BIOMEDICAL AND ENVIRONMENTAL SCIENCES **17**, 426-431 (2004)

Cu, Mn, Fe, and Zn Levels in Soils of Shika Area, Nigeria

S. A. MASHI[*,+], S. A. YARO[△], AND A. S. HAIBA[‡]

[*]Department of Geography, University of Abuja, P. M. B. 117, Abuja, NIGERIA; [△]Department of Metallurgical Engineering, Ahmadu Bello University, Zaria, Nigeria; [‡]Department of Geography, Ahmadu Bello University, Zaria, Nigeria

Objective Heavy metals presented in toxic amounts can become injurious to human health. In areas where there is a high level of human activities on soils (such as agriculture and grazing) studies are therefore required from time to time to monitor levels of such metals in the soils in order to identify the point in time when toxicity problems become real. The objective of this paper is to determine the concentrations of some trace metals (Cu, Mn, Fe, and Zn) in soils under cultivation and grazing practices in Shika, a rural area of Kaduna state of Nigeria. **Method** In this study, soil samples collected from three different categories of locations (cultivated, grazed, and uncultivated/non-grazed serving as a control) across Shika area, Nigeria, were analysed for some trace metal levels (Cu, Mn, Fe, and Zn) using atomic absorption spectrophotometry. For each category, multiple sites were chosen to accommodate all possible intra-category variations, especially in terms of land use and management history and topographic characteristics. Topsoil (0-15 cm) and subsoil (20-30 cm) samples were collected from every site and analysed for the above metals. Averaged values of the metals for the three categories revealed that Zn is the most abundant metal, followed by Fe, then Mn and Cu the least. **Results** The results obtained indicate that the cultivation practices, and to a lesser extent grazing, in the area result in higher levels of all the metals than in the control, suggesting that crop immobilization of the metals from soils of the area is low, and that their systematic accumulation is taking place in cultivated soils of the area. Prospects of having elevated soil levels of the metals due to cultivation practices in the area therefore seem quite high. **Conclusion** On the basis of the results obtained, it was concluded that grazing and cultivation practices have in general caused some significant elevations in the bioavailable (i.e the plant available forms) levels of Zn, Fe, Mn, and Cu in soils of the area.

Key words: Trace Metals; Soil Contamination; Cultivation; Grazing; Control; Nigeria

INTRODUCTION

Pollution of soils by trace metals is a worldwide problem today. At high concentrations in the environment, trace metals may enter food chain from soils and result in health hazards[1]. In the absence of human influences, background levels of such metals are relatively low and hence pose little threats to human health[2]. Human activities can however raise the bio-available forms (i.e the forms that plant can uptake, which subsequently find

[+]Correspondence should be addressed to Dr. S. A., MASHI. Tel: 234-09-234-2932. E-mail: sanimashi2000@ yahoo. com

Biographical note of the first author: Dr. S. A., MASHI is a Senior Lecturer in Geography at the University of Abuja, Abuja Nigeria. He is also the Deputy Director of the University's Center for Distance Learning and Continuing Education. His areas of research and teaching interest are Environmental applications of remote sensing and GIS and the impact of human activities on environmental quality. He has published extensively in these areas.

0895-3988/2004
CN 11-2816

ways into other living organisms through the food chain processes) of trace metals that human beings can readily take up through crops. This happens because such influences affect a number of soil factors such as organic matters, clay and pH levels, which in turn significantly raises availability of trace metal levels for the uptake by plants[3-5].

A number of authorities have linked trace metals pollution of soils to some human activities including industrial manufacturing, domestic, sewage generation, mining operations, garbage productions, metallurgical and cottage industrial activities[6-12]. Perhaps because such activities are taking place in or near urban areas, trace metals pollution of soils is largely thought to be mainly a urban problem. Chemical forms of metals in soil are affected by pH, CEC, redox potential (Eh), organic matters, and other factors. In particular, the bioavailable forms of metals are influenced by the soil level of Clay fractions, CEC, pH, and organic mattes, which can be easily altered by human activities, such as farming and grazing. Therefore, since availability of a trace metal for plant's uptake (also called bio-availability) is controlled by a number of soil factors, whose levels could be altered by human activities, it should then be expected that some rural-based human activities like cultivation, grazing, and bush burning could alter trace metal levels in soils. It is thus worthwhile conducting investigations on trace metal levels in soils under varied human activities in rural areas. This can particularly help us to know the stage in time when the levels have been raised to above what human beings can tolerate, or when they fall below the level which plants require for their effective performance.

