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Levels of Cadmium in Liver and Kidneys from Norwegian Cervides

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Investigations during the last decade have demonstrated that the environment of the southernmost parts of Norway is substantially polluted by acid precipitation originating mainly from Central and Western Europe (Overrein et al. 1980). These areas are also subjected to pollution by long-distance transport of some fairly volatile trace elements such as lead, cadmium, arsenic and selenium (Hansen et al. 1980). Accordingly, north-south concentration gradients have been demonstrated for these elements in surface soils (Allen and Steinnes 1980, Hvatum et al. 1983), in coniferous forest ecosystems (Solberg and Steinnes 1983) and in certain herbivorous animals (Frøslie et al. 1984, 1985). The purpose of the present study was to determine the cadmium burden in Norwegian cervides, with special reference to moose, and to demonstrate possible regional differences in this regard.

MATERIALS AND METHODS

Moose was found to be the most suitable species for monitoringthe cadmium levels in wild ruminants due to its distribution pattern and stationariness. Samples of liver and kidneys were collected by the local wild-life authorities during the hunting season in the autumn of 1983. In addition, organ samples were also collected from reindeer and red deer in 1983 and 1984 in connection with slaughter or hunting. Samples of roe deer were mainly collected from autopsy materials received in 1983 and 1984. The number and origin of samples are shown in Tables 1 and 2. When possible, mandibles were also collected from moose and reindeer and their ages determined by counting tooth cementum annuli (Reimers and Nordby 1968). Cadmium concentrations were determined by flame atomic absorption spectrometry after wet digestion with perchloric/nitric acid. The results are given as ppm (μg/g) on a wet weight basis. Calculations were performed on a standard computer system (Nissen 1982).

Table 1. Levels of cadmium in liver and kidney samples from Norwegian cervides

		Liver n	Liver Mean SD ppm±ww	Kidney n	Kidney Mean SD ppm±ww
Moose	*Alces alces*	775	0.6±0.5	796	2.9±2.6
Reindeer	*Rangifer tarandus*	248	1.1±0.7	204	5.7±5.2
Roe deer	*Capreolus capreolus*	77	0.4±0.5	77	2.8±2.8
Red deer	*Cervus elaphus*	17	0.1±0.08	18	0.8±0.8

Table 2. Medians (md) and ranges (rg) of cadmium levels (ppm ww) in liver (L) and kidney (K) of moose, reindeer and roe deer from different regions of Norway. The regions are illustrated in Fig.1

Region	Organ	MOOSE n	MOOSE md	MOOSE rg	REINDEER n	REINDEER md	REINDEER rg	ROE DEER n	ROE DEER md	ROE DEER rg
1	L	93	0.7	<0.1-2.3	124	1.3	0.3-4.6			
	K	105	3.2	0.2-15	78	5.9	0.9-34			
2	L	200	0.5	<0.1-2.6				57	0.3	<0.1-2.5
	K	209	2.2	0.1-12				59	2.3	0.3-14
3	L	225	0.6	0.1-3.4						
	K	232	2.5	0.2-19						
4	L	118	0.3	<0.1-1.7	92	1.0	0.3-2.5	13	0.2	<0.1-0.4
	K	118	1.4	0.3-8.3	74	4.7	0.8-30	13	1.0	0.2-4.0
5	L	89	0.2	<0.1-1.4	52	0.4	0.1-1.7			
	K	73	1.4	0.1-8.7	52	1.5	0.3-10			

Table 3. Levels of cadmium (ppm ww) in liver and kidney from moose and reindeer of different age groups

Age (years)	MOOSE Liver n	MOOSE Liver mean	MOOSE Kidney n	MOOSE Kidney mean	REINDEER Liver n	REINDEER Liver mean	REINDEER Kidney n	REINDEER Kidney mean
< ½	152	0.3	160	0.8				
½ - 1½	161	0.5	154	2.0	48	0.7	35	2.6
1½ - 3½	167	0.7	155	3.1	39	1.0	24	4.4
3½ - 5½	58	0.8	57	4.4	43	1.2	29	6.5
5½ - 8½	30	0.7	31	5.3	29	1.8	19	12.8
> 8½	21	0.7	20	6.4	10	1.8	4	19.8

RESULTS AND DISCUSSION

In general, reindeer was the species most heavily burdened (Table 1), while red deer was the one with the least burden. Moose and roe deer constituted intermediary groups. Levels in kidneys were considerably higher (on average five to eight fold) than in liver. There was a strong linear correlation between the levels in liver and kidneys, r=0.73 in moose and r=0.85 in reindeer.

