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LEAD, COPPER AND ZINC LEVELS IN SOILS ALONG KADUNA-ZARIA HIGHWAY, NIGERIA

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Abstract

Soil samples collected along the left (l) and right (r) sides of a heavy traffic Kaduna-Zaria highway were analysed for lead, copper and zinc using energy dispersive X-ray spectrometry. Levels of lead, copper and zinc from sampled soils were found to be higher than the control samples collected 2 meters away from the highway. The mean concentration ranges of Pb (l), Pb (r), Cu (l), Cu (r), Zn (l) and Zn (r) in the samples are 23-121, 21-99, 40-156, 39-262, 30-118 and 30-162 ppm respectively. Statistical analysis showed positive correlation between the elements analysed, however correlation is only partially significant between lead and zinc. Lead and zinc levels may be attributed to pollution emanating from automobile emission and contamination while copper level could be due to pollution from fungicides and insecticides.

KEYWORDS: Copper, lead, zinc, Energy Dispersive X-Ray Spectrometry, soil pollution.

INTRODUCTION

A number of chemical species are introduced into the atmosphere, soil and vegetation through the emission and contamination from fuels used by motor vehicles. The emission from automobile exhausts includes chemical species like CO, Hydrocarbons, NO, SO_2 and particulate matters. Different sources, such as oil aerosols, soot, toxic combustion products, and oil derivative heavy metals, which result from ignition of oil were found to be causative agents of environmental pollution (Hahn, 1991; Readman *et al.*, 1992). Deposition of heavy metal pollutants as emissions, from gasoline and lubricating oils, along roadside soil and vegetation are known for copper (Nyangababo and Hamya 1986), lead and zinc (Alloway, 1993). Lead is known to be toxic to human even at very low levels (29 ppb) and higher blood levels are known to impair mental development (Kletz and Unstead-Joss 1990; Cornelis *et al* 1996). Although zinc and copper are both essential for plants and animals, but at high concentration, they are potentially toxic.

It has been observed that roadside air, vegetation and soil pollution are consequences of improved road accessibility and this posses serious health hazard, particularly to those residing along the road corridor (Alloway, 1993). In developing countries, like Nigeria, improved road accessibility creates a variety of ancillary employment (Adefolalu 1980; Mabojunje 1980) which range from vehicle repairs, such

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Table I: Mean$ Concentration ± SD (ppm) of Lead, Copper and Zinc in Soil Samples along Kaduna-Zaria Highway

