

## MEASUREMENTS OF $^{137}\text{Cs}$ IN THE FOOD-CHAIN OF LAMB IN THE FAROE ISLANDS IN THE PERIOD 1990-99

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### Abstract

*Radiocaesium has been measured in the food-chain of lamb in nine uncultivated pastures in the Faroe Islands since 1990. The sampling programme includes soil from the uppermost 10 cm, mixed grass and lamb meat. Lamb faeces have been included since 1995. The results for the period 1990-99 show the following averages across the nine pastures: the  $^{137}\text{Cs}$  deposition decreased from 5.8 kBq/m<sup>2</sup> in 1990 to 5.1 kBq/m<sup>2</sup> in 1999; the  $^{137}\text{Cs}$  concentration in mixed grass decreased from 155 Bq/kg(dw) in 1990 to 51 Bq/kg(dw) in 1999; the  $^{137}\text{Cs}$  concentration in lamb meat decreased from 26.0 Bq/kg(ww) in 1990 to 10.4 Bq/kg(ww) in 1999. Large variations are, however, observed between as well as within the pastures. Averaged across the pastures, the soil-to-grass transfer factor decreased from  $30 \cdot 10^{-3}$  m<sup>2</sup>/kg(dw) in 1990 to  $13 \cdot 10^{-3}$  m<sup>2</sup>/kg(dw) in 1999, and the aggregated soil-to-lamb(meat) transfer factor decreased from  $5.5 \cdot 10^{-3}$  m<sup>2</sup>/kg(ww) in 1990 to  $2.0 \cdot 10^{-3}$  m<sup>2</sup>/kg(ww) in 1999. The effective ecological half-life of  $^{137}\text{Cs}$  in mixed grass and in lamb meat is estimated to be in the range 2.8-4.3 and 6.6-8.0 years, respectively.*

### Introduction

The Faroe Islands is a mountainous rocky country consisting of 18 islands at 62°N and 7°W. The total land surface area is about 1400 km<sup>2</sup>. Because of the Gulf Stream, the climate of the Faroes is milder throughout the year than the position of 62°N would normally permit. The yearly average air temperature is around 6-7 °C, and the average winter and summer air temperatures are around 3-4 °C and 9-10 °C, respectively (Lysgaard, 1969; Cappelen & Laursen, 1998). There are only minor temperature differences between different parts of the archipelago, but significant geographical variation are observed in precipitation rates because of combined effects from wind and topography. There are no woods in the Faroe Islands, but plenty of grass. About 94% of the land is reserved for grazing of around 70000 sheep and some cattle.

The paper presents results from measuring  $^{137}\text{Cs}$  in soil, grass and lamb meat in nine uncultivated pastures in the Faroe Islands for the years 1990-99. Effective ecological half-lives and transfer factors are presented. Chemical characteristics of the soil have earlier been considered in connection with the observations (Joensen, 1999). Faroese results for 1990-93 have been presented in a Nordic context by Hove *et al.* (1994).

### Material and methods

Soil, grass and lamb meat have been collected each year from nine uncultivated pastures across the country. Soil and grass were sampled in July-August from four randomly chosen 0.25m<sup>2</sup> microplots in each pasture. The grass was cut from each microplot before taking three soil cores with 5.7cm diameter and length 10cm. Samples from the microplots were measured separately. Neck muscle was collected from lamb at slaughter in October. Meat samples were typically taken from 5 lambs in each pasture (carcass weight around 12-13kg). Lamb faeces were collected for 1995-99 from fresh manure on the pasture ground, and measured as one sample per pasture each year. Soil samples were dried at room temperature, while grass and faeces were dried at 105 °C before measurement. Meat samples were kept frozen and thawed before individual measurement.

### Results and discussion

The  $^{137}\text{Cs}$  deposition in the uppermost 10cm soil layer is presented in Fig. 1, showing large temporal and spatial variation between and within the pastures. An exponential decay model was only acceptable for Hvalvík, where the effective ecological half-life (VAMP, 1992) was estimated to 11.6 years ( $R^2 = 0.51$ ).  $R^2$

was below 0.30 for other pastures. 50-80% of the deposition in the top 10 cm soil layer is found to be in the uppermost 5 cm. The  $^{137}\text{Cs}$  deposition, averaged across the pastures, decreased from 5.8 kBq/m<sup>2</sup> in 1990 to 5.1 kBq/m<sup>2</sup> in 1999.

