Cadmium, Lead, and Zinc Distributions Between Earthworms and Soils: Potentials for Biological Accumulation

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Earthworms are one of the most important organisms responsible for mechanical mixing of the soil and play a major role in maintaining physical soil characteristics and processes such as aeration, water permeability, and mineral turnover (SATCHELL 1967). Earthworms are key components of in natural food chains providing a food source for many small mammals and birds. Earthworms have been demonstrated to exert a significant effect on redistribution of cadmium, carbon, and cesium in soils (VAN HOOK et al. 1973, REICHLE et al. 1973). Due to this redistribution effect and the earthworm's ubiquitous occurrence in nature, these invertebrates may exert a significant influence on the distribution of trace elements in soils and in food chains by altering concentrations in tissues through bioaccumulation. In the present study, the differential accumulation by earthworms of Cd, Pb, and Zn from six soil series in east Tennessee was determined. These three trace elements were chosen because of their current importance in environmental contamination (FULKERSON et al. 1973, NRC-NAS 1971) and because of their high levels observed in earthworms (GISH et al. 1973). In addition, zinc is recognized as an essential element in plant and animal metabolism.

The six soil series included Bodine, Captina, Claiborne, Emory, Linside, and Tarklin (SWANN et al. 1942). Major earthworm genera included in our collections were Alabophera, Lumbricus, and Octolasium. Samples consisting of three replicates of 100 cm^2, taken 10 m apart, of soils and earthworms contained therein, were collected from the USAEC Reservation in east Tennessee from areas undisturbed for the past 30 years. Soil samples consisted of the top 10 cm with vegetation removed. These samples were mixed thoroughly and ashed for 24 hr at 450 C. Earthworms removed from these soils were placed in petri dishes on moist filter paper for 4 days to void their gut of soil. Earthworm genera from each sample were pooled and freeze-dried prior to ashing at 450 C for 24 hr. Ashed samples of soil and earthworms were boiled under reflux for 12 hr in nanograde aqua regia with known quantities of specific isotopes of Cd, Pb, and Zn. Electrodes were then prepared from the resulting material and determinations were made for total Cd, Pb, and Zn by isotope dilution spark source mass spectrometry. The estimated accuracy of the determinations was ±5% of the values reported.

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Mean cadmium levels in the soils and earthworms (Table 1) were 0.35 and 5.7 ppm (µg/g dry weight), respectively, giving an average concentration factor of 17. This factor, defined as the ratio of the ppm element in the earthworm tissue to that

TABLE 1

Soil and earthworm concentrations of cadmium, lead, and zinc (ppm dry weight) and concentration factors determined for east Tennessee soils.

	ppm (µg/g) ELEMENT*		
	SOIL	EARTHWORMS	CF**
Cd			
BODINE	0.32	7.2	22.5
CAPTINA	0.20	3.1	15.5
CLAIBORNE	0.28	6.1	21.8
EMORY	0.80	9.3	11.6
LINSIDE	0.28	5.1	18.2
TARKLIN	0.23	3.4	14.8
Pb			
BODINE	26	4.6	0.18
CAPTINA	15	4.5	0.30
CLAIBORNE	24	5.4	0.23
EMORY	50	5.5	0.11
LINSIDE	18	4	0.22
TARKLIN	27	4	0.15
Zn			
BODINE	37	498	13
CAPTINA	30	93	3
CLAIBORNE	40	502	13
EMORY	57	253	4
LINSIDE	41	375	9
TARKLIN	50	178	4

*Elemental concentrations determined by isotope dilution spark source mass spectrometry; estimated accuracy = 5% of the values shown.

**CF = Concentration Factor = ratio of ppm element in earthworms to ppm element in the top 10 cm of soil.

in the top 10 cm of soil, ranged from 11.6 in Emory to 22.5 in Bodine. Mean lead concentrations in soils and earthworms were 27 and 4.7 ppm, respectively. The mean earthworm concentration factor for lead was 0.2, ranging from 0.1 in Emory to 0.3 in Captina. The mean soil zinc concentration was 43 ppm, while earthworms exhibited a mean value of 317 ppm. The average concentration factor for zinc was 8 with a range of 4 to 13 in these soils.

The data obtained in this study clearly indicate a biological accumulation of cadmium and zinc in earthworms relative to native soil concentrations. The Zn:Cd ratio decreased from 139 in soils to 56 in the earthworms illustrating the higher relative accumulation of cadmium by earthworms. Lead was not biologically accumulated by these earthworm species; only 20% of the lead concentration in the soil was observed in earthworms. It is not presently known what values these concentration factors would assume in contaminated soil where the chemical form of the trace element may be different from the present case. Based on the results of this study, it appears that earthworms could serve as useful biological indicators of increased cadmium, lead, and zinc contamination of soils because of the fairly consistent relationships between these element concentrations in earthworms and soils, and because of the biomagnification observed in earthworms of cadmium and zinc. The high concentration factors observed for cadmium and zinc point out the need for information on the food chain transfer of these elements from the soil through earthworms to bird or small mammal consumers.

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