African Research Review

An International Multi-Disciplinary Journal, Ethiopia
Vol. 3 (3), April, 2009
ISSN 1994-9057 (Print) ISSN 2070-0083 (Online)

Copper and Zinc Contents in Urban Agricultural Soils of Niger State, Nigeria (Pp. 23-33)

Iyaka, Y. A. - Department of Chemistry, Federal University of Technology, Minna, Niger State, Nigeria iyaka7@yahoo.com

Kakulu, S. E. - Department of Chemistry, University of Abuja, Abuja, FCT, Nigeria

Abstract

Study of the Cu and Zn contents in urban agricultural soils is paramount in order to assess concerning the possible potential risks they may pose at high concentrations to life and environment through the food chain. Levels of Cu and Zn in soil samples collected from cultivated farmlands in the vicinity of abandoned industrial sites at two cities of Minna and Bida in Niger State, were determined using flame atomic absorption spectrophotometry technique. The concentrations were in the following ranges; 12-89mgCukg^{-1} and 2.8-41mgZnkg^{-1} for Minna and 2.4-6.5mgCukg^{-1} and 0.57-36mgZnkg^{-1} for Bida. The accumulation of Cu in Minna cultivated farmlands was apparent, with a mean Cu content of 24 $\pm$ 22ppm, which was almost five times that of the control soils, but other mean values were similar to the soil background average contents. Soil properties were also analysed, and obtained results for the cultivated farmland soils of the two cities were of the following ranges: - pH (5.0-7.5), Organic carbon (0.36-2.5)%, sand (46.4-94.2)%, silt (2.3-20.0)% and clay (1.8-33.6)%. Cu and Zn positively correlated among themselves, Cu correlated with clay content and Zn correlated with pH and organic carbon in all the soils.

Keywords: heavy metals, accumulation, environment, cultivated farmlands, abandoned industrial sites.

Introduction

In the past, most studies of the elemental contents of soils in Nigeria had focused primarily on the micronutrient status of soils or on plant-available forms of micronutrients (Udo and Fagbami, 1979; Lombin, 1983a, 1983b; Kparmwang et al.2000).However, the soil scientists particularly the environmental analytical chemists have appreciated the need for more information on the total soil trace metal concentrations determined with acid digestion procedures. Such soil total metal content, usually indicate the extent of contamination, by distinguishing soils containing elevated metal contents from soils which contain normal background levels.

Trace metals are not biodegradable, but may be biotransformed (Kong and Liu, 1995), hence, their persistence accumulation in soils creates significant phytotoxicity problem (Heckman et al., 1987). Cu and Zn in very low concentrations are essential trace elements for the survival of plant and animal life (Wild, 1994), but their increase in large amounts in soils may influence the uptake by plants, which in turn determines that of the animals and humans through the food chain (Ward, 1995), and consequently producing potentially serious hazards in all the systems (Wild, 1994) as well as in the deterioration of the quality of ground and surface waters (Wood et al.1999).

Furthermore, the concentration of trace metals in soils are generally associated with mother material; pedogenic sources, and are influenced by anthropogenic activities such as industrial and agricultural activities. Alloway and Ayres (1997) thus, observed that agricultural chemicals or materials such as impurities in fertilizers, pesticides and wastes from intensive poultry production constitute the very important non-point sources for metal pollutants like Cu and Zn in soils. The aim of this research, therefore, is to determine the extent of Cu and Zn contamination in cultivated farmlands in two major cities (Minna and Bida) in Niger State. The study also aimed at providing a data base of Cu and Zn in this area in order to assess the influence of agricultural activities particularly within the vicinity of abandoned industrial sites, since such studies are scarce for soils in Nigeria.

Materials and Methods

Soil samples were collected from cultivated farmlands within the vicinity of abandoned industrial sites from two major cities (Minna and Bida) in Niger State, Nigeria. Control soil samples were obtained from locations within the two cities that were far from any major pollution sources. The sampling approach was random and systematic; at each sampling location or point a stainless steel auger was used to collect five (5) sub-samples from the top layer at a depth of 0 – 20cm. The collected sub- samples were then pooled together, to form a composite of each individual sample. The soil samples were air-dried for one week, ground, passed through 2.0-mm sieve (for soil pH and particle size analysis), and some portion of the individual sieved sample was further pulverized to a fine powder (passed through 0.5-mm sieve) for the determination of organic carbon and total metal content.

