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^{137}Cs in uncultivated pastures in the Faroe Islands 1990-2003

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INTRODUCTION

Radioactivity from ^{137}Cs has been studied in Faroese soil, grass and lamb meat during the years 1990-2003. Levels and trends are presented together with estimates of transfer factors and effective ecological halflives. The ^{137}Cs contamination derives from the nuclear weapons tests in the 1950's and 1960's and from the reactor accident in Chernobyl in 1986.

The Faroe Islands comprise 18 islands in the North Atlantic Ocean between 61°20'N and 62°24'N and 6°15'W and 7°41'W. The total land surface area is 1399 km^2, and the number of inhabitants is about 47000. The climate changes gradually from cool temperate oceanic at the sea level to arctic in the mountains, of which the highest is 882m asl. (Cappelen & Laursen, 1998; Mortensen, 2002). The annual precipitation varies across the country, from about 800mm to about 3300mm as registered at synoptic weather stations below around 200m asl.

MATERIAL AND METHODS

Soil, grass and lamb meat have been sampled once a year from nine uncultivated pastures during the years 1990-2003. Soil and grass were sampled in July-August from four randomly chosen 0.25m^2 plots in each pasture. The grass was cut from the plots before taking three soil cores with 5.7cm diameter and a length of 10cm. Samples from the plots were measured separately. Neck muscle was collected from typically 5 lambs in each pasture at slaughter in October. The lamb carcass weight was around 12-13kg.

Soil samples were dried at room temperature, while grass samples were dried at 105°C. Meat samples were kept frozen, and thawed before individual measurement. Activity measurements were carried out with a lead shielded Germanium detector.

The loss on ignition, pH, easily soluble potassium and sodium were measured on the soil samples. Sodium and potassium were extracted with 1 M NH_4Ac, and measured with a flame-photometer. Loss on ignition was measured by heating to 520°C for 24 hours, and pH was measured in a 40% water solution of soil.

RESULTS AND CONCLUSIONS

^{137}Cs in soil, grass and lamb meat

The level of ^{137}Cs deposition in the uppermost 10cm soil layer ranged from 2000 to 8000 Bq/m^2 (Fig. 1). The levels declined considerably in some pastures, while they were more oscillating in others. The average across the pastures decreased from 5.4 kBq/m^2 in 1990 to 4.7 kBq/m^2 in 2003. 50-80% of the deposition was found in the upper 5 cm.

The soils are organic and acidic. The loss on ignition was 50-70% and pH was 4.4-5.3 (Joensen, 1999), reflecting conditions for high uptake of ^{137}Cs (e.g. Barber, 1964; Squire & Middleton, 1966).

The ^{137}Cs activity concentration in mixed grass decreased with time in most pastures (Fig. 2), though with considerable temporal and spatial variability. The highest and lowest concentrations were found in Hvalvík and Hvalba, respectively, with a difference of one order of magnitude in 1990. The average across the pastures was 144 Bq/kg(dw) in 1990 and 53 Bq/kg(dw) in 2003.

