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Environmental radioactivity in the North Atlantic Region including the Faroe Islands and Greenland. 1988 and 1989

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Abstract Measurements of fallout radioactivity in the North Atlantic region including Faroe Islands and Greenland are reported. Strontium-90, cesium-137 and cesium-134 were determined in samples of precipitation, sea water, vegetation, various foodstuffs (including milk in the Faroes), and drinking water. Estimates are given of the mean contents of ^{90}Sr and ^{137}Cs in human diet in the Faroes and Greenland in 1988 and 1989. ^{99}Tc data on marine samples, in particular sea water from the Greenland Sea, are reported.

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Abbreviations and Units

J: joule: the unit of energy; 1 J = 1 Nm (= 0.239 cal)
Gy: gray: the unit of absorbed dose = 1 J kg^{-1} (= 100 rad)
Sv: sievert: the unit of dose equivalent = 1 J kg^{-1} (= 100 rem)
Bq: becquerel: the unit of radioactivity = 1 s^{-1} (= 27 pCi)

cal: calorie = 4.186 J
rad: 0.01 Gy
rem: 0.01 Sv
Ci: curie: 3.7×10^{10} Bq (= 2.22×10^{12} dpm)

E: exa: 10^{18}
P: peta: 10^{15}
T: tera: 10^{12}
G: giga: 10^{9}
M: mega: 10^{6}
k: kilo: 10^{3}
m: milli: 10^{-3}
μ: micro: 10^{-6}
n: nano: 10^{-9}
p: pico: 10^{-12}
f: femto: 10^{-15}
a: atto: 10^{-18}

pro capite: per individual
TNT: trinitrotoluol; 1 Mt TNT: nuclear explosives equivalent to 10^9 kg TNT.

yr^{-1}: per year (a^{-1})
cpm: counts per minute
dpm: disintegrations per minute
OR: observed ratio
CF: concentration factor
FP: fission products
μR: micro-roentgen, 10^{-6} roentgen
S.U.: pCi ^{90}Sr (g Ca)$^{-1}$
O.R.: observed ratio
M.U.: pCi ^{137}Cs (g K)$^{-1}$
V: vertebrae
m: male
f: female
nSr: natural (stable) Sr

eqv. mg KCl: equivalents mg KCl: activity as from 1 mg KCl
(~ 0.96 dpm = 0.016 Bq; 1 g K = 30.65 Bq)

S.D.: standard deviation: $\sqrt{\frac{\Sigma(\bar{x} - x_i)^2}{(n-1)}}$

S.E.: standard error $\sqrt{\frac{\Sigma(\bar{x} - x_i)^2}{n(n-1)}}$

U.C.L.: upper control level
L.C.L.: lower control level
S.S.D.: sum of squares of deviation: $\Sigma(\bar{x}-x_i)^2$
f: degrees of freedom
s^2: variance
v^2: ratio of the variance in question to the residual variance
P: probability fractile of the distribution in question
η : coefficient of variation, relative standard deviation
anova: analysis of variance
A: relative standard deviation 20-33%
B: relative standard devition >33%, such results are not considered significantly different from zero activity
B.D.L.: below detection limit

In the significance test the following symbols were used:
* : probably significant (P > 95%)
** : significant (P > 99%)
***: highly significant (P > 99.9%)

1 General Introduction

From 1962 to 1982 we have published separate annual reports on Environmental Radioactivity in the Faroes (Riso Reports (Faroese) 1962-1982) and Greenland (Riso Reports (Greenland) 1962-1982). The reports for 1983 and after are contained in the new series: »Environmental Radioactivity in the North Atlantic Region. The Faroe Islands and Greenland included« (Riso Reports (North Atlantic Region) 1983-1987) of which the present report is the sixth. It includes 1988 and 1989. In the tables and figures, which are placed at the end of each chapter, 1988 is marked by A and 1989 by B.

Chapter 2 in this report corresponds to the earlier report for the Faroes and Chapter 3 to the Greenland report.

In Chapter 4 we report on environmental radioactivity studies from other parts of the North Atlantic region including some sea water data from the Faroe Islands and Greenland. Chapter 4 also includes results from samplings carried out in earlier years.

2 Environmental Radioactivity in the Faroe Islands in 1988 and 1989

2.1 Introduction

2.1.1.

The fallout programme for the Faroes, which was initiated in 1962 (Riso Reports (Faroese) 1962-1982) in close co-operation with the National Health Service and the chief physician of the Faroes, was continued with some adjustments due to the Chernobyl accident. A special sampling was carried out by Riso in July 1989 in order to compare the environmental behaviour of Chernobyl debris with that from old global fallout and with a similar sampling in 1987.

2.1.2.

The present report will not repeat information concerning sample collection and analysis already given in Riso Reports Nos. 64, 86, 108, 131, 155, 181, 202, 221, 246, 266, 292, 306, 324, 346, 361, 387, 404, 422, 448, 470, 488, 510, 528, 541, 550 and 564 (Riso Reports (Faroese) 1962-1982), (Riso Reports (North Atlantic Region) 1983-1987).

2.1.3.

The mean diet of the Faroese used in this report is still based on the 1962 estimate given by the late Professor E. Hoff-Jorgensen.

2.1.4.

The present investigation was carried out together with corresponding examinations of fallout levels in Denmark and Greenland, described in Riso Report No. 570 and in Chapter 3 of this report, respectively.

2.2 Results and Discussion

2.2.1 Strontium-90 and Radiocesium in Faroese Precipitation

Tables 2.2.1.1 and 2.2.1.3 show the ^{90}Sr and radiocesium content, respectively, in precipitation collected at Hojvig (near Thorshavn) and Klaksvig in 1988 and 1989.

The ^{90}Sr fallout in 1989 was close to the limit of detection.

The mean depositions of ^{137}Cs in 1988 and 1989 were 22 and 9 Bq m^{-2}, respectively. This corresponds to an effective halflife of about 0.5 years, shorter in Klaksvig and longer in Hojvig. Compared with Denmark the decrease is more rapid in the Faroes, corresponding to less resuspension here, probably due to the higher rain fall.

2.2.2 Strontium-90 and Radiocesium in Faroese Grass

As previously grass were collected in June and August from Thorshavn (cf. Tables 2.2.2.1.A and B).

Furthermore, Riso performed a countrywide sampling in July 1989 (Table 2.2.2.2). Compared with the corresponding sampling in 1987 the radiocesium levels were in general significantly lower in 1989 except at Sydero, where we observed a minor increase.

2.2.3 Strontium-90 and Radiocesium in Faroese Milk

Tables 2.2.3.1.A & B show the ^{90}Sr and Tables 2.2.3.2.A & B the radiocesium levels in Faroese milk in 1988 and 1989 (cf. also Figures 2.2.3.1 and 2.2.3.2). Tables 2.2.3.3-2.2.3.5 show the analysis of variances of the milk data.

Figure 2.2.3.3 shows how the relative contribution from Chernobyl Cs-137 has been decreasing in the Faroese milk. In 1987 about 80% of the ^{137}Cs in the milk was from Chernobyl; in 1990 it had decreased to about 60% (see also Figure 2.2.3.4). The decrease was more rapid in the milk from Thorshavn than in the milk from Klaksvig and particularly from Tværå. These two locations received more Chernobyl fallout than Thorshavn. Figure 2.2.3.5 shows that ^{90}Sr in Faroese milk has decreased more rapidly than ^{90}Sr in Danish milk.

Table 2.2.3.6 shows the results from the Riso whole-milk sampling in July 1989 at four Faroese locations.

2.2.4 Strontium-90 and Radiocesium in Faroese Terrestrial Animals

Tables 2.2.4.A & B show the data in lamb from 1988 and 1989, respectively, and Figure 2.2.4.1 shows the ^{90}Sr levels in lamb bone since measurements began in 1962 and Figure 2.2.4.2 shows in a similar way the ^{137}Cs concentrations in lamb meat.

In Figures 2.2.4.3 and 2.2.4.4 we have shown the decrease of Chernobyl ^{137}Cs and global fallout ^{137}Cs in Faroese lambs. The regression was highly significant for Chernobyl ($>$ 99.9%), but not for global fallout (90-95%).

The estimated effective halflives were 1.2 years for Chernobyl ^{137}Cs and 2.8 years for global fallout ^{137}Cs. This is comparable with the more solid estimates for milk (Figure 2.2.3.4). The calculated infinite time integral of ^{137}Cs in Faroese lamb from Chernobyl was 132 $e^{-0.595}/0.595$ = 123 Bq ^{137}Cs kg^{-1} yr. This comes from a mean deposition of 2.1 kBq ^{137}Cs m^{-2}. Hence the transfer factor to lambs meat became 58 Bq ^{137}Cs kg^{-1} yr per kBq ^{137}Cs m^{-2}. This may, however, be an underestimate. We expect the effective halflife of Chernobyl ^{137}Cs to increase with time and approach that of global fallout ^{137}Cs. Hence if that is assumed, we will from 1990 use the effective halflife of global fallout for Chernobyl ^{137}Cs and the transfer factor increases from 58 to 66. This is 1/3 of the earlier estimate (Aarkrog 1979) for global fallout, which was 200 Bq ^{137}Cs kg^{-1} yr per kBq ^{137}Cs m^{-2}.

2.2.5. Strontium-90 and Radiocesium in Faroese Sea Animals

The data on cod and haddock which since the early sixties have been collected quarterly from Faroese fishing waters are shown in Tables 2.2.5.1.A & B, in Figures 2.2.5.1-2.2.5.3.

As observed earlier the ^{137}Cs content of cod is significantly higher than that of haddock. It also appears that haddock contains relatively more Chernobyl ^{137}Cs than cod and that this difference between the two species has been increasing from 1987 to 1989.

The effective halflife of total ^{137}Cs in cod and haddock is a little more than two years.

The global fallout ^{137}Cs mean level (Bq kg^{-1}) in whales was 1987-1989: 0.29 ± 0.03 (± 1 S.D.; N = 4) and in puffin we found 0.145 ± 0.020 Bq ^{137}Cs kg^{-1} (± 1 S.D.; N = 3) (cf. Tables 2.2.5.2.A & B). Chernobyl ^{137}Cs was detectable in two of the four whales.

Fish samples outside our routine programme were received in 1988 (Tables 2.2.5.3 and 2.2.5.4). Salmon contained 1.23 ± 0.26 Bq ^{137}Cs kg^{-1} (± 1 S.D.; N = 10) and 66% of the ^{137}Cs came from Chernobyl. Cod and redfish contained significantly less ^{137}Cs than salmon; but the Chernobyl per cent was similar to that of salmon. This indicates a higher observed ratio between ^{137}Cs in fish and sea water for salmon than for the other species.

2.2.6 Strontium-90, Radiocesium and Tritium in Faroese Drinking Water and Other Fresh Waters

The ^{90}Sr and ^{137}Cs of Faroese drinking water (Tables 2.2.6.1.A & B and Figure 2.2.6.1) have been measured since 1987. The ^{137}Cs levels have shown a decreasing tendency in water from Thorshavn while the water from Klaksvig and Tværå has shown no clear trend.

The relative contribution of Chernobyl ^{137}Cs has been decreasing in Thorshavn drinking water, but has shown an increasing trend in the water from Klaksvig and Tværå.

The mean concentrations of global fallout ^{137}Cs in the period 1987-1990 were 1.0 Bq m^{-3} at Thorshavn, 0.2 at Klaksvig and 0.5 at Tværå. If these levels are compared with the similar ^{90}Sr mean levels, we can estimate the $^{137}Cs/^{90}Sr$ ratio from global fallout in Faroese drinking water to 0.23 ± 0.05 (± 1 S.D.; N = 3). This ratio is in agreement with what was found in New York tap water in 1964 (HASL-161 (1965)). In earlier reports (Risø Reports (Faroese) 1962-1982); (Risø Reports (Greenland) 1962-1982), (Risø Report No. 570) it has been assumed that the $^{137}Cs/^{90}Sr$ was 0.25, the present measurements support this assumption.

A special sampling was carried out in July 1989 (Table 2.2.6.2). Compared with the corresponding sampling in July 1987 (Risø Report No. 564) the 1989 levels were 0.34 ± 0.02 (± 1 S.D.; N = 4) times those in 1987, i.e. the ^{137}Cs has decayed with an effective halflife of 1.3 years.

Tables 2.2.6.3 and 2.2.6.4 show the radiocesium levels in stream and lake water, respectively, from the July 1989 sampling. The percentages of Chernobyl ^{137}Cs in these samples were 79 ± 15 (± 1 S.D. N = 7). The mean content of ^{137}Cs in these fresh waters was 5.2 ± 2.8 Bq m^{-3} (± 1 S.D.; N = 9). The corresponding 1987 sampling showed a mean of 7.2 ± 3.0 Bq ^{137}Cs m^{-3} (± 1 S.D.; N = 5).

The drinking water ^{137}Cs concentrations in July 1989 were half of those found in stream and lake waters.

The overall mean concentration of tritium in Faroese drinking water from 1988 and 1989 was 1.30 ± 0.13 kBq m^{-3} (± 1 S.D.; N = 6) (Table 2.2.6.5).

2.2.7 Strontium-90 and Radiocesium in Miscellaneous Faroese Samples

2.2.7.1 Faroese Soil

The mean deposit of ^{137}Cs in the Faroes were 8.0 ± 4.9 kBq m^{-2} (± 1 S.D.; N = 4) in July 1989 (Table 2.2.7.1.1) compared with 6.4 ± 2.2 in July 1987. The difference reflects inhomogeneities in the depositions at the four locations.

The Chernobyl mean deposit at the four locations was 1.48 ± 0.95 kBq ^{137}Cs m^{-2} in July 1989 and 1.90 ± 0.64 in July 1987 (Table 2.2.7.1.2).

In Section 2.6 the results of the soil analysis is given. The organic matter mean content in Faroese soils was 18.1 ± 11.5% (± 1 S.D.; N = 21). The mean clay content was 6.8 ± 2.7% (± 1 S.D.; N = 21), silt was 11.9 ± 4.8% and sand was 63 ± 9.7%.

The Chernobyl contributions in Table 2.2.7.1.3 were calculated from the ratio: ^{134}Cs/^{137}Cs in the samples assuming that this ratio in pure Chernobyl debris was 0.38 in July 1987 and 0.201 in July 1989. The contributions were given as a percentage of the total ^{137}Cs in the samples.

In soil and fresh water samples the Chernobyl percentage increased from 1987 to 1989 (1989 %/1987 % = 1.65 ± 0.32 (± 1 S.E.; N = 10)).

This may be explained by a delay in the transfer of the Chernobyl ^{137}Cs from the crops and the animals to the soil and further on to the water.

In biota (grass, fodder, milk and lamb) the percentage of Chernobyl ^{137}Cs decreased from 1987 to 1989 (1989 %/1987 % = 0.93 ± 0.05 (± 1 S.E.; N = 11)) if lamb meat from Stremø in 1987 is omitted as an outlier, the ratio became 0.89 ± 0.02 and is then highly significantly lower than one.

The decrease in biota is explained by the decreasing contribution from direct contamination of ^{137}Cs (resuspension included) and the consequently increasing contribution from root uptake from 1987 to 1989. While the direct contamination preferentially consisted of Chernobyl ^{137}Cs, the root uptake had a significant contribution from global fallout ^{137}Cs. Hence a decrease was to be expected.

2.2.7.2 Faroese Sea Water

The mean concentrations in surface sea water collected at Thorshavn (Tables 2.2.7.2.1.A & B) were 1.88 ± 0.12 Bq ^{90}Sr m^{-3} and 2.9 ± 0.4 Bq ^{137}Cs m^{-3} in 1988 and 1.73 ± 0.08 Bq ^{90}Sr m^{-3} and 2.6 ± 0.25 Bq ^{137}Cs m^{-3} in 1989. No ^{134}Cs was detected in the sea water samples (cf. also Figure 2.2.7.2).

2.2.7.3 Faroese Sea Plants

The mean concentrations of ^{137}Cs and ^{90}Sr in Faroese seaweed were 0.6 Bq kg^{-1} dry matter and 0.2 Bq kg^{-1} dry matter, respectively, for 1988 and for 1989 the levels were 0.8 and 0.4, respectively, (Tables 2.2.7.3.1.A & B, Table 2.2.7.3.2 and Figure 2.2.7.3). Pu and Am were determined in Faroese Fucus vesiculosus collected by Risø in July 1989 (Table 2.2.7.3.2). The mean of ^{238}Pu/^{239,240}Pu was 0.027 ± 0.004 (N = 5; ± 1 S.E.) and the mean of ^{241}Am/^{239,240}Pu was 0.150 ± 0.015 (N = 4; ± 1 S.E., an outlier was excluded). This suggests that all transuranics found in Faroese waters came from global fall-out in July 1989.

2.2.7.4 Faroese Potatoes

The mean concentrations in Faroese potatoes were 0.065 Bq ^{90}Sr kg^{-1} and 8.4 Bq ^{137}Cs kg^{-1} in 1988 and 0.130 Bq ^{90}Sr kg^{-1} and 6.9 Bq ^{137}Cs kg^{-1} in 1989 (Tables 2.2.7.4.1.A & B and Figures 2.2.7.4.1 and 2.2.7.4.2).

2.2.7.5 Faroese Bread

The ^{90}Sr levels in Faroese white bread was about 0.1 Bq kg^{-1} and rye bread contained 0.15 Bq kg^{-1}. The ^{137}Cs concentrations were 0.09 Bq kg^{-1} in rye and white bread. There was no significant difference between 1988 and 1989 (Tables 2.2.7.5.A & B).

2.2.7.6 Faroese Eggs

The ^{137}Cs levels of eggs have been decreasing since 1987 and so have the ^{90}Sr concentrations although less pronounced (Tables 2.2.7.6.A & B).

2.2.8 Humans from the Faroes

No samples in 1988 and 1989.

2.2.9 Fodder and Other Vegetation from the Faroes

Silage contained 56 ± 24 Bq ^{137}Cs kg^{-1} dry matter (± 1 S.D.; N = 3) in July 1989 (Table 2.2.9).

2.2.10 Moss from the Faroes

Apparently all radiocesium in the moss sample shown in Table 2.2.10 came from Chernobyl. The ^{90}Sr and ^{137}Cs levels in moss in 1989 were nearly unchanged from those observed in 1987.

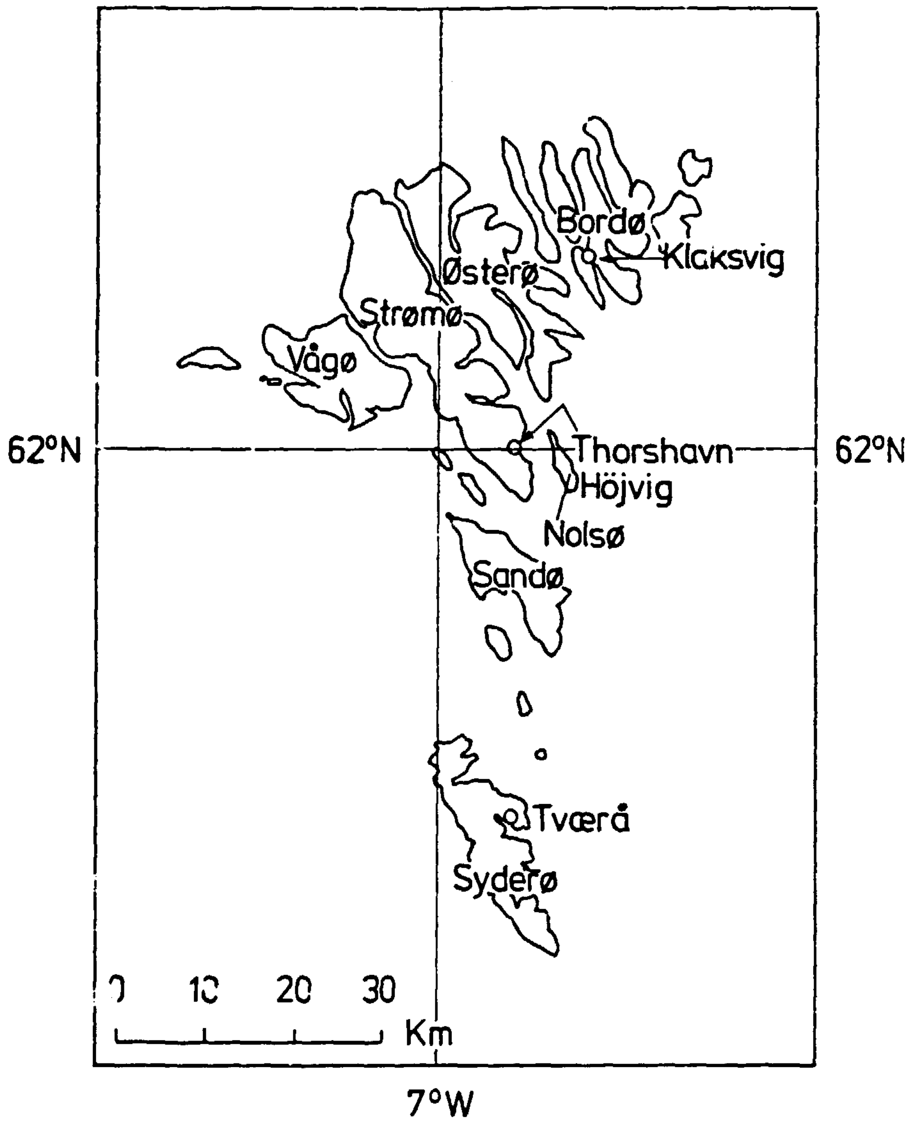


Figure 2.1. The Faroe Islands.

Table 2.2.1.1. Strontium-90 in precipitation in the Faroes in 1988 and 1989. (Sampling area: 0.02 m^2)

	Højvig			Klaksvig		
Year	Bq m^{-3}	Bq m^{-2}	mm	Bq m^{-3}	Bq m^{-2}	mm
1988	0.71	0.74	1046	0.0114	0.30	2663
1989	0.21	0.29	1398	~ 0	~ 0	2260

Figure 2.2.1. Accumulated ^{90}Sr at Klaksvig and Højvig calculated from precipitation measurements since 1962. The accumulated fallout by 1962 was estimated from the Danish fallout data (Risø Report No. 570, Appendix D) and from the ratio of the ^{90}Sr fallout at the Faroese stations to the fallout in Denmark in the period 1962-1989 (cf. Table 2.2.1.2).

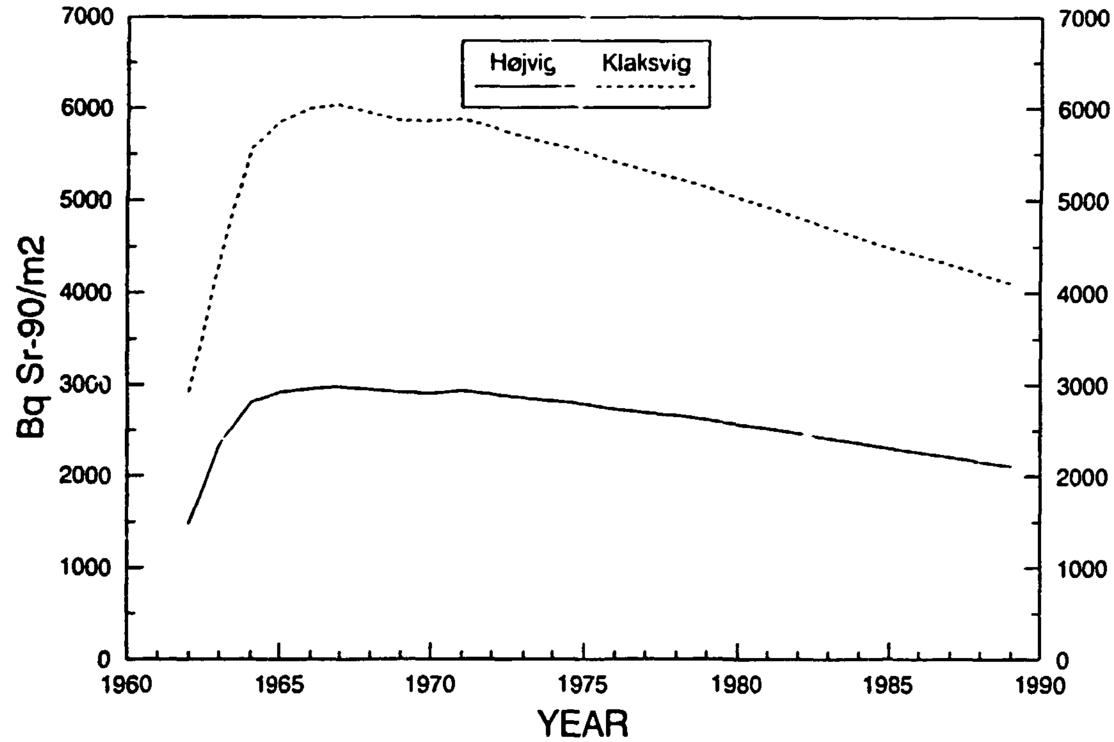


Table 2.2.1.2. Fallout rates and accumulated fallout (Unit: Bq ^{90}Sr m^{-2}) in the Faroes 1950-1989

	Höjvig		Klaksvig	
	d_i	$A_{i(29)}$	d_i	$A_{i(29)}$
1950	1.08	1.06	2.15	2.10
1951	5.21	6.12	10.34	12.14
1952	10.21	15.94	20.27	31.64
1953	25.78	40.74	51.18	80.87
1954	98.02	135.48	194.58	268.94
1955	128.96	258.20	256.00	512.54
1956	159.90	408.22	317.41	810.34
1957	159.90	554.70	317.41	1101.12
1958	221.82	758.18	440.34	1505.05
1959	314.64	1047.48	624.58	2079.33
1960	58.78	1080.14	116.69	2144.16
1961	76.36	1129.19	151.59	2241.52
1962	383.01	1476	760.31	2931
1963	913.00	2333	1503.00	4329
1964	544.00	2809	1363.00	5558
1965	181.00	2919	436.00	5852
1966	112.00	2960	289.00	5996
1967	94.70	2982	182.00	6032
1968	44.00	2955	55.50	5944
1969	41.10	2925	65.10	5867
1970	53.60	2909	141.00	5866
1971	101.00	2938	156.00	5880
1972	34.40	2903	55.10	5795
1973	24.20	2858	26.50	5684
1974	33.80	2823	58.80	5607
1975	34.40	2790	47.80	5521
1976	8.88	2733	21.60	5412
1977	27.40	2695	34.40	5318
1978	37.30	2668	47.60	5239
1979	13.90	2618	22.20	5137
1980	9.55	2566	10.29	5025
1981	18.37	2523	21.80	4928
1982	6.33	2470	3.91	4815
1983	2.75	2414	2.24	4704
1984	5.53	2363	0.87	4594
1985	0.98	2308	0.59	4486
1986	12.80	2266	28.00	4407
1987	1.40	2214	0.81	4304
1988	0.74	2162	0.30	4202
1989	0.29	2111	0	4103

1950-1961: are estimated values based upon HASL data (HASL Appendix 291, 1975) considering that the mean ratio of ^{90}Sr fallout in Denmark to New York was 0.7 in the period 1962-1974 and that the mean ratios of ^{90}Sr fallout in Höjvig to Denmark and Klaksvig to Denmark are 1.39 and 2.76, respectively (Aarkrog, 1979).

Table 2.2.1.3.A. Radiocesium in precipitation in the Faroes in 1988. (Sampling area: 0.02 m^2)

Month	Höjvig				Klaksvig			
	^{137}Cs Bq m^{-3}	^{137}Cs Bq m^{-2}	$^{134}Cs/^{137}Cs$	mm precipi-tation	^{137}Cs Bq m^{-3}	^{137}Cs Bq m^{-2}	$^{134}Cs/^{137}Cs$	mm precipi-tation
Jan-March	71	14.6	0.28	206				
April-June	36	4.3	-	121				
July-Sep	36	10.5	0.31	292				
Oct-Dec	1.2	5.2	0.30	428				
1988	$\bar{x}$ 33	Σ 35		Σ 1046	3.0	8.0	0.23 A	2663

Table 2.2.1.3.B. Radiocesium in precipitation in the Faroes in 1989. (Sampling area: 0.02 m^2)

Year	Höjvig			Klaksvig	
	^{137}Cs Bq m^{-3}	^{137}Cs Bq m^{-2}	$^{134}Cs/^{137}Cs$	^{137}Cs Bq m^{-3}	^{137}Cs Bq m^{-2}
1989	15	16	0.22	0.67	1.51

(Amounts of precipitation are shown in Table 2.2.1.1).

Table 2.2.1.4. Fallout rates and accumulated fallout in the Faroes 1950-1989. (Unit: Bq ^{137}Cs m^{-2})

	Faroese		Thorshavn		Klaksvig		Tværå	
	d_i	$A_{i(30)}$	d_i	$A_{i(30)}$	d_i	$A_{i(30)}$	d_i	$A_{i(30)}$
1950	2.59	2.53	1.73	1.69	3.44	3.36	2.15	2.10
1951	12.44	14.62	8.33	9.80	16.54	19.45	10.32	12.14
1952	24.38	38.11	16.34	25.53	32.43	50.69	20.24	31.63
1953	61.57	97.40	41.25	65.26	81.89	129.55	51.10	80.84
1954	234.08	323.91	156.83	217.02	311.33	430.81	194.29	268.85
1955	307.96	617.44	206.34	413.69	409.59	821.20	255.61	512.48
1956	381.84	976.47	255.84	654.23	507.85	1298.70	316.93	810.47
1957	381.84	1327.29	255.84	889.28	507.85	1765.29	316.93	1101.65
1958	529.73	1814.60	354.92	1215.78	704.54	2413.42	439.68	1506.12
1959	751.38	2507.37	503.42	1679.94	999.33	3334.81	623.64	2081.12
1960	140.38	2587.27	94.05	1733.47	186.70	3441.07	116.51	2147.44
1961	182.36	2706.38	122.18	1813.27	242.54	3599.48	151.36	2246.29
1962	914.65	3538.33	612.82	2370.68	1216.49	4705.98	759.16	2936.81
1963	1932.80	5346.17	1460.80	3743.97	2404.80	6948.37	1604.22	4437.32
1964	1525.60	6714.82	870.40	4508.98	2180.80	8920.66	1266.25	5573.30
1965	493.60	7043.78	289.60	4688.98	697.60	9398.58	409.69	5846.33
1966	320.80	7196.37	179.20	4756.99	462.40	9635.75	266.26	5972.99
1967	221.36	7248.31	151.52	4796.40	291.20	9700.22	183.73	6016.10
1968	79.60	7160.54	70.40	4755.64	88.80	9565.44	66.07	5943.25
1969	84.96	7080.01	65.76	4711.28	104.16	9448.74	70.52	5876.41
1970	155.68	7070.43	85.76	4687.48	225.60	9453.38	129.21	5868.46
1971	205.60	7109.84	161.60	4738.32	249.60	9481.37	170.65	5901.17
1972	71.60	7017.42	55.04	4683.88	88.16	9350.96	59.43	5824.46
1973	40.56	6896.78	38.72	4614.74	42.40	9178.81	33.66	5724.32
1974	74.08	6811.64	54.08	4562.18	94.08	9061.10	61.49	5653.66
1975	65.76	6720.32	55.04	4511.76	76.48	8928.88	54.58	5577.87
1976	24.38	6590.66	14.21	4422.60	34.56	8758.71	20.24	5470.24
1977	49.44	6488.44	43.84	4364.43	55.04	8612.45	41.04	5385.40
1978	67.92	6406.61	59.68	4323.06	76.16	8490.16	56.37	5317.49
1979	28.88	6288.50	22.24	4246.05	35.52	8330.95	23.97	5219.46
1980	15.87	6160.38	15.28	4164.01	16.46	8156.76	13.17	5113.12
1981	32.13	6051.07	29.39	4097.62	34.87	8004.53	26.67	5022.39
1982	8.19	5920.87	10.12	4013.92	6.26	7827.82	6.80	4914.32
1983	4.00	5789.54	4.40	3926.54	3.59	7652.54	3.32	4805.32
1984	5.13	5662.32	8.86	3845.51	1.40	7479.13	4.26	4699.72
1985	1.26	5534.22	1.57	3759.21	0.94	7309.23	1.04	4593.40
1986	1300.00	6678.13	660.00	4318.28	1960.00	9057.52	700.00	5172.50
1987	105.00	6628.20	121.00	4337.88	88.00	8936.63	44.00	5097.36
1988	22.00	6498.31	35.00	4273.01	8.00	8740.34	8.00	4988.75
1989	9.00	6358.68	16.00	4191.05	1.50	8542.17	4.00	4878.71

Since 1986 the d_i data are actual measurements. Before this year the data were calculated from ^{90}Sr by multiplying by 1.6.

Table 2.2.2.1.A. Strontium-90 and radiocesium in grass from Thorshavn 1988

Month	Bq ^{90}Sr kg^{-1} fresh	Bq ^{90}Sr (kg Ca)$^{-1}$	Bq ^{137}Cs kg^{-1} fresh	Bq ^{137}Cs (kg K)$^{-1}$	$\frac{^{134}Cs}{^{137}Cs}$
June	2.7	5300	8.8	1720	0.105
*August	3.5	5600	15.4	3100	0.087

*Fresh weight calculated from ash weight.

Table 2.2.2.1.B. Strontium-90 and radiocesium in grass from Thorshavn 1989

Month	Bq ^{90}Sr .g^{-1} fresh	Bq ^{90}Sr (kg Ca)$^{-1}$	Bq ^{137}Cs kg^{-1} fresh	Bq ^{137}Cs (kg K)$^{-1}$	$\frac{^{134}Cs}{^{137}Cs}$
June	1.52	2100	16	3600	0.106
August	1.88	2400	25	4800	0.082

Table 2.2.2.2. Strontium-90 and radiocesium in Faroese grass samples collected by Riso in July 1989

Location (cf. Fig. 2.1)	Bq ^{90}Sr kg^{-1} dry	Bq ^{90}Sr (kg Ca)$^{-1}$	Bq ^{137}Cs m^{-2}	Bq ^{137}Cs kg^{-1} dry	Bq ^{137}Cs (kg K)$^{-1}$	$\frac{^{134}Cs}{^{137}Cs}$	% dry matter	kg m^{-2} dry grass
Thorshavn	4.8	1010	4.7	36	1510	0.152	9	0.131
Klaksvig	6.2	2040	11.0	24	650	0.157	14	0.47
Klaksvig (fodder grass)	3.5	1570	11.0	27	860	0.104	28	0.41
Bour, Vågo	2.5	810	2.3	9.8	250	0.22	11	0.24
Øravik, Sydero	7.7	2400	54	326	13800	0.144	17	0.166

Table 2.2.3.1.A. Strontium-90 in milk from the Faroes in 1988 (Unit: Bq ^{90}Sr (kg Ca)$^{-1}$)

	Thorshavn	Klaksvig	Tværå	Mean
Jan	49 ± 3.7	52 ± 3.8	61	54
Feb	47 ± 0.9	52 ± 3.0	59	53
March	49 ± 2.4	43 ± 0.5	53	48
April	61	53	60	58
May	50	57	53 ± 2.5	54
June	57	51	72	60
July	60	55	80	65
Aug	73	65	66	68
Sept	51	52	54	52
Oct	45	49	42	45
Nov	40	66	42	50
Dec	43	56	49	49
Mean	52	54	58	55

Table 2.2.3.1.B. Strontium-90 in milk from the Faroes in 1989 (Unit: Bq ^{90}Sr (kg Ca)$^{-1}$)

	Thorshavn	Klaksvig	Tværå	Mean
*Jan	(52)	(56)	50	53
Feb	51	70	59	60
March	54	59	46	53
April	42	45	40	43
May	46	38	45	43
June	45	39	48	44
July	48	41	46	45
Aug	49	40	50	47
Sept	46	41	37	42
Oct	39	59	44	47
Nov	40	66	38	48
Dec	41	50	34	42
Mean	46	50	45	47

Figures in brackets were calculated by VAR3 (Aarkrog 1979).

