Patterns of Lead Pollution in the Zambian Environment

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INTRODUCTION

Lead is a highly toxic metal which acts as a cumulative poison in humans (Schroeder and Balassa 1961; Passow *et al* 1961; Roe and Lancaster 1964). It affects the central nervous system and results in several pathological conditions including anaemia. This latter is related to the inhibition by lead of delta-aminolevulinic acid hydratase, an enzyme controlling a step in porphyrin biosynthesis. Measurement of this effect has been recommended as a sensitive test for the detection of lead poisoning (Weissberg *et al* 1971). Lead also has an effect on lactate dehydrogenase (Singerman 1970). With the present world-wide stress on the preservation of the natural environment and prevention of toxicity due to industrial effluents and urban pollution, attention has been given to the levels of lead and other toxic metals to which mankind is exposed. The results of such investigations have caused a great deal of unease, as is testified by a recent leading article in the *British Medical Bulletin* (1971). It has been shown that environmental pollution by lead is increasing and this has been attributed largely to the use of lead in anti-knock in petrol (Chow 1970; Bryce-Smith 1971). Children living in large cities have been found to be near to potential lead poisoning (Weissberg *et al* 1971) and it has been suggested that such accumulation of lead could be a factor in mental illness (Schroeder and Tipton 1968). However this has been denied by Mills (1970) and others (Guinee 1971; Scanlon 1971). Schroeder and Nason (1971) have suggested that cultivation of a high 'index of suspicion' by clinicians would result in the discovery of previously unsuspected lead poisoning in urban dwellers who feel tired and run down. These authors think that since upwards of 85% of ingested lead can be excreted as sweat (Consolazio *et al* 1964), the sense of well-being resulting from sauna baths or "exposure to the hot and low-lead environment of the tropics" is the result of loss of body lead through sweating.

In the light of these and other reports of a similar nature, it appeared worthwhile to examine the lead status of the Zambian environment. Three areas of a contrasting nature were chosen for the survey: (1) a rural area; (2) Lusaka urban area, and (3) the vicinity of Broken Hill Lead and Zinc Mine, Kabwe. The first represents the 'hot and low-lead environment of the tropics' (Schroeder and Nason 1971), far from mining residues and petrol fumes. The second, on the verge of a busy city street and a major road (Cairo Road and the Great East Road) is exposed to various forms of industrial and urban pollution. The third is a highly contaminated area containing mining residues and lies in the path of prevailing winds that carry mineralized dust and large quantities of metal-rich sulphurous fumes from the mine smelter. The area extends right into a residential area. The toxic nature of the soil and of the wind-blown dust is clearly demonstrated by the absence of all but a very restricted vegetation in most of the area and the recent discovery there of many dead cattle egrets.

MATERIALS AND METHODS

Soil samples were collected at a depth of about 10 cm, dried in air and sieved before being extracted with sodium acetate buffer at pH 4.5. This extract which contained 'available', but not total soil metals, was filtered and the filtrate analysed directly on a Techtron Model 1000 Atomic Absorption Spectrophotometer.

Plants analysed consisted of two common roadside herbs (*Tridax procumbens* and *Rhynchosia monophylla*), three common trees (*Piliostigma thonningii*, *Toona ciliata* and *Delonix regia*) and the shrubs *Lantana spp.* and Castor Oil or *Ricinus communis*.

Plant samples were washed carefully in water, dried in an oven at 35 °C and dry ashed at 530 °C for 8 hours. The ash was dissolved in 3N HCl and the solution centrifuged and suitably diluted for atomic absorption analysis.

Extractive-free material was prepared by refluxing dried plant tissue three times for three hours with boiling water followed by an ethanol: benzene mixture (1:2 by volume) for six hours at 70 °C. Acid extraction was performed by shaking the dried plant tissue with 10% acetic acid for one hour. The residue after each extraction was washed with water and acetone, dried and ashed before being analysed for metals as above.

