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Cadmium, Copper, and Zinc in Eurasian Beaver (*Castor fiber*) From Bø, Telemark, Norway

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Heavy metals are elements present in all forms of life. Of those analysed for in the present study, cadmium (Cd) is toxic and non-essential while copper (Cu) and zinc (Zn) are essential elements, but toxic when certain levels are exceeded. There are also antagonistic interaction effects among these elements (Anthony and Kozlowsky 1982) and therefore naturally be treated as a cluster. Very little is known about the levels of these metals in beaver (*Castor* spp.). But we know that *Salix spp.*, known as strong Cd accumulating plants (Madland 1997), are important in the diet of beavers, so elevated levels could be feared even in relatively unpolluted areas such as Bø.

The aim of present study has been to investigate the levels of Cd, Cu, and Zn in Eurasian beaver (*C. fiber*), find their distribution among various organs, and how they relate to age and an index of body fat content. For Cd we were also interested to see how the levels related to maximum allowable concentrations recommended by WHO.

MATERIALS AND METHODS

The Eurasian beavers (*Castor fiber*) were collected from river systems within the municipality of Bø, Telemark County, Norway (Figure 1). It is a typical rural district in southern Norway, dominated by boreal forest and some agriculture but very little industry.

The animals, 44 females and 48 males, were shot in 1997 (n = 51) and 1998 (n= 41, both years between 14 March and 10 May. The ages ranged from one to 14 years with only 5 older than 8 years. Yearlings were determined from the pattern of tooth eruption, 2-years-olds from the degree of basal openings and older animals by counting cementum annuli in microtome sections (van Nordstrand et al. 1964, Fancy 1980). Samples were taken from liver , kidneys, heart, femoral muscles, fat and hair, wrapped in plastic bags, and kept frozen (-21°C) prior to analysis. Animals were weighed and their condition estimated based on the following fat content index: 1) lean, 2) normal, 3) fat, and 4) very fat. The frozen samples were defrosted slowly in a refrigerator prior to digestion by the Milestone 1200 Megamicrowave Digestion System using a program designed for an organic matrix containing fat. Tissue samples (1.5 g) of muscles, liver, kidneys, and fat

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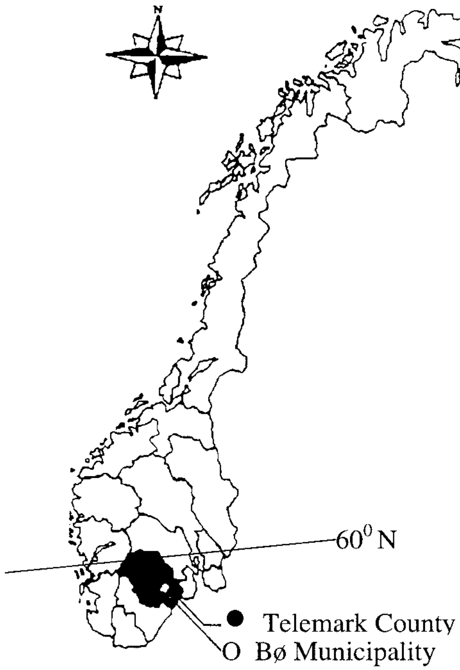

Figure 1. Location of the study area in southern Norway.

respectively, and 0.5 g of hair were weighed to ± 0.1 mg in microwave digestion vessels to which 5 mg of cons. HNO^3 were added. The concentrations of cadmium (Cd), zink (Zn), and copper (Cu) were determined by atomic absorption spectrophotometry (Perkin Elmer Atomic Absorption Spectrometer 3100) with flame and expressed as ppm wet weight (ppm ww). We used standard reference material (Bovine liver 1577b) for analytical quality assurance. The recoveries were 90% for Cd, 92 % for Cu, and 94 % for Zn. Statistical analyses were performed by using the SPSS version 8 program package.

RESULTS AND DISCUSSION

The metal concentrations in tissues and how they relate to age and condition are shown in Table 1. No significant differences in concentrations of the same metals were found in these tissues between sexes (t-test, 2-tailed, $P > 0.05$).

The Cd concentrations were generally high and similar to those found in an earlier study from the same locality (Johnsen and Kaasa 1991). With one exception, they were higher than those reported in Eurasian beaver elsewhere, e.g. the present mean kidneys level was 10.25 ppm ww compared to 3.78 ppm in material from Heide and 5.4 ppm from Elbe, both German sites (Nolet et al. 1994). In the latter study, however, the extreme value of 93 ppm ww was reported in a specimen from the river Mulde in Germany, apparently the the highest Cd concentrations ever recorded in Eurasian beaver. The present levels were also much higher than

Table 1. Concentrations (ppm ww) of heavy metals in tissues of Eurasian beaver (N=92) from Bø, Telemark, Norway, and their regression relationships (R^2) to age and fat content.

