EXTRACTABLE MICRONUTRIENTS STATUS AND THEIR RELATIONSHIP WITH SOME INLAND VALLEY SOIL PROPERTIES IN DELTA STATE, NIGERIA

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Abstract
The study was conducted in some inland valley soils of Delta State, Nigeria. The aim was to evaluate the status of extractable plant micronutrients of Iron (Fe), Zinc (Zn), Manganese (Mn), and Copper (Cu), and their relationship with some soil properties using 0.1 N dilute HCl and DTPA solutions. Four mapping units designated as pedons A, B, C and D were randomly selected for the study and in each of them, a standard profile pit representative of the pedon was dug, examined and described. Soil samples were collected from each of the horizons for the study of the soil's physical and chemical properties. The results of the study showed that 0.1 N HCl extracting solution has better affinity for extraction with mean values of 18.36 ppm for Fe; 9.12 ppm for Zn, 8.59 ppm for Mn and 2.36 ppm for Cu as against 13.62 ppm 5.71 ppm; 7.18 ppm; and 1.86 ppm for the corresponding DTPA extractable Fe, Zn, Mn and Cu. Relationship between micronutrients and some soil properties showed positive correlation between 0.1 N HCl extractable Zn and soil pH (0.3548^{X}). and DTPA extractable Mn with organic carbon (0.4217^{X}) and total nitrogen (0.3643^{X}). There was also significant correlation Mn ad Fe (0.684^{XX}), CU and Mn (0.667^{XX}) and Hcl extractable Cu and Mn (0.524^{XX}) DTPA extractable Mn ($r = 0.684^{XX}$) and Cu ($r = 0.347^{X}$). 0.1 N HCl therefore has better affinity for extraction of plant available micronutrients of Iron (Fe), Zinc (Zn), Manganese (Mn), and Copper (Cu) in the inland valley soils of Delta State, Nigeria.

Keywords*: Extractable micronutrients, inland valley and soil properties.*
http://dx.doi.org/10.4314/jafs.v9i1.6

Introduction

Micronutrients are those nutrient elements that are required by plants in trace or small quantities. This is because the range between toxic and deficiency levels are often very small thus, proper supply of micronutrients is essential for optimum plant growth (Neue and Mamaril, 1986). They are also seven out of the sixteen nutrient elements that are essential for plant growth and reproduction of all higher plants. Amongst these micronutrients as listed by Hague *et al;* (1981) and Takkar *et al;* (1989) include Iron (Fe); Copper (Cu), Zinc (Zn), Boron (Bo), Molybdenum (Mo), Manganese (Mn); and Chlorine (Cl). Their deficiencies can result to serious decrease in crop yield and under severe conditions, total crop failure may occur (Bowen and Kratky, 1983 Neue and Mamaril, 1986).

In most developing countries of the Sub-Saharan Africa, the demand for micronutrient fertilizers for crop production is low. This is because of low fertilization of the land resources for intensive cultivation and the practice of shifting cultivation and rotational bush fallow which are still in vogue. Against this background, the problems of micronutrients deficiencies have not received the desired attention. Despite the importance of micronutrients in plant nutrition, scanty attention has been given to their study and status in most soils (Amalu *et al.,* 2001). In recent times, micronutrient deficiencies are gradually becoming wide spread due to intensive continuous cropping involving the use of high yielding varieties. This problem may assume a greater dimension in the near future if not properly addressed. Thus, the key to success in handling micronutrient problems is to identify their status and correct any observed deficiencies before their visual symptoms are manifested.

Information on micronutrient status on inland valley soils scanty and restricted mainly to the well drained upland soils. Investigations in most coastal plain sands Uzu *et al*., (2003), showed that deficiencies of zinc and iron are quite obvious especially in acid sandy soils. However, Singer et al., (2004), reported that under reduced conditions of inland valley soils there is increase concentrations of some micronutrients elements. For instance, the reduction of Fe (III) and Mn (IV) to Fe (II) and Mn (II) led to their high concentration in soil solution of acid soils that are high in organic matter. Under similar conditions, the mobility of Boron (Bo), Cobalt (Co), Copper (Cu), Molybdenum (Mo) and Zinc (Zn) are equally affected (IRRI, 2001). Hence the need for their studies and documentation. It is therefore the objective of this study to assess the status of plant available micronutrients and their relationship with soil properties in some inland valley soils of Delta State, Nigeria.

