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Risø National Laboratory, DK-4000 Roskilde, Denmark
December 1985

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ENVIRONMENTAL RADIOACTIVITY IN THE NORTH ATLANTIC REGION. THE FAROE ISLANDS AND GREENLAND INCLUDED. 1984

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Abstract. Measurements of fallout radioactivity in the North Atlantic region including the Faroe Islands and Greenland are reported. Strontium-90 and cesium-137 was 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 1984. Results from samplings of surface sea water and seaweed in the Norwegian and Greenland Seas and along the Norwegian and Greenland west coasts are

(continued)

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reported. Beside radiocesium and ^{90}Sr some of these samples have also been analysed for tritium, polonium, plutonium and americium. Finally technetium-99 data on seaweed samples collected in the North Atlantic region since the beginning of the sixties are presented.

INIS Descriptors AMERICIUM 241; ANIMALS; ATMOSPHERIC PRECIPITATIONS; BONE TISSUES; CESIUM 134; CESIUM 137; DIET; DRINKING WATER; ENVIRONMENT; FAROE ISLANDS; FOOD CHAINS; GLOBAL FALLOUT; GREENLAND; LEAD 210; MAN; MILK; MOLLUSCS; POLONIUM 210; PLANTS; PLUTONIUM 238; PLUTONIUM 239; RADIOACTIVITY; SEAWATER; SEAWEEDS; SEDIMENTS; SHRIMP; STRONTIUM 90; TECHNETIUM 99.

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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)
ALI: annual limit of intake (according to ICRP)

cal: calorie = 4.186 J
rad: 0.01 Gy
rem: 0.01 Sv
Ci: curie: $3.7 \cdot 10^{10}$ Bq (= $2.22 \cdot 10^{12}$ 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: mikro: 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.

a^{-1}: per annum
OR: observed ratio
CF: concentration factor
μR: micro-roentgen, 10^{-6} roentgen
S.U.: pCi ^{90}Sr (g Ca)$^{-1}$
O.R.: observed ratio
M.U.: pCi ^{137}Cs (g K)$^{-1}$

V: vertebrae

m: male

f: female

nSr: natural (stable) Sr

eqv. mg KCl: equivalents mg KCl: activity as from 1 mg KCl (~ 0.88 dpm). 1 g K ~ 756 pCi ~ 28 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

Δ: one standard deviation due to counting

S.S.D.: sum of squares of deviation: $\Sigma(\bar{x}-x_i)^2$

f: degrees of freedom

s^2: variance

v^2: ratio between the variance in question and the residual variance

P: probability fractile of the distribution in question

η: coefficient of variation, relative standard deviation

anova: analysis of variance

Counting errors: given as relative standard deviation:

no indication: < 20%

A: 20-33%

B: >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

Since 1962 we have published separate annual reports for the Environmental Radioactivity in the Faroes[1] and in Greenland[2]. The reports on and after 1983 are contained in the new series: "Environmental Radioactivity in the North Atlantic Region. The Faroe Islands and Greenland included" of which the present report is the second.

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 marine environmental radioactivity studies from other parts of the North Atlantic region and, furthermore, include sea water data from the Faroe Islands and Greenland. Chapter 4 also includes results from samplings carried out in earlier years.

2. ENVIRONMENTAL RADIOACTIVITY IN THE FAROE ISLANDS IN 1984

2.1. Introduction

2.1.1.

The fallout programme for the Faroes, which was initiated in 1962[1] in close co-operation with the National Health Service and the chief physician of the Faroes, was continued in 1984. Samples of human bone were obtained in 1984 from Dronning Alexandrine's Hospital in Thorshavn.

