Environmental radioactivity in the North Atlantic Region including the Faroe Islands and Greenland. 1990 and 1991

Aarkrog, Asker; Buch, E.; Chen, Q.J.; Christensen, G.C.; Dahlgaard, H.; Hansen, H.; Holm, E.; Nielsen, Sven Poul; Strandberg, M.

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Risø National Laboratory, Roskilde, Denmark
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A. Aarkrog, E. Buch°, Q.J. Chen, G.C. Christensen*, H. Dahlgaard, H. Hansen, E. Holm, S.P. Nielsen and M. Strandberg**

° The Greenland Fisheries and Environmental Research Institute, Denmark
* Institute for Energy Technology, Kjeller, Norway
** University of Lund, Sweden

Risø National Laboratory, Roskilde, Denmark
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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 1990 and 1991. ^{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
μ R: 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 (Risø Reports (Faroese) 1962-1982) and Greenland (Risø 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« (Risø Reports (North Atlantic Region) 1983-1987) of which the present report is the seventh. It includes 1990 and 1991. In the tables and figures, which are placed at the end of each chapter, 1990 is marked by A and 1991 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.

2 Environmental Radioactivity in the Faroe Islands in 1990 and 1991

2.1 Introduction

2.1.1.

The fallout programme for the Faroes, which was initiated in 1962 (Risø 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 Risø in July 1991 in order to compare the environmental behaviour of Chernobyl debris with that from old global fallout and with a similar samplings in 1987 and 1989.

2.1.2.

The present report will not repeat information concerning sample collection and analysis already given in Risø 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, 564 and 571 (Risø Reports (Faroese) 1962-1982), (Risø Reports (North Atlantic Region) 1983-1989).

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-Jørgensen.

2.1.4.

The present investigation was carried out together with corresponding examinations of fallout levels in Denmark and Greenland, described in Risø Report No. 621 and in Chapter 3 of this report, respectively.

2.2 Results and Discussion

2.2.1 Strontium-90 and Cesium-137 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 Højvig (near Thorshavn) and Klaksvig in 1990 and 1991.

The mean depositions of ^{137}Cs in 1990 and 1991 were 5 and 5 Bq m^{-2}, respectively. This corresponds to an effective halflife of about 1-2 years.

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, Risø performed a countrywide sampling in Aug. 1991 (Table 2.2.2.2). The mean ratio between 1991 and the corresponding 1989 grass levels was 1.85±0.77 for ^{90}Sr and 3±4 for ^{137}Cs (5 determinations). Hence the levels had rather increased than decreased from 1989 to 1991. Faroese fodder grass contained 8.8±7.1 Bq ^{90}Sr $kg^{-1}_{d.m.}$ and 52±21 Bq ^{137}Cs $kg^{-1}_{d.m.}$ Grass sampled from the fields contained 8.1±3.7 Bq ^{90}Sr $kg^{-1}_{d.m.}$ and 126±116 Bq ^{137}Cs $kg^{-1}_{d.m.}$ The local variation is thus remarkable.

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 1990 and 1991 (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.

The effective halflife of ^{90}Sr in Faroese milk was 4 years (Figure 2.2.3.5) and that of global fallout ^{137}Cs was 3 years, while ^{137}Cs from Chernobyl decayed with 1,9 years halflife (Figure 2.2.3.4).

Table 2.2.3.6 shows the results from the Risø whole-milk sampling in Aug. 1991 at four Faroese locations. ^{90}Sr had decreased with an effective halflife of 5.9 years since 1989 but ^{137}Cs had increased by a factor of 1.1 due to higher milk levels at Klaksvik and Öravik in 1991 than in 1989; 67% of the ^{137}Cs in Faroese milk came from Chernobyl in 1991 (cf. also Figure 2.2.3.3).

2.2.4 Strontium-90 and Radiocesium in Faroese Terrestrial Animals

Tables 2.2.4.A & B show the data in lamb from 1990 and 1991, 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 1.7 years for Chernobyl ^{137}Cs and 4.8 years for global fallout ^{137}Cs. The effective halflife of ^{90}Sr in lamb bone since 1983 was 4.4 years (Figure 2.2.4.1), i.e. comparable with that of ^{90}Sr in Faroese milk if the entire period since 1962 was considered.

The observed halflife of global fallout ^{90}Sr became 5.2 (Figure 2.2.4.1) and that of ^{137}Cs in lamb 5.9 years (Figure 2.2.4.3). This shows that the continued deposition of global fallout from 1962 to around 1983 increased the observed halflives of both ^{90}Sr and ^{137}Cs by approximately one year compared with the effective halflives determined since 1983 (Figures 2.2.4.1 and 2.2.4.4).

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 Figure 2.2.5.1.

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. 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 1990-1991: 0.22 ± 0.04 (± 1 S.D.; N = 3) and in puffin we found 0.095 Bq ^{137}Cs kg^{-1} (cf. Tables 2.2.5.2.A & B).

2.2.6 Strontium-90, Cesium-137 and Tritium in Faroese Drinking Water and Other Fresh Waters

The ^{90}Sr and ^{137}Cs of Faroese drinking water (Table 2.2.6.1 and Figure 2.2.6.1) have been measured since 1962 for ^{90}Sr and since 1987 for ^{137}Cs. The ^{137}Cs levels decreased in the period 1988 to 1991 with an effective halflife of 4 years.

A special sampling was carried out in Aug. 1991 (Table 2.2.6.2). Compared with the corresponding sampling in July 1989 (Risø Report No. 571) the 1991 levels were 0.87 ± 0.29 (± 1 S.D.; N = 4) times those in 1989, i.e. the ^{137}Cs has decayed with a mean effective halflife of 10 years.

Tables 2.2.6.3 and 2.2.6.4 show the radiocesium levels in stream and lake water, respectively, from the Aug. 1991 sampling. Compared with the sampling two years ago the ^{137}Cs levels had not changed significantly 1991/1989 = 1.01 ± 0.30 (± 1 S.D.; N = 8).

The drinking water ^{137}Cs concentrations in Aug. 1991 were 40% of those found in stream and lake waters.

The mean concentration of tritium in Faroese drinking water from 1991 was 0.98 kBq m^{-3} (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 7.6 ± 3.7 kBq m^{-2} (Højvig excluded) (± 1 S.D.; N = 4) in Aug. 1991 (Table 2.2.7.1.1) compared with 6.4 ± 2.2 in July 1987 and 8.0 ± 4.9 in July 1989. The difference reflects inhomogeneities in the depositions at the four locations.

The Chernobyl mean deposit at the four locations was 1.09 ± 0.16 kBq ^{137}Cs m^{-2} by Aug. 1991 compared with 1.48 ± 0.95 kBq ^{137}Cs m^{-2} by July 1989 and 1.90 ± 0.64 by July 1987 (Table 2.2.7.1.2) corresponding to an effective halflife of Chernobyl ^{137}Cs in the 0-5 cm soil layer since 1987 of 4.8 years.

The Chernobyl contributions in Table 2.2.7.1.4 were calculated from the ratio: $^{134}Cs/^{137}Cs$ in the samples. The contributions were given as a percentage of the total ^{137}Cs in the samples (cf. also Risø-R-571).

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 1.54 ± 0.09 Bq ^{90}Sr m^{-3} and 3.3 ± 0.35 Bq ^{137}Cs m^{-3} in 1990 and 1.26 ± 0.02 Bq ^{90}Sr m^{-3} and 2.4 ± 0.14 Bq ^{137}Cs m^{-3} in 1991. No ^{134}Cs was detected in the sea water samples (cf. also Figure 2.2.7.2).

Samples of sea water were also collected in open waters around the Faroes in 1990. Table 2.2.7.2.2 shows that the surface water shows the same levels as

those in Table 2.2.7.2.1.A. The samples contained low levels of ^{99}Tc (~ 30 mBq m^{-3}).

2.2.7.3 Faroese Sea Plants

The mean concentrations of ^{137}Cs and ^{90}Sr in Faroese seaweed were 0.5 Bq kg^{-1} dry matter and 0.2 Bq kg^{-1} dry matter, respectively, for 1990 and for 1991 the levels were 0.8 and 1.3, respectively, (Tables 2.2.7.3.1.A & B, Table 2.2.7.3.2 and Figure 2.2.7.3). Table 2.2.7.3.2 shows that the mean concentration in Fucus vesiculosus collected in Aug. 1991 was 0.62±0.34 Bq ^{137}Cs $kg^{-1}_{d.m.}$ (±1 S.D.; N = 5).

2.2.7.4 Faroese Potatoes

The mean concentrations in Faroese potatoes were 0.068 Bq ^{90}Sr kg^{-1} and 3.3 Bq ^{137}Cs kg^{-1} in 1990 and 0.096 Bq ^{90}Sr kg^{-1} and 4.0 Bq ^{137}Cs kg^{-1} in 1991 (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 0.07 Bq kg^{-1} and rye bread contained 0.14 Bq kg^{-1}. The ^{137}Cs concentrations were 0.15 Bq kg^{-1} in rye and 0.06 in white bread. There was no significant difference between 1990 and 1991 (Tables 2.2.7.5.A & B).

2.2.7.6. Faroese Eggs

The ^{137}Cs level of eggs was 0.17 Bq kg^{-1} and that of ^{90}Sr was 0.03 in 1990 and 1991 (Tables 2.2.7.6.A & B).

2.2.8 Humans from the Faroes

No samples in 1990 and 1991.

2.2.9 Fodder and Other Vegetation from the Faroes

Concentrates collected in 1991 contained 0.51±0.44 Bq ^{137}Cs $kg^{-1}_{d.m.}$ Silage contained 43 Bq ^{137}Cs $kg^{-1}_{d.m.}$ (Table 2.2.9).

A special collection of wild vegetation from the Faroes was carried out in Aug. 1993. Appendix shows the ^{137}Cs and ^{40}K levels in these samples.

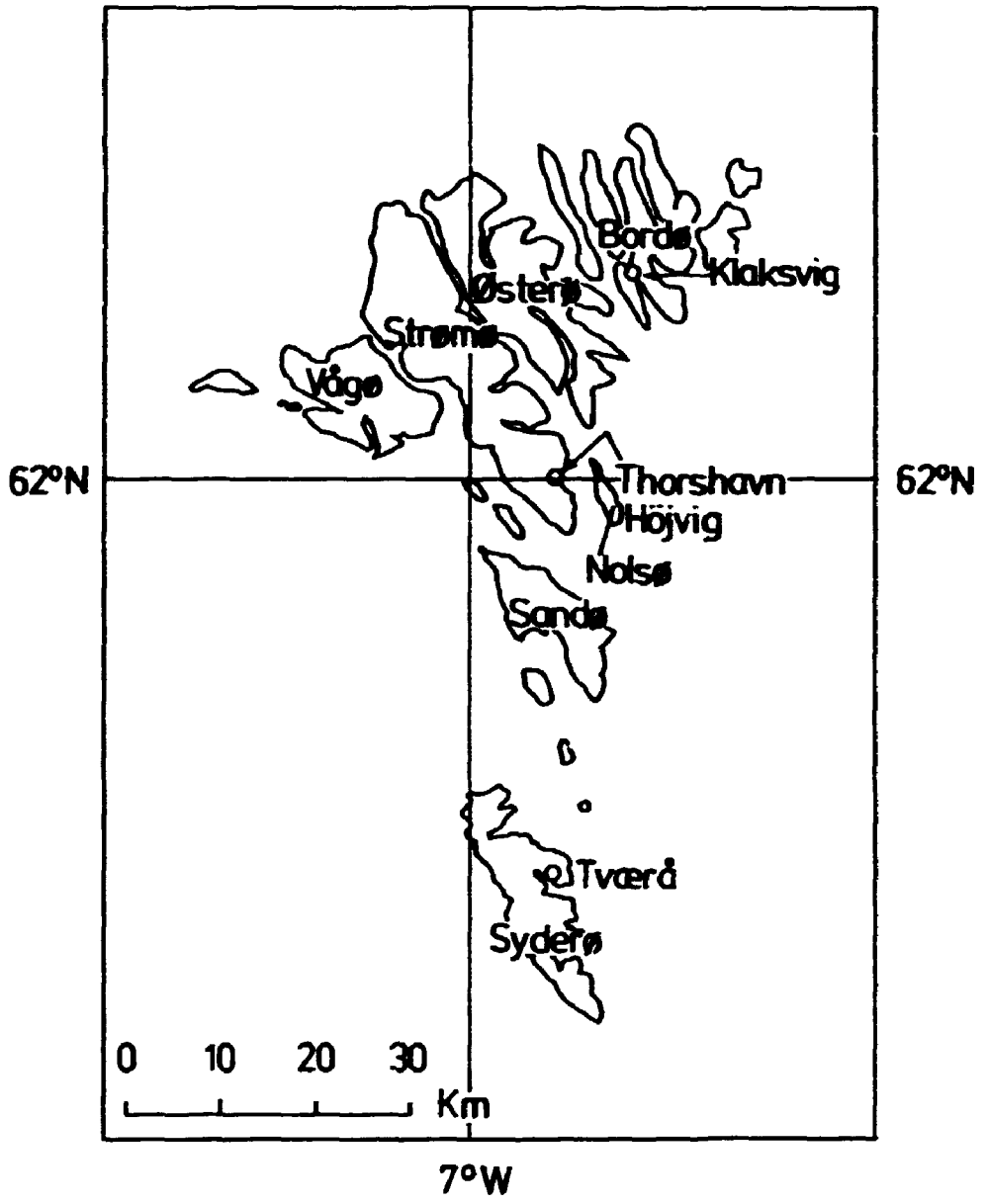
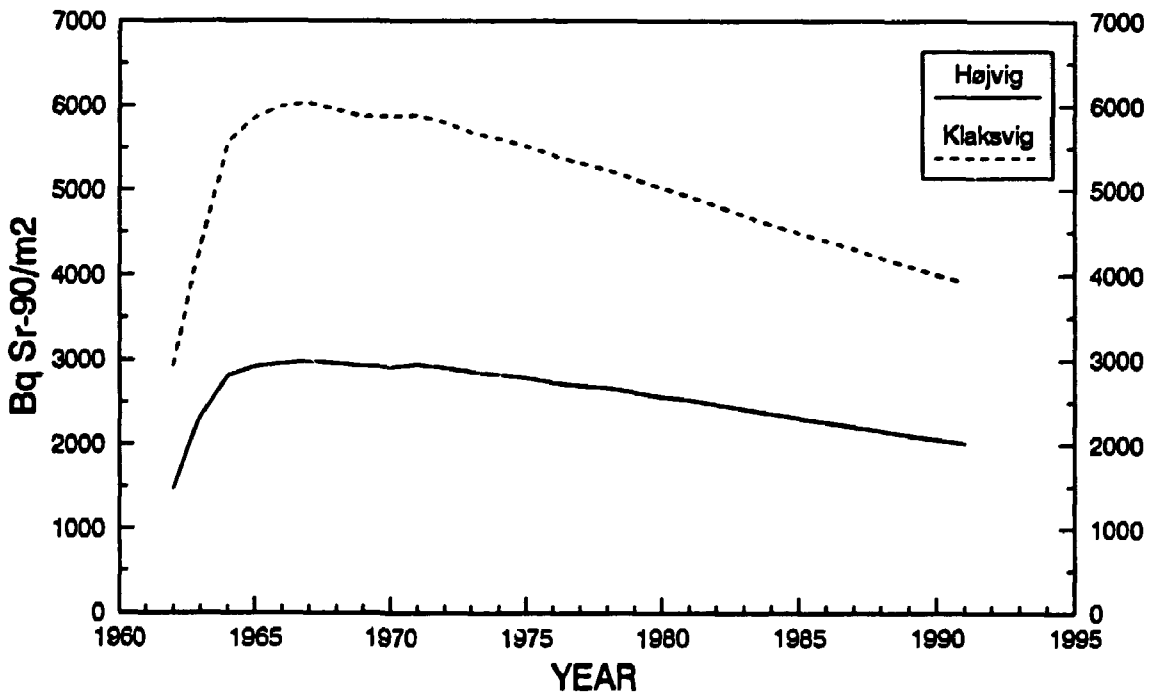


Figure 2.1. The Faroe Islands.

Table 2.2.1.1. Strontium-90 in precipitation in the Faroes in 1990 and 1991. (Sampling area: 0.02 m²)

	Højvig			Klaksvig		
Year	Bq m^{-3}	Bq m^{-2}	mm	Bq m^{-3}	Bq m^{-2}	mm
1990	0.146 A	0.177 A	1210	0.064	0.170	2664
1991	0.40	0.39	980	0.21	0.49	2345

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 1962-1991 (cf. Table 2.2.1.2).



ut rates and accumulated fallout in the Faroes 1950-1991

Höjvig		Klaksvig
$A_{i(29)}$	d_i	$A_{i(29)}$
1.06	2.15	2.10
6.12	10.34	12.14
15.94	20.27	31.64
40.74	51.18	80.87
135.48	194.58	268.94
258.20	256.00	512.54
408.22	317.41	810.34
554.70	317.41	1101.12
758.18	440.34	1505.05
1047.48	624.58	2079.33
1080.14	116.69	2144.16
1129.19	151.59	2241.52
1476	760.31	2931
2333	1503.00	4329
2809	1363.00	5558
2919	436.00	5852
2960	289.00	5996
2982	182.00	6032
2955	55.50	5944
2925	65.10	5867
2909	141.00	5866
2938	156.00	5880
2903	55.10	5795
2858	26.50	5684
2823	58.80	5607
2790	47.80	5521
2733	21.60	5412
2695	34.40	5318
2668	47.60	5239
2618	22.20	5137
2566	10.29	5025
2523	21.80	4928
2470	3.91	4815
2414	2.24	4704
2363	0.87	4594
2308	0.59	4486
2266	28.00	4407
2214	0.81	4304
2162	0.30	4202
2111	0	4103
2062	0.170	4006
2013	0.49	3912

estimated values based upon HASL data ix 291, 1975) considering that the mean out in Denmark to New York was 0.7 in the 74 and that the mean ratios of ^{90}Sr fallout in ark and Klaksvig to Denmark are 1.39 and ely (Aarkrog, 1979).

Table 2.2.1.3. Radiocesium in precipitation in the Faroes in 1990 and 1991. (Sampling area: 0.02 m²)

Year	Höjvig		Klaksvig	
	^{137}Cs Bq m^{-3}	^{137}Cs Bq m^{-2}	^{137}Cs Bq m^{-3}	^{137}Cs Bq m^{-2}
1990	6.3	7.7	1.03	2.8
1991	8.1	7.9	1.30 A	3.0 A

(Amounts of precipitation are shown in Table 2.2.1.1).

Table 2.2.1.4. Fallout rates and accumulated fallout in the Faroes 1950-1991. (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
1990	3.68	6217.05	6.33	4101.51	1.03	8348.08	1.5	4768.75
1991	5.49	6080.41	7.93	4015.58	3.04	8160.38	2.2	4661.98

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 1990

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	2.2	2400	25	5100	0.060
August	0.76	1270	11.3	3900	0.057

Table 2.2.2.1.B. Strontium-90 and radiocesium in grass from Thorshavn 1991

Month	^{90}Sr			^{137}Cs			$\frac{^{134}Cs}{^{137}Cs}$
	Bq kg^{-1} fresh	Bq kg^{-1} dry	Bq $(kg\ Ca)^{-1}$	Bq kg^{-1} fresh	Bq kg^{-1} dry	Bg $(kg\ K)^{-1}$	
June	1.15	5.0	2200	10.5	46	2100	0.050
August	0.35	2.4	430	1.14	7.8	270	-

Table 2.2.2.2. Strontium-90 and radiocesium in Faroese grass samples collected by Risø in July-August 1991

Location (cf. Fig. 2.1)	Species	Date	^{90}Sr			^{137}Cs		$\frac{^{134}Cs}{^{137}Cs}$	% dry matter	kg m^{-2} dry grass
			Bq kg^{-1} dry	Bq $(kg\ Ca)^{-1}$	Bq m^{-2}	Bq kg^{-1} dry	Bq $(kg\ K)^{-1}$			
Klaksvig	Fodder grass	3 Aug	10.9	3600	-	65	2700	0.077	-	-
Bður, Vågø	Fodder grass	5 Aug	0.80	220	-	28	1260	0.104	-	-
Øravik, Syderø	Fodder grass	1 Aug	14.6	3100	-	64	3100	0.066	-	-
Klaksvig	Grass	3 Aug	11.3	1660	56	240	14600	0.058	0.188	0.23
Bður, Vågø	Grass	5 Aug	4.5	1290	1.42	6.5	270	0.061	0.148	0.22
Øravik, Syderø	Grass	1 Aug	11.2	3300	17.4	210	7600	0.070	0.090	0.081
Höjvik	Grass	31 July	5.2	1370	5.2	49	2400	0.069	0.129	0.106

Table 2.2.3.1.A. Strontium-90 in milk from the Faroes in 1990
(Unit: Bq ^{90}Sr (kg Ca)$^{-1}$)

	Thorshavn	Klaksvig	Tværå	Mean
Jan-May	42	40	44	42
June-Sept	45	43	37	42
Oct-Dec	32	45	37	38
Mean*	41	42	40	41

*The data were weighted with the number of months when calculating the mean.

Table 2.2.3.1.B. Strontium-90 in milk from the Faroes in 1991
(Unit: Bq ^{90}Sr (kg Ca)$^{-1}$)

	Thorshavn	Klaksvig	Tværå	Mean
Jan-May	30	33	38	33
June-Sept	48	28	41	39
Oct-Dec	38	41	34	38
Mean*	39	34	38	36

*The data were weighted with the number of months when calculating the mean.

Table 2.2.3.2.A. Radiocesium in milk from the Faroes in 1990

	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	1140	740	0.097	2400	1440	0.123	4700	3300	0.116	2700	1811	0.112	0.172
Feb	-	-	-	-	-	-	-	-	-	2190	1450	0.116	0.167
March	840	530	0.086	1510	950	0.118	3200	2200	0.106	1860	1220	0.104	0.163
April	940	590	0.097	1060	650	0.112	2700	1690	0.116	1560	980	0.108	0.159
May	1360	870	0.095	990	610	0.089	1990	1330	0.099	1450	930	0.094	0.155
June	1250	810	0.083	680	430	0.094 B	2200	1500	0.100	1390	910	0.093	0.151
July	1880	1230	0.082	1420	890	0.098	4600	3000	0.100	2600	1690	0.094	0.147
Aug	2000	1310	0.080	1610	1010	0.093	5500	3600	0.090	3000	1990	0.087	0.143
Sept	1890	1240	0.075	1270	810	0.078	4000	2400	0.088	2400	1500	0.080	0.139
Oct	1240	840	0.079	1570	1040	0.092	3600	2300	0.081	2100	1390	0.084	0.136
Nov	1140	770	0.072	2300	1500	0.088	3200	2100	0.084	2200	1460	0.081	0.132
Dec	1070	700	0.066	1650	1100	0.084	3100	1940	0.093	1950	1240	0.081	0.129
Mean	1340	880	-	1490	950	-	3500	2300	-	2100	1380	-	-

Table 2.2.3.2.B. Radiocesium in milk from the Faroes in 1991

	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	1240	810	0.071	1960	1270	0.075	3600	2300	0.093	2300	1470	0.080	0.126
Feb	1040	700	0.075	1080	700	0.079	3100	2000	0.081	1740	1130	0.078	0.122
March	1180	750	0.075	1000	640	0.085	3000	1940	0.080	1730	1110	0.080	0.119
April	1170	760	0.051 A	700	440	0.079	2000	1350	0.068	1290	840	0.066	0.116
May	1170	750	0.079	530	330	0.079 A	(2000)	(1130)	-	1160	740	0.079	0.113
June	1360	850	0.054	380	240	0.104 A	1520	1020	0.060	1080	700	0.073	0.110
July	1460	920	0.053	1330	850	0.072	2100	1300	0.067	1620	1030	0.064	0.107
Aug	1850	1260	0.052	1630	1060	0.059	4900	3200	0.060	2800	1840	0.057	0.105
Sept	1530	950	0.056	1130	750	0.057	3300	1940	0.051	1970	1220	0.550	0.102
Oct	1300	840	0.050	1990	1250	0.060	2600	1690	0.059	1970	1260	0.056	0.099
Nov	1230	800	0.058	740	480	0.060	2100	1330	0.056	1350	870	0.058	0.097
Dec	1090	680	0.043	710	420	0.067	(2000)	(1210)	-	1270	770	0.055	0.094
Mean	1300	840	-	1100	700	-	2700	1700	-	1670	1080	-	-

Figure in brackets calculated from VAR3.