Materials And Methods

Study Area

The study was conducted in the inland valley landscape of Oko-anala in Delta State, Nigeria. Oko-anala is a town of about 400 km^2 square bordering River Niger that separates Anambra from Delta State. By nature of its physiographic setting, the area is characterized by an extensive inland valley system that are influenced by seasonal flooding from the River Niger. The area lies essentially within latitude 6^0 06^1 N and longitude 6^0 42^1 E of the equator and has a mean annual rainfall of 2,250mm which is bimodal in nature. Mean daily minimum and maximum temperature varies from 21 – 24^0C and 27 – 32^0C. The relative humidity varies from 75 – 82%. The land characteristic is nearly flat (1 – 2%) and underlain by cretaceous sediments of sandstones and shales which occur mostly in alternating bands within the sedimentary basins of alluvial deposits (Egbuchua, 2007).

The vegetation is quite unique comprising of grasses interspersed with clusters of water loving trees and shrubs. Dominant among such trees and shrubs are *Nutraagyna inermis, Naucles latifolia, Andropogon schriensis, Hyperhenia involcuraria and Imperate cylindrica*. (Obot, et al., 1990). The land use is mainly based on rain-fed agriculture and typical crops cultivated include rice, beans, yam, cocoyam, cassava pulses and vegetables.

Field Work

Four distinct soil units were identified through a semi-detailed soil survey and labeled as Pedons A,B,C and D. In each soil unit, a modal soil profile was dug, examined and soil samples collected from each pedogenetic horizons for laboratory analysis.

Sample Preparation/Laboratory Studies

The collected soil samples were air-dried at room temperature of 25 – 27^{0}C, crushed, and sieved to pass through a 2 mm sieve mesh, and properly labeled in envelopes for laboratory analysis. The soil pH was determined in a 1:1.5 soil/water ratio and Kcl solution using a glass electrode pH meter. Organic carbon was determined by Walkley and Black wet-oxidation method as modified by Nelson and Sommers (1982). Particle size distribution was determinbed by Bouyoucous hydrometer method using sodium hexameta phosphate (calgon) as dispersing agent (Gee and Bauder, 1986). Total nitrogen was determined by micro Kjeldahl digestion method (IITA, 1979). Cation exchange capacity (CEC) was determine by the ammonium-acetate saturation method, while exchangeable bases (Ca, Mg, K and Na) were determined by 1 N neutral ammonium acetate (IN NH_4 OAC) buffered at pH 7 (IITA, 1979). The Ca and Mg in the extract were read in an Atomic Absorption Spectrophotometer (Model 6405, Jenway UK) and K and Na determined on a flame photometer. Exchange acidity was determined by 1 N KCL (IITA, 1979). Electrical conductivity was measured in 1:2.5 saturation, using electrical conductivity meter. Available phosphorus was determined by the methods of Bray & Kurtz (1945). The plant available or extractable micro nutrients (Fe, Zn, Mn, and Cu) were extracted using the following extractants and extracting procedures

0.1 N dilute Hcl in a 1:10 soil solution ratio:

In this method, 2 g of the laboratory soil samples were weighed into a flask and 20ml Hcl added, shaken for 20 minutes and filtered.

DTPA – Diethylene triamine penta acetic – acid Method.

In this procedure, 10g of the soil samples was weighed into a conical flask and 20ml of DTPA extractant (0.005 M DTPA) and 0.01M $CaCl_2$ + 0.1M triethanolamine adjusted to pH 7.5 were added and vigorously shaken for 30 minutes and filtered. The determination of micronutrients in the two different extracting procedures were done using the Atomic absorption Spectro photometer (Model 6405 UV Jenway, UK).

Statistical Analysis

Analysis of variance (ANOVA) and simple correlation were run to test the significance of variations and show relationship among micronutrients and soil properties.

Results

Particle size distribution

The summary of some soil properties are shown in Table 1. The particle size distribution showed that sand fraction was the major soil separates across the pedons. This ranged from 34 – 50%, with a mean value of 41.50% for pedon A; 28 – 60%, with a mean value of 41.50% for pedon B;

30 – 50%, with a mean value of 41.25% for pedon C and 26 – 36% with a mean value of 31% for pedon D, respectively. Apart from pedon A in which the distribution of sand fraction followed a trend of decrease with increase in profile depth, there was irregular distribution of sand in the other pedons. The silt fraction ranged from 24 – 26%, with a mean value of 25.50% for pedon A, 12 – 22% and a mean value of 18.50% for pedon B, 24 – 30% and with a mean value of 25.75% for pedon C and 26 – 40% with a mean value of 33% for pedon D respectively. There was also no difinte pattern of distribution of silt just like the sand fraction. Clay fractions were higher in the lower horizons and this could be as a result of intense illuviation down the lower horizons. The results showed that the top soils horizons were sandy clay loam, while the sub soils were dominantly clayey.

