Bull. Environ. Contam. Toxicol. (1991) 47:845–849

Bulletin of Environmental Contamination and Toxicology

Dietary Heavy Metal Uptake by the Least Shrew, *Cryptotis parva*

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Heavy metals from sewage sludge have been reported to concentrate in producers (Bingham et al. 1975; Cunningham et al. 1975; Dowdy and Larson 1975; Hinsely et al. 1976; Stuckey and Newman 1977), in primary consumers (Anderson et al. 1982; Chaney et al 1978; Furr et al. 1976; Levine et al. 1989; Williams et al. 1978), and in detritivores (Kruse and Barrett 1985; Levine et al. 1989). Little research, however, has focused on the uptake of heavy metals from sewage sludge by secondary consumers. The Family Soricidae represents an ideal mammalian taxonomic group to investigate rates of heavy metal transfer between primary and secondary consumers.

The least shrew (*Cryptotis parva*) was used to evaluate the accumulation of heavy metals while maintained on a diet of earthworms collected from long-term sludge-treated old-field communities. This secondary consumer is distributed widely throughout the eastern United States (Whitaker 1974), and its natural diet includes earthworms which makes it a potentially good indicator of heavy metal transfer in areas treated with municipal sludge.

MATERIALS AND METHODS

This study was conducted at the Miami University Ecology Research Center located near Oxford, Ohio. Three 0.1-ha plots were treated monthly (May-September) for 11 consecutive years (1978-1988) with Milorganite, an aerobically digested, heat-dried municipal sludge, at a rate of 1792 kg $ha^{-1}mo^{-1}$ or 8960 kg $ha^{-1}yr^{-1}$ (Levine et al. 1989). Earthworms (*Lumbricus rubellus*) were collected from these plots August-November, 1989. Earthworms collected from untreated soil were used as a control group. Earthworms were rinsed free of soil particles, placed on moist filter paper in petri dishes, and maintained at 15 °C for 24 h to eliminate soil and organic matter from their alimentary tracts. They were then oven-dried at 80 °C for 48 h, pulverized, and mixed in a 1:1 ratio (dry wt) with commercial catfood (the catfood was 74.7% water; an equivalent amount of water was mixed with the worms fed to the shrews).

All shrews were 5-6 months of age and were fed a daily diet of meal worms at 0800 hr and moist catfood at 1800 hr prior to the feeding study. Each experimental group consisted of six adult least shrews (three males and three females) housed as described by Mock (1982). Each shrew was offered 10 g of either the diet

Send reprint requests to Dr. G.W. Barrett at the above address containing earthworms collected from sludge-treated plots (hereafter termed contaminated-earthworm diet) or the diet containing earthworms collected from untreated plots (hereafter termed control-earthworm diet) daily for 14 days from 2-16 March 1990. Uneaten food portions were collected daily, oven-dried at 80 °C for 48 h, and weighed to determine the mean daily ingestion rate. Animals were sacrificed at the end of the feeding study by carbon dioxide asphyxiation, weighed to the nearest 0.01 g, and the liver, kidneys, and digestive tract of each individual removed. Organs from each shrew were kept frozen until ready for heavy metal analysis.

Organ samples were digested in 10 ml HNO_3 at 120 °C until dry. Tissue residue was then redigested in 5 ml HNO_3 at the same temperature until dry, and the remaining sample diluted with 0.5 ml HNO_3 and 9.5 ml double distilled water. Samples of catfood and the earthworm/catfood mixtures were digested as described above and diluted with 2 ml HNO_3 and 18 ml distilled water, respectively. Cadmium, copper, and lead concentrations of the shrew organs were determined by furnace atomic absorption spectroscopy using a Varian SpectrAA-20 spectrophotometer. Zinc concentrations of the organs and cadmium, copper, lead, and zinc concentrations of the catfood and earthworm/catfood mixtures were measured by flame atomic absorption spectroscopy (IL 157). Mean heavy metal concentrations (Cd, Cu, Pb, Zn) of the shrew organs were analyzed using one-way ANOVA. Mean metal concentrations of the catfood, contaminated-earthworm diet, and control-earthworm diet were also analyzed using ANOVA; significant differences (P <0.05) were compared using the Scheffe F-test. Differences in daily food intake and body mass loss between treatments were compared using Student's t-tests.

RESULTS AND DISCUSSION

Significantly greater (P<0.05) amounts of Cd, Cu, and Pb were found in the contaminated-earthworm diet than in the control-earthworm diet (Table 1). Significant differences (P<0.05) were found for Cd, Cu, Pb, and Zn in the liver and for Cd in the digestive tract of the shrews fed the contaminated-earthworm diet (Table 2). Both experimental groups ingested comparable amounts of food; the control group ingested 2.48 g $\pm$ 0.29 SD dry weight and the contaminated group ingested 2.48 g $\pm$ 0.82 SD dry weight (Student's t-test; P >0.05). However, the animals fed the contaminated-earthworm diet showed a significant decrease (P<0.05) in mean body mass (1.41 g $\pm$ 0.19 SD) and percentage of mean body mass lost (27.6%) during the experimental period compared to the control group, whose values were 0.32 g $\pm$ 0.02 SD and 6.6%, respectively.