This paper reports the investigation on determining the concentrations of some trace metals (Cu, Mn, Fe, and Zn) in soils of Shika, a rural area of Kaduna state, Nigeria. It is of particular interest here because the area under investigation is experiencing some intensive cultivation practices, with intensive livestock husbandry among local inhabitants. Also at most times of the year, sheep, goats and cows are seen grazing on available plant cover that grows on soils of the area. Cultivation practices in the area mainly involve continuous cultivation of cereal crops (mainly maize and sorghum), use of organic manure and inorganic fertilizers in soil fertility maintenance, and crop and litter residue burning after every cultivation cycle.

MATERIALS AND METHODS

Selection of Sampling Sites

Twelve sampling sites, classified into three broad categories, were purposefully chosen to serve as representative samples of the main uses which soils are subjected to in the area. The first comprises of four sites chosen to represent four types of cultivation practices in the area, namely, cultivation with macronutrient (N, P, K) fertilizer application plus post-harvest crop residue burning; similar cultivation practice but without residue burning; cultivation with mixed applications of organic manure and macronutrient fertilizer plus crop residue burning; and cultivation with mixed applications of organic manure and macronutrient fertilizer but without residue burning. The second category is made up of grass fallows that are seasonally grazed by livestock. Four sites were selected under this category to ensure effective replications. The third category is permanent bush fallows that are neither being grazed nor cultivated, from which also four sites were chosen. The three categories in this study are considered as cultivated, grazed and control locations respectively. While the first two categories would allow examination of the extent of trace metal pollution under cultivation and grazing practices, the third is expected to allow examination of the levels of the metals under areas of little human influences. Since all the twelve sites are located in an area of relatively uniform climatic, geologic and geomorphic characteristics, it is expected that the mean difference in trace metal levels in the various sites should be the main determinant of the extent of use which these sites have been subjected to as a result of some human activities. In a previous paper, Abubakar[13] has described this approach (called Inferential Approach) as a reasonably good way of studying soil changes due to human activities in semi-arid areas where baseline soil data do not always exist, based upon which soil survey and re-survey results could be used to assess such changes.

Collection and Analyses of Soil Samples

Twenty Topsoil (0 cm-15 cm depth) and twenty subsoil (20 cm-30 cm depth) samples were collected using soil auger from each of the twelve plots. The collected samples were air-dried, ground and sieved through a 2-mm nylon sieve to remove gravel fractions. Three g sub-samples were then taken in crucibles to which few drops of distilled water were added to prevent sputtering. The heavy metals in each sample were extracted using EDTA Method[14]. This method was used in order to ensure that only the bio-available forms of the metals, which are those expected to enter the food chain, were extracted. The concentrations of each metal in the extractants were determined using Unicam 939/959 Atomic Absorption Spectrophotometer.

RESULTS

The results of the analyses of the soil samples, showing the mean concentrations of the various metals for each of the three categories of plots (Cultivated, Grazed, and Control), are given in Table 1. Every mean value is for four sampling sites within each category. However, an attempt was first made to investigate the significance of the differences in mean values of the four sampling sites within each of the three sampling categories. It was found out that no significant difference exists among the compared sites within each category, and hence it was thought that there is no need to illustrate the extent of such differences among the four sites as part of the results presented in Table 1.

TABLE 1

Concentrations of Cu, Mn, Fe, and Zn in Topsoil and Subsoil Samples (μg g^{-1}) Collected in Shika Area, Nigeria

Trace Metal		Sampling Category					
		Cultivated Soils		Grazed Soils		Control Soils	
		Topsoil	Subsoil	Topsoil	Subsoil	Topsoil	Subsoil
	Mean	12.16*	7.20*	8.19	9.32	6.10	4.13
Cu	SD	4.32	1.65	5.13	3.16	2.00	1.16
	CV%	35.52	22.92	62.64	33.91	32.79	28.09
Mn	Mean	23.46*	10.00	13.16*	6.16*	9.05	10.13
	SD	12.03	4.16	8.05	2.13	3.05	2.05
	CV%	51.28	41.60	61.17	34.58	33.70	20.24
Fe	Mean	38.05*	45.40*	20.13*	9.40	8.76	6.13
	SD	17.12	12.10	12.17	3.20	2.16	1.32
	CV%	44.99	26.65	60.46	34.04	24.66	21.53
Zn	Mean	65.00*	32.50*	19.50*	27.10*	12.00	9.15
	SD	23.00	17.16	8.16	5.13	4.12	1.78
	CV%	35.38	52.80	41.85	19.00	34.33	19.45

Note.*=denote the mean values for the various plots that are statistically significantly different from those of the control plot.