Table 2.2.3.3.A. Analysis of variance of ln Bq ^{90}Sr (kg Ca)$^{-1}$ in Faroese milk in 1990 (from Table 2.2.3.1.A)

Variation	SSD	f	s^2	v^2	P
Between time	0.024	2	0.012	0.651	-
Between locations	0.010	2	0.005	0.277	-
Remainder	0.073	4	0.018		

Table 2.2.3.3.B. Analysis of variance of ln Bq ^{90}Sr (kg Ca)$^{-1}$ in Faroese milk in 1991 (from Table 2.2.3.1.B)

Variation	SSD	f	s^2	v^2	P
Between time	0.059	2	0.029	0.703	-
Between locations	0.020	2	0.010	0.241	-
Remainder	0.168	4	0.042		

Table 2.2.3.4.A. Analysis of variance of ln Bq ^{137}Cs (kg K)$^{-1}$ in Faroese milk in 1990 (from Table 2.2.3.2.A)

Variation	SSD	f	s^2	v^2	P
Between months	1.772	10	0.177	2.396	> 95%
Between locations	6.660	2	3.330	45.024	> 99.95%
Remainder	1.479	20	0.074		

Table 2.2.3.4.B. Analysis of variance of ln Bq ^{137}Cs (kg K)$^{-1}$ in Faroese milk in 1991 (from Table 2.2.3.2.B)

Variation	SSD	f	s^2	v^2	P
Between months	2.734	11	0.249	2.957	> 97.5 %
Between locations	4.901	2	2.450	29.153	> 99.95%
Remainder	1.681	20	0.084		

Table 2.2.3.5.A. Analysis of variance of ln Bq ^{137}Cs m^{-3} in Faroese milk in 1990 (from Table 2.2.3.2.A)

Variation	SSD	f	s^2	v^2	P
Between months	1.712	10	0.171	2.359	>95%
Between locations	6.498	2	3.249	44.749	>99.95%
Remainder	1.452	20	0.073		

Table 2.2.3.5.B. Analysis of variance of ln Bq ^{137}Cs m^{-3} in Faroese milk in 1991 (from Table 2.2.3.2.B)

Variation	SSD	f	s^2	v^2	P
Between months	2.577	11	0.234	2.760	>97.5%
Between locations	4.898	2	2.449	28.860	>99.95%
Remainder	1.697	20	0.085		

Table 2.2.3.6. Radiocesium and Strontium-90 in whole milk collected by Risø at Faroese farms in July-August 1991

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 (Bōur)	840	510	0.088	27
Strømø (Thorshavn)	1910	1200	0.076	41
Bordø (Klaksvig)	1740	1120	0.060	31
Syderø (Õravik)	4700	2800	0.060	63

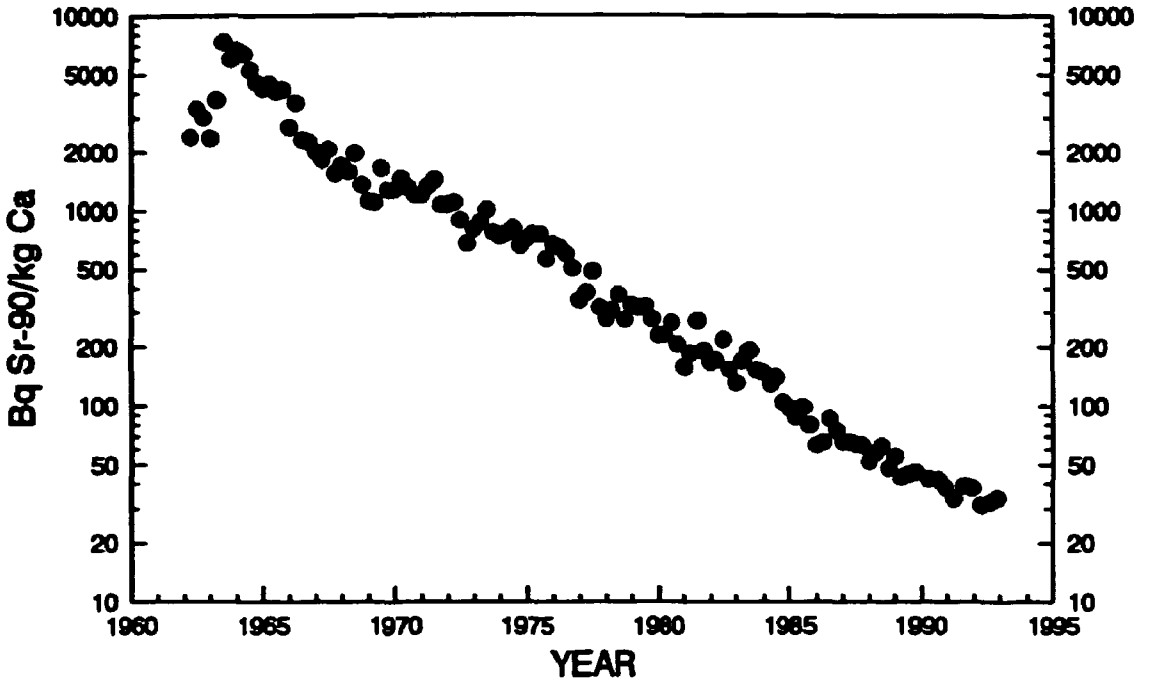
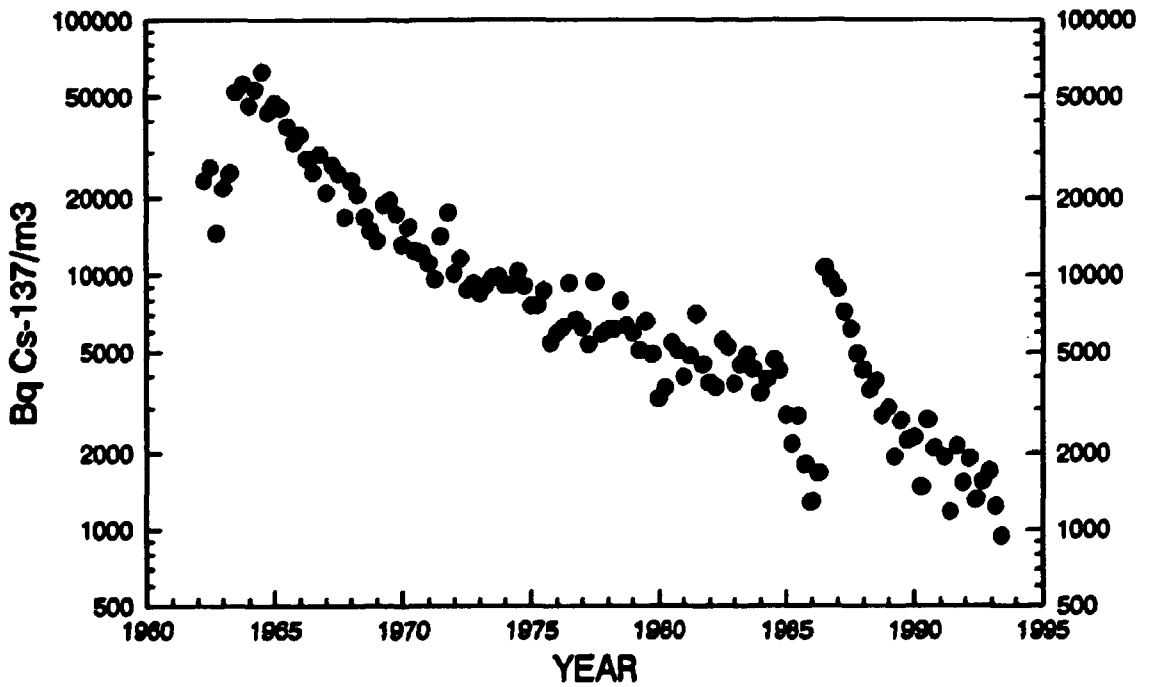


Figure 2.2.3.1. Strontium-90 in Faroese milk, 1962-1992. (Unit: Bq (kg Ca)$^{-1}$).

Figure 2.2.3.2. Cesium-137 in Faroese milk, 1962-1992. (Unit: Bq m^{-3}).



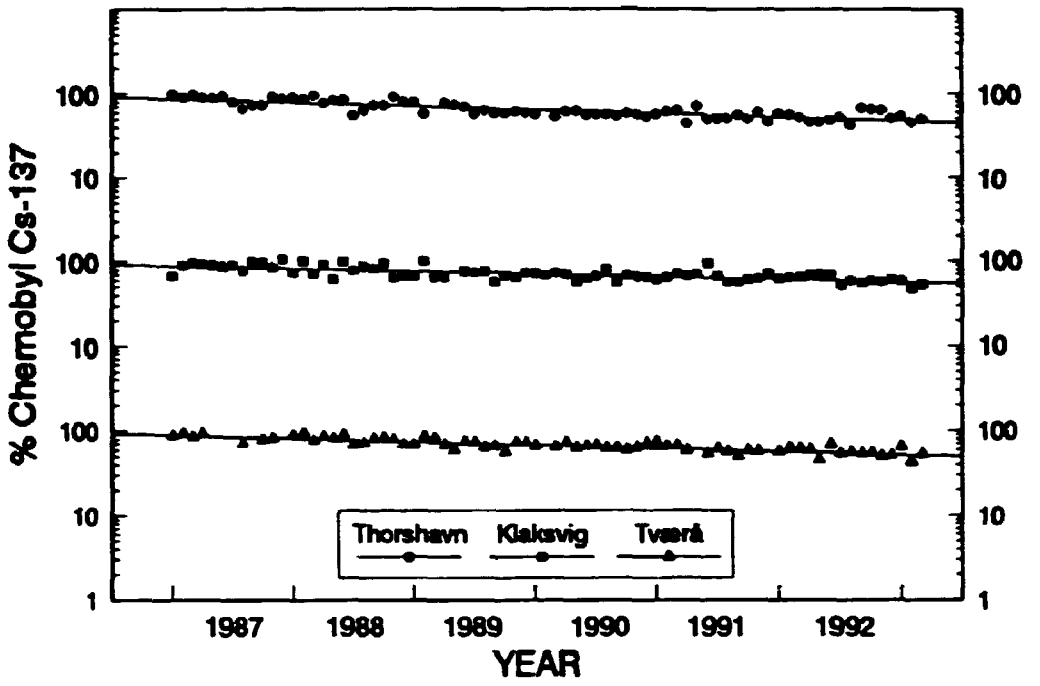
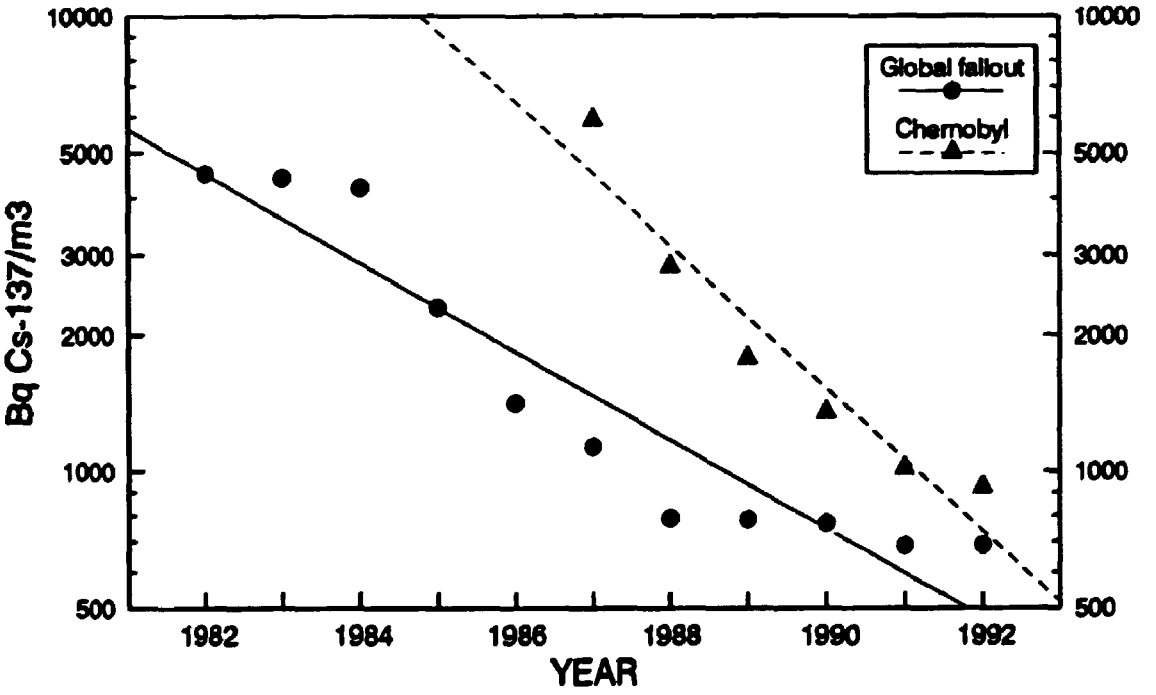


Figure 2.2.3.3. % Chernobyl ^{137}Cs in Faroese milk 1987-1992.

Figure 2.2.3.4. Cesium-137 in Faroese milk collected 1982-1992. (Unit: Bq m^{-3}).



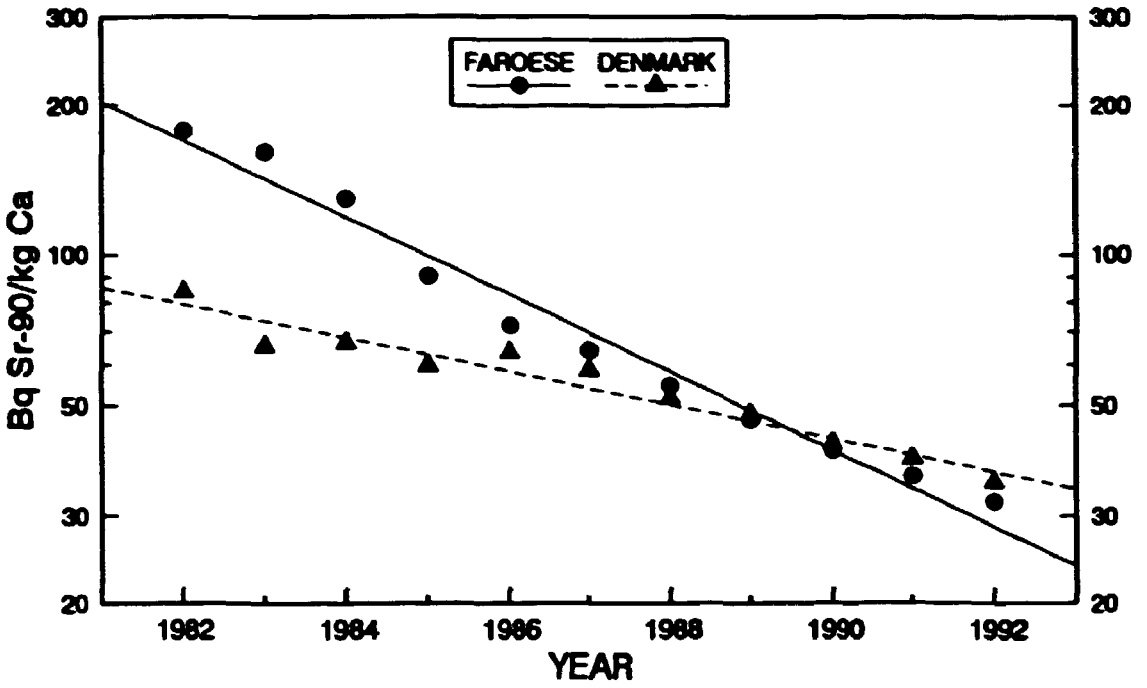


Figure 2.2.3.5. Strontium-90 in milk from Denmark and the Faroes 1982-1992. (Unit: Bq (kg Ca)$^{-1}$).

Table 2.2.4.A. Radionuclides in lamb collected in the Faroes in 1990

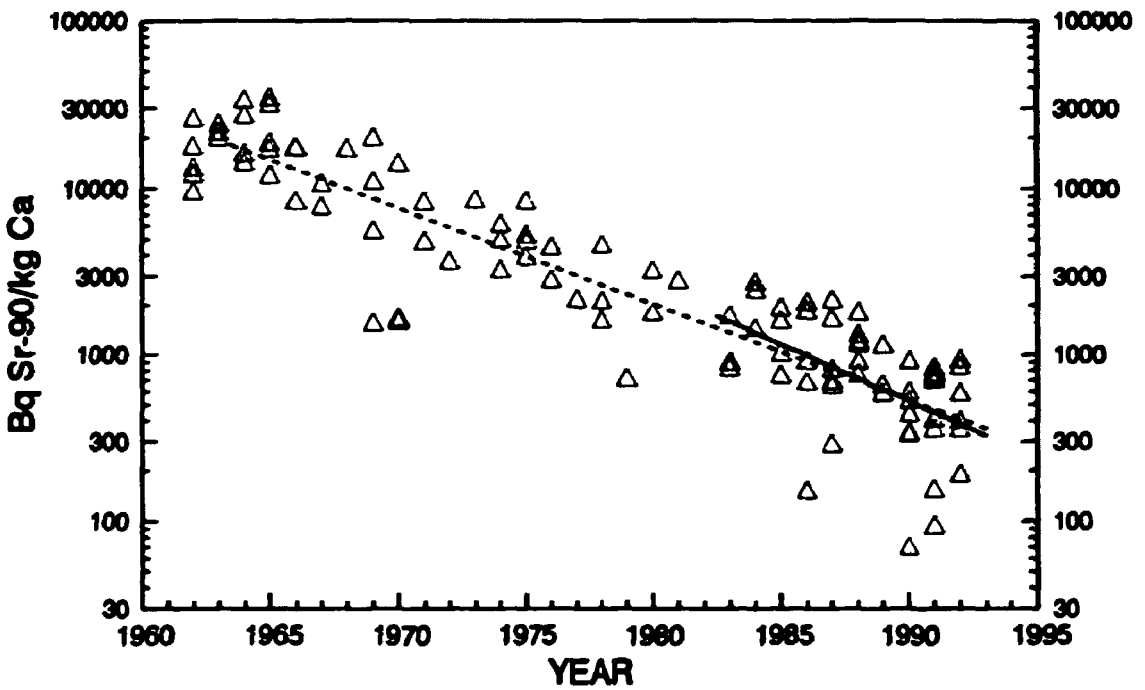
Location	Position	Date	Lamb meat				Bone	Theoretical
			Bq ^{90}Sr kg^{-1}	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs (kg K)$^{-1}$	$\frac{^{134}Cs}{^{137}Cs}$	Bq ^{90}Sr (kg Ca)$^{-1}$	$\frac{^{134}Cs}{^{137}Cs}$
Strømø	61°58'N 06°52'W	July	0.051	33	11600	0.085	510	0.147
Strømø I	61°57'N 06°50'W	July	0.0019	3.2	980	0.089	68	0.147
Strømø II	61°57'N 06°50'W	July		3.9	1120	0.113		
Sudarø Ia	61°28'N 06°50'W	Aug	0.0131	10.5	3100	0.107	320	0.143
Sudarø Ib	61°28'N 06°50'W	Aug		9.9	3100	0.114		
Sudarø IIa	61°28'N 06°50'W	Aug		13.5	3600	0.109		
Sudarø IIb	61°28'N 06°50'W	Aug		13.0	3400	0.103		
Sandø I	61°50'N 06°50'W	July	0.033	10.6	2800	0.100	580	0.147
Sudarø II	61°28'N 06°50'W	July		14.1	3100	0.101		
Klaksvig	61°13'N 06°34'W	Nov	0.0085	9.4	3100	0.068	330	0.132
Strømø	61°58'N 06°52'W	Nov	0.049	3.6	1050	0.070	430	0.132
Strømø	62°04'N 06°49'W	Nov	0.091	17.9	5400	0.057	890	0.132

I : shoulder
II: haunch

Table 2.2.4.B. Radionuclides in lamb collected in the Faroes in 1991

Location	Date	Lamb meat				Bone	Theoretical
		Bq ^{90}Sr kg^{-1}	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs $(kg\ K)^{-1}$	$\frac{^{134}Cs}{^{137}Cs}$	Bq ^{90}Sr $(kg\ Ca)^{-1}$	$\frac{^{134}Cs}{^{137}Cs}$
Streme (Kirkeby)	July	0.0091	1.39	530	0.072	91	0.107
Sande a.	July	0.046	78	10400	0.062	820	0.107
Sande b.	July		78	10400	0.061		
Våge a.	July	0.0103	7.7	1500	0.065	150	0.107
Våge b.	July		4.9	1500	0.064		
Våge lung	July		2.0	900	-		
Våge liver	July		4.7	1430	0.060		
Borde a.	July	0.027	55	7900	0.057	350	0.107
Borde b.	July		53	7400	0.055		
Sudere	July	0.043	89	27000	0.070	760	0.107
Streme	Oct	0.054	6.0	2000	0.050	730	0.099
Sande	Oct	0.034	2.9	780	0.099	400	0.099
Klaksvig/Borde	Dec	0.033	15.1	4500	0.061	690	0.094

Figure 2.2.4.1. Strontium-90 in Faroese lamb bone 1962-1992. (Unit: Bq (kg Ca)$^{-1}$). Observed halflife: 1964-1992: 5.2 y. 1983-1992: 4.4 y.



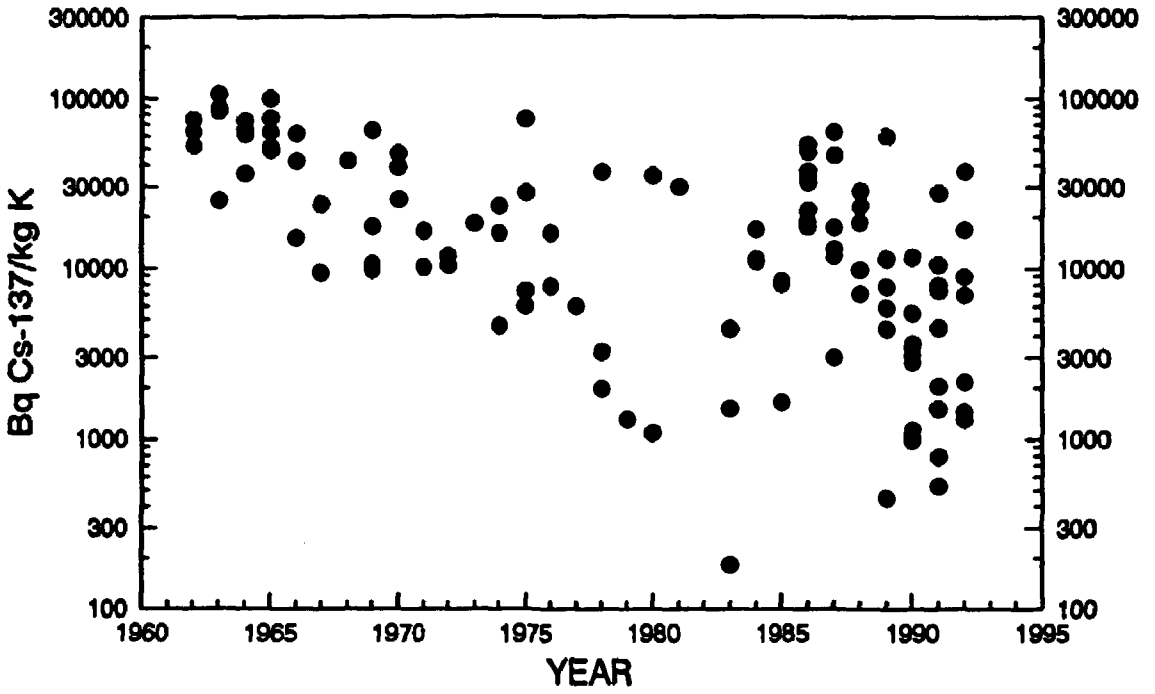
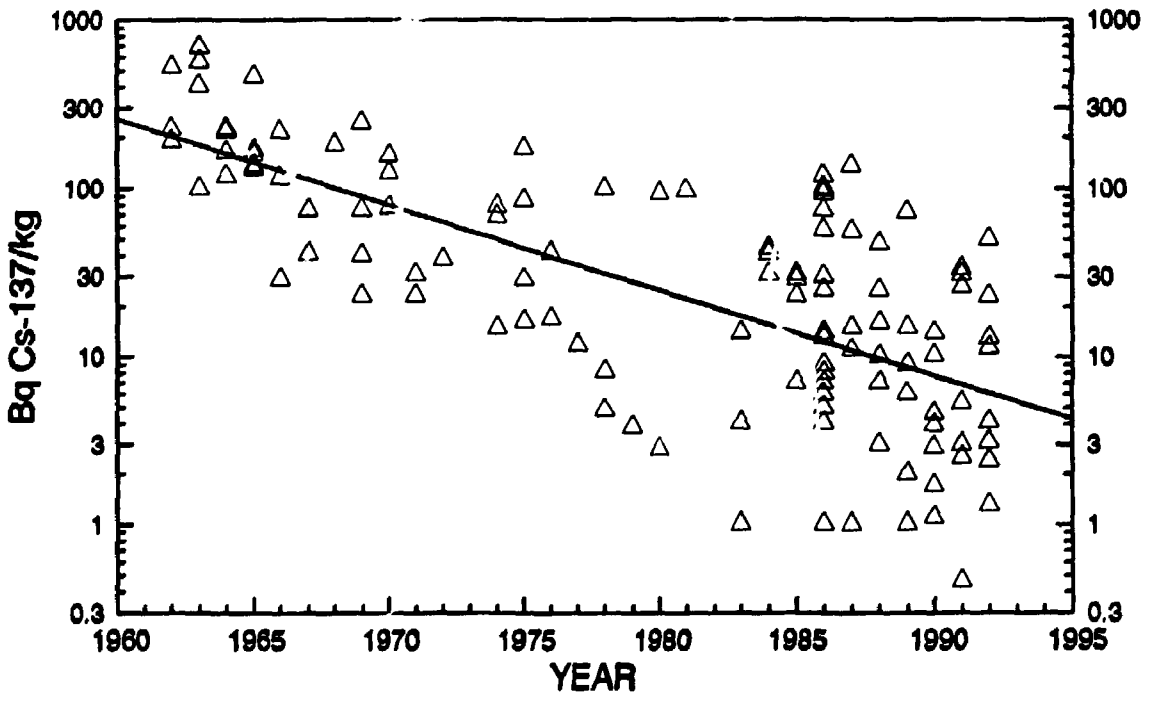


Figure 2.2.4.2. Cesium-137 in lamb meat collected in the Faroes, 1962-1992. (Unit: Bq (kg K)$^{-1}$)

Figure 2.2.4.3. Global fallout ^{137}Cs in Faroese lamb meat 1962-1992. (Unit: Bq kg^{-1}). Observed halflife: 1962-1992: 5.9 y.



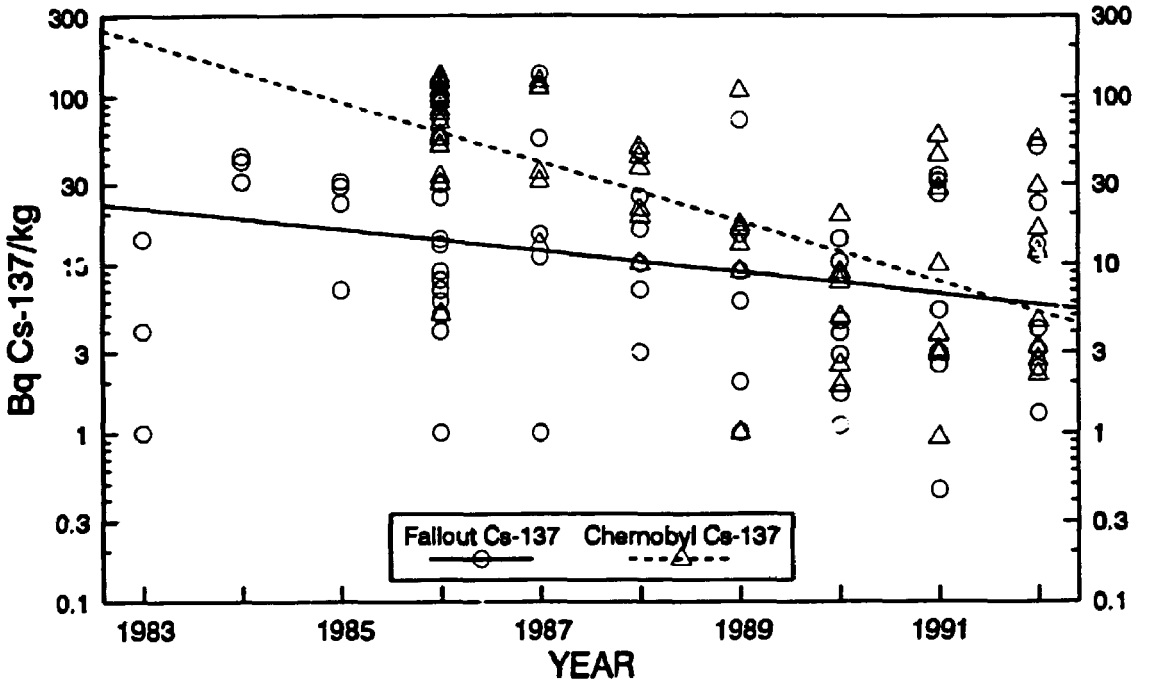


Figure 2.2.4.4. Fallout and Chernobyl ^{137}Cs in Faroese lamb meat 1983-1992. (Unit: Bq kg^{-1}). Observed halflife: Fallout: 4.75 y, Chernobyl: 1.7 y.

Table 2.2.5.1.A. Strontium-90 and radiocesium in fish flesh from the Faroes in 1990

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)$^{-1}$	$\frac{^{134}Cs}{^{137}Cs}$
April	Gadus callarias	Cod			0.35	99	
June	"				0.27	78	
Sept	"				0.23	65	
Dec	"				0.26	7	
1990			0.00083	8.5	0.27	79	
April	Gadus aeglefinus	Haddock			0.21	62	
June	"				0.199	62	0.075 A
Sept	"				0.23	60	
Dec	"				0.158	46	
1990			0.00090	13.0	0.199	57	

Table 2.2.5.1.B. Strontium-90 and Cesium-137 in fish flesh from the Faroes in 1991

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)$^{-1}$
March	Gadus callarias	Cod			0.23	74
June	"				0.22	72
Sept	"				0.24	66
Dec	"				0.22	58
1991			0.00079	5.2	0.23	68
March	Gadus aeglefinus	Haddock			0.162	48
June	"				0.126	37
Sept	"				0.120	36
Dec	"				0.136	37
1991			0.00038 A	5.0 A	0.136	39

Figure 2.2.5.1. Cesium-137 levels in meat of cod (Gadus callarias) and haddock (Gadus aeglefinus) collected in the Faroes, 1962-1992.

