Radiocesium in lichens and reindeer after the Chernobyl accident

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Abstract: After the Chernobyl accident the sampling and measuring program of the Finnish Centre for Radiation and Nuclear Safety was intensified both for surveillance and research purposes. The deposition pattern of radionuclides was more complicated than from the global fallout after the nuclear weapons tests. The radioactive deposition was very unevenly distributed in Lapland, as also in the rest of Finland. Fortunately, the amounts of deposition in Lapland were only about one-tenth of the corresponding amount of deposition in southern Finland. In 1986-87 the mean concentration of Cs-137 in lichens and in reindeer meat increased to about the same level as in 1972-73 or to about 30 per cent of the maximum levels found in 1964-65 after the nuclear weapons tests. The activity concentrations in reindeer tissues vary according to season. In winter, reindeer eat considerable amounts of lichens with high radiocesium concentrations. In summer, lichens are replaced by other forage such as leaves from trees, green plants, etc. The ratio of Cs-137 concentration in reindeer meat between summer and winter is about 0.2. The mean concentration of Cs-137 in meat for consumption from the slaughtering period 1986-87 was 720 Bq/kg fresh weight. After that time concentrations started decreasing since no new fallout was deposited.

Key words: Cs-137, seasonal variation, Lapland

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Introduction

The radiocesium concentrations in lichens and reindeer were studied intensively in Finland (Miettinen and Häsänen, 1967, Rahola and Miettinen, 1977) as in other countries in the 60s and 70s (Åberg and Hungate, 1967) after the deposition of radioactive fallout originating in the atmospheric nuclear weapons tests. During the late 70s and the first half of the 80s samples from subarctic regions were taken and results reported were more sporadic than before. In Finland, the Finnish Centre for Radiation and Nuclear Safety has operated a laboratory at Rovaniemi on the Arctic Circle since 1970. This laboratory collected samples of lichens and other fodder plants eaten by reindeer, sampled reindeer tissues, fish and game in the 70s and early 80s (Rissanen et al., 1987). The intention of this sampling was to follow changes in radioactivity levels in the foodchain lichen-reindeer-man; this foodchain is the most efficient in radiocesium enriching in Lapland.

After the Chernobyl accident a more regular and intensified sampling program was started for both surveillance and research purposes. The radioactive deposition was very unevenly

distributed in Lapland, as also in the rest of Finland. Fortunately, the amounts of deposition in Lapland were only about one-tenth of the corresponding amount of deposition in southern Finland (Arvela et al., 1987). Also in Norway (Bye, 1988, Gaare, 1986) and Sweden (Skålberg et al., 1987, Åhman et al., 1988) many investigations of lichens and reindeer were performed after the accident.

