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Trace Metal Concentrations in Squirrel (*Sciurus vulgaris*) and Black Rat (*Rattus muridae*) Inhabiting Roadside Ecosystem

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Quite a number of studies in recent years have shown, on a worldwide basis, a considerable degree of contamination of roadside vegetation from lead, copper, cadmium, zinc and nickel in traffic exhaust, in tyre wear and motor oils (Flanagan *et al* 1980 Motto *et al* 1970; Ward *et al* 1974). The levels for lead, copper, cadmium, zinc and nickel fall off rapidly with distance from the roadside and with decreasing traffic frequency (Page *et al* 1971). Small mammals living in the bush and holes that receive emissions from the motor traffic may be exposed to high concentrations of these heavy metals. An estimated 22 - 58% of lead, for example, emitted in exhaust is deposited on the ground or vegetation on roadside (Little & Wiffer, 1978). The accumulation of these heavy metals is directly proportional to traffic density (Wheeler & Rolfe, 1979). Vertebrates that feed at subsurface may receive the greatest exposure to heavy metals within terrestrial ecosystems (Jafferies & French, 1972). For example squirrels and rats feed on vegetation leaves and tubers, incidently ingesting heavy metal bearing particulate. Squirrels (*Sciurus vulgaris*) and black rats (*Rattus Muridae*) are prey of some tribes and other big mammals. Both of these small mammals, living in terrestrial habitats that receive emissions from the motor traffic, may accumulate heavy metals to levels which may be hazardous to their predators. This study is specially designed to survey Pb, Cd, Cu, Zn and Ni concentrations in these animals living in these areas, especially the roadside verge habitant which receives the highest concentration.
The squirrels and rats are suitable for the study because they spend most of their time in such area burrowing in soil and consuming the vegetation and tubers. The study also compares metal concentration for two mammals collected from highway verges with those from minor roads and from forest areas situated a considerable distance from the nearest road. Twelve such sampling sites were investigated and 52 small mammals analysed.

MATERIALS AND METHODS

Squirrels and rats were snap-trapped in the vicinity of three major roads, two minor roads and the forest area in Kampala and Kabanyolo between January and June 2000. The associated soil (0-2cm) was also sampled from these sites and in each case three soil samples were taken. On return to the laboratory the mammals were killed, slaughtered and the skin removed. The livers were then removed together with gastrointestinal tracts. The rest of the bodies were finely sliced and a 10g sample set aside for analysis. During the analysis, the 10g samples were separately transferred to the teflon-lined uniseal bomb, and this was followed by fuming nitric acid (10ml), 48% hydrofluoric acid (5ml) and 72% perchloric acid (1ml). The vessel was closed by hand tightening the screw cap containing the Teflon sealing disk. The uniseal bomb, with its contents was placed in a drying oven at 140°C for 3 hours, and then let cool to ambient temperature. The decomposed sample solution, with the precipitated metal fluoride, was transferred to polystyrene beaker. Boric acid (2.8g) was then added, stirred to dissolve metal fluorides with the help of water addition. are The soil samples were treated following the same digestion procedure except that 1.50g of soil portions were taken.

The solutions were each transferred to a 50 ml volumetric flasks, volume adjusted to the mark and stored in polyethylene containers. Lead, copper, cadmium, zinc and nickel were determined by direct aspiration of the sample solution into an atomic absorption spectrometer, instrumental laboratory Perkin-Elmer model 2380, with detection limits and recoveries checked for all elements tested and found to fall within 0.01-0.1μgml^{-1} and 93 - 101% respectively.
The traffic frequency at each sampling site was determined from early morning hours (12.00 a.m) to evening time (8.00 p.m.) by using a counter. This enabled the number of vehicles per hour to be calculated. The period chosen was to cover the three traffic peak hours that are experienced in the study area per day. The relationship between traffic frequency and soil trace metal concentrations, rat and squirrel metal concentrations was determined using linear regression analysis (Clarke & Cooke, 1981).

RESULTS AND DISCUSSION

The analysis of twenty six squirrels and thirty black rats collected from proximity of major roads (A), minor roads (B) and forest centre (FC) was accomplished for five trace metals for the period July 1999 through June 2000. Also the associated soil samples were analysed for the same metals. The results which are indicated in Tables 1, 2 and 3 show that the concentrations of lead, cadmium, copper, zinc and nickel in soil samples (Table 1) are higher than those found in squirrels (Table 2) and rats (Table 3).
In the study, the design of the sampling network, Bombo road (A_1), Jinja road (A_2) and Masaka road (A_3) were specifically chosen to represent the major roads whereas Gayaza road (B_1), Ntinda road (B_2), and Hoima road (B_3) represented the minor roads. The forest (FC) represented the uncontaminated area. The most interesting and significant results evident from Tables 2 and 3, is that the results of squirrels and rats parallel the findings of the soil pollution survey in the case of lead, cadmium, copper, zinc and nickel; there being an obvious decline in concentration of both metals with decreasing traffic frequency. Trace metals were found at highest concentrations in both squirrels and rats collected from the major roads with highest traffic frequency. The

Table 1. Concentration of trace metals in Soils from roadside verge and forest center