There were, however, large variations in the results as seen from the standard deviations. Median values were therefore used when comparing the different regions (Table 2). As seen from the table, the differences between the species were also observed within the regions. Regional differences, with clear North-South gradients were detected in both moose, reindeer and red deer. The highest ratio between the extreme regions (1) and (5) was 3.9 and was found in reindeer kidneys.

Because of its persistence within the body, cadmium tends to accumulate with age. Accumulation with age was also demonstrated in the present material of reindeer and moose (Table 3). The accumulation was most pronounced in the kidneys, but there was also a moderate accumulation in liver up to a certain age, both in moose and reindeer. The linear regression between the animals' ages and the concentrations of cadmium in kidney cortex was calculated for the different regions and the results presented in Fig. 2. The correlation coefficients (r) and the regression coefficients (b) were as follows:

Moose		Reindeer	
Region 1	r=0.77*** b=1.0	Region (1)	r=0.79*** b=1.8
2	r=0.75*** b=0.77		
3	r=0.70*** b=0.61		
4	r=0.58*** b=0.51	(4)	r=0.76*** b=1.5
5	r=0.47*** b=0.26	(5)	r=0.64** b=0.25

The greatest rate of accumulation was found in reindeer from region (1) and (4). In moose, the rate decreased successively from region 1 to region 5. The liver and kidney samples were also analysed for their content of zinc, but these results are not reported here, only the relationship to cadmium. No significant correlations ($0.03<r<0.35$) were detected between the levels of cadmium and zinc in liver or kidneys.

The present investigation thus shows thatNorwegian cervides, in particular reindeer from Southern Norway, are considerably contaminated with cadmium. It also shows that cadmium accumulates with the age of animals,

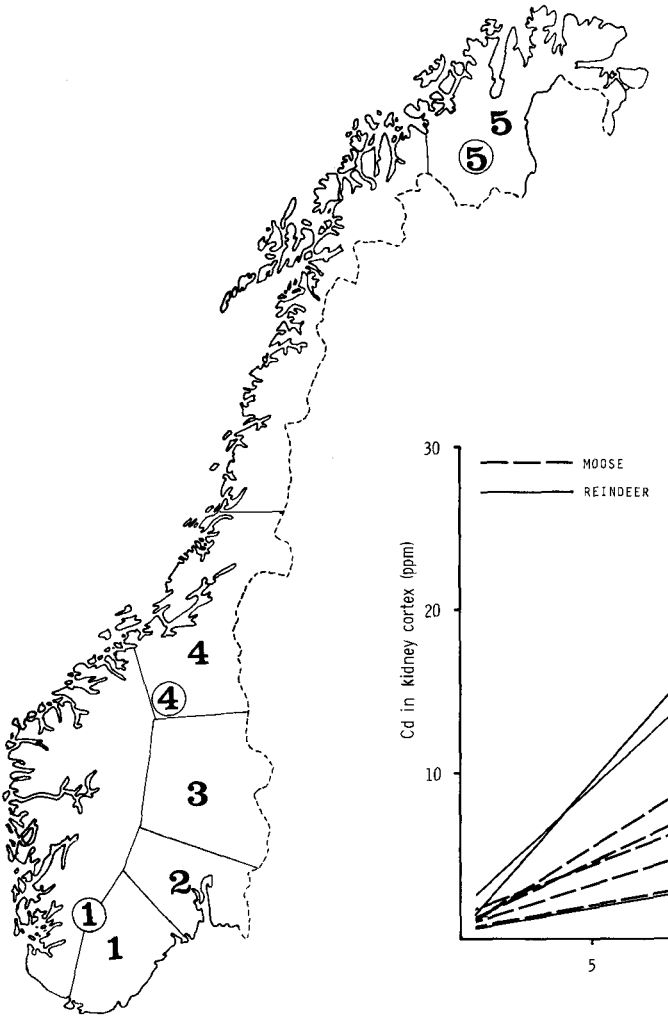

Figure 1 (left). Map of Norway illustrating roughly the regions where samples were collected. Region 1: The counties of Vest-Agder, Aust-Agder and Telemark; 2: Østfold, Vestfold, Buskerud and Akershus; 3: Hedmark and Oppland; 4: Sør-Trøndelag and Nord-Trøndelag; 5: Finnmark. The encircled numbers indicate the origin of reindeer samples: (1): The mountain plateau Hardangervidda; (4): Dovre; (5): Finnmarksvidda. Red deer originated from the coast in the south of region 4.