*A bulked sample of milk from January was analysed: 52 Bq (kg Ca)$^{-1}$.

Table 2.2.3.2.A. Radiocesium in milk from the Faroes in 1988

Month	Thorshavn			Klaksvig			Tværå			Mean			
	Bq ^{137}Cs m^{-3}	Bq ^{137}Cs $(kg\ K)^{-1}$	$^{134}Cs/^{137}Cs$	Bq ^{137}Cs m^{-3}	Bq ^{137}Cs $(kg\ K)^{-1}$	$^{134}Cs/^{137}Cs$	Bq ^{137}Cs m^{-3}	Bq ^{137}Cs $(kg\ K)^{-1}$	$^{134}Cs/^{137}Cs$	Bq ^{137}Cs m^{-3}	Bq ^{137}Cs $(kg\ K)^{-1}$	$^{134}Cs/^{137}Cs$	Theoretical $^{134}Cs/^{137}Cs$
Jan	3100	1870	0.28	3200	1810	0.23	7700	5100	0.28	4700	2900	0.26	0.32
Feb	3100	1830	0.26	2900	1580	0.30	8400	5600	0.28	4800	3000	0.28	0.31
March	3200	1920	0.28	3700	2200	0.21	2900	1800	0.22	3200	1980	0.24	0.30
April	2500	1530	0.22	3200	1980	0.26	4800	3600	0.25	3500	2400	0.24	0.30
May	2700	1620	0.23	1730	1050	0.171	5400	3400	0.23	3300	2000	0.21	0.29
June	3000	1760	0.23	2300	1470	0.27	6200	4000	0.25	3800	2400	0.25	0.28
July	3000	1760	0.145	2700	1620	0.21	7500	4600	0.183	4400	2700	0.178	0.27
Aug	3600	2200	0.162	2200	1270	0.22	5600	3500	0.183	3800	2300	0.189	0.27
Sept	2200	1320	0.184	2800	1630	0.21	5100	3200	0.20	3300	2000	0.198	0.26
Oct	2300	1430	0.179	2500	1410	0.23	3700	2300	0.20	2900	1720	0.20	0.25
Nov	1940	1120	0.22	2700	1580	0.153	3200	1940	0.188	2600	1550	0.186	0.25
Dec	2100	1200	0.188	2200	1190	0.156	4500	2900	0.163	2900	1760	0.169	0.24
Mean	2700	1630	-	2700	1570	-	5400	3500	-	3600	2200	-	-

Table 2.2.3.2.B. Radiocesium in milk from the Faroes in 1989

	Thorshavn			Klaksvig			Tværå			Mean			
Month	Bq ^{137}Cs m^{-3}	Bq ^{137}Cs $(kg\ K)^{-1}$	$\frac{^{134}Cs}{^{137}Cs}$	Bq ^{137}Cs m^{-3}	Bq ^{137}Cs $(kg\ K)^{-1}$	$\frac{^{134}Cs}{^{137}Cs}$	Bq ^{137}Cs m^{-3}	Bq ^{137}Cs $(kg\ K)^{-1}$	$\frac{^{134}Cs}{^{137}Cs}$	Bq ^{137}Cs m^{-3}	Bq ^{137}Cs $(kg\ K)^{-1}$	$\frac{^{134}Cs}{^{137}Cs}$	Theoretical $\frac{^{134}Cs}{^{137}Cs}$
Jan	1890	1080	0.186	2400	1390	0.158	4500	2800	0.162	2900	1750	0.169	0.23
Feb	1870	1080	0.132	2900	1860	0.23	5300	3500	0.195	3400	2100	0.185	0.23
March	1340	750	-	2600	1500	0.144	4200	2400	0.185	2700	1560	0.165	0.22
April	1780	1010	0.168	2000	1140	0.141	3300	1950	0.150	2300	1370	0.153	0.22
May	1460	850	0.153	780	470	-	2700	1630	0.127	1660	980	0.140	0.21
June	1510	970	0.141	1160	730	0.156	2600	1840	0.153	1770	1180	0.150	0.21
July	1780	1150	0.115	1170	740	0.149	5000	3100	0.147	2700	1650	0.137	0.20
Aug	2600	1720	0.123	1600	1050	0.149	5100	3400	0.126	3100	2000	0.133	0.196
Sept	1620	1040	0.110	1620	1070	0.108	3500	2400	0.127	2300	1510	0.115	0.190
Oct	1570	1060	0.109	2800	1880	0.126	3700	2300	0.106	2700	1760	0.114	0.186
Nov	1420	910	0.110	1780	1130	0.116	3000	1990	0.132	2100	1340	0.120	0.181
Dec	1160	740	0.103	1550	950	0.129	3100	1970	0.127	1950	1220	0.120	0.176
Mean	1667	1030	-	1870	1160	-	3800	2400	-	2500	1540	-	-

Table 2.2.3.3.A. Analysis of variance of ln Bq ^{90}Sr (kg Ca)$^{-1}$ in Faroese milk in 1988 (from Table 2.2.3.1.A)

Variation	SSD	f	s^2	v^2	P
Between months	0.538	11	0.049	8.874	>99.5%
Between locations	0.060	2	0.030	5.466	>95%
Month × location	0.396	22	0.018	3.270	-
Remainder	0.089	7	0.006		

Table 2.2.3.3.B. Analysis of variance of ln Bq ^{90}Sr (kg Ca)$^{-1}$ in Faroese milk in 1989 (from Table 2.2.3.1.B)

Variation	SSD	f	s^2	v^2	P
Between months	0.394	11	0.036	1.445	-
Between locations	0.067	2	0.034	1.357	-
Remainder	0.496	20	0.025		

Table 2.2.3.4.A. Analysis of variance of ln Bq ^{137}Cs (kg K)$^{-1}$ in Faroese milk in 1988 (from Table 2.2.3.2.A)

Variation	SSD	f	s^2	v^2	P
Between months	1.055	11	0.096	1.593	-
Between locations	4.518	2	2.259	37.514	>99.95%
Remainder	1.325	22	0.060		

Table 2.2.3.4.B. Analysis of variance of ln Bq ^{137}Cs (kg K)$^{-1}$ in Faroese milk in 1989 (from Table 2.2.3.2.B)

Variation	SSD	f	s^2	v^2	P
Between months	1.702	11	0.155	2.642	>95%
Between locations	5.510	2	2.755	47.035	>99.95%
Remainder	1.289	22	0.059		

Table 2.2.3.5.A. Analysis of variance of ln Bq ^{137}Cs m^{-3} in Faroese milk in 1988 (from Table 2.2.3.2.A)

Variation	SSD	f	s^2	v^2	P
Between months	0.936	11	0.085	1.497	-
Between locations	3.587	2	1.794	31.555	>99.95%
Remainder	1.251	22	0.057		

Table 2.2.3.5.B. Analysis of variance of ln Bq ^{137}Cs m^{-3} in Faroese milk in 1989 (from Table 2.2.3.2.B)

Variation	SSD	f	s^2	v^2	P
Between months	1.668	11	0.152	2.621	>95%
Between locations	5.179	2	2.589	44.744	>99.95%
Remainder	1.273	22	0.058		

Table 2.2.3.6. Radiocesium and Strontium-90 in whole milk collected by Risø at Faroese farms in July 1989

Location (cf. Fig. 2.1)	Bq ^{137}Cs m^{-3}	Bq ^{137}Cs (kg K)$^{-1}$	$\frac{^{134}Cs}{^{137}Cs}$	Bq ^{90}Sr (kg Ca)$^{-1}$
Vågø	1510	970	0.147	51
Strømø	2300	1650	0.153	38
Bordø	870	590	0.128	39
Syderø	4500	2900	0.147	85

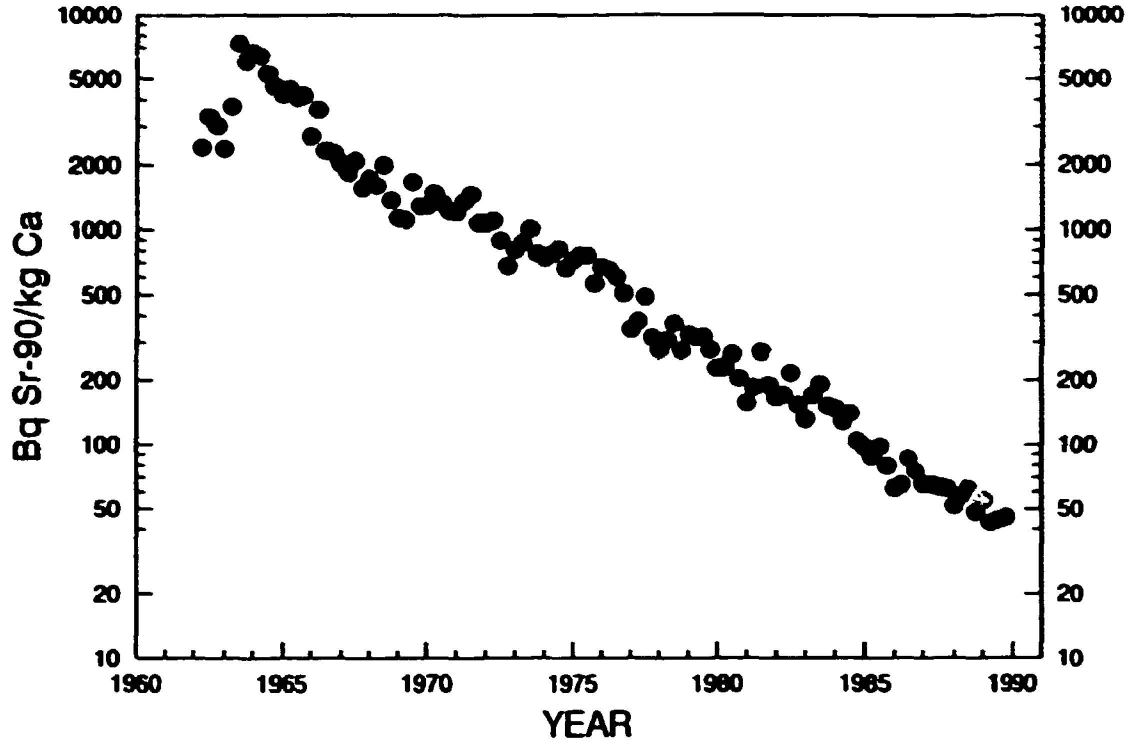
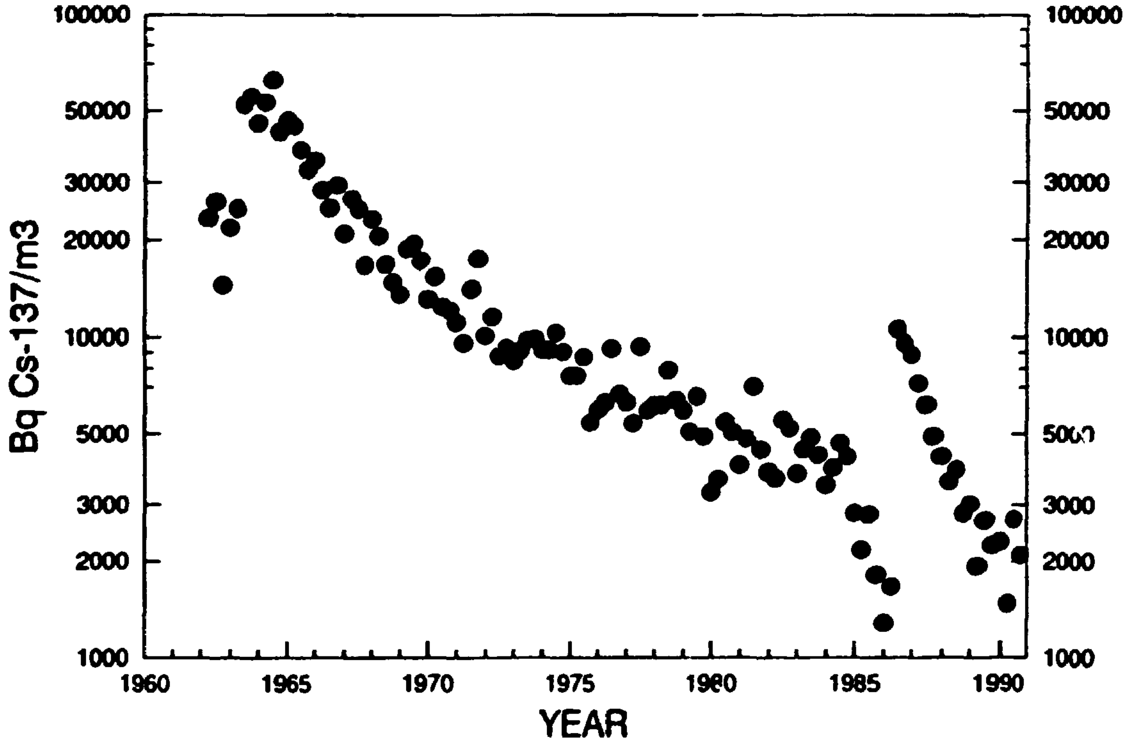


Figure 2.2.3.1. Strontium-90 in Faroese milk, 1962-1989. (Unit: Bq (kg Ca)$^{-1}$).

Figure 2.2.3.2. Cesium-137 in Faroese milk, 1962-1989. (Unit: Bq m^{-3}).



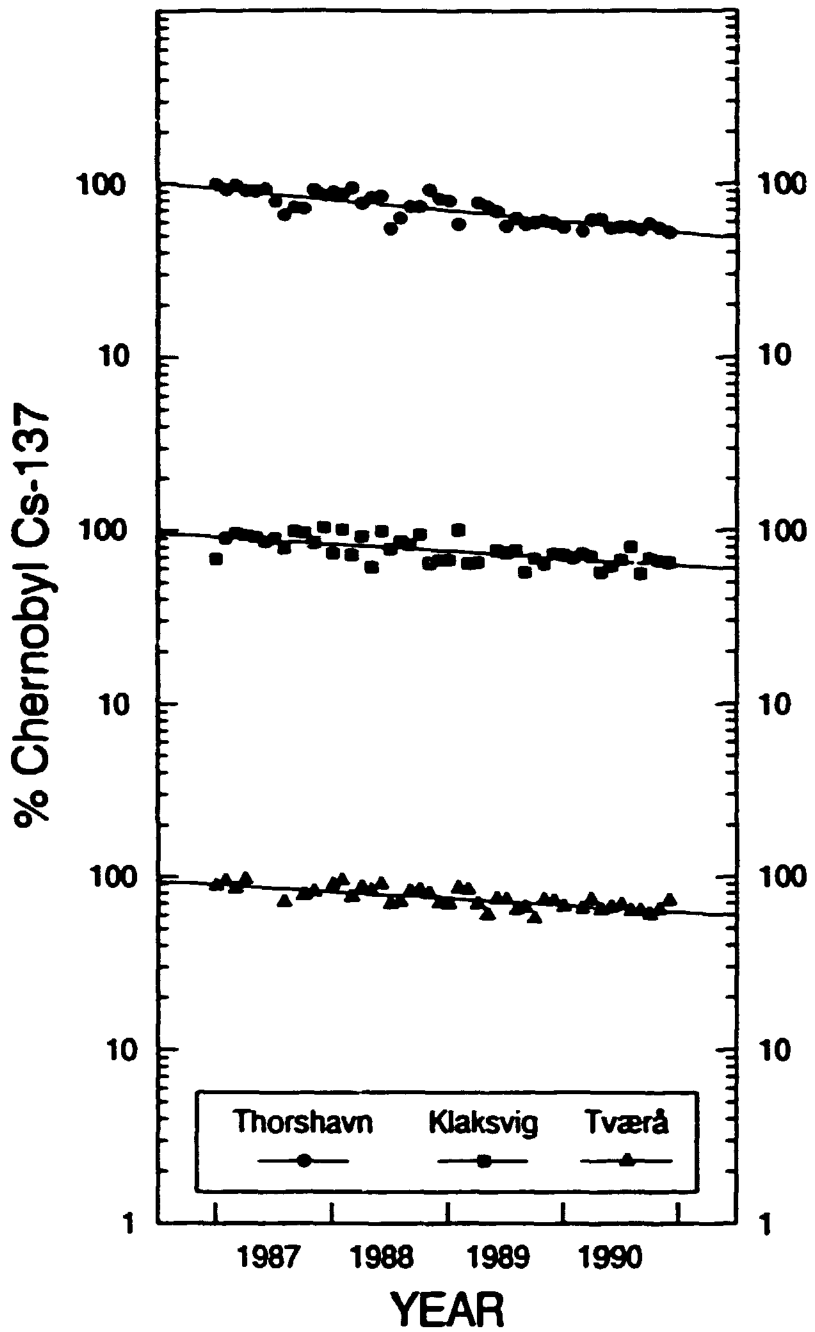


Figure 2.2.3.3. % Chernobyl ^{137}Cs in Faroese milk 1987-1990.

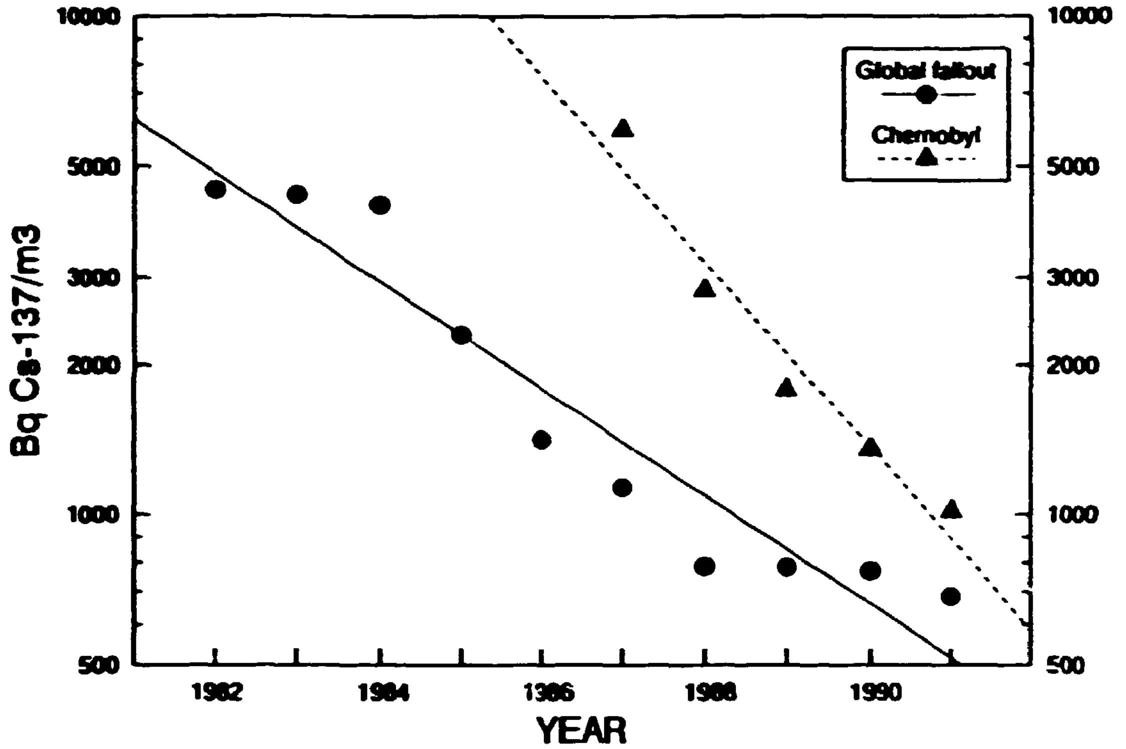


Figure 2.2.3.4. Cesium-137 in Faroese milk collected 1982-1991. (Unit: Bq m^{-3}).

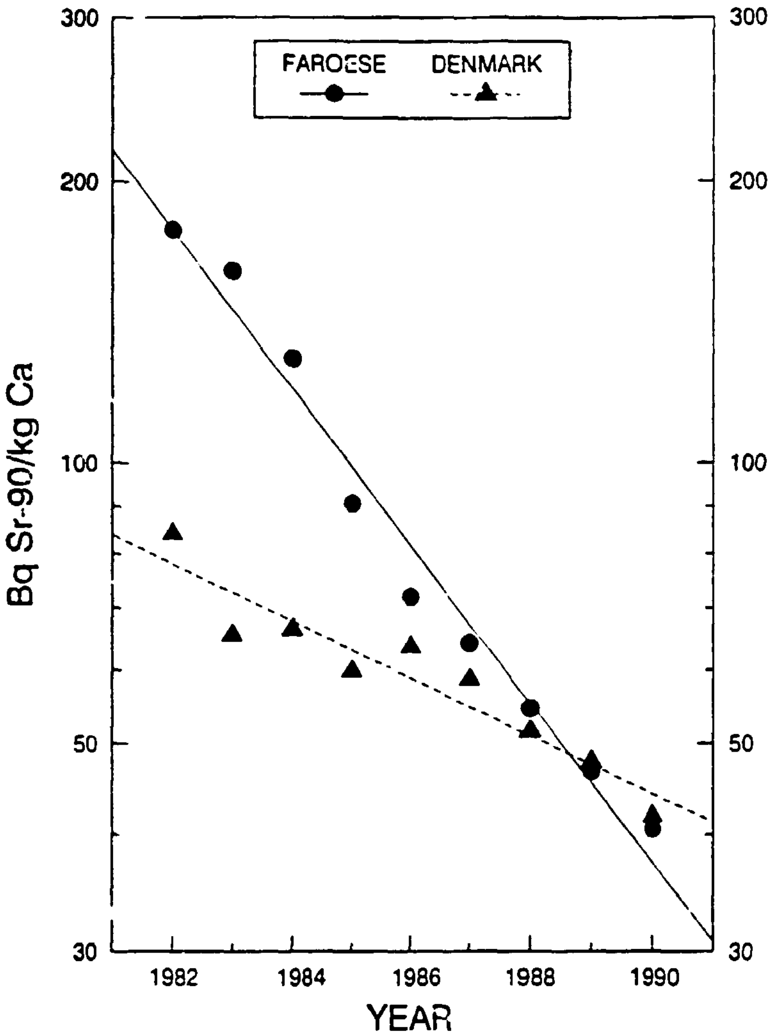


Figure 2.2.3.5. Strontium-90 in milk from Denmark and the Faroes 1982-1990. (Unit: Bq (kg Ca)$^{-1}$).

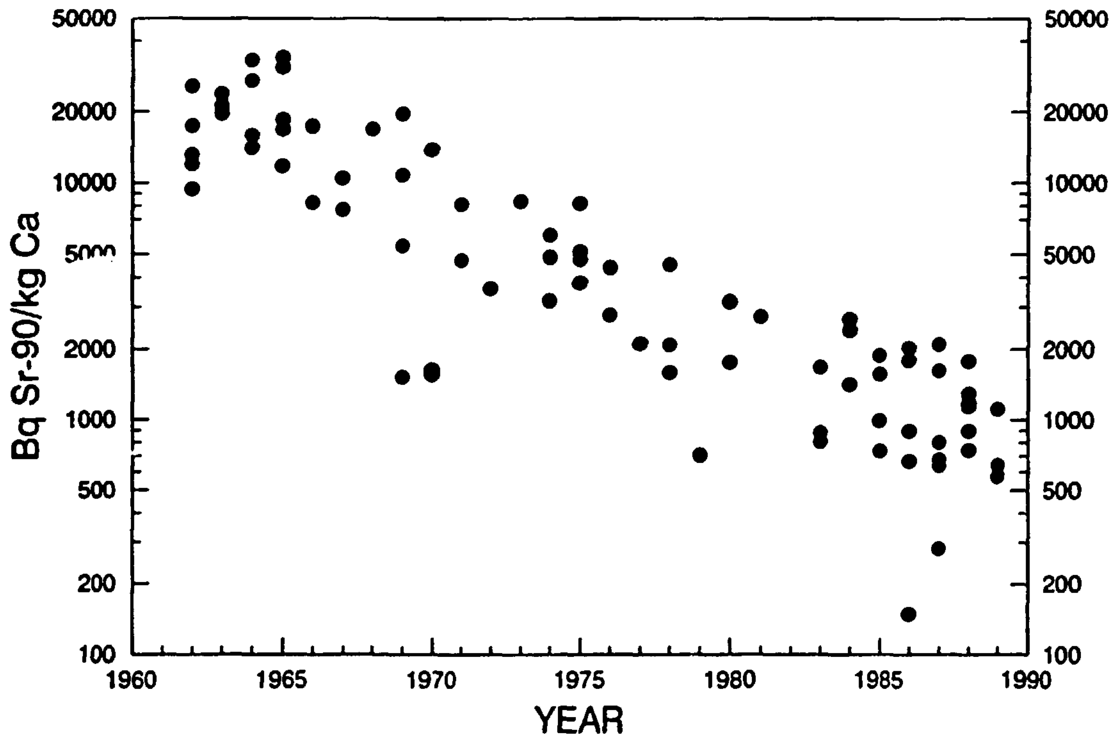
Table 2.2.4.A. Radionuclides in lamb collected in the Faroes in 1988

Location	Date	Lamb meat Bq ^{90}Sr kg^{-1}	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs (kg K)$^{-1}$	^{134}Cs / ^{137}Cs	Bone Bq ^{90}Sr (kg Ca)$^{-1}$	Theoretical ^{134}Cs / ^{137}Cs in Chernobyl debris
Sydero	Aug 27	0.040	22	7000	0.217	900	0.26
Sandø	Aug 2	0.048	28	9700	0.191	740	0.27
Kollefjord	Aug 29	0.048	90	28000	0.121	1140	0.26
Sydero	Oct	0.102	52	18400	0.172	1770	0.25
Klaksvig	Oct	0.050	74	23000	0.162	1180	0.25
Kollefjord	Oct	0.068	19.9	7100	0.128	1290	0.25

Table 2.2.4.B. Radionuclides in lamb collected in the Faroes in 1989

Location	Date	Lamb meat Bq ^{90}Sr kg^{-1}	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs (kg K)$^{-1}$	^{134}Cs / ^{137}Cs	Bone Bq ^{90}Sr (kg Ca)$^{-1}$	Theoretical ^{134}Cs / ^{137}Cs in Chernobyl debris
Sando	July	-	19.0	5800	0.138	-	0.20
Kollefjord	July	-	32	11300	0.107	-	0.20
Kirkeby	Oct	-	1.3	450	0.116	-	0.186
Thorshavn	Oct	0.040	11.3	4400	0.155	640	0.186
Klaksvig	Oct	0.021	25	7700	0.120	570	0.186
Tværå	Oct	0.126	179	59000	0.111	1110	0.186

Figure 2.2.4.1. Strontium-90 in lamb bone collected in the Faroes, 1962-1990. (Unit: Bq (kg Ca)$^{-1}$).



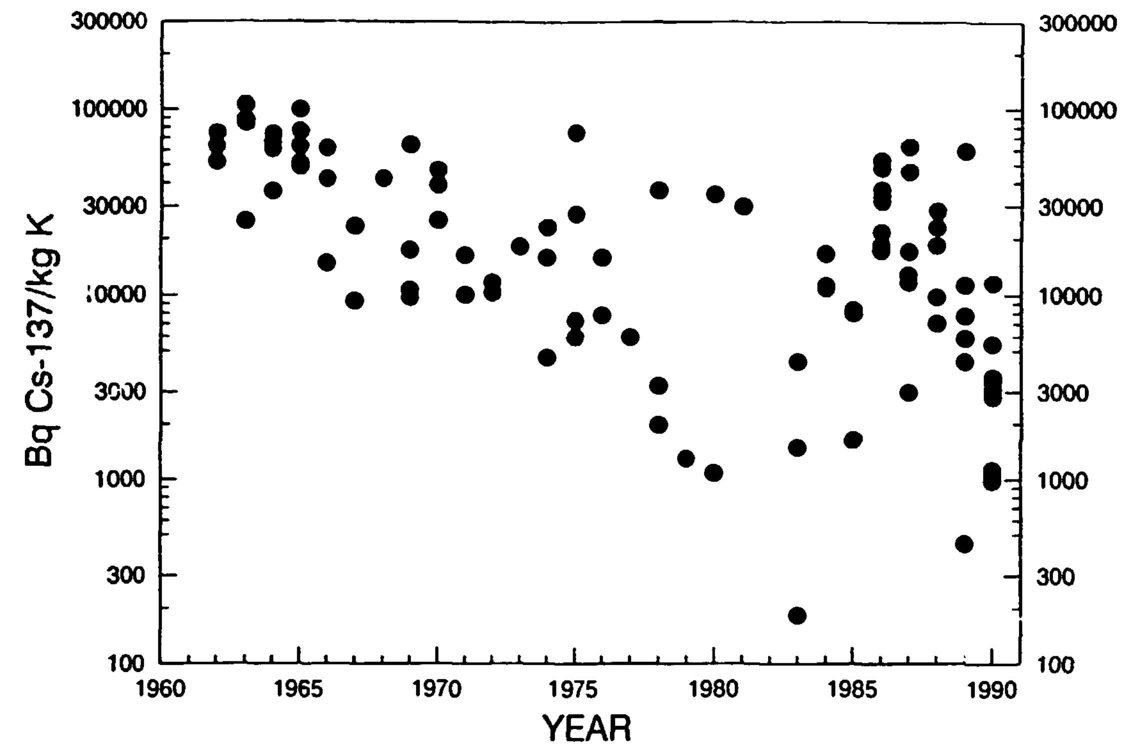
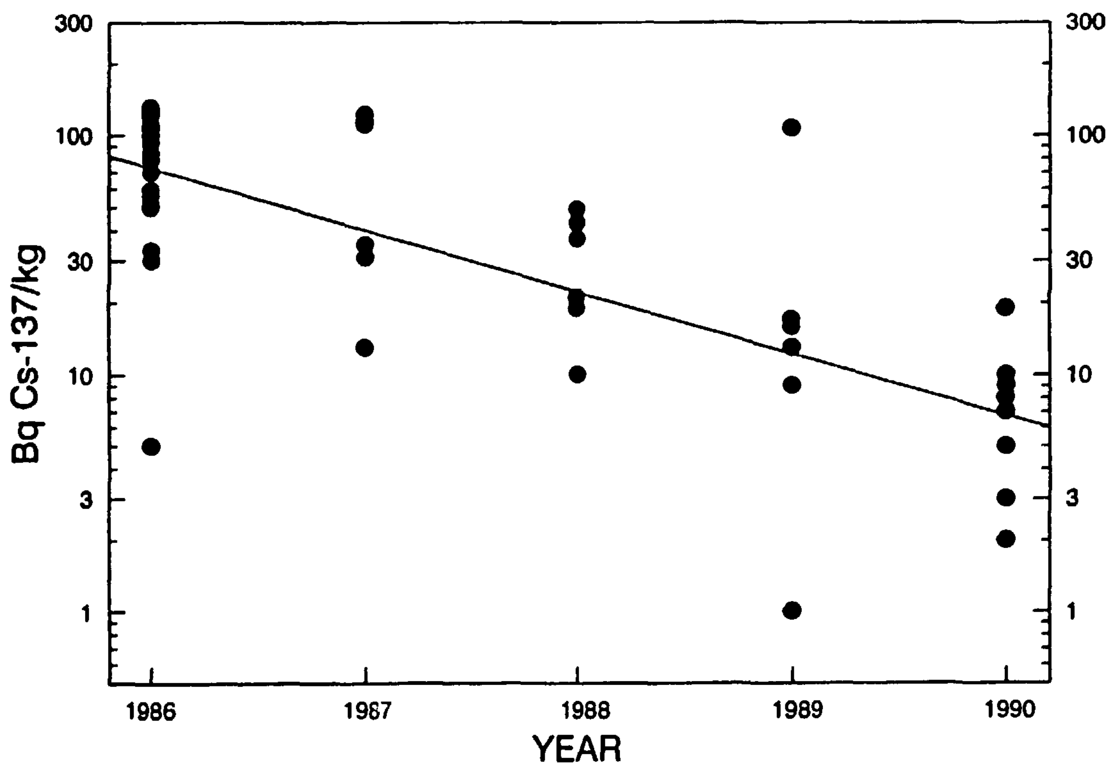


Figure 2.2.4.2. Cesium-137 in lamb meat collected in the Faroes, 1962-1990. (Unit: Bq (kg K)$^{-1}$)

Figure 2.2.4.3. Chernobyl ^{137}Cs in Faroese lamb 1986-1990. (Unit: Bq kg^{-1}).