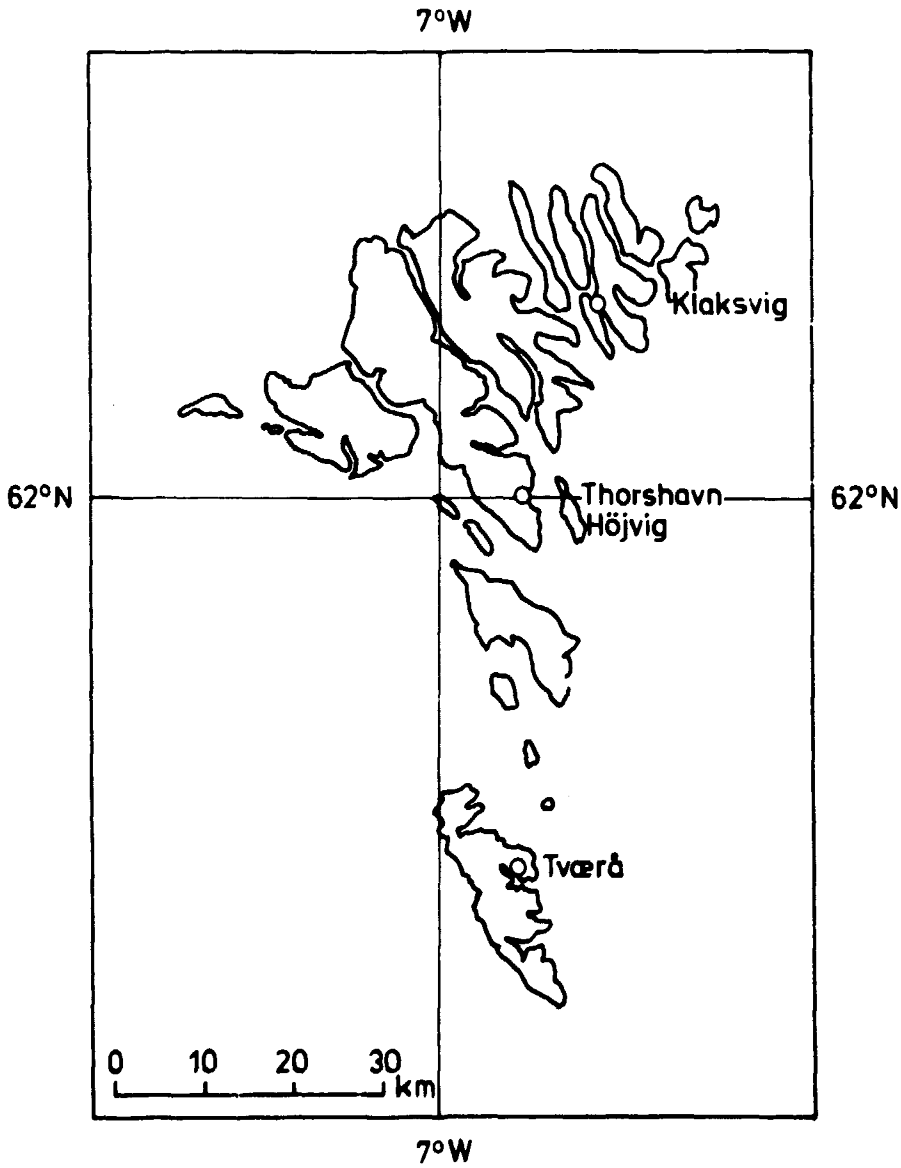


Fig. 2.1. The Faroese Islands

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, 443, 470, 488 and 510[1].

2.1.3.
The estimated mean diet of the Faroese as used in this report is still based on the estimate given by the late Professor E. Hoff-Jørgensen, Ph.D., in 1962.

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. 527 and in Chapter 3 of this report, respectively.

2.2. Results and discussion

2.2.1. Strontium-90 in Faroese precipitation

Table 2.1 shows the ^{90}Sr content in precipitation collected at Højvig (near Thorshavn) and Klaksvig in 1984. The amount of fallout at Højvig was a factor of 2.5 greater than that found at Klaksvig, although the precipitation at Højvig was only 40% of that observed at Klaksvig. The reason to this was the inexplicably high concentration found at Højvig in Jan-April 1984.

The ^{90}Sr fallout in 1984 was similar to that in 1983. In Denmark the 1984 levels were 0.8 times the 1983 levels[2].

