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Cadmium Contamination of Deer Livers in Connecticut

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Cadmium (Cd) is recognized as a hazardous environmental pollutant due to its acute toxicity to many organisms (Ruparelia *et al.* 1990). It is a naturally occurring element found in trace quantities throughout the environment (crustal abundance 0.16 mg/kg, Emsley 1989). Its use in industrial processes such as electroplating, pigment and plastics production, and battery manufacturing has increased 400 fold between 1907 and 1976 (Stansley *et al.* 1991). Releases of Cd into the environment occur from natural sources, industrial wastes, and from other practices such as coal and fossil fuel combustion, and the land application of sewage sludge and phosphate fertilizer (Robards and Worsfold 1991).

Animals exposed to Cd accumulate it in their livers and kidneys (Spierenburg *et al.* 1988). In humans, chronic exposure to Cd can result in anemia, anosmia (absence of the sense of smell), cardiovascular disease, and renal glomerular and tubular damage (Robards and Worsfold 1991). Elevated concentrations of Cd in deer livers have prompted several states to issue health advisories regarding their consumption (Stansley *et al.* 1991). Health concerns prompted the Connecticut Department of Environmental Protection to initiate a survey of Cd concentrations in Connecticut deer.

This paper presents our findings on the liver Cd concentrations in deer from Connecticut. In some cases, kidney and muscle tissues were also analyzed.

MATERIALS AND METHODS

Liver samples were collected from 59 hunter-killed deer in Connecticut (both state and private property), between 1990 and 1992, from the regions depicted in Figure 1. Upon collection, the age (Severinghaus 1949), sex, and location of the deer were recorded. The samples were placed in plastic bags and frozen. Prior to analysis, the samples were thawed slightly, rinsed with distilled deionized water (DDW), and the surface tissue was removed using a stainless steel scalpel. The interior portion of the tissue sample (10-20 grams) was again rinsed with DDW, cut into small cubes and refrozen until analyzed.

The MDS-81D microwave digestion system (CEM, Matthews, NC) was used to prepare samples for spectrophotometric analysis. Tissue samples (1.5 to

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2.5 grams, wet weight) were weighed to ± 0.1 mg into microwave digestion vessels to which 5 ml of concentrated nitric acid was added. The samples were digested for 5 minutes at 70% power, allowed to cool, brought up to 100 ml with DDW in a volumetric flask, and transferred to 120-ml polyethylene sample containers until analyzed. The Cd content was determined using a PE 5100PC graphite furnace atomic absorption spectrometer with Zeeman background correction (Perkin Elmer, Norwalk, CT). Duplicates of each tissue sample were run along with digestion blanks, spiked samples, and a reference material (NIST #1577A, Bovine Liver). There were two replicate measurements for each liquid sample. The values for the Cd concentrations in the deer tissues are expressed on a dry weight basis, calculated using an average moisture content of 69.5%.

Analysis of variance (Anderson 1987) was used for statistical analysis of the data.

RESULTS AND DISCUSSION

The average recovery for spiked samples was 95 ± 7%. The concentration of Cd in the reference material was found to be 0.32 ± 0.03 mg/kg, compared to the reference value 0.44 ± 0.06 mg/kg. Cadmium in the procedure blanks was below the solution detection limit of 0.0001 mg/kg. For quality control, the EPA solution check standard (AA-1) was run after every five determinations. The check standards averaged 0.0023 ± 0.0003 mg/kg, compared to the reference value of 0.00245 mg/kg. The mean relative standard deviation (RSD) between replicates was 4%.

The concentrations of Cd found in deer livers from four regions in Connecticut are given in Table 1. The Cd concentration in the 59 deer livers ranged from <0.002 to 9.1 mg/kg, with a mean of 1.71 ± 2.2 mg/kg. The wide range reflects the variation in location and age of deer, as noted by others (Woolf *et al.* 1982; Munshower and Neuman 1979; Stansley *et al.* 1991). The mean Cd content in liver for deer two years and older was about three times higher in deer from the northern regions (3.7 ± 3.2 mg/kg) as compared to the southern regions (1.2 ± 1.2 mg/kg). This difference was statistically significant ($p < 0.001$). In addition, 6 of the 59 deer livers analyzed exceeded the proposed action threshold of 4.8 mg/kg Cd (Stansley *et al.* 1991). These six deer were all females greater than or equal to four years of age, and five were from the northern regions.

A comparison between these results to those from other locations is given in Table 2. Overall, the mean Cd concentration found in the livers of deer located in Connecticut (1.71 mg/kg) was about the same as those from other Northeastern states and provinces. However, while only 10% of the livers tested in Connecticut exceeded the proposed action threshold, about 30% of the deer tested in New Jersey exceeded this limit.