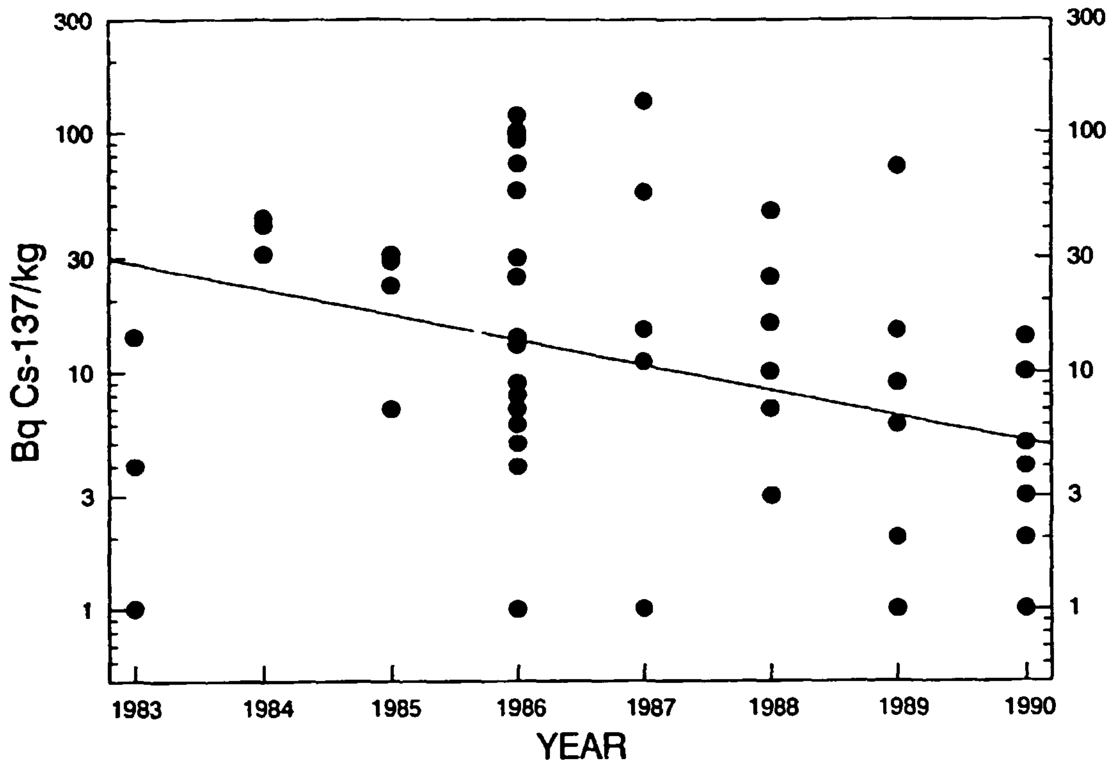


Figure 2.2.4.4. Global fallout ^{137}Cs in Faroese lamb 1983-1990. (Unit: Bq kg^{-1}).

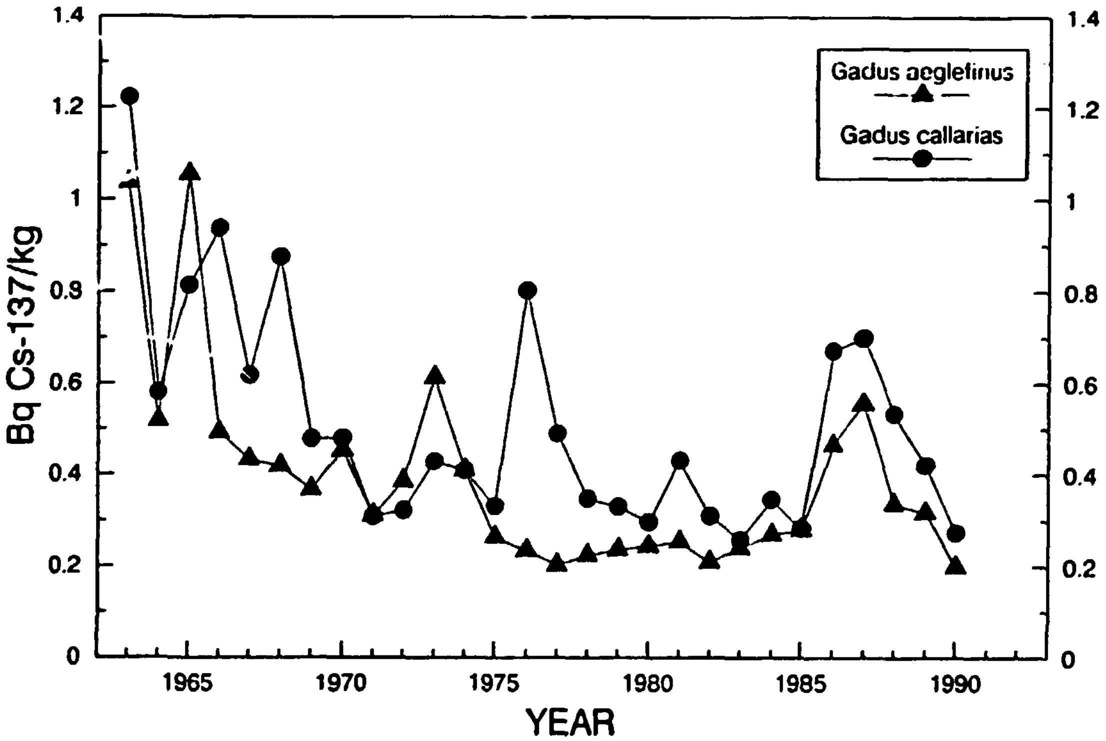
Table 2.2.5.1.A. Strontium-90 and radiocesium in fish flesh from the Faroes in 1988

Sampling month	Species	Sample type	Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr $(kg\ Ca)^{-1}$	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs $(kg\ K)^{-1}$	^{134}Cs / ^{137}Cs
March	Gadus callarias	Cod			0.48	146	0.175
June	"				0.58	162	0.151
Sept	"				0.75	159	0.135
Dec	"				0.34	95	-
1988			0.0003 B	3.6 B	0.54	140	
March	Gadus aeglefinus	Haddock			0.36	113	0.26
June	"				0.36	111	0.23
Sept	"				0.32	95	0.134
Dec	"				0.31	85	0.130
1988			0.0002 B	2.1 B	0.34	101	

Table 2.2.5.1.B. Strontium-90 and radiocesium in fish flesh from the Faroes in 1989

Sampling month	Species	Sample type	Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr $(kg\ Ca)^{-1}$	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs $(kg\ K)^{-1}$	$\frac{^{134}Cs}{^{137}Cs}$
March	Gadus callarias	Cod			0.31	87	-
June	"				0.72	220	0.038 A
Sept	"				0.33	107	0.043 B
Dec	"				0.23	71	-
1989			0.0011	7.2	0.40	121	
March	Gadus aeglefinus	Haddock			0.35	105	0.137
June	"				0.29	103	0.092 B
Sept	"				0.41	131	0.088
Dec	"				0.21	62	0.071
1989			0.0007 B	6.3 B	0.32	100	

Figure 2.2.5.1. Cesium-137 levels in meat of cod (Gadus callarias) and haddock (Gadus aeglefinus) collected in the Faroes, 1962-1990.



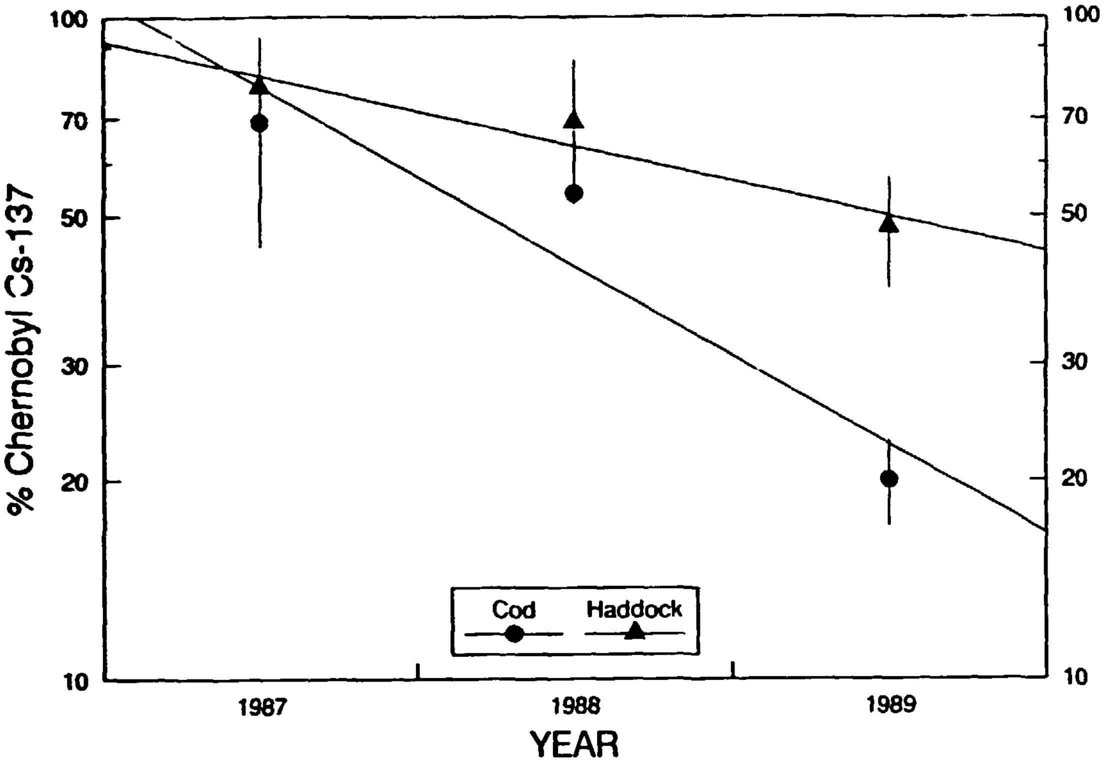


Figure 2.2.5.2. % Chernobyl ^{137}Cs in cod and haddock collected in the Faroes, 1987-1989.

Figure 2.2.5.3. Cesium-137 in cod and haddock after Chernobyl, 1987-1990. (Unit: Bq kg^{-1}).

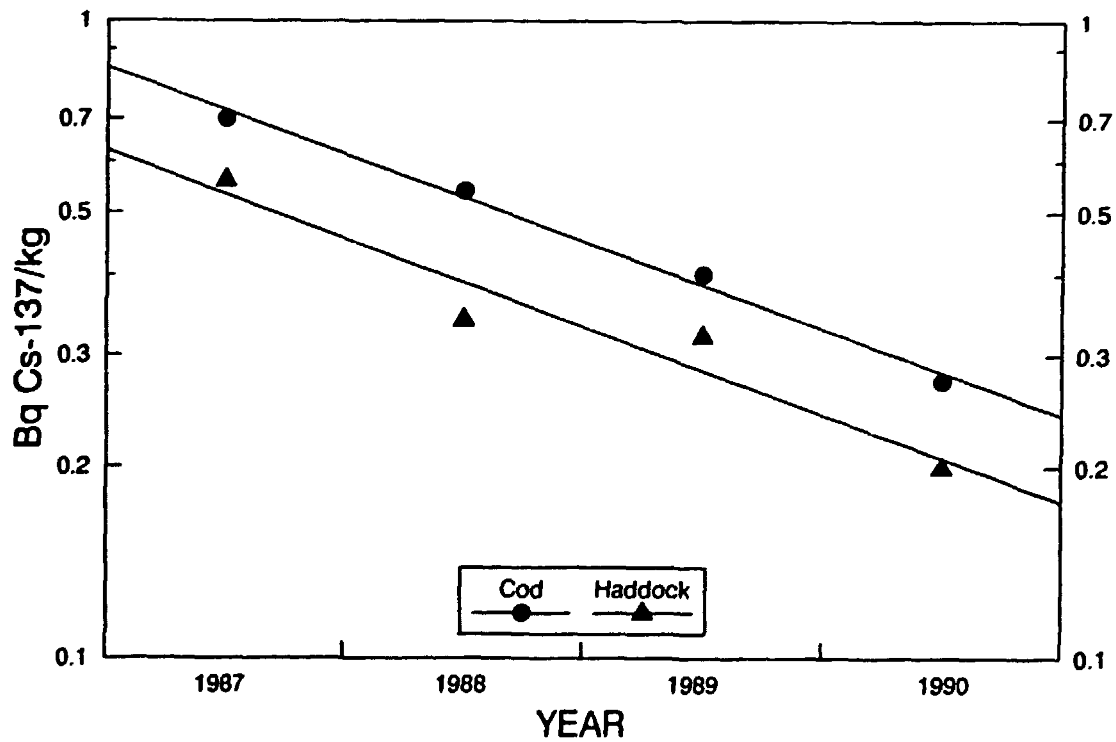


Table 2.2.5.2.A. Strontium-90 and radiocesium in various marine animals collected in July 1988

Species	Sample	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs $(kg\ K)^{-1}$	$\frac{^{134}Cs}{^{137}Cs}$	Bq ^{90}Sr $(kg\ Ca)^{-1}$	Bq ^{90}Sr kg^{-1}
Puffin (June)	flesh	0.124	42	-	-	0.005 B
" "	bone	2.9	-	-	0.9 B	-

Table 2.2.5.2.B. Strontium-90 and radiocesium in various marine animals collected in July 1989

Species	Sample	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs $(kg\ K)^{-1}$	$\frac{^{134}Cs}{^{137}Cs}$	Bq ^{90}Sr $(kg\ Ca)^{-1}$
Whale (Jan)	flesh	0.28	84	0.09 B	B.D.L.
Whale (May)	flesh	0.57	131	-	B.D.L.
Whale (Nov)	flesh	0.26	83	-	B.D.L.
Puffin (June)	flesh	0.164	43	-	B.D.L.
" "	bone	2.9	-	-	0.07 B

Table 2.2.5.3. Radi cesium in Faroese Salmon Caught in April 1988

No.	Bq ^{137}Cs kg^{-1}	Bq ^{134}Cs kg^{-1}	% Chernobyl ^{137}Cs	Bq ^{137}Cs $(kg\ K)^{-1}$
1	1.34	0.29	75	386
2	1.42	0.25	61	415
3	0.95	0.19	69	274
4	0.75	0.12	55	213
5	1.51	0.30	69	410
6	1.38	0.28	70	341
7	1.40	0.26	64	432
8	1.45	0.27	64	382
9	1.08	0.19	61	328
10	1.00	0.20	69	339
Mean	1.23	0.24	66	
1 S.D.	0.26	0.06	6	

Table 2.2.5.4. Rad. esium in Faroese Cod and Redfish Caught in February 1988

	Bq ^{134}Cs kg $^{-1}$	Bq ^{137}Cs kg^{-1}	$\frac{^{134}Cs}{^{137}Cs}$
Cod I	0.13	0.55	0.236
Cod II	0.13	0.59	0.220
Cod III	0.23	0.63	0.365
Cod IV	0.20	0.74	0.270
Cod V	0.22	0.64	0.344
Mean	0.18	0.63	0.29
±1 S.D.	0.05	0.07	0.06
Redfish I	0.089 A	0.49	0.181
Redfish II	0.080 A	0.42	0.190
Redfish III	0.24 A	0.64	0.375
Redfish IV	0.13 A	0.53	0.245
Redfish V	0.13 A	0.59	0.220
Mean	0.13	0.53	0.24
±1 S.D.	0.06	0.09	0.08

Theoretical Chernobyl $^{134}Cs/^{137}Cs$ in February 1988 was 0.43.

Table 2.2.6.1.A. Strontium-90 and radiocesium in drinking water from the Faroes in 1988. (Unit: Bq m^{-3})

Month	Thorshavn			Klaksvig			Tværå		
	^{90}Sr	^{134}Cs	^{137}Cs	^{90}Sr	^{134}Cs	^{137}Cs	^{90}Sr	^{134}Cs	^{137}Cs
Jan-June	2.9		3.2	0.25		1.42 B	2.2		3.5
July-Aug	2.9		2.6 A	1.25		2.7 A	2.3		5.1
1988	2.9	0.60	2.9	0.75	0.54 A	2.1	2.2	0.97	4.3

Table 2.2.6.1.B. Strontium-90 and radiocesium in drinking water from the Faroes in 1989. (Unit: Bq m^{-3})

Month	Thorshavn			Klaksvig			Tværå		
	^{90}Sr	^{134}Cs	^{137}Cs	^{90}Sr	^{134}Cs	^{137}Cs	^{90}Sr	^{134}Cs	^{137}Cs
Jan-June	5.3			0.61			2.6		
July-Aug	4.0			1.04			6.2		
1989	4.6	0.39	3.0	0.82	0.32	1.51	4.4	0.43	2.4

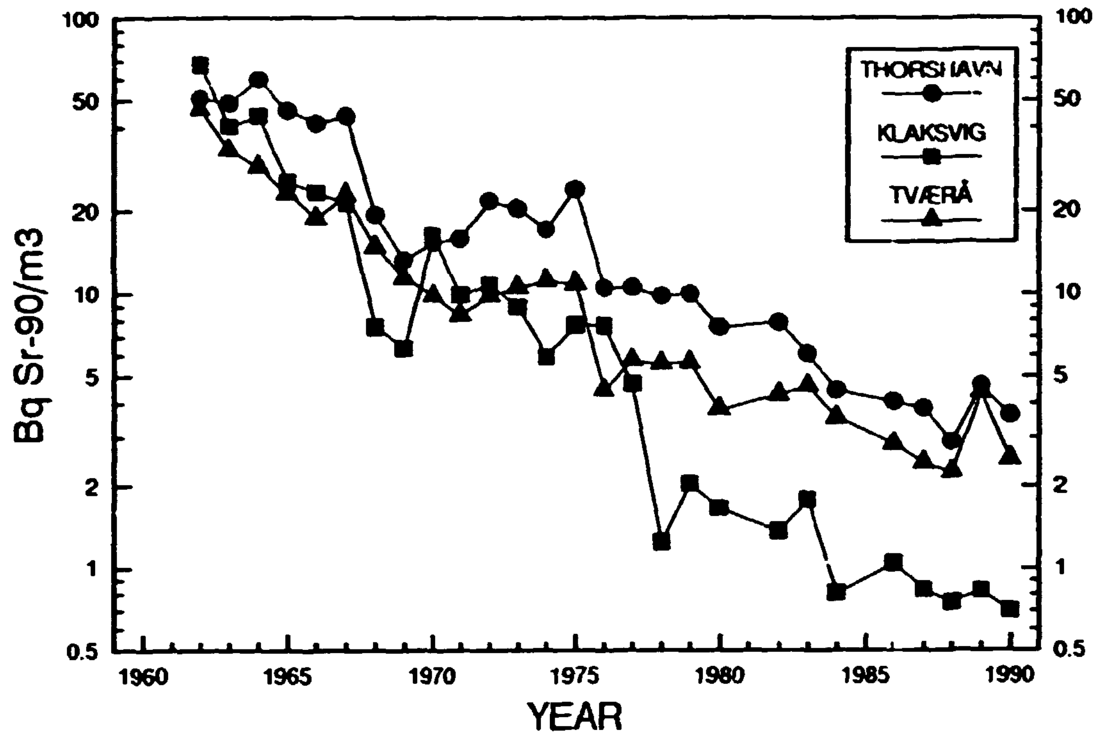


Figure 2.2.6.1. Strontium-90 in drinking water from the Faroes, 1962-1990. (Unit: Bq m^{-3}).

Table 2.2.6.2. Radiocesium in drinking water from the Faroes collected by Risø in July 1989

Location	^{134}Cs Bq m^{-3}	^{137}Cs Bq m^{-3}	^{134}Cs / ^{137}Cs
Sørvaag/Vaagø	0.60 A	2.9	0.20 A
Thorshavn/Strømø	B.D.L.	2.0	-
Klaksvig/Bordø	B.D.L.	1.0 A	-
Tværå/Sydero	1.0 B	3.5	0.29 B
Våg/Sydero	0.66 A	3.7	0.18 A

Table 2.2.6.3. Radiocesium in stream water from the Faroes collected by Risø July 13-18, 1989

Location	^{134}Cs Bq m^{-3}	^{137}Cs Bq m^{-3}	^{134}Cs/^{137}Cs
Sandå, south of Thorshavn/Strømø	0.69 A	4.2	0.16
Højdalså, north of Thorshavn/Strømø	0.98	6.1	0.16
Toftå near Højvik/Strømø	B.D.L.	3.1	-
Valdaskarå/Syderø	1.10	8.6	0.13
North of Vatnsograr/Vågø	0.75 A	3.4	0.22
Outlet in Arnefjord/Bordø	0.56 A	3.3	0.17

Table 2.2.6.4. Radiocesium in lake water from the Faroes collected by Risø July 14-18, 1989

Location	^{134}Cs Bq m^{-3}	^{137}Cs Bq m^{-3}	^{134}Cs/^{137}Cs
Leynavatn/Strømø	B.D.L.	1.84	-
Between Thorshavn and Kirkjuböur/Strømø	1.77	10.3	0.17
Søvagsvatn/Vågø	0.63 A	6.2	0.10

Table 2.2.6.5. Tritium in Faroese drinking water 1988 and 1989

Location	Year	kBq m^{-3}
Thorshavn	1988	1.35 ± 0.20
	1989	1.05 ± 0.23
Klaksvig	1988	1.30 ± 0.43
	1989	1.42 ± 0.36
Tværå	1988	1.27 ± 0.20
	1989	1.38 ± 0.09

The error term is 1 S.E. of triplicates.

Table 2.2.7.1.1. Cesium-137 in Faroese soil in July 1989. (Unit: Bq m^{-2})

Layer	Thorshavn Stromo	Klaksvig Bordo	Øravik Sydero	Böur Vaago
0-5 cm	1100	3700	1780	2060
5-10 cm	1690	3100	800	1810
10-20 cm	3900	5500	360	700
20-30 cm	2200	2020	260	230
30-40 cm	280	-	156	113
40-50 cm	58	-	73	-
Total layer	9300	14400	3400	4900

Table 2.2.7.1.2. Radiocesium and potassium (dry weight) in Faroese soils in July 1989

		0-5 cm	5-10 cm	10-20 cm	20-30 cm	30-40 cm	40-50cm
Thorshavn	Bq ^{137}Cs kg^{-1}	144	78	59	40	5.7	0.55
	^{134}Cs/^{137}Cs	0.124	0.014	-	-	-	-
	g K kg^{-1}	2.8	1.97	1.97	2.3	2.3	3.0
Klaksvig	Bq ^{137}Cs kg^{-1}	240	119	160	51	-	-
	^{134}Cs/^{137}Cs	0.118	0.022	0.006	0.015	-	-
	g K kg^{-1}	3.9	3.1	2.9	3.0	-	-
Øravik	Bq ^{137}Cs kg^{-1}	300	97	32	3.9	2.1	1.4
	^{134}Cs/^{137}Cs	0.143	0.042	-	-	-	-
	g K kg^{-1}	3.4	1.36	1.05	2.3	2.2	2.0
Bøur	Bq ^{137}Cs kg^{-1}	185	122	18.5	6.0	2.5	-
	^{134}Cs/^{137}Cs	0.066	0.019	-	-	-	-
	g K kg^{-1}	2.1	3.1	1.95	1.94	1.81	-

Table 2.2.7.1.3. Percentage of Chernobyl ^{137}Cs in samples collected at Stromo, Bordo and Sydero 1987 and 1989

		Stromo	Bordo	Sydero
Soil 0-5 cm	1987	34	53	54
	1989	62	59	71
Soil 5-10 cm	1987	2	16	6
	1989	7	11	21
Stream water	1987	67 ± 1		74
	1989	80 ± 1	85	64
Lake water	1987	63		
	1989	85		
Drinking water	1987	63	76	76
	1989			90
Grass	1987	84 ± 5	89	74
	1989	76	52	72
Fodder	1987	103	84	
	1989	78	78	82
Whole milk	1987	76 ± 0	82 ± 5	76
	1989	66 ± 10	69 ± 5	73 ± 0
Lamb*	1987	46	74	69
	1989	64 ± 7	65	60

Figures with error terms are mean values of double determinations ± 1 S.E. The lamb figure is the mean of triplicates.
*Lamb was from October and July.

Table 2.2.7.2.1.A. Strontium-90 and cesium-137 in Faroese surface sea water collected at Thorshavn (62°02'N 06°47'W) in 1988. (Unit: Bq m⁻³)

Sampling date	^{90}Sr	^{137}Cs	Salinity in ‰
April	1.84	2.8	35.1
August	2.01	2.5	35.1
December	1.78	3.3	35.0

Table 2.2.7.2.1.B. Strontium-90 and cesium-137 in Faroese surface sea water collected at Thorshavn (62°02'N 06°47'W) in 1989. (Unit: Bq m⁻³)

Sampling date	^{90}Sr	^{137}Cs	Salinity in ‰
April	1.67	2.6	35.1
September	1.70	2.4	35.0
December	1.82	2.9	35.1

Figure 2.2.7.2. Strontium-90 and cesium-137 in Faroese sea water 1962-1990. (Unit: Bq m⁻³).

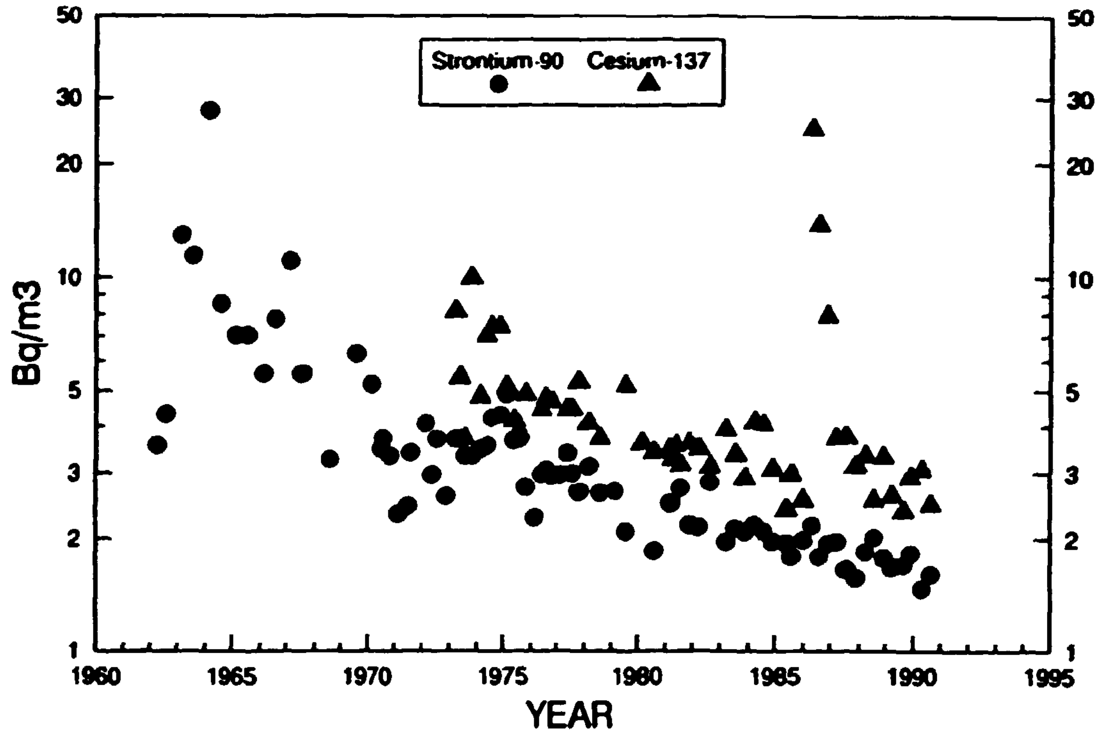


Table 2.2.7.3.1.A. Radionuclides in seaweed collected at Thorshavn in 1988.

Species	Date	^{137}Cs Bq kg^{-1} d.w.	^{137}Cs Bq (kg K)$^{-1}$	^{90}Sr Bq kg^{-1} d.w.	^{90}Sr Bq (kg Ca)$^{-1}$	^{99}Tc Bq kg^{-1} d.w.
Fucus vesiculosus	April	0.45	12.1	0.10	9.8	
Fucus vesiculosus	Aug	0.44 B	11.2	0.35	25	1.51
Laminaria	April	0.56 A	8.8 A	0.26	21	
Laminaria	Aug	0.78 B	43	0.18	19.7	0.93

Table 2.2.7.3.1.B. Radionuclides in seaweed collected at Thorshavn in 1989.

Species	Date	^{137}Cs Bq kg^{-1} d.w.	^{137}Cs Bq (kg K)$^{-1}$	^{134}Cs/^{137}Cs	^{90}Sr Bq kg^{-1} d.w.	^{90}Sr Bq (kg Ca)$^{-1}$	^{99}Tc Bq kg^{-1} d.w.
Ascophyllum	April	0.39 B	9 B	-	0.11	8	3.4
Laminaria	April	0.84 A	48	0.058 B	0.07 B	6 B	0.91
Ascophyllum	Aug	0.60	24	-	B.D.L.	-	3.8
Fucus vesiculosus	Aug	0.65	24	-	0.34	20	1.03
Laminaria	Aug	0.69	15.8	-	0.34	24	0.42 A

Figure 2.2.7.3. Strontium-90 in sea plants collected at Thorshavn, 1962-1989. (Unit: Bq (kg Ca)$^{-1}$)

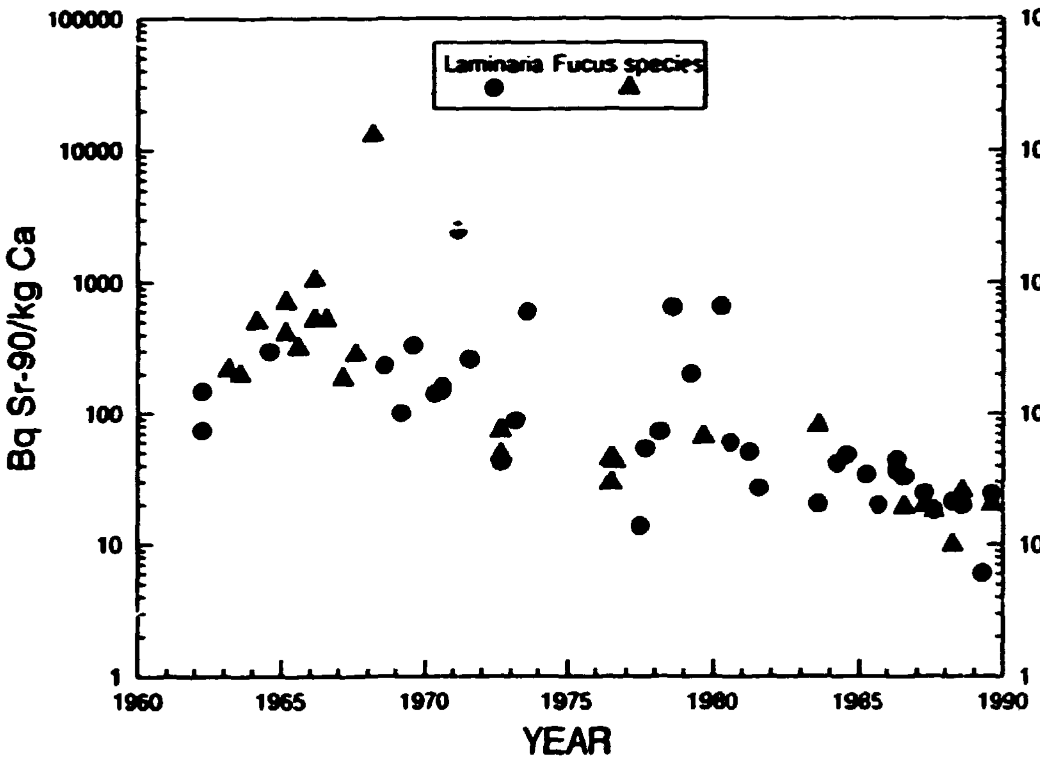


Table 2.2.7.3.2. Radionuclides in Fucus vesiculosus collected by Riso in the Faroes in July 1989.

Location	^{137}Cs Bq kg^{-1} d.w.	^{134}Cs / ^{137}Cs	^{90}Sr Bq kg^{-1} d.w.	% dry matter	Bq ^{137}Cs (kg K)$^{-1}$	Bq ^{90}Sr (kg Ca)$^{-1}$	^{238}Pu Bq kg^{-1} d.w.	$^{239,240}Pu$ Bq kg^{-1} d.w.	^{241}Am Bq kg^{-1} d.w.
Thorshavn	0.50		0.57	17.6	16.8	44	0.0014 B	0.106	0.045 A
Klaksvig	2.14*	0.18 A	0.160	21.2	94	7.9	0.0046 A	0.159	0.024
Tværå	0.41		0.43	18.7	15.3	29	0.0048	0.131	0.0142
Vagur	1.23		1.34	17.8	51	61	0.0036	0.178	0.0303
Sørvåg	0.65		0.25	22.7	23	15.9	0.0056	0.165	0.028
Global fallout mean	0.61		0.55	19.6	15.9	32	0.0040	0.148	0.028
S.D	0.37		0.47	2.3	9.1	21	0.0016	0.029	0.011

*Global fallout 0.26 Bq kg^{-1} and 6 Bq ^{137}Cs (kg K)$^{-1}$, (88% Chernobyl ^{137}Cs).

Table 2.2.7.4.1.A. Radionuclides in Faroese potatoes collected in November 1988

Location	Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr (kg Ca)$^{-1}$	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs (kg K)$^{-1}$	^{134}Cs / ^{137}Cs
Thorshavn	0.113	1540	3.2	1060	0.093
Klaksvig	0.037	1240	16.0	4800	0.136
Tværå	0.046	1660	6.1	1900	0.190

Table 2.2.7.4.1.B. Radionuclides in Faroese potatoes collected in November 1989

Location	Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr (kg Ca)$^{-1}$	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs (kg K)$^{-1}$	^{134}Cs / ^{137}Cs
Thorshavn	0.115	1290	2.11	650	0.089
Klaksvig	0.23	5200	7.2	2070	0.074
Tværå	0.058	1180	11.5	3200	0.119

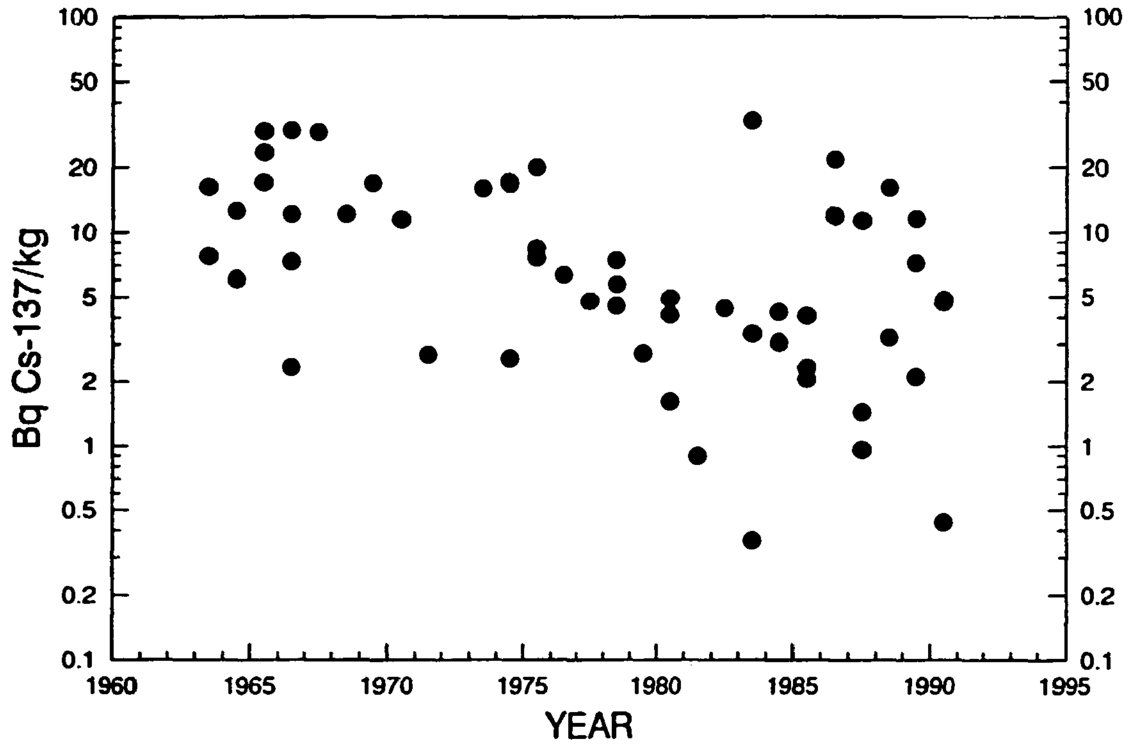


Figure 2.2.7.4.1. Cesium-137 in Faroese potatoes, 1962-1990. (Unit: Bq kg^{-1}).