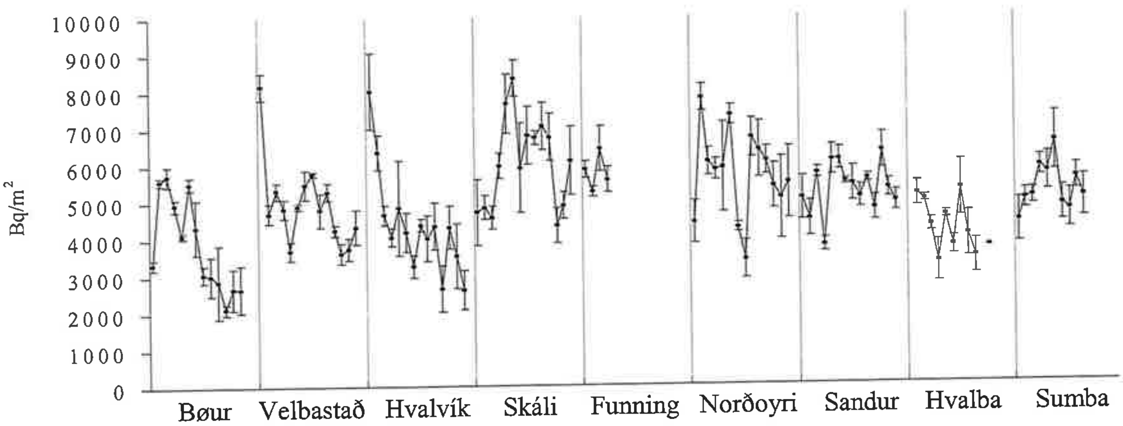

Figure 1. ^{137}Cs in 0-10 cm soil layer 1990-2003. Yearly averages ± 1 standard error.

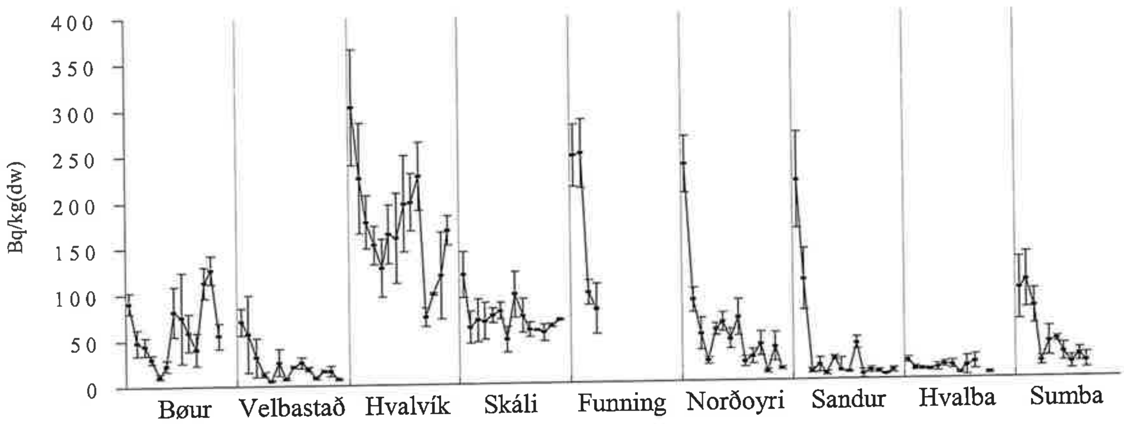

Figure 2. ^{137}Cs in mixed grass 1990-2003. Yearly averages ± 1 standard error.

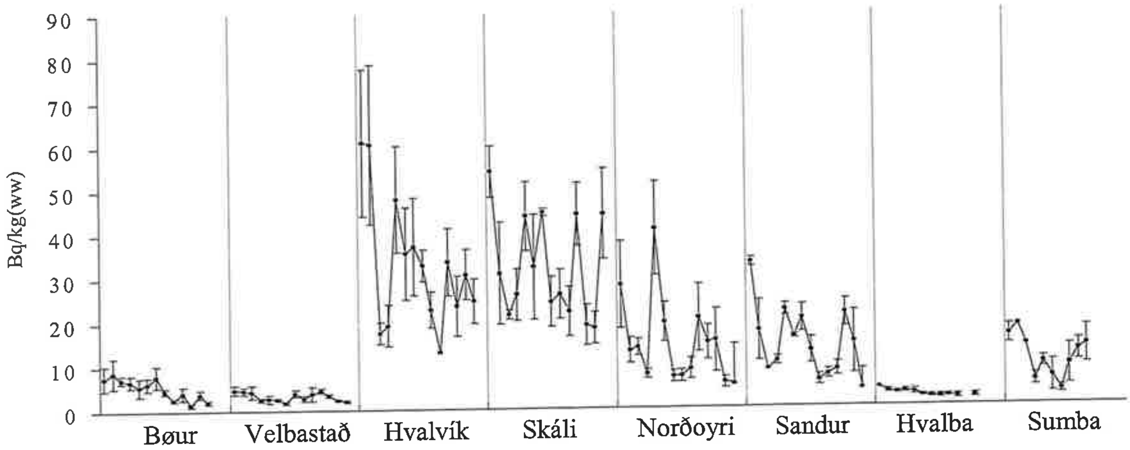

Figure 3. ^{137}Cs in lamb meat 1990-2003. Yearly averages ± 1 standard error.