Chemical Properties

The chemical properties of the soils (Table 1), showed that soils were generally acid with mean pH values of 5.10, 5.60, 5.37 and 6.0 for Pedons A, B, C and D, respectively. The contents of organic carbon ranged from 3.28 – 23.45 gkg^{-1}, with mean values of 11.19 gkg^{-1} (Pedon A), 12.92 gkg^{-1} (pedon B), 11.19 gkg^{-1} (Pedon C) and 9.95 gkg^{-1} (Pedon D), respectively. Generally, the organic carbon content of the soils tend to be highest at the upper Apg horizons of the pedons and decreased with increase in profile depth. The top soil values of organic carbon were rated high and within the range of 20 – 30 gkg^{-1} established by FMANR, (1990) as high. The total nitrogen content like organic carbon decreased with increase in profile depth. The mean values ranged from 0.54gkg^{-1}, for Pedon A, 1.17gkg^{-1} for B, 1.18gkg^{-1} for C and 1.04gkg^{-1} for Pedon D. The mean values were within the range of 1.5 – 2.0 gkg^{-1} described as medium (FMANR, 1990). The Available phosphorus also generally decreased with increase in profile depth. The mean values for the individual pedons were 10.85 $mgkg^{-1}$ for pedon A; 10.36 $mgkg^{-1}$ for B; 10.99 $mgkg^{-1}$ for C and 9.65 $mgkg^{-1}$ for pedon D. These values are within the ratings of 8 – 20 $mgkg^{-1}$ regarded as medium (FMANR, 1990). The values of cation exchange capacity (CEC) across the pedons did not follow any regular pattern (Table 1). The mean values ranged from 22.99 $Cmolkg^{-1}$, 21.85 $Cmolkg^{-1}$, 21.84 $Cmolkg^{-1}$ and 23.46 $Cmolkg^{-1}$ for Pedons A, B, C and D respectively. The lower soil horizons had the highest values of cation exchange capacity refleting the colloidal characteristics of the horizons due to high content of clay materials.

Extractable Micronutrients

The data for the extractable micronutrients using the 0.1 N HCL and DTPA extractants are presented in Table 2. The values of 0.1 N dilute HCL extractable iron (Fe) ranged from 8.54 – 30.10 ppm with a mean value of 13.37 ppm and a coefficient of variation of 40.9%. This is in contrast of 4.98 – 27.30 ppm with a mean of 13.62 ppm and a coefficient of variation of 56% obtained using the DTPA extractant. Higher values were obtained at the top soil horizons using the two extracting solutions and these generally tend to decrease with increasing profile depth. The mean values obtained using the two extracting solutions were higher than 4.5 ppm established by Neue and Mamaril, (1986) and Udo (2001) as the lowest limit for plant absorption.

The 0.1 N HCL for extractable Zn ranged from 5.15–15.50 ppm with a mean value of 9.12 ppm and a coefficient of variations value of 36.1%, while the values of DTPA extractable Zn ranged from 2.48 – 12.56 ppm with a mean value of 5.71 ppm and a coefficient of variation value of 57.4%. Highest concentrations were observed at the top soil horizons which in most cases decreased with depth of profile just like the 0.1 N HCL extractable Zn. The mean values using DTPA extracting solution were lower (5.71 ppm) when compared to 9.12 ppm using 0.1 N HCL. This implies better affinity of 0.1 N HCL extraction than the DTPA method. The same trend of consistency was observed in 0.1 N HCL extractable Mn and Cu over DTPA extractable method in relation to the same micronutrients of Mn and Cu.

The 0.1 N HCL extractation for Mn and Cu had mean values of 8.72 ppm and 2.36 ppm with coefficient of variations of 57.2%, and 31.4% respectively as against the means and coefficient of variations values of 7.18 ppm, 1.86 ppm and 50.9% and 38.2% for Mn and Cu using the DTPA methods. Higher values were also obtained in the top soil horizons which also tend to decrease with depth of profile pits. In all, the mean values were higher than established critical levels of 3.0 ppm for Mn, 4.5 ppm for Fe, 0.6 ppm for Zn and 0.8 for Cu, respectively.