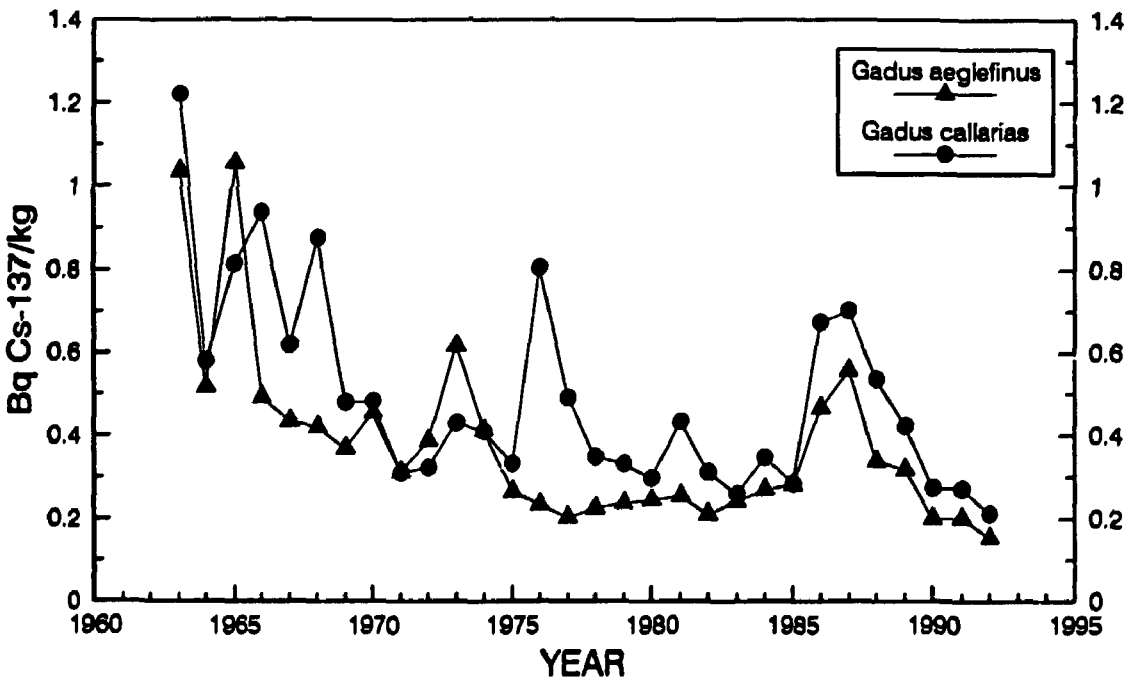


Table 2.2.5.2.A. Strontium-90 and Cesium-137 in various marine animals collected in 1990

Species	Sample	Month	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs (kg K)$^{-1}$	Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr (kg Ca)$^{-1}$
Puffin	flesh	June	0.095	32	< 0.008	< 129
"	bone	June	-	-	-	0.2 B
Grind whale	flesh	Jan	0.28	84	0.002 B	27 B
"	flesh	Sept	0.21	63	< 0.004	< 62

Table 2.2.5.2.B. Strontium-90 and Cesium-137 in various marine animals collected in 1991

Species	Sample	Month	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs (kg K)$^{-1}$	^{90}Sr kg^{-1}	Bq ^{90}Sr (kg Ca)$^{-1}$
Grind whale	flesh	Aug	0.20	`75	< 0.004	< 80

Table 2.2.6.1. Strontium-90 and Cesium-137 in drinking water from the Faroes in 1990 and 1991. (Unit: Bq m^{-3})

Year	Thorshavn		Klaksvig		Tværå	
	^{90}Sr	^{137}Cs	^{90}Sr	^{137}Cs	^{90}Sr	^{137}Cs
1990	3.6	2.4	0.70	1.72	2.5	1.3 B
1991	2.9	2.0	0.56	0.69 B	2.3	2.9

Table 2.2.6.2. Cesium-137 and tritium in drinking water from the Faroes collected by Risø in August 1991

Location	Date in August	^{137}Cs Bq m^{-3}	^{3}H kBq m^{-3}
Sørvaag/Vaagø	5	1.60	0.97±0.00
Thorshavn/Strømø	2	2.5	
Klaksvig/Bordø	3	0.9 B	
Tværå/Syderø	1	2.8	

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

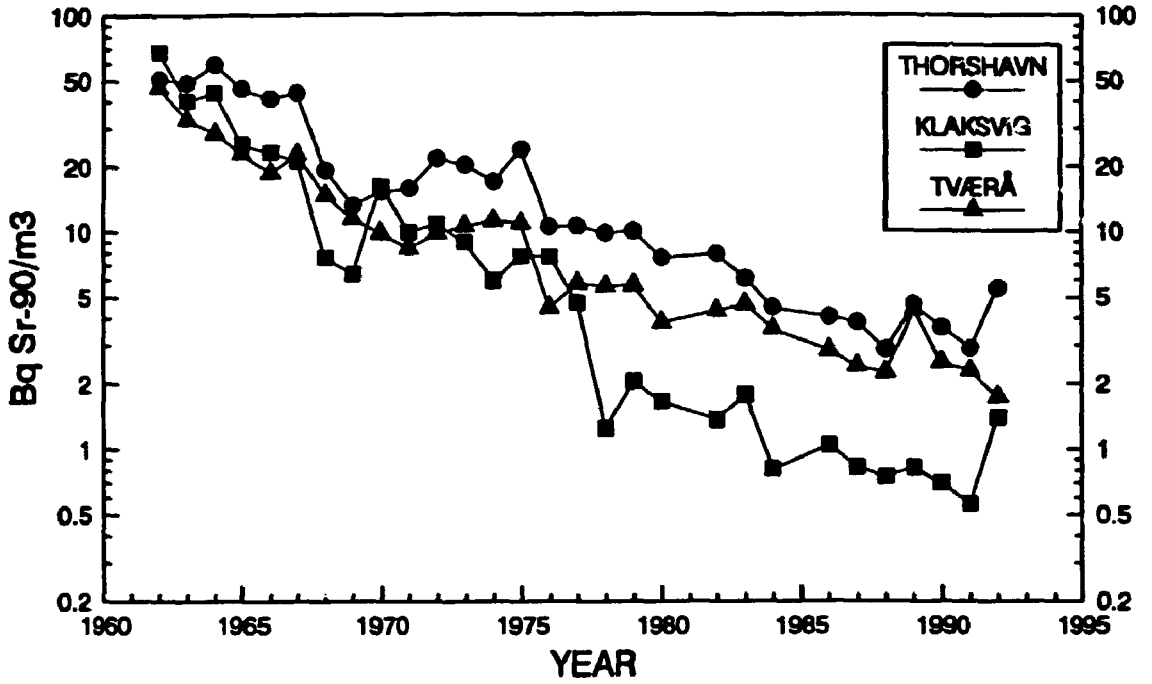


Figure 2.2.6.1. Strontium-90 in drinking water from the Faroes, 1962-1992. (Unit: Bq m^{-3}).

Table 2.2.6.3. Cesium-137 in stream water from the Faroes collected by Risø in 1991

Location	Date	^{137}Cs Bq m^{-3}
Sandå, south of Thorshavn/Strømø	31 July	4.9
Højdalså, north of Thorshavn/Strømø	31 July	5.2
Toftå near Højvik/Strømø	3 Aug	lost
Valdaskarå/Syderø	1 Aug	5.4
North of Vatnsograr/Vågø	5 Aug	4.9
Outlet in Arnefjord/Bordø	3 Aug	2.7

Table 2.2.6.4. Cesium-137 in lake water from the Faroes collected by Risø August 2-5, 1991

Location	^{137}Cs Bq m^{-3}
Leynavatn/Strømø	2.6
Between Thorshavn and Kirkjuböur/Strømø	7.9
Søvagsvatn/Vågø	6.2

Table 2.2.6.5. Tritium in Faroese drinking water 1991

Location	kBq m^{-3}
Tværå	0.98±0.18

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

Table 2.2.7.1.1. Cesium-137 in Faroese soil in August 1991. (Unit: Bq m^{-2})

Layer	Thorshavn Strømø	Klaksvig Bordø	Øravik Syderø	Bøur Vaagø	Høyvik (Thorshavn) Strømø
0-5 cm	2400	2680	1710	3200	1840
5-10 cm	2100	2800	1210	2500	1180
10-20 cm	4400±139	1020±150	910±152	663±115	680±145
20-30 cm	3900±208	480±77	250±208	185±11	197±30
Total layer	12800	6900	4100	6600	3900

Figures with error terms are mean values of triple collections ±1 S.E.

Table 2.2.7.1.2. Radiocesium and potassium (fresh weight) in Faroese soils in August 1991

	Unit	0-5 cm	5-10 cm	10-20 cm	20-30 cm
Thorshavn	Bq ^{137}Cs kg^{-1}	45	35	35 ±2.3	38 ±3.2
	^{134}Cs/^{137}Cs	0.049	-	-	-
	g K kg^{-1}	0.84	0.95	0.63±0.11	0.72 ±0.035
Klaksvig	Bq ^{137}Cs kg^{-1}	69	48	10.5 ±1.46	4.3 ±0.64
	^{134}Cs/^{137}Cs	0.053	0.0155	-	-
	g K kg^{-1}	0.53	0.67	0.63±0.023	0.68 ±0.061
Øravik	Bq ^{137}Cs kg^{-1}	40	24	9.4 ±1.60	2.5 ±0.21
	^{134}Cs/^{137}Cs	0.059	-	-	-
	g K kg^{-1}	0.46	0.24	0.15±0.018	0.07 ±0.010
Bøur	Bq ^{137}Cs kg^{-1}	67	48	6.6 ±1.13	1.64 ±0.074
	^{134}Cs/^{137}Cs	0.033	0.0063	-	-
	g K kg^{-1}	0.88	0.79	0.80±0.025	0.077±0.029
Høyvik	Bq ^{137}Cs kg^{-1}	31	21	5.9 ±1.11	1.55 ±0.165
	^{134}Cs/^{137}Cs	0.066	-	-	
	g K kg^{-1}	1.11	1.12	1.08±0.064	0.95 ±0.102

Figures with error terms are mean values of triple calculations ±1 S.E.

Table 2.2.7.1.3. Percentage dry matter in Faroese soil in August 1991.

Layer	Thorshavn Strømø	Klaksvig Bordø	Øravik Syderø	Böur Vaagø	Høyvik (Thorshavn) Strømø
0-5 cm	19.53±0.75	13.48±1.16	10.33±0.21	20.62±0.50	45.59±0.73
5-10 cm	23.73±1.41	22.34±2.56	16.47±0.66	20.88±0.69	60.55±1.38
10-20 cm	43.74±2.51	41.47±1.78	20.26±0.93	43.25±0.82	53.81±3.33
20-30 cm	40.14±1.24	44.29±1.73	13.95±0.11	44.47±0.78	60.82±6.76

Figures with error terms are mean values of triple collections ±1 S.E.

Table 2.2.7.1.4. Percentage of Chernobyl ^{137}Cs in samples collected at Strømø, Bordø and Syderø 1987, 1989 and 1991

		Strømø	Bordø	Syderø
Soil	1987	34	53	54
0-5 cm	1989	62	59	71
	1991	54±8	50	56
Soil	1987	2	16	6
5-10 cm	1989	7	11	21
	1991		15	
Stream water	1987	67±1		74
	1989	80±1	85	64
	1991			
Lake water	1987	63		
	1989	85		
	1991			
Drinking water	1987	63	76	76
	1989			90
	1991			
Grass	1987	84±5	89	74
	1989	76	52	72
	1991	65	55	66
Fodder	1987	103	84	
	1989	78	78	82
	1991	75		
Whole milk	1987	76±0	82±5	76
	1989	66±10	69±5	73±0
	1991	72	57	57
Lamb*	1987	46	74	69
	1989	64±7	65	60
	1991	59±8	52	65

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 1990. (Unit: Bq m^{-3})

Sampling date	^{90}Sr	^{137}Cs	Salinity in ‰
May	1.47	3.0	35.1
September	1.60	3.5	34.9

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 1991 (Unit: Bq m^{-3})

Sampling date	^{90}Sr	^{137}Cs	Salinity in ‰
August	1.27	2.3	35.2
December	1.24	2.5	35.0

Figure 2.2.7.2. Strontium-90 and cesium-137 in Faroese sea water 1962-1992 (Unit: Bq m^{-3}).

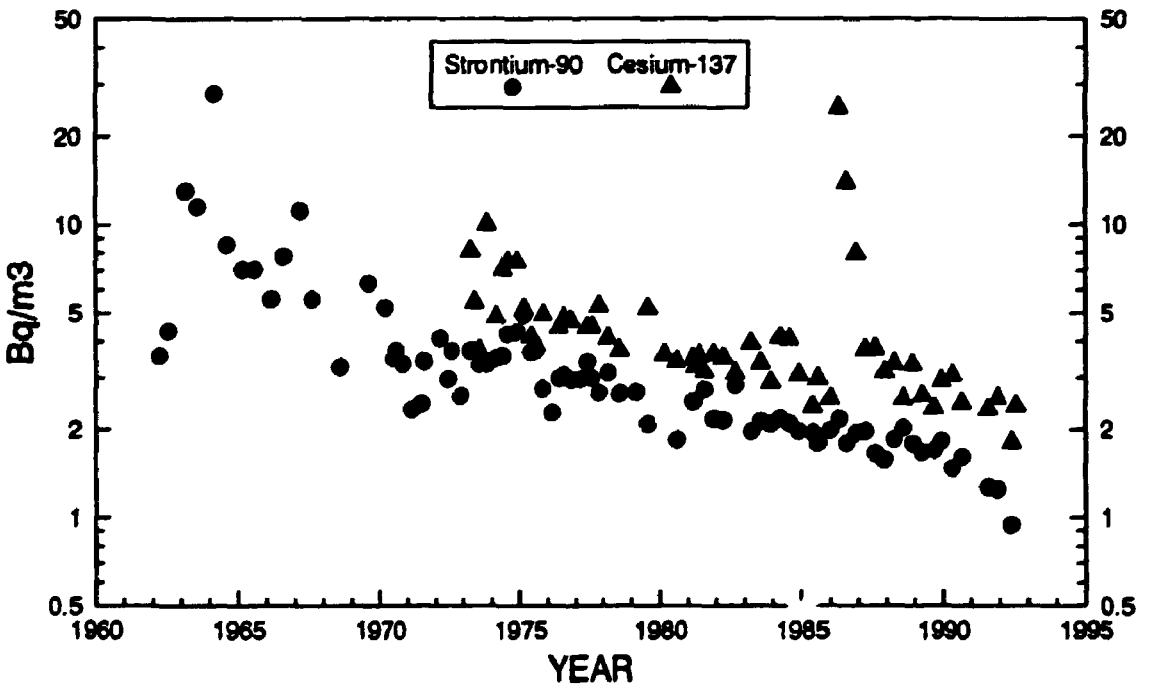


Table 2.2.7.2.2. Radionuclides in sea water collected near The Faroes in August 1990

Position N	Position W	Depth in m	Date	^{90}Sr Bq m^{-3}	^{99}Tc mBq m^{-3}	^{137}Cs Bq m^{-3}	Salinity in ‰
63°50'	06°05'	50	August 19	1.52±0.02	31	3.5	34.9±0.01
"	"	200	August 19	1.59±0.05	30±6	3.8	35.0±0.00
"	"	400	August 19	1.66±0.15	28	5.1	35.0±0.06
"	"	700	August 19	1.35	31	3.6	35.0±0.05
"	"	1000	August 19	1.14±0.13	< 12	2.7	34.7±0.16
62°20'	06°05'	50	August 20	1.40±0.01	< 19	2.5	35.1±0.03
61°20'	07°53'	50	August 20	1.71	72	-	-
"	"	200	August 20	1.28	< 11	-	-
"	"	500	August 20	1.44	24	-	-
"	"	780	August 20	1.02±0.15	25	2.1	34.9
62°30'	09°00'	50	August 21	1.30	20 A	-	-
"	"	200	August 21	1.30	< 18	-	-
"	"	350	August 21	-	< 18	-	-
"	"	520	August 21	1.33	< 33	-	-

Figures with error term are mean values of double determinations ±1 S.E.

Table 2.2.7.3.1.A. Radionuclides in seaweed collected at Thorshavn in 1990.

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)$^{-1}$
Fucus vesiculosus	April	0.35 B	9.1 B	0.106	9.5
Laminaria digitata	April	0.56 A	9.2 A	0.26	18.3

Table 2.2.7.3.1.B. Radionuclides in seaweed collected at Thorshavn in 1991.

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)$^{-1}$
Ascophyllum nodosum	May	1.36	61	2.3	165
Alaria esculenta	Dec	0.26 A	6.9	0.22	15.9

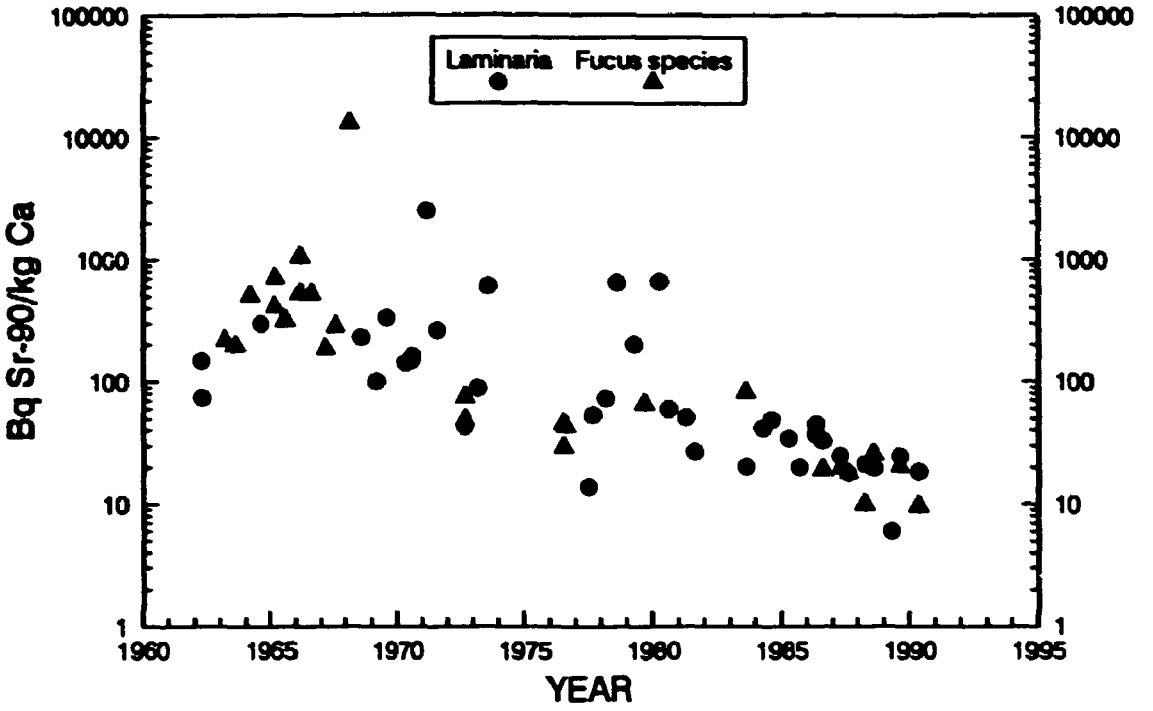


Figure 2.2.7.3. Strontium-90 in sea plants collected at Thorshavn, 1962-1990. (Unit: Bq (kg Ca)$^{-1}$)

Table 2.2.7.3.2. Cesium-137 in Fucus vesiculosus collected by Risø in the Faroes in August 1991.

Location	^{137}Cs Bq kg^{-1} d.w.	^{137}Cs (kg K)$^{-1}$	% dry matter
Thorshavn	1.18	48	16.1
Klaksvig	0.55	19.4	19.6
Tværå	0.36	21	19.6
Vagur	0.68	28	10.8
Sørvaag	0.35	16.6	16.2

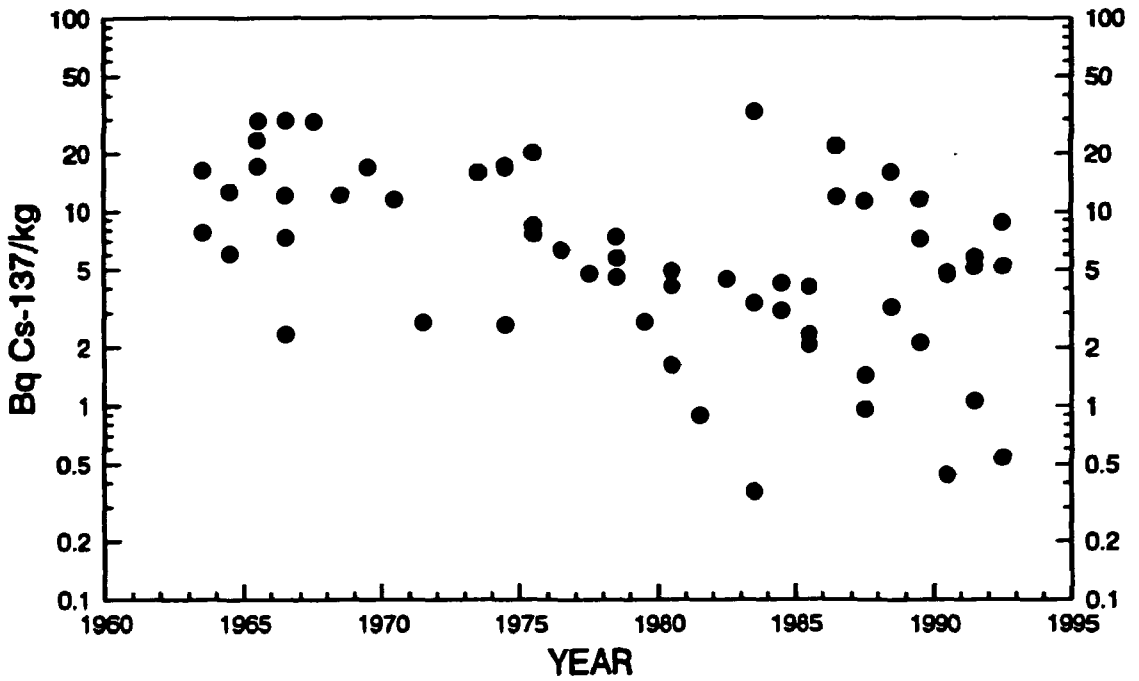
Table 2.2.7.4.1.A. Radionuclides in Faroese potatoes collected in November 1990

Location	Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr (kg Ca)$^{-1}$	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs (kg K)$^{-1}$	$\frac{^{134}Cs}{^{137}Cs}$
Thorshavn	0.050	1040	0.44	151	-
Klaksvig	0.081	2140	4.7	1660	0.081
Tværå	0.072	1820	4.8	1280	0.071

Table 2.2.7.4.1.B. Radionuclides in Faroese potatoes collected in November 1991

Location	Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr $(kg\,Ca)^{-1}$	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs $(kg\,K)^{-1}$	$\frac{^{134}Cs}{^{137}Cs}$
Thorshavn	0.075	3200	1.06	294	-
Klaksvig	0.086	2700	5.2	1550	0.056
Tværå	0.127	4800	5.8	1620	0.057

Figure 2.2.7.4.1. Cesium-137 in Faroese potatoes, 1962-1992. (Unit: Bq kg^{-1}).



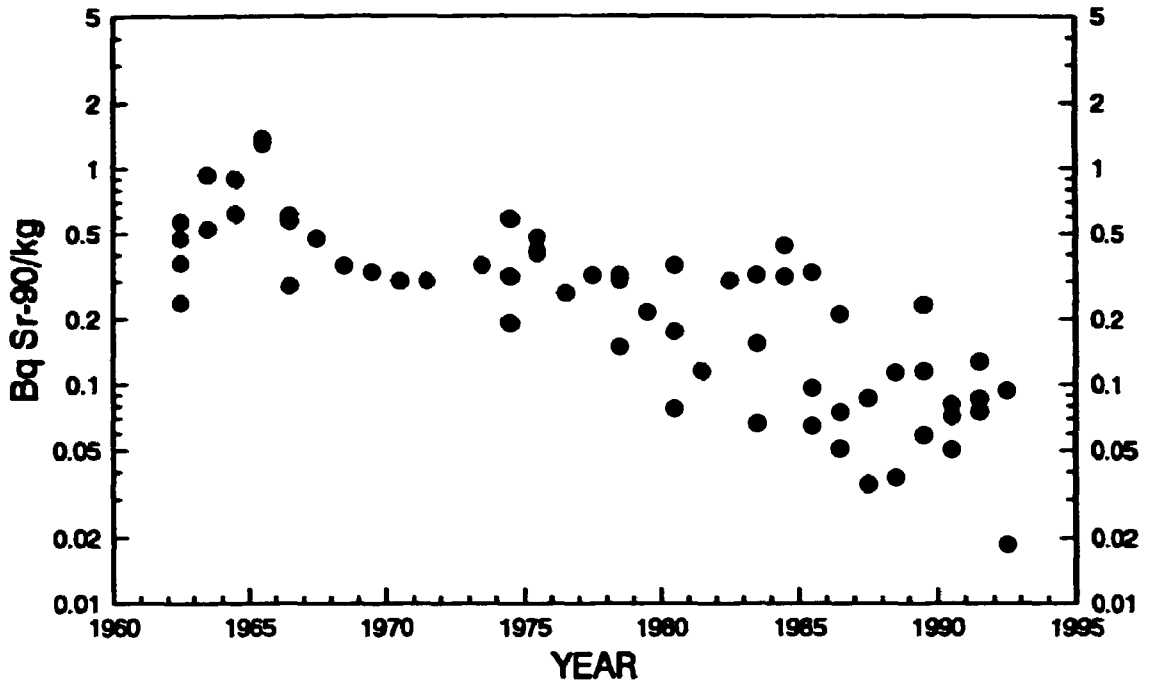


Figure 2.2.7.4.2. Strontium-90 in Faroese potatoes, 1962-1992. (Unit: Bq kg^{-1}).