Table 2.2.1.1. Strontium-90 in precipitation in the Faroes in 1984 (sampling area = 0.02 m^2)

	Höjvig		Klaksvig	
	Bq m^{-3}	Bq m^{-2}	Bq m^{-3}	Bq m^{-2}
Jan-April	14.1	4.6	1.18	1.00
May-June	2.7 A	0.18 A	1.2 B	0.06 B
July-Aug	3.1 A	0.25 A	1.6 B	0.10 B
Sept-Dec	1.68A	0.60 A	0.95	1.07
1984	6.8	Σ 5.63 Σ_m 0.830	1.07	Σ 2.23 Σ_m 2.090

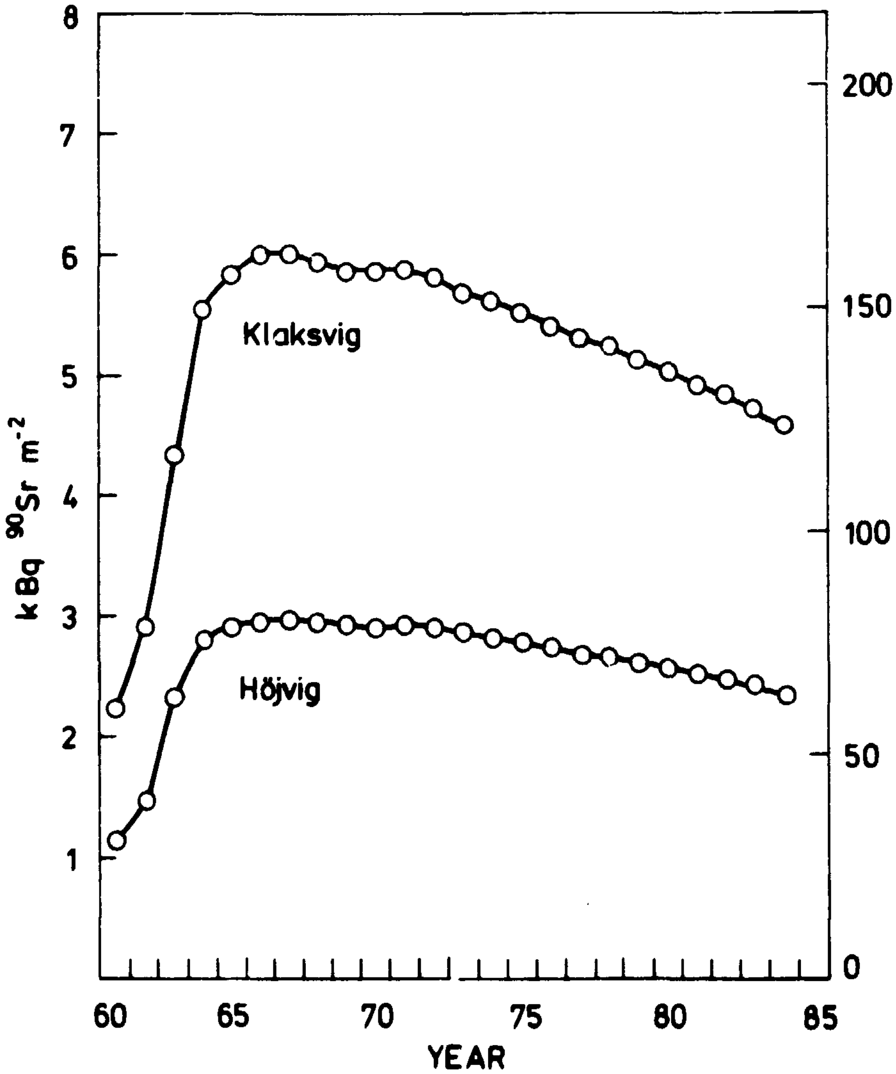


Fig. 2.2.1. Accumulated ^{90}Sr at Klaksvig and Højvig calculated from precipitation measurements since 1962. The accumulated fallout by 1962 was estimated from the Danish fallout data (cf. Risø Report No. 527[3]), Appendix D) and from the ratio between the ^{90}Sr fallout at the Faroese stations and the fallout in Denmark in the period 1962-1984 (cf. Table 2.2.1.2).

Table 2.2.1.2. Fallout rates and accumulated fallout (Bq ^{90}Sr m^{-2}) in the Faroes 1950-1984