Content			Age		Condition (fat content)	
	$\overline{X}$±SD	Range	R^2	P	R^2	P
Cd:						
Liver	1.03±0.60	0.01-4.17	0.000	0.885	0.011	0.309
Kidney	10.25±4.90	1.27-27.26	0.329	0.001**	0.074	0.009**
Muscle	0.06±0.05	0.01-0.24	0.001	0.761	0.031	0.091
Heart	0.06±0.08	0.01-0.46	0.017	0.217	0.030	0.099
Fat	0.10±0.10	0.01-0.32	0.006	0.474	0.019	0.193
Hair	2.97±3.80	0.01-19.16	0.018	0.206	0.016	0.237
Zn:						
Liver	27.66±3.10	20.27-36.10	0.008	0.441	0.012	0.300
Kidney	23.11±4.70	15.80-40.56	0.046	0.040*	0.008	0.391
Muscle	42.92±8.31	15.20-62.20	0.057	0.022*	0.024	0.142
Heart	16.57±4.17	13.20-51.16	0.001	0.746	0.020	0.184
Fat	1.85±3.53	0.01-20.51	0.002	0.650	0.149	0.001**
Hair	110.42±31.11	0.01-180.00	0.001	0.753	0.033	0.085
Cu:						
Liver	2.80±0.78	1.85-9.35	0.002	0.662	0.016	0.236
Kidney	2.17±0.55	0.45-3.09	0.003	0.576	0.021	0.168
Muscle	0.74±0.48	0.01-1.69	0.000	0.958	0.001	0.732
Heart	2.37±0.63	0.01-3.48	0.023	0.153	0.004	0.546
Fat	0.22±0.40	0.01-1.70	0.001	0.779	0.017	0.214
Hair	0.27±0.83	0.01-6.25	0.026	0.127	0.006	0.470

** significant at the 0.01 level and * at the 0.05 level

those reported in North American beaver (*C. canadensis*). In the latter, Wren (1984) found a mean of 1.44 ppm ww in kidneys from specimens collected at remote sites in Ontario and 3.76 ppm ww in specimens collected near an Ontario mining operation. The levels recorded in moose (*Alces alces*) and roe deer (*Capreolus capreolus*) kidneys from the present study area were considerably lower averaging 2.32 and 4.32 ppm ww respectively (Fimreite 1987).

The levels in kidneys increased significantly with age (Table 1) as has been documented in several studies, e.g. Fimreite (1990). We also found a significant relationship between the animals condition (fat content) and Cd concentrations in kidneys but not between such concentrations and other tissues. In kidneys and liver significant correlations were recorded between the Cd and Zn levels while the corresponding relationship was negative for hair concentrations. Between Cd and Cu concentrations the relationship was negative except for kidneys (Table 2).

The high Cd concentrations are most probably attributed to the diet. The preferred food species of Eurasian beaver are aspen (*Populus tremula*), willows (*Salix* spp.), birch (*Betula* spp.), and rowan (*Sorbus aucuparia*). Especially the former two, and to a lesser extent rowan, are pronounced Cd accumulators. This has been

Table 2. Pearson correlation of Cd, Cu, and Zn in beaver (N=92) tissue from Bø, Telemark, Norway.

	Zn-l[a]	Zn-k[a]	Zn-m[a]	Zn-h[a]	Zn-fat	Zn-ha[a]	Cu-l[a]	Cu-k[a]	Cu-m[a]	Cu-h[a]	Cu-f[a]	Cu-ha[a]
Cd in liver	0.218*						-0.064					
Cd in kidney		0.680**						0.116				
Cd in muscle			0.028						-0.605**			
Cd in heart				-0.104						-0.208*		
Cd in fat					-0.224*						-0.402**	
Cd in hair						-0.514**						-0.083
Cu in liver	0.093											
Cu in kidney		0.190										
Cu in muscle			0.197									
Cu in heart				0.160								
Cu in fat					-0.197							
Cu in hair						0.141						

[a] Abbreviations for tissues: l:liver; k:kidney; m:muscle; h:heart and ha:hair.
** means that the correlation is significant at the 0.01 level and * at the 0.05 level (2-tailed).

documented in several studies (Kålås et al.1992, Hillis and Parker 1993, Scanlon and Fimreite 1993, Nolet et al. 1994, and Madland 1997). The latter found in a study from a mountain area in Norway that certain *Salix* spp. contained up to 270 times more Cd than other plant species she investigated.

