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HEAVY METALS STATUS OF SOILS OF THE TEACHING AND RESEARCH FARM OF FEDERAL UNIVERSITY WUKARI, TARABA STATE

J. Tanimu*, C. A. Onwu, Y. Waizah and P. E. Imadojemu
Department of Soil Science & Land Resources Management, Federal University Wukari, PMB 1020, Taraba State, Nigeria
*Corresponding author: joseph.tanimu@yahoo.com

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Abstract: The contents of selected heavy metals and some physical and chemical properties of the soil were determined in sixty surface soils (0 – 30 cm depth), in a five hectare land of the Teaching and Research farm of Federal University Wukari. The soils have a mean pH value of 6.5, which is ideal for most nutrient availability and crop production. The carbon, nitrogen and phosphorus mean values are low (8.42, 0.52 and 4.83 g kg^{-1}, respectively) while potassium (0.29 cmol kg^{-1}) values are high. The calcium and sodium values were medium, while the magnesium value was high. The CEC values were medium (6.66 – 8.89 cmol kg^{-1}). The percentage base saturation ranged from 81.1 – 88.8% which showed that all the values were high. The mean values for Fe, Cu and Zn were high, though completely absent in some locations, while Cr was generally high in most locations. The mean values for Mn, Cd and Pb were generally very low. For successful and profitable crop production, there would be need to supply some of the nutrients that are low or completely absent in some of the locations in the form of either organic or inorganic fertilizers, while Cr has to be monitored in some of the locations so that it will not occur in toxic levels in some locations. The correlation studies showed that Manganese significantly ($P < 0.05$) positively correlated with exchangeable acidity. Copper also significantly ($P < 0.05$) negatively correlated with BS. The others either correlated positively or negatively with the soil properties but not at a significant level.

Keywords: Copper, iron, cadmium, zinc, lead, correlation

Introduction

Heavy metals are widely and usually applied to elements such as cadmium, chromium, copper, mercury, nickel, zinc, iron, manganese, lead etc, which are commonly associated with pollution and toxicity problems. It is a general collective term applying to the group of metals and metalloids with atomic densities greater than 5 g/cm^3 (Alloway, 1990). However, some of the elements in this group are required by most living organisms in small but critical concentrations for normal healthy growth. Those metal cations which are unequivocally essential, and whose deficiency have adverse effects on normal living conditions include Cu, Mn, Fe and Zn for both plants and animals, Co, Cr and Se for animals, B and Mo for plants (Udom *et al.*, 2012).

The toxicity effects caused by excess concentration of these metals include competition for sites with essential metabolites, replacement of essential ions and damage to cell membranes (Ernst, 1996). Generally, Zn, Cu, Pb Cd and Ni are the metals of greatest concern. Zinc, Cu and Pb are important because they can be phytotoxic, whereas, concern for Cd and Ni arises from their possible entry into the food chain (Chaney, 1994). If these metals move too rapidly in a particular soil, they can pollute ground water table. Reports have showed that Cu-contaminated soils at pH 7 can mitigate it's toxicity by reducing the bioavailability of the Cu (Alloway and Ayres, 1997). Copper is also highly toxic to the soil microbial biomass and this can affect various aspects of soil fertility.

Studies on micronutrients status of soils in Nigeria and Taraba State in particular, have not been given the necessary attention probably due to non-prevalence of deficiency symptoms. The traditional methods of soil fertility restoration involving the use of long fallow periods and organic matter incorporation (Sarmiento, 2000), as well as subsistence level of farming among others, might have provided adequate micronutrients to crop plants (Mustapha and Singh, 2003).

Increasing demand for agricultural land by the teeming population leading to consequent reduction in the length of the fallow period, intensification of farming, use of nutrient-intensive high yielding varieties as well as improved agro-technology and land use of high analysis chemical fertilizers have lead to micronutrient deficiencies in some soils (Mortvedt *et al.,* 1991; Lombin, 1983). Besides, there is increasing awareness of the concept of "balanced plant nutrition" among farmers, including the farmers of Taraba state. These soils have a lot of agricultural value as they are intensively cultivated to crops like yams, cassava, maize, sorghum, groundnut, soyabeans, egusi melon, etc.

