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TRACE METAL LEVELS IN SOILS AND VEGETATION FROM SOME TIN MINING AREAS IN NIGERIA.

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ABSTRACT

Samples of soil and vegetation from some tin mining areas of Nigeria were analysed for lead, zinc, copper and cadmium content. The levels of Pb and Zn were found to be high in some samples. The mean levels of metal in the vegetation were: 86.6± 36.0, 49.6± 28.3, 12.6±4.8 and 1.4±0.8 $\mu g g^{-1}$ dry weight for Pb, Zn, Cu and Cd respectively whilst those in the soil were 736±120, 690± 216, 43± 18 and 18±12 $\mu g g^{-1}$ dry weight for Pb, Zn, Cu and Cd respectively. The variability of metal levels in the area indicates that in addition to mining, other anthropogenic sources of metal contribute significantly to metal levels in the area. The EDTA – extractable metal fractions suggest that trace metals are being mobilised in the soil and made available to crops. The metal levels in the vegetation samples were higher than those recorded for areas of low atmospheric metal pollution in Nigeria with no identifiable sources. Although, there has been no cases of recorded metal toxicity in the area, there is the need to regulate and control mining wastes in order to prevent the effects of metal pollution in the area.

Key words: metals, environmental samples, mining areas.

INTRODUCTION

The contamination of soils and plants with trace metals through atmospheric deposition is well known (Ruhling et al, 1968; Lagerwerff et al, 1979; Nriagu, 1990 and Kakulu 1993). The release of trace metals, such as lead, zinc, cadmium copper, mercury, manganese and iron from mingin has been estimated to exceed the rate from natural cycling (Matttigod et al, 1983) by a factor of ten or more. About 55-80% of metal pollution in soils are accounted for by large quantities of various metal containing wastes that are discarded on land (Nriagu, 1990). For instance, agricultural and animal wastes, solid wastes from metal fabrication and discarded manufactured products account for large quantities of zinc, cadmium, copper and lead in soils. Owing to the toxic nature of trace metals, much attention has been focused on their ecological impact. The impact of mineral exploitation on the environment depends upon such factors as mining procedures, local hydrologic conditions as well as rock types. Trace metals leached from mining wastes and concentrated in water, soil or plants may be toxic to people or animals who drink the water, eat the plants or use the soil.

The effect of excessive concentration of metals in soils on man are well known. For instance, cadmium poisoning from rice grown in cadmium contaminated soil caused itai-itai disease in man (Hodges, 1973). It is also known that metals reduce the availability of nutrients to plants when present in high concentration in soils, as they affect biological processes in soil such as the rates of litter decomposition, soil respiration and nitrogen mineralisation as well as the activity of key soil enzymes (Tyler, et al, 1989). Toxic amounts of lead in soil have been attributed to be the cause of death of many plants, hence lead contaminated soils are often devoid of vegetation (Thornton, 1988).

It is known that most plants often suffer toxicities from B, Cu, Ni and Zn. On the other hand, Cd, Hg and Pb are known to have the greatest potential to affect human health (Logan et al, 1993).

Tin mining in Nigeria dates back to the beginning of the 20th century. As a result of this, mine wastes which often contain metals are leached, transported and deposited along the fluvial plains which are often used for agriculture. In view of the fact that mining is one major source of metal into the environment, as well as the fact that the operations employed in most cases rely on pollution prone technologies, the aim of this work is to determine the trace metal levels in the soils and vegetation in some tin mining areas of Nigeria. The study would also evaluate the potential health hazards of the trace metals on the population as well as give an insight into the contribution of the metals by anthropogenic agents.

