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Heavy Metals in Muscle, Liver, and Kidney from Finnish Reindeer in 1990–91 and 1991–92

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Heavy metals were analyzed from reindeer by the Finnish National Veterinary and Food Research Institute. The analyses were part of a larger project during the period 1990-1993, in which residues in vegetables, milk, berries, fish and reindeer were monitored. The main aim of the reindeer study was to investigate possible differences between the heavy metal contents of reindeer samples from northern, eastern, western and southern Lapland. Another objective of the study was also to clarify the environmental effects of industrial activities in the Kola Peninsula and in Tornio on the food products of Finnish Lapland. Analyses of organochlorine compounds from reindeer samples were also perfomed, but these results will be published later after a larger number of samples has been studied. Results of the reindeer analyses were also compared with previous reindeer and elk studies of the Finnish National Veterinary Institute (1980) and Niemi (1993) and with two Norwegian studies (Frøslie 1984 and 1986).

MATERIALS AND METHODS

Samples for heavy metal determinations were collected in the autumn slaughtering seasons 1990-1991 and 1991-1992 from northern, eastern, western and southern Lapland. A map of the study areas is shown in Figure 1. A total of 325 muscle, 219 liver and 325 kidney samples of adult reindeer (over 2 yr) and calves (under 1 yr) were studied. During the first slaughtering season 1990-1991 samples were taken from both adult reindeer and calves and during the second season 1991-1992 mainly from calves.

Sample prework was done as described by Niemi et al. (1993). Cadmium, lead, chromium and nickel were measured by graphite furnace atomic absorption spectrofotometry using pyrolytic THGA-tubes (= transverse heated graphite atomizer tubes) in a Perkin Elmer 5100 PC atomic absorption spectrofotometer with a Zeeman furnace module. Cadmium was measured at 228.8, lead at 283.3, chromium at 357.9 and nickel at 232.0 nm with hollow cathode lamps. Copper contents were measured at 324.8 nm by flame absorption spectrophotometry (Perkin Elmer 5100 PC AAS) with an air-acetylene flame. Cadmium, lead, chromium, nickel and copper measurements were carried out using direct comparison with standard solutions in 0.1 M nitric acid. Standard solutions were made from Titrisol ampoules (Merck, Cd Art. 9960, Pb Art. 9969, Cr Art. 9948, Ni Art. 9989 and Cu Art. 9987).

For mercury analyses 2 g of sample was weighed accurately and the organic part was

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wet-digested by heating with conc. sulfuric and nitric acid (1:1). Mercury was determined by the cold vapor technique using sodium borohydride ($Na(BH_4)$) as reductant and using a Perkin Elmer 2380 atomic absorption spectrofotometer with the mercury/hydride system MHS-20. The wavelength used for mercury was 253.7 nm and lamp was an EDL-model (electrodeless discharge lamp). Standard solution for mercury analysis was prepared from a Titrisol ampoule (Merck).

Figure 1. Map of the sample areas in Finnish Lapland; A= Southern Lapland, B=Western Lapland, C= Eastern Lapland and D= Northern Lapland.

The laboratory has quality system based on GLP and EN 45001 standard (1989). The determination limits for the metals in the sample materials were Cd 0.001, Pb 0.01, Cr 0.01, Ni 0.01, Cu 0.2 and Hg 0.005 mg/kg wet weight. Standard reference materials were used and analysed in duplicate together with each sample series (see Table 1). The analysis results of standard reference materials are shown in Table 1. Calibration of the all metal analyses was continuously checked using standard samples in different concentrations. The recoveries of metals were studied by adding known amounts of standard solutions to samples. The amounts added were selected so that they would be close to the amounts normally found in reindeer meat, liver and kidney. The mean recoveries ± SD in different sample materials were 91 % ± 16 in muscle, 90 % ± 11 in liver and 101 % ± 24 in kidney for cadmium; 85 % ± 8 in muscle, 74 % ± 5 in liver and 75 % ± 8 in kidney for lead; 102 % ± 12 in muscle and 93 % ± 16 in kidney for chromium; 84 % ± 7 in muscle and 74 % ± 6 in kidney for nickel; 103 % ± 15 in muscle, 104 % ± 12 in liver and 97 % ± 8 in kidney for copper.

Table 1. Results of the analyses of standard reference materials (SRM) during reindeer metal determinations. The metal concentrations are expressed as mg/kg wet wt. Numbers of samples are given in parentheses (SD= standard deviation).