The ^{137}Cs activity concentration in lamb meat varied widely within and between pastures (Fig. 3). The maximum difference between pastures was about one order of magnitude in 1990. The average across the pastures was 26.0 Bq/kg(ww) in 1990 and 16.0 Bq/kg(ww) in 2003.

Halflives

Effective ecological halflives (e.g. VAMP, 1992) are shown in Table 1. The estimates are based on linear regression between time and natural logarithm of yearly average ^{137}Cs activities.

Table 1. Effective ecological halflife in years. R^2 from linear regression between time and natural logarithm of ^{137}Cs activity is shown in brackets. No estimate is given when $R^2 < 0.300$.

	Bøur	Velbastað	Hvalvík	Skáli	Norðoyri	Sandur	Hvalba	Sumba
Meat	5.8	-	-	-	-	-	9.9	-
	(0.682)	(0.172)	(0.174)	(0.071)	(0.221)	(0.248)	(0.781)	(0.069)
Grass	-	6.8	-	-	4.8	4.0	-	3.6
	(0.121)	(0.327)	(0.293)	(0.188)	(0.536)	(0.419)	(0.150)	(0.667)
Soil	11.4	23.9	12.6	-	-	-	-	-
	(0.528)	(0.334)	(0.597)	(0.017)	(0.014)	(0.044)	(0.253)	(0.035)

Transfer factors

Soil-to-grass transfer factors for ^{137}Cs were calculated for every plot used for grass and soil sampling, as Bq/kg(dw) in grass divided by kBq/m^2 in the top 10cm soil layer (Fig. 4). Large variability is observed, both geographically and within the pastures. A decline with time is seen in some pastures. The highest values were found in Hvalvík, and the lowest in Hvalba. The minimum and maximum estimates for a pasture during the study period were $0.97 \cdot 10^{-3}$ m^2/kg(dw) and $64 \cdot 10^{-3}$ m^2/kg(dw), respectively.

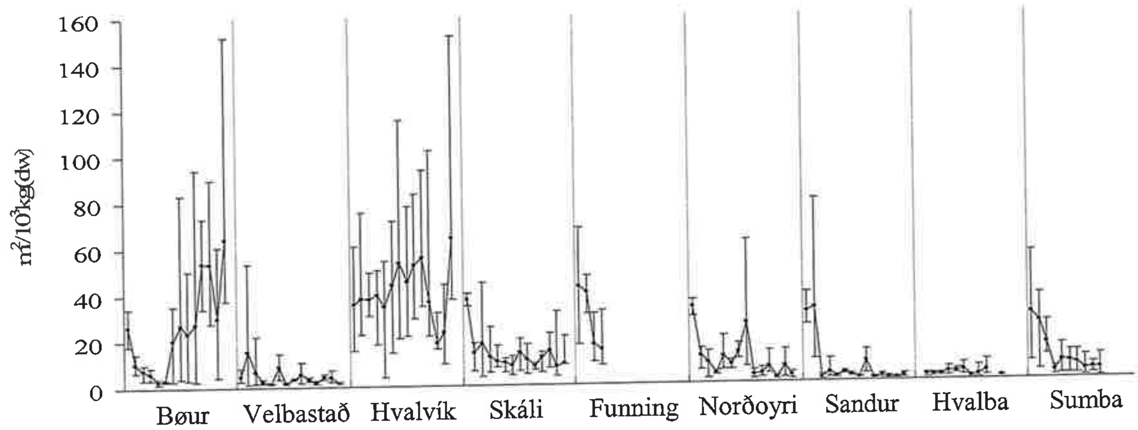

Figure 4. Soil-to-grass transfer factor for ^{137}Cs 1990-2003. Yearly averages and ranges.