	Höjvig		Klaksvig	
	d_i	$A_{i(29)}$	d_i	$A_{i(29)}$
1950	1.08	1.06	2.15	2.10
1951	5.21	6.12	10.34	12.14
1952	10.21	15.94	20.27	31.64
1953	25.78	40.74	51.18	80.87
1954	98.02	135.48	194.58	268.94
1955	128.96	258.20	256.00	512.54
1956	159.90	408.22	317.41	810.34
1957	159.90	554.70	317.41	1101.12
1958	221.82	758.18	440.34	1505.05
1959	314.64	1047.48	624.58	2079.33
1960	58.78	1080.14	116.69	2144.16
1961	76.36	1129.19	151.59	2241.52
1962	383.01	1476.48	760.31	2930.93
1963	913.00	2333.05	1503.00	4329.21
1964	544.00	2809.10	1363.00	5557.77
1965	181.00	2919.48	436.00	5852.21
1966	112.00	2959.88	289.00	5996.17
1967	94.70	2982.44	182.00	6032.25
1968	44.00	2954.96	55.50	5943.97
1969	41.10	2925.30	65.10	5867.15
1970	53.60	2908.54	141.00	5866.25
1971	101.00	2938.46	156.00	5880.02
1972	34.40	2902.65	55.10	5794.94
1973	24.20	2857.73	26.50	5683.95
1974	33.80	2823.23	58.80	5607.12
1975	34.40	2790.14	47.80	5521.36
1976	8.88	2732.91	21.60	5412.05
1977	27.40	2695.12	34.40	5317.81
1978	37.30	2667.89	47.60	5238.69
1979	13.90	2618.45	22.20	5136.64
1980	11.70	2568.03	12.60	5027.63
1981	22.50	2529.35	26.70	4934.95
1982	7.75	2477.18	4.79	4823.08
1983	3.37	2421.96	2.75	4711.85
1984	6.78	2371.38	1.07	4601.61

1950-1961: are estimated values based upon HASL data (HASL Appendix 291, 1975) considering that the mean ratio between ^{90}Sr fallout in Denmark and New York was 0.7 in the period 1962-1974 and that the mean ratios between ^{90}Sr fallout in Höjvig and Denmark and between Klaksvig and Denmark are 1.39 and 2.76, respectively[5].

2.2.2. Strontium-90 and Cesium-137 in Faroese grass

Grass samples were collected near Thorshavn in 1984. Table 2.2.2 shows the results. The 1984 ^{137}Cs mean level in grass was 1.16 times the 1983 level. As compared with Danish grass in 1984[3] we found the ^{90}Sr level (Bq (kg Ca)$^{-1}$) in the Faroese grass to be higher by a factor of approximately 8.5 in the summer months, which is in agreement with the observations in previous years.

Table 2.2.2. Strontium-90 and Cesium-137 in grass from Thorshavn 1984

Month	Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr (kg Ca)$^{-1}$	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs (kg K)$^{-1}$	$^{137}Cs/^{90}Sr$
June	1.94	4400	7.6	1970	5.3
August			13.1	3700	

2.2.3. Strontium-90 and Cesium-137 in Faroese milk

As previously[1], weekly samples of fresh milk were optained from Thorshavn, Klaksvig, and Tværå. Strontium-90 and ^{137}Cs were determined in bulked monthly samples.

Table 2.2.3.1 shows the results and Tables 2.2.3.2, 2.2.3.3 and 2.2.3.4 the analysis of variance of the Bq ^{90}Sr (kg Ca)$^{-1}$, Bq ^{137}Cs (kg K)$^{-1}$, and Bq ^{137}Cs m^{-3} figures, respectively. As also observed earlier, the variation between locations was significant for ^{137}Cs and probably also for ^{90}Sr. The highest levels were found in the milk from Tværå and Klaksvig, and the lowest in Thorshavn milk.

Figure 2.2.3.1 shows the quarterly Bq ^{90}Sr (kg Ca)$^{-1}$ values and Fig. 2.2.3.2 the quarterly Bq ^{137}Cs m^{-3} levels since 1962. The annual mean values for 1984 were 159 Bq ^{90}Sr (kg Ca)$^{-1}$ (4.3 S.U.) and 4100 Bq ^{137}Cs m^{-3} (111 pCi ^{137}Cs l^{-1}), i.e. the ^{90}Sr levels in 1984 were 81% of the 1983 concentration, while the ^{137}Cs levels were approximately 96% of the 1983 mean levels. In Danish milk the ^{90}Sr concentration in 1984 was equal to the 1983 level, and the 137Cs 1984 level was also unchanged.