Table 2.2.7.5.A. Strontium-90 and Cesium-137 in Faroese bread in June 1990

Sort	Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr (kg Ca)$^{-1}$	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs (kg K)$^{-1}$
White bread	0.060	124	0.075	59
Rye bread	0.146	770	0.140	75

Table 2.2.7.5.B. Strontium-90 and Cesium-137 in Faroese bread in June 1991

Sort	Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr (kg Ca)$^{-1}$	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs (kg K)$^{-1}$
White bread	0.079	210	0.044	32
Rye bread	0.125	660	0.158	73

Table 2.2.7.6.A. Strontium-90 and Cesium-137 in Faroese eggs collected in 1990

Date	Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr (kg Ca)$^{-1}$	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs (kg K)$^{-1}$
June	0.026	42	0.149	115

Table 2.2.7.6.B. Strontium-90 and Cesium-137 in Faroese eggs collected in 1991

Date	Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr (kg Ca)$^{-1}$	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs (kg K)$^{-1}$
June	0.031	55	0.20	210

Table 2.2.9. Radiocesium in fodder collected in the Faroes by Risø in July-August 1991

Species	Location	Date	Bq ^{137}Cs kg^{-1} (d.w.)	Bq ^{137}Cs (kg K)$^{-1}$	$\frac{^{134}Cs}{^{137}Cs}$
Silage	Højvik	July 31	43	3400	0.079
Concentrates	Højvik	July 31	0.20	17.2	-
Mash	Klaksvig	Aug 3	0.080	340	-
Concentrates	Klaksvig	Aug 3	1.02	74	-
Concentrates	Bõur	Aug 5	0.32	33	-

2.3 Estimate of the Mean Contents of ^{90}Sr and ^{137}Cs in the Faroese Human Diet in 1990 and 1991

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 1990 was $1.2 \times (0.75 \times 0.041 + 0.25 \times 0.035) = 0.047$ Bq ^{90}Sr kg^{-1}, and the ^{137}Cs content was $0.75 \times 2.1 + 0.25 \times 0.125 = 1.61$ Bq ^{137}Cs kg^{-1} (cf. 2.2.3 and Risø-R-621). 1 kg milk contains 1.2 g Ca.

For 1991 we get: $1.2 \times (0.75 \times 0.036 + 0.25 \times 0.039) = 0.044$ Bq ^{90}Sr kg^{-1} and $0.75 \times 1.67 + 0.25 \times 0.092 = 1.28$ 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: 0.35 Bq ^{90}Sr kg^{-1} and 0.088 Bq ^{137}Cs kg^{-1} in 1990 and 0.33 and 0.064, respectively, in 1991.

2.3.4 Grain Products

As most grain products are imported from Denmark, the Danish figures (Risø Report No. 621) 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 1990 were 0.167 Bq ^{90}Sr kg^{-1} and 0.110 Bq ^{137}Cs kg^{-1}, and in 1991 they became 0.155 and 0.116, 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. 0.068 Bq ^{90}Sr kg^{-1} and 3.3 Bq ^{137}Cs kg^{-1} in 1990, and 0.096 and 4.0, respectively, in 1991.

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. 621) were used. In 1990 the mean content in vegetables other than potatoes was 0.26 Bq ^{90}Sr kg^{-1} and 0.067 Bq ^{137}Cs kg^{-1} and the mean content in fruit was 0.039 Bq ^{90}Sr kg^{-1} and 0.036 Bq ^{137}Cs kg^{-1}. In 1991 the levels became 0.22, 0.038, 0.036 and 0.038, 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 1990, i.e. 0.035 Bq ^{90}Sr kg^{-1} (in 1991: 0.032) and 13.1 Bq ^{137}Cs kg^{-1} (in 1991: 33). Whale meat contained 0 Bq ^{90}Sr kg^{-1} and 0.22 Bq ^{137}Cs kg^{-1}, sea birds contained 0 Bq ^{90}Sr kg^{-1} and 0.095 Bq ^{137}Cs kg^{-1}, and eggs (cf. 2.2.5.2 and 2.2.7.6): 0.029 Bq ^{90}Sr kg^{-1} and 0.18 Bq ^{137}Cs kg^{-1}. The means of 1990 and 1991 data were used for whale, sea birds and eggs. Hence we estimate the mean content of ^{90}Sr in meat and eggs consumed in 1990 to be $0.50 \times 0.035 + 0.25 \times 0 + 0.25 \times (0 + 0.029)/2 = 0.021$ Bq ^{90}Sr kg^{-1} and the ^{137}Cs content to be $0.50 \times 13.1 + 0.25 \times 0.22 + 0.25 \times (0.095 + 0.18)/2 = 6.64$ Bq ^{137}Cs kg^{-1}. For 1991 the concentrations became 0.0196 Bq ^{90}Sr kg^{-1} and 16.6 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 0.00087 Bq ^{90}Sr kg^{-1} and 0.23 Bq ^{137}Cs kg^{-1} in 1990 and 0.00059 and 0.18, respectively, in 1991.

2.3.9 Coffee and Tea

The Danish figures (Risø Report No. 621) were used for both 1990 and 1991, i.e. 0.26 Bq ^{90}Sr kg^{-1} and 0.44 Bq ^{137}Cs kg^{-1}.

2.3.10 Drinking Water

The mean values found in Table 2.2.6.1 were used, i.e. 0.0023 Bq ^{90}Sr kg^{-1} and 0.00181 Bq ^{137}Cs kg^{-1} in 1990, and 0.00192 and 0.00186, respectively, in 1991.

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 1990

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	0.047	6.86	17.7
Cheese	7.3	0.35	2.56	6.6
Grain products	80	0.167	13.36	34.5
Potatoes	91	0.068	6.19	15.9
Vegetables	20	0.26	5.20	13.4
Fruit	18	0.039	0.70	1.8
Meat and eggs	37	0.021	0.78	2.0
Fish	91	0.00087	0.08	0
Coffee and tea	7.3	0.26	1.90	4.9
Drinking water	548	0.0023	1.26	3.2
Total			38.89	

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 65.

Table 2.3.1.B. Estimate of the mean content of ^{90}Sr in the human diet in the Faroe Islands in 1991

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	0.044	6.42	16.5
Cheese	7.3	0.33	2.41	6.2
Grain products	80	0.155	12.40	32.0
Potatoes	91	0.096	8.74	22.6
Vegetables	20	0.22	4.40	11.4
Fruit	18	0.036	0.65	1.7
Meat and eggs	37	0.0196	0.73	1.9
Fish	91	0.00059	0.05	0.1
Coffee and tea	7.3	0.26	1.90	4.9
Drinking water	548	0.00192	1.05	2.7
Total			38.75	

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 65.

Table 2.3.2.A. Estimate of the mean content of ^{137}Cs in the human diet in the Faroe Islands in 1990

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	1.61	235.1	28.8
Cheese	7.3	0.088	0.64	0.0
Grain products	80	0.110	8.8	1.1
Potatoes	91	3.3	300.3	36.7
Vegetables	20	0.067	1.34	0.2
Fruit	18	0.036	0.65	0.0
Meat and eggs	37	6.64	245.7	30.1
Fish	91	0.23	20.9	2.6
Coffee and tea	7.3	0.44	3.2	0.4
Drinking water	548	0.00181	0.99	0.1
Total			817.6	

The mean annual intake of potassium is estimated to be approx. 1.2 kg. Hence the ratio: Bq ^{137}Cs (kg K)$^{-1}$ becomes 681.

Table 2.3.2.B. Estimate of the mean content of ^{137}Cs in the human diet in the Faroe Islands in 1991

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	1.28	186.9	15.6
Cheese	7.3	0.064	0.47	0
Grain products	80	0.116	9.3	0.8
Potatoes	91	4.0	364.0	30.4
Vegetables	20	0.038	0.76	0.1
Fruit	18	0.038	0.68	0.1
Meat and eggs	37	16.6	614.2	51.2
Fish	91	0.18	16.4	1.4
Coffee and tea	7.3	0.44	3.2	0.3
Drinking water	548	0.00186	1.0	0.1
Total			1196.9	

The mean annual intake of potassium is estimated to be approx. 1.2 kg. Hence the ratio: Bq ^{137}Cs (kg K)$^{-1}$ becomes 997.

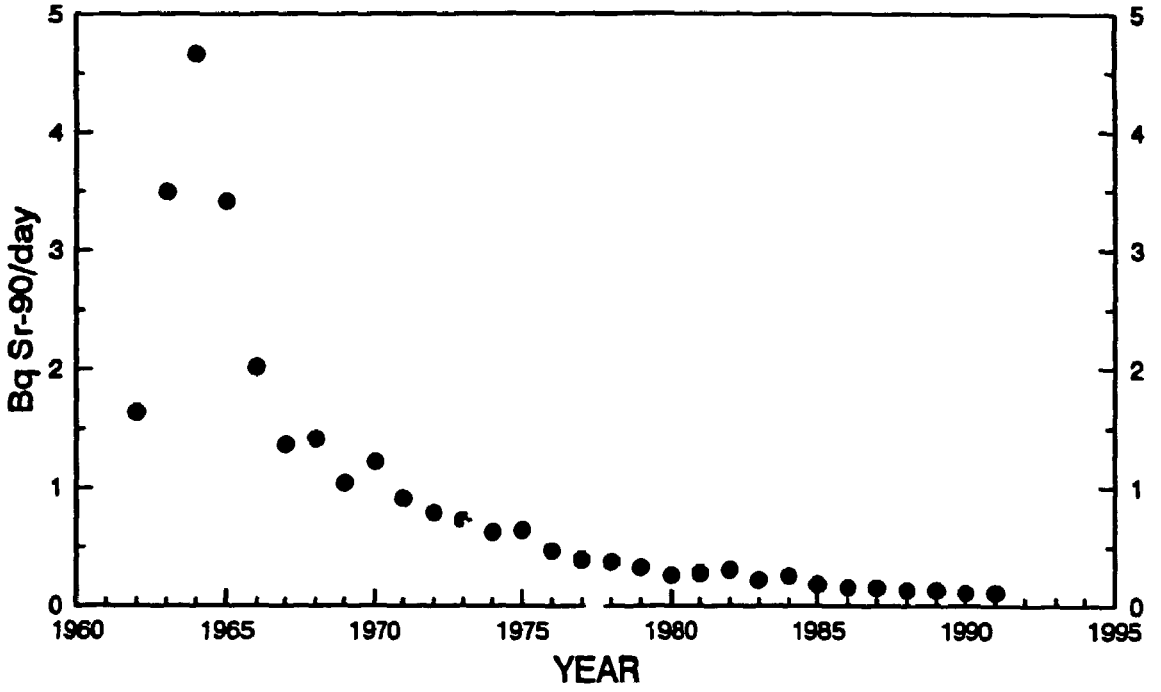
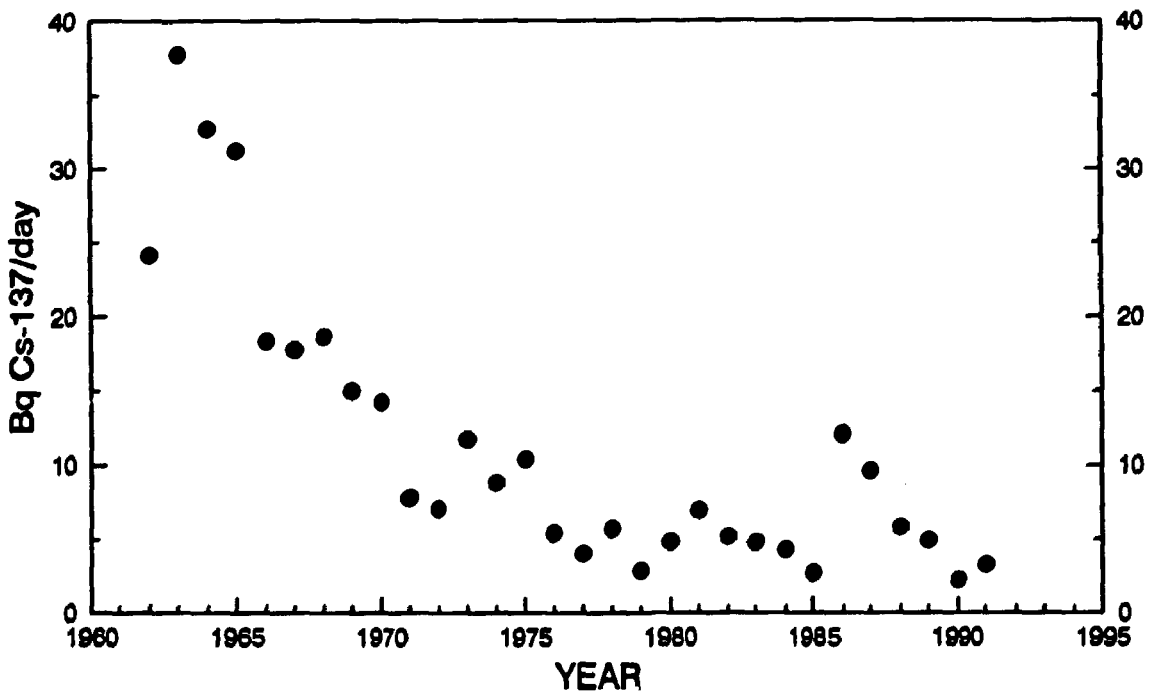


Figure 2.3.1. Strontium-90 in Faroese diet, 1962-1991. (Unit: Bq day^{-1}).

Figure 2.3.2. Cesium-137 in Faroese diet, 1962-1991. (Unit: Bq day^{-1}).



2.4 Conclusion

2.4.1.

The ^{90}Sr fallout rate in the Faroes in 1990 was approximately 0.2 Bq ^{90}Sr m^{-2} and in 1991 it was 0.4. The accumulated fallout by the end of 1991 was estimated to be approximately 2960 Bq ^{90}Sr m^{-2} (80 mCi km^{-2}) (the mean at Thorshavn and Klaksvig).

The ^{137}Cs mean deposit was 5 Bq m^{-2} in 1990 and 5 in 1991.

2.4.2.

The mean level of ^{90}Sr in Faroese milk was 41 Bq $(kg\ Ca)^{-1}$ in 1990 and 36 in 1991. The ^{137}Cs concentration was 2100 Bq ^{137}Cs m^{-3} in 1990 and 1670 in 1991.

Lamb contained 13 Bq ^{137}Cs kg^{-1} in 1990 and 33 in 1991. Fish showed mean levels of 0.23 and 0.18 Bq ^{137}Cs kg^{-1}, respectively.

The mean content of ^{90}Sr in drinking water was 2.3 Bq m^{-3} in 1990 and 1.9 in 1991.

The mean daily pro capite intakes resulting from the Faroese diet in 1990 were estimated to be 0.11 Bq ^{90}Sr and 2.2 Bq ^{137}Cs in 1990 and 0.1 and 3.3, respectively, in 1991.

2.4.3.

In terrestrial samples (grass, milk, lamb, and fodder) collected in the Faroes in 1991 63% of the ^{137}Cs came from Chernobyl.

The relative contribution of Chernobyl ^{137}Cs to total ^{137}Cs in biota has been decreasing from 1987 to 1991.

2.5 Predictions and Observations of ^{90}Sr and ^{137}Cs in Faroese Samples in 1990 and 1991

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 1990 and 1991.

Table 2.5.A. Comparison between observed and predicted ^{90}Sr and ^{137}Cs concentrations in Faroese samples collected in 1990

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}	3.6	1	8.8	0.41	C.1.4.1 No. 9
Drinking water, Klaksvig	Bq ^{90}Sr m^{-3}	0.70	1	1.24	0.56	C.1.4.1 No. 10
Drinking water, Tværå	Bq ^{90}Sr m^{-3}	2.5	1	1.80	1.39	C.1.4.1 No. 11
Sea water	Bq ^{90}Sr m^{-3}	1.54 ±0.07	2	1.64	0.94 ±0.04	C.1.5.1 No. 3
Sea water	Bq ^{137}Cs m^{-3}	3.3 ±0.3	2	-	-	C.1.5.1 No. 3 (×1.6)
Grass	Bq ^{90}Sr (kg Ca)$^{-1}$	11840 ±570	2	4400	0.42 ±0.13	C.2.4.1 No. 4
Grass	Bq ^{137}Cs (kg K)$^{-1}$	14500 ±600	2	3500	1.29 ±0.17	C.2.4.2 No. 3
Potatoes	Bq ^{90}Sr kg^{-1}	0.068 ±0.009	3	0.186	0.37 ±0.05	C.2.5.1 No. 11
Potatoes	Bq ^{137}Cs kg^{-1}	3.3 ±1.44	3	9.4	0.35 ±0.15	C.2.5.3 No. 8
*Milk	Bq ^{90}Sr (kg Ca)$^{-1}$	38 ±1.6	12	245	0.16 ±0.007	C.3.3.1 No. 1
*Milk Thorshavn	Bq ^{137}Cs (kg K)$^{-1}$	890 ±66	12	2300	0.39 ±0.03	C.3.3.2 No. 1
*Milk Klaksvig	Bq ^{137}Cs (kg K)$^{-1}$	850 ±103	12	3000	0.28 ±0.03	C.3.3.2 No. 3
*Milk Tværå	Bq ^{137}Cs (kg K)$^{-1}$	2200 ±195	11	6000	0.37 ±0.03	C.3.3.2 No. 5
Cod fish	Bq ^{90}Sr (kg Ca)$^{-1}$	10.8 ±2.3	2	16.5	0.65 ±0.14	C.3.5.1 No. 3
Cod fish	Bq ^{137}Cs kg^{-1}	0.23 ±0.02	8	0.28	0.82 ±0.07	C.3.5.2 No. 2
Lamb meat	Bq ^{90}Sr (kg Ca)$^{-1}$	370 ±86	7	710	0.52 ±0.12	C.3.4.1 No. 5
Lamb meat	Bq ^{137}Cs (kg K)$^{-1}$	4100 ±1380	7	8400	0.49 ±0.16	C.3.4.2 No. 5
Lamb bone	Bq ^{90}Sr (kg Ca)$^{-1}$	450 ±97	7	1720	0.26 ±0.06	C.3.4.3 No. 1

*"Milk year": June 1990 - May 1991.

Table 2.5.B. Comparison between observed and predicted ^{90}Sr and ^{137}Cs concentrations in Faroese samples collected in 1991

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	1	8.5	0.34	C.1.4.1 No. 9
Drinking water, Klaksvig	Bq ^{90}Sr m^{-3}	0.56	1	1.11	0.50	C.1.4.1 No. 10
Drinking water, Tværå	Bq ^{90}Sr m^{-3}	2.3	1	1.68	1.37	C.1.4.1 No. 11
Sea water	Bq ^{90}Sr m^{-3}	1.26 ±0.02	2	1.57	0.80 ±0.01	C.1.5.1 No. 3
Sea water	Bq ^{137}Cs m^{-3}	2.4 ±0.1	2	-	-	C.1.5.1 No. 3 (×1.6)
Grass	Bq ^{90}Sr (kg Ca)$^{-1}$	1910 ±410	9	4300	0.44 ±0.10	C.2.4.1 No. 4
Grass	Bq ^{137}Cs (kg K)$^{-1}$	3800 ±1530	9	1910	1.99 ±0.80	C.2.4.2 No. 3
Potatoes	Bq ^{90}Sr kg^{-1}	0.096 ±0.016	3	0.181	0.53 ±0.09	C.2.5.1 No. 11
Potatoes	Bq ^{137}Cs kg^{-1}	4.0 ±1.49	3	8.5	0.47 ±0.18	C.2.5.3 No. 8
*Milk	Bq ^{90}Sr (kg Ca)$^{-1}$	36 ±2.0	12	237	0.15 ±0.008	C.3.3.1 No. 1
*Milk Thorshavn	Bq ^{137}Cs (kg K)$^{-1}$	800 ±55	12	1920	0.42 ±0.03	C.3.3.2 No. 1
*Milk Klaksvig	Bq ^{137}Cs (kg K)$^{-1}$	770 ±112	12	2500	0.31 ±0.04	C.3.3.2 No. 3
*Milk Tværå	Bq ^{137}Cs (kg K)$^{-1}$	1680 ±178	11	5500	0.31 ±0.03	C.3.3.2 No. 5
Cod fish	Bq ^{90}Sr (kg Ca)$^{-1}$	5.1 ±0.1	2	15.5	0.33 ±0.006	C.3.5.1 No. 3
Cod fish	Bq ^{137}Cs kg^{-1}	0.182 ±0.02	8	0.26	0.70 ±0.08	C.3.5.2 No. 2
Lamb meat	Bq ^{90}Sr (kg Ca)$^{-1}$	430 ±82	8	640	0.67 ±0.13	C.3.4.1 No. 5
Lamb meat	Bq ^{137}Cs (kg K)$^{-1}$	6800 ±3100	8	7100	0.96 ±0.44	C.3.4.2 No. 5
Lamb bone	Bq ^{90}Sr (kg Ca)$^{-1}$	500 ±102	8	1660	0.30 ±0.06	C.3.4.3 No. 1

*"Milk year": June 1991 - May 1992.

3 Environmental Radioactivity in Greenland in 1990 and 1991

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. A number of the Greenland food samples were obtained from K.N.I. (Kalaallit Niuerfiat) (Greenland Trade).

3.1.3.

A new diet composition has been introduced as the old composition from 1962 did not correspond to the actual food habits. The new diet was based on information from Tine Pars, Nuuk.

3.1.4.

The environmental studies in Greenland were carried out together with corresponding investigations in Denmark (cf. Risø Report No. 621) 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.A & B show the results of the measurements.

The ^{90}Sr fallout in 1990 and 1991 at the Greenland stations were generally lower as compared with 1988 and 1989, but the data were sparse.

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 shows the samplings carried out in 1990.

3.2.3 Strontium-90 and Radiocesium in Greenland Terrestrial Mammals

Reindeer collected in 1990 and 1991 contained 11% and 1-10% (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). Ptarmigan contained in 1990 and 1991 about 1.2 Bq $^{137}Cs\ kg^{-1}$; the bone level was 860 Bq $^{90}Sr\ (kg\ Ca)^{-1}$ (Tables 3.2.3.2.A & B).

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 about 0.3 Bq ^{137}Cs kg^{-1} (fish, shrimp, seal and whale) (see also Tables 3.2.4.2.A & B and Figure 3.2.4).

3.2.5 Radionuclides in Greenland Vegetation

No samples in 1990 and 1991.

3.2.6 Strontium-90 and Tritium in Greenland Drinking Water

The mean ^{90}Sr concentration in Greenland drinking water was 8.0 and 10 Bq m^{-3} in 1990 and 1991, respectively, and the corresponding tritium mean levels were 2.05 and 1.58 kBq ^{3}H m^{-3}. The relatively high ^{90}Sr levels in Greenland drinking water have been discussed in previous reports (Risø-R-571). Since 1962 quarterly drinking water samples from Greenland have been analysed for ^{90}Sr. (Since 1990 only annual samples were analysed). An anova of the total data set showed no significant difference between quarterly samples. Hence, the quarterly samples were used as replicates within a year in the anova. An anova of the total material now showed a significant interaction between locations and years. A plot revealed that the annual pattern of Uperbavik and Godhavn was different from that of the other stations (Danmarkshavn, Scoresby Sund, Prins Christians Sund and Godthåb). Hence two new anovas were carried out separately on these two sets of stations and the interaction disappeared. The two new anovas showed significant differences between years as well as between stations (cf. Figures 3.2.6.1 and 3.2.6.2). Figure 3.2.6.5 shows the mean concentrations of ^{90}Sr in Greenland precipitation and drinking water for the 3 decades: 1962-1971, 1972-1981 and 1982-1991. The means were calculated by means of VAR3, which filled in missing quarterly values before calculating the mean concentrations for each decade.

In the first decade the drinking water concentrations were lower than those in precipitation. In the years 1972-1981 the concentrations in the two media were on the average nearly the same and in the last decade drinking water at all locations contained higher levels that the precipitation. It is evident from the figure that the different stations show different ratios between precipitation and drinking water ^{90}Sr concentrations. Thus Godthåb and Scoresby Sund showed a ratio in 1962-1971 of about 3, in 1972-1981 of about 1 and in 1982-1991 of around 0.3. Prins Christians Sund showed ratios of 1.3, 0.3 and 0.1, respectively; Danmarkshavn og 8, 1 and 0.5; Godhavn of 40, 5 and 1, and Upernavik of 20, 3 and 0.5.

The ratios suggest that at Prins Christians Sund recent precipitation was of relative great importance for the drinking water concentrations, whereas at Godhavn, Upernavik and Danmarkshavn old precipitation (inland ice) influenced the drinking water levels significantly. Godthåb and Scoresby Sund were in between.

We have made empirical models for the ^{90}Sr in drinking water from each of the 6 stations. The models intend to predict the ^{90}Sr mean drinking water concentrations (D_i) for the periods (i) 1962-1971, 1972-1981 and 1982-1991 from the mean precipitation concentrations (P_i) in the periods 1952-1961, 1962-1971, 1972-1981 and 1982-1991 (before 1952 there was no ^{90}Sr in precipitation).

The model is: $D_i = a \cdot P_i + b\,P_{i-10} + c\,P_{i-20} + d\,P_{i-30} + e\,P_{i-40}$.
The following values were determined by »trial and error«:

	a	b	c	d	e
Danmarkshavn	0.12	0.05	0.025	0.0125	0.0063
Scoresby Sund	0.30	0.10	0.05	0.025	0.0125
Prins Christians Sund	0.50	0.30	0.15	0.05	0
Godthåb	0.30	0.10	0.05	0.025	0.0125
Godhavn	0.02	0.015	0.015	0.010	0.010
Upernavik	0.04	0.03	0.02	0.01	0.005

The ^{90}Sr concentration in precipitation for 1952-1961 were assumed to be 0.51 times the concentrations found in 1962-1971, 0.51 was the ratio between the ^{90}Sr depositions in 1952-1961 and in 1962-1971 according to Danish observations and calculations (Risø-R-621, 1992). As an example the calculation of ^{90}Sr in drinking water from Danmarkshavn collected in 1982-1991 is shown:

$$0.12 \cdot 8.2 + 0.05 \cdot 47 \cdot e^{-\lambda \cdot 10} + 0.025 \cdot 625\, e^{-\lambda \cdot 20} + 0.0125 \cdot 625 \cdot 0.51 \cdot e^{-\lambda \cdot 30} = 14.4$$

where $\lambda = \frac{\ln 2}{28.82.}$

Table 3.2.6.3 shows a comparison between observed and predicted drinking water levels.

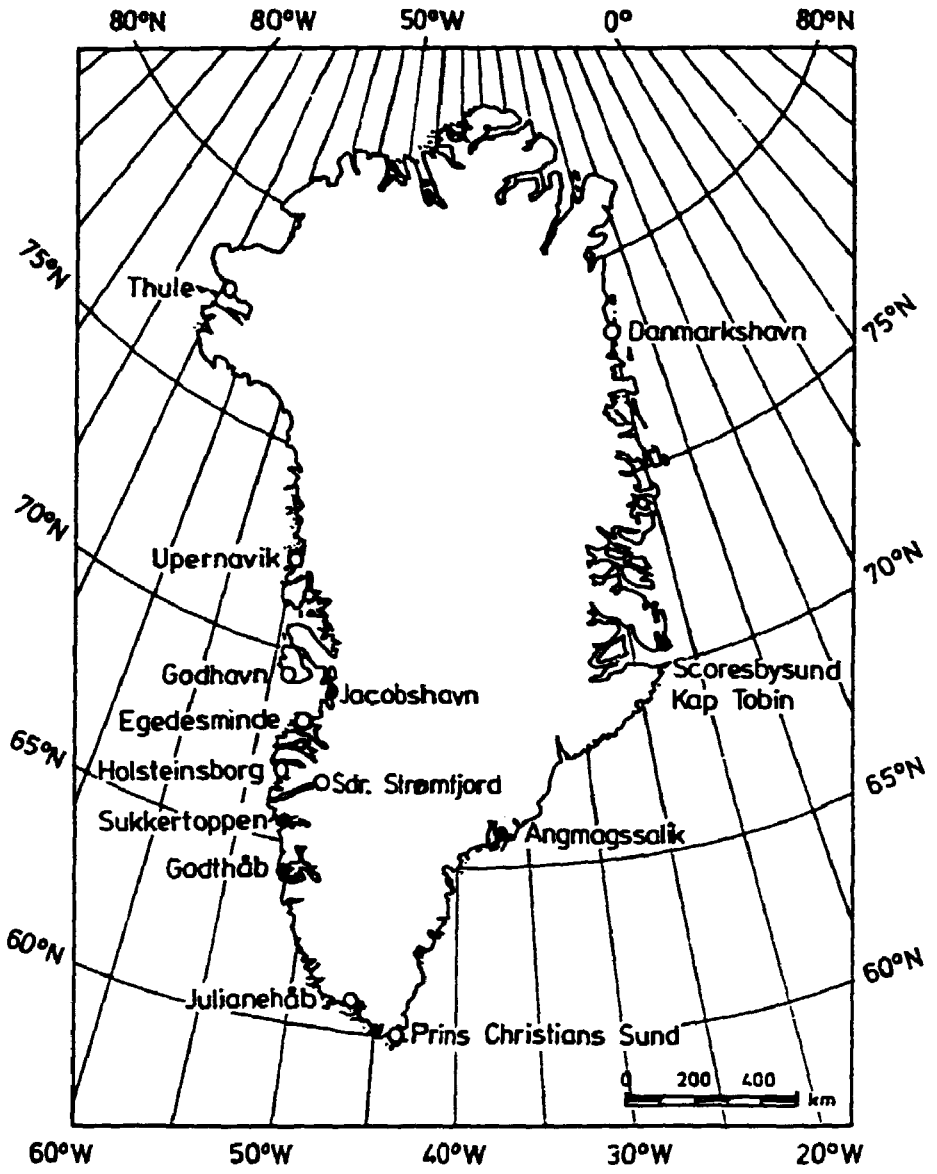


Figure 3.1. Greenland (DMH: Danmarkshavn, SCO: Scoresbysund, PCS: Prins Christians Sund, GHB: Godthåb, GDH: Godhavn, UPE: Upernavik).

