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Heavy Metals in Lamb Liver: Contribution from Atmospheric Fallout

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Local and distant sources of air pollution may contribute significantly to the heavy metal load of natural terrestrial ecosystems. Heavy metal contamination of natural surface soils from atmospheric deposition may be pronounced even at very long distance from the major source region (Allen and Steinnes 1980; Steinnes 1984). Plants growing in areas affected by heavy metal deposition may get elevated levels of these metals by uptake from the contaminated soil or from direct deposition on the leaves (Tjell et al. 1979). Herbivorous animals feeding on the plant material may in turn receive an increased body burden of the metals concerned.

In Norway the atmospheric deposition of lead, cadmium, and some other relatively volatile trace elements is about tenfold higher in the southernmost part of the country than in the more northerly regions, mainly due to long-distance atmospheric transport from other parts of Europe (Hanssen et al. 1980). A very similar trend is shown to be evident for the geographical distribution of the same elements in natural surface soils (Allen and Steinnes 1980) and vegetation from coniferous forest ecosystems (Solberg and Steinnes 1983). The present study was carried out in order to see if similar regional differences were detectable in the heavy metal load of domestic animals grazing on natural pasture land in different parts of Norway.

MATERIALS AND METHODS

The study was focused on lambs born during the period of April - May of 1979 and left with their mothers for the summer season (normally June - September) on natural pastures in mountains and other wilderness areas. Eleven localities distributed throughout the country were selected for this study, as shown in Fig. 1. During the slaughtering season (October - November) liver samples were obtained from suitable livestocks by the aid of local veterinarians. These lambs which were of nearly the same age had been fed on mothers milk and grass from unfertilized land during almost their entire life-span. Five samples were selected from each locality and submitted to the analytical laboratories in a frozen state.

The concentration of arsenic, mercury, molybdenum, and selenium in the liver samples were determined by radiochemical neutron activation analysis (Steinnes 1975). Copper and zinc were determined by flame and cadmium and lead by graphite furnace atomic absorption spectrometry, after a nitric acid/perchloric acid and nitric acid decomposition,respectively. The standard addition technique was employed in the graphite furnace analyses.

RESULTS AND DISCUSSION

The atmospheric deposition pattern in Norway for the elements studied in this work except mercury is known from an extensive study of moss samples from more than 500 sites all over the country, supplemented by analyses of precipitation collected in a limited number of stations (Rambæk and Steinnes 1980; Hanssen et al. 1980). As an example relative deposition figures for lead, expressed as ppm Pb in the forest moss *Hylocomium splendens*, are presented in Fig. 1 for the eleven sites selected in the present work. The deposition figures in the southern and south-western parts of Norway are substantially higher than those for Central and Northern Norway as indicated above. The elements arsenic, cadmium, and selenium show similar distribution trends, whereas the north - south gradient is not so pronounced for molybdenum and zinc and even lower for copper.

Mean values and ranges of the eight elements concerned in lamb liver are shown in Table 1 for all eleven locations. Correlation coefficients for lamb liver content versus atmospheric deposition are the following:

Pb : 0.94***	Mo : 0.30
Cd : 0.78**	Zn : 0.04
Se : 0.73**	Cu :-0.21
As : 0.66*	

The results strongly indicate that there is a relation between atmospheric deposition and intake of lead in the lambs. Also for cadmium and selenium, and even for arsenic, a similar connection is indicated. For the elements molybdenum, zinc and copper the atmospheric deposition does not appear to be a significant source of supply. These relations are further illustrated in Fig. 2 where corresponding lamb liver and relative

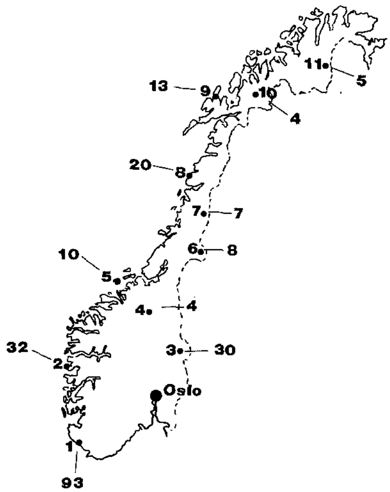

Figure 1. Location of eleven areas in Norway selected for the present work, and relative figures for the atmospheric deposition of lead expressed as ppm Pb in moss.