The pH in the soil is found to be between 4.4 and 5.3, and loss on ignition is 50-70% (Joensen, 1999), both reflecting conditions for high uptake of radiocaesium.

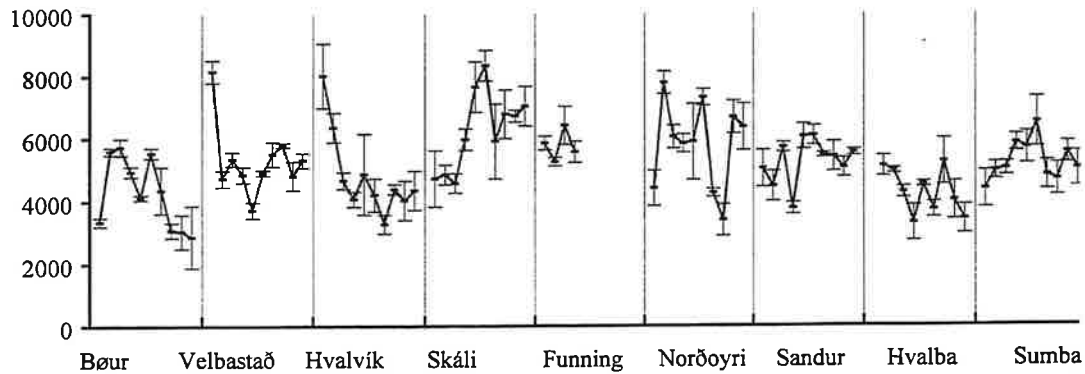


Figure 1.  $^{137}\text{Cs}$  (Bq/m<sup>2</sup>) in 0-10cm soil layer 1990-99. Yearly averages  $\pm$  1 standard error.

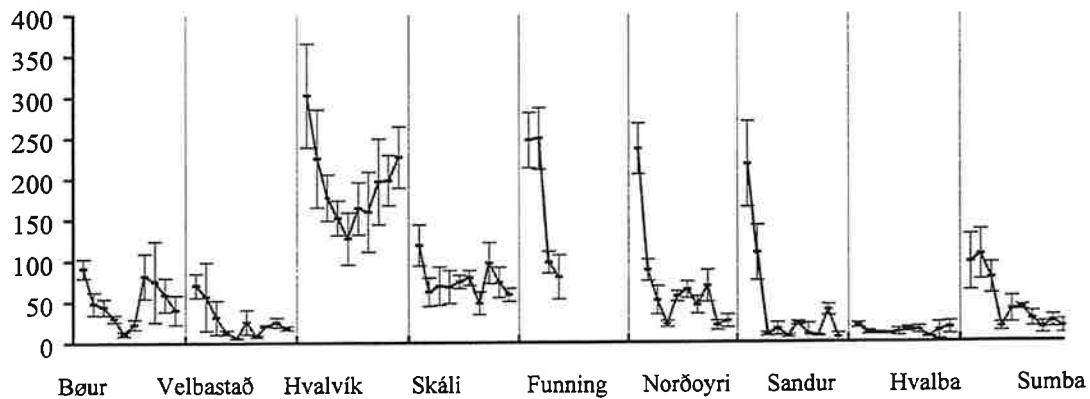


Figure 2.  $^{137}\text{Cs}$  (Bq/kg dw) in mixed grass 1990-99. Yearly averages  $\pm$  1 standard error.