Table 2.2.3.1. Strontium-90 and Cesium-137 in milk from the Faroes in 1984

Month	Thorshavn			Klaksvig			Tværå			Mean		
	Bq ^{90}Sr (kg Ca)$^{-1}$	Bq ^{137}Cs m^{-3}	Bq ^{137}Cs (kg K)$^{-1}$	Bq ^{90}Sr (kg Ca)$^{-1}$	Bq ^{137}Cs m^{-3}	Bq ^{137}Cs (kg K)$^{-1}$	Bq ^{90}Sr (kg Ca)$^{-1}$	Bq ^{137}Cs m^{-3}	Bq ^{137}Cs (kg K)$^{-1}$	Bq ^{90}Sr (kg Ca)$^{-1}$	Bq ^{137}Cs m^{-3}	Bq ^{137}Cs (kg K)$^{-1}$
Jan	119	1690	970	137	7040	3770	373	3140	2100	210	4000	2300
Feb	99±1	1490	900	210±2	3560	2090	190±16	3290	2100	166	2800	1700
March	115±2	1330	820	212±14	6160	3150	160±7	3350	2320	162	3600	2100
April	220	1130	680	129	7030	4080	152	3490	2240	168	3900	2300
May	127	1150	760	182	6550	3950	131	3150	1810	147	3600	2200
June	129	1870	1150	151	7200	4500	189	3590	2190	156	4200	2600
July	205	2330	1560	160	6130	3670	190	4260	2700	185	4200	2600
Aug	139	3230	1890	136	6640	4330	219	7140	4470	165	5700	3600
Sept	107	2090	1200	165	5250	3810	215	4950	2730	162	4100	2600
Oct	102±4	1080	620	96±19	7870	5090	123±23	3460	2040	107	4100	2600
Nov	102	1430	1010	160	9780	5590	124	3110	1930	129	4800	2800
Dec	74±8	1400	810	250±25	5880	3500	114	3970	2430	146	3800	2200
Mean	128	1680	1030	166	6600	3960	182	3900	2420	159	4100	2500

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

Table 2.2.3.2. Analysis of variance of ln Bq ^{90}Sr (kg Ca)$^{-1}$ in Faroese milk in 1984 (from Table 2.2.3.1)

Variation	SSD	f	s^2	v^2	P
Between months	1.217	11	0.111	0.857	-
Between locations	1.395	2	0.698	5.403	> 97.5%
Month × loc.	2.841	22	0.129	6.416	> 99.5%
Remainder	0.221	11	0.020		

Table 2.2.3.3. Analysis of variance of ln Bq ^{137}Cs (kg K)$^{-1}$ in Faroese milk in 1984 (from Table 2.2.3.1)

Variation	SSD	f	s^2	v^2	P
Between months	1.298	11	0.118	2.171	-
Between locations	11.966	2	5.983	110.086	> 99.95%
Remainder	1.196	22	0.054		

Table 2.2.3.4. Analysis of variance of ln Bq ^{137}Cs m^{-3} in Faroese milk in 1984 (from Table 2.2.3.1)

Variation	SSD	f	s^2	v^2	P
Between months	1.159	11	0.105	1.743	-
Between locations	12.181	2	6.091	100.736	> 99.95%
Remainder	1.330	22	0.060		