Table 3.2.1.1.A. Strontium-90 in precipitation in Greenland in 1990.
(Sampling area: 0.02 m²)

Location	m precipitation	Bq m^{-3}	Bq m^{-2}
Godthåb	0.673	0.77	0.52
Scoresbysund	0.651	B.D.L.	B.D.L.
*Danmarkshavn	0.170	1.12	0.191

*April-December

Table 3.2.1.1.B. Strontium-90 in precipitation in Greenland in 1991.
(Sampling area: 0.02 m²)

Location	m precipitation	Bq m^{-3}	Bq m^{-2}
Godthåb	0.673	1.85	1.25
Scoresbysund	0.638	< 0.35	< 0.22
*Danmarkshavn	0.096	< 2.8	< 0.27

*Jan.-Sept.

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 (cf. Risø Report No. 509[3]), Appendix D) and from the ratio of the ^{90}Sr fallout at the Greenland stations to that in Denmark in the period 1962-1974.

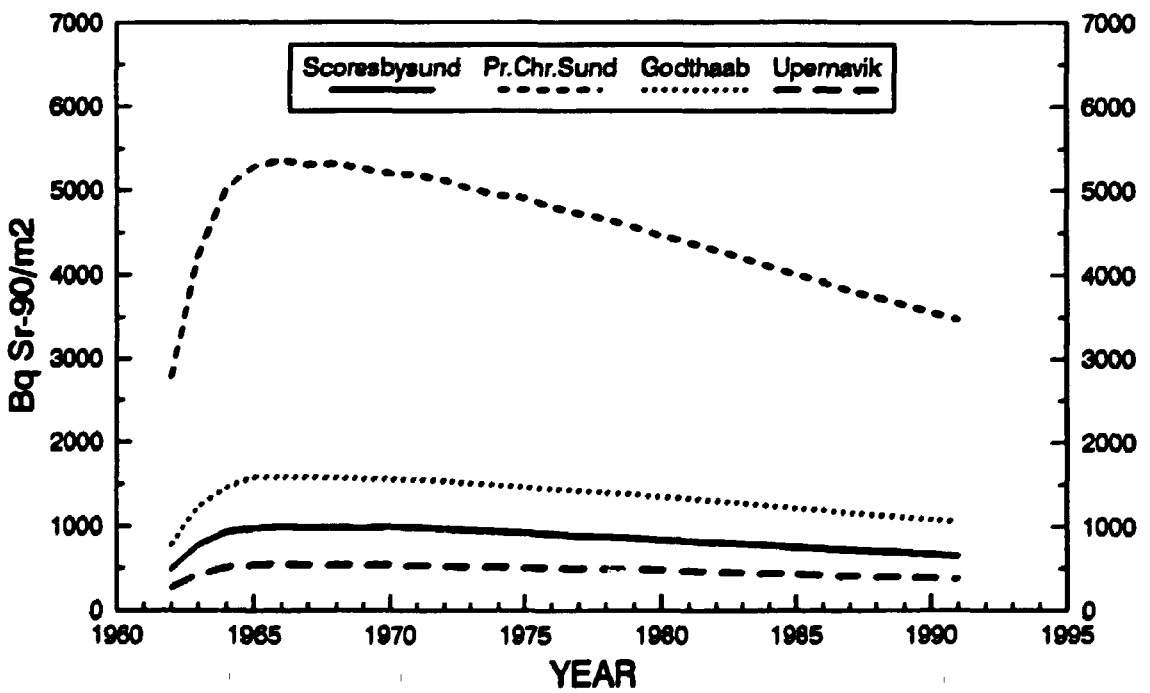


Table 3.2.1.2. Fallout rates and accumulated ^{90}Sr fallout (Bq m^{-2}) in Greenland 1950-1991

	Scoresbysund (Kap Tobin)		Pr.Chr.Sund		Godthåb		Upernavik	
	di	$Ai_{(29)}$	di	$Ai_{(29)}$	di	$Ai_{(29)}$	di	$Ai_{(29)}$
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
1990	~0.2	~669	-	~3560	0.52	1082	-	~384
1991	~0.2	~653	-	~3475	1.25	1058	-	~375

Figure 3.2.1.1. The variation of Bq ^{90}Sr m^{-3} in precipitation from Greenland among years. The bars are the levels relative to the grand mean: 102.7 Bq ^{90}Sr m^{-3} (= 1 at the relative scale) calculated from the anova.

Figure 3.2.1.2. The variation of Bq ^{90}Sr m^{-3} in precipitation from Greenland among locations. The bars are the levels relative to the grand mean: 102.7 Bq ^{90}Sr m^{-3} (= 1 at the relative scale) calculated from the anova.

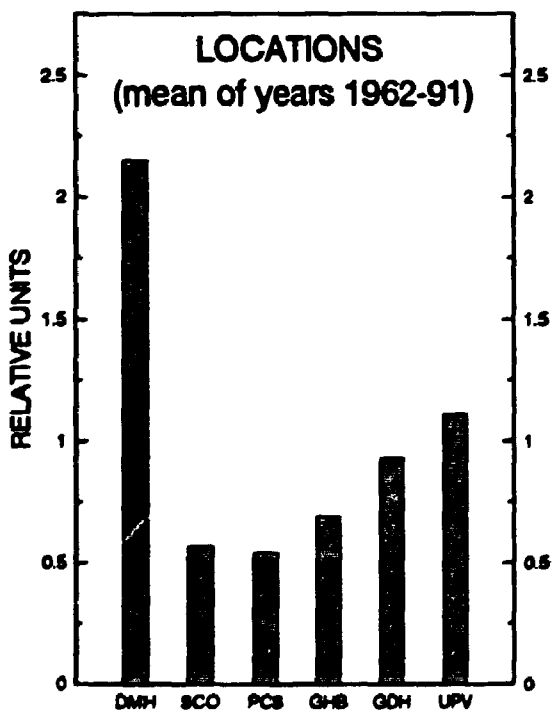


Table 3.2.2.A. Radionuclides in surface sea water collected in Greenland in the autumn of 1990

Location	Bq ^{137}Cs m^{-3}	Bq ^{90}Sr m^{-3}	Salinity ‰
Danmarkshavn	5.7	3.6	21.5

Table 3.2.2.B. Radionuclides in surface sea water collected in Greenland in the autumn of 1991

No samples in 1991.

Table 3.2.3.1.A. Radiocesium and strontium-90 in Greenland wild reindeer collected in 1990

Location	Sample	Month	Bq ^{137}Cs kg^{-1} meat	$\frac{^{134}Cs}{^{137}Cs}$	Bq ^{90}Sr kg^{-1} meat	Bq ^{90}Sr $(kg\ Ca)^{-1}$ bone	g K kg^{-1} meat	g Ca kg^{-1} meat
Holsteinsborg	I	March	42	0.020	0.101 ±0.0073	2100±109	3.1	0.044±0.0025
Holsteinsborg	II	March	19.5	0.027	0.099 ±0.0005	1080±17	3.3	0.053±0.0024
Holsteinsborg	I	August	12.3	0.005 A	0.0146±0.0012	470±5	3.3	0.054±0.0033
Holsteinsborg	II	August	14.2	< 0.005	0.0141±[illegible]032	430±24	3.4	0.056±0.0010

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

Table 3.2.3.1.B. Radiocesium and strontium-90 in Greenland reindeer collected in 1991

Location	Sample	Month	Bq ^{137}Cs kg^{-1} meat	$\frac{^{134}Cs}{^{137}Cs}$	Bq ^{90}Sr kg^{-1} meat	Bq ^{90}Sr $(kg\ Ca)^{-1}$ bone	g K kg^{-1} meat	g Ca kg^{-1} meat
KNI		-	62	0.010 A	0.22	5800	3.3	0.069
Egedesminde	back	Sept.	70*	0.0022	0.12*	956	3.2*	0.100*
Egedesminde	shoulder	Sept.	87	0.0012	0.060	900	3.2	0.070

*Calculated.

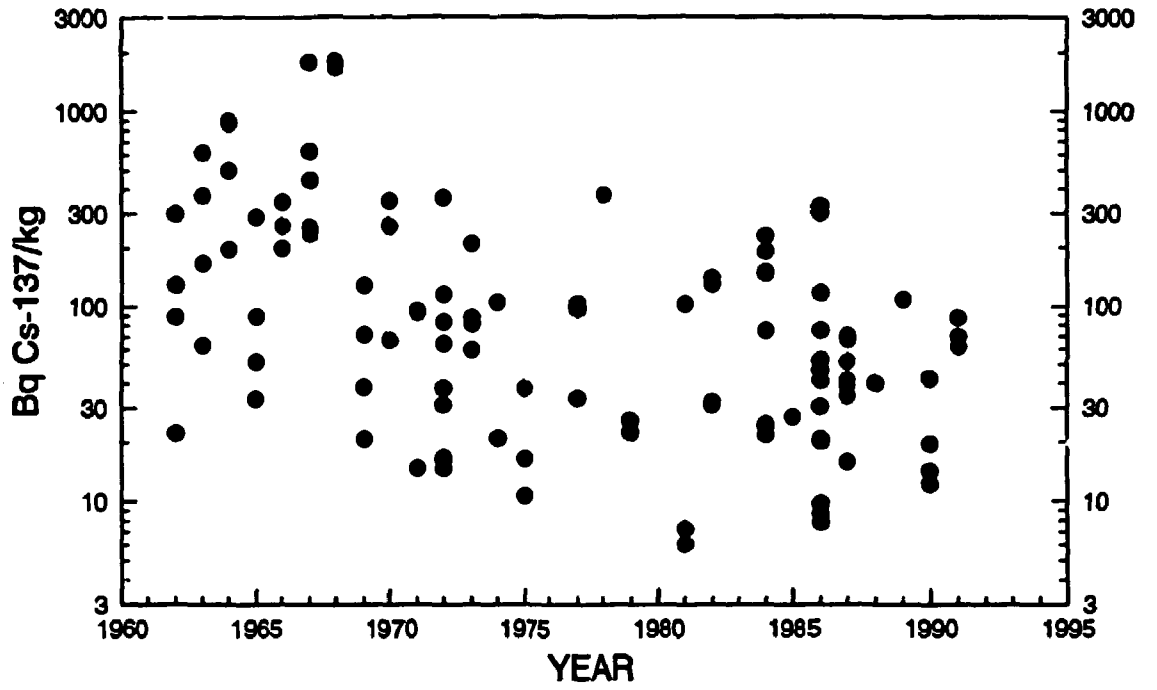
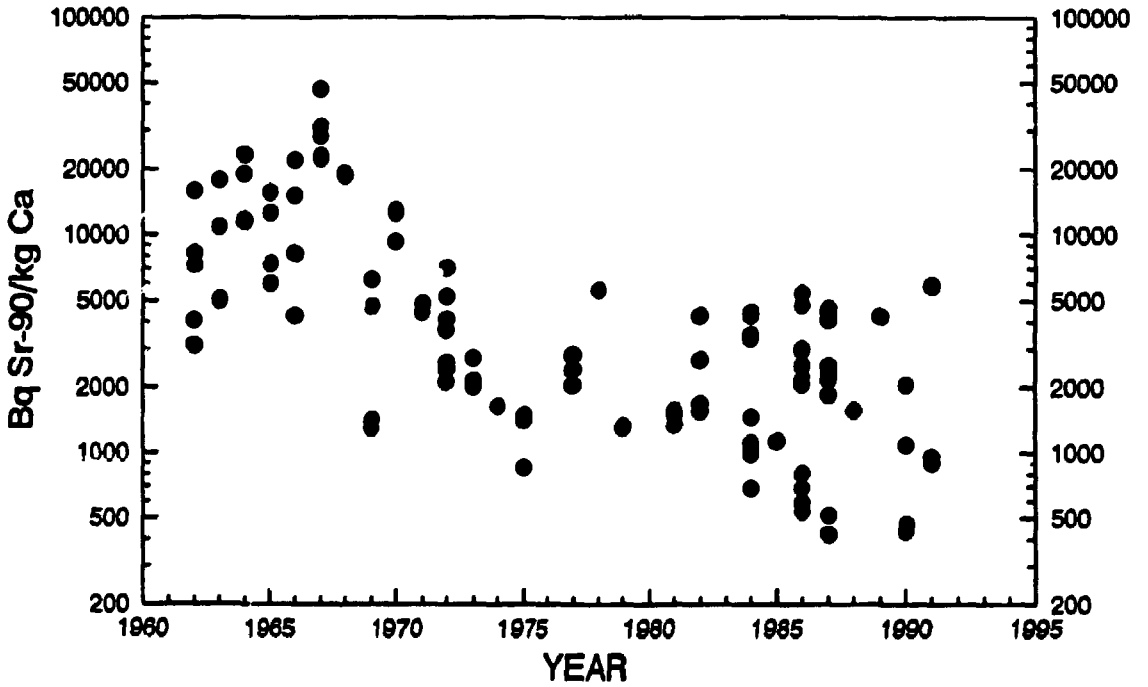


Figure 3.2.3.1. Cesium-137 in reindeer meat from Greenland, 1962-1991. (Unit: Bq kg^{-1}).

Figure 3.2.3.2. Strontium-90 in reindeer bone from Greenland, 1962-1991. (Unit: Bq (kg Ca)$^{-1}$).



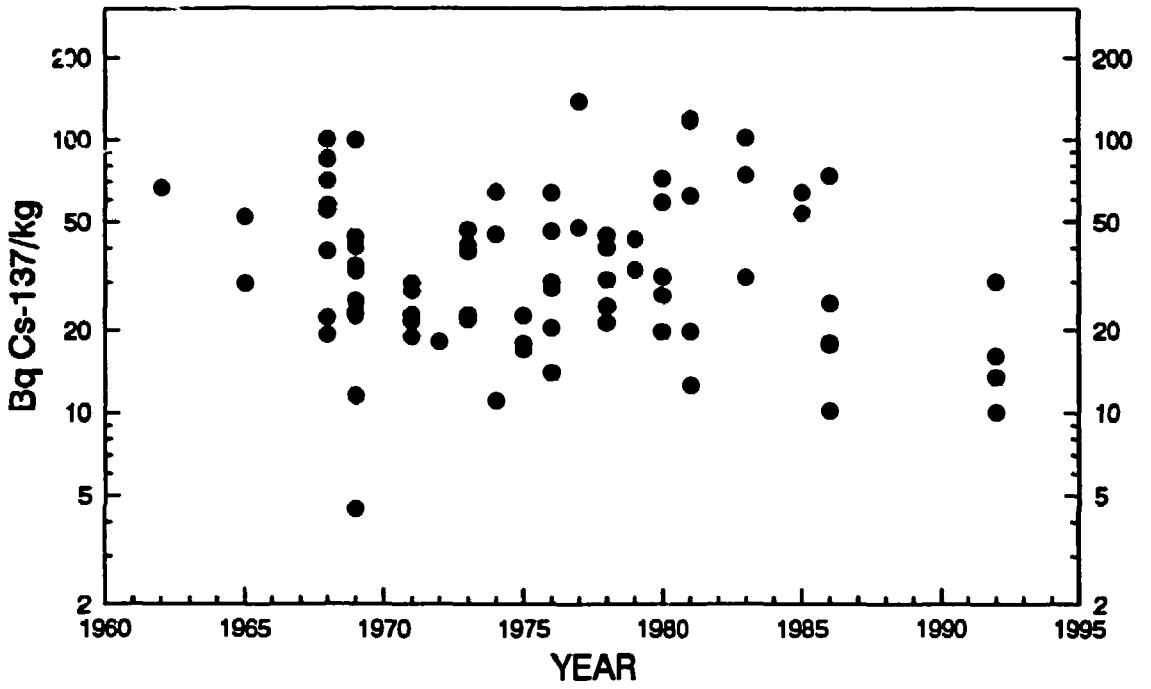


Figure 3.2.3.3. Cesium-137 in Greenland mutton, 1962-1992. (No samples in 1987, 1988, 1989, 1990 and 1991).

Table 3.2.3.2.A. Cesium-137 and strontium-90 in Greenland terrestrial animals collected in 1990

Species	Sample	Location	^{90}Sr Bq kg^{-1}	^{90}Sr Bq (kg Ca)$^{-1}$	^{137}Cs Bq kg^{-1}	^{137}Cs Bq (kg K)$^{-1}$
Ptarmigan	meat	Holsteinsborg	0.24	1130	1.58	510
Ptarmigan	bone	Holsteinsborg		990		

Table 3.2.3.2.B. Cesium-137 and strontium-90 in Greenland terrestrial animals collected in 1991

Species	Sample	Location	^{90}Sr Bq kg^{-1}	^{90}Sr Bq (kg Ca)$^{-1}$	^{137}Cs Bq kg^{-1}	^{137}Cs Bq (kg K)$^{-1}$
Ptarmigan	meat	KNI	0.31	1610	0.89	280
Ptarmigan	bone	KNI		730		

Table 3.2.4.1.A. Cesium-137 in aquatic animals (flesh) from Greenland in 1990

Species	Location	^{137}Cs Bq kg^{-1}	g K kg^{-1}
Salmon	KNI	0.35	3.04
Shrimps	KNI	0.087	1.08
Seal	KNI	0.46	1.68

Table 3.2.4.1.B. Cesium-137 in aquatic animals (flesh) from Greenland in 1991

Species	Location	Month	^{137}Cs Bq kg^{-1}	g K kg^{-1}
Seal	KNI		0.29	2.24
Seal	Egedesminde	Sept.	0.23	1.91
Piked whale	Egedesminde	July	0.66	2.71
Cod	KNI		0.44	3.51
Halibut	KNI		0.25	3.68
*Angmagssats	Egedesminde		0.124	3.28

*Total (flesh + bone).

Figure 3.2.4. Cesium-137 in seal and whale meat from Greenland 1962-1991. (Unit: Bq kg^{-1}).

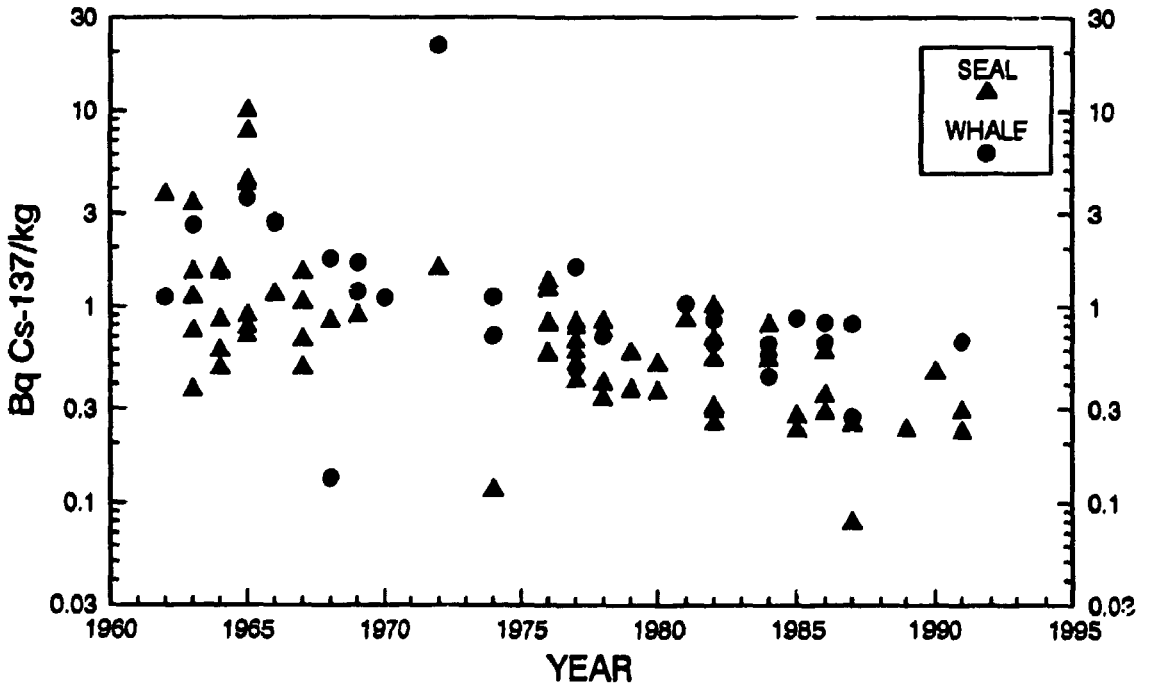


Table 3.2.4.2.A. Strontium-90 in aquatic animals from Greenland in 1990

Species	Location	^{90}Sr Bq kg^{-1} flesh	^{90}Sr Bq (kg Ca)$^{-1}$ bone	g Ca kg^{-1} flesh
Salmon	KNI	B.D.L.	2.6	0.50
Shrimps	KNI	B.D.L.		0.48
Seal	KNI	B.D.L.	0.66	0.100

Table 3.2.4.2.B. Strontium-90 in aquatic animals from Greenland in 1991

Species	Location	Month	^{90}Sr Bq kg^{-1} flesh	^{90}Sr Bq (kg Ca)$^{-1}$ bone	g Ca kg^{-1} flesh
Seal	KNI		0.0013 A	3.2	0.060
Seal	Egedesminde	Sept.	< 0.002	3.1	0.020
Piked whale	Egedesminde	July	0.0090		
Cod	KNI		0.0077	5.9	0.84
Halibut	KNI		0.0083	1.84	0.47
*Angmagssats	Egedesminde		< 0.006		3.4

*Total (flesh + bone).

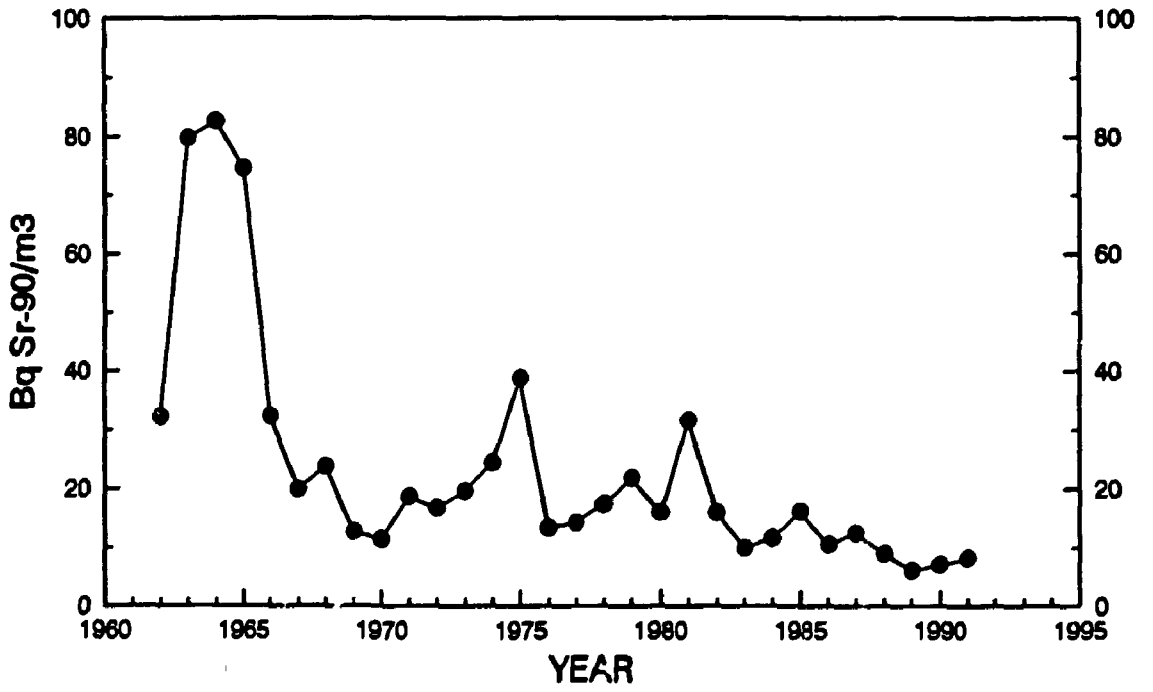
Table 3.2.6.1.A. Strontium-90 in drinking water collected in Greenland in 1990 (Unit: Bq m^{-3})

Location	1990
Danmarkshavn	12.6
Godthåb	4.9
Scoresbysund	3.7
Upernavik	10.6

Table 3.2.6.1.B. Strontium-90 in drinking water collected in Greenland in 1991 (Unit: Bq m^{-3})

Location	1991
Danmarkshavn	20
Godthåb	5.2
Scoresbysund	3.7
Upernavik	11.6

Figure 3.2.6. Strontium-90 in Greenland drinking water (geometric mean), 1962-1991. (Unit: Bq m^{-3}).