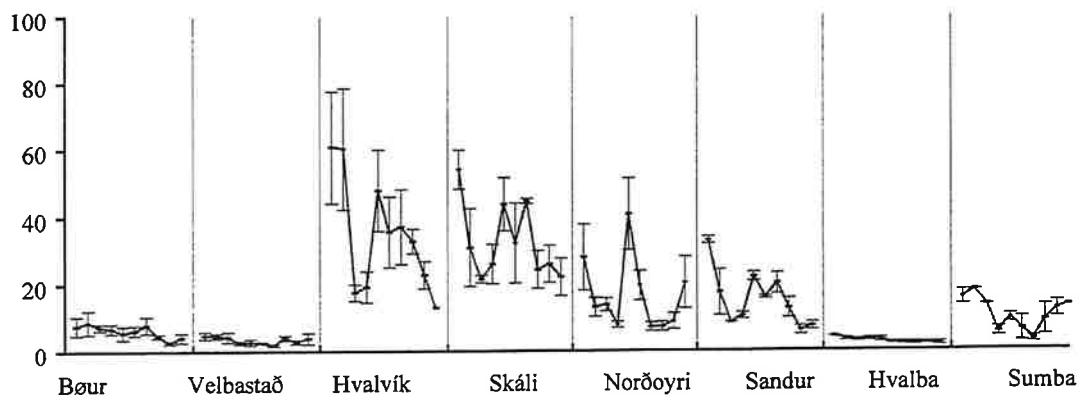


Figure 3.  $^{137}\text{Cs}$  (Bq/kg ww) in lamb meat 1990-99. Yearly averages  $\pm$  1 standard error.

**Table 1.** Effective ecological half-life in years. Numbers in brackets represent  $R^2$  from a linear regression between time and natural logarithm of  $^{137}\text{Cs}$  concentration in the samples. No estimates if  $R^2 < 0.300$ .

	Bøur	Velbastað	Hvalvík	Skáli	Norðoyri	Sandur	Hvalba	Sumba
Grass	- (0.000)	- (0.221)	- (0.036)	- (0.104)	4.3 (0.438)	2.8 (0.379)	- (0.005)	3.6 (0.667)
Meat	7.2 (0.661)	- (0.162)	7.2 (0.300)	- (0.174)	- (0.089)	6.6 (0.493)	8.0 (0.873)	- (0.069)

The  $^{137}\text{Cs}$  concentration in mixed grass (undetermined botanical composition) is observed to decrease in most pastures, with highest concentration in Hvalvík and lowest concentration in Hvalba (Fig. 2). Estimated effective ecological half-lives are presented in Table 1. The average  $^{137}\text{Cs}$  concentration across the pastures was 155 Bq/kg(dw) in 1990 and 51 Bq/kg(dw) in 1999.

The  $^{137}\text{Cs}$  concentration in lamb meat is presented in Fig. 3 (no meat samples from Funningur). Large standard errors express large variations between animals. An effective ecological half-life could be estimated in four pastures (Table 1). The average concentration across the pastures was 26.0 Bq/kg(ww) in 1990 and 10.4 Bq/kg(ww) in 1999.

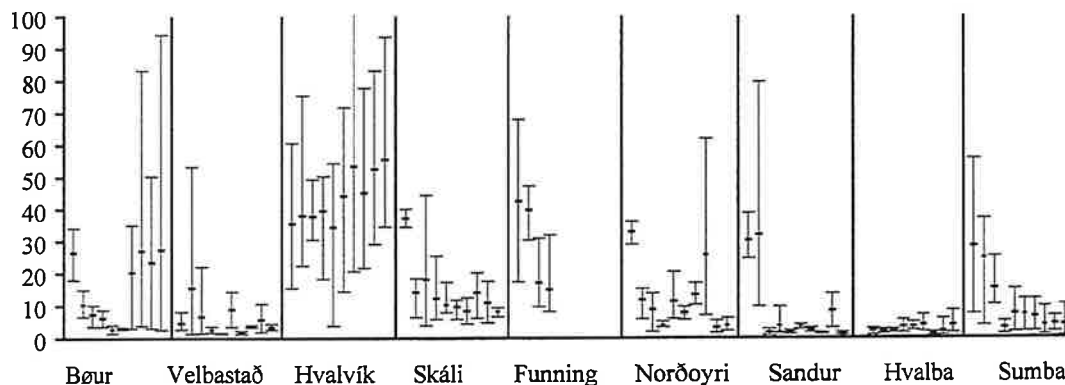


Figure 4. Soil-to-grass transfer factor for  $^{137}\text{Cs}$  ( $10^{-3} \text{ m}^2/\text{kg dw}$ ) 1990-99. Yearly averages and ranges.