Relationship with Soil Properties

The correlation analysis which showed relationship with some soil properties are presented in Table 3. There was a positive correlation between HCL extractable Zn and soil pH ($r = 0.3348^{X}$), manganese and organic carbon ($r = 0.4217^{XX}$) and total nitrogen ($r = 0.3643^{X}$). On the other hand, DTPA extractable Fe showed positive correlation with organic carbon ($r = 0.3455^{X}$) and nitrogen ($r = 0.3641^{x}$) but negatively correlated with clay (r = - 0.2784), soil pH (r = - 0.0275) and CEC (r = - 0.2674).

Relationship among Micronutrients

Table 4 dipicts relationship among micronutrients. DTPA extractable iron (Fe) correlated positively with DTPA extractable Mn ($r = 0.684^{XX}$) and Cu ($r = 0.347^{X}$). Similarly, DTPA extractable Mn also correlated positively with DTPA extractable Cu ($r = 0.667^{XX}$)

Discussion

Soil Properties

The particle size distribution across the pedons showed that sand was the dominant soil separates which decreased with depth of profile with no definite pattern of distribution. On the other hand, clay contents increased with depth of profiles. The textures of the soils varied from sandy clay loam, clay loam to dominantly clayey at the subsoil horizons. This however accounts for the low permeability of most inland valley soils. The clay fractions of the individual pedons were found to increase with depth of profiles. This is an indication of clay migration by lessivage. Observers of this clay sequence in relation to total sand dominance at the surface horizons suggest that the soil forming factors may have been from a variety of origins (Zonn, 1986). This study affirmed the findings of Udo (2001), Amalu et al., (2001), Ayolagha (2001) and Yaro et al., (2006) respectively in their various studies on soil characteristics of wetland soils of the humid tropics. The observed acidic nature of the soils could be attributed to the rainfall characteristics and distribution in the environment. These tend to leach extensively the basic cations from the soil (Udo, 2001, Ayolagha 2001 and Egbuchua 2007). The pH range as observed in the study is an indication that nutrient availability could be varied within this range. The organic carbon and total nitrogen contents were moderate especially at the surface horizons. These also tend to decrease with depth of profiles. The values obtained were within the range of 20 – 30gkg^{-1} for organic matter and 1.5 – 2.0gkg^{-1} for total nitrogen established by FMANR, (1990) as sufficient for most Nigerian soils. These values also agreed with the findings of Udo (2001), Ayolagha (2001) and Egbuchua (2007) respectively on wetland soils. The Available phosphorus contents were low and below 15mgkg^{-1} established for all crops in the ecological zone (FMANR, 1990). The low phosphorus content of the soils implied that sesquioxides are likely to fix phosphorus in various forms. This also agreed with the reports of Udo (2001) who affirmed thesame fixation process by sesquioxodes in acid soils. The cation exchange capacity in the various top soil horizons were higher than 20 Cmokg^{-1} established by the FMANR, (1990) as being suitable for crop production if other factors are favourable.

Extractable Micronutrients

The results of the study showed that 0.1 N HCl showed superiority in oxtracting of plant available micronutrients of Fe, Zn, and Cu than the DTPA extractant for the same micronutrients. Both 0.1 N HCl and DTPA extractable Fe were higher than the critical level of 4.5 mgkg^{-1} for acid soils of the tropics as reported by Lindsay and Norvell (1978). The implication is that deficiency of iron is not likely to be an impediment for crop production in these areas. Furthermore, the values for Zinc (Zn] using the two extractants were above the critical level of 0.6 mgkg^{-1} in acid soils as established by Katyal, (1985) for most tropical soils. The values obtained for Manganese (Mn) were also above the critical level of 3.0 mgkg^{-1} for soils (Takkar *et al.,* 1989). The high DTPA extractable Mn across the various pedons may not be unconnected with the high moisture content of the soils. Sharma *et al.,* (2001) have reported that manganese availability in any given soil is affected by moisture availability and this agreed with the findings in this study.

Relationship among micronutrients and soil properties showed positive correlation between DTPA extractable Iron (Fe) and organic carbon. This is an indication that DTPA extractable (Fe) is associated with organic matter. Other workers such as Katyal and Sharma (1991) and Sharma *et al.,* (2001) have also reported positive relationship of DTPA and extractable Fe as well as organic carbon. There was also a significant relationship between HCl extractable Mn and organic carbon. The same significant relationship have also been reported by Kparnwang *et al.,* (1995). The DTPA extractable Cu did not correlate significantly with soil particle size fractions. This is an indication that particle size fractions are not the dominant soil factors affecting available copper in any given soil. This result is in conformity with the reports of Yaro *et al.,* (2006) who made the same observations in some Nigeria soils.