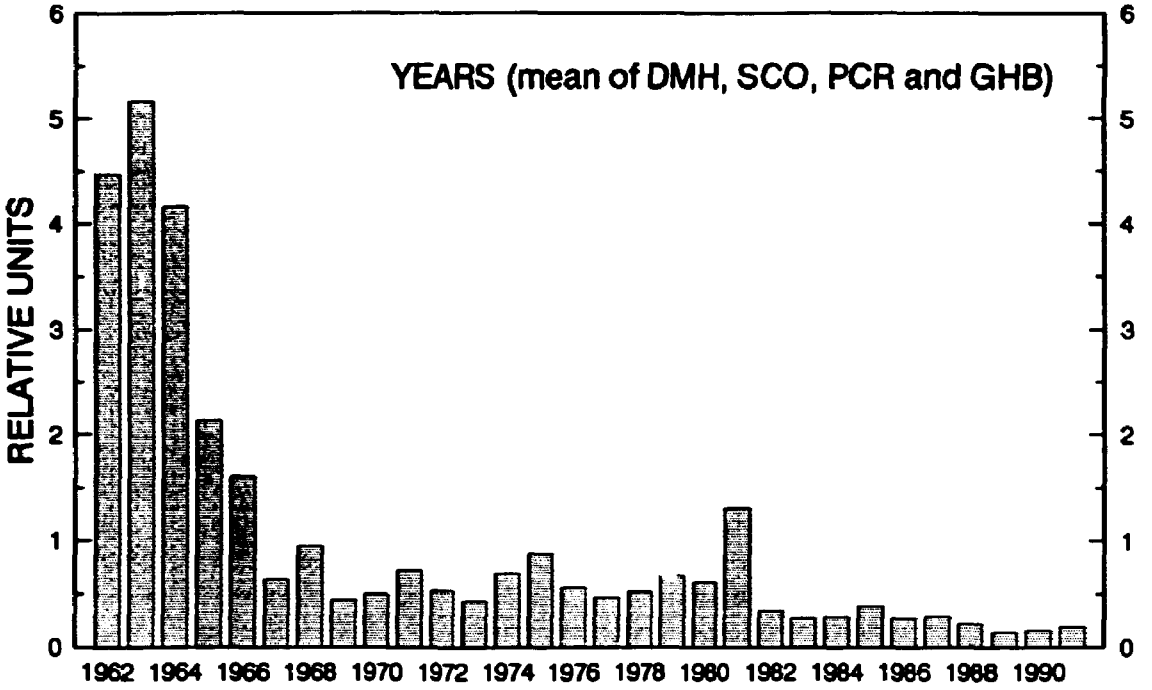
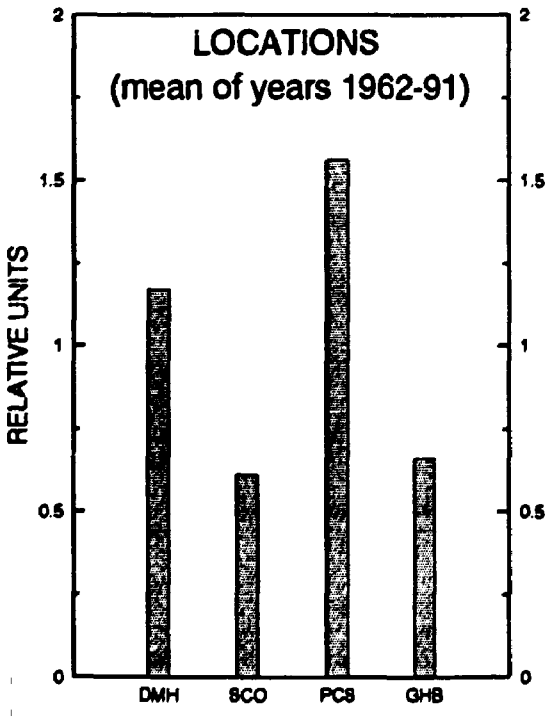


Figure 3.2.6.1. The variation of Bq ^{90}Sr m^{-3} in drinking water from Greenland among years. The bars are the levels relative to the grand mean: 48.70 Bq ^{90}Sr m^{-3} (= 1 at the relative scale) calculated from the anova.

Figure 3.2.6.2. The variation of Bq ^{90}Sr m^{-3} in drinking water from Greenland among locations. The bars are the levels relative to the grand mean: 48.70 Bq ^{90}Sr m^{-3} (= 1 at the relative scale) calculated from the anova.



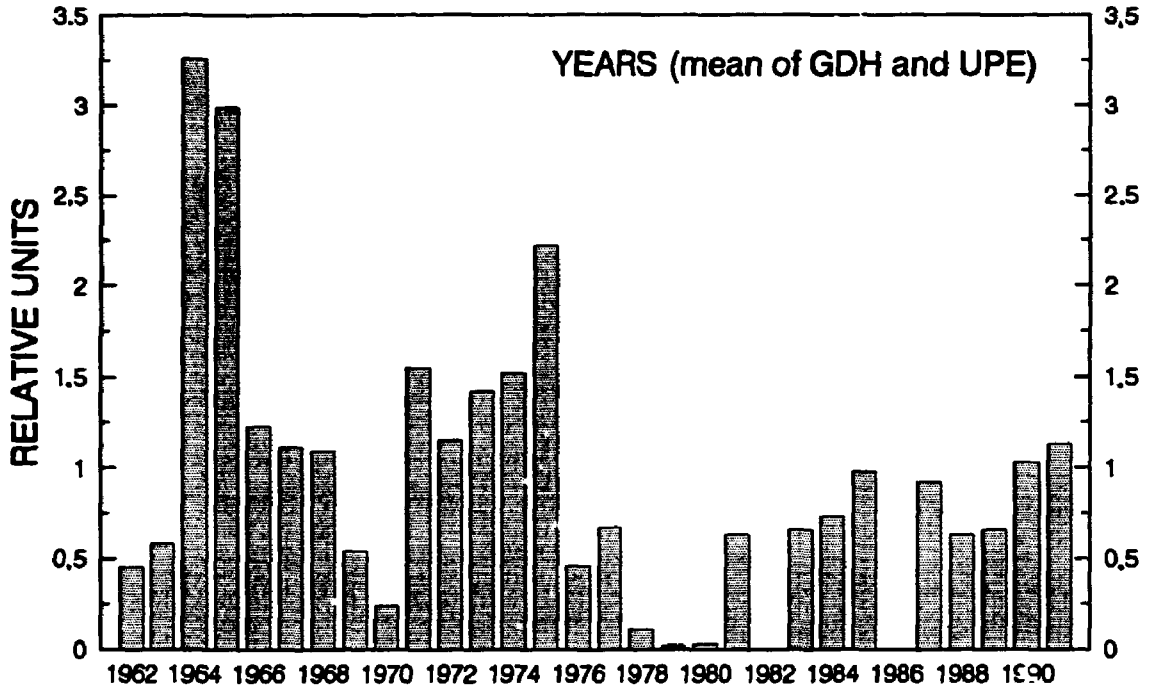
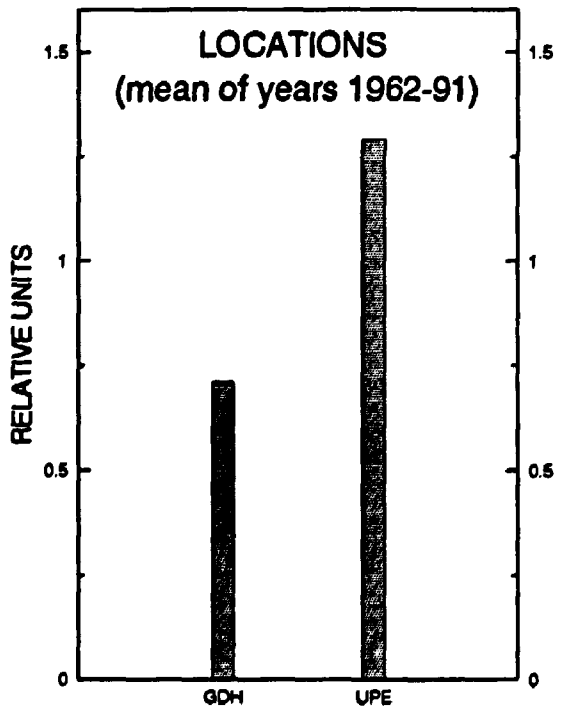


Figure 3.2.6.3. The variation of Bq ^{90}Sr m^{-3} in drinking water from Greenland among years. The bars are the levels relative to the grand mean: 7.95 Bq ^{90}Sr m^{-3} (= 1 at the relative scale) calculated from the anova.

Figure 3.2.6.4. The variation of Bq ^{90}Sr m^{-3} in drinking water from Greenland among locations. The bars are the levels relative to the grand mean: 7.95 Bq ^{90}Sr m^{-3} (= 1 at the relative scale) calculated from the anova.



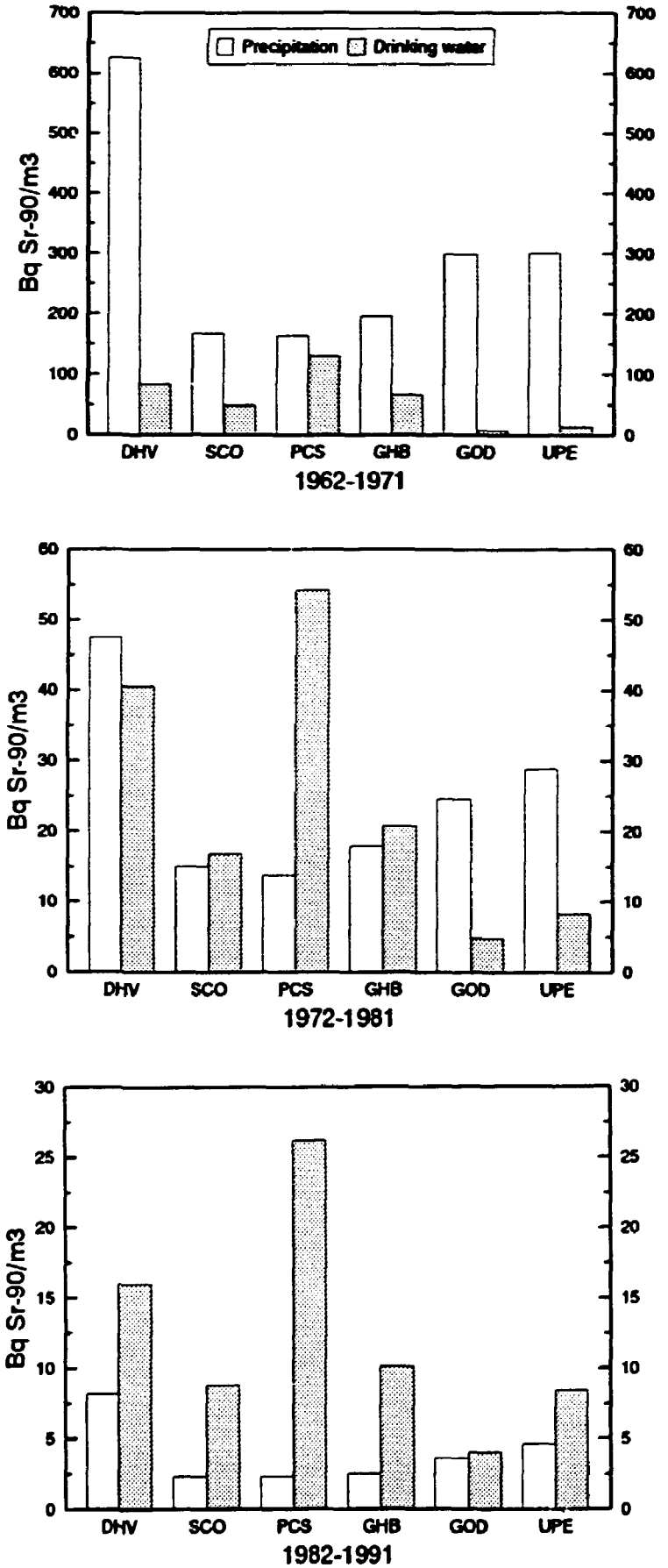


Figure 3.2.6.5. Strontium-90 in precipitation and drinking water collected in Greenland, 1962-1991. (Unit: Bq m^{-3}).

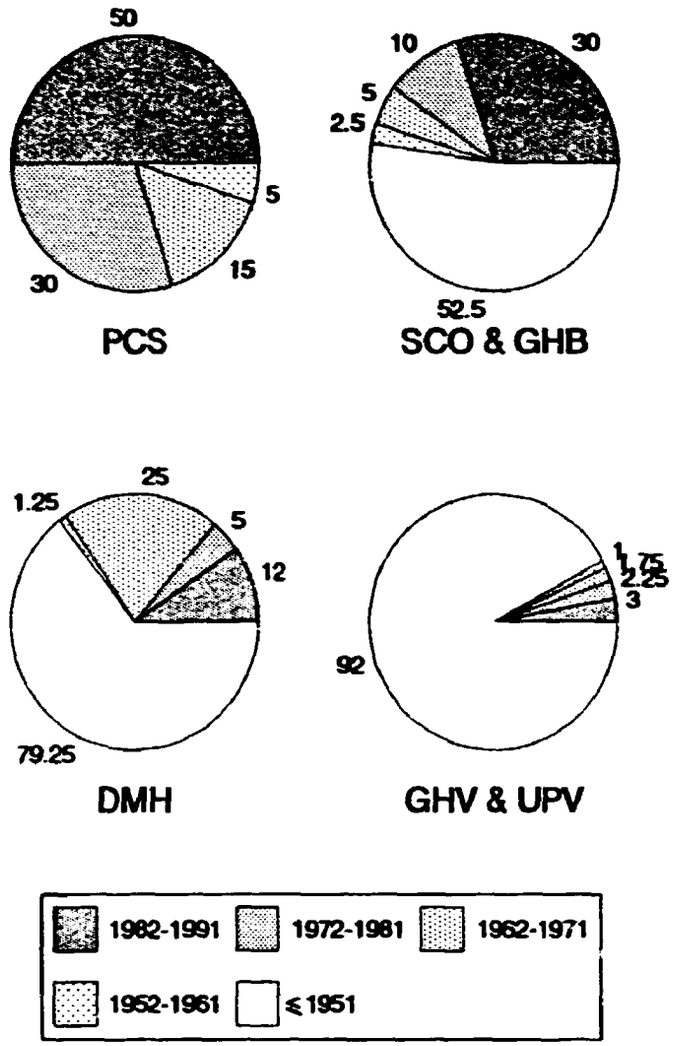


Figure 3.2.6.6. Precipitation vintage in % in drinking water from Greenland, 1982-1991 (according to model, cf. 3.2.6).

Table 3.2.6.2.A. Tritium in drinking water collected in Greenland in 1990 (Unit: kBq m^{-3})

Location	1990
Scoresbysund	1.34±0.19
Danmarkshavn	1.99±0.13
Godthåb	2.37±0.15
Upernavik	2.50±0.04

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

Table 3.2.6.2.B. Tritium in drinking water collected in Greenland in 1991 (Unit: kBq m^{-3})

Location	1991
Scoresbysund	1.16±0.00
Danmarkshavn	1.65±0.10
Godthåb	1.71±0.08
Upernavik	1.79±0.17

Table 3.2.6.3. Observed/predicted ^{90}Sr concentrations in Greenland drinking water according to the above model (cf. 3.2.6)

	1962-1971	1972-1981	1982-1991
Danmarkshavn	83/88 =0.9	40/35 =1.1	16/14.4=1.1
Scoresbysund	48/57 =0.8	16.8/20.2=0.8	8.8/8.0 =1.1
Prins Christians Sund	129/101 =1.3	54/53 =1.0	26/21 =1.2
Godthåb	66/66 =1.0	21/24 =0.9	10.1/9.4 =1.1
Godhavn	6.8/7.8 =0.9	4.8/5.4 =0.9	4.0/3.9 =1.0
Upernavik	13.8/15.6=0.9	8.2/10.2=0.8	8.4/5.3 =1.6

3.3 Estimate of the Mean Contents of ^{90}Sr and ^{137}Cs in the Human Diet in Greenland in 1990 and 1991

3.3.1 The Annual Quantities

The estimate of the intake of ^{90}Sr and ^{137}Cs with diet in Greenland is based upon a new diet composition based upon information received in 1992 from Tine Pars, Nuuk. For comparison the old estimates of the different foods in Greenland is based on the figures given in 1962 by the late Professor E. Hoff-Jørgensen, in Risø Report No. 65 (Risø Reports (Greenland) 1962-1982) are also given.

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 1990 was 0.050 Bq ^{90}Sr kg^{-1} and 0.125 Bq ^{137}Cs kg^{-1} (Risø Report No. 621) and in 1991: 0.046 and 0.92, respectively.

Cheese was also imported from Denmark and contained 0.35 Bq ^{90}Sr kg^{-1} and 0.088 Bq ^{137}Cs kg^{-1} in 1990 and 0.33 and 0.064, respectively, in 1991.

3.3.3 Grain Products

All grain was imported from Denmark. We will therefore use the Danish cereal for 1990 and 1991 as given in Risø-R-621 in Tables 5.9.1 and 5.9.2. The concentrations were 0.167 Bq ^{90}Sr kg^{-1} and 0.110 Bq ^{137}Cs kg^{-1} in 1990 and 0.155 and 0.116, respectively in 1991.

3.3.4 Potatoes, Other Vegetables, and Fruit

The Danish mean levels for 1990 and 1991 were used (Risø Report No. 621), since the local production is insignificant compared with imports from Denmark.

The Danish mean levels in 1990 were: in potatoes 0.033 Bq ^{90}Sr kg^{-1} and 0.09 Bq ^{137}Cs kg^{-1} (in 1991: 0.029 and 0.078, respectively), in other vegetables 0.26 Bq ^{90}Sr kg^{-1} and 0.067 Bq ^{137}Cs kg^{-1} (in 1991: 0.22 and 0.038, respectively), and in fruit 0.039 Bq ^{90}Sr kg^{-1} and 0.036 Bq ^{137}Cs kg^{-1} (in 1991: 0.036 and 0.038, respectively).

3.3.5 Meat

60% of all meat consumed in Greenland is assumed to be of local origin, the remaining part comes from Denmark, i.e. 40%. Approximately 12% comes from sheep, 5% from reindeer, 40% from seals and 3% from whales.

The activities in reindeer were estimated from 3.2.3. Seal and whale were estimated from 3.2.4. The levels of lamb were 1992 data and sea birds (and eggs) were 1987 data. Hence the mean levels in Greenland meat from 1990 were 0.017 Bq ^{90}Sr kg^{-1} and 3.9 Bq ^{137}Cs kg^{-1} (1991: 0.022 and 5.9, respectively).

1990: (^{90}Sr: 0.4×0.0038 + 0.05×0.057 + 0.4×0.001 + 0.03×0.009 + 0.12×0.10 = 0.017 Bq kg^{-1})

(^{137}Cs: 0.4×1.28 + 0.05×22 + 0.4×0.46 + 0.03×0.66 + 0.12×17 = 3.9 Bq kg^{-1})

1991: (^{90}Sr: 0.4×0.0036 + 0.05×0.16 + 0.4×0.001 + 0.03×0.009 + 0.12×0.10 = 0.022 Bq kg^{-1})

(^{137}Cs: 0.4×.47 + 0.05×70 + 0.4×0.26 + 0.03×0.66 + 0.12×17 = 5.9 Bq kg^{-1})

3.3.6 Fish

All fish consumed was of local origin, and the mean levels from 1990 were used, i.e. 0.008 Bq ^{90}Sr kg^{-1} (1991 data used) and 0.22 Bq ^{137} Cs kg^{-1} (1991: 0.008 and 0.27, respectively).

3.3.7 Coffee and Tea

The Danish figures for 1990 and 1991 (Risø Report No. 621) were used for coffee and tea, i.e. 0.26 Bq ^{90}Sr kg^{-1} and 0.44 Bq ^{137}Cs kg^{-1}.

3.3.8 Drinking Water

The geometric mean calculated in 3.2.6.1 was used as the mean level of ^{90}Sr in drinking water, i.e. 7.0 Bq ^{90}Sr m^{-3} (in 1991: 8.2 Bq ^{90}Sr m^{-3}. The ^{137}Cs content was approximately 2 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 new diet composition reduced the estimated ^{90}Sr intake by the Greenland population from 31 to 29 Bq per year pro capite in 1990 and from 30 to 28 in 1991, i.e. by 6-7%. However, the ^{137}Cs was increased by the new composition from 202 to 329 Bq per year pro capite in 1990 and from 311 to 479 in 1991, i.e. by 63 and 54%, respectively. The reason for this significant change for ^{137}Cs was the higher consumption of meat (reindeer and lamb) in the new estimate.

Table 3.3.1.A. Estimate of the mean content of ^{90}Sr in the human diet in Greenland in 1990. (Figures in brackets are from the old model)

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	92 (78)	0.050	4.60 (3.90)	16.0 (12.5)
Cheese	5.8 (2.5)	0.35	2.03 (0.88)	7.1 (2.8)
Grain products	57 (95.6)	0.167	9.52 (15.97)	33.1 (51.2)
Potatoes	28 (32.8)	0.033	0.92 (1.08)	3.2 (3.4)
Vegetables	11.6 (5.5)	0.26	3.02 (1.43)	10.5 (4.6)
Fruit	36 (13.5)	0.039	1.40 (0.53)	4.9 (1.7)
Meat (and eggs)	76.1 (45.6)	0.017 (0.014)	1.29 (0.64)	4.5 (2.1)
Fish	23.4 (127.6)	0.008	0.19 (1.02)	0.7 (3.3)
Coffee and tea	7.3 (7.3)	0.26	1.90 (1.90)	6.6 (6.1)
Drinking water	548 (548)	0.0070	3.84 (3.84)	13.4 (12.3)
Total			28.71 (31.19)	

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 1990 was 51 (56) Bq ^{90}Sr (kg Ca)$^{-1}$ and the daily intake was 0.079 (0.085) Bq ^{90}Sr.

Table 3.3.1.B. Estimate of the mean content of ^{90}Sr in the human diet in Greenland in 1991. (Figures in brackets are from the old model)

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	92 (78)	0.046	4.23 (3.59)	15.2 (11.9)
Cheese	5.8 (2.5)	0.33	1.91 (0.83)	6.8 (2.8)
Grain products	57 (95.6)	0.155	8.84 (14.82)	31.7 (49.1)
Potatoes	28 (32.8)	0.029	0.81 (0.95)	2.9 (3.1)
Vegetables	11.6 (5.5)	0.22	2.55 (1.21)	9.1 (4.0)
Fruit	36 (13.5)	0.036	1.30 (0.49)	4.7 (1.6)
Meat (and eggs)	76.1 (45.6)	0.022 (0.019)	1.67 (0.87)	6.0 (2.9)
Fish	23.4 (127.6)	0.008	0.19 (1.02)	0.7 (3.4)
Coffee and tea	7.3 (7.3)	0.26	1.90 (1.90)	6.8 (6.3)
Drinking water	548 (548)	0.0082	4.49 (4.49)	16.1 (14.9)
Total			27.89 (30.17)	

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 1991 was 50 (54) Bq ^{90}Sr (kg Ca)$^{-1}$ and the daily intake was 0.076 (0.083) Bq ^{90}Sr.

Table 3.3.2.A. Estimate of the mean content of ^{137}Cs in the human diet in Greenland in 1990. (Figures in brackets are from the old model)

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	92 (78)	0.125 (0.125)	11.50 (9.75)	3.5 (4.8)
Cheese	5.8 (2.5)	0.088 (0.088)	0.51 (0.22)	0.2 (0.1)
Grain products	57 (95.6)	0.110 (0.110)	6.27 (10.52)	1.9 (5.2)
Potatoes	28 (32.8)	0.09 (0.09)	2.52 (2.95)	0.8 (1.5)
Vegetables	11.6 (5.5)	0.067 (0.067)	0.78 (0.37)	0.2 (0.2)
Fruit	36 (13.5)	0.036 (0.036)	1.30 (0.49)	0.4 (0.2)
Meat (and eggs)	76.1 (45.6)	3.9 (3.2)	296.79 (145.92)	90.1 (72.0)
Fish	23.4 (127.6)	0.22 (0.22)	5.15 (28.07)	1.6 (13.9)
Coffee and tea	7.3 (7.3)	0.44 (0.44)	3.21 (3.21)	1.0 (1.6)
Drinking water	548 (548)	0.0018 (0.0018)	0.99 (0.99)	0.3 (0.5)
Total			329.02 (202.49)	

The mean annual potassium intake is estimated to be approx. 1.2 kg. Hence the $^{137}Cs/K$ ratio becomes 274 (169) Bq ^{137}Cs (kg K)$^{-1}$. The daily intake in 1990 from food was 0.90 (0.55) Bq ^{137}Cs.

Table 3.3.2.B. Estimate of the mean content of ^{137}Cs in the human diet in Greenland in 1991. (Figures in brackets are from the old model)

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	92 (78)	0.092 (0.092)	8.46 (7.18)	1.8 (2.3)
Cheese	5.8 (2.5)	0.064 (0.064)	0.37 (0.16)	0.1 (0.1)
Grain products	57 (95.6)	0.116 (0.116)	6.61 (11.09)	1.4 (3.6)
Potatoes	28 (32.8)	0.078 (0.078)	2.18 (2.56)	0.5 (0.8)
Vegetables	11.6 (5.5)	0.038 (0.038)	0.44 (0.21)	0.1 (0.1)
Fruit	36 (13.5)	0.038 (0.038)	1.37 (0.51)	0.3 (0.2)
Meat (and eggs)	76.1 (45.6)	5.9 (5.5)	448.99 (250.80)	93.6 (80.5)
Fish	23.4 (127.6)	0.27 (0.27)	6.32 (34.45)	1.3 (11.0)
Coffee and tea	7.3 (7.3)	0.44 (0.44)	3.21 (3.21)	0.7 (1.0)
Drinking water	548 (548)	0.0021 (0.0021)	1.15 (1.15)	0.2 (0.4)
Total			479.10 (311.32)	

The mean annual potassium intake is estimated to be approx. 1.2 kg. Hence the $^{137}Cs/K$ ratio becomes 399 (259) Bq ^{137}Cs (kg K)$^{-1}$. The daily intake in 1991 from food was 1.31 (0.85) Bq ^{137}Cs.