Soil pH was measured in 1:1 (soil to water ratio) according to Tan (1996), organic carbon was determined by Walkley-Black titration method and particle size was determined using hydrometer method of soil mechanical analysis. Soil samples were digested with HNO_3 – H_2O_2 – HCl using USEPA SW-846, method 3050(1986). The concentrations of Cu and Zn in the digestion solution were determined with a Unicam 969 Atomic Absorption Spectrophotometer – solar in the flame mode. At least one reagent blank and one duplicate sample were run for every batch of 5 samples for background correction and to verify the precision of the method. Accuracy was assessed by analyzing three (3) replicates of certified reference materials, soil sample S0-1, obtained from Canada Centre for Mineral and Energy Technology (CANMET). Mean fractional recoveries were satisfactory, often being in excess of 90% for Cu and Zn analysed.

Results and Discussion

Soil properties

The interpretation data for rating the obtained values of the soil general properties were adapted from Kparwang et al.(2000) and Baize(1993). All the soils studied from the cultivated farmlands in the vicinity of abandoned industrial sites were weakly acid or neutral (Tables 1 and 2). The pH values ranged from 5.7-7.3 and from 5.0-7.5 with mean values of 6.5 $\pm$ 0.5 and 6.3 $\pm$ 0.7 respectively for Minna and Bida cultivated farmland soils (Table 3). The general average pH value of 6.4 $\pm$ 0.6 obtained from all the soils of the cultivated farmlands in the vicinity of the abandoned industrial sites is higher than the mean pH value of 5.2 reported by

Indexed African Journals Online: www.ajol.info

Onofiok and Ojobo (1993) in their study of some Nigerian soils. This higher mean value may be ascribed to the buffering effect of carbonate-containing materials often experienced in cities (Savoskull and Drechsel, 2003).

The soil organic carbon concentrations ranged from 0.36–2.5% and from 0.43–1.7% for Minna and Bida cultivated farmlands respectively, with an average concentration of 0.81$\pm$0.5% (Table 3) for all soils from the cultivated farmlands of the two cities. The soils from the studied cultivated farmlands were generally low in organic carbon contents with 87.5% and 66.7% of the study soil samples from Minna and Bida respectively (Tables 1 and 2) having organic carbon values of less than 1.0%. Baize (1993) suggested that the role of silts and sands must be considered when sampled soils contain less than 35% clay. Thus, in this study of the cultivated farmlands in the vicinity of abandoned industrial sites, the soils were very sandy with a mean of 75.1+13.8% for the two cities (Table 3). The clay contents ranged from 25.6-33.6% for Minna and from 1.8-23.5% for Bida cultivated farmlands. Nevertheless, Mbila et al.(2003) in their previous study of soils at University of Nigerian, Nsukka had reported a similar clay content range of 14.0-26.0% and an average sand concentration of 78.4%.

Copper

In the soils studied, total Cu contents varied considerably from 12ppm–89ppm for Minna and from 2.4ppm–6.5ppm for Bida cultivated farmlands (Table 4). All the soil samples from Minna cultivated farmlands had Cu levels that were higher than 12.0mgCukg^{-1} reported by Berrow and Reaves (1984) as background level for world soils. The mean Cu concentration of 24$\pm$22ppm obtained for Minna cultivated farmland soil samples was higher than the mean concentration for world soils of about 20.0ppm for Cu(Alloway,1995) and also higher than 21.4mg Cukg^{-1} reported by Zauyah et al.(2004) in their study of some cultivated soils of Malaysia Peninsula. However, the obtained mean Cu level from Minna cultivated farmland soils is lower than standard for Maximum Allowable Limits (MAL) in soils of different countries(Kabata- Pendias, 1995), except for soil samples from the Eastward direction (0.0m and 50.0m) with 89mgCukg^{-1} and 60mgCukg^{-1} (Table 1) that are higher than the 50.0mgCukg^{-1} established as the maximum allowable limit for Cu in Germany(Kabata-Pendias,1995),and Switzerland guide values(FOEFL,1987). The high Cu contents obtained from these two locations could probably be due to the passing of railway lines across them.

