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## **Soils and Chromium Distribution in some Communities in South-Eastern, Nigeria.**

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### **Abstract**

*Total chromium was determined in soil samples collected from pedons of polluted Oguta communities in Imo State, South-east Nigeria. One profile pit was sunk in each of the four areas, described and sampled according to guidelines of FAO. Soil laboratory routine analysis was carried out with the prepared samples and they were analyzed for chromium by the simple sequential extraction procedure and spectrophotometric analysis. Results showed that the soils were from similar parent material and were predominantly sand (mean = 82.26 g kg<sup>-1</sup>). Sand, bulk density, pH and CEC varied little (CV ≥ 4.89 ≤ 14.10) in the study area while Cr concentration, organic matter, total exchangeable bases and silt-clay ratio varied highly (CV ≥ 39.22 ≤ 96.49). Silt-clay ratio of the soils (mean = 1.89) indicated that the soils were senile, almost at the last stage of its development and were acidic (mean pH = 4.44). The soils had low cation exchange capacity (mean = 6.12 CMol kg<sup>-1</sup>), organic matter (mean = 0.76%) and base saturation (mean = 53.43%). Cr correlated negatively with total exchangeable bases, percentage base saturation, organic matter, cation exchange capacity and clay ( $r \geq 0.05 \leq 0.50$ ,  $P < 0.05$ ) whereas it correlated ( $r = 0.12$ ,  $P < 0.05$ ) insignificantly but positively with pH. The concentration of soil Cr (mean = 7.23 mg kg<sup>-1</sup>) shows that it has reached levels that would have detrimental effects on plant if the source of contamination or addition to the soil was not checked.*

Keywords: Contamination, total chromium, heavy metals, toxicity, profile pit

## 1.0 Introduction

Chromium and other heavy metals occur in soils either due to anthropogenic activities or natural weathering of rocks and minerals. Rocks of different types vary considerably in their mineralogical and elemental composition giving rise to marked differences in soil properties even when no significant additions have been made from external sources. With the exceptions of Vanadium and Titanium used by animals in their metabolic process, most heavy metals including Chromium are associated with profound health hazards. The release of heavy metals into the environment comes as a result of atmospheric emission of fossil fuel, industrial and municipal waste disposal, mining and smelting activities (Alloway, 1995; Adriano, 2001). Bourque *et al.* (1997) reported that cadmium (Cd), arsenic (As), chromium (Cr), nickel (Ni), mercury (Hg), vanadium (V) and lead (Pb) are associated with toxicity at above critical levels.

Chromium exists in nature in two stable forms: Cr (III) and Cr (VI) which is predominantly contained in the chromite ore and is highly resistant to weathering (Becquer, Vittorio and Weinberg, 2003). Cr (VI) is considered the most toxic form of chromium and it occurs in association with oxygen as chromate ( $\text{CrO}_4^{2-}$ ) or dichromate ( $\text{Cr}_2\text{O}_7^{2-}$ ) oxyanions. Cr (III) is less mobile, less toxic and is mainly found bound to organic matter in soil and aquatic environments (Becquer, Quantin, Sciot and Boudot, 2003). Cr (III) is required in small quantity for proper functioning of biological systems. In comparison, Cr (VI) is 100-1000 times more carcinogenic, toxic and mutagenic for human health and because of its higher solubility in water it contaminates water bodies too (Zayed and Terry, 2003). Cr and Ni are considered to be essential micronutrients for plants and animals and required in less quantity, however at higher concentrations it becomes biologically toxic and results in carcinogenic effect primarily through respiratory pathway (Goyer, 1996). A minimum concentration of  $0.5 \text{ mg kg}^{-1}$  in water and  $5 \text{ mg kg}^{-1}$  of Cr in soil results in detrimental effects of plants (Turner and Rust, 1971). The complex electronic chemistry of chromium has been a major problem in explaining its toxicity mechanism in plant. Chromium toxicity in plants is seen at multiple ways from reduced yield through effects on leaf and root growth to inhibition on enzymatic activities and mutagenesis. It was estimated that between 14 and  $11 \times 10^3$

tons of chromium are added to soil each year as a result of disposal of sewage sludge globally (Nriagu and Pacyna, 1988). The depth of the contaminated soil depends on the depth to which sewage sludge is physically incorporated by ploughing or presence of cracks or channels in the soil at the time of application of the sludge. There is little evidence of significant downward movement of chromium in sludge soils. He, Zhang, Calvert, Stoffella, Yang and Yu (2004), reported that the mobility of chromium depends on the concentration in soil and the soil properties.