The soil-to-grass transfer factor has been calculated for each  $0.25 \text{ m}^2$  microplot used for the grass and soil sampling, as the  $^{137}\text{Cs}$  concentration, Bq/kg(dw), in grass divided by the  $^{137}\text{Cs}$  deposition, kBq/m<sup>2</sup>, in the top 10 cm soil layer. The results in Fig. 4 show large geographical variations of the soil-to-grass transfer factors, and large differences between the microplots within the pastures. It is important to know the chemical characteristics of the soil in order to explain these observations. Knowledge to botanical composition of the mixed grass could also be a valuable explaining factor.

The soil-to-meat aggregated transfer factors have been calculated for a given pasture by averaging the ratio of the  $^{137}\text{Cs}$  concentrations in individual meat samples to the averaged  $^{137}\text{Cs}$  deposition in the pasture. The minimum and maximum mean values in a pasture for the period 1990-99 were  $0.33 \cdot 10^{-3} \text{ m}^2/\text{kg(ww)}$  and  $11.5 \cdot 10^{-3} \text{ m}^2/\text{kg(ww)}$ , respectively.

The averages across the pastures showed the following results: the soil-to-grass transfer factor decreased from  $30 \cdot 10^{-3} \text{ m}^2/\text{kg(dw)}$  in 1990 to  $13 \cdot 10^{-3} \text{ m}^2/\text{kg(dw)}$  in 1999, and the soil-to-meat aggregated transfer factor decreased from  $5.5 \cdot 10^{-3} \text{ m}^2/\text{kg(ww)}$  in 1990 to  $2.0 \cdot 10^{-3} \text{ m}^2/\text{kg(ww)}$  in 1999.

$^{137}\text{Cs}$  has been measured in lamb faeces in the period 1995-99. The concentration was between 18 and 126 Bq/kg(dw), and the yearly average across the pastures was between 53 and 72 Bq/kg(dw). The average across the pastures for the meat/faeces concentration ratio and of the faeces/grass concentration ratio was 0.20 [Bq/kg(ww) per Bq/kg(dw)] and 2.1 [Bq/kg(dw) per Bq/kg(dw)], respectively.

Results from a multiple linear regression between transfer factors and chemical parameters in the top 10 cm of the soil are presented in Table 2 (adapted from Joensen, 1999). Of the three chemical predictors, loss on ignition is found to be most significant. The regression coefficient (not reported) was always negative for pH and potassium and positive for loss on ignition.

**Table 2.** Results from multiple linear regression between transfer factors and chemical parameters in the top 10 cm soil layer. P-values from t-test of the coefficients for the chemical parameters are given in brackets in the same order as the parameters in the header.

	Potassium and pH	Potassium and Loss on Ignition	Potassium, pH and Loss on Ignition
Soil-to-Grass Transfer	$R^2 = 0.15$ , $p = 0.007$ (0.020; 0.043)	$R^2 = 0.29$ , $p < 0.0005$ (0.002; 0.0005)	$R^2 = 0.30$ , $p < 0.0005$ (0.003; 0.262; 0.001)
Soil-to-Meat Aggr. Transfer	$R^2 = 0.12$ , $p = 0.019$ (0.264; 0.011)	$R^2 = 0.13$ , $p = 0.015$ (0.114; 0.009)	$R^2 = 0.19$ , $p = 0.007$ (0.156; 0.054; 0.040)

## Conclusion

Although the Faroe Islands has a total land area of only about 1400 km<sup>2</sup>, large temporal and spatial variations are found for the measured <sup>137</sup>Cs activities and the calculated transfer factors. The effective ecological half-life has been estimated to be 2.8-4.3 years for grass and 6.6-8.0 years for lamb meat. Deposition of <sup>137</sup>Cs has not decreased significantly over the study period except for one pasture, where the effective ecological half-life was 11.6 years. These are of course rough estimates, because large variability is associated with this kind of measurements. Among the tree soil parameters potassium, pH and loss on ignition, loss on ignition is found to be most important for the transfer of <sup>137</sup>Cs in the food chain of lamb.

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