	Distance (km)	Pb		Cu		Zn	
		Left	Right	Left	Right	Left	Right
	3	114 ± 34*	65 ± 20*	83 ± 30*	126 ± 44*	118 ± 37*	162 ± 50*
	6	48 ± 18	99 ± 29*	56 ± 20	63 ± 26*	37 ± 12	128 ± 40*
	9	58 ± 16*#	51 ± 11#	88 ± 43*#	120 ± 25#	75 ± 23*#	55 ± 18#
	12	30 ± 10#	22 ± 9	156 ± 28#	56 ± 22	65 ± 18#	40 ± 15
	15	55 ± 11*	32 ± 18#	67 ± 31*	79 ± 32#	75 ± 23*	62 ± 28#
	18	32 ± 10	28 ± 12	54 ± 10	53 ± 20	70 ± 24	64 ± 26
	21	45 ± 14	38 ± 13#	45 ± 19	262 ± 81#	30 ± 11	89 ± 31#
	24	28 ± 10#	29 ± 10#	126 ± 26#	75 ± 23#	43 ± 15#	77 ± 17#
	27	121 ± 15*	68 ± 13*	146 ± 32*	155 ± 31*	99 ± 23*	112 ± 22*
	30	56 ± 20*	46 ± 17	57 ± 20*	60 ± 21	59 ± 24*	36 ± 14
	33	41 ± 13	26 ± 9	40 ± 18	49 ± 21	63 ± 22	42 ± 16
	36	41 ± 13	36 ± 12	42 ± 18	39 ± 19	33 ± 12	35 ± 15
	39	33 ± 11#	95 ± 16*#	100 ± 36#	159 ± 36*#	32 ± 12#	64 ± 24*#
	42	41 ± 11#	30 ± 12	89 ± 26#	69 ± 24	41 ± 14#	37 ± 16
	45	42 ± 14#	31 ± 11	108 ± 39#	48 ± 19	95 ± 32#	32 ± 12
	48	27 ± 13	30 ± 11#	58 ± 20	83 ± 35#	31 ± 12	58 ± 24#
	51	33 ± 12#	35 ± 11#	77 ± 31#	84 ± 29#	51 ± 21#	129 ± 40#
	54	32 ± 11	31 ± 11	63 ± 28	51 ± 22	50 ± 20	40 ± 15
	57	23 ± 9	22 ± 9	55 ± 25	43 ± 20	30 ± 12	30 ±11
	60	46 ± 15#	29 ± 10#	80 ± 32#	80 ± 30#	112 ± 36#	38 ± 16#
	63	47 ± 15#	49 ± 16#	116 ± 40#	77 ± 32#	83 ± 28#	71 ± 26#
	66	38 ± 13#	41 ± 11#	115 ± 40#	176 ± 29#	90 ± 30#	73 ± 18#
	69	26 ± 9#	21 ± 8	71 ± 29#	56 ± 25	61 ± 23#	32 ± 16
Control A	9	32 ± 11		48 ± 22		35 ± 17	
Control B	21	25 ± 9		49 ± 20		35 ± 16	
Control C	27	25 ± 9		52 ± 20		35 ± 15	
Control D	42	28 ± 13		47 ± 20		37 ± 18	
Control E	54	27 ± 11		55 ± 20		39 ± 16	
Control F	63	22 ± 8		45 ± 20		30 ± 12	

* = Sites close to petrol filling station # = Sites close to farmland and/or settlement
All other sites are wasteland $ Mean of triplicate determination

as mechanics, vulcanizers and welders, to auto-electricians, battery chargers and dealers in other facilitators of motor transportation. Migration of settlements and agricultural activity (the most common occupation of rural dwellers) in response to new road development is very high.

This study attempts to investigate th level of contamination by lead, copper an zinc of soil along a major highway, Kaduna Zaria expressway in the northern part c