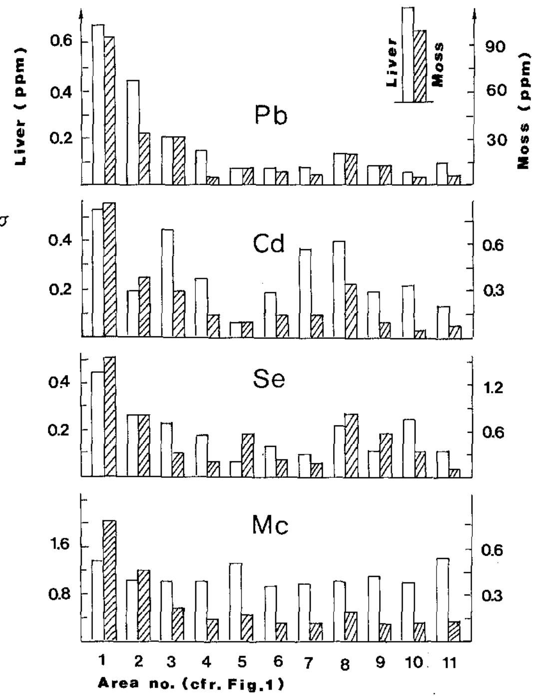

Figure 2. Comparison of trace element deposition (expressed as ppm in moss) with concentration in lamb liver (ppm wet weight), at the eleven different localities indicated in Figure 1.

deposition values of lead, cadmium, selenium, and molybdenum are shown for all sites. The excess intake of some elements in areas more exposed to air pollution may not only be due to the metal concentration of grass and other plant material, but could also be affected by ingestion of soil (Healy 1976) since surface soils show a contamination pattern very similar to the atmospheric deposition pattern for several of the elements. A possible connection between heavy metals in precipitation and metal intake in animals was also indicated in a recent study of kidneys from cattle in Denmark (Gydesen and Rasmussen 1981). For mercury the geographic deposition pattern is not very well known, but the results do indicate regional differences in the supply of mercury to lambs. In general the mercury contents are higher in Southern Norway, but also certain locations further north (nos. 6 and 10) show values somewhat in contrast to the very low level present in material from other sites in the North (5, 8, 9, 11).

In Table 2 the present values from Southern Norway for zinc, cadmium, and mercury are compared with data from a somewhat similar investigation in Bavaria, FRG (Knöppler et al. 1979). According to recent measurements (Nürnberg et al. 1982) the wet deposition levels for lead and cadmium in rural areas of FRG not strongly affected by local industry are similar to those registered in southernmost Norway (Hanssen et al. 1980). It is therefore not surprising that the average levels of lead in lamb liver are the same in Bavaria and Southern Norway. Also for mercury the similarity between the two regions is rather high, whereas for cadmium the Bavarian values are almost an order of magnitude lower. The mobility of cadmium in soils is known to be very dependent of the soil pH, and it is possible that differences in soil properties between the two regions leading to different uptake of cadmium in plants may account for the distinctly higher cadmium values in Norwegian lamb liver. The trace element concetrations observed in the present material do not represent any toxicological problem from a veterinary point of view, neither do they imply any warning against using for human consumption lamb liver from the areas most severly affected by atmospheric deposition. The enhanced uptake of cadmium in Southern Norway and the strong accumulation of this element in kidneys (Knöppler et al. 1979) suggest the need for a more general study of cadmium accumulation in sheep and wild ruminants in different parts of Norway (Holt et al. 1983).

As far as selenium is concerned, elevated levels in lamb liver from Southern Norway compared to other regions of the country was also observed in an independent study (Frøslie et al. 1980). Selenium is important in sheep nutrition in Norway because of the occurence in some regions of nutritional muscular dystrophy known to be associated with selenium deficiency. The concentrations of about 0.15 ppm Se or below apparently typical for sheep liver in most parts of Norway are quite close to the level where deficiency symptoms may occur. It is thus possible that the extra selenium supply occurring in Southern and Southwestern Norway due to long-distance atmospheric transport of polluted air may play a beneficial role in this respect.

Previous studies of selenium in natural surface soils in Norway have shown that significantly higher concentrations occur in coastal areas than in districts further inland (Låg and Steinnes 1974, 1978), even in parts of the country not receiving appreciable input of atmospheric pollutants. This trend is also revealed in the regional deposition study based on moss analysis

Table 1. Mean values (n=5) and ranges of eight trace elements in lamb liver (wet weight) from eleven different localities in Norway