The major route of exposure to chromium is inhalation and experts find the overall evidence for development of respiratory cancer in human due to inhaled chromium compounds. This is based on epidemiological studies, carcinogenicity studies in animals and information on mechanism of toxic action by chromium compounds. In mining, this element intrigues the skin and the breathing and digestive systems (Market, 2002). Chromium is known as one of the heavy metals that can be found in a crude oil polluted environment such as the study area. The objective of the research was therefore to investigate the total distribution of chromium in soils of some oil-rich communities in Imo State, Nigeria.

## **2.0 Materials and Methods**

### **2.1 Description of the Study Area**

The study was conducted in four areas/communities in Oguta local government area of Imo State, Nigeria, namely; Izombe, Obokofia, Uba Agwa and Obudi Agwa. Soils of the locations were derived from coastal plain sands and have been altered by cultivation and other anthropogenic activities such as oil exploration. Some of the crops grown in the area include; cassava, maize, vegetables, oil palm, plantain and cowpea. Oguta is located between latitude 5° 29' and 5° 41' N and longitude 6° 37' and 6° 49' E within a humid tropical climate characterized by rainy season (February/March – November) and dry season (November – February/March). The area has an annual rainfall ranging from 2000-2500 mm. This is as a result of the constant influence of the maritime air mass. The temperature of the area ranges from 26-29°C with a relative humidity of 70-80%.

## 2.2 Soil Sampling and Laboratory Analysis

Reconnaissance field trip was undertaken and the field work was embarked upon. In the field, sampling was carried out using free survey technique and profile pits were prepared (one each for the four different areas), described and sampled according to genetic horizons for characterization according to Keys to Soil Taxonomy (Soil Survey Staff, 2006). Samples were collected from the bottom most horizon to the top most to avoid contamination from horizons. The samples were bagged in fresh clean polyethene bags and taken to the laboratory. In the laboratory, the samples were prepared by air-drying and sieving with 2mm mesh sieve in readiness for analyses of its properties. Particle size analysis was performed using the Bouyoucous hydrometer method (Gee and Bauder, 1986). Bulk density was determined using the core method as described by Blake and Hartge (1986). Exchangeable base cations (Ca, Mg, K, and Na) were extracted with 1 N  $\text{NH}_4\text{OAc}$  (pH 7) (Thomas, 1982). Exchangeable calcium and magnesium were determined by EDTA complexio-metric titration while exchangeable potassium and sodium were determined by flame photometry (Jackson, 1962). Cation Exchange Capacity (CEC) was determined by ammonium saturation ( $\text{NH}_4\text{OAc}$ ) displacement method conducted at pH 7.0 as was explained in the Laboratory Manual for Agronomic Studies in Soil, Plant and Microbiology, University of Ibadan (Odu *et al*; 1986). Soil organic carbon was analyzed by Walkley and Black wet digestion method (Nelson and Sommers, 1982). Thereafter, organic matter was derived by multiplying the value of organic carbon by a factor of 1.724 (Factor of Splenycl). Soil pH was measured potentiometrically in both water and 0.1 N KCl at the soil- liquid ratio of 1:2.5. Total chromium analysis was carried out by spectrophotometric analysis of soil samples by atomic absorption spectrophotometer after pre-extraction of chromium cation with dithionite-citrate carbonate according to the methods of Hesser (1977) as follows; 2.5 g of each air-dried soil sample was weighed into a beaker and the same quantity of sodium dithionite was added. This was prepared by adding 88.23 g of sodium citrate to 21.02 g of citric acid in two liter flask and made to mark with distilled water to give exactly 0.15 M sodium citrate and 0.5 M citric acid. The beaker was shaken over night in a shaking machine and later filtered with whatman no.42 filter paper. A pipette was

used to transfer 25 ml of the extract into a 200 ml beaker and 5 ml of 30 % H<sub>2</sub>O<sub>2</sub> was added in the glass. The mixture was then allowed to cool. At this stage, 10 ml of HNO<sub>3</sub>-H<sub>2</sub>SO<sub>4</sub> acid mixture was added in a fume chamber with the latter mixture and digested for 3 ½ hours until the extract became clear. The extract was allowed to cool and was diluted with distilled water and made to 100 ml in a volumetric flask. Concentration of chromium was determined thereafter using Perk Elme model 2280/2380 atomic absorption spectrophotometer.