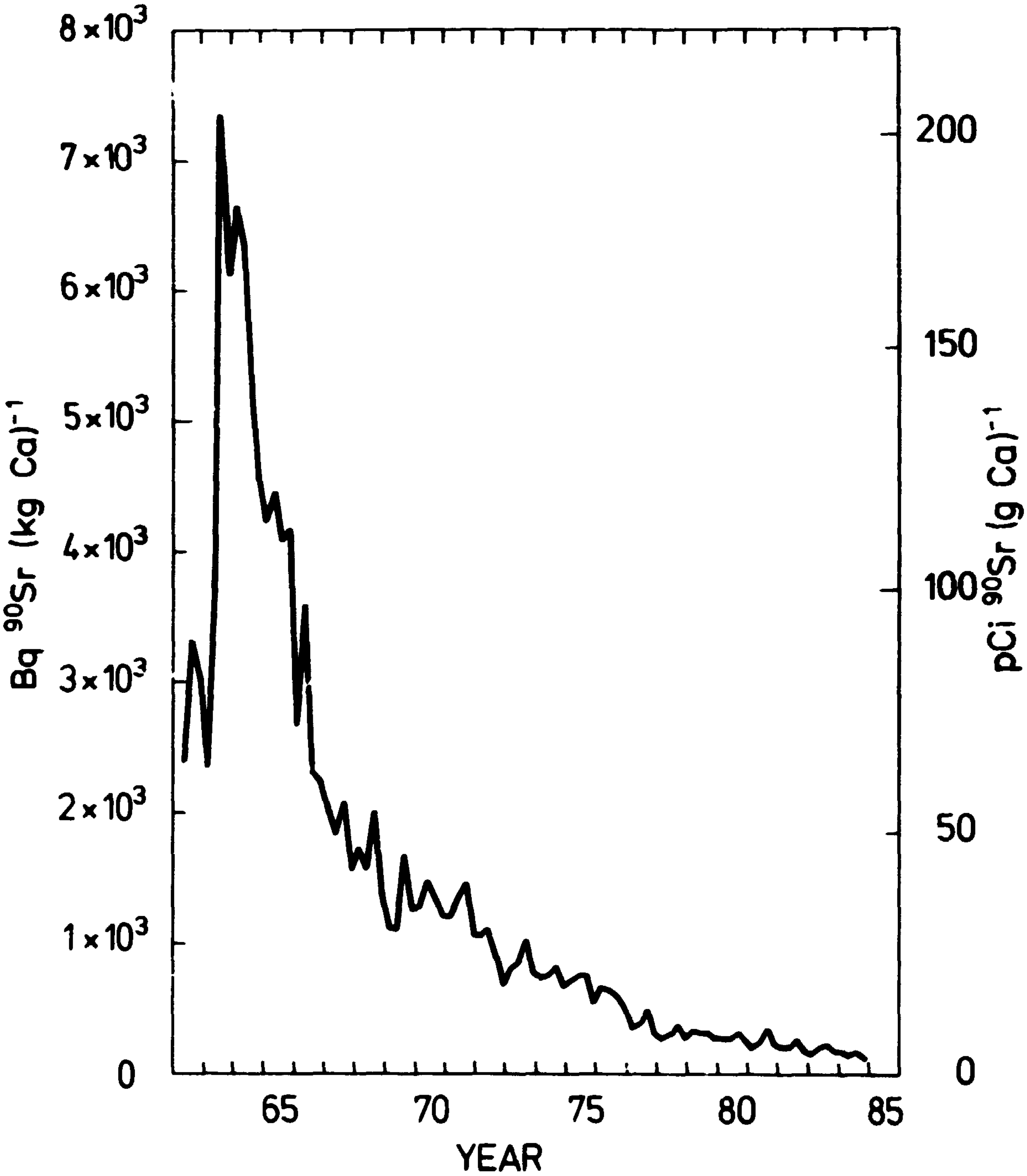
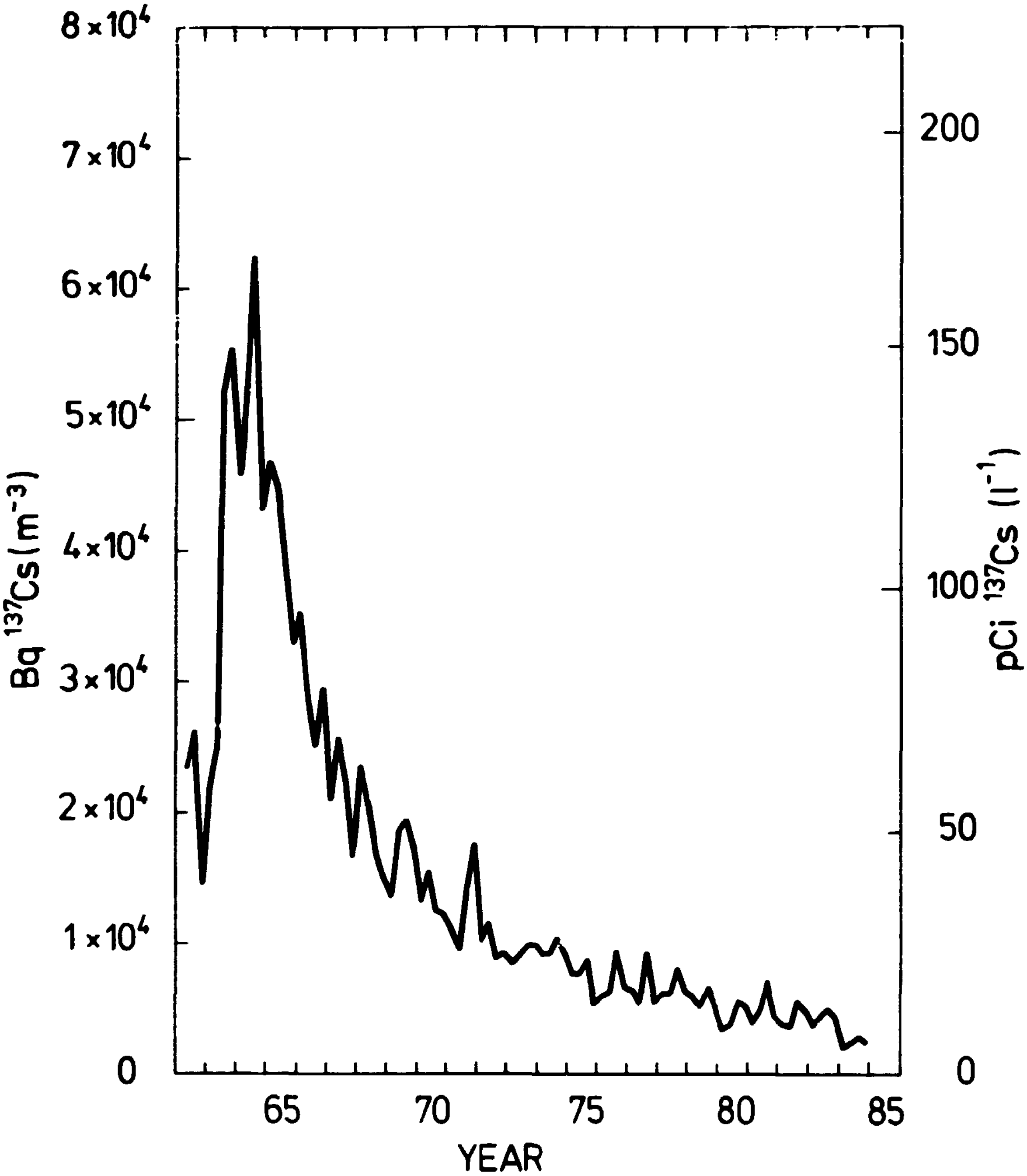