Figure 2.2.7.4.2. Strontium-90 in Faroese potatoes, 1962-1990. (Unit: Bq kg^{-1}).

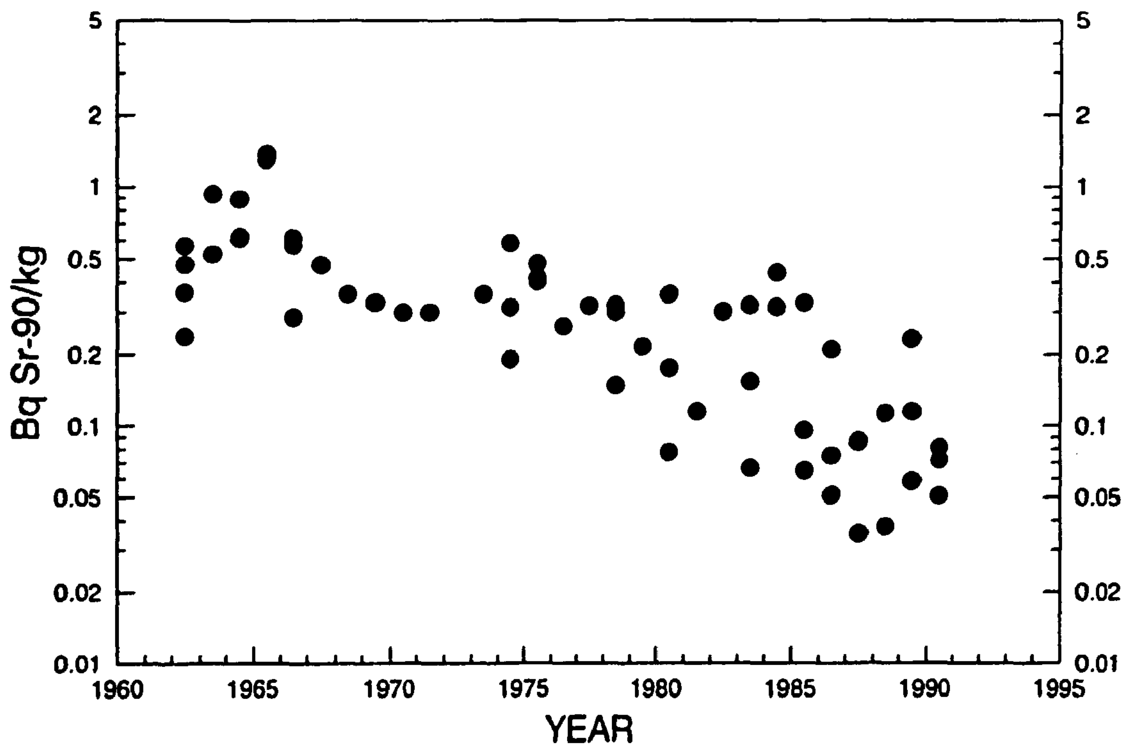


Table 2.2.7.5.A. Strontium-90 and radiocesium in Faroese bread in June 1988

Sort	Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr (kg Ca)$^{-1}$	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs (kg K)$^{-1}$	$\frac{^{134}Cs}{^{137}Cs}$
White bread	0.121	290	0.083	61	0.29
Rye bread	0.159	230	0.099	49	-

Table 2.2.7.5.B. Strontium-90 and radiocesium in Faroese bread in June 1989

Sort	Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr (kg Ca)$^{-1}$	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs (kg K)$^{-1}$	$\frac{^{134}Cs}{^{137}Cs}$
White bread	0.089	71	0.099	76	0.114 B
Rye bread	0.143	620	0.076	34	-

Table 2.2.7.6.A. Strontium-90 and radiocesium in Faroese eggs collected in 1988

Date	Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr (kg Ca)$^{-1}$	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs (kg K)$^{-1}$	$\frac{^{134}Cs}{^{137}Cs}$
June	0.028	47	0.21	178	0.18 A

Table 2.2.7.6.B. Strontium-90 and radiocesium in Faroese eggs collected in 1989

Date	Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr (kg Ca)$^{-1}$	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs (kg K)$^{-1}$	$\frac{^{134}Cs}{^{137}Cs}$
June	0.021	306	0.149	115	-

Table 2.2.9. Radiocesium in fodder collected in the Faroes by Risø in July 1989

Species	Location	Date	Bq ^{137}Cs kg^{-1} (d.w.)	Bq ^{137}Cs (kg K)$^{-1}$	$\frac{^{134}Cs}{^{137}Cs}$
Silage	Højvik	July 12	43	3500	0.158
Silage	Böur	July 15	41	1990	0.117
Silage	Øravik	July 13	86	7700	0.164

Table 2.2.10. Radionuclides in moss collected at Thorshavn (Kirkeby) in the Faroes by Risø in July 1989

Species	Unit	^{90}Sr	^{134}Cs	^{137}Cs	^{40}K*	$\frac{^{134}Cs}{^{137}Cs}$
Moss	Bq kg^{-1} dry	9.6	122	620	2.05	0.20
	Bq m^{-2}	34	440	2200		

*Unit: g kg^{-1} dry.

2.3 Estimate of the Mean Contents of ^{90}Sr and ^{137}Cs in the Faroese Human Diet in 1988 and 1989

2.3.1 Annual Quantities

The annual quantities are still based on the estimate made by the late Professor E. Hoff-Jørgensen in 1962 (Risø Reports (Faroese) 1962-1982) assuming a daily pro capite intake of approximately 3000 calories (12.6 MJ).

2.3.2 Milk and Cream

75% of the milk consumed in the Faroes is of local origin, and the remainder comes from Denmark. Hence the ^{90}Sr content in milk consumed in the Faroes in 1988 was $1.2 \times (0.75 \times 0.054 + 0.25 \times 0.054) = 0.065$ Bq ^{90}Sr kg^{-1}, and the ^{137}Cs content was $0.75 \times 3.6 + 0.25 \times 0.28 = 2.77$ Bq ^{137}Cs kg^{-1} (cf. 2.2.3 and Risø-R-570). 1 kg milk contains 1.2 g Ca.

For 1989 we get: $1.2 \times (0.75 \times 0.047 + 0.25 \times 0.048) = 0.054$ Bq ^{90}Sr kg^{-1} and $0.75 \times 2.46 + 0.25 \times 0.178 = 1.89$ Bq ^{137}Cs kg^{-1}.

2.3.3 Cheese

Nearly all cheese consumed in the Faroes is of Danish origin, and the Danish figures from ref. 3 were used: 0.41 Bq ^{90}Sr kg^{-1} and 0.135 Bq ^{137}Cs kg^{-1} in 1988 and 0.44 and 0.153, respectively, in 1989.

2.3.4 Grain Products

As most grain products are imported from Denmark, the Danish figures (Risø Report No. 570) were used in the calculation of the Faroese levels. The mean daily consumption of grain products in the Faroes is, as in Denmark, 80 g rye flour, 120 g wheat flour, and 20 g grits. Hence the mean concentrations in grain products consumed in the Faroes in 1988 were 0.232 Bq ^{90}Sr kg^{-1} and 0.106 Bq ^{137}Cs kg^{-1}, and in 1989 they became 0.181 and 0.110, respectively.

2.3.5 Potatoes

All potatoes consumed in the Faroes are assumed to be of local origin. The values from 2.2.7.4 were used, i.e. 0.065 Bq ^{90}Sr kg^{-1} and 8.4 Bq ^{137}Cs kg^{-1} in 1988, and 0.130 and 6.9, respectively, in 1989.

2.3.6 Other Vegetables and Fruit

As the amount of vegetables and fruit grown in the Faroes is limited, the Danish figures (Risø Report No. 570) were used. In 1988 the mean content in vegetables other than potatoes was 0.22 Bq ^{90}Sr kg^{-1} and 0.095 Bq ^{137}Cs kg^{-1} and the mean content in fruit was 0.034 Bq ^{90}Sr kg^{-1} and 0.049 Bq ^{137}Cs kg^{-1}. In 1989 the levels became 0.185, 0.089, 0.020 and 0.054, respectively.

2.3.7 Meat and Eggs

Meat and egg consumption in the Faroes is estimated to consist of 50% locally produced mutton (or lamb), 25% local whale meat, and 25% sea birds and eggs.

For lamb we use the mean of the samples obtained in 1988, i.e. 0.059 Bq ^{90}Sr kg^{-1} (in 1989: 0.062) and 48 Bq ^{137}Cs kg^{-1} (in 1989: 45). Whale meat contained 0 Bq ^{90}Sr kg^{-1} and 0.37 Bq ^{137}Cs kg^{-1}, sea birds contained 0 Bq ^{90}Sr kg^{-1} and 0.14 Bq ^{137}Cs kg^{-1}, and eggs (cf. 2.2.5.2 and 2.2.7.6): 0.025 Bq ^{90}Sr kg^{-1} and 0.18 Bq ^{137}Cs kg^{-1}. The means of 1988 and 1989 data were used for whale, sea birds and eggs. Hence we estimate the mean content of ^{90}Sr in meat and eggs consumed in 1988 to be $0.50 \times 0.059 + 0.25 \times 0 + 0.25 \times (0 + 0.025)/2 = 0.033$ Bq ^{90}Sr kg^{-1} and the ^{137}Cs content to be $0.50 \times 48 + 0.25 \times 0.37 + 0.25 \times (0.14 + 0.18)/2 = 24.1$ Bq ^{137}Cs kg^{-1}. For 1989 the concentrations became 0.034 Bq ^{90}Sr kg^{-1} and 22.6 Bq ^{137}Cs kg^{-1}.

2.3.8 Fish

All fish consumed in the Faroes is of local origin, and the mean content in fish, obtained from Table 2.2.5.1, was 0.00025 Bq ^{90}Sr kg^{-1} and 0.44 Bq ^{137}Cs kg^{-1} in 1988 and 0.0009 and 0.36, respectively, in 1989.

2.3.9 Coffee and Tea

The Danish figures (Risø Report No. 570) were used for both 1988 and 1989, i.e. 0.25 Bq ^{90}Sr kg^{-1} and 3.82 Bq ^{137}Cs kg^{-1}.

2.3.10 Drinking Water

The mean values found in Table 2.2.6.1 were used, i.e. 0.00195 Bq ^{90}Sr kg^{-1} and 0.0031 Bq ^{137}Cs kg^{-1} in 1988, and 0.0033 and 0.0023, respectively, in 1989.

Tables 2.3.1 and 2.3.2 show the diet estimates of ^{90}Sr and ^{137}Cs, respectively.

Table 2.3.1.A. Estimate of the mean content of ^{90}Sr in the human diet in the Faroe Islands in 1988

Type of food	Annual quantity in kg	Bq ^{90}Sr per kg	Total Bq ^{90}Sr	Percentage of total Bq ^{90}Sr in food
Milk and cream	146	0.065	9.49	20.7
Cheese	7.3	0.41	2.99	6.5
Grain products	80	0.23	18.40	40.0
Potatoes	91	0.065	5.92	12.9
Vegetables	20	0.22	4.40	9.6
Fruit	18	0.034	0.61	1.3
Meat and eggs	37	0.033	1.22	2.7
Fish	91	0.00025	0.02	0
Coffee and tea	7.3	0.25	1.83	4.0
Drinking water	548	0.00195	1.07	2.3
Total			45.95	

The mean annual calcium intake is estimated to be 0.6 kg (approx. 200-250 g of creta praeparata). Hence the ratio: Bq ^{90}Sr (kg Ca)$^{-1}$ in total Faroese diet was 77 (2.1 pCi ^{90}Sr (g Ca)$^{-1}$).

Table 2.3.1.B. Estimate of the mean content of ^{90}Sr in the human diet in the Faroe Islands in 1989

Type of food	Annual quantity in kg	Bq ^{90}Sr per kg	Total Bq ^{90}Sr	Percentage of total Bq ^{90}Sr in food
Milk and cream	146	0.054	7.88	17.0
Cheese	7.3	0.44	3.21	6.9
Grain products	80	0.181	14.48	31.1
Potatoes	91	0.130	11.83	25.5
Vegetables	20	0.185	3.70	8.0
Fruit	18	0.020	0.36	0.8
Meat and eggs	37	0.034	1.26	2.7
Fish	91	0.0009	0.08	0.2
Coffee and tea	7.3	0.25	1.83	3.9
Drinking water	548	0.0033	1.81	3.9
Total			46.44	

The mean annual calcium intake is estimated to be 0.6 kg (approx. 200-250 g of creta praeparata). Hence the ratio: Bq ^{90}Sr (kg Ca)$^{-1}$ in total Faroese diet was 77 (2.1 pCi ^{90}Sr (g Ca)$^{-1}$).

Table 2.3.2.A. Estimate of the mean content of ^{137}Cs in the human diet in the Faroe Islands in 1988

Type of food	Annual quantity in kg	Bq ^{137}Cs per kg	Total Bq ^{137}Cs	Percentage of total Bq ^{137}Cs in food
Milk and cream	146	2.77	404.4	19.1
Cheese	7.3	0.135	1.0	0.0
Grain products	80	0.106	8.5	0.4
Potatoes	91	8.4	764.4	36.0
Vegetables	20	0.095	1.9	0.1
Fruit	18	0.049	0.9	0.0
Meat and eggs	37	24.1	891.7	42.1
Fish	91	0.44	40.0	1.9
Coffee and tea	7.3	0.82	6.0	0.3
Drinking water	548	0.0031	1.7	0.1
Total			2120.5	

The mean annual intake of potassium is estimated to be approx. 1.2 kg. Hence the ratio: Bq ^{137}Cs (kg K)$^{-1}$ becomes 1770 (48 pCi ^{137}Cs (g K)$^{-1}$).

Table 2.3.2.B. Estimate of the mean content of ^{137}Cs in the human diet in the Faroe Islands in 1989

Type of food	Annual quantity in kg	Bq ^{137}Cs per kg	Total Bq ^{137}Cs	Percentage of total Bq ^{137}Cs in food
Milk and cream	146	1.89	275.9	15.4
Cheese	7.3	0.153	1.1	0.1
Grain products	80	0.110	8.8	0.5
Potatoes	91	6.9	627.9	35.0
Vegetables	20	0.089	1.8	0.1
Fruit	18	0.054	1.0	0.1
Meat and eggs	37	22.6	836.2	46.6
Fish	91	0.36	32.8	1.8
Coffee and tea	7.3	0.82	6.0	0.3
Drinking water	548	0.0023	1.3	0.1
Total			1792.8	

The mean annual intake of potassium is estimated to be approx. 1.2 kg. Hence the ratio: Bq ^{137}Cs (kg K)$^{-1}$ becomes 1490 (40 pCi ^{137}Cs (g K)$^{-1}$).

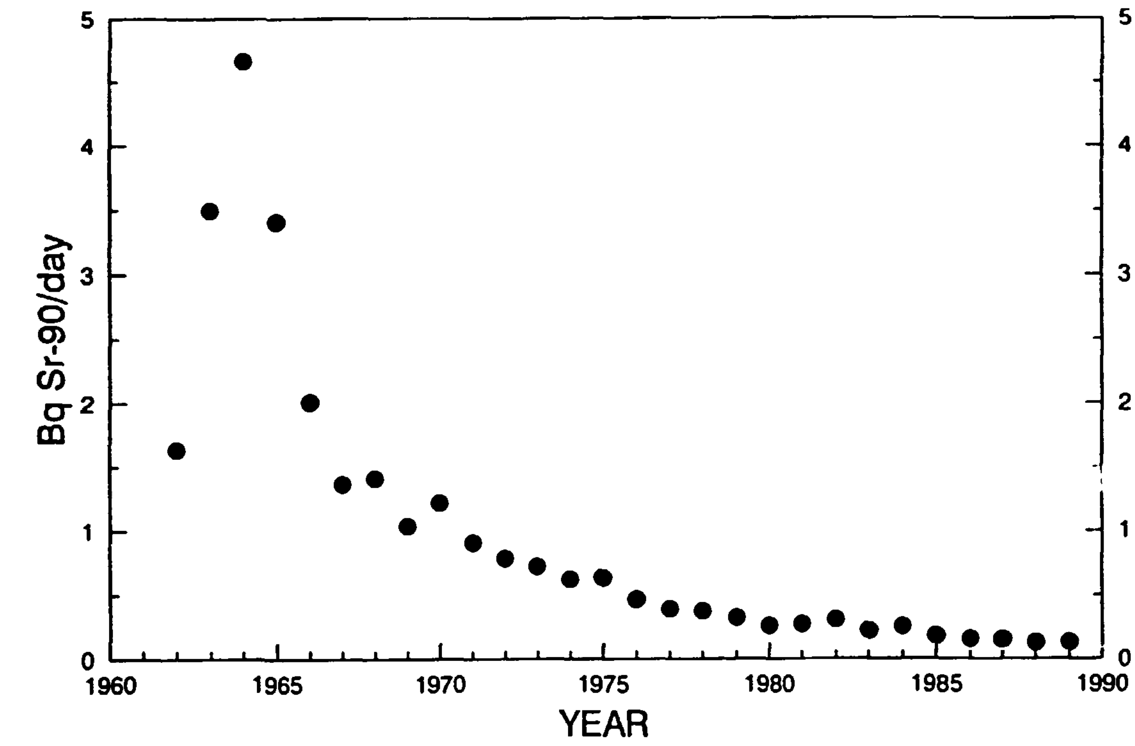
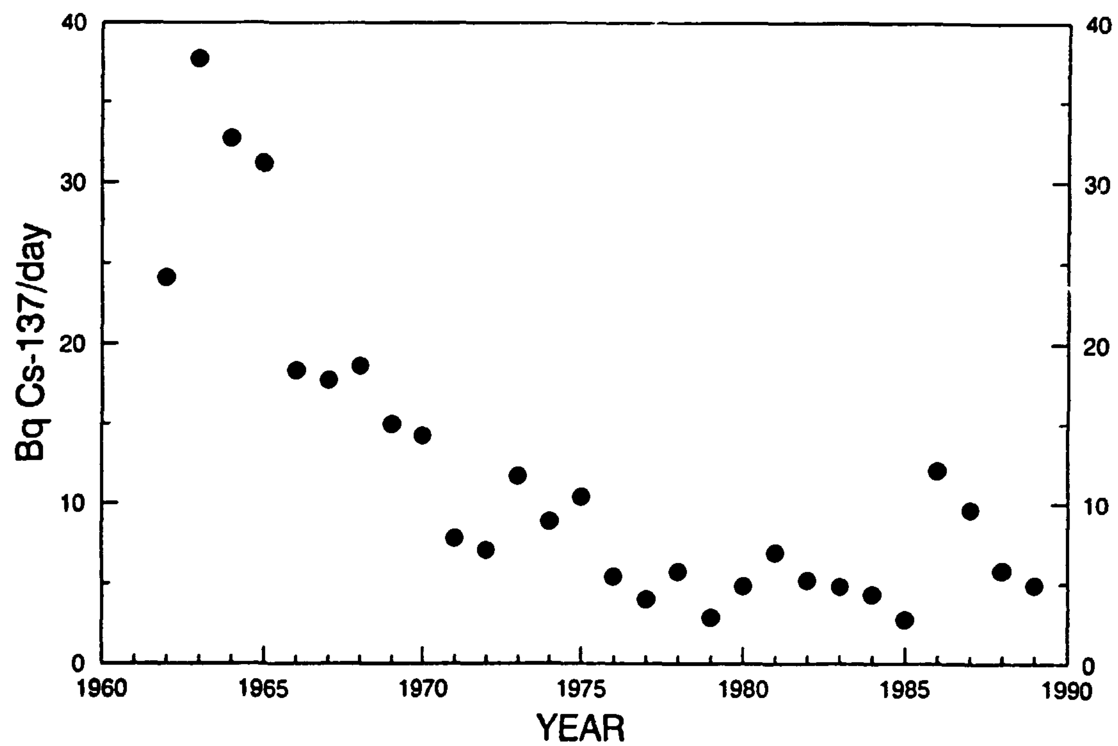


Figure 2.3.1. Strontium-90 in Faroese diet, 1962-1989. (Unit: Bq day^{-1}).

Figure 2.3.2. Cesium-137 in Faroese diet, 1962-1989. (Unit: Bq day^{-1}).



2.4 Conclusion

2.4.1.

The ^{90}Sr fallout rate in the Faroes in 1988 was approximately 0.5 Bq ^{90}Sr m^{-2} and in 1989 it was 0.2. The accumulated fallout by the end of 1989 was estimated to be approximately 3100 Bq ^{90}Sr m^{-2} (84 mCi km^{-2}) (the mean at Thorshavn and Klaksvig).

The ^{137}Cs mean deposit was 14 Bq m^{-2} in 1988 and 9 in 1989.

2.4.2.

The mean level of ^{90}Sr in Faroese milk was 54 Bq (kg Ca)$^{-1}$ in 1988 and 47 in 1989. The ^{137}Cs concentration was 3600 Bq ^{137}Cs m^{-3} in 1988 and 1780 in 1989.

Lamb contained 48 Bq ^{137}Cs kg^{-1} in 1988 and 45 in 1989. Fish showed mean levels of 0.44 and 0.36 Bq ^{137}Cs kg^{-1}, respectively.

The mean content of ^{90}Sr in drinking water was 1.95 Bq m^{-3} in 1988 and 3.3 in 1989.

The mean daily pro capite intakes resulting from the Faroese diet in 1988 were estimated to be 0.13 Bq ^{90}Sr and 5.8 Bq ^{137}Cs in 1988 and 0.13 and 4.9, respectively, in 1989.

2.4.3.

In terrestrial samples (grass, milk, lamb, drinking water, and fodder) collected in the Faroes in 1989 about 70% of the ^{137}Cs came from Chernobyl. In marine fish 40% of the ^{137}Cs was from the Chernobyl accident in 1989 (in 1988: 60%).

The relative contribution of Chernobyl ^{137}Cs to total ^{137}Cs in biota has been decreasing from 1987 to 1989.

2.5 Predictions and Observations of ^{90}Sr and ^{137}Cs in Faroese Samples in 1988 and 1989

The models used for the predictions shown in Table 2A were based on data collected 1962-1976 (Aarkrog 1979). We observe that nearly all models overestimated the levels in 1988 and 1989, except those for ^{137}Cs in cod fish and in lamb. The mean levels for these two sample types were, however, encumbered with large standard errors.

Table 2.5.A. Comparison between observed and predicted ^{90}Sr and ^{137}Cs concentrations in Faroese samples collected in 1988

Sample	Unit	Observed ±1 S.E.		Number of samples	Predicted	Obs./pre. ±1 S.E.		Model in Risø-R-437 (Aarkrog 1979)
Drinking water, Thorshavn	Bq ^{90}Sr m^{-3}	2.9	±0.0	2	9.2	0.32	±0.00	C.1.4.1 No. 9
Drinking water, Klaksvig	Bq ^{90}Sr m^{-3}	0.75	±0.50	2	1.61	0.47	±0.31	C.1.4.1 No. 10
Drinking water, Tværå	Bq ^{90}Sr m^{-3}	2.1	±0.6	2	2.1	1.00	±0.29	C.1.4.1 No. 11
Sea water	Bq ^{90}Sr m^{-3}	1.88	±0.07	3	1.75	1.07	±0.04	C.1.5.1 No. 3
Sea water	Bq ^{137}Cs m^{-3}	2.9	±0.2	3	-	-		C.1.5.1 No. 3 (× 1.6)
Grass	Bq ^{90}Sr (kg Ca)$^{-1}$	5400	±150	2	4700	1.15	±0.03	C.2.4.1 No. 4
Grass	Bq ^{137}Cs (kg K)$^{-1}$	2400	±690	2	12800	0.19	±0.05	C.2.4.2 No. 3
Potatoes	Bq ^{90}Sr kg^{-1}	0.065	±0.024	3	0.194	0.34	±0.13	C.2.5.1 No. 11
Potatoes	Bq ^{137}Cs kg^{-1}	8.4	±3.9	3	11.7	0.72	±0.33	C.2.5.3 No. 8
*Milk	Bq ^{90}Sr (kg Ca)$^{-1}$	53	±2	12	265	0.20	±0.01	C.3.3.1 No. 1
*Milk Thorshavn	Bq ^{137}Cs (kg K)$^{-1}$	1300	±121	12	4100	0.32	±0.03	C.3.3.2 No. 1
*Milk Klaksvik	Bq ^{137}Cs (kg K)$^{-1}$	1380	±101	12	4900	0.28	±0.02	C.3.3.2 No. 3
*Milk Tværå	Bq ^{137}Cs (kg K)$^{-1}$	2900	±260	12	7500	0.39	±0.03	C.3.3.2 No. 5
Cod fish	Bq ^{90}Sr (kg Ca)$^{-1}$	2.8	±0.7	2	18.9	0.148	±0.037	C.3.5.1 No. 3
Cod fish	Bq ^{137}Cs kg^{-1}	0.44	±0.06	8	0.32	1.38	±0.19	C.3.5.2 No. 2
Lamb meat	Bq ^{90}Sr (kg Ca)$^{-1}$	890	±163	6	880	1.01	±0.18	C.3.4.1 No. 5
Lamb meat	Bq ^{137}Cs (kg K)$^{-1}$	15500	±3600	6	11900	1.30	±0.30	C.3.4.2 No. 5
Lamb bone	Bq ^{90}Sr (kg Ca)$^{-1}$	1170	±145	6	1860	0.63	±0.08	C.3.4.3 No. 1

*"Milk year": June 1988 - May 1989.

Table 2.5.B. Comparison between observed and predicted ^{90}Sr and ^{137}Cs concentrations in Faroese samples collected in 1989

Sample	Unit	Observed ±1 S.E.		Number of samples	Predicted	Obs./pre. ±1 S.E.		Model in Risø-R-437 (Aarkrog 1979)
Drinking water, Thorshavn	Bq ^{90}Sr m^{-3}	4.6	±0.6	2	8.8	0.52	±0.07	C.1.4.1 No. 9
Drinking water, Klaksvig	Bq ^{90}Sr m^{-3}	0.82	±0.22	2	1.43	0.57	±0.15	C.1.4.1 No. 10
Drinking water, Tværå	Bq ^{90}Sr m^{-3}	4.4	±1.8	2	1.91	2.30	±0.94	C.1.4.1 No. 11
Sea water	Bq ^{90}Sr m^{-3}	1.73	±0.05	3	1.67	1.04	±0.03	C.1.5.1 No. 3
Sea water	Bq ^{137}Cs m^{-3}	2.6	±0.2	3	-	-		C.1.5.1 No. 3 (× 1.6)
Grass	Bq ^{90}Sr (kg Ca)$^{-1}$	1760	±250	7	4400	0.40	±0.06	C.2.4.1 No. 4
Grass	Bq ^{137}Cs (kg K)$^{-1}$	3600	±1810	7	6700	0.54	±0.27	C.2.4.2 No. 3
Potatoes	Bq ^{90}Sr kg^{-1}	0.134	±0.050	3	0.187	0.72	±0.27	C.2.5.1 No. 11
Potatoes	Bq ^{137}Cs kg^{-1}	6.9	±2.7	3	10.6	0.65	±0.25	C.2.5.3 No. 8
*Milk	Bq ^{90}Sr (kg Ca)$^{-1}$	44	±1	12	251	0.175	±0.004	C.3.3.1 No. 1
*Milk Thorshavn	Bq ^{137}Cs (kg K)$^{-1}$	940	±98	11	2900	0.32	±0.03	C.3.3.2 No. 1
*Milk Klaksvik	Bq ^{137}Cs (kg K)$^{-1}$	1020	±113	11	3800	0.27	±0.03	C.3.3.2 No. 3
*Milk Tværå	Bq ^{137}Cs (kg K)$^{-1}$	2300	±198	11	6500	0.35	±0.03	C.3.3.2 No. 5
Cod fish	Bq ^{90}Sr (kg Ca)$^{-1}$	7.7	±1.4	2	17.4	0.44	±0.08	C.3.5.1 No. 3
Cod fish	Bq ^{137}Cs kg^{-1}	0.36	±0.06	8	0.30	1.20	±0.20	C.3.5.2 No. 2
Lamb meat	Bq ^{90}Sr (kg Ca)$^{-1}$	800	±320	3	780	1.03	±0.41	C.3.4.1 No. 5
Lamb meat	Bq ^{137}Cs (kg K)$^{-1}$	14800	±9000	6	10100	1.46	±0.89	C.3.4.2 No. 5
Lamb bone	Bq ^{90}Sr (kg Ca)$^{-1}$	780	±170	3	1770	0.44	±0.10	C.3.4.3 No. 1

*"Milk year": June 1989 - May 1990.

2.6 Texture and Soil Analysis

Table 2.6.1. Texture and soil analysis on soil collected at Thorshavn July 12, 1989

	Percentage					Rt	Pt	Kt	
Depth in cm	Humus (Organic matter)	Clay < 0.002 mm	Silt 0.002-0.02 mm	Fine sand 0.02-0.2 mm	Sand 0.2-2 mm	pH + 0.5	Extractable phosphate mg P/100 g soil	Exchangeable potassium mg K/100 g soil	Specific weight kg/dm³ soil
0-5	21	7.0	10.0	35.8	26.2	5.4	3.9	24.4	0.35
5-10	17	6.6	9.6	40.2	26.6	4.9	1.0	8.6	0.60
10-20	16	4.1	9.3	42.6	28.0	4.8	0.9	7.9	0.60
20-30	13	3.9	9.6	44.1	29.4	4.8	1.3	14.2	0.75
30-40	8.3	5.4	13.2	44.8	28.3	5.0	0.5	15.2	0.75
40-50	2.0	6.2	21.2	39.4	31.2	5.2	0.7	26.9	-

Table 2.6.2. Texture and soil analysis on soil collected at Klaksvig July 17, 1989

	Percentage					Rt	Pt	Kt	
Depth in cm	Humus (Organic matter)	Clay < 0.002 mm	Silt 0.002-0.02 mm	Fine sand 0.02-0.2 mm	Sand 0.2-2 mm	pH + 0.5	Extractable phosphate mg P/100 g soil	Exchangeable potassium mg K/100 g soil	Specific weight kg/dm³ soil
0-5	25	5.1	7.6	46.9	15.4	4.7	13.5	86.5	0.45
5-10	19	3.8	8.9	41.6	26.7	4.6	9.8	83.6	0.65
10-20	14	5.1	10.5	42.7	27.7	5.1	7.1	70.8	0.75
20-30	5.9	6.6	18.2	33.3	36.0	5.0	3.6	73.1	-

Table 2.6.3. Texture and soil analysis on soil collected at Bour July 15, 1989

	Percentage					Rt	Pt	Kt	
Depth in cm	Humus (Organic matter)	Clay < 0.002 mm	Silt 0.002-0.02 mm	Fine sand 0.02-0.2 mm	Sand 0.2-2 mm	pH + 0.5	Extractable phosphate mg P/100 g soil	Exchangeable potassium mg K/100 g soil	Specific weight kg/dm³ soil
0-5	25	4.5	8.1	53.8	8.6	5.9	7.5	77.2	0.50
5-10	21	5.6	8.6	52.4	12.4	4.9	5.9	50.5	0.60
10-20	18	7.5	11.1	45.6	17.8	4.9	3.0	26.8	0.65
20-30	17	6.4	12.1	51.5	13.0	4.9	2.4	11.6	0.55
30-40	18	6.1	13.7	47.8	14.4	5.0	2.6	4.3	0.50

Table 2.6.4. Texture and soil analysis on soil collected at Oravik July 14, 1989

	Percentage					Rt	Pt	Kt	
Depth in cm	Humus (Organic matter)	Clay < 0 002 mm	Silt 0 002-0 02 mm	Fine sand 0 02-0 2 mm	Sand 0 2-2 mm	pH - 0 5	Extractable phosphate mg P 100 g soil	Exchangeable potassium mg K 100 g soil	Specific weight
0-5	51	11 6	7 4	28 3	1 7	5 6	1 4	50 3	0 20
5-10	35	7 5	6 0	44 1	6 4	4 7	1 1	9 5	0 34
10-20	30	10 4	8 5	47 6	3 5	4 6	0 6	4 2	0 45
20-30	4 2	14 8	19 1	57 7	4 2	4 7	0 2	1 8	0 75
30-40	3 0	9 0	23 0	61 8	3 2	5 1	0 3	1 9	0 60
40-50	15	5 9	13 8	62 5	2 8	4 7	0 0	1 4	0 60

3 Environmental Radioactivity in Greenland in 1988 and 1989

3.1 Introduction

3.1.1.

The sampling programme was similar to that used previously to Chernobyl.

3.1.2.

As hitherto, samples were collected through the local district physicians and the head of the telestations. However, we have also obtained samples collected by the Greenland Fisheries and Environmental Research Institute. A number of the Greenland food samples were obtained from K.N.I. (Kalaallit Niuerfiat) (Greenland Trade).

3.1.3.

The estimated mean diet in Grenland was the same as that in 1962, i.e.. it agreed with the estimate given by the late Professor E. Hoff-Jørgensen.

3.1.4.

The environmental studies in Greenland were carried out together with corresponding investigations in Denmark (cf. Risø Report No. 570) and in the Faroes (cf. Chapter 2 in this report).

3.1.5.

The present report does not repeat information concerning sample collection and analysis already given in Risø Reports (Greenland) 1962-1982.

3.2 Results and Discussion

3.2.1 Strontium-90 in Greenland Precipitation.

Tables 3.2.1.1.A & B show the results of the measurements.