It is clear from the table that the topsoil mean values of the various metals in all the three plots are in most cases higher (sometimes by as much as above 100%) than those of the subsoil. This is probably due to the fact that the upper soil layer typically contains more organic materials (hence greater CEC as well) than the lower layer because the latter is in more direct interaction with the biosphere than the latter layer. Soil data obtained in the area by Chude *et al.*[5] have indicated that topsoil organic matters and CEC levels are typically about 80% to 140% higher than those in the subsoil. The distributional trend of the metals as obtained here thus suggests that variation in levels of the metals among the major soil horizons in the area is closely related to the distribution of organic materials.

Comparison of levels of the metals for the three plots reveal that for all the four metals, the topsoil values are highest under the cultivated and least under the control. This indicates clearly that there is consistency in distribution of the metals in the topsoil layers of the three plots which suggests that similar set of factors are most likely to be responsible for their availability in topsoils of the area. In the subsoil, however, the distributional trends of the four metals in the three plots are not the same. For instance, while Cu is highest under the grazed plot and least under the control, Mn is highest under the control and least under the grazed plot. In the case of Fe and Zn, the cultivated plot maintains the highest value of the metal and controls the least. It is possible that in the study area, subsoil distribution of the four metals is more of a function of the underlying geological material than the influence of CEC and organic matter level. In general, however, it can be observed from the data contained in the table that the cultivated soils maintain higher concentrations of the various metals, followed by the grazed soils and least by the control in the area which suggests that cultivation and grazing practices have elevated the levels of the studied metals in the area.

DISCUSSION

It is interesting that all the metals depict similar trends across the considered plots, suggesting that the metals have relatively similar sources in soils of the area. In the cultivated soils, organic manure application is expected to be increasing the level of soil organic matters, which would increase the bioavailability of the metals considered. This will also promote the retention of the metals in the soils and prevent their loss through leaching, ionic displacement from soil exchange sites and erosion. Litter burning is also expected to promote higher releases of exchangeable bases to the soil from the burnt litter. Such releases could raise pH level of the soils[15,16]. This will consequently make the metals become more available in the soils. In the grazed plots no direct additions of organic manure are involved, but dropping of livestock wastes could result in some incorporations of manure into the soils[17], though at much lower rates than where direct manure applications are involved. On the control plots where neither manure applications nor litter burning are involved; it is therefore little surprising that they maintain the lowest levels of the metals considered.

Zn was found to be the most abundant of the heavy metals considered in the soils, followed by Fe, then Mn, and Cu is the least (Table 1). In separate studies, a number of research workers have observed some elevated levels of Zn above other trace metals in vegetation and soils of some locations around major highways[18-22]. This was explained to have been a result of Zn emission by motor vehicles, as Zn additives are often used in vehicles’ lubricating oils. Shika area lies along the Zaria-Sokoto highway, one of the busiest in northern Nigeria. It is therefore little surprising for Zn levels in soils of the area to be higher than those of some other metals. This Zn emitted from vehicle exhausts, is beside the additions through other human activities like organic manuring and litter burning in the area.

Data on spatial variability of the metals over the studied plots are also summarized in Table I as percentage coefficient of variation (CV%) values. A close look at the data reveals that the metals have more topsoil than subsoil CV% values, meaning that they are more variable, at the topsoil. This is expected since intensity of the human activities that are associated with the presence of the metals is higher at the topsoil. In general the metals exhibit high spatial variability over the studied soils, suggesting perhaps that anthropogenic factors, more than geological, have greater influences on availability of the considered metals in soils of the area.

CONCLUSION

It is apparent from the results obtained here that grazing and cultivation practices have in general caused some significant elevations in the bioavailable (i.e the plant available forms) levels of Zn, Fe, Mn, and Cu in soils of Shika area, Nigeria. Though no attempt was made in this study to evaluate the extent to which such metals have been accumulating in grasses and cultivated crops, it is nonetheless reasonable to assume that such metals have been finding their ways into the food chain processes of the area since they are in bio-available forms. Further researches are thus needed to examine whether such metals have been accumulating in intolerable amounts in grasses and cultivated crops in the area.