The data, classified by age and sex, are shown in Figure 2. Due to the wide deviations about the means, no significant differences ($p > 0.05$) in the Cd content between age groups were found. There was, however, an upward trend ($p < 0.25$) of Cd content in female deer with age. These findings are in agreement with Munshower and Neuman (1979) who found no age related increases of Cd in deer livers. Conversely, Woolf *et al.* (1982) and Stansley *et al.* (1991) reported increases in Cd content in deer livers with age.

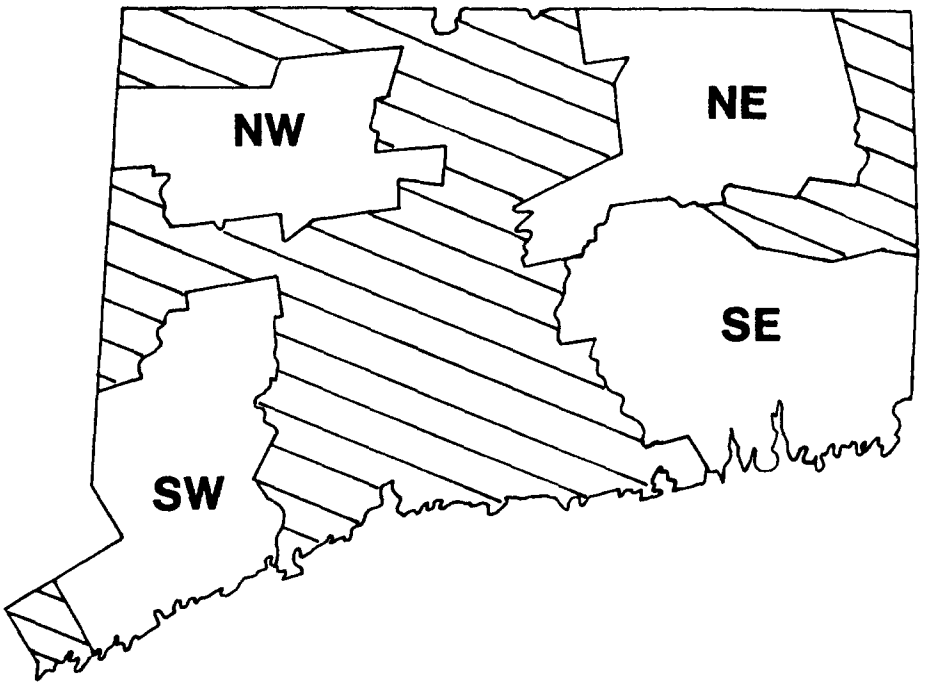

Figure 1. Locations where deer liver samples were collected.

Table 1. Cadmium concentrations in deer livers (mg/kg, dry weight).

Region	Age	Range	Mean	SD	n
Northwest	0-1				0
	2-4	1.1-9.1	4.73	3.26	3
	5-9	0.3-7.6	3.33	3.01	5
Northeast	0-1	0.3-2.0	0.96	0.53	10
	2-4	0.02-3.1	1.19	1.21	4
	5-9	3.9-9.1	6.63	2.16	3
Southwest	0-1	<0.002-0.9	0.43	0.43	2
	2-4	0.3-3.3	1.39	1.09	6
	5-9	0.03-5.2	1.42	1.38	9
Southeast	0-1	0.02-3.8	0.84	1.08	11
	2-4	0.7-2.0	1.15	0.49	4
	5-9	0.03-.07	0.05	0.02	2
All Samples			1.71	2.17	59

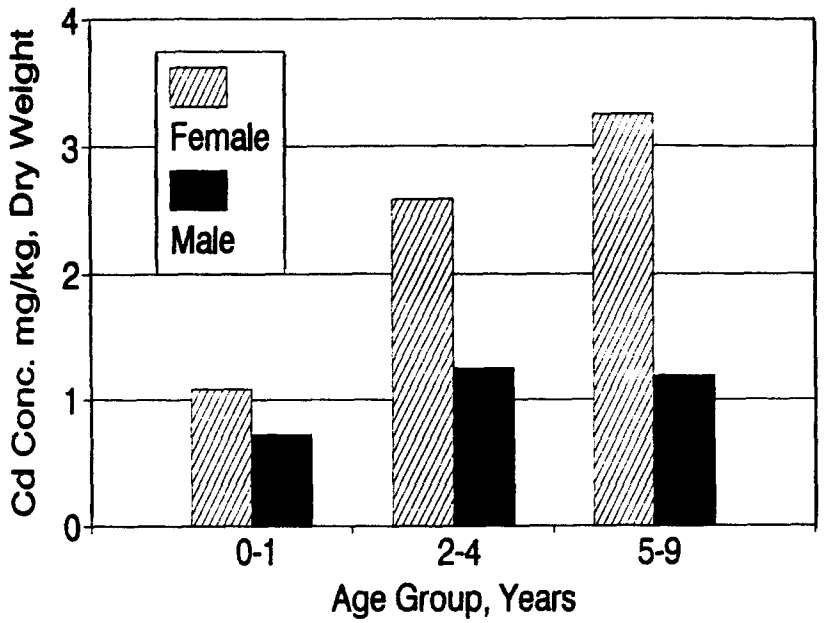

Figure 2. Mean liver Cd concentration versus sex and age for all samples. The standard deviations and number of samples are (left to right) 1.1, 9; 0.6, 14; 2.8, 8; 0.9, 9; 3.1, 13; and 1.3, 6.