The ^{90}Sr fallout in 1988 and 1989 at the Greenland stations were generally lower as compared with 1987.

Figure 3.2.1 shows the accumulated ^{90}Sr at the various stations in Greenland since measurements began in 1962 (cf. also Table 3.2.1.2).

3.2.2 Radionuclides in Greenland Sea Water

Tables 3.2.2.A & B show the samplings carried out in 1988 and 1989.

The Chernobyl contribution to total ^{137}Cs in sea water from East Greenland in 1988 was about 20% (Table 3.2.2.A).

3.2.3 Strontium-90 and Radiocesium in Greenland Terrestrial Mammals

Reindeer collected in 1988 and 1989 contained 15% and 11% (compared to total ^{137}Cs), respectively, of Chernobyl ^{137}Cs (Tables 3.2.3.1.A & B) (cf. also Figures 3.2.3.1-3.2.3.3).

3.2.4 Strontium-90 and Radiocesium in Greenland Aquatic Animals

It appears from Tables 3.2.4.1.A & B that the ^{137}Cs levels in marine biota were generally lower in 1988 and 1989 than the concentrations measured in 1987, and the Chernobyl signal had almost disappeared (see also Tables 3.2.4.2.A & B and Figure 3.2.4).

3.2.5 Radionuclides in Greenland Vegetation

Tables 3.2.5.1.A & B show that Chernobyl ^{137}Cs was detectable in seaweed in 1988. The percentage (to total ^{137}Cs) was nearly 60% and in 1989 it was about 50%. Technetium-99 was measured in 1988 and the levels were similar to those seen 1987. The ^{90}Sr concentrations in Fucus in 1988 and 1989 were twice those observed in 1987.

A turf with moss and lichen was collected at Scoresbysund in 1988 (cf. Table 3.2.5.2.A). The total deposition of ^{137}Cs measured to a depth of 5 cm was 1.43 kBq m^{-2}, the contribution from Chernobyl was 0.12 kBq m^{-2}.

Chernobyl ^{137}Cs was also detected in grass and lichen from Godthåb, the Chernobyl contribution to the total ^{137}Cs amounted to 10% for grass; in case of lichen we found only 4%.

3.2.6 Strontium-90 and Tritium in Greenland Drinking Water

The levels in drinking water (Tables 3.2.6.1.A & B and Figure 3.2.6) are still surprisingly high compared with present rain concentrations (cf. Tables 3.2.1.1.A & B). We have suggested that evaporation from the drinking water reservoirs was responsible for the higher ^{90}Sr levels. Tritium measurements show (Tables 3.2.6.2.A & B) that Greenland drinking water shows similar tritium levels as rain from Denmark (Risø Report No. 570); hence evaporation seems to be a possible explanation. The high ^{90}Sr levels may, however, also be due to the extraction of old deposited ^{90}Sr activity from the soil by the water collected for drinking or to a migration of Sr-90 in the ice which might enrich certain layers (and deplete others). This would also be compatible with "normal" tritium concentrations. If old ice (e.g. from the early sixties) had been the source, we would have expected high tritium concentrations.

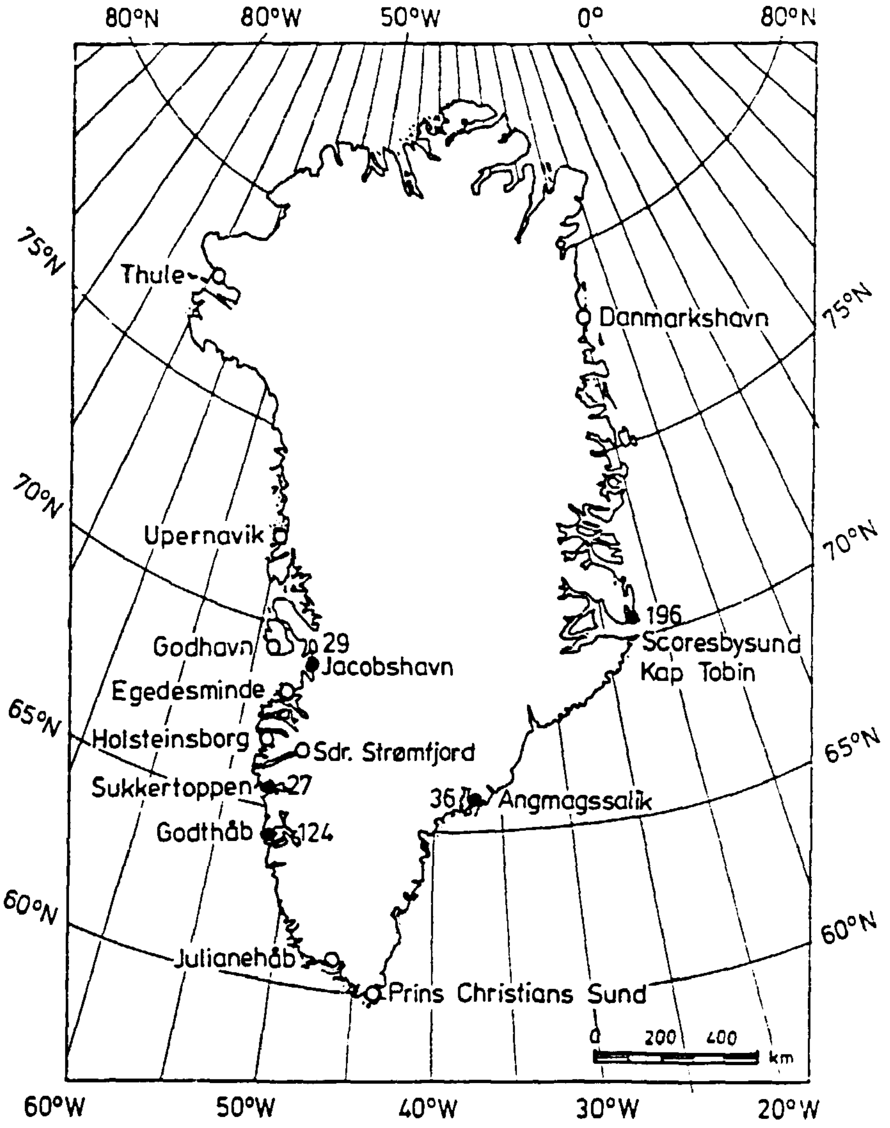


Figure 3.1. Greenland (Bq ^{137}Cs m^{-2} from Chernobyl is indicated).

Table 3.2.1.1.A. Strontium-90 in precipitation in Greenland in 1988. (Sampling area: 0.02 m²)

Location m precipitation	Unit	Jan-March	April-June	July-Sept	Oct-Dec	1988
Godthåb	Bq m-3	1.72	1.87	0.9 B	0.89 A	1.26
Σ 0.737	Bq m-2	0.31	0.23	0.2 B	0.15 A	0.93
Scoresbysund	Bq m-3	0.6 B	0.8 B	0.1 B	0.5 B	0.48
Σ 0.420	Bq m-2	0.08 B	0.07 B	0.01 B	0.05 B	0.20
Danmarkshavn	Bq m-3	6 B	12.6	7 B	12 A	10
Σ 0.067	Bq m-2	0.1 B	0.33	0.05 B	0.20 A	0.68
Prins Chr.Sund	Bq m-3	0.64 A	0.08 B	2.7	9.0	2.8
Σ (1.209)	Bq m-2	0.18 A	0.03 B	0.78	2.5	3.4

Table 3.2.1.1.B. Strontium-90 in precipitation in Greenland in 1989. (Sampling area: 0.02 m²)

Location m precipitation	Unit	Jan-March	April-June	July-Sept	Oct-Dec	1989
Godthåb	Bq m-3	1.3 A	1.68	0.2 B	0.7 B	0.71
Σ 0.653	Bq m-2	0.12 A	0.20	0.08 B	0.06 B	0.46
Scoresbysund	Bq m-3	0.2 B	0.7 B	0.06 B	0.8 B	0.4
Σ 0.594	Bq m-2	0.04 B	0.08 B	0.005B	0.1 B	0.2
Danmarkshavn	Bq m-3	1 B	1 B		1 B	1
Σ (0.145)	Bq m-2	0.1 B	0.04 B		0.04 B	0.2

Table 3.2.1.2. Fallout rates and accumulated fallout (Bq m^{-2}) in Greenland 1950-1989

	Scoresbysund (Kap Tobin)		Pr.Chr.Sund		Godthåb		Upernavik	
	d_i	$A_{i(29)}$	d_i	$A_{i(29)}$	d_i	$A_{i(29)}$	d_i	$A_{i(29)}$
1950	0.37	0.36	2.04	1.99	0.57	0.56	0.20	0.20
1951	1.76	2.06	9.79	11.50	2.77	3.25	0.97	1.14
1952	3.44	5.38	19.19	29.97	5.42	8.46	1.90	2.97
1953	8.70	13.74	48.47	76.59	13.69	21.63	4.81	7.60
1954	33.06	45.69	184.28	254.71	52.05	71.94	18.29	25.28
1955	43.49	87.08	242.45	485.41	68.48	137.10	24.06	48.17
1956	53.93	137.67	300.61	767.46	84.91	216.76	29.83	76.16
1957	53.93	187.08	300.61	1042.85	84.91	294.54	29.83	103.49
1958	74.81	255.70	417.04	1425.40	117.79	402.59	41.39	141.45
1959	106.11	353.27	591.53	1969.29	167.07	556.21	58.70	195.43
1960	19.82	364.28	110.51	2030.68	31.21	573.55	10.97	201.52
1961	25.75	380.83	143.57	2122.90	40.55	599.60	14.25	210.67
1962	129.17	497.95	720.07	2775.83	203.38	784.01	71.46	275.46
1963	290.45	769.78	1545.12	4218.89	475.45	1229.72	160.58	425.75
1964	180.93	928.26	929.07	5026.38	258.63	1453.19	100.27	513.59
1965	68.82	973.53	383.32	5281.93	166.50	1581.44	38.11	538.67
1966	37.37	987.02	207.94	5360.21	43.29	1586.36	20.72	546.18
1967	18.13	981.41	73.63	5305.51	32.56	1580.68	12.21	545.20
1968	24.42	982.08	136.16	5313.15	37.00	1579.48	13.32	545.33
1969	18.13	976.59	72.89	5258.83	22.20	1563.85	6.73	539.03
1970	33.30	986.03	59.20	5192.43	34.41	1560.51	12.58	538.58
1971	15.17	977.56	122.84	5189.73	32.56	1555.44	8.14	533.81
1972	12.58	966.75	55.50	5121.35	15.17	1533.52	4.07	525.17
1973	3.40	947.24	17.91	5017.88	6.92	1504.06	2.78	515.48
1974	12.21	936.79	45.88	4944.16	18.83	1486.92	13.14	516.13
1975	4.48	919.04	86.21	4911.57	19.57	1470.91	8.44	512.18
1976	3.00	900.26	11.17	4806.47	4.85	1440.91	2.44	502.46
1977	5.18	884.06	34.78	4726.91	14.06	1420.60	7.03	497.46
1978	10.36	873.29	54.39	4668.38	14.43	1401.14	7.77	493.30
1979	2.81	855.41	10.36	4568.24	9.99	1377.80	3.70	485.26
1980	2.57	837.72	5.74	4465.95	3.87	1349.04	3.02	476.75
1981	4.50	822.33	27.79	4387.60	10.57	1327.50	4.53	469.91
1982	1.97	804.83	5.19	4289.05	2.15	1298.24	1.27	460.05
1983	1.18	786.97	(10.1)	4197.63	2.98	1270.49	1.53	450.68
1984	0.87	769.23	(1.65)	4100.10	1.62	1242.06	1.79	441.78
1985	1.36	752.39	(1.6)	4004.82	(1.7)	1214.38	(~0.3)	431.64
1986	1.14	735.76	~1.5	3911.73	1.64	1187.34	~0.3	421.75
1987	0.23	718.61	~1	3820.32	1.19	1160.46	(~0.2)	411.98
1988	~0.2	702	3.4	3733.4	0.93	1134	-	~402
1989	~0.2	685	-	~3645	0.46	1108	-	~393

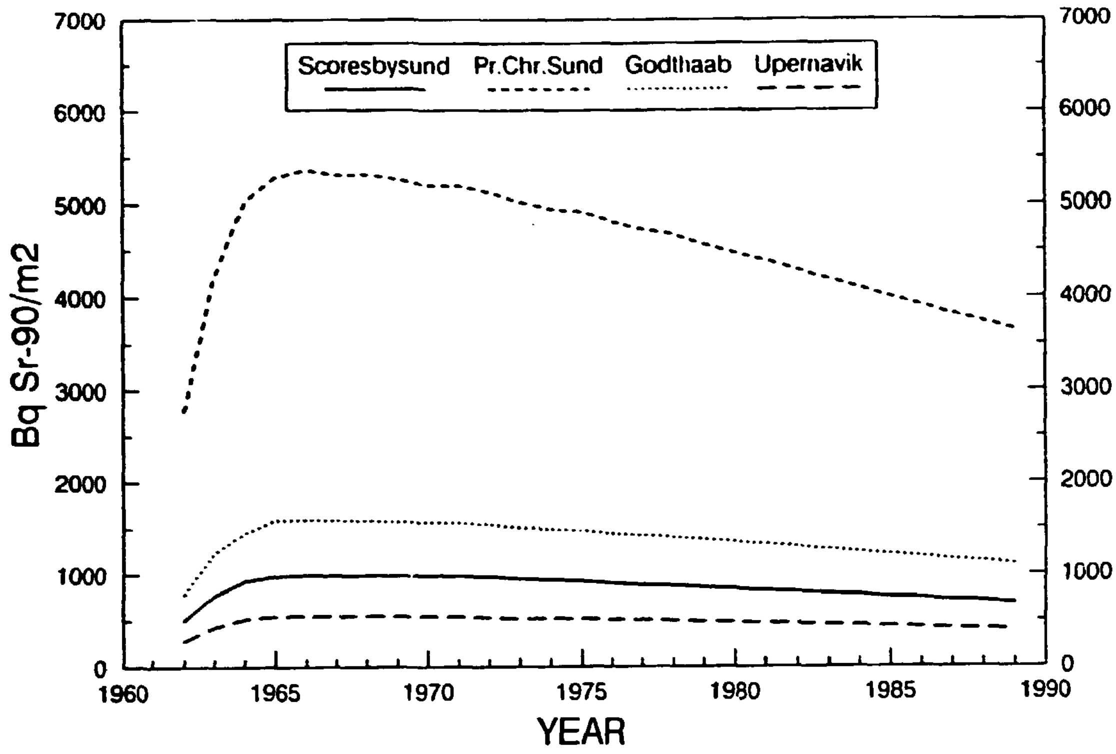


Figure 3.2.1. Accumulated ^{90}Sr at Prins Chr. Sund, Godthåb, Scoresbysund (Kap Tobin) and Upernavik calculated from precipitation measurements since 1962. The accumulated fallout by 1962 was estimated from the Danish data (Risø Report No. 509, Appendix D) and from the ratio of the ^{90}Sr fallout at the Greenland stations to that in Denmark in the period 1962-1974.

Table 3.2.2.A. Radionuclides in surface sea water collected in Greenland in the autumn of 1988

Location	Bq ^{137}Cs m^{-3}	Bq ^{90}Sr m^{-3}	Salinity ‰	$^{134}Cs / ^{137}Cs$
Danmarkshavn	8.1	4.4	28.7	0.044 A
Prins Chr. Sund	6.5	3.7	30.5	0.072

Table 3.2.2.B. Radionuclides in surface sea water collected in Greenland in the autumn of 1989

Location	Bq ^{137}Cs m^{-3}	Bq ^{90}Sr m^{-3}	Salinity ‰
Danmarkshavn	8.7	4.5	31.7
Upernavik	2.5	1.79	30.5

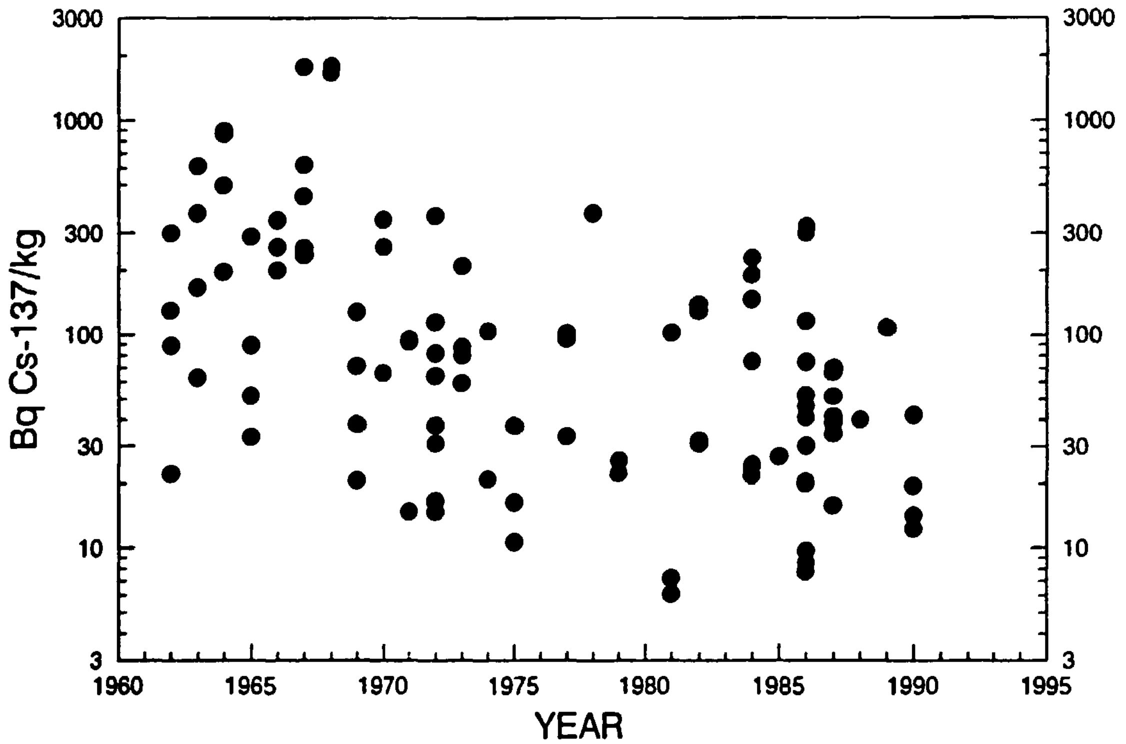
Table 3.2.3.1.A. Radiocesium and strontium-90 in Greenland reindeer collected in 1988

Location	Sample	Bq ^{137}Cs kg^{-1} meat	^{134}Cs / ^{137}Cs	Bq ^{90}Sr kg^{-1} meat	Bq ^{90}Sr (kg Ca)$^{-1}$ in bone	g K kg^{-1} meat	g Ca kg^{-1} meat
KNI	II	40	0.041	0.042	1560	3.8	0.061

Table 3.2.3.1.B. Radiocesium and strontium-90 in Greenland reindeer collected in 1989

Location	Bq ^{137}Cs kg^{-1} meat	^{134}Cs / ^{137}Cs	Bq ^{90}Sr kg^{-1} meat	Bq ^{90}Sr (kg Ca)$^{-1}$ in bone	g K kg^{-1} meat	g Ca kg^{-1} meat
KNI	108	0.021	0.20	4200	3.5	0.091

Figure 3.2.3.1. Cesium-137 in reindeer meat from Greenland, 1962-1990. (Unit: Bq kg^{-1}).



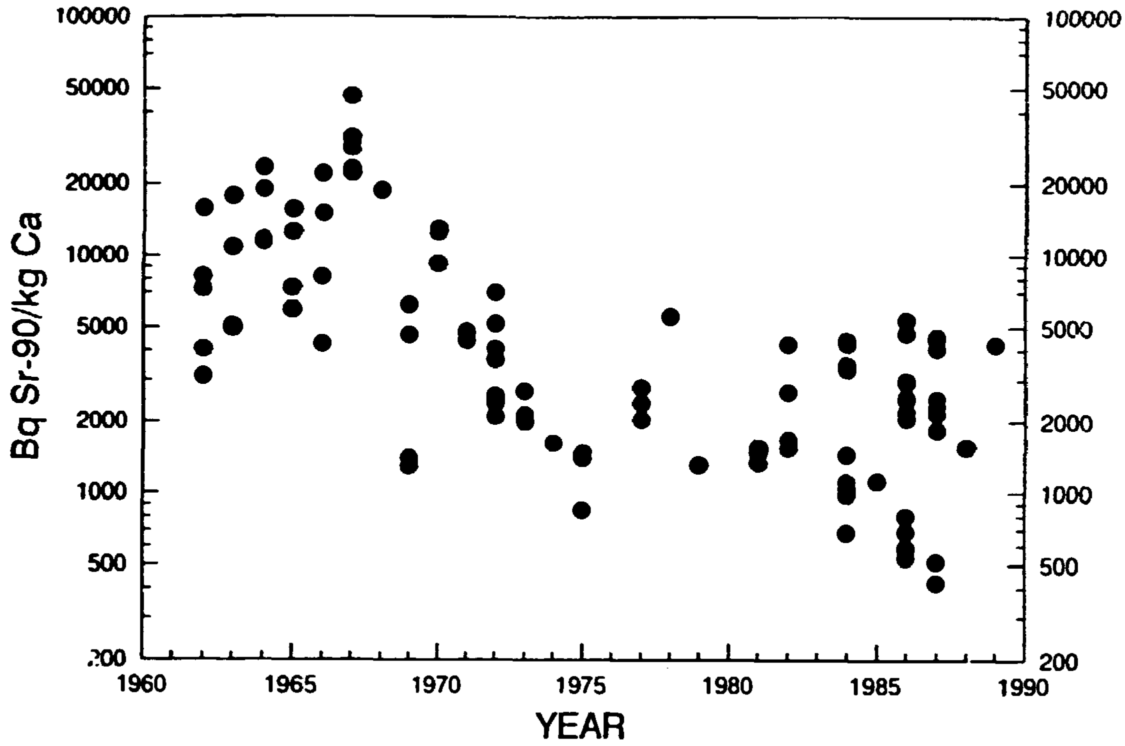


Figure 3.2.3.2. Strontium-90 in reindeer bone from Greenland, 1962-1989. (Unit: Bq (kg Ca)$^{-1}$).

Figure 3.2.3.3. Cesium-137 in Greenland mutton, 1962-1989. (Unit: Bq kg^{-1}). (No samples in 1987, 1988 and 1989).

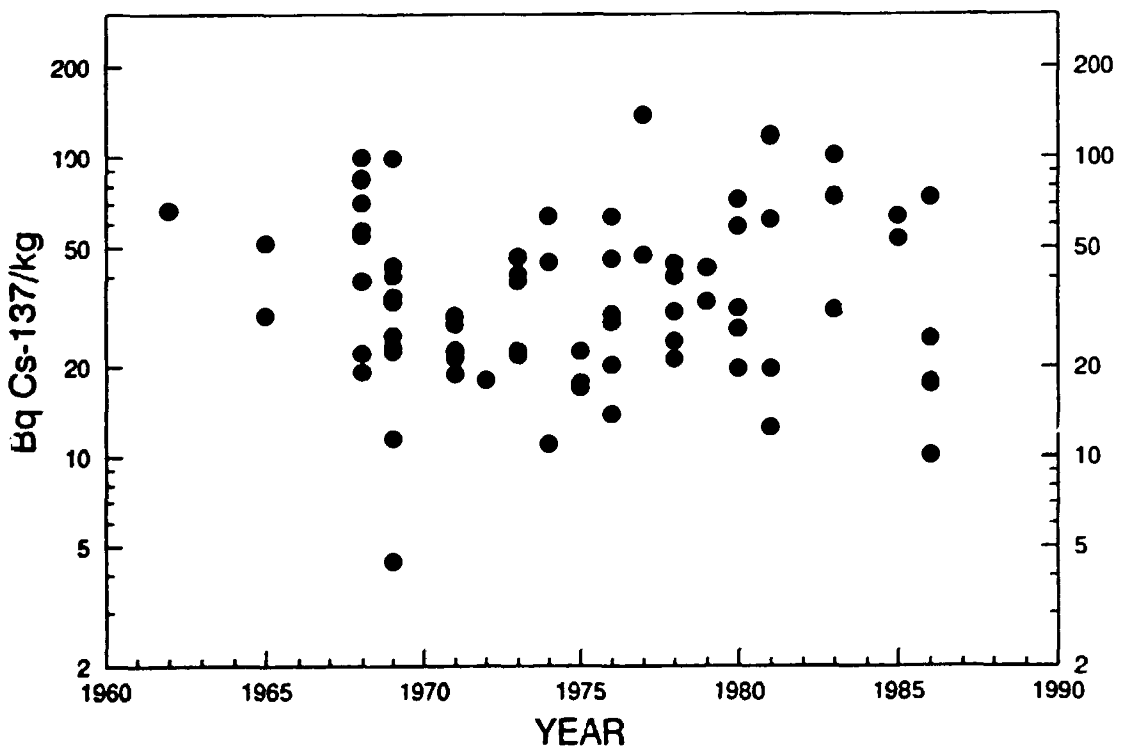


Table 3.2.4.1.A. Radiocesium in aquatic animals from Greenland in 1988

Species	Location	Month	^{137}Cs Bq kg^{-1}	$\frac{^{134}Cs}{^{137}Cs}$	g K kg^{-1}
Halibut	KNI	July	0.31	-	4.5
Shrimps	KNI		0.082	-	1.25

Table 3.2.4.1.B. Radiocesium in aquatic animals from Greenland in 1989

Species	Location	^{137}Cs Bq kg^{-1}	$\frac{^{134}Cs}{^{137}Cs}$	g K kg^{-1}
Seal	KNI	0.24	-	2.15
Salmon	KNI	0.32	0.10 A	3.8
Shrimps	KNI	0.072	-	1.40
Razor Bill	KNI	0.31	-	3.3

Figure 3.2.4. Cesium-137 in seal and whale meat from Greenland 1962-1990. (Unit: Bq kg^{-1}).

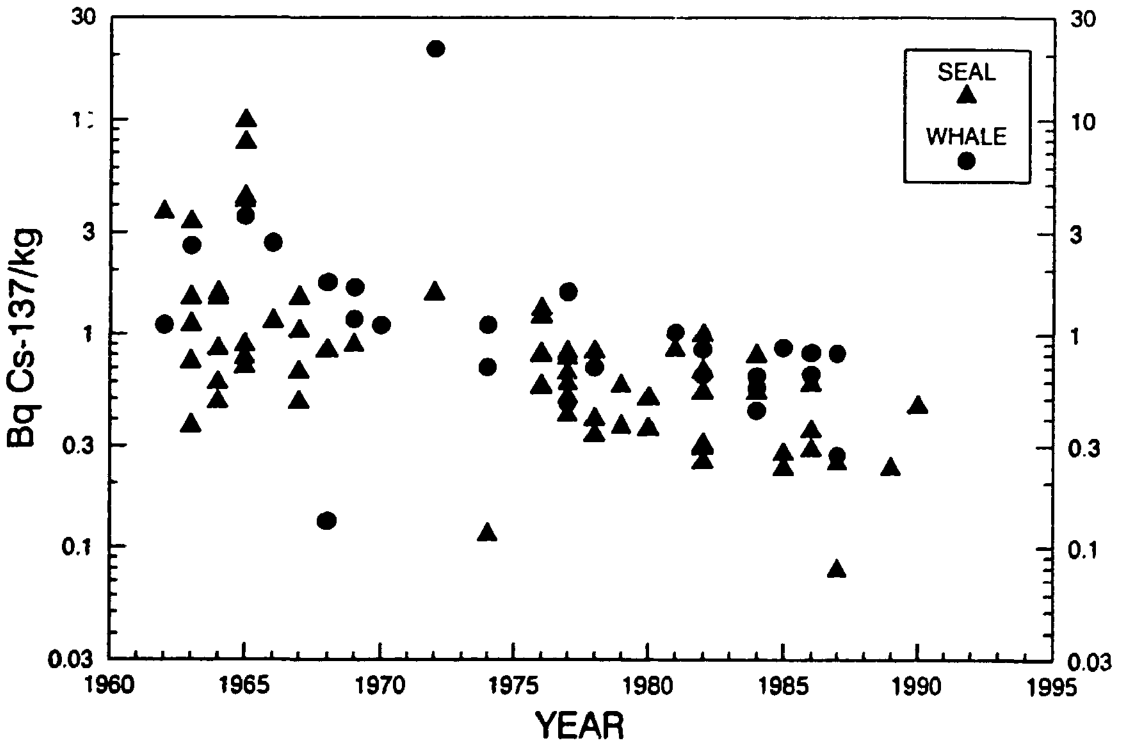


Table 3.2.4.2.A. Strontium-90 in aquatic animals from Greenland in 1988

Species	Location	Month	^{90}Sr Bq kg^{-1} flesh	^{90}Sr Bq (kg Ca)$^{-1}$ bone	g Ca kg^{-1} flesh
Halibut	KNI	July	0.001 B	0.4	0.47
Shrimps	KNI		0.011		0.45

Table 3.2.4.2.B. Strontium-90 in aquatic animals from Greenland in 1989

Species	Location	^{90}Sr Bq kg^{-1} flesh	^{90}Sr Bq (kg Ca)$^{-1}$ bone	g Ca kg^{-1} flesh
Seal	KNI	0.004 B	1.7 A	0.132
Salmon II	KNI	0.0034	20	0.12
Shrimps	KNI	0.005 B		0.52
Razor Bill	KNI	0.001 B	0.3 B	0.1

Table 3.2.5.1.A. Radionuclides in seaweed collected at Godthåb in 1988

Species	Date	^{90}Sr Bq kg^{-1} dry	^{90}Sr Bq (kg Ca)$^{-1}$	^{99}Tc Bq kg^{-1} dry	^{137}Cs Bq kg^{-1} dry	g K kg^{-1} dry	g Ca kg^{-1} dry	^{134}Cs / ^{137}Cs
Fucus vesiculosus	31/8	0.64	48	4.4	0.70	24	13.2	-
Ascophyllum nodosum	31/8	0.3 B	20 B	11.1	1.25	21	16.9	0.15 A

Table 3.2.5.1.B. Radionuclides in seaweed collected at Scoresbysund in 1989

Species	Date	^{90}Sr Bq kg^{-1} dry	^{90}Sr Bq (kg Ca)$^{-1}$	^{137}Cs Bq kg^{-1} dry	g K kg^{-1} dry	g Ca kg^{-1} dry	^{134}Cs / ^{137}Cs
Fucus vesiculosus	27/9	0.52	43	3.1	53	12.1	0.089 A

Table 3.2.5.2.A. Radionuclides in lichen, moss, and grass collected in Greenland in 1988

Species	Location	Month	^{90}Sr Bq kg^{-1} dry	^{90}Sr Bq m^{-2}	^{137}Cs Bq kg^{-1} dry	^{137}Cs Bq m^{-2}	^{134}Cs / ^{137}Cs
Lichen	Godthåb	August	27 ± 1	25.6 ± 0.3	410 ± 50	440 ± 20	0.0115 ± 0
Grass	Godthåb	August	1.80		135	-	0.026
Moss, lichen							
Peat: 0-3 cm	Scoresbysund	September	-	-	153	650	0.046
Peat: 3-5 cm	Scoresbysund	September	-	-	86	780	-

Table 3.2.6.1.A. Strontium-90 in drinking water collected in Greenland in 1988 (Unit: Bq m⁻³)

Location	Jan-Mar	April-June	July-Sept	Oct-Dec
Scoresbysund	7.4	10.4	3.8	3.0
Prins Chr. Sund	42	40	5.1	17.6
Godthåb		7.3		
Upernavik	6.9	6.4	6.1	

Table 3.2.6.1.B. Strontium-90 in drinking water collected in Greenland in 1989 (Unit: Bq m⁻³)

Location	Jan-Mar	April-June	July-Sept	Oct-Dec
Danmarkshavn	27	4.4	4.6	
Scoresbysund	2.8	5.8	3.5	4.8
Upernavik	9.1	9.7	4.4	5.5

Figure 3.2.6. Strontium-90 in Greenland drinking water (geometric mean), 1962-1989. (Unit: Bq m⁻³).

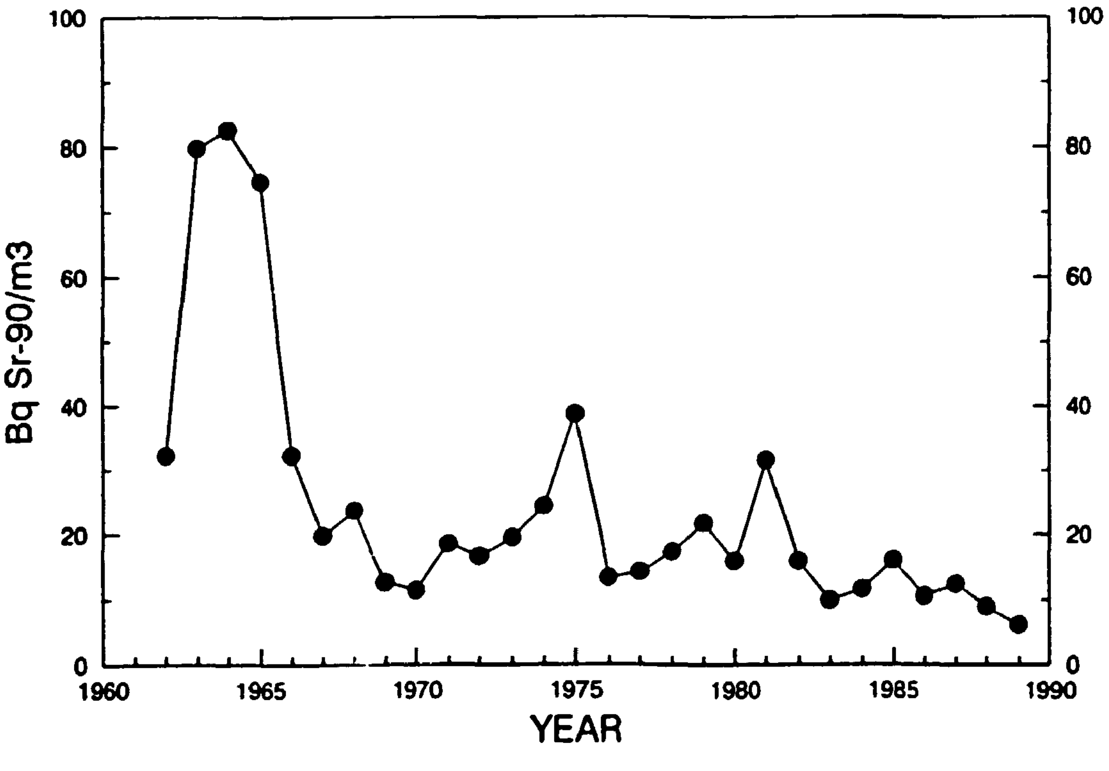


Table 3.2.6.2.A. Tritium in drinking water collected in Greenland in 1988 (Unit: kBq m^{-3})

Location	Jan-March
Scoresbysund	1.93 ± 0.29
Prins Chr. Sund	1.74 ± 0.28
Godthåb (April-June)	1.74 ± 0.10
Upernavik	2.41 ± 0.38

The error term is 1 S.E. of the mean of double determinations.