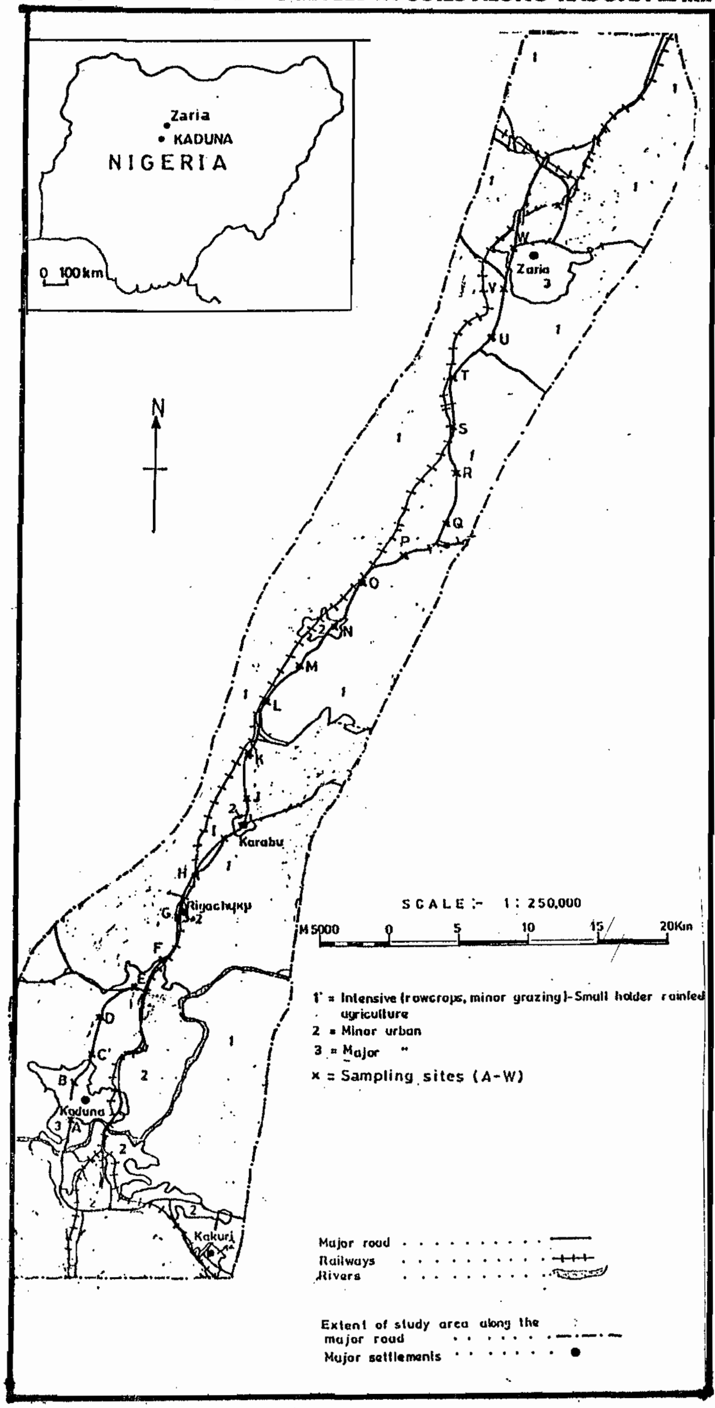

Figure 1: The Topography along Kaduna-Zaria Highway, Nigeria, Showing Soil Sample Collection Sites

Nigeria. This highway was chosen because since its dualisation in 1988-89, there has been a tremendous increase in human activity along the road. Secondly, it is a major access road to major towns and villages in the northern part of Nigeria and the traffic volume is very high.

MATERIAL AND METHODS

Sample collection and Preparation

Three composite spot samples were collected and pooled at forty-six sample sites along the 70 km Kaduna – Zaria Expressway, Nigeria, in March, 1999. The sampling sites are shown in Figure 1. The samples were collected using an Auger at three-kilometer intervals, on the left and right sides of the road, at a depth of about 10 cm and distance of 2 m from the road. Small-labelled polyethylene bags were used for the storage of the soil samples after collection. Six pooled control samples were collected 12 m from the roadsides at kilometers 9, 21, 30, 42, 54 and 63 sites (Control A, B, C, D, E and F respectively).

The samples were oven-dried at 110°C for three hours to obtain a constant weight. They were ground using an agate mortar and pestle; and then, the samples were sieved using a 300 mesh sieve, producing 0.05 mm size soil particle (Alloway, 1993, Kump, 1996).

Sample Analysis

The ground samples were each homogenized with 3 drops of organic liquid binder (polystyrene dissolved in toluene) and pellets prepared from about 0.3 g of each sample using a 19 mm diameter-die with a hydraulic press. The spectra of each sample were then measured using an Energy Dispersive X-Ray Fluorescence (EDXRF) system.

The EDXRF system is based on ^{109}Cd-isotope excitation and it consists of a 925 MBq ^{109}Cd annular isotopic source with a Canberra Si(Li) detector having a resolution of 170 eV at 5.9keV. The X-ray spectra were acquired with a computer based MCA card (Trump 8k). The set up provides for dead-time correction and pile-up rejection. Sensitivity calibration of the system was performed using thick pure metal foils and stable chemical compounds.

Measurement time for spectra collection was 50 minutes and the AXIL software package was used for spectra analysis (Van-Espen *et al* 1989, Bernasconi 1996). An absorption measurement method using a thick foil as target material for the evaluation of concentration of the elements (Kump 1996, Angeyo *et al.* 1998, Funtua 1999) was used. Triplicate measurements were carried out for each sample.