This study will provide data base information on the current status of some heavy metals status in the soils of the Teaching and Research Farm of Federal University Wukari and for Taraba State at large. A correlation will also be run to observe the effects of some chemical and physical properties of the soil on status of some of the heavy metals.

Materials and Methods

The study was carried out at the Teaching and Research Farm of Federal University Wukari, Taraba State (Lat. 7° 50'N and Long. 9° 46' E). The farm is at an elevation of between 159 to 166 meters above sea level. Wukari is situated within the Southern Guinea Savanna zone of Nigeria. It is characterized by a distinct rainy (March – October) and dry (November – February) seasons. The annual rainfall averages around 1,205 mm (World Atlas and Climate Data Organisation, 2015). The soil types are alfisols.

Soil sampling and handling

Sixty composite soil samples were collected in five hactares of the Teaching and Research Farm, at 0 – 30 cm depth. Each composite soil sample consisted of three sub-samples collected within each site of about 833.33 m^2. The samples were air dried and sieve using a 2 mm sieve for laboratory analysis.

Laboratory analysis

Thesoils were characterized for some of their physical and chemical properties following standard laboratory procedures (Westerman *et al.,* 1990). Particle size analysis was determined by Bouyocous hydrometer method (Ashworth *at al.,* 2001). Soil reaction (pH) was determined potentiometrically in water using 1:2.5 soil/water ratios, while organic carbon was determined following the procedures of Walkley and Black (Nelson and Sommers, 1996), from where organic matter was calculated. Total nitrogen was determined by the micro-Kjeldahl method, while available phosphorus was determined by Bray-1 method. Available potassium and sodium were determined by flame photometer. Exchangeable cations and cation exchange capacity were determined by the saturated ammonium acetate (1 Normal NH_4 OAc at pH 7.0) method. Exchangeable acidity (EA) was extracted with 1 Normal KCl and the percentage base saturation (PBS) was calculated as the sum of the bases (total exchangeable bases) divided by CEC and expressed as percent. The heavy metals were extracted with 0.1M HCl solution (Mortvedt *et al., 1991*) and determined on an Atomic Absorption Spectrophotometer.

Results and Discussion

Physico-chemical properties of the soil

The physico-chemical properties of the site under study are presented in Table 1. The results showed that the sand fraction dominated the particle-size distribution in the soils leading to a sandy loam soil texture. This shows that the top soil may have good drainage characteristics. Soil pH values showed a distribution of medium acidity to slightly acidic. The average value was pH 6.5, which is slight acidity and ideal for most crop production. The organic carbon mean value was low (8.42 g kg^{-1}), though it ranged from 3.0 – 19.6 g kg^{-1}. Soils in the Savanna are generally low in organic carbon due to the high temperatures that encourages high rate of decomposition of organic matter which is the major source of organic carbon. Areas that have been under cultivation have been reported to be low in organic carbon. The total nitrogen varied between 0.30 – 1.15 g kg^{-1}, while the mean value was 0.52 g kg^{-1}. This is rated as very low in Nigerian soils. The available phosphorus ranged from 3.4 – 6.3 mg kg^{-1} with a mean value of 4.83 mg kg^{-1}. This is also considered to be very low based on soil fertility classes for Nigerian soils. Onyilola and Chude (2010); Chude *et al*. (2011) had earlier reported low values of organic carbon, total nitrogen and available phosphorus in the Nigerian Savanna soils. This showed that the application of inorganic nitrogen and phosphorus fertilizer will definitely give a positive response to crop yield.