Table 3.2.6.2.B. Tritium in drinking water collected in Greenland in 1989 (Unit: kBq m^{-3})

Location	Jan-March
Danmarkshavn	1.88 ± 0.25
Scoresbysund	1.65 ± 0.30
Upernavik	2.36 ± 0.40

The error term is 1 S.E. of the mean of triple determinations.

3.3 Estimate of the Mean Contents of ^{90}Sr and ^{137}Cs in the Human Diet in Greenland in 1988 and 1989

3.3.1 The Annual Quantities

The estimate of the daily pro capite intake of the different foods in Greenland is still based on the figures given in 1962 by the late Professor E. Hoff-Jorgensen, in Riso Report No. 65 (Riso Reports (Greenland) 1962-1982).

3.3.2 Milk Products

All milk consumed in Greenland was imported as milk powder from Denmark. The mean radioactivity content in milk prepared from Danish dried milk produced in 1988 was 0.062 Bq ^{90}Sr kg^{-1} and 0.28 Bq ^{137}Cs kg^{-1} (Riso Report No. 570) and in 1989: 0.058 and 0.178, respectively.

Cheese was also imported from Denmark and contained 0.41 Bq ^{90}Sr kg^{-1} and 0.135 Bq ^{137}Cs kg^{-1} in 1988 and 0.44 and 0.153, respectively, in 1989.

3.3.3 Grain Products

All grain was imported from Denmark. It is assumed that only grain from the harvest of the previous year was consumed in Greenland during a given year. The daily pro capite consumption was: rye flour (100% extraction): 80 g; wheat flour (75% extraction): 110 g; rye flour (70% extraction): 20 g; biscuits (rye, 100% extraction): 27 g, and grits: 25 g. The content of ^{90}Sr in these five products was 0.43, 0.08, 0.09, 0.32, and 0.23 Bq kg^{-1}, respectively. Hence the mean content of ^{90}Sr in grain products was 0.23 Bq kg^{-1}. The content of ^{137}Cs in the five products was 11.1, 0.29, 2.22, 8.22, and 0.37 Bq kg^{-1}. Hence the mean content of ^{137}Cs in grain products was 4.56 Bg kg^{-1}.

The activity levels in rye flour (100% extraction), wheat flour (75% extraction), and grits were all taken from Tables 5.9.1.A & B and 5.9.2.A & B in Risø Report No. 570. The calculations of the ^{90}Sr level in rye flour (70% extraction) was made similarly to that of the level in wheat flour (75% extraction), i.e. as one-fifth of the whole- grain activity. The ^{137}Cs content in rye flour (70% extraction) was calculated as one-half of the whole-grain level in rye in analogy with the ratio of ^{137}Cs in whole wheat grain to wheat flour (75% extraction) (Risø Report No. 570). The ^{90}Sr and ^{137}Cs contents in biscuits were calculated by dividing the levels of the rye flour (100% extraction) by 1.35, since 1 kg flour yields 1.35 kg bread (Risø Report No. 570).

3.3.4 Potatoes, Other Vegetables, and Fruit

The Danish mean levels for 1988 and 1989 were used (Risø Report No. 570), since the local production is insignificant compared with imports from Denmark.

The Danish mean levels in 1988 were: in potatoes 0.037 Bq ^{90}Sr kg^{-1} and 0.094 Bq ^{137}Cs kg^{-1} (in 1989: 0.036 and 0.114, respectively), in other vegetables 0.22 Bq ^{90}Sr kg^{-1} and 0.095 Bq ^{137}Cs kg^{-1} (in 1989: 0.185 and 0.089, respectively), and in fruit 0.034 Bq ^{90}Sr kg^{-1} and 0.049 Bq ^{137}Cs kg^{-1} (in 1989: 0.020 and 0.054, respectively).

3.3.5 Meat

Nearly all meat consumed in Greenland is assumed to be of local origin. Approximately 10% comes from sheep, 5% from reindeer, 60% from seals, 5% from whales, and 20% from sea birds and eggs.

The activities in reindeer were estimated from 3.2.3. Seal and whale were estimated from 3.2.4. The levels of lamb and sea birds (and eggs) were taken from last year's measurements (Risø Reports (North Atlantic Region) 1983-1987). Hence the mean levels in Greenland meat from 1988 were 0.013 Bq ^{90}Sr kg^{-1} and 5.1 Bq ^{137}Cs kg^{-1} (1989: 0.022 and 8.5, respectively).

1988: (^{90}Sr: $0.1 \times 0.097 + 0.05 \times 0.042 + 0.6 \times 0.002 + 0.05 \times 0.001 + 0.2 \times 0 = 0.013$ Bq kg^{-1})

(^{137}Cs: $0.1 \times 29 + 0.05 \times 40 + 0.6 \times 0.16 + 0.05 \times 0.54 + 0.2 \times 0.44 = 5.1$ Bq kg^{-1})

1989: (^{90}Sr: $0.1 \times 0.097 + 0.05 \times 0.20 + 0.6 \times 0.004 + 0.05 \times 0.001 + 0.2 \times 0.001 = 0.022$ Bq kg^{-1})

(^{137}Cs: $0.1 \times 29 + 0.05 \times 108 + 0.6 \times 0.24 + 0.05 \times 0.54 + 0.2 \times 0.31 = 8.5$ Bq kg^{-1})

3.3.6 Fish

All fish consumed was of local origin, and the mean levels from 1988 were used, i.e. 0.001 Bq ^{90}Sr kg^{-1} and 0.34 Bq ^{137}Cs kg^{-1} (1989: 0.0034 and 0.32, respectively).

3.3.7 Coffee and Tea

The Danish figures for 1988 and 1989 (Risø Report No. 570) were used for coffee and tea, i.e. 0.25 Bq ^{90}Sr kg^{-1} and 0.82 Bq ^{137}Cs kg^{-1}.

3.3.8 Drinking Water

The geometric mean calculated in 3.2.6 was used as the mean level of ^{90}Sr in drinking water, i.e. 8.9 Bq ^{90}Sr m^{-3} (in 1989: 6.1 Bq ^{90}Sr m^{-3}. The ^{137}Cs content was approximately 3 Bq ^{137}Cs m^{-3}).

Tables 3.3.1 and 3.3.2 show the diet estimates of ^{90}Sr and ^{137}Cs, respectively.

3.3.9 Discussion

The most important ^{90}Sr source in the Greenland diet is still grain products, which contribute nearly 60% of the total ^{90}Sr content in the diet. Approximately 85% of the ^{90}Sr in the food consumed in Greenland in 1988-1989 originated from imported (Danish) food.

Meat is still an important ^{137}Cs source in the Greenland diet, contributing 70-80% of the total content in 1988-1989. About 85-90% of the ^{137}Cs in the Greenland diet in 1988-1989 came from local products.

The ^{137}Cs levels were about half that found in 1987. As discussed earlier (Risø Reports (Greenland) 1962-1982), the great variations from year to year are primarily due to the variations in the ^{137}Cs levels in the lamb and reindeer samples obtained.

Table 3.3.1.A. Estimate of the mean content of ^{90}Sr in the human diet in Greenland in 1988

Type of food	Annual quantity in kg	Bq ^{90}Sr per kg	Total Bq ^{90}Sr	Percentage of total Bq ^{90}Sr in food
Milk and cream	78	0.062	4.84	12.1
Cheese	2.5	0.41	1.02	2.6
Grain products	95.6	0.25	23.90	59.7
Potatoes	32.8	0.037	1.21	3.0
Vegetables	5.5	0.22	1.21	3.0
Fruit	13.5	0.034	0.46	1.1
Meat and eggs	45.6	0.013	0.59	1.5
Fish	127.6	0.001	0.13	0.3
Coffee and tea	7.3	0.25	1.82	4.5
Drinking water	548	0.089	4.88	12.2
Total			40.06	

The mean annual calcium intake is estimated to be 0.56 kg (approx. 0.2-0.25 kg creta praeparata). Hence the $^{90}Sr/Ca$ ratio in Greenland total diet in 1988 was 72 Bq ^{90}Sr (kg Ca)$^{-1}$ and the daily intake was 0.110 Bq ^{90}Sr.

Table 3.3.1.B. Estimate of the mean content of ^{90}Sr in the human diet in Greenland in 1989

Type of food	Annual quantity in kg	Bq ^{90}Sr per kg	Total Bq ^{90}Sr	Percentage of total Bq ^{90}Sr in food
Milk and cream	78	0.058	4.52	13.8
Cheese	2.5	0.44	1.10	3.4
Grain products	95.6	0.19	18.16	55.3
Potatoes	32.8	0.036	1.18	3.6
Vegetables	5.5	0.185	1.02	3.1
Fruit	13.5	0.020	0.27	0.8
Meat and eggs	45.6	0.022	1.00	3.0
Fish	127.6	0.0034	0.43	1.3
Coffee and tea	7.3	0.25	1.82	5.5
Drinking water	548	0.0061	3.34	10.2
Total			32.84	

The mean annual calcium intake is estimated to be 0.56 kg (approx. 0.2-0.25 kg creta praeparata). Hence the $^{90}Sr/Ca$ ratio in Greenland total diet in 1989 was 59 Bq ^{90}Sr (kg Ca)$^{-1}$ and the daily intake was 0.090 Bq ^{90}Sr.

Table 3.3.2.A. Estimate of the mean content of ^{137}Cs in the human diet in Greenland in 1988

Type of food	Annual quantity in kg	Bq ^{137}Cs per kg	Total Bq ^{137}Cs	Percentage of total Bq ^{137}Cs in food
Milk and cream	78	0.28	21.84	6.8
Cheese	2.5	0.135	0.34	0.1
Grain products	95.6	0.11	10.52	3.3
Potatoes	32.8	0.094	3.08	1.0
Vegetables	5.5	0.095	0.52	0.2
Fruit	13.5	0.049	0.66	0.2
Meat and eggs	45.6	5.1	232.56	72.6
Fish	127.6	0.34	43.38	13.5
Coffee and tea	7.3	0.82	5.99	1.9
Drinking water	548	0.0022	1.21	0.4
Total			320.10	

The mean annual potassium intake is estimated to be approx. 1.2 kg. Hence the $^{137}Cs/K$ ratio becomes 267 Bq ^{137}Cs $(kg\ K)^{-1}$. The daily intake in 1988 from food was 0.88 Bq ^{137}Cs.

Table 3.3.2.B. Estimate of the mean content of ^{137}Cs in the human diet in Greenland in 1989

Type of food	Annual quantity in kg	Bq ^{137}Cs per kg	Total Bq ^{137}Cs	Percentage of total Bq ^{137}Cs in food
Milk and cream	78	0.178	13.88	3.0
Cheese	2.5	0.153	0.38	0.1
Grain products	95.6	0.11	10.52	2.2
Potatoes	32.8	0.114	3.74	0.8
Vegetables	5.5	0.089	0.49	0.1
Fruit	13.5	0.054	0.73	0.2
Meat and eggs	45.6	8.5	387.60	83.3
Fish	127.6	0.32	40.83	8.8
Coffee and tea	7.3	0.82	5.99	1.3
Drinking water	548	0.0015	0.82	0.2
Total			464.98	

The mean annual potassium intake is estimated to be approx. 1.2 kg. Hence the $^{137}Cs/K$ ratio becomes 387 Bq ^{137}Cs $(kg\ K)^{-1}$. The daily intake in 1989 from food was 1.27 Bq ^{137}Cs.

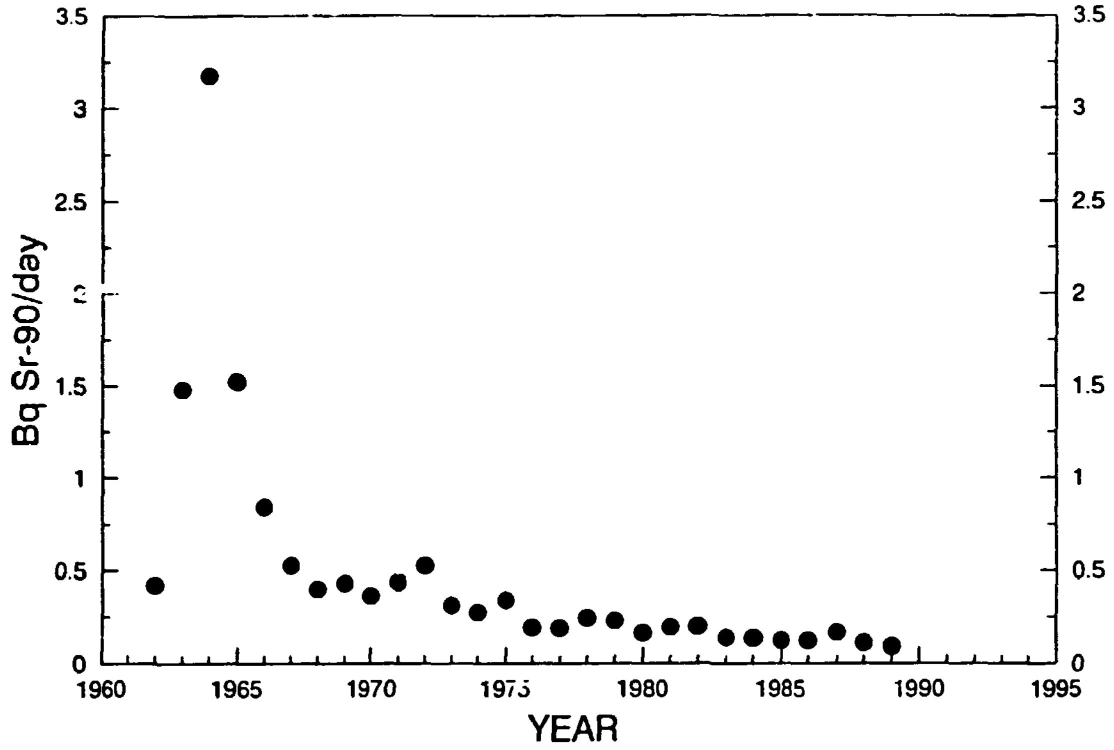
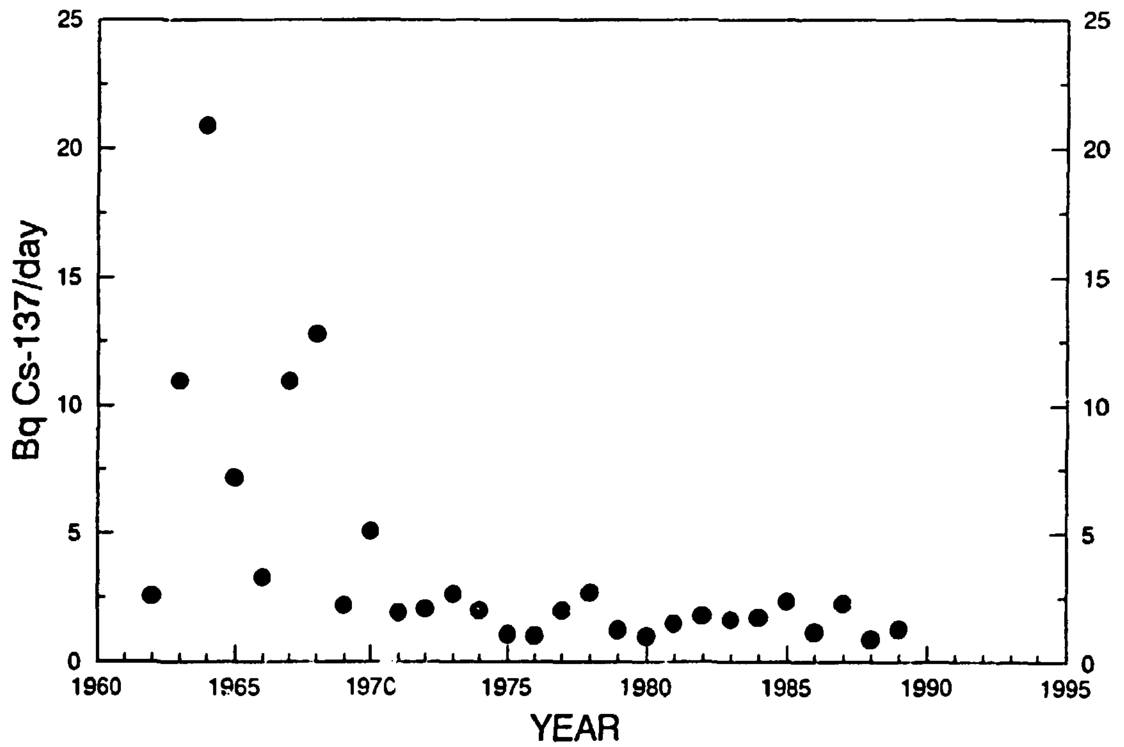


Figure 3.3.1. Strontium-90 in Greenland diet, 1962-1989. (Unit: Bq day^{-1}).

Figure 3.3.2. Cesium-137 in Greenland diet, 1962-1989. (Unit: Bq day^{-1}).



3.4 Conclusion

3.4.1.

The ^{90}Sr fallout rates in 1988 and 1989 were less than 1 Bq m^{-2} per year.

3.4.2.

The food consumed in Greenland in 1988 and 1989 contained on the average 66 Bq ^{90}Sr (kg Ca)$^{-1}$, and the daily mean intake of ^{137}Cs was estimated as 1.1 Bq. The most important ^{90}Sr contributor to the diet was grain products. Cesium-137 originated mainly from meat (reindeer and lamb). Chernobyl radiocesium was detectable in Greenland food, but did not influence the ^{137}Cs level significantly.

3.4.3.

No ^{90}Sr analyses of human bone samples have hitherto been carried out on the population of Greenland. Considering the estimated ^{90}Sr levels in the diet, it seems probable (Risø Reports (North Atlantic Region) 1983-1987), however, that the 1988-1989 ^{90}Sr levels of humans in Greenland were on the average rather similar to those found in Denmark, i.e. the mean levels in human bone in Greenland were approximately 18 Bq ^{90}Sr (kg Ca)$^{-1}$ (vertebrae). From diet measurements, the ^{137}Cs content in Greenlanders was estimated as 1000 Bq ^{137}Cs (kg K)$^{-1}$.

4 Environmental Radioactivity in the North Atlantic Region

4.1 Monthly Surface Sea Water Samples from Utsira, Norway

Institute of Energy Technology, Kjeller, Norway, collects monthly sea water samples at Utsira 59°19'N, 4°54'E in SW-Norway. From this station it is possible to monitor the radioactivity in the Norwegian Coastal Current, which carries the activity from the North Sea to the Arctic waters in the north.

Tables 4.1.1.A & B show the results from 1988 and 1989, respectively. 68% of the ^{137}Cs in the sea water from Utsira in 1988 was from Chernobyl, in 1989 the contribution had decreased to 48% (see also Figures 4.1.1 and 4.1.2).

The annual mean concentrations of ^{99}Tc in sea water at Utsira may be correlated to the discharges of ^{99}Tc from Cap de la Hague (in TBq y^{-1}).

The following relation was found for a year (i) in the period 1986-1991:

$$\text{Bq m}^{-3}{}_{(i)} = 0.08 \text{ TBq y}^{-1}{}_{\frac{(i-2)+(i-1)}{2}}$$

Table 4.1.1.A. Radiocesium and Technetium in surface sea water collected in 1988 from Utsira, Norway. 59°19'N, 4°54'E. (Unit: Bq m^{-3})

Date	^{99}Tc	^{137}Cs	^{134}Cs / ^{137}Cs	Salinity in ‰
February 2	1.14	42	0.114 A	31.8
June 16	0.94	37	0.143 A	31.4
July	1.39	22	0.180	29.1
August 26	lost	29	0.114	31.2
September 14	1.12	31	0.155	30.4
October 10	1.21	23	0.156	26.3
November 14	1.19	27	0.113 A	30.7
December 15	0.73	26	0.092 A	33.6
Mean	1.10	30		30.6
1 S.D.	0.21	6.9		2.1
Relative S.D.	19%	23%		7%

Table 4.1.1.B. Radiocesium and Technetium in surface sea water collected in 1989 from Utsira, Norway. 59°19'N, 4°54'E. (Unit: Bq m^{-3})

Date	^{99}Tc	^{137}Cs	^{134}Cs / ^{137}Cs	Salinity in ‰
Januuary 16	0.55	19.4	0.116 B	33.3
February 14	1.11	19.1		33.5
March 14		29		33.2
April 18	1.39	26		31.8
May 18	1.02	23	0.086 B	31.5
June 15	0.72	20	0.128 A	31.5
July 13	0.72	25	0.118	31.3
August 14	0.54	19.8	0.052 B	32.2
September 15	0.58	24	0.100 A	31.9
October 14	0.50	17.3		32.7
November 15	0.39	14.7		35.5
Mean	0.75	22		32.6
1 S.D.	0.32	4.2		1.2
Relative S.D.	42%	19%		4%

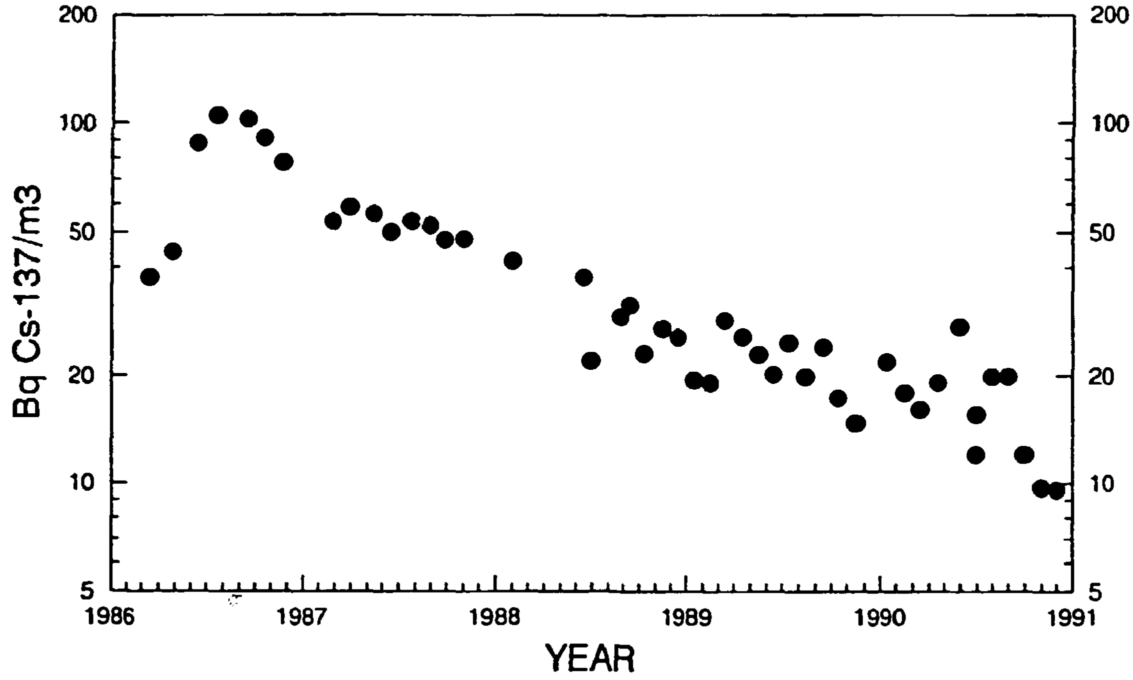
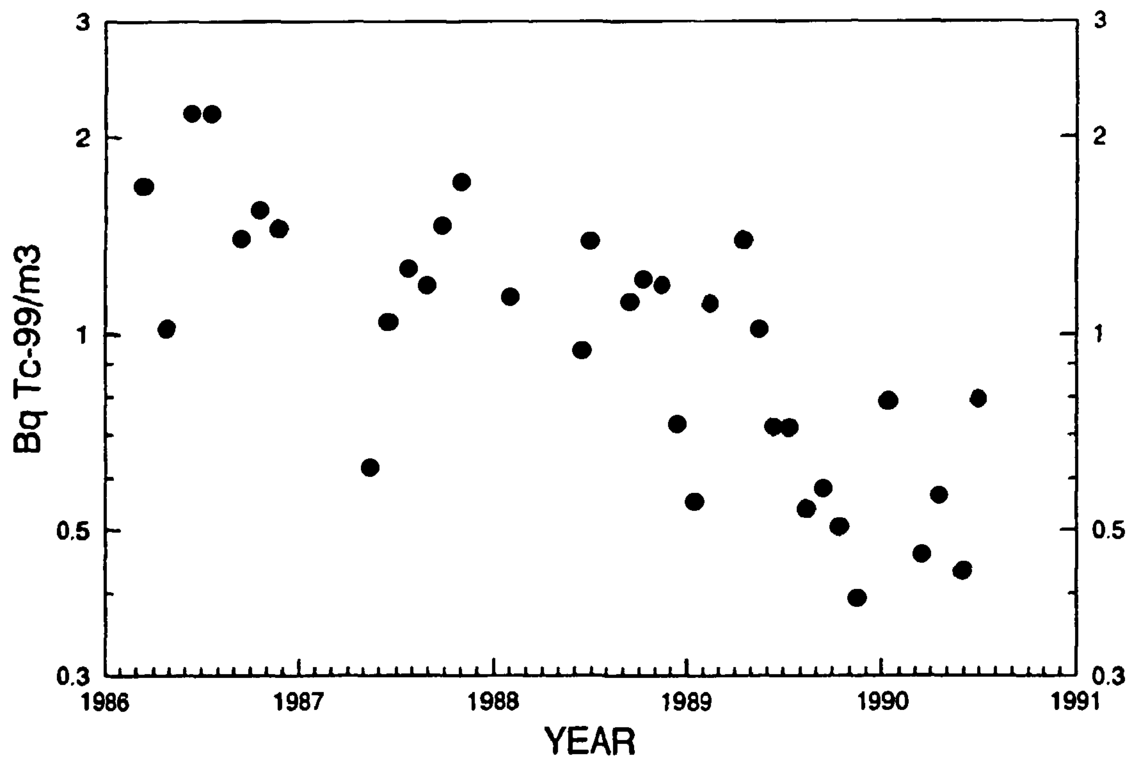


Figure 4.1.1. Cesium-137 in surface sea water collected at Utsira (59°19'N, 4°54'E), 1986-1990. (Unit: Bq m^{-3}).

Figure 4.1.2. Technetium-99 in surface sea water collected at Utsira (59°19'N, 4°54'E), 1986-1990. (Unit: Bq m^{-3}).



4.2 Surface Sea Water Samples Collected in West Greenland Waters in 1988 by The Greenland Fisheries and Environmental Research Institute

The sampling in 1988 was the seventh since this programme began in July 1983. The ^{137}Cs data were treated by two-sided anovas (cf. Table 4.2.2).

The variation between locations was significant; the southern locations at 64°N contained 1.4 times higher concentrations than the northern at about 71°N. The levels have been decreasing throughout the years (cf. the discussion in Risø-R-564).

Table 4.2.1. Cesium-137 in surface sea water off West Greenland in June-July 1988

Latitude N	Longitude W	Name of Location	^{137}Cs Bq m^{-3}	Salinity in ‰
63°57'	52°22'	Fylla Banke (Nuuk)	4.4	33.5
63°48'	53°56'	Fylla Banke (Nuuk)	4.6	33.2
65°06'	52°55'	Sukkertoppen (Maniitsoq)	4.5	33.2
65°06'	53°59'	Sukkertoppen (Maniitsoq)	4.8	33.5
65°06'	54°58'	Sukkertoppen (Maniitsoq)	4.3	33.4
66°53'	54°10'	Holsteinsborg (Sisimiut)	4.0	33.6
66°46'	55°36'	Holsteinsborg (Sisimiut)	4.5	33.6
66°41'	56°38'	Holsteinsborg (Sisimiut)	3.8	33.6
68°00'	55°00'	Egedesminde (Aasiaat)	4.5	33.4
68°04'	56°00'	Egedesminde (Aasiaat)	3.9	33.4
68°08'	57°17'	Egedesminde (Aasiaat)	4.2	33.2
68°14'	58°40'	Egedesminde (Aasiaat)	3.4	31.6
69°30'	54°54'	Disko fjord	3.8	33.1
69°30'	56°00'	Disko fjord	4.1	33.3
69°30'	58°20'	Disko fjord	3.6	31.4
70°45'	55°00'	Nugssuaq	3.0	33.3
70°45'	57°00'	Nugssuaq	3.6	33.0
69°42'	51°38'	Arveprinsen	3.4	32.4
69°20'	51°41'	Jacobshavn	3.4	33.0
68°56'	53°12'	Godhavn-Egedesminde	5.2	33.4
68°55'	52°24'	Skansen-Akunaq	3.6	33.0

Table 4.2.2. Anova of ln Bq ^{137}Cs m^{-3} surface water collected off West Greenland July 1983 - July 1988 (cf. Table 4.2.1 and Risø-R-510, 528, 541 and 564)

Variation	SSD	f	s^2	v^2	P
Between samplings	1.023	6	0.171	15.05	>99.95
Between locations	1.594	33	0.048	4.26	>99.95
Interaction	1.065	94	0.011	0.55	-
Remainder	0.021	1	0.021		

4.3 "Bjarni Sæmundson" Cruise to the Denmark Strait and the Southern Greenland Sea in September 1988 (GSP Project)

Table 4.3 show the results of the ^{90}Sr, ^{99}Tc and radiocesium analyses from samples collected by "Bjarni Sæmundson" in September 1988 (Dahlgaard et al., 1991) (see also Figures 4.3.2-4.3.13).

Below is given a procedure for estimation of Sellafield derived ^{137}Cs in East Greenland waters in 1988:

The measured ^{90}Sr concentration: S_m is corrected for ^{90}Sr from Sellafield: S_s by subtraction of $4.26 \times T_m$, where T_m is the measured ^{99}Tc in Bq m^{-3} in the sample, and 4.26 is the ratio between ^{90}Sr and ^{99}Tc in the Sellafield releases 1978-1988. We then get ^{90}Sr due to fallout S_f

$$S_f = S_m - 4.26 \times T_m \qquad (1)$$

A possible contribution of ^{99}Tc from global fallout is neglected in this calculation.

The contribution of Atlantic water fallout (x) and Arctic water fallout (1-x) is calculated from the equation:

$$1.65x + (1-x)\,3.15 = S_f,$$

$$x = \frac{3.15 - S_f}{1.50} = 2.1 - \frac{S_f}{1.5} \qquad (2)$$

If $S_f \le 1.65$ we assume the sample to consist of Atlantic water only and if $S_f \ge 3.15$ we assume the sample to consist of 100% Arctic water. 1.65 is the calculated fallout level: Bq ^{90}Sr m^{-3} in Atlantic water in 1988 and 3.15 is the corresponding figure for Arctic water. The equations used for these calculations were based upon observations at the Faroe Islands and in the East Greenland Current since 1974 ($t = 0$):

Atlantic ^{90}Sr Bq m^{-3} in year t: $3.52\,e^{-0.054\,t}$

Arctic ^{90}Sr Bq m^{-3} in year t: $7.1\,e^{-0.058\,t}$

The measured ^{137}Cs: C_m is corrected for Chernobyl derived ^{137}Cs: C_c by subtraction of the measured ^{134}Cs divided by 0.2603 (in September 1988). $C_c = {}^{134}Cs/0.2603$. The remaining ^{137}Cs after this subtraction consists of fallout ^{137}Cs: C_f and Sellafield ^{137}Cs: C_s.

The fallout ^{137}Cs: C_f is estimated from the equation: $C_f = x \cdot 2.32 + (1-x) \cdot 3.64$, where x was determined above for ^{90}Sr: $x = 2.1 - S_f/1.5$ and 2.32 is Bq ^{137}Cs m^{-3} in Atlantic water in 1988 and 3.64 is the corresponding figure for Arctic water. These concentrations were determined from observations since 1974 ($t = 0$) as for ^{90}Sr above:

Atlantic ^{137}Cs Bq m^{-3} in year t: $6.0\,e^{-0.068\,t}$
Arctic ^{137}Cs Bq m^{-3} in year t: $10.4\,e^{-0.075\,t}$

$$C_f = 3.64 - 1.32x = 3.64 - 1.32\,(2.1 - S_f/1.5) = 0.87 + 0.88 \times S_f \qquad (3)$$

$$C_s = C_m - C_c - C_f = C_m - (^{134}Cs/0.2603) - 0.87 - 0.88 \times S_i$$
$$= C_m - (^{134}Cs/0.2603) - 0.87 - 0.88\, S_m + 3.75\, T_m \qquad (4)$$

Using the above calculation procedure we came to Figure 4.3.1 showing how the calculated contributions of ^{137}Cs from Sellafield correlate with the measured ^{99}Tc concentrations in the surface waters between Iceland and Greenland.

The correlation implies that the ^{137}Cs concentrations from Sellafield effluents present in East Greenland surface waters in 1988 were 23 ± 6 times higher than the ^{99}Tc concentrations. If we assume that the Sellafield effluents seen in the surface waters between Iceland and Greenland in 1988 were due to discharges from Sellafield in 1978-1981 (corresponding to a transit time of 7-10 years) the ratio between ^{137}Cs (decay corrected) and ^{99}Tc in these discharges was 35. This is in reasonable agreement with the above figure of 23 ± 6 taking into account that some ^{137}Cs has gone to the sediments on its long way to Greenland.