Conclusion

The results of the study showed that 0.I N HCl extractant has better and stronger affinity for extracting plant available forms of Fe, Cu, and Zn micronutrients in acid soils than the DTPA extracting solution which only showed superiority in manganese extraction. Positive relationship existed between 0.I N H Cl extractable Zn and soil properties such as organic carbon, and total nitrogen. DTPA extractable Fe also showed positive relationship with organic carbon and total nitrogen but negatively correlated with clay, soil pH and CEC.

The behaviours of some soil properties in relation to plant available micronutrients as well as the positive coefficient of correlation corroborated with those of earlier researchers (Katyal and Sharma 1991; Kparmwang *et al*., 1995; Osher and Buol 1998; and Yaro et al., 2006) on micronutrient status of soils.

Table 1: Some physico-chemical properties of an inland valley soils in Delta State, Nigeria

Pedon	Horizon design	Dept (cm)	Sand (%)	Silt (%)	Clay (%)	Text. Class	pH (H_20)	Org. C (gkg^{-1})	Total N (gkg^{-1})	Avail P ($mgkg^{-1}$)	CEC $Cmolkg^{-1}$
A	Apg	0 – 25	50	26	20	SCL	4.8	21.45	1.75	12.34	22.45
	Bag	25 – 50	42	28	30	CL	4.9	12.34	1.32	12.78	18.14
	2 Btg^1	50 – 75	40	24	36	CL	4.5	8.12	0.97	10.12	21.21
	2 Btg^2	75 -120	34	24	42	C	6.1	4.35	0.54	8.14	30.14
		$\overline{X}$	**41.50**	**25.50**	**33.0**		**5.10**	**11.57**	**1.15**	**10.85**	**22.99**
B	Apg	0 – 17	60	20	20	SCL	4.7	23.45	1.68	12.45	21.72
	Bag	17 – 45	42	20	38	CL	5.2	13.47	1.25	13.10	18.47
	2 Btg^1	45 – 75	28	22	50	C	6.7	8.45	1.10	8.76	23.12
	2 Btg^2	75-125	36	12	52	C	6.3	6.32	0.65	7.12	24.10
		$\overline{X}$	**41.50**	**18.50**	**40.0**		**5.60**	**12.92**	**1.17**	**10.36**	**21.85**
C	Apg	0-20	50	24	26	SCL	4.7	21.35	1.75	12.76	22.10
	Bag	20-45	45	25	30	CL	5.2	10.12	1.28	12.98	21.21
	2 Btg^1	45-65	40	24	36	CL	5.3	7.13	0.95	10.14	18.75
	2 Btg^2	65-120	30	30	40	C	6.3	6.15	0.74	8.10	25.28
		$\overline{X}$	**41.25**	**25.75**	**33.0**		**5.37**	**11.19**	**1.18**	**10.99**	**21.84**
D	Apg	0-15	36	40	24	CL	5.3	21.35	Q.15	13.14	21.76
	Bag	15-45	32	38	30	CL	5.7	9.72	1.24	13.72	20.14
	2 Btg^1	45-80	26	30	44	C	6.4	5.44	0.78	6.91	30.10
	2 Btg^2	80-120	30	26	44	C	6.6	3.28	0.38	5.34	30.15
		$\overline{X}$	**31.0**	**33.0**	**35.50**		**6.0**	**9.95**	**1.04**	**9.65**	**23.46**

Abbreviations: SCL = Sandy clay loam, CL = clay loam, C = clay

Table 2: Micronutrient Content of an Inland Valley Soils in Delta State of Nigeria