IAEA SOIL-7 certified reference material was used for quality control measurements; and the results obtained are for lead 62 ± 11 (62 ± 3); copper 12 ± 3 (12 ± 1) and Zinc 93 ± 22 (111 ± 5) ppm, with the certified IAEA values in bracket.

RESULTS AND DISCUSSION

The total mean concentrations of the heavy metals lead, copper and zinc obtained from the soil samples at the forty-six sites are presented in Table I.

The total mean concentration for the soil samples were found to be of the magnitude of Cu (86ppm) > Zn (64ppm) > Pb (44ppm). The concentration levels normally encountered in remote or recently settled areas soils are 10-30ppm for Pb, 20-30ppm for Cu and 20-50ppm for Zn (Alloway, 1993); however the levels of these metals in the control soil samples along the site under study are 22-32ppm for lead, 45-55ppm for copper and 35-39ppm for zinc. This is an indication of some level of pollution by these metals along the highway. For example, the control sample 'A' taken at kilometer 9 site had lead level of about 32 ± 11ppm; compared with 58±16ppm and 51±11ppm on the left and right sides of the highway respectively. A similar observation is true for copper and zinc at similar sites along the highway.

In general a fluctuating range in the mean concentrations of the metals was observed within the 46 sample sites, even for sites on adjacent sides of the highway (Table 1). A graphical (Figure 2) and statistical (Table 2) analysis show positive correlation between the metals, with significant correlations between Pb (l) and Zn (l) [correlation coefficient, r = 0.61]; Pb (r) and Zn (l) [r = 0.58]; Pb (l) and Pb (r) [r = 0.59]. The correlation of copper with the other elements, under investigation, is not strong. The correlation between lead and zinc levels [r = 0.57] along the highway, though not particularly high, may be an indication of some similar source for the elements. The sources of copper are probably different from

Table 2: Statistical Correlation Analysis of the Metals in the Soil Samples

	Pb (l)	Pb (r)	Cu (l)	Cu (r)	Zn (l)	Zn (r)
Pb (l)		0.458	0.247	0.343	0.609	0.589
Pb (r)			0.118	0.369	0.014	0.583
Cu (l)				0.160	0.414	0.123
Cu (r)					0.067	0.438
Zn (l)						0.220
Zn (r)						
Pb (l+r)				0.293*		0.574*
Cu (l+r)						0.430*
Zn (l+r)						