Fig. 2.2.3.1. Strontium-90 in Faroese milk, 1962-1984.



<u>Fig. 2.2.3.2.</u> **Cesium-137 in Faroese milk, 1962-1984.**

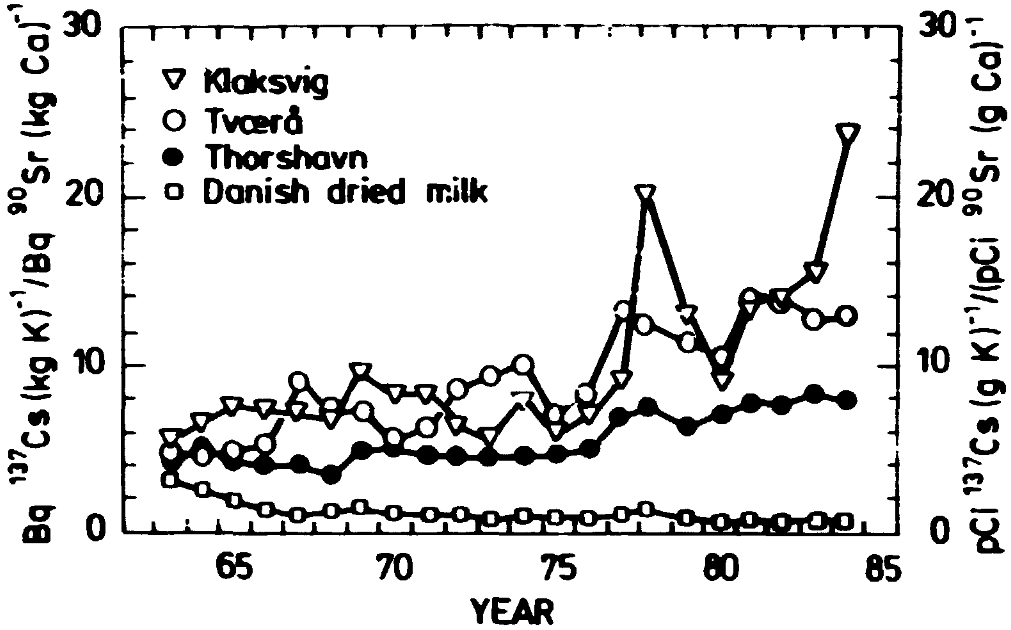


Fig. 2.2.3.3. $\frac{\text{M.U.}}{\text{S.U.}}$ ratios in Faroese and Danish milk, 1963-1984.