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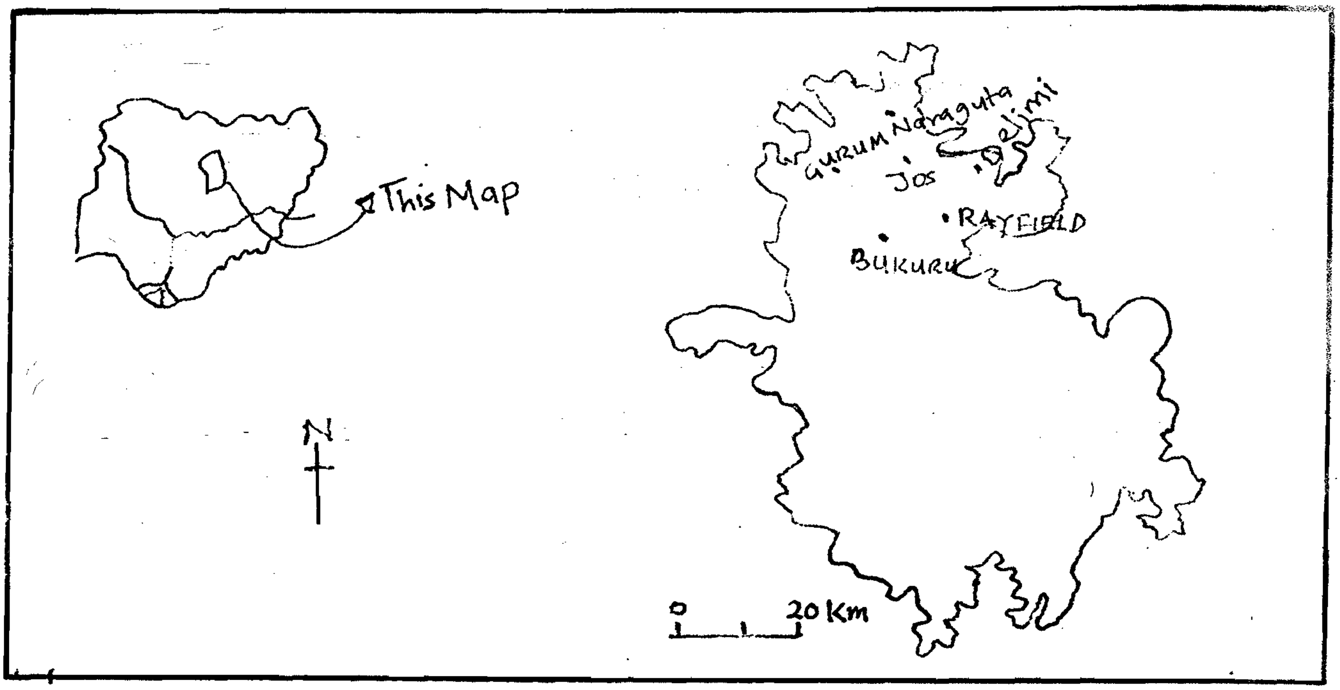

Fig. 1: Map of Jos Plateau showing some sampling sites

MATERIALS AND METHODS

The Study Area

Jos Plateau, the main tin mining area of Nigeria is situated between latitude 9° 15' – 10° N and longitude 8° 45' – 9° 25' E. Fig. 1 shows a map of the Jos Plateau with some of the sampling sites. Apart from mining the area is also noted for the grazing of cattle, sheep and goats as well as for the cultivation of food crops which are essentially the staple foods of the resident population.

Sample collection and preparation

Soil samples at an average depth of 10 cm from five areas (Jos, Gurum, Bukuru Ray Field and Delimi) were collected for analysis. Equally, collected for analysis were vegetation samples.

Both the soil and vegetation samples were collected from ten different locations in each area and these were categorised into areas in which mining is currently going on, uninhabited abandoned mine areas and inhabited abandoned mine areas. The vegetation used in the study were members of the Graminae family as they are commonly used as fodder for animals. The leaves were used in the analysis. The soil and vegetation samples were stored in polythene bags which had been previously cleaned with nitric acid (1:4) for 24 hours and rinsed with distilled water. The soil samples were air dried and later sieved to pass through a 2mm sieve. The fractions passing through the sieve were used for the analysis. The vegetation samples were oven dried at 50°C for 3 hours after which they were ground in a porcelain mortar and stored in polythene bags prior to analysis.

Analytical procedures

The nitric acid – perchloric acid (4:1) mixture was used in the digestion of the vegetation samples (Zasoski et al, 1987). The acid mixture (20 cm^3) was added to the vegetation sample (3g) in a 100 cm^3 beaker and left to digest over night. This was followed by refluxing on a hot place for six hours. The digests were quantitatively transferred into 100 cm^3 volumetric flask and diluted to volume with distilled water. The total metal in the soil samples were extracted by digesting with nitric acid-perchloric acid mixture (Schalscha et al, 1987). Each soil sample (1g) was refluxed with 50 cm^3 of the acid mixture on a hot plate. On cooling this was filtered into a 100 cm^3 volumetric flask and diluted to volume with distilled water.