Table 1: Some physical and chemical properties of sixty soil samples of Teaching and Research Farm, Federal University Wukari

Properties	Values	
	Range	Mean
Sand (g kg^{-1})	739.2 – 776.4	754.5
Silt (g kg^{-1})	100.0 – 130.0	129.5
Clay (g kg^{-1})	116.4 – 140.8	115.9
Texture	Sandy loam	
pH (H_2O)	5.9 – 6.9	6.5
O C (g kg^{-1})	3.0 – 19.6	8.42
N (g kg^{-1})	0.30 – 1.15	0.52
P (mg kg^{-1})	3.4 – 6.30	4.83
K (cmol(+) kg^{-1})	0.22 – 0.36	0.29
Na (cmol(+) kg^{-1})	0.21 – 0.32	0.27
Mg (cmol(+) kg^{-1})	2.30 – 3.50	2.99
Ca (cmol(+) kg^{-1})	2.70 – 3.80	3.22
EB (cmol(+) kg^{-1})	5.45 – 7.86	6.77
EA (cmol(+) kg^{-1})	0.99 – 1.28	1.10
CEC (cmol(+) kg^{-1})	6.66 – 8.89	7.87
BS (%)	81.8 – 88.8	85.9

The available potassium (K) ranged from 0.22 – 0.36 cmol kg^{-1} with a mean value of 0.29 cmol kg^{-1}. This is rated to be high compared to 0.25 cmol kg^{-1} in most Nigerian soils that has been classified as high. The exchangeable calcium (Ca) ranged between 2.70 – 3.80 cmol kg^{-1} and the mean value of 3.22 cmol kg^{-1}. This has been classified as medium (2.0 – 5.0 cmol kg^{-1}) with 2.6 cmol kg^{-1} as the critical value. Similarly, the exchangeable magnesium (Mg) content of the soils ranged from 2.30 – 3.50 cmol kg^{-1} with a mean value of 2.99 cmol kg^{-1}. This is rated to be very high, compared to greater than 1.00 cmol kg^{-1}, which is considered to be high in Nigerian soils (Chude *et al*., 2011). The extractable Sodium (Na) content ranged from 0.21 – 0.32 cmol kg^{-1} with a mean value of 0.29 cmol kg^{-1}. This is rated to be medium (0.1 – 0.3 cmol kg^{-1}) in Nigerian soils. This could be taken as an advantage, because Na concentration is not recommendable to high level as it deteriorates soil structure and make the soil liable for soil erosion and devoid of beneficial organisms. The principal saturating cations in the soils is Ca^{2+}, followed by Mg^{2+}, which is similar to what was reported by Onyilola and Chude (2010).

The total exchangeable bases ranged from 5.45 – 7.86 cmol kg^{-1} with a mean value of 6.77 cmol kg^{-1}. Cation Exchange Capacity (CEC) values ranged from 6.66 – 8.89 cmol kg^{-1} with a mean value of 7.87 cmol kg^{-1}. This is rated as medium as reported by Chude *et al*. (2011). Cation exchange capacity is the dominant factor in measuring soil fertility which affects exchange of ions on the clay surface. According to Chude *et al*. (2011) less than 6.0 cmol kg^{-1} is low and 6.0 - 12.0 cmol kg^{-1} is medium and greater than 12 cmol kg^{-1} is reported as high. The low to medium CEC of the soils could be attributed to the low organic matter content as well as low to medium levels of clay content in the soil. The values for percentage base saturation ranged from 81.1 – 88.8% with the mean value of 85.9%. The percentage base saturation classification indicates that, less than 50% is low and between 50 – 80% medium and greater than 80% is high (Chude *et al*., 2011). This showed that, all the values were high.