Pedon	Horizon design	Depth (cm)	Fe. (0.1 N HCl)	Zn. (0.1 N HCl)	Mn. (0.1 N HCl)	Cu. (0.1 N HCl) (ppm)	Fe. (DTPA)	Zn. (DTPA)	Mn. (DTPA)	Cu. (DTPA)
A	Apg	0 – 25	29.20	13.75	13.35	2.75	25.75	10.25	12.14	2.50
	Bag	25 – 50	19.57	7.86	8.41	1.95	12.20	5.27	8.35	1.65
	2 Btg_1	50 – 75	17.20	7.86	5.21	2.25	9.34	3.75	4.10	1.45
	2 Btg_2	75 - 120	12.10	6.25	3.10	2.25	7.26	2.48	2.75	1.24
B	Apg	0 – 17	29.47	15.50	17.24	3.95	23.76	12.56	13.38	3.50
	Bag	17 – 45	17.54	8.12	9.15	2.10	14.10	5.26	9.01	2.10
	2 Btg_1	45 – 75	12.38	6.25	7.05	2.10	8.71	3.18	6.34	1.75
	2 Btg^2	75-125	10.75	5.15	4.28	1.05	4.98	2.49	3.10	0.98
C	Apg	0-20	30.10	14.38	14.31	3.10	27.30	10.75	10.37	2.85
	Bag	20-45	21.35	10.07	8.11	1.85	18.47	6.38	7.15	1.28
	2 Btg^1	45-65	15.24	5.29	6.31	1.85	9,76	3.12	5.21	1.25
	2 Btg^2	65-120	8.54	8.75	4.05	3.01	5.47	5.31	2.75	2.08
D	Apg	0-15	28.76	12.78	15.10	3.56	22.78	9.43	13.14	2.75
	Bag	15-45	19.34	9.55	9.21	1.85	13.31	5.24	8.22	1.45
	2 Btg_1	45-80	12.05	7.27	7.40	2.10	9.45	3.10	5.10	1.25
	2 Btg_2	80-120	10.10	7.09	5.21	1.98	5.17	2.75	3.75	1.75
		$\overline{X}$	18.36	9.12	8.72	2.36	13.62	5.71	7.18	1.86
		$\overline{Sd}$	18.38	3.29	4.99	0.74	7.63	3.28	3.66	0.71
		CV %	40.9	36.1	57.2	31.4	56.0	57.4	50.9	38.2

Table 3: Correlation Coefficient between micronutrient and some soil properties of an inland valley soils in Delta State, Nigeria

Extractant	Sand (%)	Silt (%)	Clay (%)	pH. (H_20)	Org. C. (gkg^{-1})	N. (gkg^{-1})	P. ($mgkg^{-1}$)	CEC ($Cmolkg^{-1}$)
HCl – Fe	-0.1078	-0.0207	-0.1725	0.0438	0.3455^{XX}	0.2143	0.2541	-0.0548
DTPA- Fe	0.0215	0.2085	-0.2784	-0.0275	0.1154	0.3641^{XX}	0.3432^{XX}	-0.0674
HCl- Zn	0.0275	-0.1454	0.1375	0.3548^{XX}	0.2054	0.2548	0.2431	0.1752
DTPA-Zn	-0.1870	0.3245^{XX}	-0.1350	0.0422	-0.1738	-0.1731	0.3341^{XX}	-0.1887
HCl- Mn	0.0435	0.0435	-0.0742	0.1534	0.4217^{XX}	0.3643^{XX}	0.3518^{XX}	0.2634
DTPA-Mn	0.0632	0.0632	-0.2122	-0.0862	0.2433	0.1478	0.2171	-0.2347
HCl-Cu	0.2345	0.2345	0.1125	-0.2174	-0.0315	-0.0217	-0.0112	-0.0018
DTPA-Cu	-0.0756	-0.0756	0.2117	0.2347	0.2454	0.2111	0.2147	0.2566

X = Significant at 5 % level.

XX = Significant at both 5 % and 1 % levels.

Table 4: Correlation matrix for HCl and DTPA extractable Fe, Zn, Mn and Cu of an inland valley soils in Delta State, Nigeria.

	HCl-Fe	DTPA-Fe	HCl-Zn	DTPA-Zn	HCl-Mn	DTPA-Mn	HCl-Cu	DTPA-Cu
HCl-Fe	-							
DTPA-Fe	0.115	-						
HCl-Zn	0.038	0.047	-					
DTPA-Zn	-0.155	-0.112	-0.033	-				
HCl-Mn	0.068	0.073	-0.215	-0.027	-			
DTPA-Mn	0.045	0.684^{XX}	-0.274	-0.254	0.145	-		
HCl- Cu	-0.187	-0.165	-0.165	-0.217	0.524^{XX}	0.273	-	
DTPA-Cu	0.276	0.347^{X}	0.272	0.238	-0.163	0.667^{XX}	-0.137	-

X = Significant at 5 % levels of probability.

XX = Significant at 5 % and 1 % levels of probability.

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