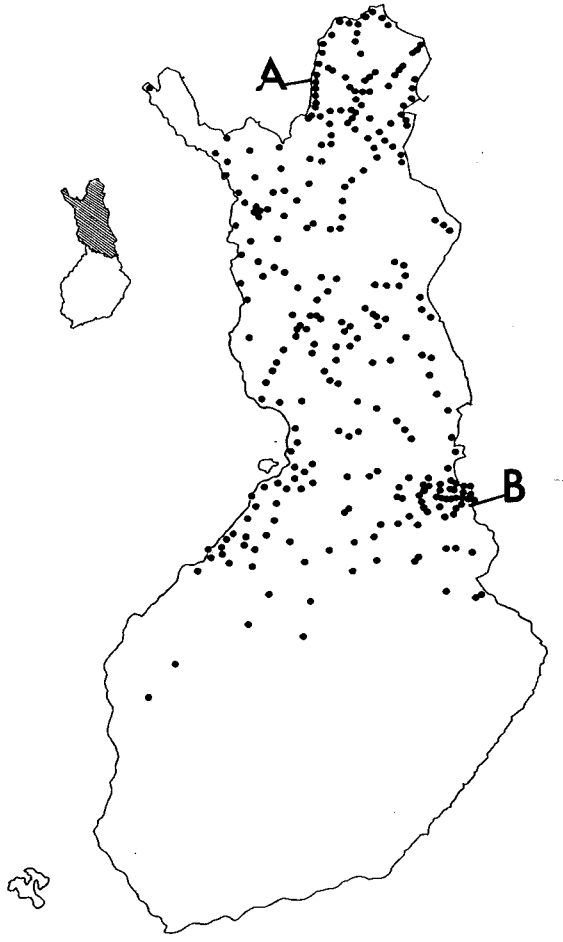

Fig. 1. Sampling locations for reindeer lichen in 1986 - 1987. All samples from the reindeer herding area (lined on the inserted map) are indicated but south of that area only the communities from which samples were taken. Results for the sample square collected from location A (Inari) are given in Table 1 and for those from location B (Kuhmo) in Table 2.

Material and methods

Lichen samples were collected by the Rovaniemi laboratory annually after the accident at Chernobyl. The collection locations for reindeer lichen are shown in Fig. 1. During 1986 and 1987 altogether 450 lichen samples were collected from the reindeer herding area and 200 samples south of this area. The species collected were *Cladonia stellaris*, *Cladonia mitis* and *Cladonia rangiferina*, the most important ground lichen species used as winter fodder by the reindeer (Fig. 2).

Fig. 2. 1) *Cladonia stellaris* a) whole, b) cleaved, 2) *Cladonia mitis* and 3) *Cladonia rangiferina*

After the Chernobyl accident about 11000 reindeer meat samples from all over Lapland were taken during the slaughtering season 1986-87 for surveillance and research purposes, and 4000 samples during the slaughtering season 1987-88. About 130 000 animals were slaughtered from a total of about 360 000 during each of these seasons.

All plant samples were dried and homogenized before the gammaspectrometric measurements. The meat samples were measured either fresh or dried and always homogenized. The measurements were performed with HPGe or GeLi detectors as described by Rissanen et al. (1987). All results presented are for plants given in Bq/kg dry material and for meat in Bq/kg fresh material.

Results

The Cs-137 concentrations in lichens collected in 1986 and 1987 from the reindeer herding area are presented in Fig. 3. The mean concentration in these lichen samples was 900 Bq/kg in 1986 and 800 Bq/kg in 1987, the concentrations varying from 200 to 2100 Bq/kg in both years. In Fig. 4, the Cs-137 concentration in lichen for the period 1961 to 1987 is presented. Only in Halla in a small corner (area V in Fig. 6) of the southeasternmost part of the reindeer herding district was the Cs-137 concentration in lichen higher, varying from 3 000 to 10 000 Bq/kg. Further south, Cs-137 concentrations even higher than 50 000 Bq/kg dry weight were measured, but fortunately no reindeer herding takes place at those locations.

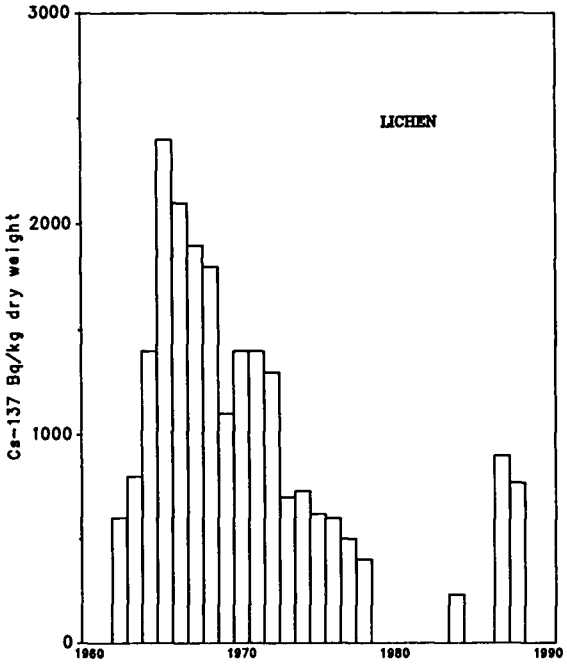

Fig. 3. Concentrations of Cs-137 (Bq/kg dry weight) in lichen collected in 1986 and 1987 from the reindeer herding area.

