate the similarity and dissimilarity for analyzing relationships among the observed variables (Rahman *et al*., 2017). Principal component analysis was performed for 18 parameters and 4 were selected (Table 4). The extracted components contributed a total variance of 84.76% in the data set. On PC_1, 7 soil parameters with positive values loaded significantly. These parameters include soil Ca (0.94), Mg (0.93), TP (0.90), ECEC (0.84), Sand (0.80), MC (0.77) and TEA (0.70). This component (PC_1) was regarded as measuring the soil chemical properties and this first principal axis accounted for 35.3% of the total variance. This component together with PC_2 and PC_3 can be regarded as measuring the soil chemical properties. The positive loading implies that the above parameters increase as the intensity of mining increases.

TABLE 3: Correlation among the soil physico-chemical properties studied

Variables	Clay	MC	BD	OC	pH	ECEC	%BS
Clay	-	-	-	-	-	-	-
MC	0.27^{**}	-	-	-	-	-	-
BD	0.41^{**}	0.313^{**}	-	-	-	-	-
OC	ns	ns	0.47^{**}	-	-	-	-
pH	0.42^{**}	0.56^{**}	0.86^{**}	0.38^{**}	-	-	-
ECEC	ns	0.71^{**}	0.25^{*}	-0.20^{*}	0.52^{**}	-	-
%BS	ns	0.26^{*}	ns	ns	ns	0.48^{**}	-
TEA	0.39^{**}	0.41^{**}	0.34^{**}	ns	0.52^{**}	0.43^{**}	-0.49^{**}
AvP	0.22^{*}	0.35^{**}	0.80^{**}	0.54^{**}	0.81^{**}	0.43^{**}	ns
Na	ns	0.47^{**}	ns	ns	0.24^{*}	0.83^{**}	0.57^{**}
K	ns	0.25^{*}	0.22^{*}	ns	0.27^{**}	0.69^{**}	0.54^{**}
Ca	0.29^{**}	0.78^{**}	0.31^{**}	ns	0.62^{**}	0.93^{**}	0.28^{**}
Mg	ns	0.75^{**}	ns	ns	0.48^{**}	0.86^{**}	0.34^{**}
TN	ns	ns	0.55^{**}	0.91^{**}	0.56^{**}	ns	ns
Sand	ns	0.58^{**}	0.54^{**}	ns	0.78^{**}	0.72^{**}	0.24^{*}
Silt	0.38^{**}	ns	0.68^{**}	0.61^{**}	0.57^{**}	ns	-0.51^{**}
SCR	-0.40^{**}	ns	0.46^{**}	0.56^{**}	0.37^{**}	ns	-0.22^{*}
TP	0.23^{*}	0.70^{**}	0.37^{**}	ns	0.75^{**}	0.77^{**}	ns

TABLE 4: Rotated principal component analysis

Variables	Components			
	1	**2**	**3**	**4**
Ca	<u>0.94</u>	-0.01	0.23	0.17
Mg	<u>0.93</u>	-0.01	0.18	-0.14
TP	<u>0.90</u>	0.27	0.05	0.07
ECEC	<u>0.84</u>	-0.02	0.51	0.11
Sand	<u>0.80</u>	0.40	0.21	-0.14
MC	<u>0.77</u>	0.07	0.15	0.12
TEA	<u>0.70</u>	0.05	-0.44	0.42
OC	-0.20	<u>0.89</u>	-0.01	-0.14
TN	0.07	<u>0.88</u>	0.00	-0.07
BD	0.26	<u>0.79</u>	0.06	0.37
Silt	-0.04	<u>0.77</u>	-0.35	0.37
AvP	0.46	<u>0.76</u>	0.09	0.16
SCR	0.04	0.69	-0.26	-0.46
pH	0.60	0.68	0.03	0.31
%BS	0.10	-0.10	<u>0.88</u>	-0.25
K	0.32	0.00	<u>0.77</u>	0.20
Na	0.46	-0.05	<u>0.72</u>	0.08
Clay	0.11	0.11	-0.01	<u>0.93</u>
Eigenvalues	**6.71**	**4.54**	**2.97**	**1.88**
% Variance	**35.30**	**23.91**	**15.65**	**9.90**
Cumulative %	**35.30**	**59.21**	**74.86**	**84.76**

Similarly, PC_2 positively loaded 5 parameters strongly [OC(0.89), TN(0.88), BD (0.79), Silt (0.77), AvP (0.76)]. This component contributed 23.91% of the total variance. On PC_3, 3 parameters including AvP (0.88), SCR (0.77) and pH (0.72) were heavily loaded. This component contributed 15.65% of the entire variance. Moreover, on PC_4, only clay(0.93) was strongly loaded with 9.9% variance. This component was assumed to measure the soil physical properties. In general therefore, results of PCA in this study demonstrated that apart from SCR and pH all the physico-chemcial parameters studied was significantly increased with the intensity of mining in the quarry sites because of their positive heavy loadings.

IV. Conclusion

It was clearly showed that most of the soil physico-chemcial properties varied significantly especially amongst the locations and sampling distances. Nigercem had greater silt, SCR, BD, OC and TN, CNCC had greater clay, pH and K, CDC had higher MC, TP, Ca, Mg, Na, ECEC and %BS while contents of Sand, AvP and TEA were higher in soils from Ngbo. On average, higher concentrations of silt, clay, SCR, pH, AvP, Ca, Mg, K, Na, TEA, ECEC and %BS were in Ebonyi central while higher sand, MC, TP, OC and TN were in Ebonyi North agricultural zone, indicating that most of the soil physico-chemcial properties were better in Ebonyi central than Ebonyi North agricultural zone. Considering the sampling distance, farer distances from the quarry sites especially 150m away had superior soil physico-chemcial properties including lowest BD, highest TP, OC, TN, AvP, K, Na and ECEC. The result of this study revealed valuable information about the degree of soil related problems in the area which will be beneficial in suggesting appropriate reclamation measure. Also given the higher concentrations of these properties at farer distances, efforts should be made to locate farmlands as far away from the quarry site as possible.

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