RESULTS AND DISCUSSION

The acetate buffer-extractable lead contents of six samples of soil from each of the areas were (in ppm dry weight): Rural, 1.1±0.1; Urban, 14.5±3.4; Kabwe, 1487±530. It is clear that proximity to busy roads and still more to the mine results in higher soil lead relative to rural levels. Similar results have been obtained from more industrially developed and heavily populated regions of the world. MacLean (1969) reported that the concentration of lead in soils and plants increased with proximity to a highway in Canada. It would be interesting to monitor the actual concentration of lead in the air over Zambian roads to see if the high levels of lead in the urban areas can be attributed, as it has been elsewhere, to industrial and transport effluents that are held in suspension as particulate matter in the atmosphere (Chow 1970; Goodman and Roberts 1971).

The very high levels of lead in soils even at a distance of approximately 1 km from the Kabwe smelter gives

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only an indication of the actual total concentration of the metal in the soils of the area. Such pollution of surrounding land by smelter and mining residues is a well known and unfortunate side effect of the mining industry. The toxic properties of the air and soil at Kabwe (where, as has been mentioned, dead birds have been found) is paralleled elsewhere. Rains (1971) has recorded the poisoning of horses which had been fed on hay grown on land which had been exposed to lead smelter dust and fumes.

Other metals which might result from industrial and urban pollution were also analysed in the soil samples. For copper the distribution was 0.7, 0.8 and 45 ppm, and for zinc, 0.7, 1.3 and 7700 ppm for the rural, urban and Kabwe areas respectively. Again, high levels at Kabwe reflect the mineralized nature of the area and of the wind-borne dusts. It would not appear that copper or zinc are major causes of pollution in the Lusaka urban area. The same might not hold true for the Copperbelt.

Accumulation of lead by plant tissues is related to soil content as is shown by Table I. The very high levels in the Kabwe specimens may to some extent be due to superficial contamination by dust adhering to leaf surfaces and thus not represent true uptake through the roots. However, since in the case of the trees examined, the woody tissue from which all the external cortex had been removed still showed a relatively high lead content, it seems that at least some of the metal is taken up via the plant roots. Even were the lead entirely on the outer surfaces of the leaves, contamination at the levels found in Kabwe and even in Lusaka could still pose a major health hazard if the plants involved were vegetables for human consumption. We did examine one important food plant from the Kabwe mine township. This was maize which had 77 ppm lead in its leaf tissue (after careful washing) and 28 ppm of the metal in its grains. Meal made from such corn would contain a considerable level of lead.

The lead contaminating the leaves is not easily removed. Washing with cold water has very little effect.

Table 1: Distribution of lead in tissues of plants from different areas

Plant species	Tissue	Lead content (ppm)		
		Rural	Lusaka	Kabwe
Tridax procumbens	leaf	5.26 ± 1.98(8)	6.20 ± 2.18(6)	1020 ± 160(4)
Rhynchosia monophylla	leaf	3.70 ± 1.84(10)	14.14 ± 7.05(7)	312 ± 72(4)
Piliostigma thonningii	leaf	2.96 ± 1.15(5)	3.40 ± 1.00(4)	1427 ± 342(3)
Piliostigma thonningii	wood	1.74 ± 1.31(5)	2.10 ± 0.40(4)	120 ± 40(5)
Toona ciliata	leaf	6.68 ± 1.63(5)	10.20 ± 1.54(4)	401 ± 241(5)
Toona ciliata	wood	1.82 ± 1.44(5)	2.35 ± 1.05(4)	42 ± 16(4)
Delonix regia	leaf	8.80 ± 3.20(4)	23.46 ± 9.22(4)	800 ± 120(4)
elonix regia	wood	2.93 ± 1.13(4)	3.40 ± 2.90(5)	118 ± 18(4)
ntana spp.				
camara or .. trifolia)	leaf	2.43 ± 0.77	8.40 ± 5.60(5)	1342 ± 254(4)

ults are expressed as ppm (mg/kg, dry weight) ± standard deviation; number of specimens analysed is given in parentheses in each case