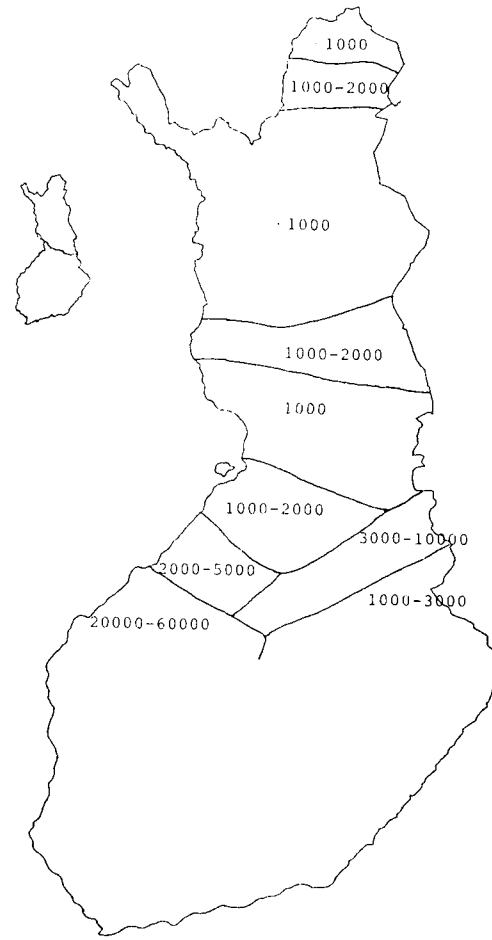

Fig. 4. Concentrations of Cs-137 (Bq/kg dry weight) in lichen from Lapland from 1960 to 1987.

In different lichen species collected from the same location, differences in activity concentrations could be detected as shown in Table 1 and 2. In *Cladonia stellaris* the activity was distributed so that the concentration in the top layer of the lichen was twice the concentration in the middle layer. The Cs-137 concentration in the whole lichen was about 70 per cent of that in the top layer. The amount of Cs-134 was 140 Bq/m^2 and of Cs-137 1200 Bq/m^2 calculated as a sum for all three *Cladonia* from Inari (marked A on map in Fig.6). The amount of Cs-134 was 3300 Bq/m^2 and of Cs-137 9200 Bq/m^2, calculated as a sum for all three *Cladonia* from Kuhmo (marked B on map in Fig. 6) to the south of the reindeer herding area. (Note: These figures include debris and top soil.)

Table 1. Measured Cs-134 and Cs-137 concentrations (Bq/kg dry weight) in different parts of three *Cladonia* species collected in 1987 at Muotkatunturi, Inari. The sampled area was 0.5 m^2.

Part of lichen	*Cladonia stellaris*		*Cladonia mitis*		*Cladonia rangiferina*	
	^{134}Cs	^{137}Cs	^{134}Cs	^{137}Cs	^{134}Cs	^{137}Cs
Top layer	340	1400	—[a]	—	—	—
Middle layer	130	610	—	—	—	—
Lower layer	89	450	—	—	—	—
Whole lichen	190	850	150	870	180	870
Debris[b]			54	510		
Top soil[b] 1-2 cm			0[c]	160		

[a]not separated into layers
[b]debris and top soil from the sampled area 0.5 m^2
[c]below detection limit

Table 2. Measured Cs-134 and Cs-137 concentrations (Bq/kg dry weight) in different parts of three *Cladonia* species collected in 1987 at Lipukkajärvi, Kuhmo. The sampled area was 0.25 m^2.