Similar Cu enriched soils have been reported for urbanized soils of Port Jackson, Sydney by Snowdon and Birch (2004). Furthermore, the highest obtained total Cu content of 89ppm from Minna cultivated farmland soils is also higher than the agricultural acceptable limit of 63ppm in Canadian soil Quality Guidelines for the protection of Environmental and Human Health (CCME, 1999).

The Cu concentrations obtained from Bida cultivated farmland soils in the vicinity of an abandoned industrial site are generally lower than found for Minna cultivated farmland soils in this study. This may be ascribed to duration of time that these soils have been utilized. Madrid et al.(2002) had reported that the extent of heavy metal pollution in soils varied with age, particularly for Cu and Pb. However, mean extractable Cu contents of 1.3ppm and 2.1ppm that are lower than 4.3$\pm$1.3ppm obtained from Bida cultivated farmland soils have been reported respectively by Adepetu et al.(1979) in their study of surface soils of Ondo State in Nigeria, and Fagbami et al.(1985) in their study of the basement complex soils of tropical dry rain forest of South-Western Nigeria.

Zinc

A summary of the Zn concentrations in the studied soils of cultivated farmlands in the vicinity of abandoned industrial sites at Minna and Bida is presented in Table 4. Zn total contents for Minna cultivated farmland soil samples varied from 2.8ppm–41ppm, but were mainly between 2.8ppm and 7.5ppm (Table 1). The average Zn concentration obtained from the analysed soils of the Minna cultivated farmlands was lower, than the mean content of 20mgZnkg^{-1} found in Florida agricultural surface soils (Holmgren et al., 1993), and also lower that the average 45ppm value reported in the literature for world sandy soils by Kabata-Pendias and Pendias(1992). The Zn concentrations of the Minna cultivated farmland soils are however, within the range of 1.0-170mgZnkg^{-1} reported for surface soil samples of South Carolina(Canova,1999), and similar to 2.8- 12.0mgZnkg^{-1} reported by Gough et al.(1994) in their investigation of the baseline elemental contents of the Bull Island soils.

About 45% (Table 2) of the soil samples examined from Bida cultivated farmlands in the vicinity of an abandoned industrial site had Zn concentrations of less than 2.8ppm obtained as minimum level from Minna site (Table 1). This may be attributed to the duration of the land usage, plant uptake and smaller amount of clay. Nevertheless, the Zn content range of 0.57-36ppm obtained from the study of Bida cultivated farmland soils is higher than 0.418-0.832mgZnkg^{-1} obtained by Francis (2005) in his study of heavy metals in contaminated soils in the vicinity of livestock farmland in Southern Nigeria. Generally, the very low Zn concentration obtained in soils from the cultivated farmlands in the vicinity of abandoned industrial sites in this study could probably be ascribed to much less application of fertilizers and potential leaching due to sandy soil texture.

Correlation analysis

Correlation studies of Cu and Zn contents with soil properties (Table 5) show that for Minna cultivated farmlands in the vicinity of an abandoned industrial site, both metals correlated positively with clay content, while Cu alone correlated with pH and Zn correlated with organic carbon content. However, for Bida cultivated farmlands, only Zn correlated positively with both pH and organic carbon, and for all the soil samples from the two sites, Cu correlated with clay content and Zn correlated significantly with both the pH and organic carbon. Furthermore, Table 6 indicates that there is correlation between the two metals in Minna cultivated farmlands and in all soils from the two sites of our study.

Conclusion

Cu levels in Minna cultivated farmlands in the vicinity of an abandoned industrial site were substantially higher than in control soils, with a mean Cu content of almost five times that of the control. However, the obtained mean Cu value of Bida cultivated farmland soils in the vicinity of an abandoned industrial site and average Zn concentrations in the two sites of this study are lower than found in control soils. Hence, location and age or duration of pollution tends to be significant factors in heavy metal accumulation in soils, particularly for Cu. The findings of this study also depicts that there is need for constant monitoring or watch on levels of the heavy metals in urban agricultural soils in order to be able to assess concerning their possible potential risks at high concentrations to life and environment.