Table 2: Extraction of lead from leaf tissue of different plants

Plant species	Source	Lead content (ppm)		
		Original	Water and solvent extracted residue	Acetic acid extracted residue
Rhynchosia monophylla	Lusaka	15.5	15.0	7.5
Rhynchosia monophylla	Kabwe	276	242	200
Toona ciliata	Lusaka	5.8	5.7	4.5
Toona ciliata	Kabwe	1072	712	720
Tridax procumbens	Kabwe	1280	204	—
Ricinus communis	Kabwe	480	256	—

Table 3: Zinc and copper content of soils and leaves from different areas

Plant species	Metal content (ppm)					
	Rural		Lusaka		Kabwe	
	Zn	Cu	Zn	Cu	Zn	Cu
Tridax procumbens	2140	25.2	1800	20.8	1440	37.6
Rhynchosia monophylla	940	22.0	840	18.4	880	20.0
Delonix regia	16.0	10.4	40	12.4	48.8	12.4
Soil:	0.7	0.7	1.3	0.8	7700	45

Moreover, as is shown in Table 2, even prolonged extraction with hot water and organic solvents or shaking with dilute acid, did not remove a great deal. It is probable that the metal is chemically bound to organic groups, possibly on the external surface of the leaf tissue. Thus washing of vegetables grown under similar conditions, or straining them free of water in which they had been boiled, would have little effect in making them less toxic to humans. Rains (1971) found that in the case of lead-contaminated wild oats, water removed very little, dilute HCl about half and 0.01 M EDTA upwards of 90% of the metal. It is unlikely that the vegetable growers of Kabwe will use a chelating agent such as EDTA to decontaminate their vegetables.

It is of interest that while soil zinc and copper are also high in the vicinity of the mine, these high concentrations are not reflected in the levels of metal found in plant leaves (Table 3). The results suggest that surface contamination of leaves is not important in the case of zinc and copper since the concentration of the metals varies little between the plants of one species collected at the different sites. This is particularly striking when it is noted that soil zinc at Kabwe is approximately 10,000 times the rural and 6,000 times the Lusaka levels. Moreover, total uptake of zinc by the plants apparently depends rather on the particular species than on the soil level. This has been noted in a previous paper (Reilly *et al* 1970) and it is significant in the light of claims made by Stocks and Davies (1960 and 1964) that copper and zinc levels in soils of vegetable gardens (and consequently, it is presumed, in the vegetables themselves) are related to the incidence of cancer of the stomach of residents of certain areas in Wales. However, the possibility of toxicity due to the inhalation of zinc fumes rather than by oral ingestion of zinc-contaminated vegetables, remains a real danger for people living in proximity to zinc smelters (Clinton and Drinker 1948).

In spite of the high soil copper at Kabwe the results do not show evidence of high levels of accumulation by plants. This ability of certain plants to avoid excessive uptake of copper from metal-rich soils has been reported elsewhere previously. Moreover, what is accumulated by such plants is normally bound in insoluble and non-digestible form within the plant tissue, as has been shown in the case of the Zambian 'Copper Flower', *Becium homblei* (Reilly and Stone 1971). Such copper-containing plants are usually non-toxic to animals (Mills 1954).

Zambia's main towns and cities are relatively small in size and are mainly confined to the line-of-rail. Thus, in spite of the evidence of some urban lead pollution, possibly due to petrol fumes, the country is far from the danger levels of atmospheric and other forms of pollution met in the vast conurbations of the United States of America, Great Britain and other highly industrialised and heavily populated countries. We do, however, have an area of extreme pollution in the Kabwe area. While no clinical evidence of lead poisoning is presented here, cases do undoubtedly occur. It is a revealing indication of the attitudes of former administrators to find that workers' homes and a school lie within the polluted area, in the path of the prevailing wind. Motorists who travel along the Great North Road are familiar with the sulphurous and noxious fumes carried by the wind from the mine area. It is not hard to imagine what permanent residence there must be like. It is to be hoped that an overspill from international opinion on environmental pollution and health hazards will hasten the transfer of these residents to a more salubrious site.

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