### 2.3 Statistical Analysis

Data collected were summarized using descriptive statistics, and normality of distribution was tested with skewness and kurtosis. Coefficient of variation was determined to find out how variables varied in the study sites. Correlation analysis was carried out to find out the way variables relate with each other. All statistical analysis was carried out with the aid of SAS (SAS, 1999).

### 3.0 Results and Discussion

Table 1 shows the descriptive statistics of soil properties of the study sites. The mean and median were used as primary estimates of central tendency while standard deviation, coefficient of variability (CV), minimum and maximum were used as estimates of variability. The mean and median were similar showing that the soils have similar soil properties and thus might have come from the same parent material- coastal plain soils. Similarity of means and median of several physical, chemical and biological soil properties had been reported by Obi *et al.* (2015), Obi and Ogunkunle (2009) and Cambardella *et al.* (1994). To enhance the pragmatic aspect of the study, no transformation was attempted although Parkin and Robin (1992) had previously reported that soil properties are log-normally distributed. The soils were predominantly sand having a mean of 82.26 g kg<sup>-1</sup> in the study area. Silt-clay ratio of the soils

**Table 1: Descriptive Statistics of Physical and Chemical Properties of the Soils**

Variable	Mean	SD	Min.	Max.	Median	CV	Skewness	Kurtosis
Sand (gkg <sup>-1</sup> )	82.26	4.69	75.92	91.36	81.28	5.71	0.39	-0.82
Silt (gkg <sup>-1</sup> )	11.51	4.42	2.48	17.76	12.32	38.41	-0.50	-0.05
Clay (gkg <sup>-1</sup> )	6.25	1.23	4.48	10.00	6.16	19.64	1.64	4.27
SCR	1.89	0.74	0.34	3.06	1.93	39.22	-0.50	-0.04
BD (gcm <sup>-3</sup> )	1.45	0.13	1.27	1.71	1.40	8.65	0.75	-0.22
pH in KCl	4.44	0.22	4.04	4.80	4.51	4.89	-0.49	-0.81
Na (CMolkg <sup>-1</sup> )	0.28	0.44	0.01	1.04	0.03	158.09	1.19	-0.64
K (CMolkg <sup>-1</sup> )	0.01	0.01	0.01	0.04	0.01	52.41	2.12	5.54
Mg (CMolkg <sup>-1</sup> )	0.21	0.13	0.07	0.67	0.18	61.70	2.70	9.20
Ca (CMolkg <sup>-1</sup> )	0.46	0.27	0.29	1.55	0.39	59.26	3.80	15.55
TEB (CMolkg <sup>-1</sup> )	0.88	0.55	0.39	2.28	0.68	62.66	1.63	1.45
BS (%)	53.43	15.87	17.03	82.61	51.52	29.69	-0.18	0.52
OM (%)	0.76	0.46	0.28	1.99	0.62	60.52	1.63	2.05
CEC (CMolkg <sup>-1</sup> )	6.12	0.86	4.26	7.22	6.34	14.10	-0.96	0.23
Cr (mg kg <sup>-1</sup> )	7.23	6.97	0.56	29.91	6.12	96.49	2.02	5.55

SCR- Silt clay ratio, BD- Bulk density, TEB- Total exchangeable bases, BS- Base saturation, OM- Organic matter, CEC- Cation exchange capacity, SD- Standard deviation, CV- Coefficient of variation

(mean = 1.89) indicated that the soils have long been weathered almost to the least stage of its development. The soils were acidic (mean pH = 4.44) and since the pH presented was taken in soil-KCl mixture it was expected that more of the hydrogen ion concentration was made available in soil solution. Wild (1993) stated that heavy metals occur at high concentrations in the soil at low pH. The low pH nature of soils of the study area is adduced to the industrial waste material or soil contamination from the oil exploration activities. Turner and Rust (1971) stated that a minimum concentration of 0.5 mg kg<sup>-1</sup> in water and 5 mg kg<sup>-1</sup> of Cr in soil results in detrimental effects of plants. The concentration of Cr (mean = 7.23 mg kg<sup>-1</sup>) showed that the soil's pH contributed to its availability and there was an additional 2.23 mg kg<sup>-1</sup> concentration when compared with the findings of Turner and Rust (1971) on the minimum concentration that will have detrimental effects on plant. The soils had low cation exchange capacity (mean = 6.12 CMolkg<sup>-1</sup>), organic matter (mean = 0.76%) and base saturation (mean = 53.43%). Adarsh and Subodh (2013) earlier reported that Ultramafic soil (soil rich in Cr, Ni, Mn,

Co, Pb etc.) is deficient in N, P, K, Ca, cation exchange capacity etc. The percentage base saturation deviated mostly from the mean ( $53.43 \pm 15.87$ ) having an additional 15.86 deviation from the least deviated means. Sand, bulk density, pH and CEC varied little ( $CV \geq 4.89 \leq 14.10$ ) in the study area while Cr concentration, organic matter, total exchangeable bases and silt-clay ratio varied highly ( $CV \geq 39.22 \leq 96.49$ ).