Metal	Standard Reference Material	Our results mean ± SD	Certified value ± uncertainty
Cadmium	NBS 1577a bovine liver[a]	0.47 ± 0.04 (17)	0.44 ± 0.06
	NIST 1577b bovine liver[b]	0.51 ± 0.04 (37)	0.50 ± 0.03
	BCR 184 bovine muscle[c]	0.016 ± 0.020 (17)	0.013 ± 0.002
	BCR 185 bovine liver[c]	0.280 ± 0.020 (12)	0.298 ± 0.025
	BCR 186 pig kidney[c]	2.72 ± 0.29 (22)	2.71 ± 0.15
Lead	NBS 1577a bovine liver	0.142 ± 0.022 (17)	0.135 ± 0.015
	NIST 1577b bovine liver	0.179 ± 0.065 (36)	0.129 ± 0.004
	BCR 184 bovine muscle	0.198 ± 0.059 (13)	0.239 ± 0.011
	BCR 185 bovine liver	0.437 ± 0.093 (14)	0.501 ± 0.027
	BCR 186 pig kidney	0.285 ± 0.034 (26)	0.306 ± 0.011
Copper	NBS 1577a bovine liver	161 ± 5 (17)	158 ± 7
	NIST 1577b bovine liver	175 ± 13 (39)	160 ± 8
	BCR 184 bovine muscle	2.54 ± 0.13 (11)	2.36 ± 0.06
	BCR 185 bovine liver	188 ± 21 (14)	189 ± 4
	BCR 186 pig kidney	32.7 ± 1.7 (16)	31.9 ± 0.4
Mercury	MA-A-2 fish flesh homogenate[d]	0.45 ± 0.05 (15)	0.47 ± 0.02

[a]National Bureau of Standards: Standard Reference Material
[b]National Institute of Standards & Technology: Standard Reference Material
[c]Community Bureau of Reference-BCR: Certified Reference Material
[d]International Atomic Energy Agency: Reference Material MA-A-2 (TM)

RESULTS AND DISCUSSION

The cadmium concentrations in muscle, liver and kidney samples of adult reindeers and calves from different areas are shown in Table 2. Cadmium contents of muscle samples of both adult reindeer and calves in Lapland were low and practically at the limit of determination 0.001 mg/kg wet wt. The cadmium contents of reindeer muscle samples were at same level as in muscle samples of Finnish pigs and cattle (Niemi et al. 1991) and in Finnish elks in 1990-91 (Niemi et al. 1993). Näyä el al. (1991) concluded that reindeer meat could be the reason for high cadmium contents in the blood of reindeer herders, but this is not supported by our results. More probably the reason for high cadmium concentrations may be the custom of eating reindeer inner organs, which can cause a higher intake of cadmium.

The cadmium contents of reindeer liver and kidney samples were rather high. The results (Table 2) indicate cadmium accumulation in kidneys with age and also show rather wide variation of cadmium contents between samples. Really lower cadmium contents of reindeer muscle, liver and kidney samples were detected in southern Lapland than in other areas. The results for reindeer liver samples of southern Lapland were about at the same level as measured from reindeer liver samples in Karasjok (Frøslie et al. 1984) and Finnmarksvidda (Frøslie et al. 1986) in Norway. Cadmium contents of

Table 2. The cadmium concentrations (mg/kg wet wt) of muscle, liver and kidney from adult reindeer and calves from southern, western, eastern and southern Lapland in the slaughtering seasons 1990-91 and 1991-92 (n=number of samples, x=mean, SD=standard deviation).

Cadmium	Southern Lapland			Western Lapland			Eastern Lapland			Northern Lapland		
	n	x	SD	n	x	SD	n	x	SD	n	x	SD
Adult reindeer 1990-1991:												
muscle	14	0.002	0.001	15	0.003	0.004	10	0.003	0.002			
liver	30	0.402	0.358	30	0.758	0.483	19	0.958	0.537			
kidney	30	1.72	1.55	30	4.62	4.41	19	4.25	3.89			
1991-1992:												
muscle										15	0.006	0.004
liver										24	0.546	0.431
kidney										24	2.84	3.32
Calves 1990-1991:												
muscle	10	0.001	-	16	0.001	-	13	0.002	0.001			
	5	<0.001		1	<0.001		3	<0.001				
liver	30	0.190	0.073	30	0.233	0.076	32	0.388	0.254			
kidney	30	0.525	0.206	30	0.903	0.308	32	1.22	1.02			
1991-1992:												
muscle	30	0.001	0.001	27	0.001	-	30	0.002	0.001	15	0.002	0.001
				3	<0.001							
liver										24	0.310	0.096
kidney	30	0.538	0.193	30	0.650	0.298	46	0.938	0.383	24	1.03	0.52

adult reindeer liver and kidney samples from other areas were at about the same level as found in 1990-91 from Finnish elk liver and kidney samples (Niemi et al. 1993). In this study slightly higher contents of cadmium were measured from reindeer liver and kidney samples than were found in a previous study of Finnish reindeers (Salmi and Hirn 1981). Niemi et al. (1993) also reported a slight increase in the cadmium concentration of elk samples in years 1990-91 compared with samples in 1980-81. This trend may be a sign of long-distance transport of pollutants from industry, waste burning and mining in both central and eastern Europe and the Kola Peninsula area.