Soil-to-meat aggregated transfer factors were calculated as the ratio between ^{137}Cs concentrations in individual meat samples and averaged ^{137}Cs deposition in the corresponding pasture (Fig. 5). The minimum and maximum estimates for a pasture during the study period were $0.33 \cdot 10^{-3}$ m^2/kg(ww) and $12.3 \cdot 10^{-3}$ m^2/kg(ww), respectively.

The averages across the pastures were as follows: the soil-to-grass transfer factor decreased from $30 \cdot 10^{-3}$ m^2/kg(dw) in 1990 to $24 \cdot 10^{-3}$ m^2/kg(dw) in 2003, and the soil-to-meat aggregated transfer factor decreased from $5.5 \cdot 10^{-3}$ m^2/kg(ww) in 1990 to $5.1 \cdot 10^{-3}$ m^2/kg(ww) in 2003.

Multiple linear regression between transfer factors and the four soil parameters pH, loss on ignition, easily soluble potassium and sodium in the top 10 cm soil showed that loss on ignition is the most significant soil parameter (Joensen, 1999). The regression coefficient was always negative for pH and potassium and positive for loss on ignition. This may partly explain that the highest and lowest soil-to-grass transfer factors (Fig. 4) are found in respectively Hvalvík (pH: 4.8; loss on ignition: 67%, potassium: 51.4 mg/100ml) and Hvalba (pH: 5.1; loss on ignition: 63%; potassium: 77.2 mg/100ml).

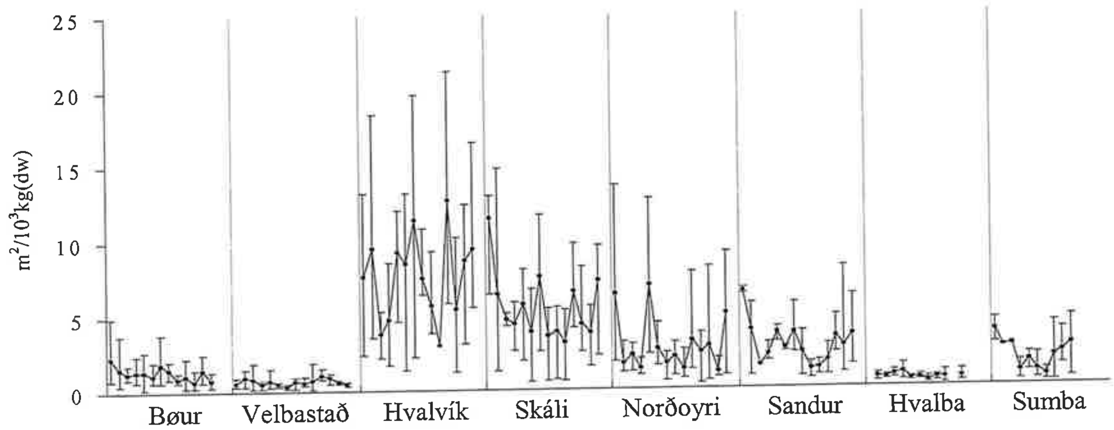

Figure 5. Soil-to-meat transfer factor for ^{137}Cs 1990-2003. Yearly averages and ranges.

Conclusions

The ^{137}Cs activities and transfer factors vary considerably both temporally and spatially, even though the Faroe Islands cover a small geographical area. Relatively fast early declines are observed in ^{137}Cs activity concentrations in grass and soil-to-grass transfer factors in some pastures, presumably due to declining inputs of ^{137}Cs from Chernobyl. An exponential decay model could be used for the ^{137}Cs activity in soil, grass and meat in a few pastures, whereas more non-monotonic decline was observed in other pastures.

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