The extractable metal in the soil was determined by shaking with 0.05M disodium ethylenediamine tetracetic acid (EDTA) (Leita, 1989). Each of the soil samples (10g) was extracted with 50 cm^3 of 0.05M EDTA by shaking at 25°C for two hours. The suspension was filtered and the clear solutions analysed for metal levels. The effect of reagents purity on metal levels was determined by preparing blank solutions and these were found to have no significant effect on metal levels.

Standard stock solutions of metal (1000 µg/1) were prepared from either the metal or a soluble salt of the metal (analytical reagent grade) manufactured by BDH, England and the working standards were prepared by the serial dilutions of the stock solution. A GBC 901 atomic absorption spectrophotometer was used in the determination of cadmium, copper, lead and zinc in the vegetation digests and soil extracts using the conditions stated in the operations manual.

The digestion procedure for the determination of metal in the vegetation samples was ascertained by the analysis of eight replicates followed by runs of recovery. The recovery study involved the spiking of six vegetation samples. The precision and average per cent recovery were cadmium 14.4%, 79.8± 9.3%, copper 6.0%, 9.5.4±5.0, lead 10.25%, 88.9±8.0% and zinc 4.7%, 96.7± 4.0% respectively.

RESULTS AND DISCUSSION

The trace metal content of the vegetation samples from the study area showed a great degree of variation. The summary of Cd, Cu, Pb and Zn levels in the vegetation samples is listed in Table 1. The lead levels varied from 56-240 μgg^{-1} dry weight. Generally, the Pb levels were high with those within Jos being the highest. These ranged from 75-240 μgg^{-1} dry weight compared to 56-100 μgg^{-1} dry weight for lead levels in vegetation samples in Gurum. The high levels could be due to mining and urbanisation since Jos is a state capital with a much higher population and traffic density compared to other sites. Generally, the zinc levels were lower than those of lead and the levels ranged from 25-91 μgg^{-1} dry weight with a mean of 49.6±28.3 μgg^{-1} dry weight. The copper and cadmium levels were low compared to the lead and zinc levels in most sites. Their levels varied from 5-21 μgg^{-1} dry weight and 0.8-4.0 μgg^{-1} dry weight for copper and cadmium respectively with mean values of 12.6±4.8 µg. copper g^{-1} dry weight and 1.4±0.8 µg cadmium g^{-1} dry weight. The correlation coefficients between metals in the vegetation samples were Cd-Cu 0.09, Zn-Cd 0.34, Cd-Pb 0.36. Cu-Zn 0.09, Cu-Pb 0.10 and Pb-Zn 0.98. Only the zinc levels correlated with the lead levels in the vegetation samples from all the sites and

Table 1: Trace metal levels in vegetation samples from some mining areas in Jos Plateau, Nigeria.

Area	Conc. in μgg^{-1} dry weight			
	Pb	Zn	Cu	Cd
Gurum	69±26[a] (56-100)	39±25 (25-76)	8±4 (6-15)	1.0±0.8 (0.8-1.5)
Bukuru	76±28 (68-106)	58±35 (31-84)	6±4 (5-15)	2.0±1.0 (1.5-3.2)
Rayfield	93±37 (60-186)	41±28 (33-66)	10±5 (5-18)	1.5±0.8 (1.0-2.1)
Delimi	88±21 (65-151)	51±30 (29-81)	8±6 (6-15)	1.0±0.7 (0.8-2.0)
Jos	106±36 (75-240)	56±21 (38-91)	12±8 (6-21)	2.5±0.9 (0.8-4.0)
Mean	86.6 ±36.0 (56-240)	49.6±28.3 (25-91)	12.6±4.8 (5-21)	1.40±0.8 (0.8-4.0)

a = standard deviation

Values in bracket = range.

Table 2: Mean Total Trace Metal Contents in Soils from some mining areas in Jos Plateau, Nigeria.