The fact that Cd, Cu, Pb, and Zn accumulated in significantly higher levels in the livers of the shrews fed earthworms collected from sludge-treated old-field plots after only two weeks of dietary exposure indicates a potential health hazard to higher trophic level organisms. Also, this concentration potential is especially acute since the earthworms in these long-term sludge-treated plots have been shown to concentrate Cd and Zn by 30x and 6x, respectively (Levine et al. 1989). The significant weight loss in shrews fed the contaminated-earthworm diet may be a symptom of metal toxicity. Ma (1989) reported significantly lower weights of wood mice (*Apodemus sylvaticus*) inhabiting an area contaminated with Pb than those inhabiting a control site. Goyer et al. (1970) reported that decreased body weight is a symptom of Pb toxicity because Pb interferes with normal metabolic processes.

Table 1. Mean metal concentrations (ug.g dry weight^{-1} $\pm$ SE) in catfood and earthworm/catfood mixtures. Sample size indicated in parentheses.†

Metal	Catfood (n=5)	Control diet (n=14)	Contaminated diet (n=12)
Cd	0.12 $\pm$ 0.09 a	8.22 $\pm$ 0.65 b	28.87 $\pm$ 1.29 c
Cu	5.65 $\pm$ 0.24 a	7.59 $\pm$ 0.42 b	10.13 $\pm$ 0.39 c
Pb	3.01 $\pm$ 0.16 a	6.15 $\pm$ 0.52 a	10.56 $\pm$ 0.97 b
Zn	52.34 $\pm$ 0.48 a	131.18 $\pm$ 11.43 ab	183.26 $\pm$ 25.42 bc

† Means within each row followed by different letters are significantly different (P<0.05; Scheffe F-test).

Table 2. Mean metal concentrations (ug.g dry weight^{-1} $\pm$ SE) in shrew organs from the contaminated and control groups.†

Tissue	Control	Contaminated
	Cd	
liver	0.18 $\pm$ 0.02 a	0.44 $\pm$ 0.12 b
kidneys	0.32 $\pm$ 0.06 a	0.39 $\pm$ 0.08 a
digestive tract	0.35 $\pm$ 0.06 a	1.09 $\pm$ 0.26 b
	Cu	
liver	3.59 $\pm$ 0.18 a	5.22 $\pm$ 0.47 b
kidneys	5.40 $\pm$ 0.78 a	5.97 $\pm$ 0.61 a
digestive tract	2.49 $\pm$ 0.09 a	2.65 $\pm$ 0.11 a
	Pb	
liver	0.21 $\pm$ 0.01 a	0.34 $\pm$ 0.02 b
kidneys	0.54 $\pm$ 0.06 a	0.62 $\pm$ 0.07 a
digestive tract	0.31 $\pm$ 0.02 a	0.33 $\pm$ 0.02 a
	Zn	
liver	15.65 $\pm$ 1.47 a	25.31 $\pm$ 3.05 b
kidneys	17.09 $\pm$ 2.96 a	20.44 $\pm$ 2.24 a
digestive tract	31.93 $\pm$ 2.72 a	33.04 $\pm$ 1.50 a

†n=6 samples per treatment, except sludge livers n=5. Means within each organ followed by a different letter are significantly different (P<0.05; ANOVA).

Shrews have been previously suggested as indicators of metal contamination because they concentrate higher levels of metals than herbivorous small mammals (Andrews et al. 1984; Goldsmith and Scanlon 1977; Hegstrom and West 1989; Hunter and Johnson 1982; Roberts and Johnson 1978). Shrews have also been shown to accumulate significant levels of heavy metals from contaminated ecosystems. Andrews et al. (1984), for example, reported significantly higher Cd levels in a wild population of shrews (*Sorex araneus*) collected from a reclaimed mine site as compared to those individuals collected at an uncontaminated control site. Hegstrom and West (1989) also reported significantly higher levels of Cd, Cu, Pb, and Zn in a wild population of Trowbridge's shrews (*Sorex trowbridgii*) inhabiting an area treated with sewage sludge compared to those inhabiting untreated areas. Hunter and Johnson (1982) suggested that shrews accumulate higher levels of metals in contaminated habitats because their diet contains detritivores (e.g., earthworms) and ground-living invertebrates. Our feeding study helps to explain these reported differences in heavy metal content of shrews inhabiting sludge-treated and untreated ecosystems.

Acknowledgments. We thank Mary Truax for her assistance in the atomic absorption spectrophotometry. We also thank Dr. Orin B. Mock, Kirksville College of Osteopathic Medicine, for the donation of the test animals and for his helpful advice. This research was partially funded by a Miami University Undergraduate Research Grant awarded to C. C. Brueske and by EPA Grant R-815033-01-1 awarded to G.W. Barrett and D.H. Taylor.

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Received June 4, 1991; accepted August 7, 1991.