Table 2 present the results of the heavy metals of the study area. Iron ranged from 10.68 – 703.60 mg kg^{-1} with a mean value of 92.22 mg kg^{-1}. This is high and the result corroborates the work of Zaku *et al*. (2011). They reported high values of iron in the soils of Donga, Ibi and Wukari, which ranged from 10.39 – 42.53 mg kg^{-1} in Wukari. Themedium value for Fe has been reported to be 2.5 mg kg^{-1}, while the critical level is 20,000.00 mg kg^{-1}. Available Fe is generally high in the tropical soils; localized deficiencies are known to occur (Enwezor, 1990). The manganese (Mn) values ranged from 0.00 – 4.88 mg kg^{-1} with a mean of 3.64 mg kg^{-1}, this is low. This is again in line with the work of Zaku *et al*. (2011) who also reported 0 – 4.40 mg kg^{-1} in some farms in Wukari. Its medium value has been reported to be 8.50 mg kg^{-1} and the critical value is 5.50 mg kg^{-1} in Nigerian soils (Chude *et al*., 2011). Copper (Cu) varied from 0.00 – 37.08 mg kg^{-1} with a mean value of 1.21 mg kg^{-1}. The Cu classification showed that, less than 0.2 mg kg^{-1} is low, 0.2 – 2.0 mg kg^{-1} is medium while greater than 2.0 mg kg^{-1} is high (Chude *et al*., 2011). If this is applied to the values obtained in this study, it could be predicted that the deficiency of Cu will occur in some locations of the farm under study because of zero values experienced in most locations. The Zinc (Zn) varied from 0.00 – 33.38 mg kg^{-1} with a mean value of 16.56 mg kg^{-1}. This showed that the Zn was absent in some locations and high in other locations. Less than 0.80 mg kg^{-1} has been described as low, 0.18 – 2.0 mg kg^{-1} as medium, while greater than 2.0 mg kg^{-1} is high. The critical value of Zn has been reported as 50 mg kg^{-1}. Zinc could also be deficient in some locations because of the zero values obtained in many locations. The Cadmium (Cd) ranged from 0.00 – 0.68 mg kg^{-1} and the mean was 0.38 mg kg^{-1}. The Cd critical value is 3.0 /mg kg^{-1}. This showed that the values are generally very low, below the critical level and it may not most likely going to pose any problem in this soil. Chromium (Cr) ranged from 0.00 – 564.48 mg kg^{-1} in the soils with a mean value of 231.34 mg kg^{-1}. The critical level of Cr in the soil is 50.00 mg kg^{-1}. This showed that, its content in the soil was low for some locations and high for others. It is also suggesting that, Cr may exist in toxic levels in some of the locations. Lead content varied from 0.00 – 93.23 mg kg^{-1}. The mean value was 31.09 mg kg^{-1}, which was far lower than the 100 mg kg^{-1} critical level reported in literature.

Table 2: Heavy metals content of soils of the Teaching and Research Farm of Federal University Wukari (mg kg^{-1})

