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Heavy Metals in Muscle, Liver, and Kidney from Finnish Elk in 1980–81 and 1990

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Pollution of the environment with heavy metals is a serious problem, which is recognized in most countries all over the world. Air pollution of local or distant origin may contribute significantly to the load of heavy metals in natural terrestrial ecosystems. Deposition of metals in the surface soils may induce elevated levels in plants. Herbivorous animals such as elk, which feed during the winter on branches of leafy trees and pine, may in turn increase their metal by eating the plants. Plants may also be contaminated by direct deposition from the air (Frøslie et al.1984). Spreading of airborne lead, cadmium, copper and zinc from industrial sources has been studied by analysing moss samples taken from the forest floor. According these studies over the half of the total Finnish emissions of cadmium and copper originate from South Western Finland (Harjavalta) (Jussila et al.1991, Jokinen et al.1991).

The first extensive investigation of lead, cadmium, copper and zinc in elk (Alces alces) was performed at the National Veterinary Institute in 1980-81 (Valtonen et al.1982). The study included over 300 elk. In the autumn of 1990 a new investigation of heavy metals was started by collecting samples in the same three areas as ten years earlier (the game management areas of South Western, Southern and Central Finland).

The aim of the present study was to compare the results obtained with those of the earlier study and thus monitor possible changes in pollution of the environment. The geographical distribution of evidence of pollution between the three areas was also a factor of interest.

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MATERIALS AND METHODS

Samples from adult elk were collected during the autumn of 1990 after the Hunters Central Organisation granted permission to take advantage of hunting in the game management areas of South Western (Satakunta), Southern (Uusimaa) and Central Finland. Packing materials and instructions for taking samples were sent to hunting clubs before the beginning of the shooting season. The number of samples was 25 in the game management area of South Western Finland, 19 in Southern Finland and 31 in Central Finland. In addition samples (18 livers, 1 muscle) sent by the College of Environmental Studies in South Western Finland were added to the samples of Satakunta. Muscle, liver and kidney samples were packed separately, frozen and sent to the laboratory in temperature-controlled containers containing coolant canisters frozen before mailing. The samples were stored at -18°C until analysis.

Samples of muscle, liver and the cortex of the kidneys were homogenized separately. 5.0 g of the fresh homogenate of liver and kidneys and 10 g of muscle were weighed into quartz dishes and evaporated to dryness on a water bath. Dried samples were ashed in a thermostat-controlled muffle-furnace (L 47/T Naber, Bremen, FRG) at 450°C overnight (Salmi et al.1981, Niemi et al.1991). Ashed samples were cooled to room temperature, after which deionized water and 0.5 ml of concentrated nitric acid were added and the samples were re-evaporated and heated to 450°C overnight in the muffle-furnace. The ash was dissolved in 0.5 ml concentrated nitric acid and adjusted to 20 ml with deionized water. Cadmium and lead were measured by graphite furnace atomic absorption spectrophotometry using a Perkin-Elmer 5000 atomic absorption spectrophotometer fitted with a Perkin-Elmer HGA 500 graphite furnace and a Zeeman background corrector, an AS-40 autosampler, PRS-10 printer (Norwalk, USA) and a 561 recorder (Hitachi, Tokyo, Japan). Cadmium was measured at 228.8 nm and lead at 283.3 nm with hollow cathode lamps. The measurements were carried out by direct comparison with standard solutions in 0.1 M nitric acid (lead, Titrisol, Merck Art. 9969 and cadmium, Titrisol, Merck Art. 9960). The limit of the lead determination was 10 ug/kg and of the cadmium determination 1 ug/kg.

The determinations of copper and zinc were made from the same samples as those used for the determination of lead and cadmium. Copper and zinc were measured by air acetylene absorption spectrophotometry (Perkin-Elmer 5000 atomic absorption spectrophotometer). Copper was measured at 324.8 nm and zinc at 213.9 nm with hollow cathode lamps. The measurement was carried out using direct comparison with standard solutions in 0.1 M nitric acid (copper, Titrisol, Merck Art.9987 and zinc, Titrisol, Merck Art.9953). The limits of the copper and zinc determinations were 0.2 mg/kg.

For the determination of age the front teeth of elk were also needed. Determination of age was made at the Game and Fishery Research Institute. The teeth were analysed microscopically and age was estimated on the basis of the cement layers correlating with age of the animal.

RESULTS AND DISCUSSION

The cadmium, lead, copper and zinc concentrations in muscle, liver and kidney from elk in the game management areas of South Western (Satakunta), Southern (Uusimaa) and Central Finland in the years 1980-81 and 1990 are presented in Table 1 (a), (b), (c) and (d).