The lead concentrations in muscle, liver and kidney samples of adult reindeer and calves from different areas are shown in Table 3. The lead contents of reindeer muscle samples from both adult reindeer and calves in Lapland were low and practically at the determination limit of 0.01 mg/kg wet wt. The lead content of reindeer muscle samples were at the same level as in muscle samples of Finnish pigs and cattle (Niemi et al. 1991) and Finnish elks in 1990-91 (Niemi et al. 1993). Niemi et al. (1993) reported lower lead concentrations in elk liver and kidney samples in 1990-91 than in samples taken in 1980-81. The trend is not as clear with reindeer as with elks, but the lead contents of reindeer muscle, liver and kidney samples appear to be lower in this study than in the previous study of Finnish reindeers *(FNVI 1980)*(Table 3).

Table 3. The lead concentrations (mg/kg wet wt) of muscle, liver and kidney in adult reindeer and calves from southern, western, eastern and southern Lapland in the slaughtering seasons 1990-91 and 1991-92 (n=number of samples, x=mean, SD=standard deviation).

Lead	**Southern Lapland** n x SD	**Western Lapland** n x SD	**Eastern Lapland** n x SD	**Northern Lapland** n x SD	**Finnish Lapland** n x SD
Adult reindeer 1990-1991:					*FNVI (1980):* **Reindeer (1-3 yr)**
muscle	15 0.01 0.004	7 0.01 0.004	6 0.01 0.005		11 0.12 0.18
	6 <0.01	8 <0.01	4 <0.01		
liver	30 0.16 0.11	30 0.36 0.18	19 0.37 0.15		11 0.49 0.28
kidney	30 0.27 0.09	30 0.28 0.08	19 0.34 0.10		11 0.50 0.21
1991-1992:					
muscle				15 0.02 0.006	
liver				24 0.43 0.28	
kidney				24 0.29 0.09	
Calves 1990-1991:					*FNVI (1980):* **Calves (under 1 yr)**
muscle	3 0.01 -	5 0.01 0.004	6 0.01 0.004		35 0.09 0.06
	12 <0.01	10 <0.01	10 <0.01		
liver	30 0.13 0.06	30 0.17 0.09	32 0.28 0.08		35 0.42 0.15
kidney	30 0.33 0.09	30 0.25 0.08	32 0.25 0.07		35 0.55 0.37
1991-1992:					
muscle	24 0.01 0.004	17 0.01 -	21 0.01 0.005	15 0.02 0.01	
	6 <0.01	13 <0.01	9 <0.01		
liver				24 0.36 0.16	
kidney	24 0.22 0.07	30 0.15 0.05	46 0.20 0.08	24 0.18 0.03	

Niemi et al. (1993) reported clearly lower lead concentrations in elk liver and kidney samples than those found in reindeer samples in this study. Frøslie et al. (1984) reported somewhat higher lead concentrations in reindeer liver samples than in this study. Generally, high lead contents of reindeer liver and kidney samples may be attributed to the lead content of lichen. Lichens are effective accumulators of heavy metals, but changes in the level of atmospheric lead are reflected in reindeer organ samples only slowly, because of the long lifetime of lichens. The lead contents of reindeer liver samples from southern Lapland were lower than those of samples from other areas but generally no great differences were observed between areas. This may be a result of the use of commercial feeds in southern Lapland.

The chromium concentrations in muscle and kidney samples of adult reindeers and calves were low. Mean concentrations varied generally between 0.01 and 0.03 mg/kg wet wt and in many samples the chromium contents were below the determination limit of 0.01 mg/kg wet wt. Generally the concentrations of chromium in reindeer samples were at same level as in muscle, liver and kidney samples of Finnish pigs and cattle during the years 1988-91 *(FNVI 1992)*. The reindeer muscle and kidney samples from eastern Lapland in 1990-1991 were exceptional, with mean chromium concentrations between 0.07 and 0.10 mg/kg wet wt. However the mean chromium concentrations of reindeer samples from eastern Lapland in 1991-1992 were again low: 0.02 mg/kg wet wt. The reason for the different contents could be normal sample variation in the population or it could also be a sign of areal differences in the environmental chromium intake.

Kubin (1990) used epiphytic lichen as an indicator of airborne substances and reported higher chromium concentrations in eastern and southern Lapland than in the north and west, which may be locally linked to steel works and mining in these areas. In the case of reindeer samples from southern Lapland there was no sign of higher concentrations. This may be the result of the use of feeding in that area. Juntto (1992) also measured high chromium and copper concentrations from samples of airborne substances near the research station of Värriö in eastern Lapland.