Sample ID	Fe	Mn	Cu	Zn	Cd	Cr	Pb
A1	36.75	1.53	0.60	3.65	0.28	63.90	18.50
A2	54.48	1.47	0.60	4.30	0.36	139.82	16.15
A3	72.20	1.40	0.75	4.95	0.43	215.73	13.80
A4	49.55	0.08	0.73	16.83	0.65	29.10	34.13
A5	68.78	1.40	0.00	13.00	0.80	223.73	47.95
A6	64.50	0.00	0.00	4.65	0.38	314.10	49.78
B1	37.60	1.28	0.00	8.78	0.55	308.88	50.03
B2	26.48	0.00	0.00	2.95	0.53	0.00	60.73
B3	33.33	0.00	0.00	3.78	0.48	0.00	61.75
B4	101.70	0.00	0.00	2.50	0.00	269.00	64.35
B5	67.51	0.00	0.00	6.24	0.00	134.50	58.10
B6	33.33	0.00	0.00	9.98	0.00	0.00	51.85
C1	47.00	0.00	0.20	1.05	0.00	25.98	18.25
C2	56.40	1.08	0.00	0.90	0.00	247.60	1.30
C3	101.70	0.33	0.00	1.55	0.00	0.00	1.96
C4	66.87	0.17	0.00	0.78	0.06	0.00	1.63
C5	32.05	0.00	0.00	0.00	0.13	0.00	1.30
C6	87.15	1.20	0.00	12.55	0.00	148.55	11.48
D1	667.70	2.60	0.00	2.38	0.00	206.08	0.78
D2	63.23	2.90	0.18	1.28	0.68	332.10	93.28
D3	46.13	1.08	0.00	3.65	0.35	0.00	0.00
D4	554.90	2.38	0.00	22.58	0.08	0.00	22.40
D5	89.70	1.90	0.28	5.95	0.28	0.00	13.03
D6	25.63	3.48	0.00	7.68	0.33	104.28	10.68
E1	107.20	2.28	0.00	8.78	0.00	0.00	12.25
E2	22.65	2.65	0.00	11.98	0.00	0.00	0.00
E3	28.20	0.16	0.00	9.88	0.10	0.00	6.00
E4	57.25	1.33	0.00	6.83	0.00	0.00	9.65
E5	58.10	1.84	0.00	11.39	0.05	74.20	7.81
E6	58.95	2.35	0.00	15.95	0.10	148.40	6.00
F1	66.23	1.65	0.00	6.35	0.10	377.03	14.85
F2	59.38	2.73	0.23	8.40	0.00	229.63	8.85
F3	37.59	2.44	0.11	7.32	0.22	397.06	13.80
F4	15.80	2.15	0.00	6.23	0.43	564.48	18.75
F5	703.60	2.40	0.00	15.68	0.10	515.78	3.65
F6	58.10	2.15	0.33	5.95	0.10	26.65	6.78
G1	43.15	0.25	0.00	4.88	0.00	0.00	19.55
G2	70.48	2.28	0.00	6.40	0.00	312.33	0.00
G3	62.38	3.43	0.00	7.83	0.68	490.63	0.00
G4	49.99	3.23	0.30	9.99	0.56	313.96	0.00
G5	37.60	3.03	0.60	12.15	0.43	137.28	0.00
G6	62.38	2.35	0.28	12.33	0.40	0.00	2.08
H1	62.80	2.53	2.73	7.98	0.05	31.38	0.00
H2	52.98	2.56	1.50	8.93	0.08	180.18	0.00
H3	43.15	2.59	0.28	9.88	0.10	328.98	0.00
H4	106.60	1.80	3.64	11.64	0.05	164.49	0.00
H5	170.00	1.01	7.00	13.40	0.00	0.00	0.00
H6	52.13	0.25	2.25	3.28	0.00	0.00	20.08
I1	33.75	3.73	3.18	9.20	0.00	0.00	0.00
I2	28.20	4.25	1.48	6.40	0.23	0.00	0.00
I3	516.10	2.73	0.40	5.00	0.28	0.00	3.13
I4	29.48	3.23	0.38	33.38	0.28	0.00	0.00
I5	40.37	1.74	0.53	22.16	0.14	0.00	10.29
I6	51.25	0.25	0.68	10.93	0.00	0.00	20.58
J1	33.75	1.38	0.50	2.15	0.15	0.00	4.43
J2	10.68	4.88	0.60	13.43	0.10	0.00	0.00
J3	27.77	4.24	2.16	9.24	0.05	0.00	0.00
J4	44.85	3.60	3.71	5.05	0.00	0.00	0.00
J5	114.90	4.43	0.50	16.05	0.00	0.00	0.00
J6	30.75	2.98	0.15	6.70	0.40	0.00	56.55
Range	10.68 –703.60	0.00 – 4.88	0.00 – 37.08	0.00 – 33.38	0.00 – 0.68	0.00 – 564.48	0.00 – 93.23
Mean	92.22	3.64	1.21	16.56	0.38	231.34	31.09

Table 3: Correlation matrix between heavy metals and some soil physical and chemical properties of part of the Teaching and Research Farm, Federal University Wukari