	Cladonia stellaris		*Cladonia mitis + rangiferina*	
	^{134}Cs	^{137}Cs	^{134}Cs	^{137}Cs
Top layer	4100	11000	—[a]	—
Middle layer	2200	6000	—	—
Lower layer	1800	4800	—	—
Whole lichen	3000	8100	3300	8800
Debris[b]	1340	3600		
Top soil[b] 1-2 cm	200	730		

[a]not separated into layers
[b]debris and top soil (1-2 cm) from the sampled area 0.25 m^2

Cs-137 concentrations in reindeer meat since 1960 are presented in Fig. 5, the highest concentration, 2600 Bq/kg, being measured in 1964. The meat still contained 300 Bq/kg in 1985-86. After the Chernobyl accident in the winter of 1986-87 the level was 720 Bq/kg and

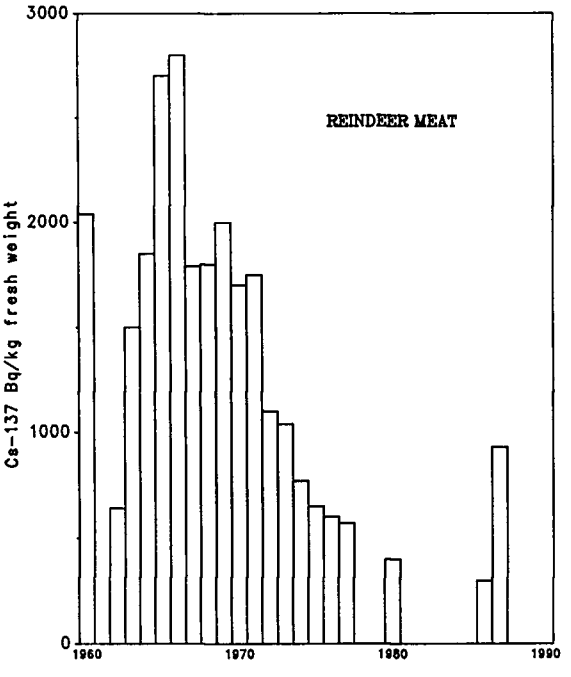

Fig. 5. Concentrations of Cs-137 (Bq/kg fresh weight) in reindeer meat in 1960 - 1987. The meat samples were collected during the first quarter of the year.

one year later 640 Bq/kg fresh weight. In the Halla area (area V in Fig. 6), the concentrations were higher and therefore samples were taken from each slaughtered reindeer for surveillance purposes.

The Cs-137 concentrations, Bq/kg fresh weight in reindeer meat, in the five areas (Fig. 6) of the reindeer herding district from June 1986 to March 1988 are presented in Fig. 6. The seasonal variation can be clearly seen in this figure. The Cs-137 concentration in summer is about 20 per cent of that of the winter maximum.

Discussion

The higher radiocesium concentrations in lichen in region V of the reindeer herding area result in higher radiocesium concentrations also in reindeer tissues. Only less than 1 per cent of all Finnish reindeer live in this region with a tenfold radiocesium deposition compared to the rest of the reindeer herding area. Samples from every reindeer slaughtered in area V were taken. Based on these sample measurements it was decided whether the meat could be delivered for consumption or not.

The activity concentrations in reindeer tissues vary largely from one season to another due to the composition of the diet of the reindeer. During winter, the semidomestic reindeer eat considerable amounts of lichen. Lichens contain higher amounts of activity than other forage. In summer, when the reindeer start eating tree leaves and green plants, the activity concentration in the meat decreases rapidly. In Finland, the main slaughtering period of reindeer is from October to January. From Fig. 6 it can be seen that this period is more favourable for slaughtering than would be the period December to March regarding activity concentrations.

After the Chernobyl accident the Cs-137 concentrations in reindeer tissues varied much more than before the accident depending on sampling location. This was a consequence of the unevenly distributed deposition and a similar variation could be found all over Finland. Thus it is important to have detailed knowledge of the factors influencing activity concentrations in sampled foodstuffs before drawing conclusions about the necessity for restrictive measures to protect the population from receiving unacceptably high radiation doses.