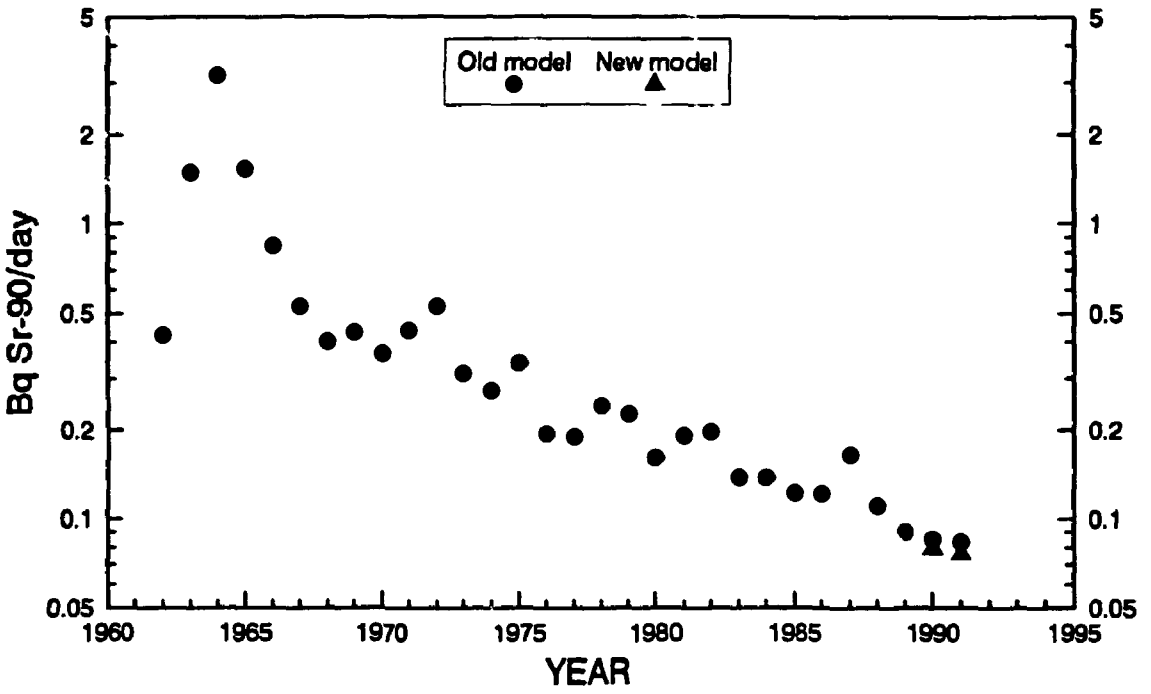
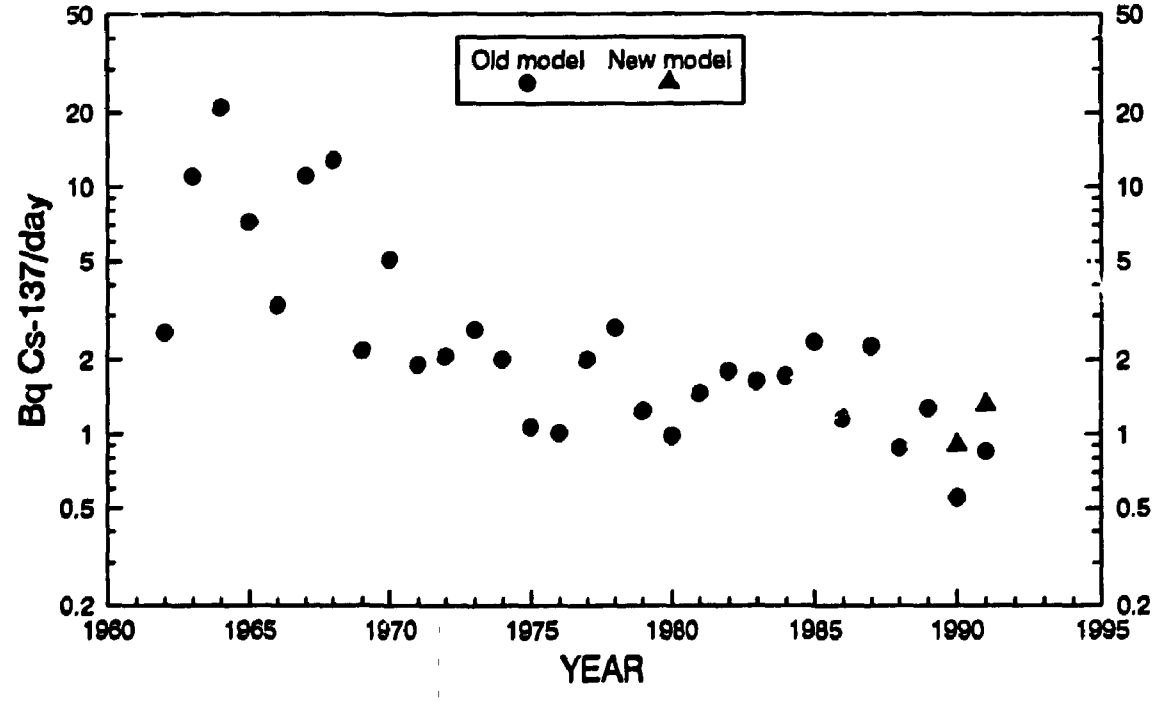


Figure 3.3.1. Strontium-90 in Greenland diet, 1962-1991. (Unit: Bq day^{-1}).

Figure 3.3.2. Cesium-137 in Greenland diet, 1962-1991. (Unit: Bq day^{-1}).



3.4 Conclusion

3.4.1.

The ^{90}Sr fallout rates in 1990 and 1991 were less than 1 Bq m^{-2} per year.

3.4.2.

The food consumed in Greenland in 1990 and 1991 contained on the average 50 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).

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 1990-1991 ^{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 17 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.

Compared with 1988-1989 the ^{137}Cs levels in 1990-1991 were lower. However, from 1990 to 1991 the annual mean increased a little. This may be due to the outflow of Chernobyl contaminated Baltic water through the Danish Straits and Skagerak (cf. Risø-R-621).

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:

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

Table 4.1.1.A. Radiocesium and Technetium in surface sea water collected in 1990 from Utsira, Norway. 59°19'N, 4°54'E. (Unit: Bq m^{-3})

Date	^{99}Tc	^{137}Cs	$\frac{^{134}Cs}{^{137}Cs}$	Salinity in ‰
January 12	0.79	22	0.080	33.0
February 15	lost	17.9		33.2
March 15	0.46	16.1		33.8
April 18	0.56	19.1		33.2
June	0.43	27		33.6
July	0.77±0.02	13.8±1.8		31.0±0.4
August	-	19.8		29.8
September	-	19.9		31.2
October	1.26	12.0		32.8
November	0.70	9.7		-
December	0.88	9.6		-
Mean	0.73	17.0		32.4
1 S.D.	0.27	5.39		1.39
Relative S.D.	37%	32%		4%

Table 4.1.1.B. Radiocesium and Technetium in surface sea water collected in 1991 from Utsira, Norway. 59°19'N, 4°54'E. (Unit: Bq m^{-3})

Date	^{99}Tc	^{137}Cs	$\frac{^{134}Cs}{^{137}Cs}$	Salinity in ‰
February 15	0.54	19.3		32.0
March	0.42	18.1		32.0
April	0.34	26		30.9
May	0.42	23	0.118	30.0
June	0.31	12.4		33.8
July	0.40	22		31.2
August	0.37	-		31.0
September	0.54	18.8		32.6
October	0.52	19.0		34.8
November	0.46	13.4		31.6
December	0.74	13.2		32.8
Mean	0.46	18.5		32.1
1 S.D.	0.121	4.49		1.38
Relative S.D.	26%	24%		4%

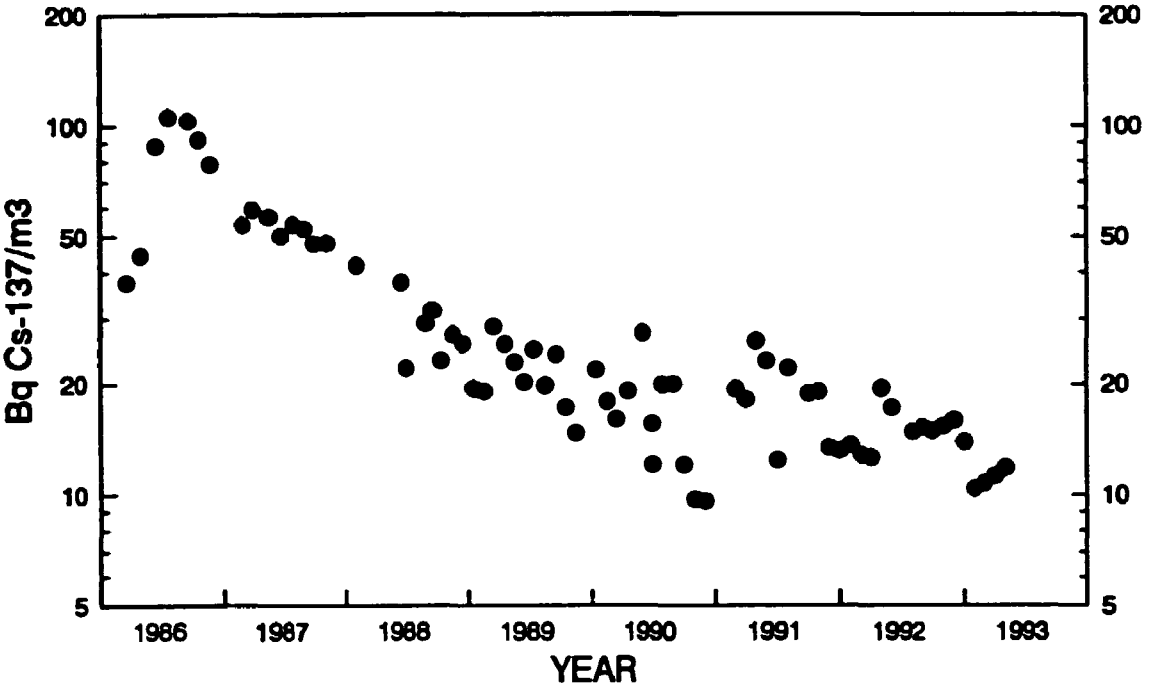
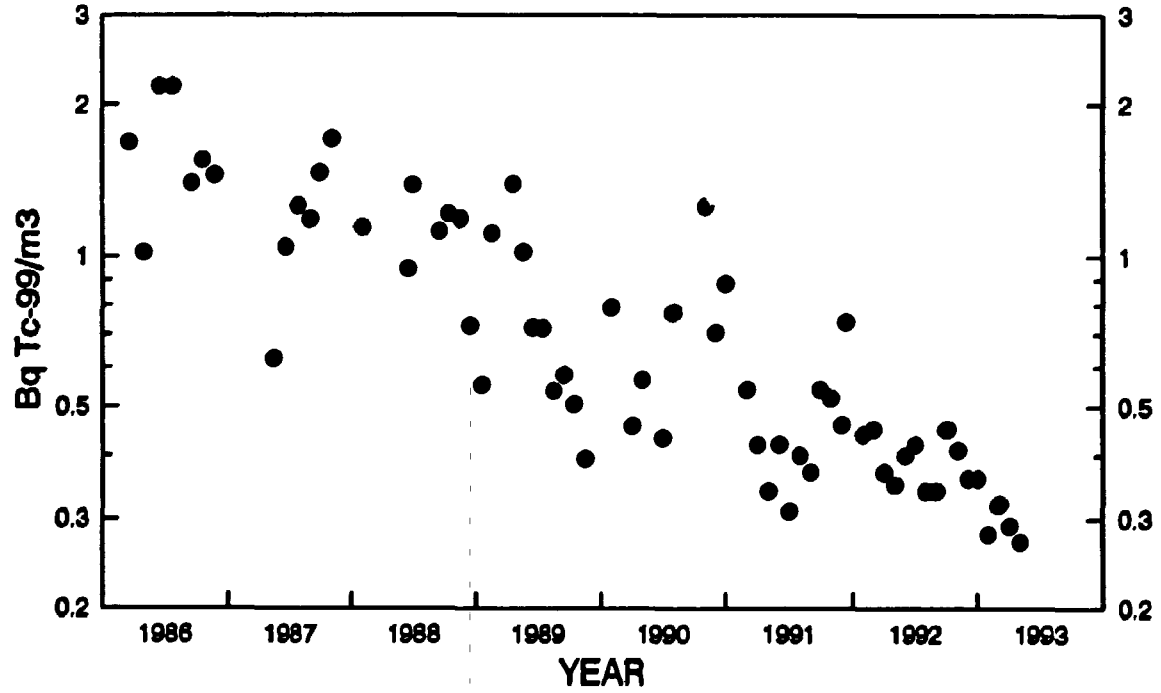


Figure 4.1.1. Cesium-137 in surface sea water collected at Utsira (59°19'N, 4°54'E), 1986-1993. (Unit: Bq m^{-3}).

Figure 4.1.2. Technetium-99 in surface sea water collected at Utsira (59°19'N, 4°54'E), 1986-1993. (Unit: Bq m^{-3}).



4.2 "Bjarni Sæmundson" Cruise to the Denmark Strait and the Southern Greenland Sea in September 1990 (GSP Project)

Table 4.2 shows the results of the ^{90}Sr, ^{99}Tc and ^{137}Cs analyses of samples collected by "Bjarni Sæmundson" in September 1990 (cf. Figures 4.2.1-4.2.8). Furthermore, a few determinations of plutonium and americium were carried out. A detailed discussion of the results are given in Dahlgaard et al., 1994.

Table 4.2. Radionuclides in sea water collected from »Bjarni Sæmundsen« (Greenland Sea Project) in the Greenland Sea and Denmark Strait in September 1990

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}	^{137}Cs Bq m^{-3}	$^{239,240}Pu$ mBq m^{-3}	^{241}Am mBq m^{-3}	H no.
66°15'	25°25'	4	5	6.8	34.1	2.5		5.3			192/193
64°55'	24°09'	4	5	10.8	34.3	1.62		2.2			191
64°27'	22°56'	4	5	10.9	34.0	1.84		2.4			190
67°54'	24°39'	6	5	1.9	31.6	2.8		8.6			201
67°54'	24°39'	6	500		34.9	1.38		4.6			202
67°54'	24°39'	6	1000		34.9	2.0	36	5.7			203
67°54'	24°39'	6	1400		34.9	0.81	16	1.72			204
67°31'	23°46'	6	5	4.3	34.1	2.0		4.7			197
67°31'	23°46'	6	80		34.5	2.0		5.5			198
67°31'	23°46'	6	150		34.8	1.60		5.6			199
67°31'	23°46'	6	500		34.9	1.57		4.6			200
67°09'	22°54'	6	5	6.5	34.4	2.1		4.1			194
67°09'	22°54'	6	125		34.7	2.2		5.0			195
67°09'	22°54'	6	200		34.8	1.99		4.0			196
68°26'	25°46'	7	5	0	29.8	3.8		7.7	5.4±0.16	0.75 A	209/210
68°08'	25°15'	7	5	0.5	30.0	3.6	92	8.8			205
68°08'	25°15'	7	80		33.4	3.8	96	9.2			206
68°08'	25°15'	7	150		32.2	3.6	105	8.6			207
68°08'	25°15'	7	500		34.4	2.6	33	6.7			208
71°00'	17°18'	11	5	2.4	32.5	2.4	50	6.9			216
71°00'	17°18'	11	125		35.0	1.96	28	4.7			217
71°00'	17°18'	11	300		34.9	1.77	49	5.2			218
71°00'	17°18'	11	750		34.9	1.51	32	3.5			219
71°00'	17°18'	11	1400		34.9	0.80	21	1.62			220
71°00'	17°18'	11	1600		34.9	0.63		1.07 A			221
71°00'	14°21'	11	5	5.2	34.6	1.77	63	4.8			211
71°00'	14°21'	11	80		34.8	1.89	35	5.0			212
71°00'	14°21'	11	300		34.9	1.66	37	4.5			213
71°00'	14°21'	11	500				41	3.8			214
71°00'	14°21'	11	950		34.9	0.96	19 A	2.5			215
71°00'	20°26'	12	5	0.1	31.1	3.5	56	7.4			222
70°59'	19°28'	13	5	-0.4				7.4			229
70°59'	19°28'	13	80		33.4	3.9		9.7			230
70°59'	19°28'	13	300		35.0	1.96		5.5			231
70°59'	19°28'	13	500					4.8			232
70°59'	19°28'	13	750		34.9	1.45		3.5			233
70°59'	18°49'	13	5	1.4	30.9	2.8	53	6.9			223
70°59'	18°49'	13	80			2.1		5.3			224
70°59'	18°49'	13	300		35.0	1.85	44	5.5			225
70°59'	18°49'	13	500		34.9	1.57	27	4.2			226
70°59'	18°49'	13	1100		34.9	1.02	19 A	2.9			227
70°59'	18°49'	13	1350		34.9	0.80	16 A	1.66 A			228
71°00'	09°30'	15	5	6.1			26	4.2	9.9±0.54		234-238
71°00'	17°56'	17	5	2					10.3±0.51	1.8±0.11	239/240
69°10'	20°12'	19	5	-0.2			75±2.7*	10.1	9.6±1.08	1.0 A	241-245

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

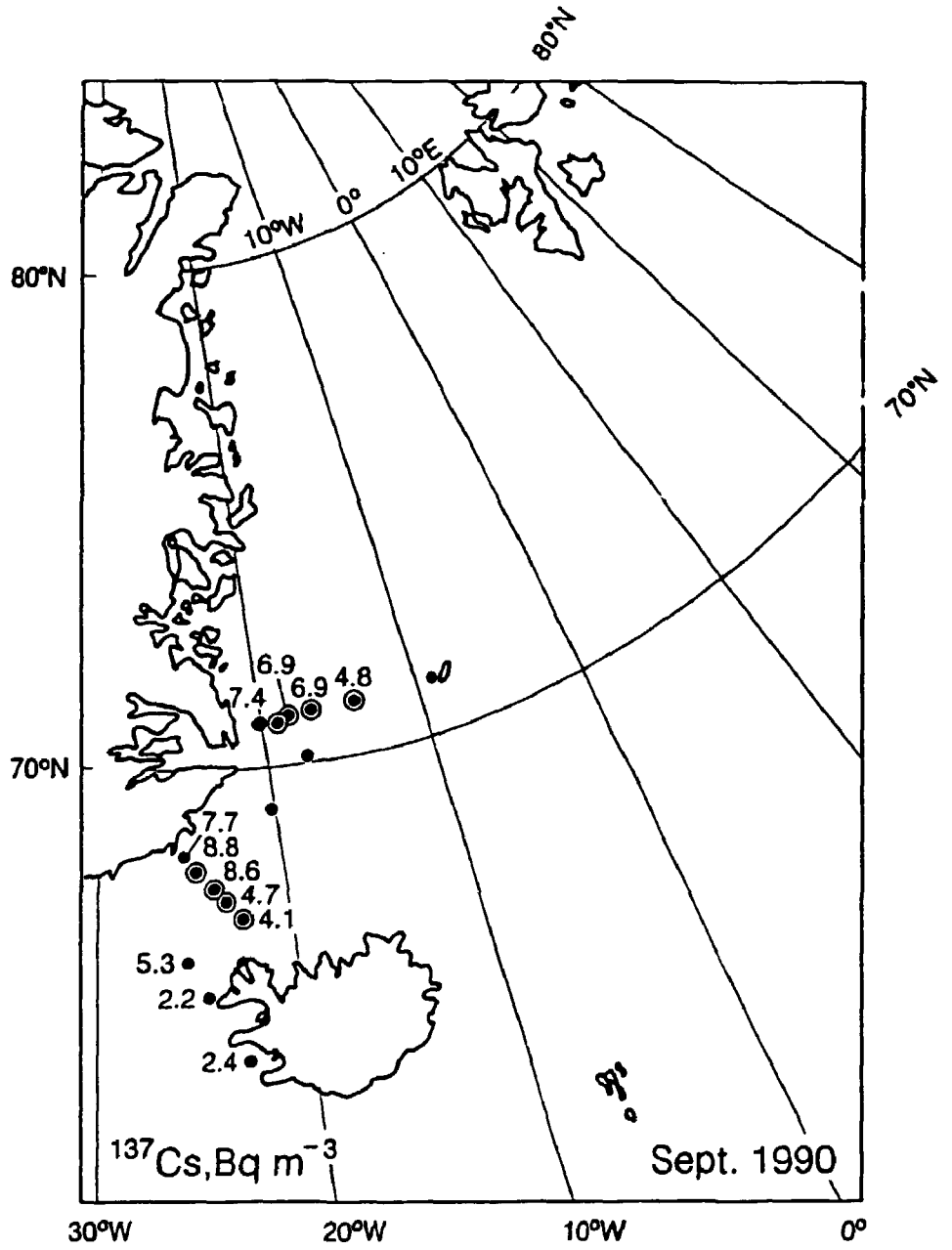


Figure 4.2.1. Cesium-137 in surface sea water from Greenland Sea Project September 1990. ●: sampling location, ○: profile. (Unit: Bq m^{-3}).

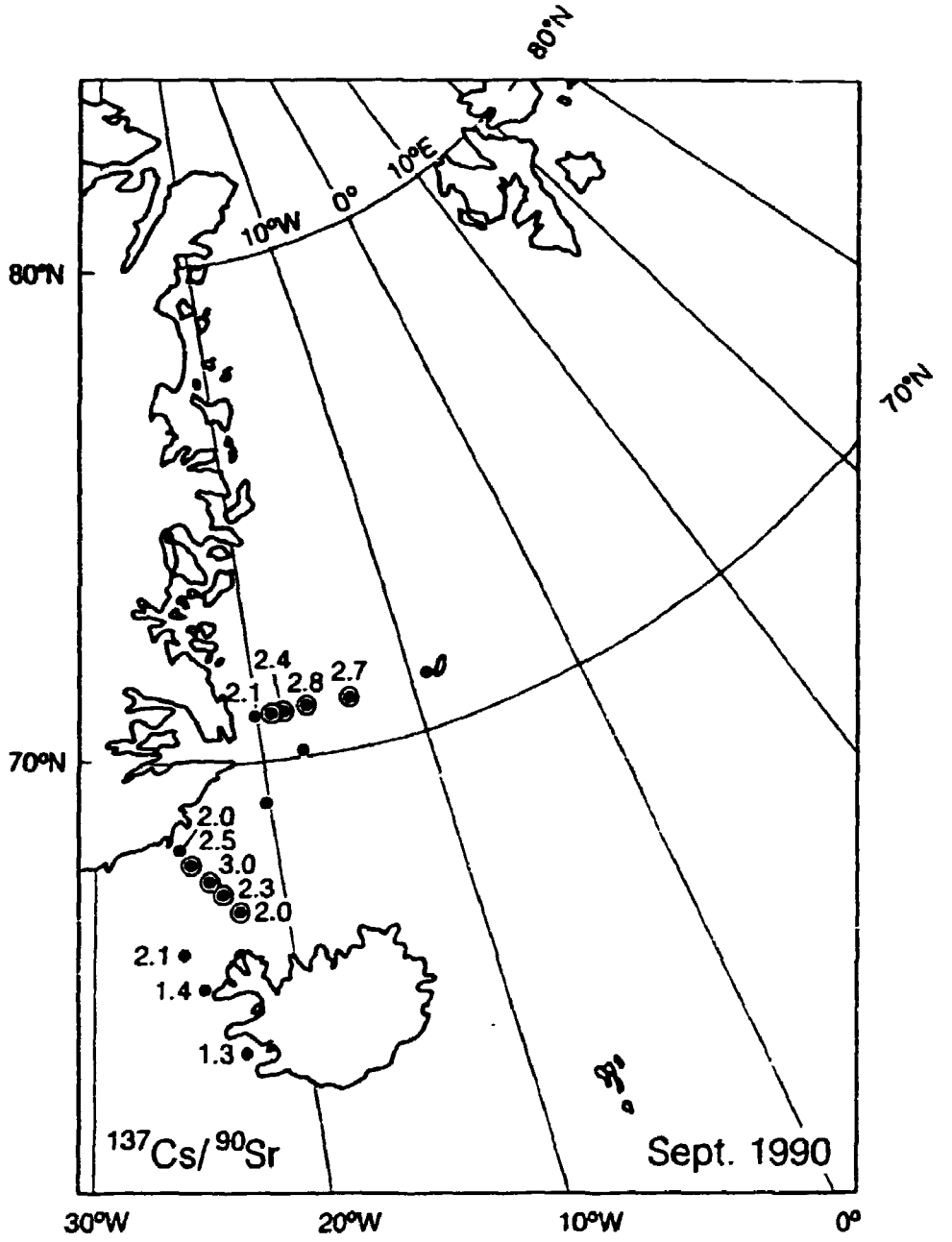


Figure 4.2.2. $^{137}Cs/^{90}Sr$ in surface sea water from Greenland Sea Project September 1990. ●: sampling location, ○: profile. (Unit: Bq m^{-3}).

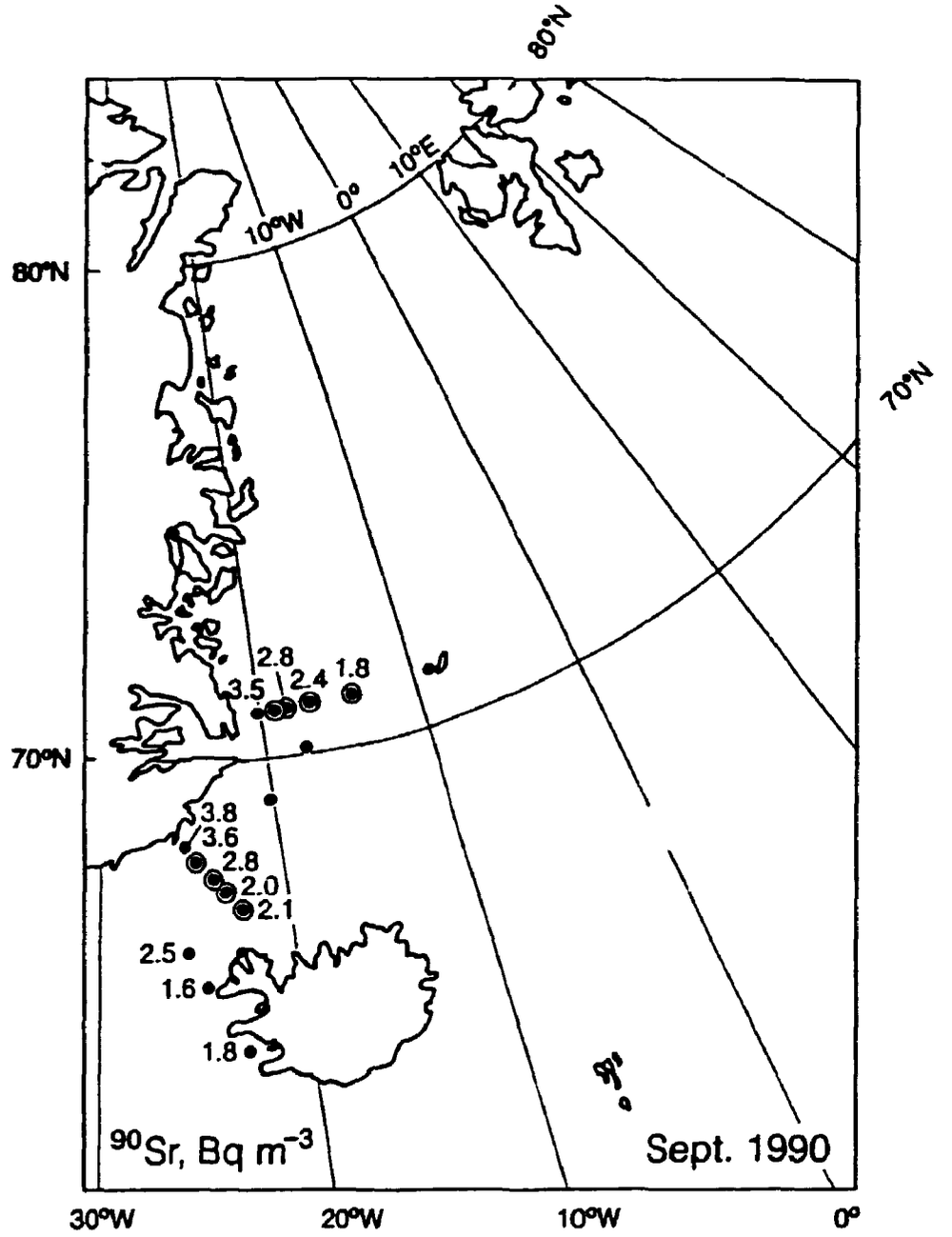


Figure 4.2.3. Strontium-90 in surface sea water from Greenland Sea Project September 1990. ●: sampling location, ○: profile. (Unit: Bq m^{-3}).