Table 4.3. Radionuclides in sea water collected from »Bjarni Sæmundsen« (Greenland Sea Project) in the Greenland Sea and Denmark Strait in September 1988

Position N	Position W	Date in Sept	Depth in m	Temp in °C	Salinity in ‰	^{90}Sr Bq m^{-3}	^{99}Tc mBq m^{-3}	^{134}Cs Bq m^{-3}	^{137}Cs Bq m^{-3}	Calculated ^{137}Cs Fall-out	Calculated ^{137}Cs Sellafield	Calculated ^{137}Cs Chernobyl	Nr
65°41'	24°23'	7	5		34.6	1.58	11.0 A	B.D.L.	2.8	2.3	0.5		248
66°29'	23°03'	7	5		34.5	1.65	20.7	0.14 A	2.9	2.4		0.5	249
70°59'	14°20'	11	5	4.9	34.2	2.5	45	0.52	6.4	3.2	1.2	2.0	250
70°59'	14°20'	11	86	0.4	34.6	2.4	40	0.54 B	7.1	3.1	1.9	2.1	251
70°59'	14°20'	11	327	0.6	34.9	1.96	42	B.D.L.	5.6	2.6	3.0		252
70°59'	14°20'	11	535	0.0	34.9	1.89	24	0.16 B	4.3	2.6	1.1	0.6	253
70°59'	14°20'	11	1017	0.5	34.9	1.30	34	B.D.L.	2.5	1.9	0.6		254
71°00'	17°17'	12	5	1.9	32.8	3.4	79	0.40	8.7	4.1	3.1	1.5	255
71°00'	17°17'	12	86	0.2	34.6	2.7	74	0.68	7.4	3.3	1.5	2.6	256
71°00'	17°17'	12	327	0.9	34.9	2.2	45	0.70	6.4	2.9	0.8	2.7	257
71°00'	17°17'	12	803	0.4	34.9	1.60	36	0.48	3.9	2.1		1.8	258
71°00'	17°17'	12	1660	0.8	34.9	0.84	30	0.14	2.3	1.3	0.5	0.5	259
70°59'	18°48'	13	5	1.6	32.6	3.4	78	0.40	8.8	3.9	3.4	1.5	260
70°59'	18°48'	13	80	0.0	34.5	2.6	67	0.66	7.5	3.4	1.6	2.5	261
70°59'	18°48'	13	300	1.0	34.9	2.1	48	0.64	6.8	2.8	1.5	2.5	262
70°59'	18°48'	13	500	0.2	34.9	2.0	44	0.39	4.7	2.8	0.4	1.5	263
70°59'	18°48'	13	750	0.3	34.9	1.85	32	0.70	4.5	1.8		2.7	264
70°59'	18°48'	13	1350	0.8	34.9	2.0	56	1.01	6.5	2.6		3.9	265
71°00'	20°25'	15	5	0.5	31.5	4.1	110	0.33 A	9.4	4.9	3.2	1.3	266
71°00'	20°25'	15	80	1.6	33.1	5.0	96	B.D.L.	10.1	6.0	4.1		267
71°00'	20°25'	15	300	0.6	34.8	2.0	42	0.78 A	6.5	2.8	0.7	3.0	268
70°59'	19°26'	15	5	0.6	32.2	3.7	106	0.38	9.1	4.4	3.2	1.5	269
70°59'	19°26'	15	80	1.5	34.2	3.1	86	0.41	8.1	3.7	2.8	1.6	270
70°59'	19°26'	15	300	1.3			42	0.90	7.0				271
70°59'	19°26'	15	500	1.0	34.9	2.0	40	B.D.L.	6.5	2.8			272
70°59'	19°26'	15	750	0.3	34.9	1.37	28	B.D.L.	4.7	2.0	2.7		273
71°00'	09°30'	18	5		34.5	2.3	45	0.59	8.1	3.0	2.8	2.3	274
70°00'	17°56'	19	5				59						275
70°00'	21°47'	20	5		28.8	4.0	78	0.35	9.2	4.9	3.0	1.3	276
68°30'	18°55'	21	5				33						277
68°39'	26°20'	24	5		30.2	3.6	68	0.14	7.8	4.4	2.9	0.5	279
68°08'	25°13'	25	5	0.2	31.3	3.9	65	0.27	8.4	4.7	2.7	1.0	280
68°08'	25°13'	25	80	0.4	32.0	3.5	78	0.24	8.2	4.3	3.0	0.9	281
68°08'	25°13'	25	150	1.6	34.1	3.3	29	0.42 B	8.1	3.9	2.6	1.6	282
68°08'	25°13'	25	500	0.8	34.9	2.1	30	B.D.L.	5.8	2.8	3.0		283
67°08'	22°54'	25	5	1.7	33.3	3.0	92	0.38	7.4	3.6	2.3	1.5	284
67°08'	22°54'	25	100	3.7	34.1	3.0	46	0.26 B	6.5	2.8	2.7	1.0	285
67°08'	22°54'	25	200	1.6	34.8	1.96	66	B.D.L.	4.3	2.7	1.6		286

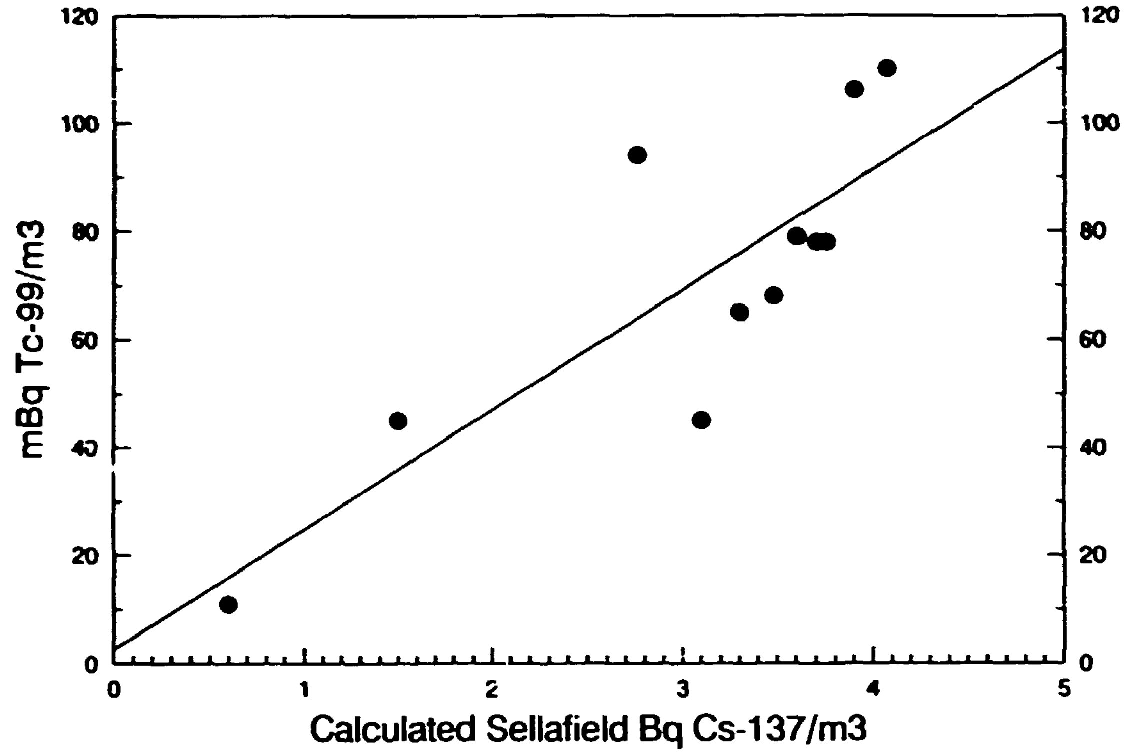


Figure 4.3.1. Technetium-99 in surface sea water 65°N-71°N collected between Iceland and Greenland September 1988 related to Cesium-137 from Sellafield.

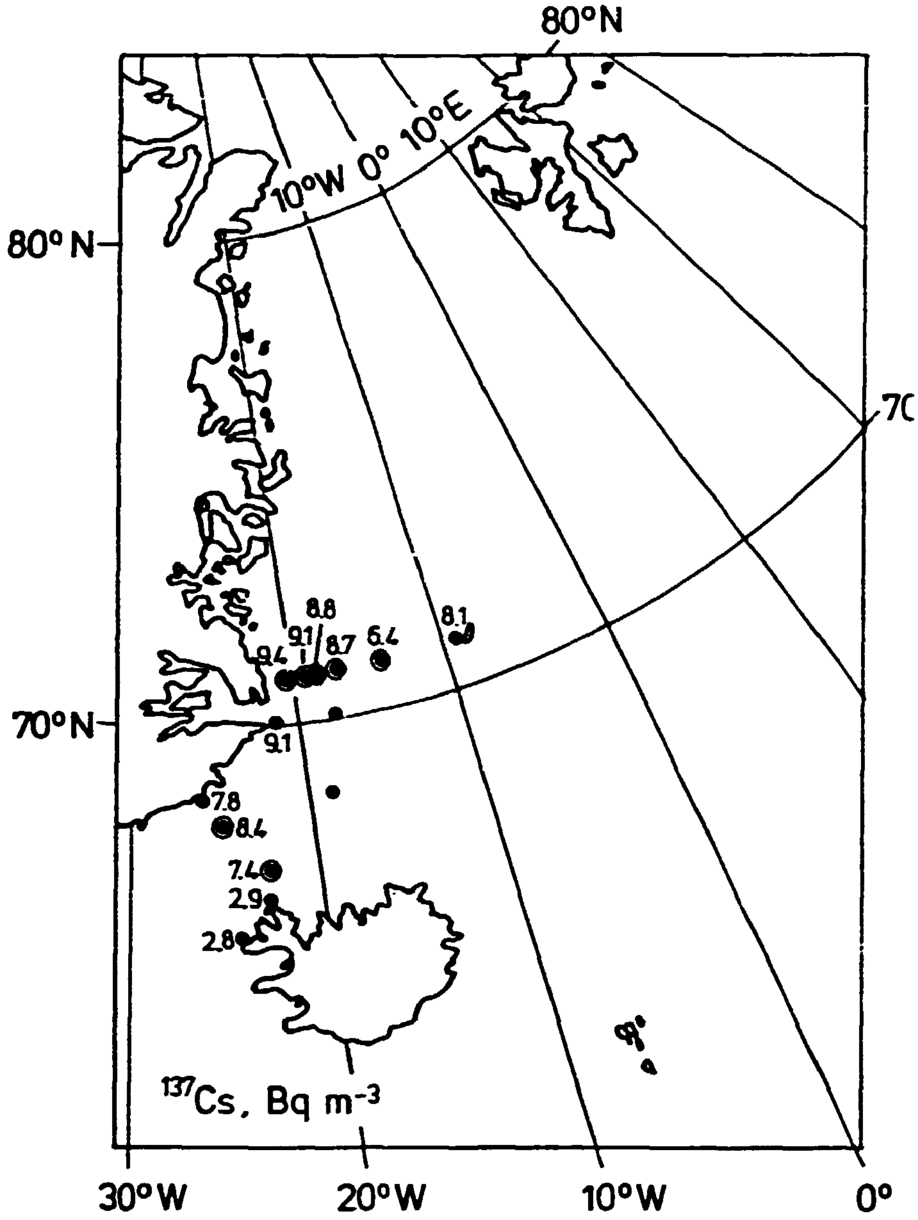


Figure 4.3.2. Cesium-137 in surface sea water from Greenland Sea Project September 1988. ●: sampling location, : profile. (Unit: Bq m^{-3}).

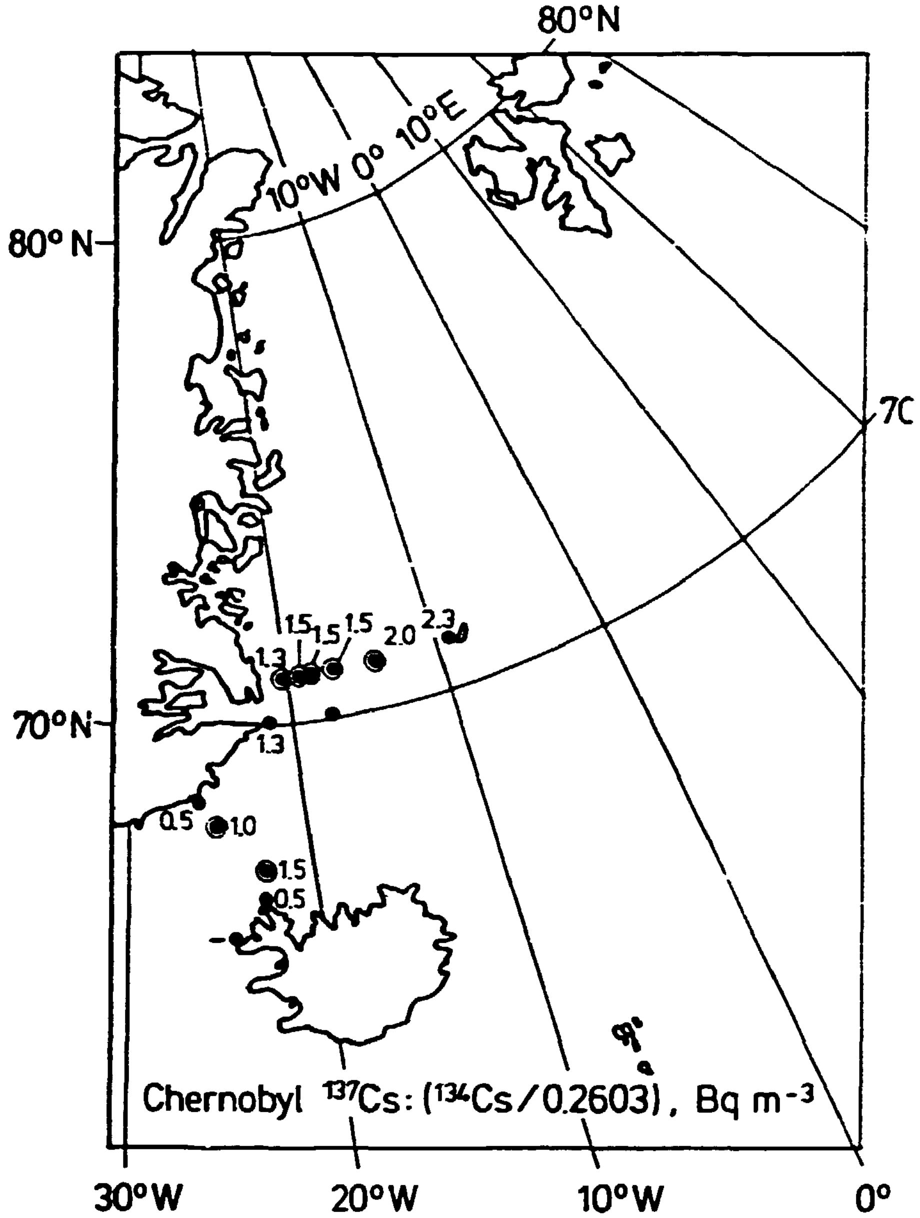


Figure 4.3.3. Chernobyl ^{137}Cs in surface sea water from Greenland Sea Project September 1988. ●: sampling location, : profile. (Unit: Bq m^{-3}).

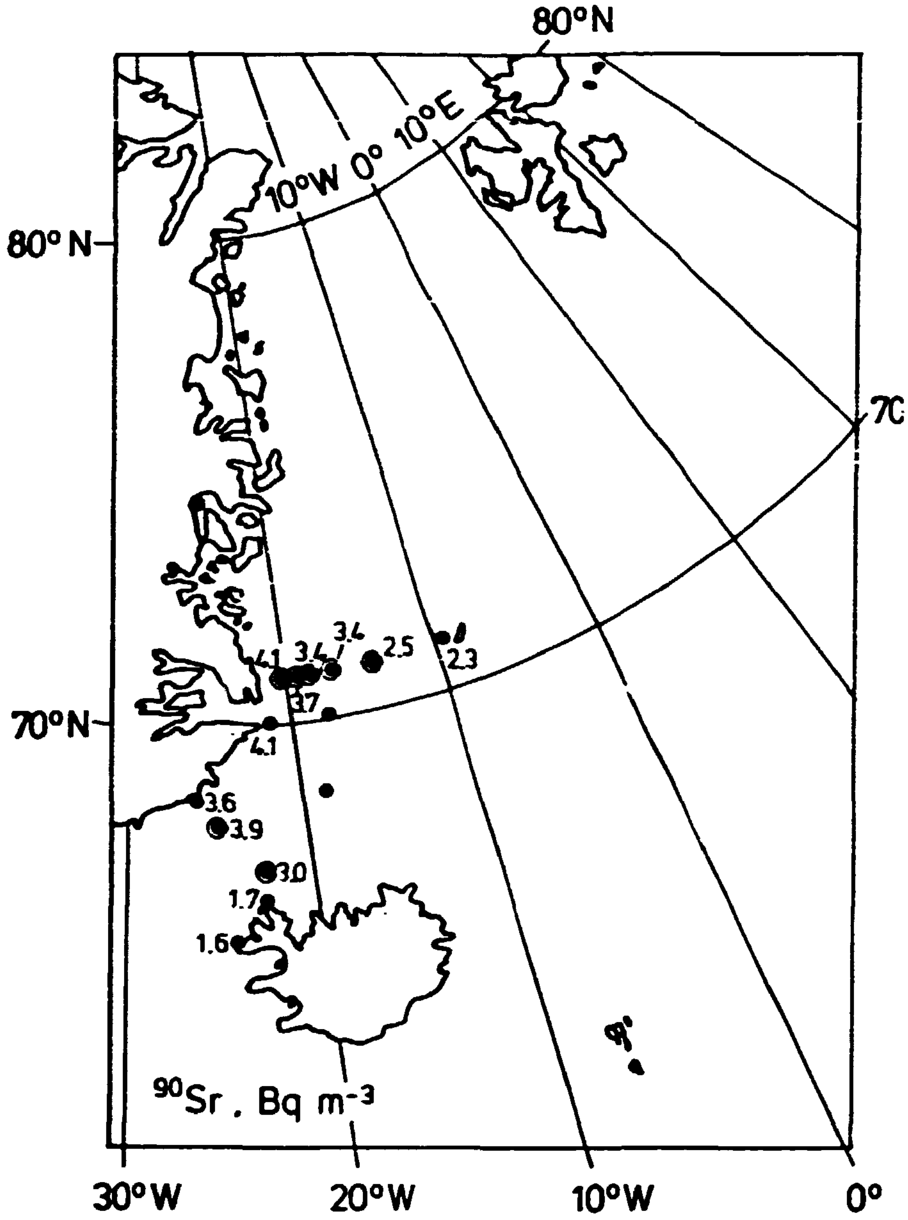


Figure 4.3.4. Strontium-90 in surface sea water from Greenland Sea Project September 1988. ●: sampling location, .: profile. (Unit: Bq m^{-3}).

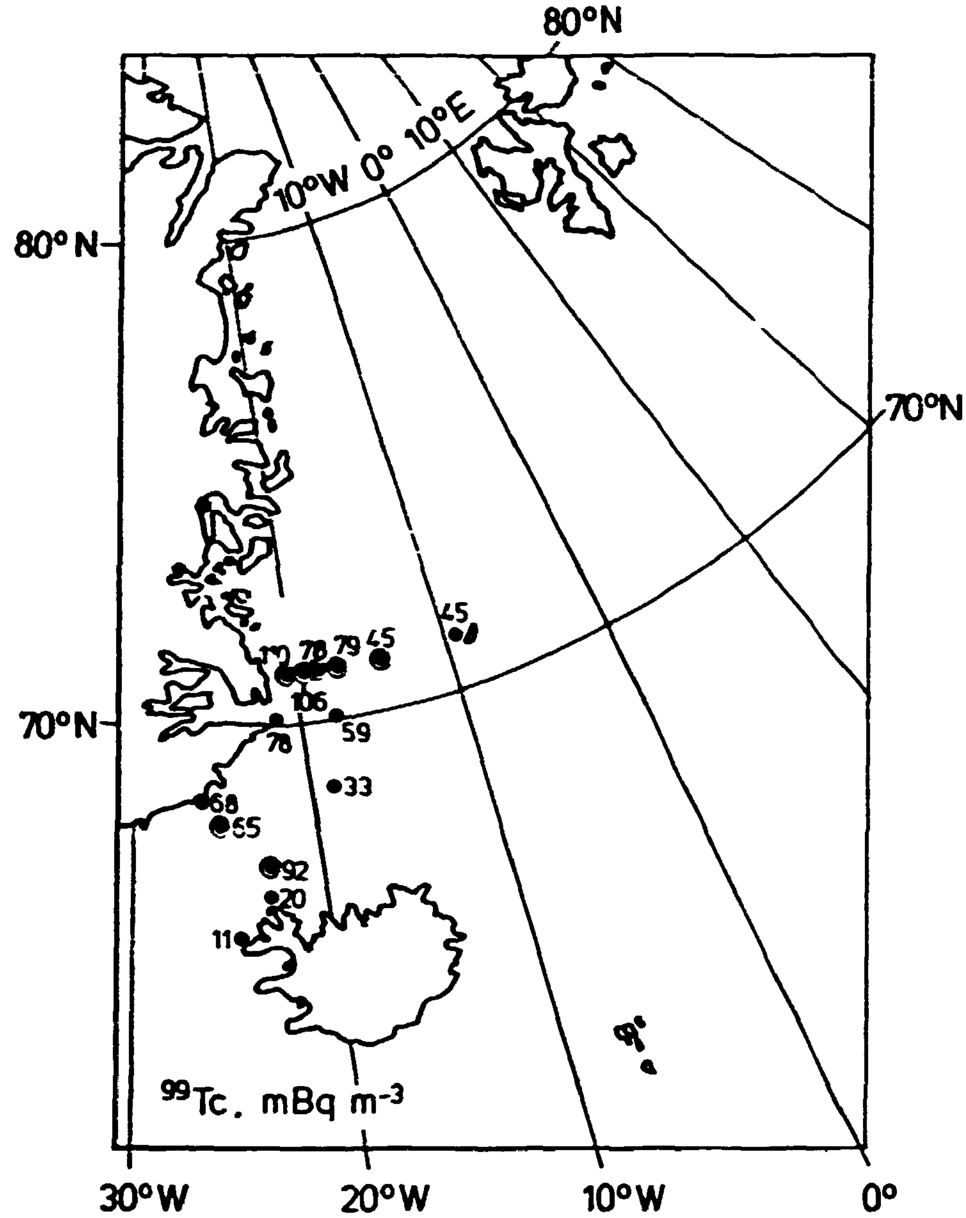


Figure 4.3.5. Technetium-99 in surface sea water from Greenland Sea Project September 1988. ●: sampling location, : profile. (Unit: mBq m^{-3}).

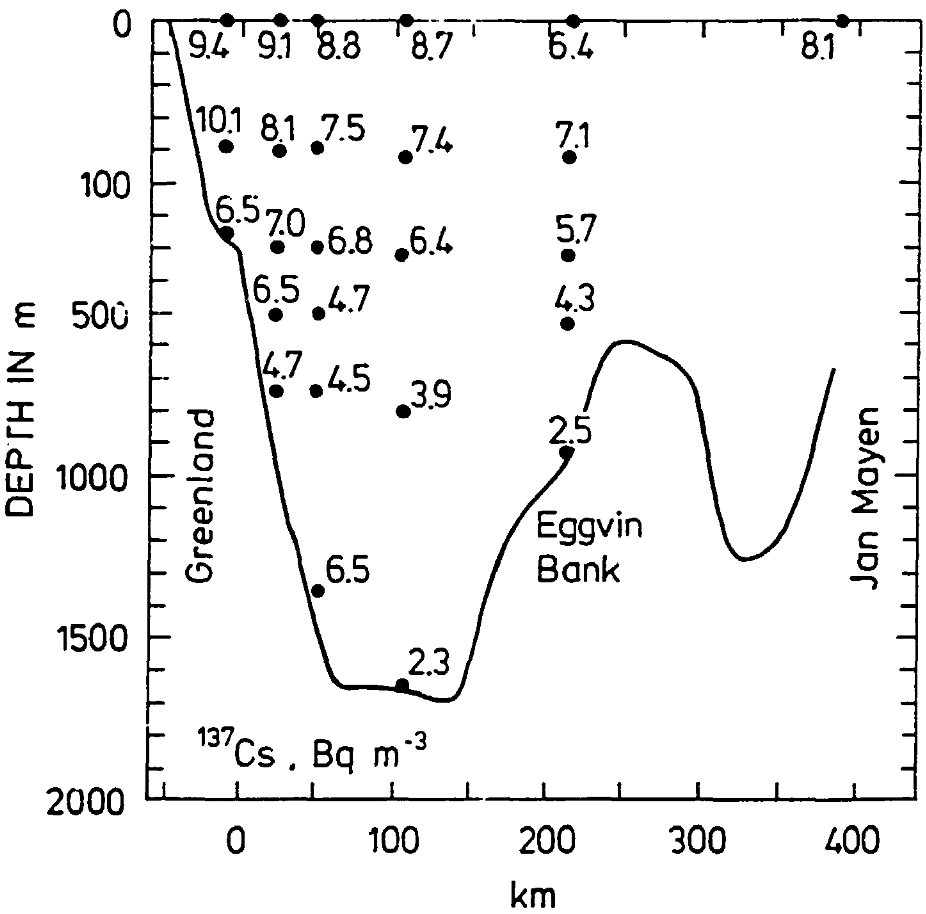


Figure 4.3.6. Cesium-137 in the 71°N section of the Greenland Sea Project September 1988. (Unit: Bq m^{-3}).

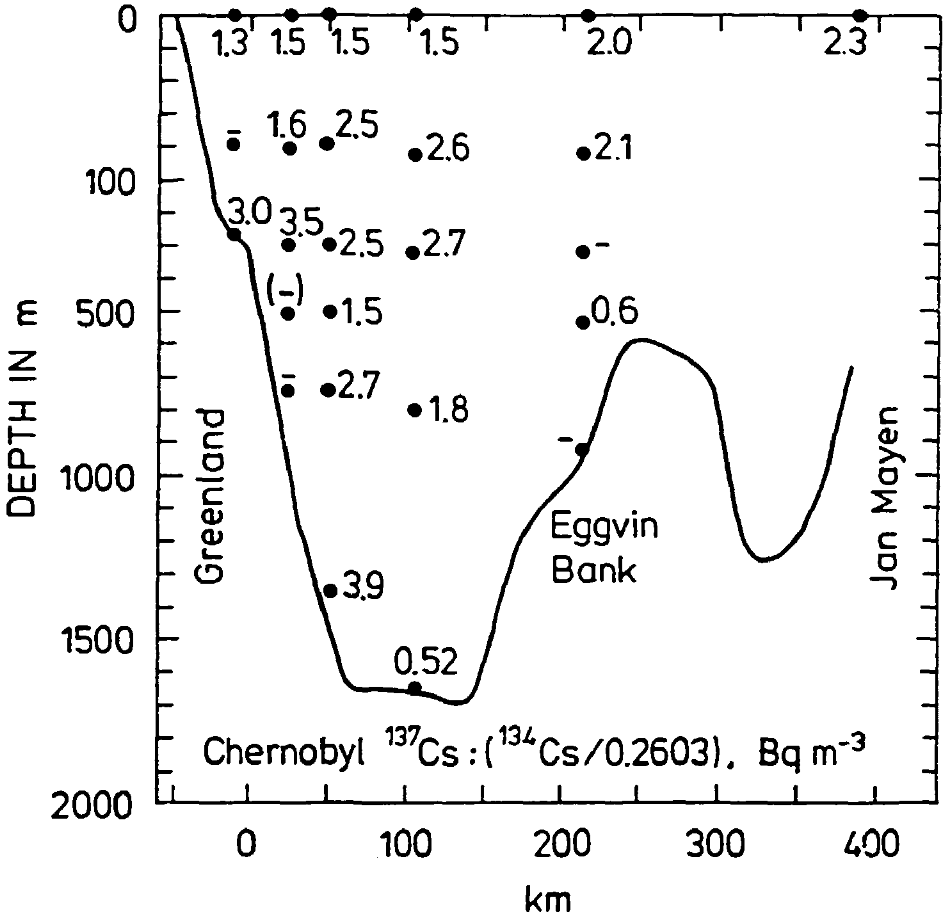


Figure 4.3.7. Chernobyl ^{137}Cs in the 71°N section of the Greenland Sea Project September 1988. (Unit: Bq m^{-3}).

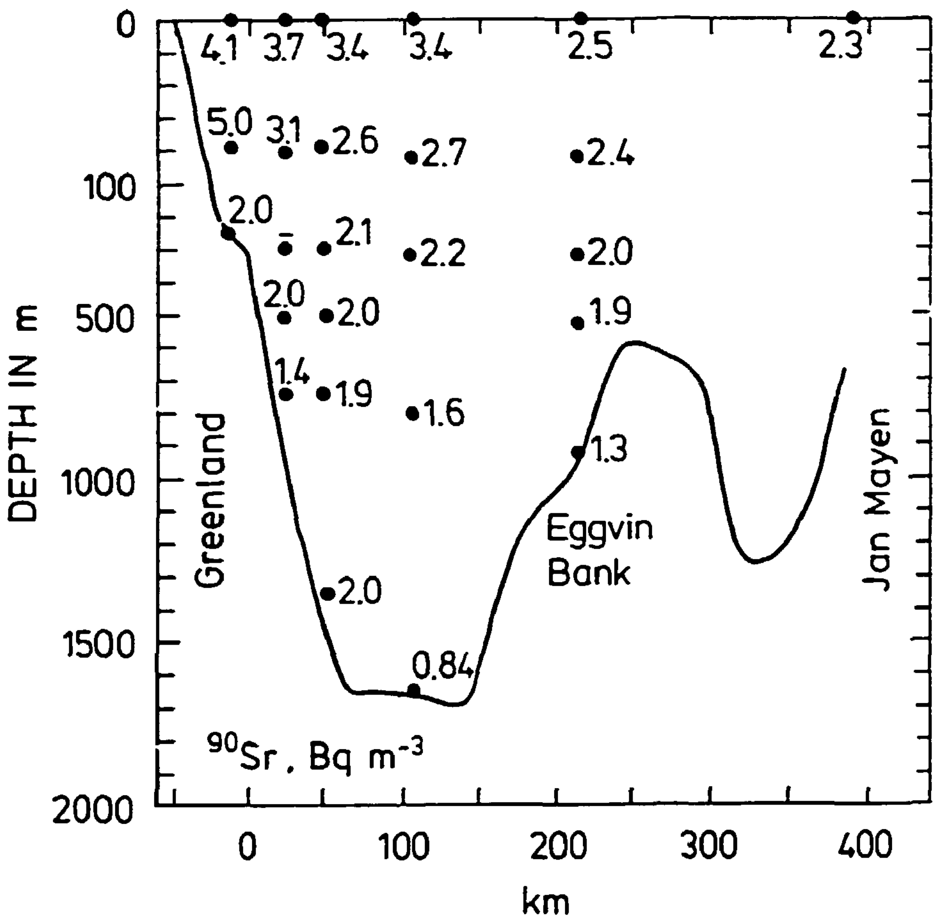


Figure 4.3.8. Strontium-90 in the 71°N section of the Greenland Sea Project September 1988. (Unit: Bq m^{-3}).

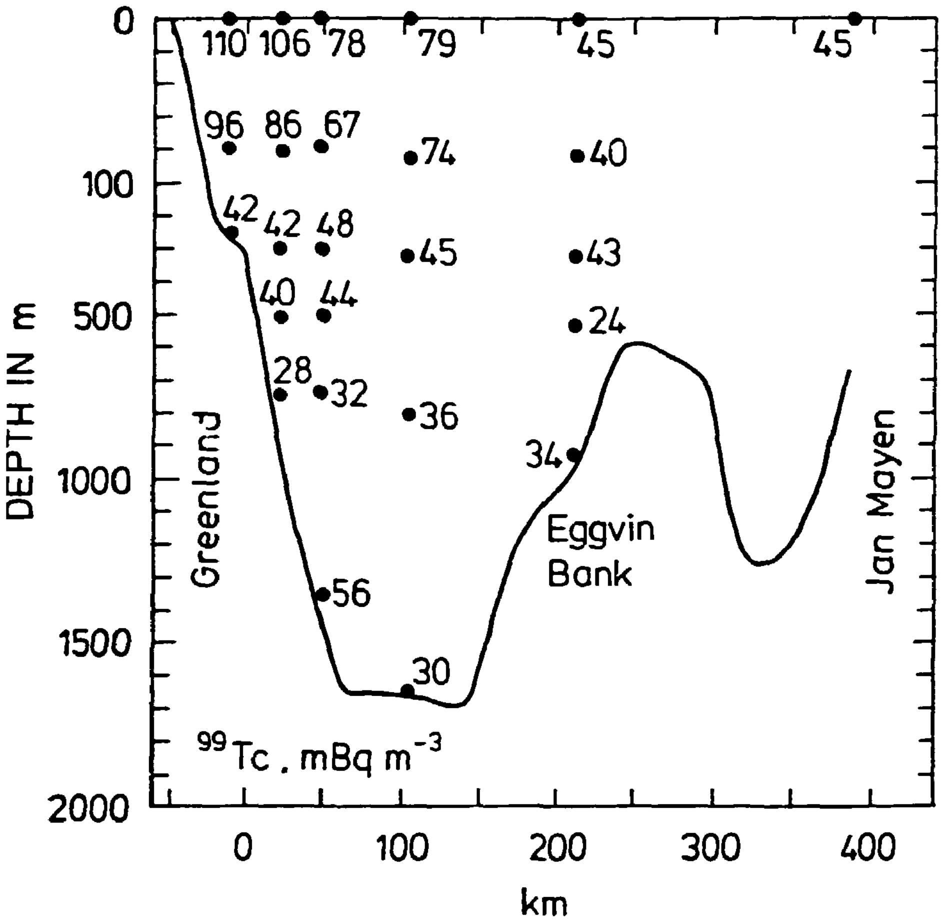


Figure 4.3.9. Technetium-99 in the 71°N section of the Greenland Sea Project September 1988. (Unit: mBq m^{-3}).