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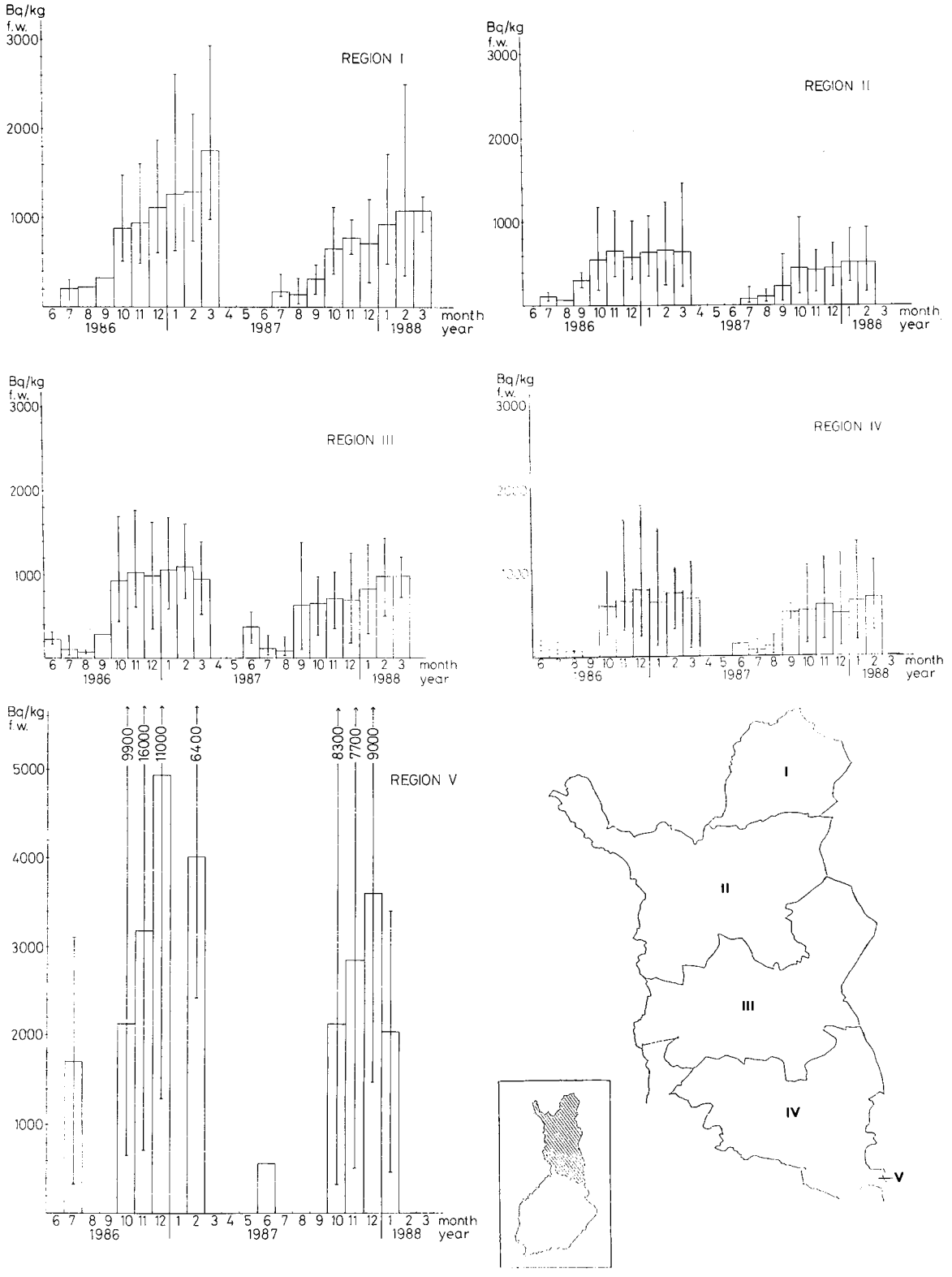

Fig. 6. Concentrations of Cs-137 (Bq/kg fresh weight) in reindeer meat from five different regions of the reindeer herding area from June, 1986 to March, 1988.

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