Area	Conc. in μgg^{-1} dry weight			
	Pb	Zn	Cu	Cd
Gurum	572±250[a] (168-710)	498±175 (280-650)	56±21 (18 - 76)	14±6 (10-21)
Bukuru	641±185 (460-775)	670±210 (315-907)	38±20 (19-56)	18±10 (8-23)
Rayfield	660± 250 (175-900)	598±316 (188-969)	58±28 (19-83)	18±12 (9-25)
Delimi	316±120 (95-430	401±170 (190-678)	31±16 (18-51)	13±10 (10-19)
Jos	811±105 (304-1803)	936±283 (380-1350)	27±19 (17-63)	23±11 (11-30)
Mean	736±120 (168-1803)	690±216 (188-1350)	43±18 (17-83)	18±12 (8-30)

a = standard deviation
Values in bracket = range

this could be attributed to the same sources of input into the area. The mean total trace metal contents in the soil samples from the study area are listed in Table 2. The metals cadmium, copper, lead and zinc were unevenly distributed in the area. The total lead content in the soils from the study area varied from 168-1803 μ/g dry weight with a mean of 736±120 μgg^{-1} weight. The total zinc levels were lower than those of Pb and these ranged from 188-1350 μgg^{-1} with a mean of 690±216 μgg^{-1} dry weight. Although the mean total Zn levels were lower than those of lead, some sites recorded higher Zn than Pb. For instance, a site within the Rayfield recorded a total Zn level of 969 μgg^{-1} dry weight whilst the corresponding total cadmium and copper levels in these soils were much lower than those of lead and zinc. The mean total Cd and Cu levels in the soils were 18±12 (8-30) μgg^{-1} dry weight and 43±18 (17-83) μgg^{-1} dry weight respectively.

The levels of EDTA-extractable metal in the soil samples are listed in Table 3. Usually, this is used to give an index of either weathering or availability of metals to plants (Lietal et al, 1980). Generally, the levels of these metals in the extractable fractions were lower than the total metal levels. The mean EDTA – extractable fractions varied accordingly: lead > zinc >> copper > cadmium. The mean extractable metal levels in the soils were 270±85 (98-718), 205±68 (65-793), 6±3 (2-12) and 5±3 (3- 13) μgg^{-1} dry weight for lead, zinc, copper and cadmium respectively. With the exception of total lead and the total zinc in the soil, no other two metals correlated with one another ($r=0.976$, $p<0.01$). The total metal levels correlated with EDTA extractable metal levels for each metal determined apart from Jos where there are evidences of atmospheric metal pollution (Kakulu 1993). The data on the EDTA – extractable metal levels in soils confirm that these metals can be available to plants for absorption by roots and translocated to foliage. Table 4 shows the variation of the Pb and Zn contents in the soil and vegetation samples from current mining area, uninhabited abandoned mined area and inhabited abandoned mined area. Areas which previously experienced mining and now inhabited recorded the highest levels of Pb and Zn whilst there was little or no significant difference between the levels found in abandoned mined areas and areas where mining is still taking place. For instance, Naraguta area of Jos which is an area that experienced mining but now inhabited, recorded 1803 and 1350 μgg^{-1} dry weight of Pb and Zn in the soil respectively compared to 180 and 210 μgg^{-1} dry weight for Pb and Zn respectively in the soils of an area of Delimi where mining is currently taking place. A similar trend was also found in the vegetation samples from the areas (Table 4). The high levels of metal in previously mined areas which are now inhabited could be due to urbanisation. It is possible that automobile exhaust emissions and discarded manufactured products which are known for inputs of trace metals into soils might have contributed significantly to levels of these metals (Nriagu, 1990). It is also known that the use of agricultural and animal wastes is a greater contributor of Zn into soils than lead (Nriagu et al, 1988) hence some sites recorded higher total zinc than Pb levels in the soils. The concentrations of the metals in the vegetation samples were generally below toxicity levels for cattle since a daily intake of 6-7 mg lead kg^{-1} of body weight had been found to be a minimum cumulative total dosage for cattle (Aronson 1973) and this represents lead concentrations in excess of 200 μgg^{-1} of ration for cattle. A comparison of the metal levels in the soils of the study area with the levels in world soils and crustal abundances shows that the metal levels in the soils of the study area are high. For instance, the mean metal contents in world soils and crustal abundances are: lead 10.0, 12.0; Zn 50.0, 70.0; Copper 20.0, 55.0 and cadmium 0.30 and 0.20 ppm respectively (Bini et al, 1988), compared to mean values of 736±120 (168-1803) μgg^{-1} dry weight for total lead, 690±216 (188-1350) μgg^{-1} dry weight for total zinc, 18±12 (8-30) dry weight for total cadmium and 43±18 (17-83) μgg^{-1} dry weight for total copper. The levels of lead and Zinc in the EDTA-extractable fractions in the soils of the study area were high (Table 3) compared to 0.05-138 and 0.05-62 μgg^{-1} dry weight for lead and zinc respectively in some Northern Ireland soils without a mining history and 40% of the extractable copper in the soils were less than 6 μgg^{-1} compared to about 91% and 75% for Finnish and Danish soils (Dickson et al, 1983)