The lead concentrations in muscle, liver and kidney were considerably lower in 1990 than ten years earlier. Sampling and analysing methods may have improved during ten years. However, the validity of the method was already tested in 1980-81 with certificated standard reference material (Natural Bureau of Standards, bovine liver 1577). The method for lead determination was also tested in two other laboratories at the same time.The atomic absorption spectrophotometer used in 1980 was a Perkin Elmer 5000 fitted with a deuterium background corrector, whereas the present samples were analysed with a Zeeman background corrector. Although the consumption of petrol has increased during the intervening period, the lead concentration of petrol has at the same time effectively been decreased. Nowadays the lead concentration of leaded petrol is only one quarter of that used twenty years ago. Already about half of the total petrol consumed in Finland is unleaded. When the geographical locations of the three game management areas were studied with regard to the lead concentrations in elk obtained in 1990, no differences were observed although the density of car traffic is greatest in Southern Finland. In 1980-81 the differences were still notable, all the highest lead concentrations in kidney from elk being recorded in Southern Finland.

The highest cadmium concentrations were in the game management area of South Western Finland. A similar situation was also observed in 1980-81. This evidently originates from industrial emissions in the south western part of the country. High concentrations of cadmium are often associated with e.g. mining and smelting operations. Levels of cadmium in liver and kidney of elk in 1980-81 and 1990 in different age

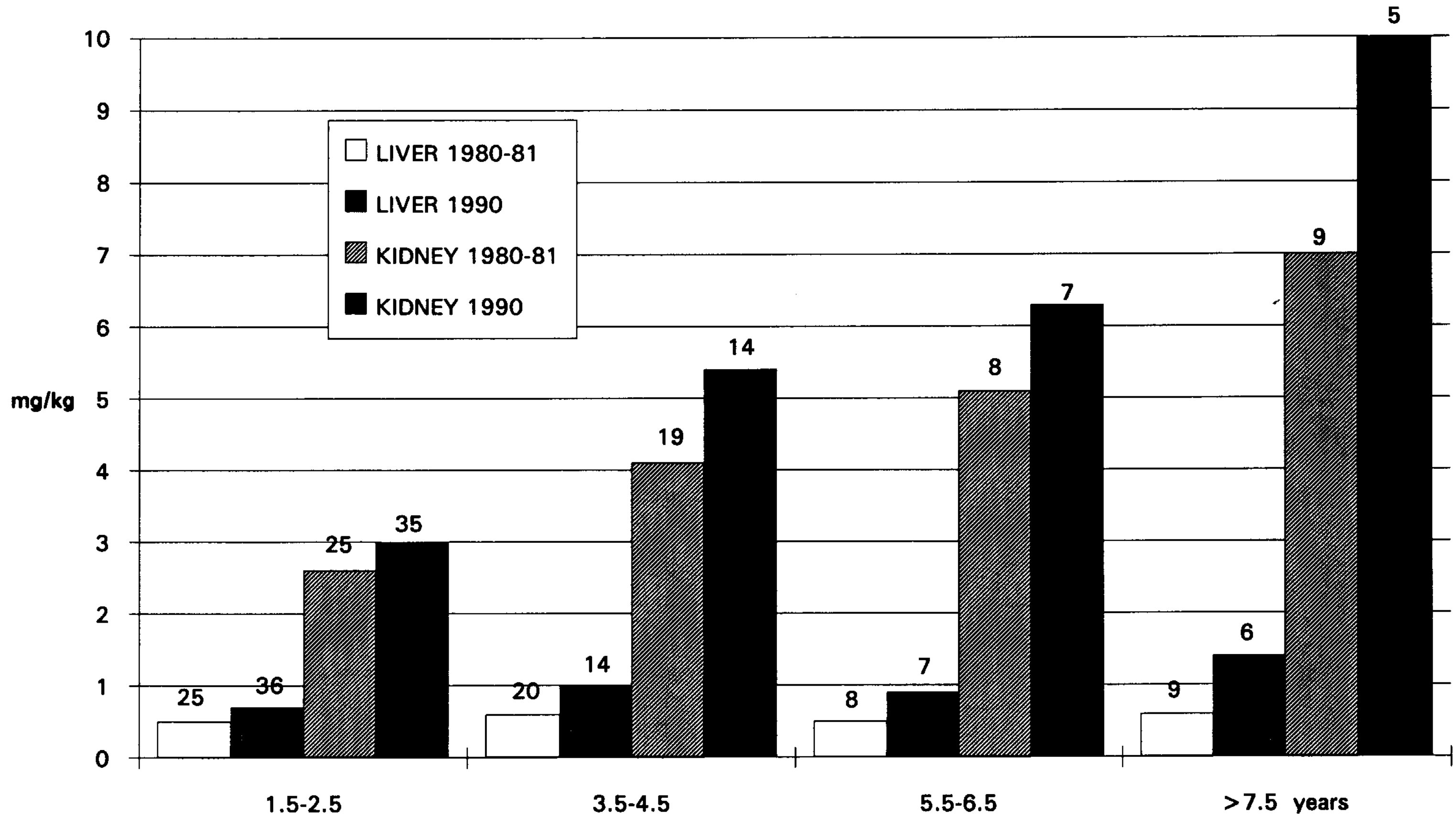

Figure 1. Levels of cadmium (mg/kg) in livers and kidneys of elks in different age groups. The number of samples is shown on the top of the bar graph.