Table 2. Cadmium concentrations in deer livers (mg/kg, dry weight).

Location	Range	Mean	n	Ref
Connecticut (USA)	<0.002-9	1.7	59	(a)
New Jersey (USA)	0.07-23	4	86	(b)
Illinois (USA)	0.2-6.5	0.4	190	(c)
Maine (USA)	0.4-3.3	1.3	9	(b)
Montana (USA)	--	0.5	30	(d)
New Brunswick (Canada)	<0.05-6	1.5	67	(e)
Quebec (Canada)	0.8-2.6	--	181	(f)

(a) This work; (b) Stansley *et al.* (1991);
(c) Woolf *et al.* (1982); (d) Munshower and Neuman (1979);
(e) Redmond (1987); (f) Crete *et al.* (1987).

Table 3. Cadmium concentrations (mg/kg) in deer livers and kidneys.

Age	Sex	Liver	Kidney	K/L Ratio
0	M	<0.002	<0.002	
3	F	0.61	6.5	11
5	F	5.2	3.9	1
5	F	0.44	14.3	32
7	M	0.33	10.5	32
7	F	1.2	12.5	11
8	F	1.1	20	18
8	F	1.3	48	38
Average		1.45	16.4	20

In addition, the mean Cd concentration in female deer 5-9 years old was significantly higher than male deer of the same age group ($p < 0.05$). Our findings on sex- related differences contrasts Stansley *et al.* (1991) and Woolf *et al.* (1982), who found no differences in deer-liver Cd concentrations by sex.

For eight deer, kidney as well as liver samples were collected, and in two cases muscle tissue samples were also obtained. The mean Cd concentrations of the muscle tissues were below the detection limit of 0.002 mg/kg. The Cd concentrations in the kidneys compared to the livers are shown in Table 3. The Cd concentrations of the kidneys generally exceeded that of the livers by a factor of at least ten. Higher accumulations of Cd in kidneys compared to livers in deer, antelope and domestic slaughter animals by a factor of 4-10 have also been reported (Munshower and Neuman 1979; Salisbury *et al.* 1991; Spierenburg *et al.* 1988).

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REFERENCES

Anderson RL (1987) Practical statistics for analytical chemists. Van Nostrand Reinhold, New York, NY

Crete M, Potvin F, Walsh P, Bendetti J, Lefebvre MA, Weber J, Paillard G, Gagnon J (1987) Pattern of cadmium contamination in the liver and kidney of moose and white-tailed deer in Quebec. Sci Total Environ 66:45-53

Emsley J (1989) The elements, Clarendon Press, Oxford, UK

Munshower FF, Neuman DR (1979) Metals in soft tissues of mule deer and antelope. Bull Environ Contam Toxicol 22:827-832

Redmond G (1987) Status report: cadmium levels in deer and moose in New Brunswick. Dept. of Natural Resources, Fish and Wildlife Branch, Fredericton, New Brunswick

Robards K, Worsfold P (1991) Cadmium: toxicology and analysis. Analyst 116:549-568

Ruparelia SG, Verma Y, Saiyed SR, Rawal UM (1990) Effect of cadmium on blood of tilapia, *Oreochromis mossambicus* (Peters), during prolonged exposure. Bull Environ Contam Toxicol 45:305-312

Salisbury CDC, Chan W, Sashenbrecker PW (1991) Multielement concentrations in liver and kidney tissues from five species of Canadian slaughter animals. J Assoc Off Anal Chem 74:587-591
Severinghaus CW (1949) Tooth development and wear as criteria of age in white-tailed deer. J Wildl Manage 13:195-216
Spierenburg ThJ, De Graaf GJ, Baars AJ, Brus DHJ, Tielen MJM, Arts BJ (1988) Cadmium, zinc, lead, and copper in livers and kidneys of cattle in the neighborhood of zinc refineries. Environ Mon and Assess 11:107-114
Stansley W, Roscoe DE, Hazen R (1991) Cadmium contamination of deer in New Jersey; human health risk assessment. Sci Total Environ 107:71-82
Woolf A, Smith JR, Small L (1982) Metals in livers of white-tailed deer in Illinois. Bull Environ Contam Toxicol 28:189-194

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