Table 3: Mean EDTA-Extractable Metal Contents in Soils from Some mining areas in Jos Plateau, Nigeria.

	Conc. in μgg^{-1} dry weight			
Area	**Pb**	**Zn**	**Cu**	**Cd**
Gurum	257±115^{a} (130-676)	169±78 (760-450)	7±3 (2-13)	4±3 (3-6)
Bukuru	256±108 (118-598)	356±60 (100-611)	5±3 (4-7)	5±3 (4-7)
Rayfield	219±91 98-540)	238±141 (65-492)	7±2 (4-11)	5±2 (4-9)
Delimi	301±201 (175-510)	154±65 (70-300)	6±4 (3-11)	4±2 (3-7)
Jos	411±135 (185-718)	315±150 (120-793)	8±3 (3-10)	6±4 (3-12)
Mean	270±85 (98-718)	205±68 (65-798)	6±3 (2-13)	5±3 (3-12)

Values in bracket = range a = standard deviation

Table 4: Variation Pb and Zn Levels in soils and vegetation From different mining areas Conc. In µg/g dry weight.

Area	SOILS		VEGETATION	
	Pb	Zn	Pb	Zn
Current Mining area.	326±108[a] (95-653)	241±78 (188-535)	80±26 (56-110)	45±18 (25-63)
Uninhabited abandoned mined area	353±87 (105-734)	207±96 (190-507)	77±143 (58-103)	49±21 (29-68)
Inhabited abandoned mined area	774±216 (480-1803)	703±143 (406-1350)	134±31 (94-240)	60±16 (51-91)

a = mean
Values in bracket = range

respectively. These are soils which have been subjected to agricultural use.

The levels of metal in the vegetation of the study area were also higher than those recorded in areas of low atmospheric metal pollution in the North-Eastern Nigeria (Kakulu, 1993) and those from the South-West Nigeria (Onianwa et al, 1987) which like most of the sites in the study area are essentially in villages with no major sources of atmospheric metal input. The range of Pb and Cd levels in plant monitors used for assessing atmospheric metal pollution in low pollution zones are 3.7-36.5 and 0.05-0/71 µgg^{-1} dry weight for lead and cadmium respectively (Onianwa et al, 1987) compared to 56 – 240 and 0.8-4.0 µgg^{-1} dry weight for lead and cadmium respectively in the vegetation of the study area. It is known that Pb in food and animal feed comes from aerial deposition and Pb rich soil particles adhering to plants surfaces (Hodges, 1973). There is no correlation between plant soil metal levels in this study, for the simple soil plant relationship of plant element uptake is often modified by environmental factors such as pH, organic matter, cation exchange capacity, etc. Only a small proportion of elemental variability in plants can be achieved by element concentration in soils (Dudka, et al, 1999). As an agricultural zone, the use of phosphate fertilizers in the area would also have contributed to the levels of Cd in the soils of the area (Forstner et al, 1996).