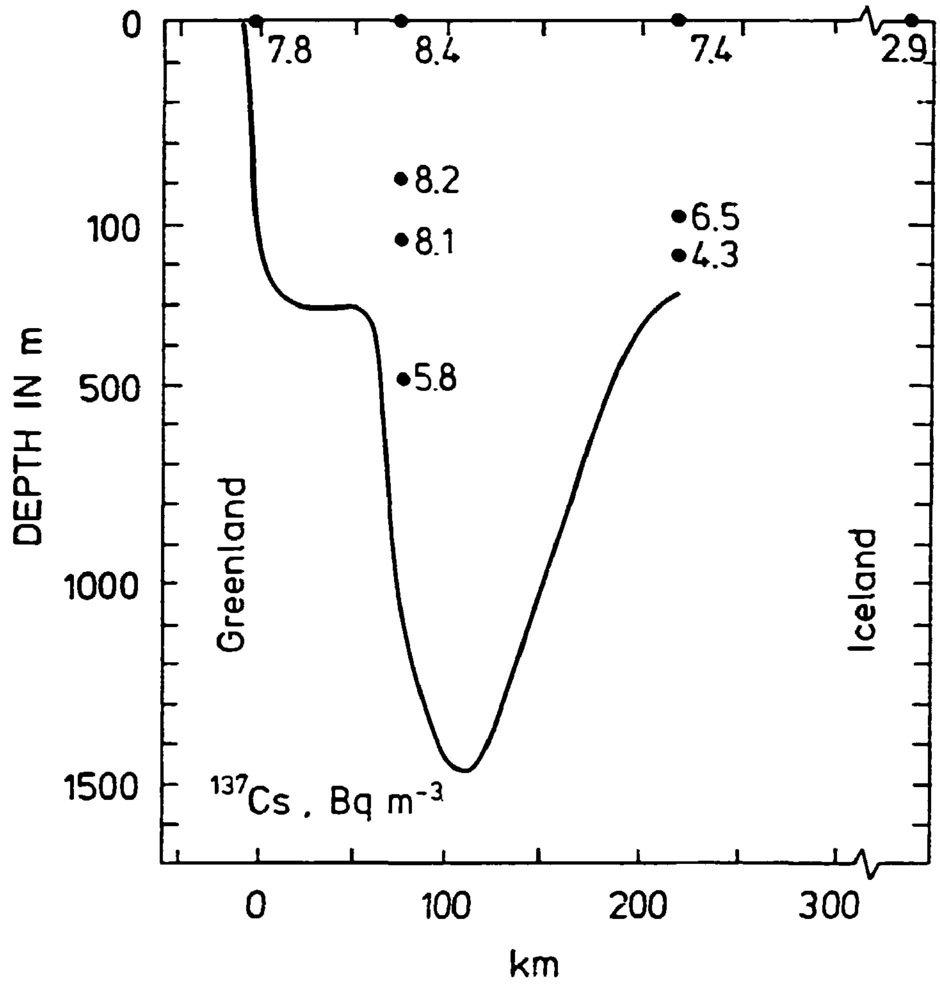


Figure 4.3.10. Cesium-137 in the Denmark Strait section of the Greenland Sea Project September 1988. (Unit: Bq m^{-3}).

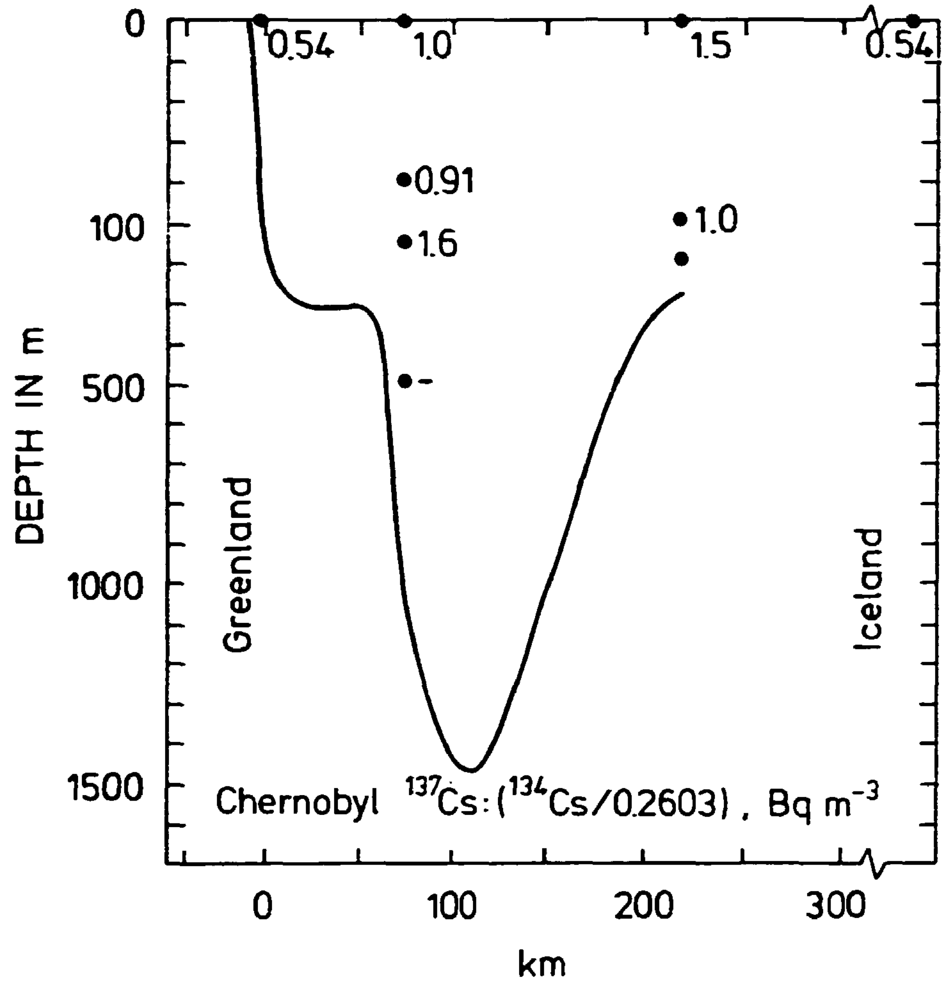


Figure 4.3.11. Chernobyl ^{137}Cs in the Denmark Strait section of the Greenland Sea Project September 1988. (Unit: Bq m^{-3}).

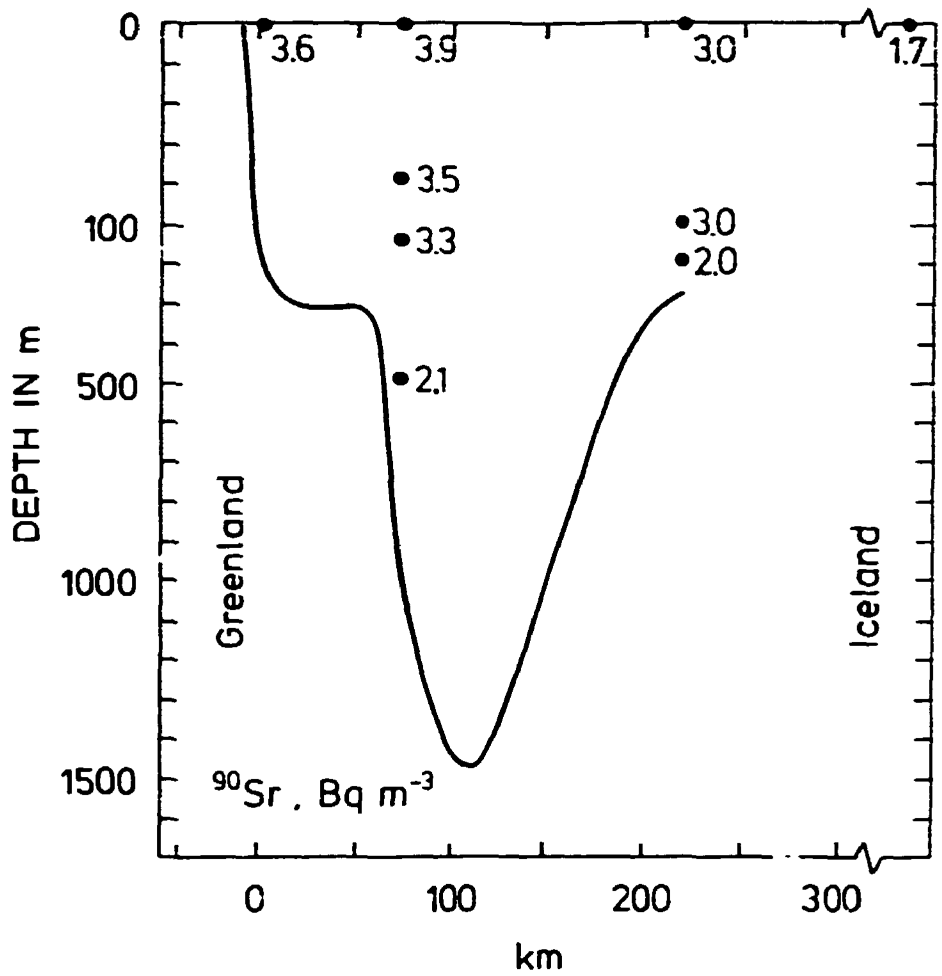


Figure 4.3.12. Strontium-90 in the Denmark Strait section of the Greenland Sea Project September 1988. (Unit: Bq m^{-3}).

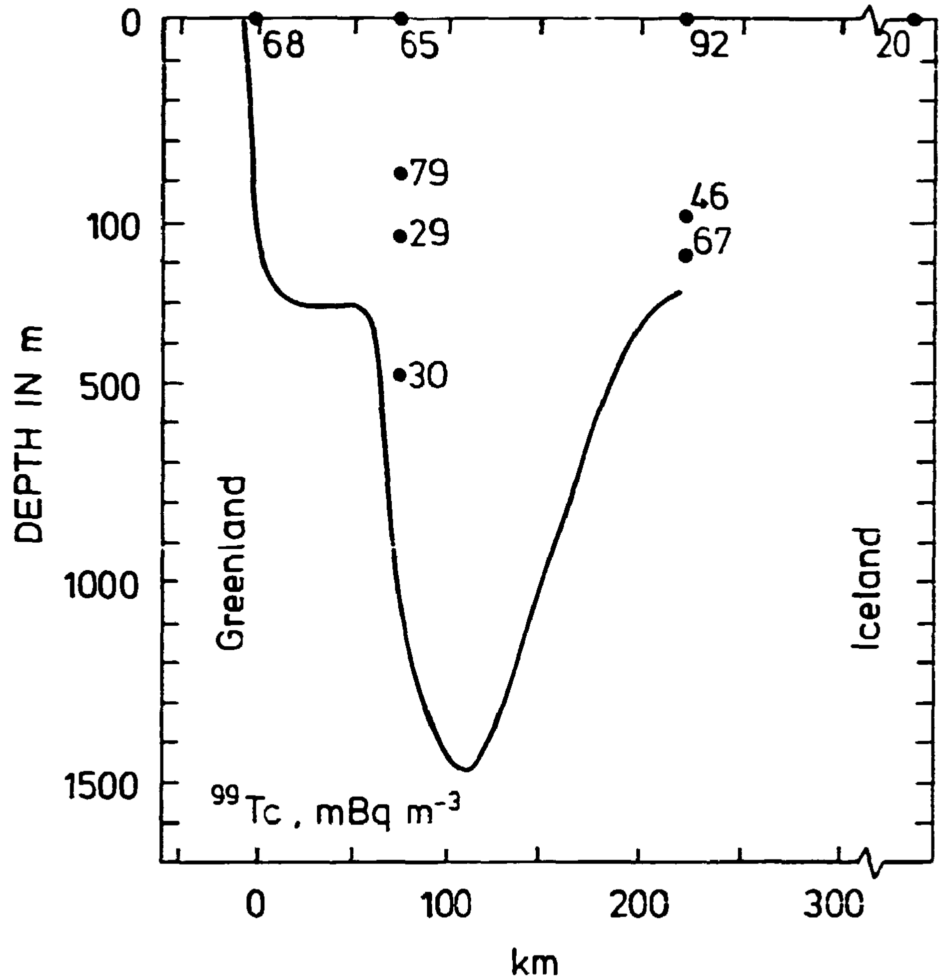


Figure 4.3.13. Technetium-99 in the Denmark Strait section of the Greenland Sea Project September 1988. (Unit: mBq m^{-3}).

4.4 Radionuclides in Lichen Collected at a Norwegian Location 1985-1991

Every summer since 1985 lichen samples (Cladonia stellaris) have been collected 30 km southeast of Alvdal at Belling (62°02'N, 10°48'E) in Norway. The sampling site is an open plateau covered with a thick carpet of lichen. Table 4.4 shows the results. The ratios of other radionuclides relative to ^{137}Cs were all decay corrected to April 26, 1986, when the Chernobyl accident began. Figures 4.4.1-4.4.5 show that the effective half-life of ^{137}Cs is longer in Norwegian lichen than in the Danish.

Table 4.4. Radionuclides in Norwegian lichen collected 1985-1991 at 62°02'N 10°48'E

Year & date	Bq ^{137}Cs kg^{-1} dry	Bq ^{137}Cs m^{-2}	g K kg^{-1} dry	Bq ^{137}Cs $(kg\ K)^{-1}$	$^{134}Cs/^{137}Cs$	$^{60}Co/^{137}Cs$	$^{95}Zr/^{137}Cs$	$^{103}Ru/^{137}Cs$	$^{106}Ru/^{137}Cs$	$^{110m}Ag/^{137}Cs$	$^{144}Ce/^{137}Cs$
					at 26 April 1986						
20 Aug 1985	80	160	-	7.5	-	-	-	-	-	-	-
20 July 1986	5500	5200	-	-	0.57	0.0002 8	0.073	0.28	0.077	0.0112	0.36[illegible]
21 Aug 1987	1810	4400	0.60	3000	0.59	0.00152	-	-	0.069	0.0103	0.354
24 Aug 1988	4000	2500	1.34	3000	0.59	0.00046	-	-	0.055	0.0094	-
24 Aug 1988	5600	3200	1.31	4400	0.59	0.00035	-	-	0.045 A	0.0091	-
25 Aug 1989	4500	4400	1.61	2800	0.59	-	-	-	-	-	-
25 Aug 1989	4100	4400	0.81	5100	0.52	-	-	-	-	-	-
21 Aug 1990	5200	7400	1.05	5000	0.59	-	-	-	-	-	-
21 Aug 1990	4600	6800	0.96	4600	0.59	-	-	-	-	-	-
28 Aug 1991	4300	8600	1.18	3700	0.59	-	-	-	-	-	-
28 Aug 1991	4600	9500	1.27	3600	0.58	-	-	-	-	-	-
23 Aug 1989**	6800	7100	3.25	2100	0.58	-	-	-	-	-	-
8 July 1986*	3600	3900	2.63	1370	0.58	0.0002 8	0.03 8	0.39	0.100	0.0101	-

*Collected at Valdres Aria (~ 61°N, ~9°E) $^{125}Sb/^{137}Cs$ 0.0121

**Cetraria nivalis collected at Beitostølen, Valdres

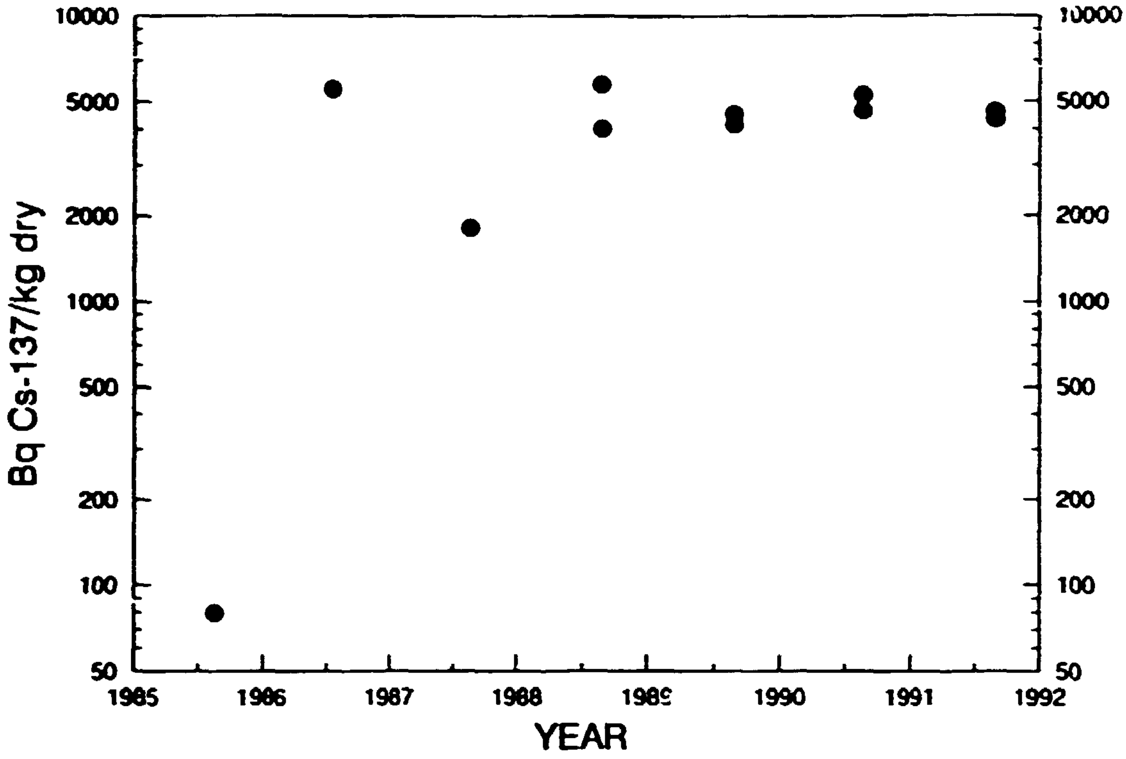
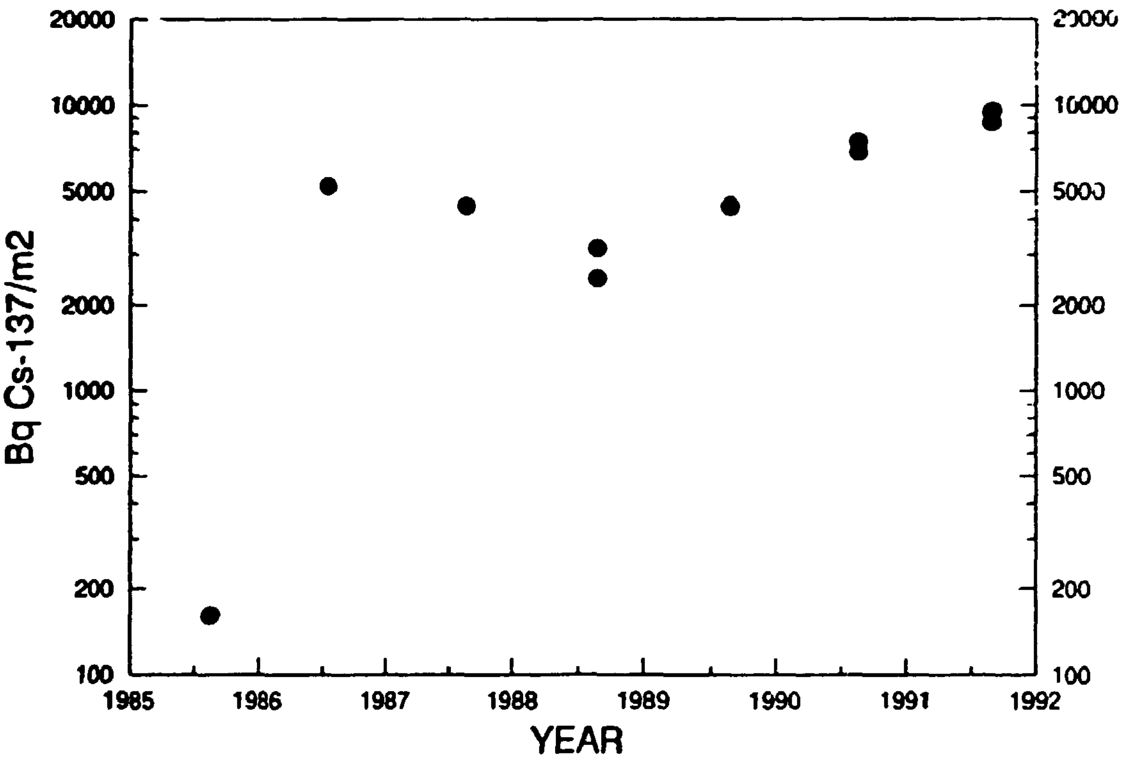


Figure 4.4.1. Cesium-137 in Norwegian lichen collected 1985-1991 at 62°02'N 10°48'E. (Unit: Bq kg^{-1} dry).

Figure 4.4.2. Cesium-137 in Norwegian lichen collected 1985-1991 at 62°02'N 10°48'E. (Unit: Bq m^{-2}).



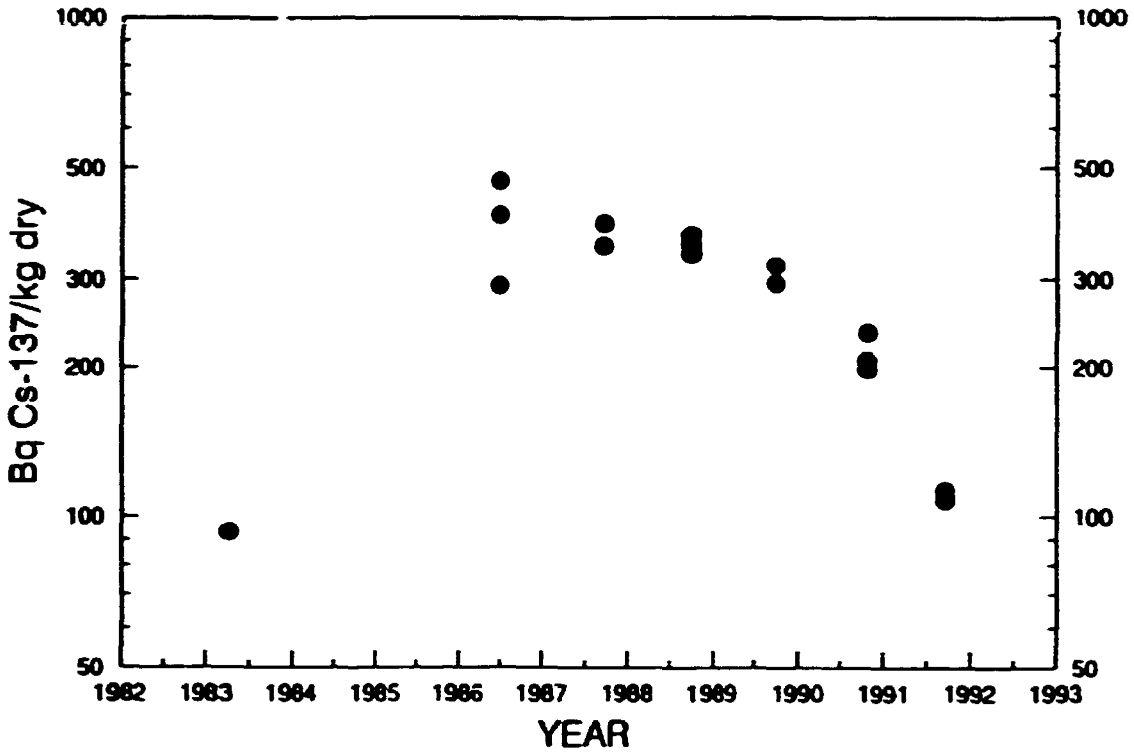
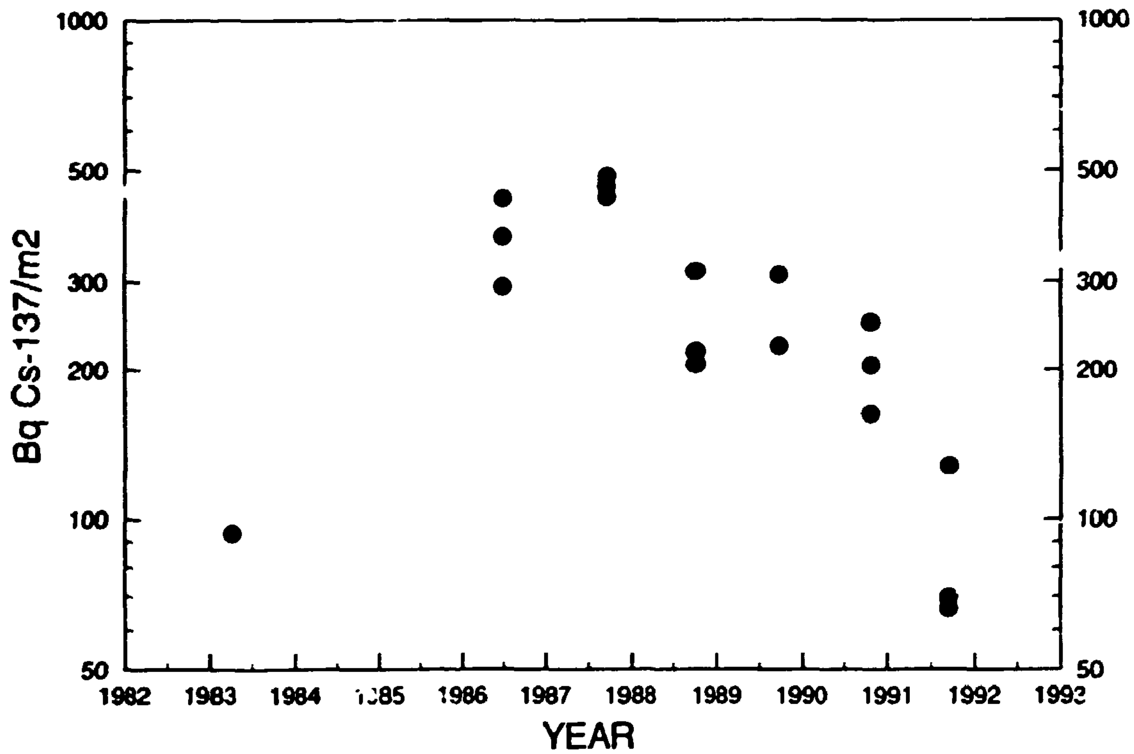


Figure 4.4.3. Cesium-137 in lichen from Skagen, Denmark, 1983-1991. (Unit: Bq kg^{-1} dry).

Figure 4.4.4. Cesium-137 in lichen from Skagen, Denmark, 1983-1991. (Unit: Bq m^{-2}).



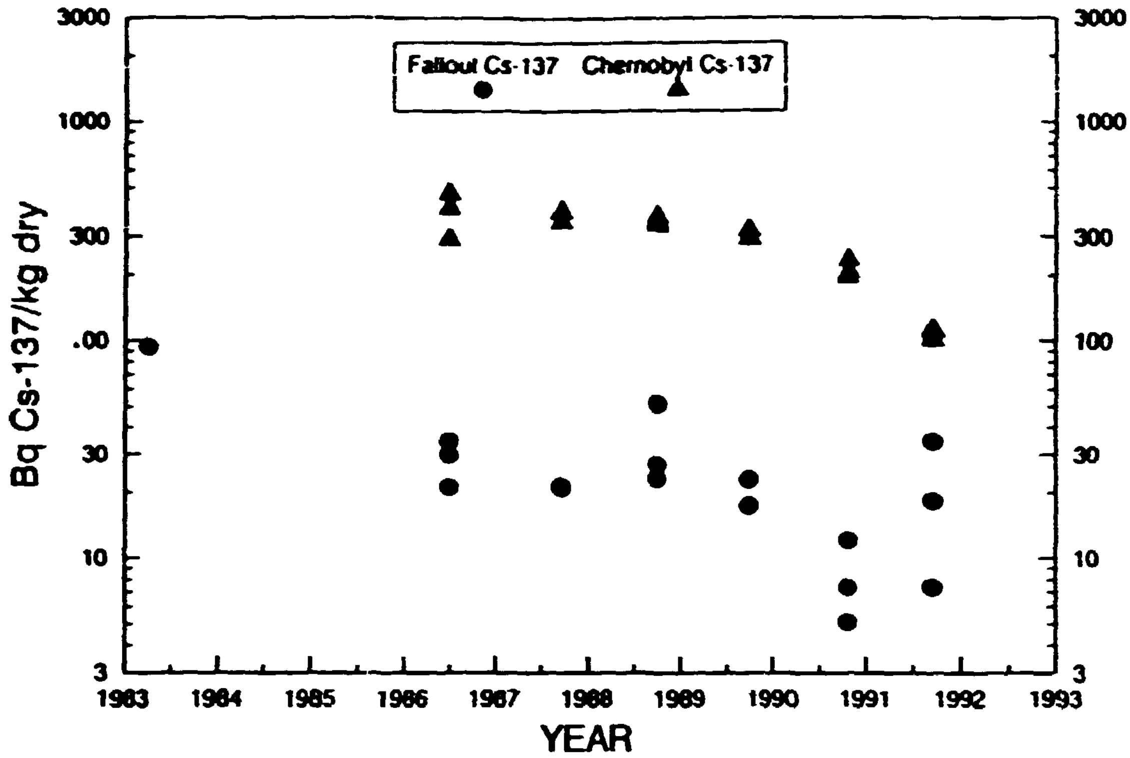


Figure 4.4.5. Chernobyl and fallout Cesium-137 in lichen from Skagen, Denmark, 1983-1991. (Unit: Bq kg^{-1} dry).

4.5 Radionuclides in Fucus Vesiculosus and Fucus Serratus Collected at a Norwegian Location 1984-1990

Table 4.5 shows that the relative contribution of Chernobyl ^{137}Cs decreased from 100% in 1986 to 75% in 1990 in Fucus collected at Trondheim Fjord in Norway.

Table 4.5. Radionuclides in Norwegian Fucus vesiculosus and Fucus serratus collected 1984-1990 at 63°35'N 9°16'

Species	Date	^{99}Tc Bq kg^{-1} dry	^{137}Cs Bq kg^{-1} dry	^{40}K g kg^{-1} dry	$\frac{^{134}Cs}{^{137}Cs}$	$\frac{^{54}Mn}{^{137}Cs}$	$\frac{^{60}Co}{^{137}Cs}$	$\frac{^{65}Zn}{^{137}Cs}$	$\frac{^{95}Zr}{^{137}Cs}$	$\frac{^{103}Ru}{^{137}Cs}$	$\frac{^{106}Ru}{^{137}Cs}$	$\frac{^{110m}Ag}{^{137}Cs}$	‰ dry matter
					at 26 April 1986								
Fu.ve.	13 Aug 1984	81	4.5	22.0									-
Fu.se.	13 Aug 1984	65	5.6	26.8									-
Fu.ve.	19 Aug 1985	47	4.1	19.7									30.1
Fu.se.	19 Aug 1985	47	3.4	23.8									24.1
Fu.ve.*	20 July 1986		77	26.9	0.55	0.034	0.020	0.062 A	0.188 A	2.59	0.87	1.47	25.4
Fu.se.	20 July 1986		47	27.2	0.59	0.065	0.053	0.087 A		4.20	0.80 A	2.17	23.8
Fu.ve.	21 Aug 1987		22	25.9	0.45							1.43	24.0
Fu.se.	21 Aug 1987		14.5	29.4	0.39		0.054					2.17	22.0
Fu.ve.	22 Aug 1988		10.5	25.3	0.34								19.7
Fu.se.	22 Aug 1988		7.2	22.5	0.46								23.2
Fu.ve.	25 Sept 1989		5.2	18.9	0.45								28.2
Fu.se.	25 Sept 1989		4.3	23.3	0.34								17.1
Fu.ve.	19 Aug 1990		3.2	23.5									40.0
Fu.se.	19 Aug 1990		2.9	23.0	0.41								25.1

* $\frac{^{144}Ce}{^{137}Cs}$: 0.084 B

4.6 Environmental Samples from Iceland

Tables 4.6.1-4.6.3 show radiocesium levels in soil, meat and vegetation collected in Iceland in 1985, 1988 and 1989.

A few samples contained ^{134}Cs suggesting the presence of Chernobyl debris. The soil sample from Gljufurholt showed a Chernobyl deposition of about 56 Bq ^{137}Cs m^{-2}. The reindeer sample contained 32% ^{137}Cs from Chernobyl. The Blåfjäll moss showed a Chernobyl deposition of 105 Bq ^{137}Cs m^{-2} and the grass from Gullfoss contained 26 Bq ^{137}Cs m^{-2}.

Table 4.6.1. Soil samples (0-10 cm layer) collected in Iceland, October 31, 1988 (Pall Theodorsson, University of Iceland)

Position N	Position W	Location	^{137}Cs Bq kg^{-1} fresh	^{137}Cs Bq m^{-2}	^{134}Cs Bq kg^{-1} fresh	^{134}Cs Bq m^{-2}	^{40}K g kg^{-1} fresh
63°54.7'	17°49.4'	Seljaland	92	6400	B.D.L.	B.D.L.	3.54
63°28.4'	19°16.6'	Pètursey	100	9200	"	"	6.00
63°43.4'	20°14.4'	Puerà	31	3700	"	"	9.14
63°58.8'	21°08.8'	Gljufurholt	26	2200	0.2 B	14 B	2.42
65°26.5'	19°11.0'	Silfrastadir	34	2200	< 0.5		5.09
64°48.1'	21°28.1'	Dalsmynni	73	5000	B.D.L.	B.D.L.	3.60
64°16'	15°11'	Höfn Mornafjordur	33	4000	< 0.12		3.11

Table 4.6.2. Meat samples collected in Iceland November 9, 1988 (Pall Theodorsson, University of Iceland)

Species	Bq ^{137}Cs g^{-1} ash	Bq ^{134}Cs g^{-1} ash	g ^{40}K $(g\ ash)^{-1}$	Bq ^{137}Cs $(kg\ K)^{-1}$
Lamb	0.62	B.D.L.	0.104	5900
Reindeer	0.44	0.035	0.084	5300

Table 4.6.3. Radionuclides in seaweed, moss and soil (grass) collected in Iceland 1985-1989. (Sample obtained from Pall Theodorsson, University of Iceland and Kári Indridason, SIS, Iceland)

Position N	Position W	Location	Species	Date	^{137}Cs Bq kg^{-1} dry	^{137}Cs Bq m^{-2}	^{134}Cs Bq kg^{-1} dry	^{134}Cs Bq m^{-2}	^{99}Tc Bq kg^{-1} dry	[illegible] g kg^{-1} dry
63°50'	22°27'	Grindavik	As no	10 Oct 1985	0.22 A					19.46
66°33'	18°00'	Grimsey	Fu ve	14 Dec 1989	< 0.9				2.3 ± 0.03	34.42
63°26'	20°16'	Vestmannaeyjar	Fu ve	14 Dec 1989	< 0.8				1.12 ± 0.05	36.04
64°10'	22°01'	Reykjavik	Fu ve *	6 Sep 1988	1.05 A				1.27	34.46
64°03'	21°30'	Blafjall	Moss	6 Sep 1988	440	5100	2.4	27		[illegible]
64°19'	20°08'	Gullfoss	Grass with soil	6 Sep 1988	169	1740	0.67	6.9		[illegible]

As no. Ascophyllum nodosum.
Fu-Ve. Fucus vesiculosus.

*63% dry matter.

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Measurements of fallout radioactivity in the North Atlantic region including the Faroe Islands and Greenland are reported. Strontium-90, cesium-137 and cesium-134 were determined in samples of precipitation, sea water, vegetation, various foodstuffs (including milk in the Faroes), and drinking water. Estimates are given of the mean contents of ^{90}Sr and ^{137}Cs in human diet in the Faroes and Greenland in 1988 and 1989. ^{99}Tc data on marine samples, in particular sea water from the Greenland Sea, are reported.

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