	Fe	Mn	Zn	Cu	pH	Sand	Clay	Silt	OC	N	P	CEC	BS	K	Na	Mg	Ca	EA
Fe																		
Mn	0.099																	
Zn	0.126	0.340**																
Cu	-0.068	0.284*	-0.037															
pH	-0.189	0.091	-0.051	0.179														
Sand	-0.17	-0.042	0.018	0.048	0.539**													
Clay	0.178	0.005	0.01	-0.155	-0.394**	-0.746**												
Silt	0.083	0.07	-0.038	0.075	-0.425**	-0.780**	0.167											
OC	0.044	-0.041	-0.064	-0.134	-0.470**	-0.622**	0.520**	0.434**										
N	-0.004	-0.017	-0.094	-0.048	-0.410**	-0.457**	0.458**	0.246	0.909**									
P	0.075	-0.081	-0.103	-0.24	-0.473**	-0.521**	0.446**	0.353**	0.834**	0.761**								
CEC	0.078	0.085	0.083	-0.113	-0.260*	-0.485**	0.472**	0.287*	0.0695**	0.625**	0.616**							
BS	0.146	-0.128	0.004	-0.254*	-0.537**	-0.539**	0.435**	0.390**	0.654**	0.556**	0.736**	0.731**						
K	0.114	0.07	0.036	-0.134	-0.321*	-0.485**	0.404**	0.346**	0.734**	0.662**	0.719**	0.826**	0.661**					
Na	0.145	0.154	0.099	-0.096	-0.284*	-0.502**	0.450**	0.328*	0.689**	0.613**	0.667**	0.884**	0.697**	0.946**				
Mg	0.112	0.034	0.063	-0.15	-0.300*	-0.508**	0.466**	0.323*	0.703**	0.613**	0.653**	0.968**	0.805**	0.831**	0.885**			
Ca	0.048	0.094	0.075	-0.149	-0.365**	-0.491**	0.453**	0.312*	0.679**	0.621**	0.613**	0.959**	0.804**	0.756**	0.817**	0.930**		
EA	-0.128	0.259*	0.086	0.248	0.517**	0.264*	-0.135	-0.252	-0.243	-0.177	-0.441**	-0.007	-0.681**	-0.087	-0.076	-0.145	-0.165	1

** = Significant at $P < 0.01$, * = Significant at $P < 0.05$, ns = not significant

Correlation studies

The correlation between heavy metals and some of the soil chemical and physical properties are shown in Table 3. The results showed that, Fe correlated negatively with the soil pH, Sand, N and EA but not significantly. It also correlated positively with Clay, Silt, OC, P, CEC, BS, K, Na, Mg and Ca which was also not significantly. Manganese significantly ($P < 0.05$) positively correlated with EA. Manganese however, negatively correlated with Sand, OC, N, P, and BS, while it positively correlated with the rest of the parameters but all were not significant. In the case of positive correlation it showed that, as the EA increases the availability of Mn in the soil increases. It has been reported that, most micronutrients including Mn becomes readily available when the pH of the soil is low. Zinc was also either negatively or positively correlated with the physical or chemical properties but not significantly. Copper significantly ($P < 0.05$) negatively correlated with BS, while with the other parameters it was either positively or negatively correlated but not significantly.

The positive correlation means, increase in one parameter results to the increase of the other parameter, while the negative correlation means an increase in one parameter leads to the decrease of the other parameter.

Conclusion

The result obtained from this study has shown that, the soils of the farm are generally sandy loam in texture. The soils have a mean pH value of 6.5, which is ideal for most nutrient availability and crop production. The carbon, nitrogen and phosphorus mean values are low (8.42, 0.52 and 4.83 g kg^{-1}, respectively) while potassium (0.29 cmol kg^{-1}) values are high. The calcium and sodium values are medium, while the magnesium value is high. The CEC values are medium (6.66 – 8.89 cmol kg^{-1}). The percentage base saturation ranged from 81.1 – 88.8% which showed that all the values were high. The mean values for Fe, Cu and Zn were high, though completely absent in some locations, while Cr was low and high for some locations. The mean values for Mn, Cd and Pb were generally very low and even absent for some locations. For successful and profitable crop production, there would be need to supply some of the nutrients that are low or completely absent in some of the locations. Careful attention should be given to heavy metals like Cr which occur in toxic levels as some of the values in some locations are greater than the critical levels. The correlation studies showed that Manganese significantly ($P < 0.05$) positively correlated with Exchangeable Acidity. Copper also significantly ($P < 0.05$) negatively correlated with Base Saturation. The others either correlated positively or negatively with the soil properties but not at a significant level.

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Conflict of Interest

Authors have declared that there is no conflict of interest reported in this work

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