CONCLUSION

In conclusion, mining in the Jos Plateau area of Nigeria has had a significant impact on the levels of metal in the soils and vegetation of the area. The fact that metal levels were higher in areas with a history of mining and now inhabited, suggest that other anthropogenic sources of metals, such as automobile exhaust emission, discarded manufactured products and the use of fertilisers, in addition to mining contribute to their levels in the area. This has been shown by the higher levels of metal in the vegetation of the area compared to low atmospheric pollution areas in Nigeria (Onianwa et al, 1987) which are mainly villages without any identifiable atmospheric metal source. From the data on the EDTA-extractable fractions, it can be suggested that trace metals are being mobilised in the soil and made available to crops. By this process, they may enter the food chain through the plant – herbivore system. They may also be leached through the soil layers to the point where they reach the ground waters. The fact that the total metal levels and the EDTA-extractable levels in the soils of the study area are higher than the levels in world soils show that human activity such as mining has had an impact on their levels in the area. Although, the present levels of some metals, for instance, lead, pose no toxicity problems, there is the need to regulate and control the wastes produced from mining activities in order to prevent the effects of metal pollution since the area is essentially an agricultural zone.

REFERENCES

Aronson, A.L.. 1978. Outbreaks of plumbism in animals. In: F.W. Ocheme (editor) Toxicity of Heavy Metals in the Environment, art I Marcel Dekker, Inc., New York, 470 pp.

Bini, C., Dall'Aglio, M.., Ferrett, O. and Gragnani, R., 1988 Background Levels of Microelements in Soils of Italy. Environ. eochem. And Health 10:63-69.

Dickkson, E.L. and Stevenson, R.J., 1983.Extractable Copper, Lead, Zinc and Cadmium in Northern Ireland Soils, J. Sci. Food Agric. 34: 1197-1205.

Dudka, S. and Millera, W.P., 1993. Accumulation of Potentially Toxic elements in plants and their transfer to human food Chain. environ. Sci. Health B34(4): 681-708.

Fornster, U. and Wittmann, G.T.W.. 1979. Metal Pollution in the Aquatic Environment. Springer-Verlag, Berlin, 486 pp.

Hodges, L., 1973. Environmental Pollution. Holt, Rinehart and Winston. New York. 396 pp.

Kakulu, S.E., 1993. Biological Monitoring of Atmospheric Trace Metal deposition in North Eastern Nigeria. Environ.Monit.Assess.28:137-143.

Lagerwerff, J.V. and Specht, A.V., 1970. Contamination of roadside Soil and vegetation with cadmium, nickel, lead and zinc. Environ. Sci. Technol. 4:583-586.

Leita, L.,De Nobili, M., Pardini, G., Ferrari, F and Sequi, P., 1989.Anomalous content of heavy metals in soils and vegetation of a mine area in S.W. Sardinia, Italy, Water, Air and Soil Pollut. 48: 428-433.

Logan, T.J. and Traina, S.J.. 1993. Trace metal in agricultural soils. In: H.E. Allen, E.M. Perdue and D.S. Brown (editors) Metals In Groundwater. Lewis Publishers, Boca Raton 410 pp.

Mattigod, S.V. and Page, A.L., 1983. Assessment of metal pollution in Soils. In: I. Thornton (editor) Applied Environmental Geochemistry. Academic Press. New York, 488 pp.

Nriagu, J. O. and Pacyna, J.M., 1988. Quantitative Assessment of Worldwide contamination of Air, Water and Soils with Trace Metals. Nature 333:134-139.

Nriagu, J.O.. 1990. Global Metal Pollution: Poisoning the biosphere. Environment 32:7-33.

Onianwa, P.C. and Ajayi, S.O., 1987. Heavy metal contents of epiphytic acrocarpus mosses within inhabited sites in South-West Nigeria. Environ. Int. 13:191-196.

Ruhling, A. and Tyler, G., 1968. An Ecological approach to the lead problem. Bot. Notiser 121:321-342.

Schalscha, E.B., Morales, M. and Pratt, P.F. 1987 Lead and Molybdenum in soils and forage near atmospheric source. Environ, Qual. 16:313-315.

Thornton, I., 1983.Geochemistry applied to Agriculture. In: I. Thornton (editor) Applied Environmental Geochemistry. Academic Press, New York. 488 pp.

Tyler, G., Pahsson, A.M.B., Bengtsson, G., Baath, E. and Trranvik, L., Heavy Metal ecology of terrestrial plants. Microorganisms and invertebrates. Water, Air and Soil Pollt. 47:189-213.

Zasoski, R.J. and Burean, R.G.. 1977. A rapid nitric acid perchloric Acid digestion method for multielement tissue Analysis Comm. Soil Sci. Plant Anal. 8:425-43.