Figure 2 (right). Relationships between kidney cortex concentrations of cadmium and age in moose and reindeer. The graphes illustrate linear regression lines. The numbers indicate the origin of the samples (see Fig. 1.).

especially in the kidneys, and that the rate of accumulation in the kidneys is as good indicator of the levels of contamination. The most notable findings are, however, the north-south concentration gradients detected in moose, reindeer as well as roe deer. These findings support the indications found in a previous study, which only included a limited number of samples, that the southernmost parts of Norway are more heavily contaminated with cadmium than the northern regions (Frøslie et al. 1984). Similar regional differences have also been demonstrated in liver cadmium levels of lambs grazing natural pastures (Frøslie et al. 1985). Fimreite and Scanlon (pers. comm.) have also analysed liver and kidney samples from moose and roe deer from the county of Telemark (region 1) in 1983 and 1984. They found means of 16.4 ppm and 1.9 ppm on a dry matter basis in kidneys (n=52) and liver (n=56) of moose, and 11.7 ppm in kidneys (n=20) and 1.2 ppm in liver (n=22) of roe deer. Converted to wet weight basis, these results are quite similar to those found in the present investigation in samples from the same region.

The difference in cadmium levels between reindeer on the one hand and moose and roe deer on the other may be explained from differences in their nutritional habits. Reindeer from regions (1) and (4) feed mainly on lichens on mountain plateaus, while moose and roe deer, living in the deciduous and coniferous woods, feed mainly on annual grasses, herbaceous plants and foliage. Moose and roe deer also feed on coniferous trees. Slowly growing lichens are probably more contaminated than other plants with cadmium, just as they are with mercury (Steinnes and Krog 1977). Reindeer from region (5) are semidomestic and nomadic, i.e. they graze grasses and herbaceous plants at the coast in the summer, while they are moved to the inland plateau in Finnmark in the winter, where their diet consists mainly of lichens. This migration to the coast in the summer may explain why these reindeer have a cadmium burden which is no greated than moose from the same region.

Grouse (Lagopus lagopus) from the Hardangervidda (region (1)) are also highly contaminated with cadmium (Holt et al. unpublished results) with a median of 7.0 ppm ww (n=10) in liver, while hares (Lepus timidus) from southern Norway (region 1, 2 and 3), living in a woodland habiat, had medians of 0.6 ppm in liver (n=52) and 6.1 ppm (n=49) in kidneys. It therefore seems that herbivorous animals from southern Norway are in general significantly contaminated with cadmium.

From Sweden Frank et al. (1981), Mattsson et al.

(1981), Frank and Petersson (1984) and Frank (pers. comm.) have reported cadmium determinations in more than 4,000 wild animals, mainly moose. In general, significantly higher levels were detected in Swedish moose compared with those found in Norway. The regression coefficient between age and kidney concentrations in moose from the south of Sweden was close to double that found in moose from southern Norway. Levels of cadmium found in moose from Finland, however, are of the same magnitude as those found in Norway (Valtonen and Vikberg 1982). In six month old moose calves, the levels in kidneys were about 1 ppm ww, in 3 year old animals about 3 ppm, and in animals older than 5 years about 5 ppm. Liver levels were up to 0.3 ppm in calves and from 0.5-0.6 ppm in older animals. There were no significant regional differences in the contamination in Finish moose. Finish reindeer had a mean of 0.88 ppm ww in kidneys and 0.19 ppm in liver (Salmi and Hirn 1981). These levels are considerably lower than those detected in reindeer from Norway. The Finish reindeer were, however, very young (78% less than six months old). Furthermore, reindeer in Finland feed mainly in forests, and not on mountain plateaus as do reindeer from southern Norway included in this study, which may explain differences in the cadmium burden.

Hecht et al. (1984) have recently reported cadmium levels in liver and kidneys of roe deer from south German areas. They found medians of 0.12 ppm ww in liver and 0.80 ppm in kidneys, about half the levels found in samples from Norwegian roe deer. They also demonstrated accumulation with age, the oldest age group having levels of 0.18 and 2.44 ppm in liver and kidney, respectively. Differences between districts, related to local contamination, were also detected. There are several other reports on cadmium levels in wild ruminants from Central Europe, e.g. Anke (1979), Holm (1979) and Backhaus and Backhaus (1983).