Although high, the concentrations recorded here are considerably below those associated with known detrimental effects in mammals when such concentrations rise slowly as must be expected in the present case. For humans, Cd levels must reach 200 ppm ww in the kidneys before renal tubular dysfunction can be documented (Friberg et al.1986). Based on a review of the literature, Cooke and Johnson (1996) suggested that 100 mg of Cd/kg ww should be considered as the critical kidney concentration on a whole organ basis. Above this level Cd poisoning might be expected. The studies they refer to were largely laboratory experiments with rats and mice, and although inter-species variation in susceptibility to Cd intoxication may exist, the maximum concentration recorded in the present study was 27.26 ppm ww and therefore most likely safe.

These Cd levels in kidneys and liver, however, are clearly in excess of what WHO recommends as maximum allowable concentrations in foodstuffs (0.1 mg/kg). Kidneys of beaver should therefore not be eaten, and even liver should not be consumed on a large scale. The low concentrations recorded in muscles, however, indicate that beaver meat is safe for human consumption.

Zinc concentrations were highest in hair samples (mean 110.4 ppm) but with a pronounced range between individuals. They were also high in muscle with a mean of 42.92 ppm ww which is about twice that recorded in the liver and kidneys. The levels in kidneys and muscle were positively correlated with age, and they decreased significantly with the fat content (Table 1).

Very little is known about Zn levels in Eurasian beaver. Those recorded in the present study are slightly less than those found in North American beaver (Wren 1984) and comparable to those found in moose from Finland (Niemi et al. 1993), in raccoon (*Procyon lotor*) and river otter (*Lutra canadensis*) from Canada (Wren 1983) and in roe deer from Slovenia (Pokorny and Ribaric-Lasnik 2000). From contaminated sites in Pennsylvania, USA, however, Everett and Anthony (1977) reported as much as 81.2 ppm ww in liver and 305 ppm ww in bones of muskrat (*Ondatra zibethicus*). If no significant species differences exist in requirement or tolerance for Zn, there is reason to believe that the present concentrations are adequate. The wide variation between individuals in Zn concentrations revealed in our study has also been shown in other species, e. g. in river otter by Anderson-Bledsoe and Scanlon (1983) In the latter study, the Zn levels in the liver varied beteen 0.08 and 801 ppm dry w.

Anthony and Kozlowski (1982) suggested a high Cd/Zn ratio as an indicator of potential hazard as zink interacts with cadmium in a way that reduces its toxicity. Accordingly, the higher this ratio, the higher the potential for toxic effects. From a contaminated area in USA they reported Cd/Zn ratios of 2.79 and 0.44 in mice (*Peromyscus leucopus*) and 1.33 and 0.24 in voles (*Microtus* spp.) for kidneys and liver respectively. The Zn levels in the present study were comparatively high as the same ratios were 0.44 in kidneys and 0.037 in the liver, and therefore from a toxic viewpoint propitious.

The copper levels were generally low, though highest in liver with an average of 2.80 ppm ww and maximum 9.35. These values are similar to those found in other studies involving copper concentrations in beaver (Wren 1984, Hillis and Parker 1993). The latter found a negative correlation between age and Cu concentrations in North American beaver, which is believed to be the result of an antagonistic effect of Cd that counteracts the uptake of Cu as the Cd concentrations increased with age. We found, on the contrary, no such correlation between Cu concentrations and age.

In moose Frank et al.(1994) regarded a Cu concentration of less than 5 ppm ww in liver as an indication of severe Cu deficiency. The present mean level is considerably lower and therefore deserves attention. Other metals like iron (Fe), Cd, molybdenum (Mo), and especially Zn interact with copper metabolically. For this reason, and as pointed out by Davis and Mertz (1996), it is impossible to give a maximum or minimum tolerable dietary Cu level based on the Cu content alone. But recently Cu deficiency with deadly outcome has been recorded in farmed red deer (*Cervus elaphus*) in Norway with Cu concentrations in the same range as found in the present study (*Olav Rosef, personal communation*). So, in spite of possible species differences and the fact that the animals collected in the present study generally looked healthy, the Cu content in Eurasian beaver should be given attention in further studies.

The concentrations of Cd in beaver found here were high compared to those generally found in other mammals. This is likely related to the the high proportion of cadmium accumulating plants in the diet. No detrimental effects, however, can be expected from these levels, especially since the level of Zn, which is known to counteract metabolic effects of cadmium, also was relatively high. The Cu concentrations were quite low and although no signs of Cu deficiency were observed the condition deserves further attention since accompanyning levels of the antagonistic metals Zn and Cd were observed.

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