REFERENCES

1. Odero, D. R., Semu, E., and Kamau, G. N. (2000). Assessment of cottage industry derived heavy metal pollution of soils within Ngara and Gikomba areas of Nairobi city, Kenya. *African Journal of Science and Technology* **1**(2), 52-62.
2. Nriagu, J. O. (1992). Global metal pollution. *Environment* **32**, 7-11.
3. Korte, N. E., Skopp, J., Fuller, W. H., Niebla, E. E., and Alesh, B. A. (1976). Trace element movement in soils: Influence of soil physical and chemical properties. *Soil Science* **122**, 350-359.
4. Tisdale, S. L., Nelson, W. L., and Beaton, J. D. (1985). Soil Fertility and Fertilisers. Macmillan, New York.
5. Chude, V. O., Amapu, I. V., Ako, P. A. C., and Pam, S. G. (1993). Micronutrient research in Nigeria. *Samaru Journal of Agricultural Research* **10**, 117-138.
6. Forstner, U. and Wittman, G. T. W. (1976). Metal Pollution in the Aquatic Environment. Springer-Verlag, New York.
7. Adriano, D. C. (1986). Trace elements in the terrestrial environment. Spring-Verlag, New York.
8. Kitagashi, K. and Yamane, I. (1981). Heavy Metal Pollution in Soils of Japan. Japan Science Society, Tokyo. pp 302.
9. Zheng, Liv, Zhi, O. O., and Tang, L. H. (1983). Micronutrients in the main soils of China. *Soil Science* **135**, 40-46.
10. Jeng, A. S. and Bergseth, H. (1992). Chemical and mineralogical properties of Norwegian alum shale soils, with particular emphasis on heavy metal content and availability. *Acta Agriculturae Scandinavica, Section B, Soil and Plant Science* **42**, 89-93.
11. Singh, B. R. and Steinnes, E. (1994). Soil and Water Contamination by Heavy Metals. Lewis Publishers, Boca Raton. pp 233-271.
12. Mmbaga, T. M. (1997). Contents of Heavy Metals in Some Soils of the Marogoro Municipality, Tanzania, as a Result of Cottage-Scale Metal working Operations. Special Project Report. Department of Soil Science, Sokoine University of Agriculture, Marogoro, Tanzania. 47p.
13. Abubakar, S. M. (1997a). Monitoring land degradation in the semi arid tropics using an inferential approach: The Kabomo basin case study, Nigeria. *Land Degradation and Development* **8**, 311-323.
14. van Loon, J. C. (1985). Selected methods of trace metal analysis biological and environmental samples. In: P. J. Elving, Winefordner, J. D., Kolthoff, I. M. (eds): Chemical Analysis. New York, John Wiley. pp. 94-96.
15. Stromgaard, P. (1991). Soil nutrients accumulation under traditional agriculture in the *Miombo* woodland of Zambia. *Tropical Agriculture* (Trinidad) **68**(1), 74-80.
16. Araki, S. (1993). Effects on soil organic matter and soil fertility of *Chitemene* slash and burn practice used in northern Zambia. In: K. Mulongoy and R. Merckx (eds): Soil organic Matter Dynamics and Sustainability of

Tropical Agriculture. John Wiley, Chichester. pp 367-375.

17. Abubakar, S. M. (1997b). Impact of controlled grazing on soil condition in a part of Nigeria's semi arid region. *Danmasani Journal* **3**, 11-18.
18. Flanagan, J. T., Wade, K. J., Currie, A., and Curtis, D. J. (1980). The deposition of lead and zinc from traffic pollution on two roadside shrubs. *Environmental Pollution* **1**, 17-22.
19. Nyagababo, J. T. and Hamya, J. W. (1986). The deposition of lead, cadmium, zinc, and copper from motor traffic on Brachiaria eimini and soil along a major Bombo road in Kampala city. *International Journal of Environmental Studies* **27**, 115-119.
20. Fatoki, S. O. and Ayodele, E. T. (1991). Zinc and copper in tree barks as indicators of environmental pollution. *Environment International* **17**, 455-460.
21. Fatoki, O. S. (1996). Trace zinc and copper concentrations in roadside soils and vegetation-measurement of local atmospheric pollution in Alice, South Africa. *Environment International* **22**(6), 759-762.
22. Odukoya, O. O., Arowolo, T. A., and Bamgbose, O. (1999). Lead, zinc and copper levels in tree barks as indicators of atmospheric pollution. *Bioscience Research Communications* **11**(4), 299-306.

(*Received December* 26, 2003 *Accepted January* 19, 2004)