The nickel concentrations in muscle and kidney samples of adult reindeer and calves were low. Mean concentrations varied between 0.01 and 0.05 mg/kg wet wt. Furthermore, in many samples from southern, western and eastern Lapland the nickel contents were below the determination limit. Although no significant differences were found between the studied areas, no samples below the determination limit were taken in northern Lapland and the mean concentrations of reindeer kidney samples were somewhat higher in the north than in kidney samples from other areas. The mean concentrations of nickel in muscle, liver and kidney samples from pigs and cattle generally varied between 0.01 and 0.03 mg/kg wet wt *(FNVI 1992)* and the concentrations measured in this study where at same level.

Kubin (1990) found areally rather high nickel concentrations in lichen samples from northern and eastern Finnish Lapland. Niskavaara and Lehmuspelto (1992) also and Pulkkinen (1992) reported rather high nickel levels in moss samples from northern Finnish Lapland. In the Kola Peninsula of Russia, evidently great amounts of nickel, copper and sulphur reach the atmosphere from e.g. the Petshenganikel mines and smelters. However, in this study there were no great differences between northern and eastern Lapland compared with other areas in Lapland. One explanation for this may be that long-distance transport to Finnish Lapland is only occasional because the prevailing winds in Finnish Lapland blow from the south-west.

Mercury was determined from reindeer muscle tissue because of the extensive use of reindeer meat as food, although, other sample materials, e.g. hair would have been better indicators of mercury levels in reindeer. The mean mercury content of all reindeer muscle samples from all the studied areas were low, varying between 0.005 and 0.006 mg/kg wet wt and in fact most of the samples were below the determination limit for mercury, 0.005 mg/kg wet wt. Mercury content of reindeer muscle samples were at same level as in muscle samples of Finnish reindeer measured previously *(FNVI 1980)* and of Finnish pigs and cattle *(FNVI 1992)*.

Table 4. The copper concentrations (mg/kg wet wt) of muscle, liver and kidney from adult reindeer and calves from southern, western, eastern and southern Lapland in the slaughtering seasons 1990-91 and 1991-92 (n=number of samples, x=mean, SD=standard deviation).

Copper	Southern Lapland			Western Lapland			Eastern Lapland			Northern Lapland			Finnish Lapland		
	n	x	SD	n	x	SD	n	x	SD	n	x	SD	n	x	SD
Adult reindeer 1990-1991:													*FNVI (1980):* **Reindeers (1-3 yr)**		
muscle	30	1.77	0.18	30	1.83	0.17	19	1.63	0.16				11	1.35	0.48
liver	30	55.2	29.5	30	29.7	13.4	19	71.0	26.6				11	25.0	14.6
kidney	30	5.41	0.47	30	4.75	0.45	19	4.55	0.43				11	4.11	0.49
1991-1992:															
muscle										24	1.91	0.18			
liver										24	67.7	24.6			
kidney										24	4.14	0.46			
Calves 1990-1991:													*FNVI (1980):* **Calves (under 1 yr)**		
muscle	30	1.83	0.17	30	1.92	0.11	32	1.65	0.20				39	1.50	0.32
liver	30	53.5	33.1	30	29.2	24.2	32	68.6	16.4				39	27.6	17.4
kidney	30	5.68	0.59	30	5.07	0.47	32	4.33	0.51				35	4.19	0.60
1991-1992:															
muscle	30	1.84	0.32	30	1.96	0.24	30	1.93	0.16	24	1.89	0.16			
liver										24	82.2	27.7			
kidney	30	5.00	0.69	30	4.79	0.39	46	4.27	0.44	24	4.02	0.48			

The copper concentrations in muscle, liver and kidney samples of adult reindeers and calves from different areas are shown in Table 4. There were no great differences in reindeer muscle and kidney copper concentrations between the studied areas or when comparing with the copper concentrations of muscle and kidney samples in the previous study *(FNVI 1980)*(Table 4). Copper accumulates mainly in liver tissue and it is a better indicator than other tissues when investigating differences between areas. Higher copper contents were detected in reindeer liver samples of northern and eastern Lapland than in samples from other areas. Furthermore, copper concentrations of reindeer liver samples, excluding samples from western Lapland, appear to be higher than the concentrations in reindeer liver samples in the earlier study of *FNVI (1980)*(Table 4). Kubin (1990) reported a high copper content of lichen samples from northern and eastern Lapland. Niskavaara and Lehmuspelto (1992) also reported similar results from moss samples of northern Lapland. However, the higher copper concentrations of reindeer liver samples from northern and eastern Lapland were at the same level as normally found in liver samples of Finnish cattle *(FNVI 1992)*.

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