References

Adepetu, J.A. et al. (1979). "A Preliminary Survey of the Fertility Status of Soils in Ondo State under Traditional Cultivation". *Ife Journal of Agriculture.* ***1****:* 134 – 149.

Alloway, B. J.(1995). *Heavy Metals in Soils.* 2nd ed. Glasgow, U.K: Chapman and Hall.

Alloway, B.J., Ayres, D.C. (1997). *Chemical Principles of Environmental Pollution.* London: Blackie Academic and Professional.

Baize, D.(1993). *Soil Science Analysis. A Guide to Current Use*. New York: John Wiley and Sons.

Berrow, M.L., Reaves, G.A.(1984). "Background levels of trace elements in soils". In the Proceedings of the First International Conference on Environmental Contamination'. Pp 333 – 340. Edinburgh, Scotland: CEP Consultants:

Canadian Council of Ministers of the Environment.(1999). Canadian soil quality guidelines for the protection of environmental and human health: Summary tables. In: Canadian environmental quality guidelines. (1999) Canadian Council of Ministers of the Environment, Winnipeg.

Canova, J.L. (1999). Elements in South Carolina inferred background soil and stream sediment samples. *S. C. Geol.* ***41***: 11 – 25.

Fagbami, A., Ajayi, S.O., Ali, E.M.(1985). Nutrient distribution in the basement complex soils of tropical dry rain forest of South-Western Nigeria. 2. Micronutrients – zinc and copper. *Soil Science* ***139****:* 531 – 537.

Federal Office of Environment, Forests and Landscape. (1987). Commentary on the Ordinance Relating to Pollutants in Soil. *FOEFL, Bern*, Switzerland.

Francis, D.A.(2005). Trace heavy metal contamination of soils and vegetation in the vicinity of livestock in Nigeria. *Electron J. Environ. Agric. Food Chem.* ***4****:* 863 – 870.

Gough, L.P., Severson, R.C., Jackson, L.L., (1994). Baseline element concentrations in soils and plants, Bull Island, Cape Romain National Wildlife, Refuge, South Carolina, U.S.A. *Water Air Soil Pollut.* ***74****:* 1 – 17.

Heckman, J.R., Angle, J.S, Chaney, R.L.(1987). Residual effects of sewage sludge on soybean: I. Accumulation of heavy metal. *J. Environ. Qual.* ***16***: 113 – 117.

Holmgren, G.G.S., Meyer, M.W., Chaney, R.L. (1993). Cd, Pb, Zn, Cu and Ni in agricultural soils of the United States of America. *J. Environ. Qual.* ***22***: 335 – 348.

Kabata – Pendias, A.(1995). Agricultural Problems Related to Excessive Trace Metal contents of soil. In *Heavy metals (Problems and Solutions*. (Eds W. Salomons, U. Forstner, P. Mader) Pp. 3 – 18. Berlin, Heidelberg, New York, London, Tokyo: Springer Verlag.

Kabata-Pendias, A., Pendias, H. (1992). 'Trace elements in soils and plants'. London: CRC Press.

Kong, J., Liu, S. (1995). Determination of heavy metals distribution in the Anoxic sediment slurries. *Chemical Sequential Fractionation. Ecotoxicology and Environmental Safety.* ***32:*** 34 – 38.

Kparmwang, T. et al. (2000). Extractable micronutrients in some soils developed on sandstone and shale in Benue Valley, Nigeria. *Nig. J. Soil. Res.* ***1:*** 42 – 48.

Lombin, G.(1983a). Evaluating the micronutrient fertility of Nigeria's semi-arid savanna: 1. Copper and Manganese. *Soil Science* ***135*** : 377 – 384.

Lombin, G., (1983b). Evaluating the micronutrient fertility of Nigeria's semi-arid savanna: Zinc. *Soil Science.* ***136***: 42 – 47.

Madrid, L., Diaz-Barrientos, E., Madrid, F. (2002). Distribution of heavy metal contents of urban soils in parks of Seville. *Chemosphere.* ***49***: 1301 – 1308.