Locality	Cu ppm	Zn ppm	As ppb	Se ppm	Mo ppm	Cd ppm	Hg ppb	Pb ppm
1. Lund/Sokndal	73 16-119	42 36-49	2.6 1.8-3.6	0.44 0.26-0.50	1.35 1.24-1.46	0.54 0.17-0.85	14 7-26	0.67 0.52-0.81
2. Lindås/Manger	79 53-118	58 48-70	3.1 2.2-3.8	0.26 0.15-0.40	0.98 0.70-1.42	0.19 0.04-0.34	11 7-18	0.44 0.27-0.53
3. Trysil	106 70-138	32 22-37	2.8 1.0-4.7	0.23 0.12-0.37	1.00 0.64-1.61	0.45 0.32-0.63	24 1-60	0.20 0.10-0.33
4. Dovre/Dombås	81 57-118	43 36-47	1.8 0.9-2.7	0.17 0.05-0.26	1.00 0.85-1.09	0.24 0.16-0.39	22 2-50	0.14 0.11-0.19
5. Smøla	41 29-55	45 43-49	2.0 0.9-3.7	0.06 0.04-0.07	1.30 1.09-1.59	0.06 0.03-0.08	5 4-7	0.07 0.04-0.15
6. Lierne	83 30-126	39 33-47	1.5 1.0-2.3	0.13 0.08-0.17	0.92 0.58-1.25	0.18 0.09-0.31	51 9-100	0.07 0.04-0.09
7. Hattfjelldal	122 87-135	47 35-61	1.3 0.8-2.0	0.10 0.06-0.12	0.97 0.83-1.10	0.38 0.07-1.08	3 1-7	0.07 0.04-0.09
8. Lurøy/Meløy	56 18-105	51 37-70	2.4 1.0-3.8	0.22 0.10-0.39	1.00 0.87-1.11	0.41 0.15-0.60	5 1-7	0.13 0.07-0.18
9. Andøya/Sortland	45 21-88	39 35-46	1.3 1.0-1.8	0.11 0.08-0.13	1.10 0.89-1.28	0.19 0.14-0.32	3 1-7	0.07 0.05-0.13
10. Målselv	87 55-150	37 33-39	1.1 0.8-1.8	0.28 0.24-0.35	0.98 0.81-1.20	0.22 0.16-0.30	37 22-53	0.05 0.03-0.07
11. Karasjok	30 13-68	41 39-44	1.1 0.9-1.4	0.11 0.07-0.22	1.40 0.91-1.76	0.13 0.09-0.17	3 2-6	0.09 0.05-0.12

Table 2. Comparison of lead, cadmium and mercury values from the present work (ppm wet weight) with Bavarian data (Knöppler et al. 1979) and some recent data from Southern Norway (Mjør-Grimsrud et al. 1983)

Region		Lead		Cadmium		Mercury	
		Lamb	Sheep	Lamb	Sheep	Lamb	Sheep
Southern Norway (Areas 1 - 3)	Liver, mean	0.44		0.39		0.016	
	range	0.10-0.81		0.04-0.85		0.01-0.060	
Northern Norway (Areas 9 - 11)	Liver, mean	0.07		0.18		0.004 1)	
	range	0.03-0.13		0.09-0.32		0.001-0.007	
Southern Norway (Literature data)	Liver, mean		0.55		0.27		0.01
	range		0.10-1.5		0.14-0.44		<0.01-0.04
	Kidney, mean		0.33		0.60		0.02
	range		0.29-0.39		0.28-1.1		<0.01-0.09
Bavaria (Agricultural and industrial areas)	Liver, mean	0.40	0.33	0.049	0.082	0.016	0.011
	range	0.01-2.08	0.05-0.78	0.005-0.168	0.013-0.192	0.002-0.078	0.003-0.048
	Kidney, mean	0.32	0.19	0.092	0.33	0.046	0.021
	range	0.03-1.35	0.02-0.39	0.017-0.46	0.022-0.74	0.005-0.200	0.009-0.092

1) Areas 7, 8, 9, 11

(Rambæk and Steinnes 1980), as illustrated e.g. by the relatively high figures for moss i Fig. 2 for location 5, 8 and 9. A similar trend is not observed in the lamb liver.

The copper load of sheep is not only dependent on the levels of copper in the forages, but is highly dependent on levels of interfering elements like sulphur, zinc, and especially molybdenum. Molybdenum is a metabolic antagonist to copper and high levels of molybdenum induce copper deficiency while low levels of molybdenum induce copper poisoning (Blood et al. 1983). The copper status of sheep is therefore more related to the Cu:Mo ratio than the levels of the single elements.

Sheep in the inland districts of Norway are generally heavily loaded with copper (Frøslie 1977) and chronic copper poisoning is well known in these districts. It seems that this accumulation is mainly caused by low levels of molybdenum in the forages (Frøslie and Norheim 1983). It is, therefore, not surprising that there is no correlation between the copper levels in lamb liver and atmospheric deposition. Even for molybdenum, however, there is only a weak but insignificant correlation between the content in lamb liver and the atmospheric deposition. Likewise there is no correlation ($r = -0.20$) between copper in lamb liver and the Cu:Mo ratio in deposition. It must therefore be concluded that atmospheric deposition probably does not play a role in connection with chronic copper poisoning in sheep in Norway.

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