Sample number	Traffic Frequency	Concentration($\mu g\ g^{-1}dw$) Ni	Zn	Cu	Cd	Pb
Major roads						
A_1	35000	47±4	203±18	48±08	2.78±02	148±5
A_2	21000	21±3	89±21	14±0.7	1.42±0.2	57±4
A_3	20000	18±3	60±17	10±0.6	1.05±0.2	34±4
Minor roads						
B_1	10000	18±3	43±17	7±0.8	0.93±02	40±5
B_2	8000	4±2	19±18	5±0.6	1.03±0.2	22±3
B_3	3000	6±2	20±18	3±0.5	0.69±0.2	15±3
Forest center	-	4±2	12±20	2±0.5	0.43±0.2	7±1

lowest concentrations of these metals were found in the squirrels and rats from forest centre (FC). The forest center, where trace metals are accumulated at levels ranging from 0.43 to 11.52 µg/g appears to be relatively clean.
Simple correlation coefficients of trace metal concentration and traffic frequency have been evaluated by least-squares regression analysis. The statistical evaluation has been applied to all the data obtained from the analysis of squirrels, rats and associated soil samples. In this statistical investigation, $n = 5$ and the number of freedom is $n - 2 = 3$. For this number of data used, correlation coefficients of about 0.88 and greater would indicate a statistically significant ($P > 0.05$) relationship (Clarker & Cooke 1981). Typical values from such analysis are represented in Table 4.
Similar statistical calculations were carried out for simple correlation coefficients of metal pairs and mean metal concentrations in *S. Vulgaris* versus

Table 2. Concentration of trace metals in *Sciurus vulgaris* from road side and forest center

Sample number	Traffic Frequency	Concentration ($\mu g\ g^{-1}$ dw) Ni	Zn	Cu	Cd	Pb
Major roads						
A_1	35000	5.8 ±0.5	108±5	45±5	4.7±0.3	67±4
A_2	21000	4.2 ±0.4	49±4	34±5	2.9±0.3	35±4
A_3	20000	3.7 ±0.5	30±4	23±4	1.6±0.3	17±2
Minor roads						
B_1	10000	1.5 ±0.2	18±5	11±4	1.2±0.2	21±2
B_2	8000	0.18±0.2	14±4	10±2	0.7±0.2	9±2
B_3	3000	1.1 ±0.3	11±4	8±2	0.4±0.2	8±2
Forest center	-	0.72±0.2	6±2	8±2	0.2±0.2	5±2

Table 3. Concentration of trace metals in *Rattus muridae* from road side and forest center

Sample number	Traffic Frequency	Ni	Zn	Cu	Cd	Pb
		Concentration (μg g^{-1} dw)				
Major roads						
A_1	35000	4.2±0.8	97±6	4±0.2	2.9±0.5	17±2
A_2	21040	5.9±0.8	64±6	5±0.2	1.6±0.5	10±2
A_3	20000	1.6±0.6	48±6	3±0.2	1.1±0.4	9±2
Minor roads						
B_1	10000	2.0±0.6	22±8	2±0.2	1.1±0.3	5±4
B_2	8000	1.8 ±0.6	12±6	1±0.2	0.9±0.3	3±4
B_3	3000	0.8 ±0.5	9±6	0.8±0.2	0.8±0.3	2±2
Forest center	-	0.6±0.52	4±6	0.5±0.2	0.5±0.3	2±3

traffic frequency and *R. Muridae* with traffic frequency. In general the correlation coefficients analysis showed that a number of interspecies relationship do exit for the *S. vulgaris*, Pb/Cu, Pb/Ni, Cd/Cu, Cd/Ni and Zn/Ni, the values are 0.94, 0.93, 0.,98, 0.97 and 0.93 respectively and for the *R. muridae,* the values are 0.83,, 0.93, 0.73, 0.65, and 0.75 respectively. There appears to be significant differences in these relationships for the data obtained for analysis of rats. It is worthy noting that in Table 4 all trace elements are highly correlated. It is thought that these strong relationships may be due to similarities in the particle size of these elements; similar source of emission of these elements and actual chemical association of these elements. The mammals definitely receive particles emitted by motor-traffic, and these particles are of course of the same physico-chemical composition. The same particles containing the trace metals have been found to be heavily deposited on leaves and twigs of vegetation close to the motor ways (Flanagan et al 1980),

Table 4 Simple correlation coefficients of metal pairs and mean metal concentrations in soil with traffic frequency[a]

	Pb	Cd	Cu	Zn	Ni
Pb	1.00				
Cd	0.99**	1.00			
Cu	0.98**	0.61	1.00		
Zn	0.99**	0.98**	0.99**	1.00	
Ni	0.97**	0.93*	0.96**	0.98**	1.00

[a]Significant correlation at the 95% confidence level is indicated by * and at the 99% confidence level by **

and these plants may obtain trace metals through both leaves and roots with little translocation within the plant (Motto et al 1970). Therefore the squirrels and rats, while feeding on leaves, twigs and roots, take in trace metals of the same origin and composition. On the other hand, the rats seems to have an extra source of the trace metals as indicated by low correlation coefficients for the elemental pairs Pb/Cu, Pb/Ni, Cd/Cu, Cd/Ni, and Zn/Ni. The extra source in rats must come from the non-vegetation component of their diet.

Based on the results obtained in this study, people who feed on the squirrels and rats collected within the vicinity of the roads are exposed to toxic levels of trace metals and are likely, over time, to show pathological symptoms. This study was unable to find any evidence of a general detrimental effect of road traffic pollution on the people who feed on these two mammals, however, specific effects like immunity suppression by trace metals (Nriagu 1988) on certain individuals groups, cannot be ruled out and this is worthy of further investigation.

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