Mbila, M.O. et al. (2003). Morphological and chemical properties of selected sludge – amended Nigerian soils. *Soil Science.* ***168***: 660 – 669.

Onofiok, O.E., Ojobo, G.O. (1993). Inventory of some physico-chemical characteristics of some Nigerian soils and their relationship with moisture retention, plasticity and sealing propensity. *Samaru Journal of Agricultural Research.* ***10:*** 15 – 27.

Savoskull, O.S., Drechsel, P. (2003). Heavy metal concentrations in urban and peri-urban gardens of Dzerzhinsk and Nizhny Novgorod, Russia, City farmer, Canada's office of urban agriculture.

Snowdon, A., Birch, G.F. (2004). The nature and distribution of copper lead and zinc in soils of highly urbanized sub-catchment (Iron Cave) of Port Jackson, Sydney. *Australian Journal of Soil Research.* ***42:*** 329 – 338.

Tan, K.M.(1996). *Soil Sampling Preparation and Analysis.* (Mercel Dekkes. Inc: New York. Basel. Hong Kong).

Udo, E.J., Fagbami, A.A. (1979). The profile distribution of total and extractable zinc in selected Nigerian soils. *Comm. in Soil Sc. and Plant Analysis.* ***10***: 1141 – 1161.

United States Environmental Protection Agency.(1986). Test Methods for evaluating solid wastes. *USEPA SW – 846*. U. S. Govt Print. Office, Washington, D. C.

Ward, N.I.(1995). Trace elements. In *Environmental Analytical Chemistry*. (Eds F.W. Fifield, H.R.J. Blackie) pp 321 – 351. Glasgow: Academic and Professional.

Wild, A.(1994). *Soils and the Environment: An introduction*. New York: Cambridge UniversityPress.

Wood, B.H. et al. (1999). Seasonal surface runoff losses of nutrients and metals from soils fertilized with broiler litter and commercial fertilizer. *J. Environ. Qual.* ***28:*** 1210 – 1218.

Zauyah, S. et al. (2004). Concentration and Speciation of Heavy metals in some cultivated and uncultivated ultisols and Inceptisols in *Peninsular Malaysia. Super Soil 2004*. The Regional Institute Ltd.

Table 1: Total metal contents (mgkg^{-1}) and soil properties of Minna cultivated farmland in the vicinity of an abandoned industrial site

Sample Location	Distance from factory (m)	Cu	Zn	pH (H_2O)	OC*	Sand	Silt	Clay
		mgkg^{-1}			%			
East	0.0	89	3.9	7.2	0.43	66.4	16.0	27.6
East	50.0	60	37	6.5	0.88	66.4	4.0	29.6
South	0.0	21	3.7	6.2	0.43	60.4	12.0	27.6
South	50.0	12	3.7	6.6	0.54	66.4	8.0	25.6
South	100.0	12	3.1	6.0	0.43	66.4	8.0	25.6
West	0.0	14	6.3	7.0	0.82	60.4	10.0	29.6
West	15.0	13	7.5	6.1	0.74	62.4	10.0	27.6
West	100.0	13	6.3	6.2	0.42	66.4	8.0	25.6
North west	0.0	23	33	7.3	2.5	54.4	18.0	27.6
North west	50.0	14	5.2	6.7	0.46	66.4	8.0	25.6
North west	100.0	14	4.0	5.9	0.48	64.4	10.0	25.6
North	0.0	15	16	6.9	0.58	46.4	20.0	33.6
North	50.0	13	4.1	5.7	0.42	62.4	10.0	27.6
North	100.0	14	6.1	6.1	0.38	66.4	8.0	25.6
North East	0.0	13	2.8	6.2	0.36	66.4	8.0	27.6
North East	50.0	43	41	7.2	1.8	54.4	16.0	29.6

* Organic carbon

Table 2: Total metal contents ($mgkg^{-1}$) and soil properties of Bida cultivated farmland in the vicinity of an abandoned industrial site