Table 2 shows the Pearson correlation coefficients for soil properties of the studied area. The results show that Cr correlated negatively with total exchangeable bases, percentage base saturation, organic matter, cation exchange capacity and clay ( $r \geq 0.05 \leq 0.50$ ,  $P < 0.05$ ). It was reported that Ultramafic soil (soil rich in Cr, Ni, Mn, Co, Pb etc.) is deficient in N, P, K, Ca, cation exchange capacity etc. The results have shown that an increase in concentration of Cr will bring about a resultant decrease in total exchangeable bases, percentage base saturation, organic matter contents, cation exchange capacity and clay. It has been found out that biogeochemical processes are interwoven and do not occur without the cascade effect of one property on another. This can be seen from the results as Cr correlated ( $r = 0.12$ ,  $P < 0.05$ ) insignificantly but positively with pH. Neither total exchangeable base, percentage base saturation, organic matter, cation exchange capacity nor clay was used as a predictor for a dependency equation because it is obvious that the concentration of soil Cr does not depend on any of them. pH would have been used as a predictor but the pH of the soils will depend on the nature of their parent material as well as the quantity and kind (hydrocarbon concentration) of crude oil contaminant in the soil. Such an analysis will yield a poor or fair fit to the regression line since the contaminant is an addition to the soil and the major predictor.

#### 4.0 Conclusion

The means and median of the soil properties were similar and this shows that outliers did not dominate the measure of central tendency but a true indication of soils that come from same parent material. The soils are sandy. The oil contaminants played a major role in contributing to the Cr concentration of the soils. The silt-clay ratio of the soils indicated that they are old soils (soils at the last stage of development). The



concentration of the soil Cr was  $2.23 \text{ mg kg}^{-1}$  more than what was stated which result in toxicity to the plants growth. There was a negative correlation of Cr with total exchangeable bases, percentage base saturation, organic matter, cation exchange capacity and clay and this is in line with the finding of other researchers. A regression analysis was not attempted as none of these (total exchangeable bases, percentage base saturation, organic matter, cation exchange capacity and clay) will serve as a good predictor of Cr concentration of the soils.

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**Table 2: Pearson Correlation Coefficients for Soil Properties of the Studied Sites**

	Sand	Silt	Clay	SCR	BD	pH	Na	K	Mg	Ca	TEB	BS	OM	CEC
Silt	-0.96**													
Clay	-0.35	0.08												
SCR	-0.77**	0.91**	-0.31											
BD	-0.56*	0.57*	0.13	0.53*										
pH	-0.34	0.37	-0.03	0.40	0.60*									
Na	0.51*	-0.54*	0.004	-0.55*	-0.61**	-0.61**								
K	0.02	0.01	-0.08	0.03	-0.32	-0.44	0.54*							
Mg	0.31	-0.31	-0.07	-0.28	-0.29	0.06	0.14	0.29						
Ca	0.34	-0.32	-0.13	-0.28	-0.28	0.09	0.08	0.21	0.91**					
TEB	0.36	-0.40	0.02	-0.39	-0.45	-0.21	0.51*	0.59**	0.81**	0.72**				
BS	0.33	-0.43	0.24	-0.56*	-0.60**	-0.39	0.58**	0.38	0.56*	0.53*	0.78*			
OM	0.71**	-0.69**	-0.20	-0.59**	-0.54*	-0.26	0.46*	0.40	0.70**	0.70**	0.67**	0.56*		
CEC	0.49*	-0.53*	0.01	-0.54*	-0.89**	-0.56*	0.59**	0.37	0.19	0.26	0.43	0.58**	0.47*	
Cr	0.16	-0.04	-0.42	0.19	0.20	0.12	-0.23	0.003	-0.24	-0.15	-0.13	-0.50*	-0.20	-0.05

SCR- Silt clay ratio, BD- Bulk density, TEB- Total exchangeable bases, BS- Base saturation, OM- Organic matter, CEC- Cation exchange capacity, \*\*- Correlation is significant at 1%, \*- Correlation is significant at 5%.