r = 0.45, p < 0.05, n = 23 or 45*

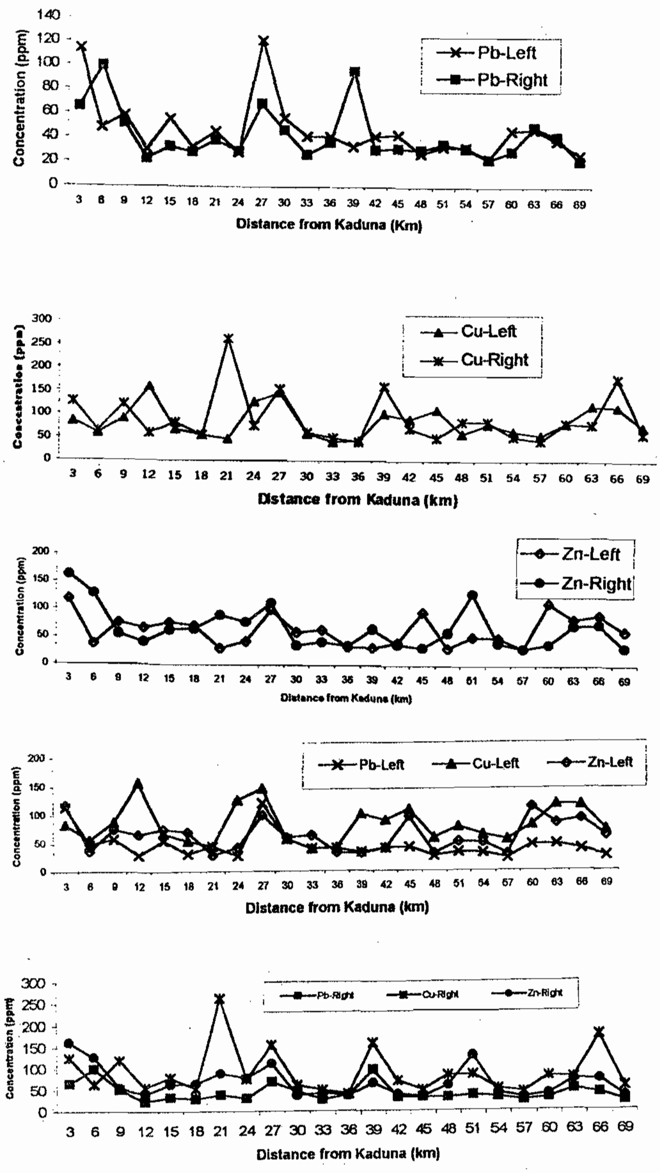

Figure 2: Variations of Lead, Copper and Zinc along the Left and Right Sides of the Kaduna-Zaria Highway

those of the other elements and varied; and may be from sources other than motor traffic e.g. through fertilizer and manure application.

All the samples with Pb levels > 55ppm were collected from sites where automobile-related human activities (petrol filling stations and/or motor mechanics, welders, battery chargers, etc) are prevalent. Sites at kilometers 3 (l & r), 6 (r), 9 (l), 15 (l), 27 (l & r), 30 (r) and 39 (r); were beside petrol filling stations.

Although increase in lead concentration in roadside soil is not particularly surprising as it had been reported that lead contents of soils increases steeply, as one approaches a highway with high volume of traffic (Alloway, 1993). However the levels obtained from this study are particularly high enough to be toxic to plants, including plant grazing animals and human food plants can take up lead from the soil.

The highest levels of copper (> 70ppm) are found in farmlands and/or settlements soil samples at sites [9 (l, r), 12 (l), 15 (r), 21 (r), 24 (l, r), 39 (l, r), 42 (l), 45 (l), 48 (r), 51 (l, r), 60 (l, r), 63 (l, r), 66 (l, r), and 69 (l)]. It is interesting to note that fungicides, insecticides, fertilizers and manures contain significant levels of copper (Alloway, 1993), which may have been extensively used on farmlands along this highway.

The pattern observed for zinc is similar to that observed for lead (r = 0.57), although high levels were also found on farmlands. This is not surprising as zinc is use in agrochemicals and as an additive in lubricating oils.

The levels of copper and zinc in soils are fairly critiçal for healthy plant growth, as both elements are known to activate certain enzyme systems in plants (Alloway, 1993). At high concentrations they can be harmful pollutants.

The concentration levels of lead and

zinc in the roadside soils can be attributed primarily to pollution originating from automobile-related emissions and contamination. The concentration level of copper maybe from varied sources of which pesticides contamination seems to be the principal source. With the correlation established between soil zinc and plant zinc (Fatoki and Ayodele, 1991; Fatoki 1996); and soil lead and plant lead (Alloway, 1993); and the fact that cultivated and grazing lands are located along this roadside, the possible uptake of these metals by crops and consequent adverse effects on the crops themselves and on livestock and human diet should be of concern.

CONCLUSION

Soil samples collected along a heavy traffic Kaduna-Zaria highway was found to contain lead, copper and zinc levels higher than the control soil samples collected some distance away from the highway, an indication of some level of pollution. The mean concentration of the metals in the soil are in the order of Cu (86ppm) > Zn (64ppm) > Pb (44ppm). Statistical analysis show some correlation between lead and zinc level, however the general trend is that of a fluctuating variation in the concentration of the metals analysed along the highway and on either sides of the road. Although, automobile-related activities and fertilizer application could be identified as sources of contamination, other sources cannot be entirely ruled out. The levels of the metals at some sites are high enough to be of concern to both plants and animals along the highway.

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