In general, it seems that Norwegian cervides, and also some other herbivorous wild animals, have a burden of cadmium comparable to, or even higher than, those found in Central Europe in areas which are not locally contaminated. Reindeer from Svalbard are also quite heavily burdened with cadmium (Norheim et al. unpublished results), with medians of 0.6 ppm ww in liver (n=55) and 3.3 ppm in kidneys (n=44). Both these findings indicate a general contamination that may be of long distance origin. In addition, the north-south gradient detected in Norway (and also in Sweden) fits very well with data for acid precipitation (Overrein et al. 1980), atmospheric fall-out (Hansen et al. 1980) and concentration gradients of cadmium in Norwegian surface soils (Allen and Steinnes 1980), ombrotrophic

bogs (Hvatum et al. 1983) and coniferous ecosystems (Solberg and Steinnes 1983). It is, therefore, reasonable to associate the demonstrated cadmium contamination of Norwegian herbivorous wild animals with acid precipitaion and/or atmospheric fall-out of mainly distant origin.

There are no indications of any toxic effects of the cadmium levels detected in Norwegian cervides. According to recommendations by Hecht et al. (1984), organs of adult roe deer from Germany should not be considered as fit for human consumption. Though similar recommendations may also be indicated in Norway, there is no health hazard involved in the consumption of meat from wild ruminants.

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REFERENCES

Allen RO, Steinnes E (1980) Contribution from longrange atmospheric transport to the heavy metal pollution of surface soil. In: Drabløs D, Tollan A (eds) Ecological impact of acid precipitation. SNSF project, Oslo-Ås, pp 102-103

Anke M, Grün M, Briedermann L, Missbach K, Henning A, Kronemann H (1979) Die Mengen- und Spurenelementversorgung der Wildwiederkauer.1.Mitt. Arch Tierernähr 29:829-844

Backhaus B, Backhaus R (1983) Die Cadmium-Belastung des Rehwildes in Eggegebirge. Z Jagdwiss 29:213-217

Frank A, Petersson L (1984) Assessment of bioavailability of cadmium in the Swedish environment. Fresenius Z Anal Chem 317:652-653

Frank A, Petersson L, Mörner T (1981) Bly- och kadmiumhalter i organ från älg, rådjur och hare. Sv Vet T 33:151-156

Frøslie A, Norheim G, Rambæk JP, Steinnes E (1984) Levels of trace elements in liver from Norwegian moose, reindeer and red deer in relation to atmospheric deposition. Acta vet scand 25:333-345

Frøslie A Norheim G, Rambæk JP Steinnes E (1985) Heavy metals in lamb liver: Contribution from atmospheric fallout. Bull Environ Contam Toxicol 34:175-182

Hanssen JE, Rambæk JP, Semb A, Steinnes E (1980) Atmospheric deposition of trace elements in Norway. In: Drabløs D,Tollan A (eds) Ecological impact of acid precipitation. SNSF project, Oslo-Ås, pp. 116-117

Hecht H, Schinner W, Kreuzer W (1984) Endogene und exogene Einflusse auf die Gehalte an Blei und Cadmium in Muskel- und Organproben von Rehwild. 1. Mitt.

Fleischwirtsch 64:838-845,967-970
Holm J (1979) Blei-, Cadmium- und Arsengehalte in Fleisch und Organproben von Wild aus unterschiedlich schadmetallbelasteten Regionen. Fleischwirtsch 59:1345-1349
Hvatum OØ, Bølviken B, Steinnes E (1983) Heavy metals in Norwegian ombrotrophic bogs. In: Hallberg R (ed) Environmental biochemistry Ecol Bull Stockholm, 35:351-356
Mattsson P, Albanus L, Frank A (1981) Kadmium och vissa andra metaller i lever och njure från älg. Vår Föda 33:335-345
Nissen Ø (1982) Statistikkprogram for CP/M-maskiner. Agricultural University of Norway. Report No 202. Institutt for plantekultur, 55 pp
Overrrein LN, Seip HM, Tollan A (1980) Acid precipitation-effects on forest and fish. Final report of the SNFS-project 1972-1980, Oslo-Ås 175 pp
Reimers E, Nordby Ø (1968) Relationship between age and tooth cementum layers in Norwegian reindeer. J Wildl Mgmt 32:957-961
Salmi A, Hirn J (1981) The cadmium content of muscle, liver and kidney from Finnish horse and reindeer. Fleischwirtsch 61:4-5
Solberg W, Steinnes E (1983) Heavy metal contamination of terrstrial ecosystems from long-distance atmospheric transport. In: Proc Conf Heavy Metals in the Environment, Heidelberg. CEP Consultants, Edinburgh, pp 170-173
Steinnes E, Krog H (1977) Mercury, arsenic and selenium fall-out from an industrial complex studied by means of lichen transplants. Oikos 38:160-164
Valtonen M, Vikberg P (1982) Höga kadmiumhalter i älgens lever, njurar och vinternäring. Jägaren (6):20-21
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