Sample Location	Distance from factory (m)	Cu	Zn	pH (H_2O)	OC	Sand	Silt	Clay
		$mgkg^{-1}$			%			
East	0.0	2.5	4.0	6.2	0.76	90.2	7.0	2.8
East	50.0	5.2	4.5	6.1	0.94	93.2	5.0	1.8
East	100.0	2.8	1.7	5.1	0.70	91.2	6.0	2.8
South East	0.0	3.6	16	7.5	1.7	88.2	8.0	3.8
South east	50.0	5.4	32	7.3	1.3	94.2	4.0	1.8
South East	100.0	4.8	1.2	5.0	1.0	92.2	4.0	3.8
South	0.0	4.3	8.8	7.3	1.1	85.2	7.0	7.8
South	50.0	3.9	1.6	5.5	0.46	93.2	4.0	2.8
South	100.0	2.4	0.57	5.9	0.52	82.2	3.0	14.8
South west	0.0	6.3	7.6	6.3	0.64	87.2	7.0	5.8
South west	50.0	5.3	1.8	6.6	0.58	92.2	4.5	3.3
South west	100.0	5.4	2.2	6.2	0.80	87.2	5.3	7.5
West	0.0	6.5	36	6.6	1.4	75.2	6.0	18.8
West	50.0	5.3	16	6.5	0.90	88.2	3.5	8.3
West	100.0	3.8	36	6.4	0.94	81.2	2.3	16.5
North west	0.0	4.1	7.5	6.4	1.1	74.2	5.0	20.8
North west	50.0	3.9	1.3	6.4	0.43	88.2	3.0	8.8
North west	100.0	2.4	1.8	6.7	0.58	74.2	2.3	23.5

Table 3: Ranges and Mean of soil properties of the cultivated farmland in the vicinity of the abandoned industrial sites.

City		Parameter				
		pH (H_2O)	OC	Sand	Silt	Clay
			%			
Minna	Range	5.7 – 7.3	0.36 –2.5	46.4 – 66.4	4.0 – 20.0	25.6 – 33.6
(n* = 16)	Mean	6.5	0.73	62.2	10.9	27.6
	SD**	0.5	0.6	5.9	4.4	2.2
Bida	Range	5.0 – 7.5	0.43– 1.7	74.2 – 94.2	2.3 – 8.0	1.8 – 23.5
(n = 18)	Mean	6.3	0.88	86.6	4.8	8.6
	SD	0.7	0.4	6.6	1.7	7.1
	Range	5.0 – 7.5	0.36– 2.5	46.4 – 94.2	2.3 – 20.0	1.8 – 33.6
All soils	Mean	6.4	0.81	75.1	7.7	17.6
(n = 34)	SD	0.6	0.5	13.8	4.4	11.0

* Numbers of soils within a site ** Standard Deviation

Table 4 Summary of the total metal contents (mgkg^{-1}) of the cultivated farmlands in the vicinity of abandoned industrial sites.

City	Metal	Range	Median	Mean ± SD*
Minna	Cu	12 – 89	14	24 ± 22
(n=16)	Zn	2.8 – 41	5.7	12 ± 13
Bida	Cu	2.4 – 6.5	4.2	4.3 ± 1.3
(n=18)	Zn	0.57 – 36	4.3	10 ± 12
All soils	Cu	2.4 – 89	6.4	14 ± 18
(n=34)	Zn	0.57 – 41	4.9	11 ± 13
Control	Cu	4.2 - 7.0		5.4 ± 1.2
(n=4)	Zn	8.4 – 16		12 ± 3.2

* Standard deviation

Table 5: Correlation coefficient of Cu and Zn contents with soil properties of cultivated farmlands

City	Metal	pH	OC	Clay
Minna	Cu	O.585*	0.441	0.548*
	Zn	0.436	0.703**	0.541*
Bida	Cu	0.195	0.349	-0.146
	Zn	0.645**	0.726**	0.106
All	Cu	0.227	-0.185	0.785**
Soils	Zn	0.576**	0.568**	0.307

* Correlation is significant at the 0.05 level
** Correlation is significant at the 0.01 level

Table 6 Correlation coefficients among Cu and Zn contents in cultivated farmland soils.

City			Zn	
		Correlation Coefficient	P value	Significant
Minna	Cu	0.510*	0.044	Yes
Bida	Cu	0.411	0.091	No
All soils	Cu	0.393*	0.022	Yes

* Correlation is significant at the 0.05 level.