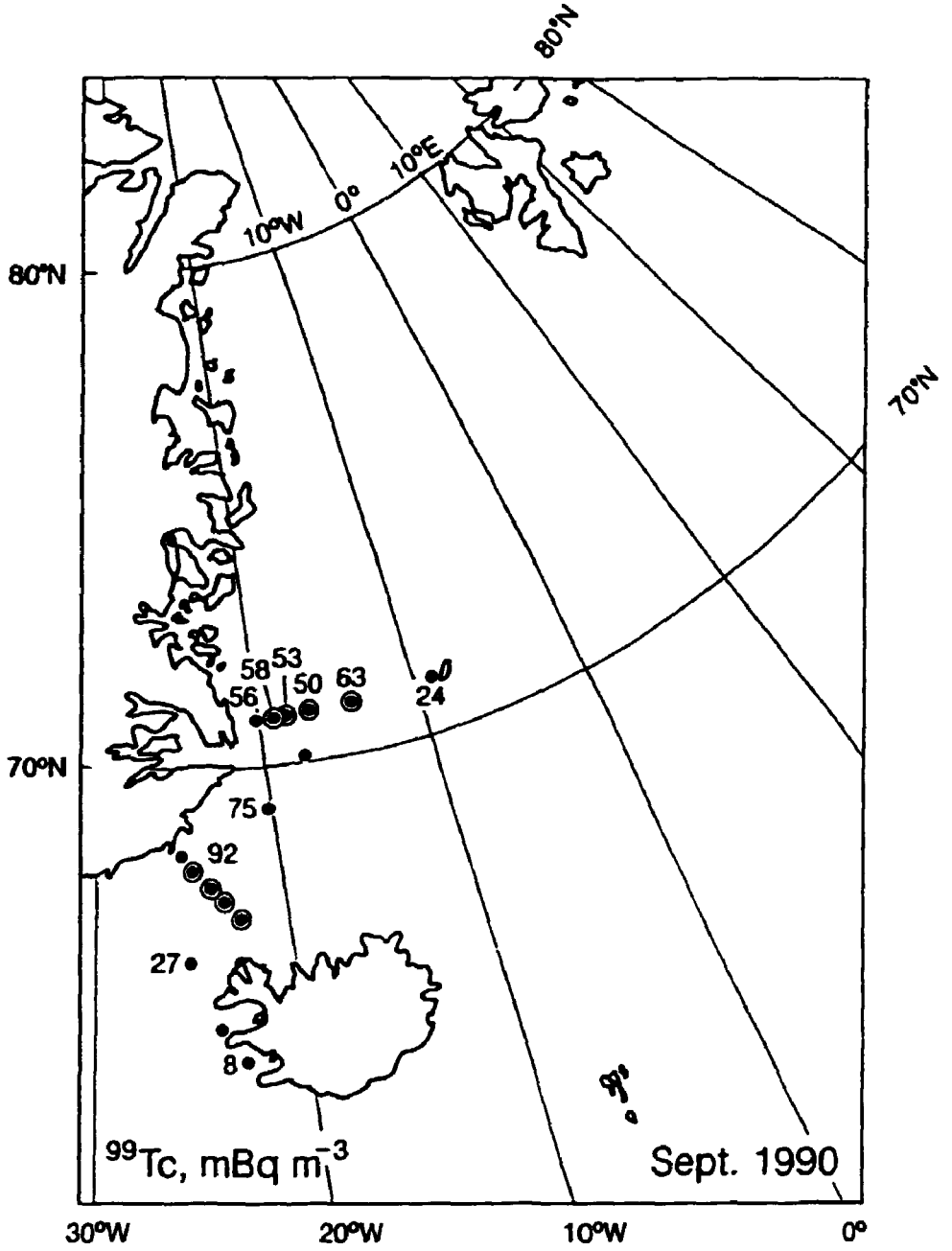
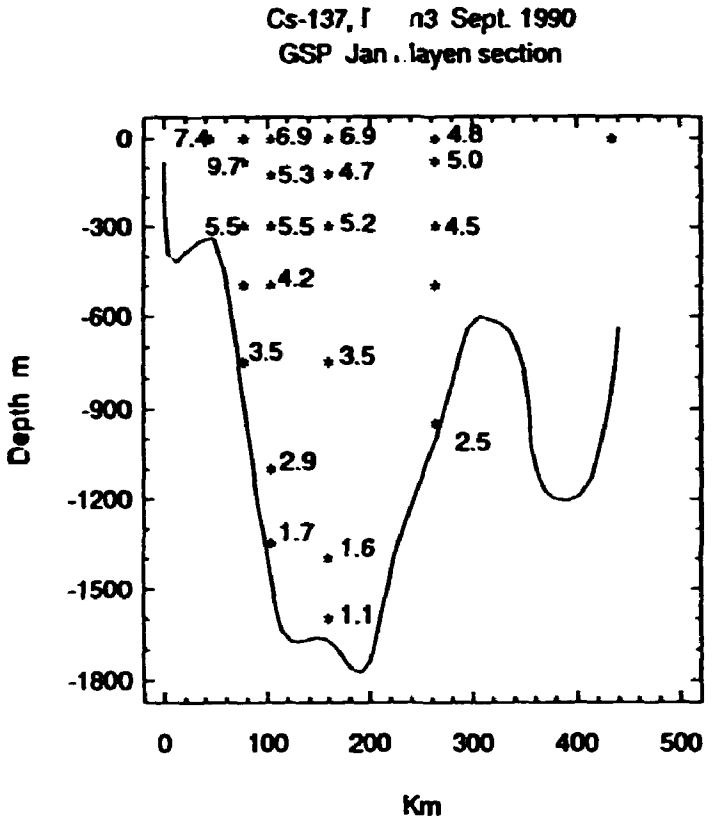


Figure 4.2.4. Technetium-99 in surface sea water from Greenland Sea Project September 1990. ●: sampling location, ○: profile. (Unit: Bq m^{-3}).



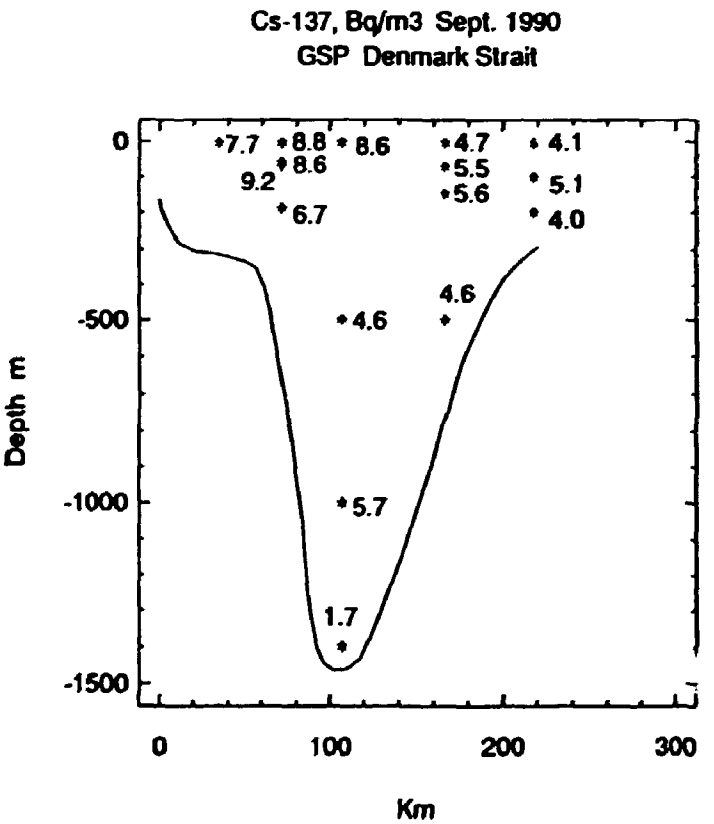
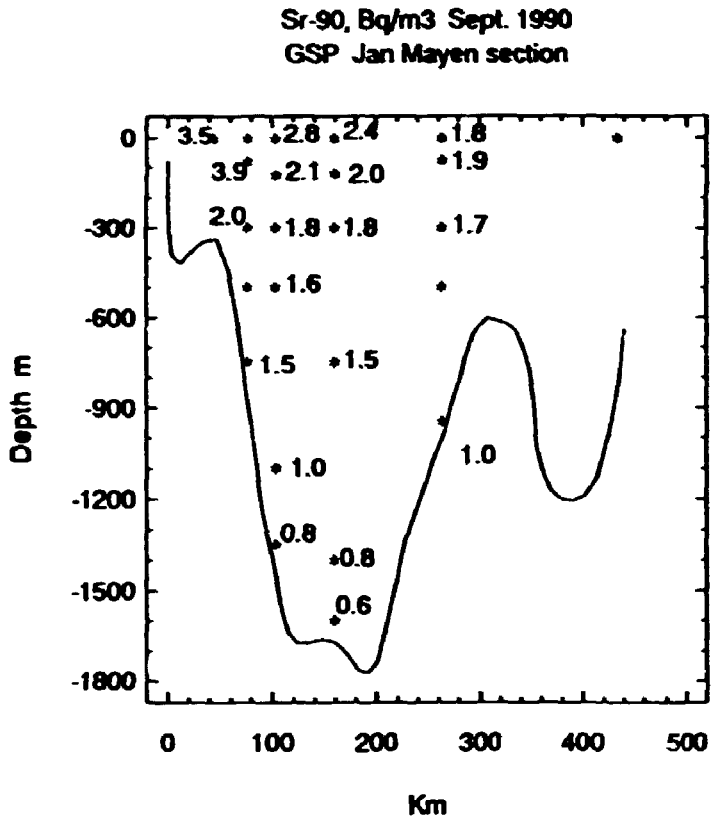


Figure 4.2.5. Cesium-137 data from the two deep water sections, September 1990.



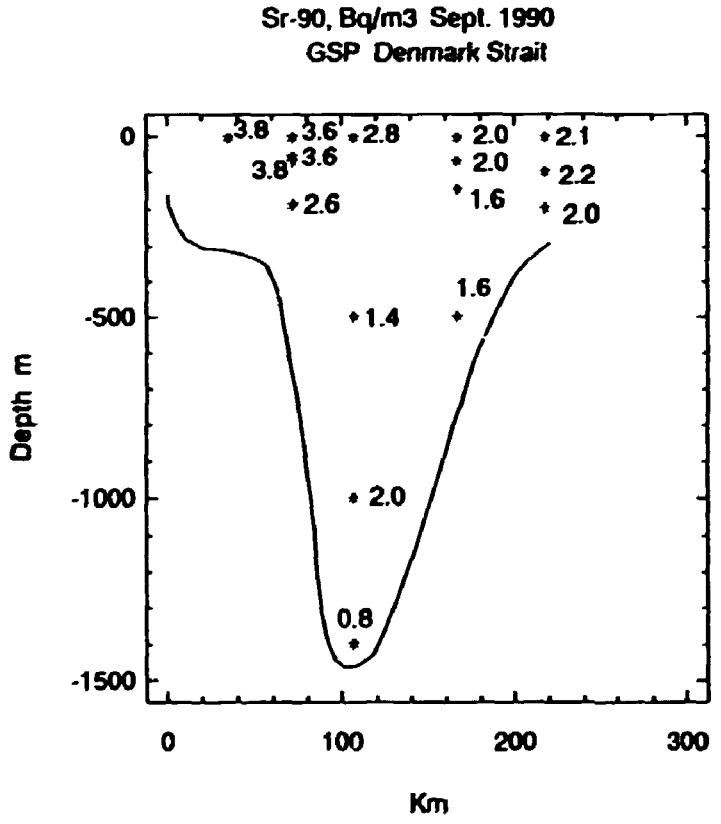
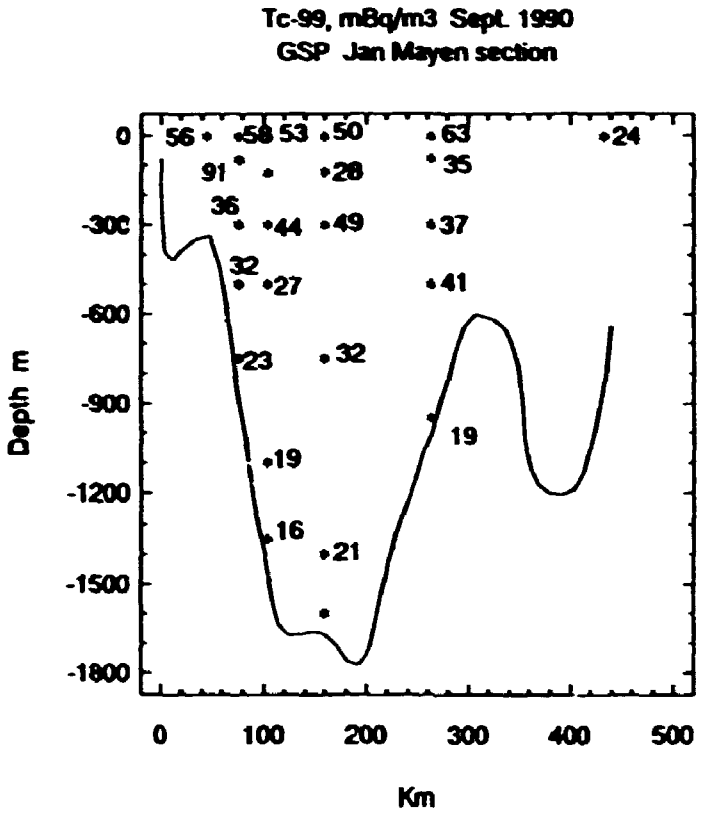


Figure 4.2.6. Strontium-90 data from the two deep water sections, September 1990.



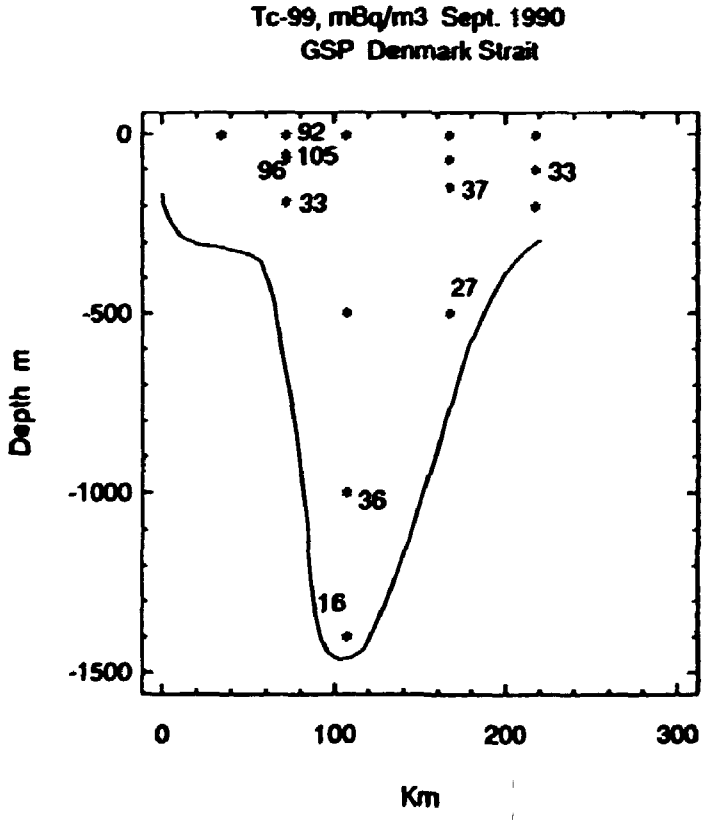
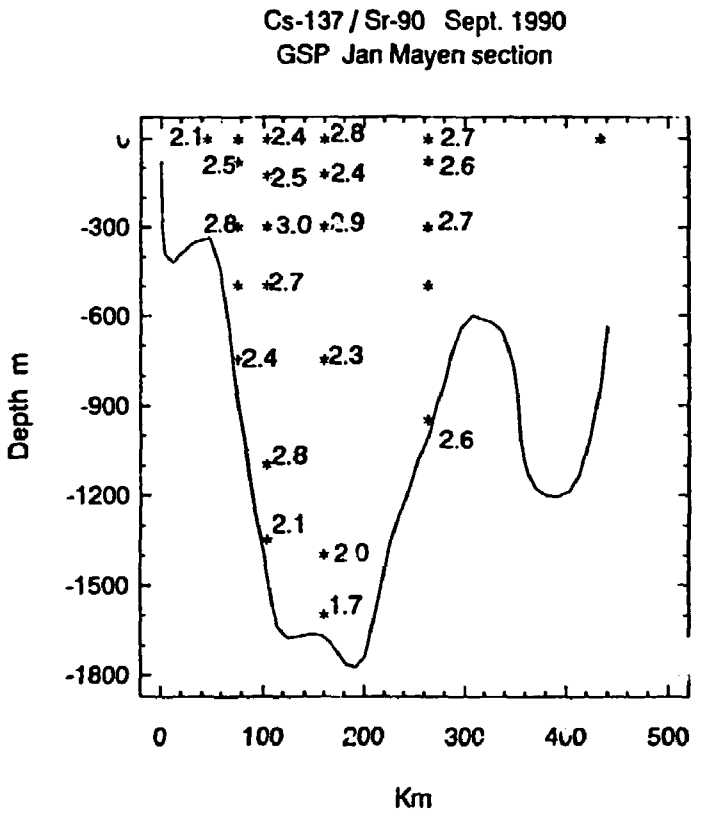


Figure 4.2.7. Technetium-99 data from the two deep water sections, September 1990.



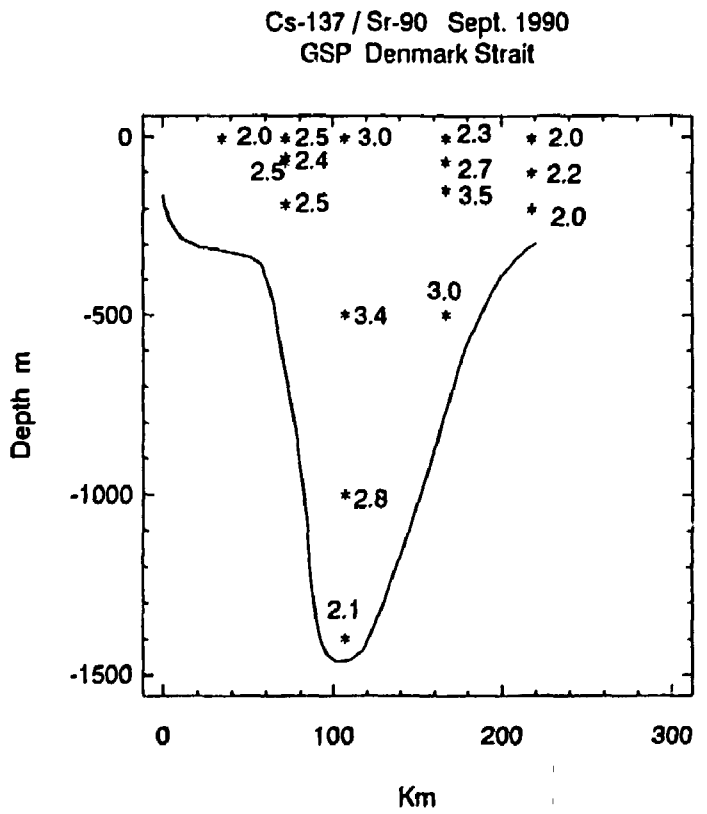


Figure 4.2.8. Cs-137/Sr-90 data from the two deep water sections, September 1990.

4.3 Radiocesium in Terrestrial Vegetation in the Faroes Collected by Risø in July-August 1991

In the summer of 1991, six selected plant species were collected at 10 sites in the Faroe Islands (cf. Table 4.3.1). The samples were analysed for ^{137}Cs, ^{134}Cs and ^{40}K and an analysis of variance were carried out on the data. The following conclusions were drawn:

The ^{40}K content differed significantly between species: *Calluna vulgaris* ~ *Polytrichum commune* ≤ *Vaccinium myrtillus* ≤ *Deschampsia flexuosa* ≤ *Eriophorum angustifolium* ~ *Molinia caerulea*.

There was no significant local variation with respect to ^{40}K in the vegetation.

The ^{137}Cs concentrations (Bq kg^{-1}) did not differ significantly neither between species nor between sites, but Bq ^{137}Cs (g $K)^{-1}$ differed between species: *Molinia caerulea* ~ *Deschampsia flexuosa* ~ *Eriophorum angustifolium* < *Vaccinium myrtillus* ~ *Polytrichum commune* < *Calluna vulgaris*.

The $^{134}Cs/^{137}Cs$ ratio did not differ significantly neither between species nor between sampling sites.

The large local variation and inhomogeneities of semi-natural ecosystems make a detection of significant interspecial differences for radiocesium difficult; this was demonstrated in the Faroese sampling. Table 4.3.2 shows the mean values of ^{137}Cs obtained from the analysis of variance. The $^{134}Cs/^{137}Cs$ ratio indicates that about 50-75% of the ^{137}Cs in Faroese vegetation in 1991 was of Chernobyl origin.

Table 4.3.1. Radiocesium in terrestrial vegetation in the Faroese collected by Risø 1991

Species	Date	Position E	Position W	Bq ^{137}Cs kg^{-1} dry	g ^{40}K kg^{-1} dry	^{134}Cs / ^{137}Cs
Polytrichum commune	Aug. 3	62°15'	7°10'	90	8.17	0.040 A
	Aug. 3	62°15'	6°31'	5.3	2.41	
	Aug. 2	62°08'	7°01'	10.8	3.22	
	Aug. 3	62°06'	7°22'	12.9	3.48	
	July 31	62°02'	6°47'	173	5.72	0.054
	Aug. 2	62°02'	6°47'	56	5.40	0.086
	Aug. 1	61°32'	6°48'	149	3.21	0.081
	Aug. 1	61°32'	6°48'	86	3.63	0.074
Polytrichum juniperinum	Aug. 3	62°15'	6°31'	12.7	5.72	
Eriophorum angustifolium	Aug. 3	62°15'	7°10'	3.3	17.22	
	Aug. 3	62°13'	6°34'	40	13.53	
	Aug. 2	62°08'	7°01'	104	10.11	
	Aug. 5	62°06'	7°22'	15.7	12.98	
	July 31	62°02'	6°47'	54	9.78	0.059
	Aug. 2	62°02'	6°47'	163	12.30	0.028
	Aug. 1	61°32'	6°48'	53	9.31	0.053
Deschampsia flexuosa	Aug. 2	62°08'	7°01'	4.7	13.59	
	Aug. 5	62°06'	7°22'	9.8	11.33	
	Aug. 5	62°06'	7°22'	4.5	2.40	
	Aug. 5	62°04'	7°13'	44	10.82	
	July 31	62°02'	6°47'	52	9.77	0.076 A
Nardus stricta	Aug. 3	62°13'	6°34'	7.7	9.88	
	Aug. 5	62°06'	7°22'	3.4	6.65	
	July 31	62°02'	6°47'	114	6.47	
	Aug. 2	62°02'	6°47'	54	8.51	
	Aug. 2	62°02'	6°47'	21	6.91	
	Aug. 1	61°32'	6°48'	250	14.07	0.026
Calluna vulgaris	Aug. 3	62°13'	6°34'	163	5.44	0.061
	Aug. 5	62°06'	7°22'	14.6	3.13	
	Aug. 5	62°05'	7°15'	94	2.70	0.055
	Aug. 5	62°04'	7°13'	20	2.37	0.056 A
	July 31	62°02'	6°47'	390	4.72	0.063
	Aug. 1	62°02'	6°47'	100	3.92	0.077
	Aug. 2	62°02'	6°47'	92	5.79	0.070
	Aug. 4	62°02'	6°47'	78	2.70	0.078
Vaccinium myrtillus	Aug. 5	62°04'	7°13'	142	7.63	
	July 31	62°02'	6°47'	79	6.97	0.065 A
	Aug. 2	62°02'	6°47'	53	5.38	
Agrostis tenuis	Aug. 1	62°32'	6°48'	116	20.29	0.060
	Aug. 3	62°13'	6°34'	19.6	23.22	
	Aug. 5	62°06'	7°22'	2.4	15.85	

Table 4.3.1. (continued)

Species	Date	Position E	Position W	^{137}Cs kg^{-1} dry	g ^{40}K kg^{-1} dry	$\frac{^{134}Cs}{^{137}Cs}$
Festuca vivipara	Aug. 3	62°15'	6°31'	34	16.64	
	Aug. 2	62°08'	7°01'	11.2	13.09	
	Aug. 5	62°06'	7°22'	3.2	7.29	
	Aug. 2	62°02'	6°47'	116	11.55	
	Aug. 1	61°32'	6°48'	118	8.00	
Alopecurus geniculatus	Aug. 1	61°32'	6°48'	11.1	23.71	
Holcus lanatus	Aug. 3	62°13'	6°34'	7.8	16.64	
	Aug. 5	62°06'	7°22'	2.3 B	19.20	
	Aug. 1	61°32'	6°48'	36	12.50	
Molinia caerulea	Aug. 3	62°15'	7°10'	18.1	15.15	
	Aug. 3	62°15'	6°31'	29	14.35	
	Aug. 3	62°13'	6°34'	4.8	13.13	
	Aug. 3	62°13'	6°34'	17.0	16.05	
	Aug. 3	62°13'	6°34'	37	13.14	
	Aug. 5	62°09'	7°10'	9.0	11.36	
	Aug. 4	62°02'	6°47'	18.3	11.64	

Table 4.3.2. Radiocesium in Faroese vegetation collected 31st July - 1st August 1991 (mean values obtained from anova)

Species	Bq ^{137}Cs kg^{-1} d.m.	Bq ^{137}Cs $(g\ K)^{-1}$	$\frac{^{134}Cs}{^{137}Cs}$
Polytrichum commune	47	11.3	0.054
Eriophorum angustifolium	58	3.8	0.056
Deschampsia flexuosa	33	2.5	0.076
Calluna vulgaris	104	17.4	0.070
Vaccinium myrtillus	46	8.7	0.055
Molinia caerulea	24	1.9	0.079

Chernobyl $^{134}Cs/^{137}Cs$ = 0.106 (1 August 1991).

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Environmental Radioactivity in the North Atlantic Region Including the Faroe Islands and Greenland. 1990 and 1991

A. Aarkrog, E. Buch, Q.J. Chen, G.C. Christensen, H. Dahlgaard, H. Hansen, E. Holm, S.P. Nielsen and M. Strandberg

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Abstract (Max. 2000 characters)

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 1990 and 1991. ^{99}Tc data on marine samples, in particular sea water from the Greenland Sea, are reported.

Descriptors INIS/EDB

ACCIDENTS; ANIMALS; ATMOSPHERIC PRECIPITATIONS; CESIUM 134; CESIUM 137; CHERNOBYLSK-4 REACTOR; COASTAL WATERS; DIET; DRINKING WATER; ENVIRONMENT; FALLOUT DEPOSITS; FAROE ISLANDS; FOOD; FOOD CHAINS; GLOBAL FALLOUT; GREENLAND; ICELAND; MAN; NORWAY; PLANTS; RADIOACTIVITY; SEAWATER; SOILS; STATISTICAL DATA; STRONTIUM 90; TECHNETIUM 99

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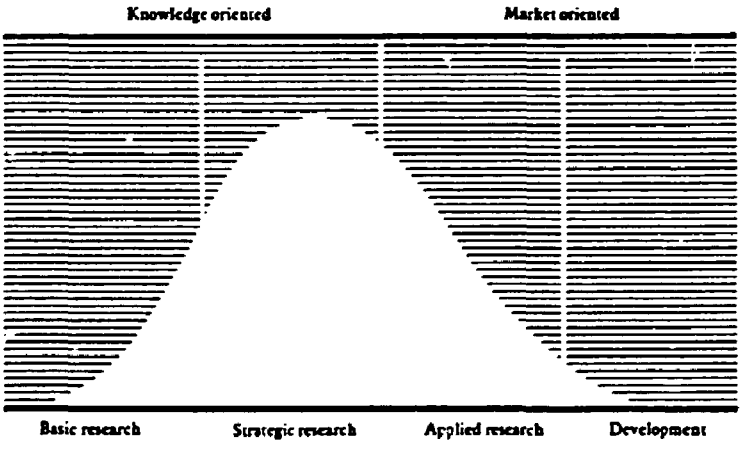

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