Table 1. Cadmium (a), lead (b), copper (c) and zinc (d) concentrations in muscle, liver and kidney from elk in the game management areas of South Western, Southern and Central Finland in the years 1980-81 and 1990. The metal concentrations are expressed as mg/kg wet weight. n, total number of samples; x, mean; SD, standard deviation.

CADMIUM (a)

		South west			South			Central		
		n	x	SD	n	x	SD	n	x	SD
1980-81	Muscle	32	0.012	0.02	23	0.009	0.01	16	0.005	0.01
	Liver	49	0.6	0.3	43	0.45	0.2	22	0.76	0.53
	Kidney	48	4.43	2.52	43	3.01	1.82	22	3.74	2.13
1990	Muscle	26	0.009	0.02	19	0.003	0.003	31	0.003	0.002
	Liver	43	0.84	0.36	19	0.69	0.37	31	0.85	0.6
	Kidney	25	5.25	2.66	19	3.08	1.53	31	4.29	2.57

LEAD (b)

		South west			South			Central		
		n	x	SD	n	x	SD	n	x	SD
1980-81	Muscle	31	0.05	0.03	22	0.07	0.06	16	0.06	0.05
	Liver	49	0.21	0.18	42	0.25	0.17	22	0.21	0.09
	Kidney	48	0.36	0.29	42	0.53	0.65	22	0.36	0.33
1990	Muscle	23	0.02	0.03	11	0.03	0.03	22	0.02	0.03
		2	<0.01		7	<0.01		8	<0.01	
	Liver	43	0.07	0.04	19	0.05	0.02	31	0.05	0.03
	Kidney	25	0.07	0.04	19	0.08	0.05	31	0.07	0.04

COPPER (c)

		South west			South			Central		
		n	x	SD	n	x	SD	n	x	SD
1980-81	Muscle	32	1.04	0.19	23	1.3	0.51	16	0.92	0.27
	Liver	49	29.7	13.9	43	26.2	16.1	22	38.9	16.5
	Kidney	48	2.81	0.61	43	3.05	0.48	22	2.86	0.47
1990	Muscle	26	1.03	0.15	19	1.06	0.17	31	1.13	0.2
	Liver	43	46	17.4	19	46.1	14.6	31	54.4	23.4
	Kidney	25	3.53	0.39	19	3.72	0.33	31	3.73	0.54

ZINC (d)

		South west			South			Central		
		n	x	SD	n	x	SD	n	x	SD
1980-81	Muscle	32	34.1	13.1	23	33.8	10.8	16	34.3	14.1
	Liver	49	20.1	9.9	43	17.5	5.1	22	19.9	12.4
	Kidney	48	22.2	4.5	43	18.9	3.5	22	19.9	4.7
1990	Muscle	26	53.9	12.1	19	54.4	8.5	31	54.2	10.9
	Liver	43	24.6	13.1	19	22	4.1	31	26.4	11.1
	Kidney	25	28.5	5.2	19	27.5	3.1	31	28.1	3.6

groups are presented in Figure 1. A slight increase can be seen in the concentrations of 1990 compared with those recorded in 1980-81. Cadmium is an accumulating heavy metal, mainly in the kidney but also in liver in older animals.

Copper and zinc concentrations increased considerably in 1990 compared with the results obtained in 1980-81. Copper accumulates mainly in the liver and the copper concentrations in liver in the present investigation were slightly higher in Central Finland compared with the concentrations reccorded in South Western and Southern Finland. The situation was similar to that observed in 1980-81. The high copper concentrations in Central Finland may be caused by long-distance transport. There is namely high copper accumulation in the west of Finland near the coast of the Bothnian Sea, evidently attributable to a copper refinery in the region and another in eastern Finland in the vicinity of a copper mine (Kubin 1990).

Zinc concentrations were similar in all three game management areas. Zinc accumulates mainly in muscle and it showed a remarkable increase in the results of 1990. The area associated with high zinc values in south western Finland coincides with that for copper, and other high points also occur near certain mining districts (Kubin 1990).

There are no official recommendations concerning heavy metals in muscle, liver and kidney of elk. The results of this study were compared to the values recommended for liver and kidney from pigs and cattle (The Contaminant Group subordinated to the Nordic Council of Ministers, 1991). The maximum cadmium concentration for liver of pigs and cattle has been proposed as 0.5 mg/kg and correspondingly for kidney 1 mg/kg. The cadmium concentrations in liver and kidney of elk exceed considerably the proposed maximum concentrations. The proposal for maximum lead concentration in liver and kidney from pigs and cattle is 0.5 mg/kg. In regard to this limit the lead concentrations in liver and kidney of elk were very small in the present study. The maximum cadmium and lead concentrations for muscle of pigs and cattle has been proposed as 0.05 mg/kg in Finland. According to these proposals the cadmium and lead concentrations recorded in muscle of elk were below this proposed limit.

At present there are no recommendations concerning the maximum zinc and copper concentrations in foods of animal origin.

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