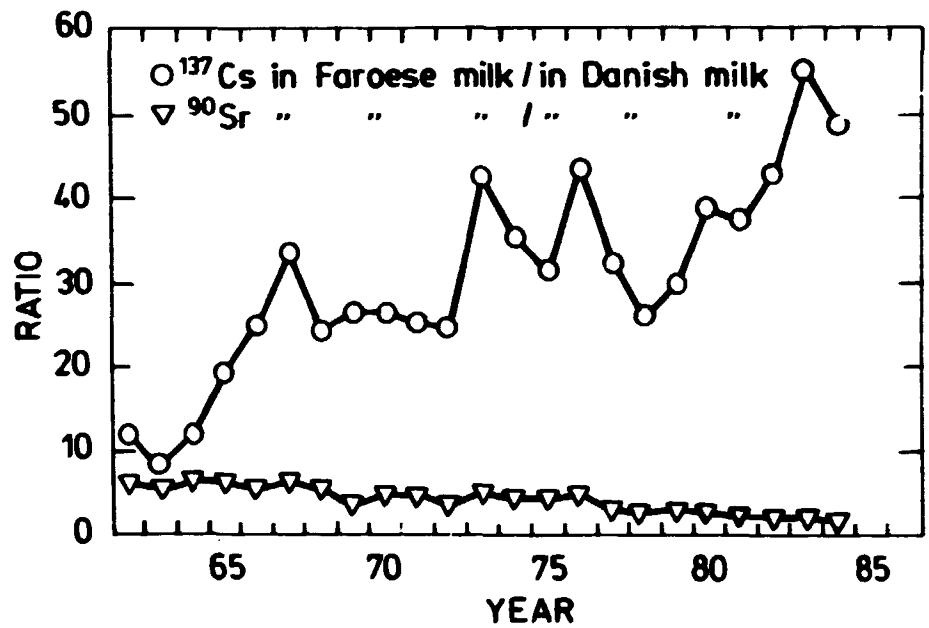


Fig. 2.2.3.4. A comparison between Faroese and Danish milk levels, 1962-1984.

The annual mean values of the ratio: Bq ^{137}Cs (kg K)$^{-1}$/Bq ^{90}Sr (kg Ca)$^{-1}$ in Faroese milk are shown in Fig. 2.2.3.3. The annual mean ratio in 1984 for the three locations was 15.1±4.7 (1 S.E.).

Figure 2.2.3.4 shows a comparison between the ^{90}Sr and ^{137}Cs levels in Faroese- and Danish-produced milk. It is evident that indirect contamination plays an important role for the ^{137}Cs levels in the Faroes, because the ratio between ^{137}Cs in Faroese and Danish milk increases when the fallout rate decreases. The ratios between the ^{90}Sr levels in Faroese and Danisk milk have shown a slight tendency to decrease through the years.

2.2.4. Strontium-90 and Cesium-137 in Faroese terrestrial animals

The mean concentration in lamb meat was 39 Bq ^{137}Cs kg^{-1} in 1984. The ^{90}Sr mean level in bone was 2600 Bq ^{90}Sr (kg Ca)$^{-1}$ and in meat we found 0.12 Bq ^{90}Sr kg^{-1}. As it appears from Figs. 2.2.4.1 and 2.2.4.2 the 1984 concentrations followed the decreasing trend seen in the previous years.

A sample of puffins contained 0.31 Bq ^{137}Cs kg^{-1} meat and 1.1 (A) Bq ^{90}Sr (kg Ca)$^{-1}$ in the bones. In meat the concentration was 0.003 Bq ^{90}Sr kg^{-1} (B).

Table 2.2.4. Strontium-90 and Cesium-137 in lamb collected in the Faroes in October 1984

Location	Sample type	Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr (kg Ca)$^{-1}$	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs (kg K)$^{-1}$
Thorshavn	Meat	0.116	1460 (3300)	31	10900
Tværå	Meat	0.196	2400 (2900)	44	16600
Østerø	Meat	0.050	820 (1730)	41	11200

Bone levels are shown in brackets.

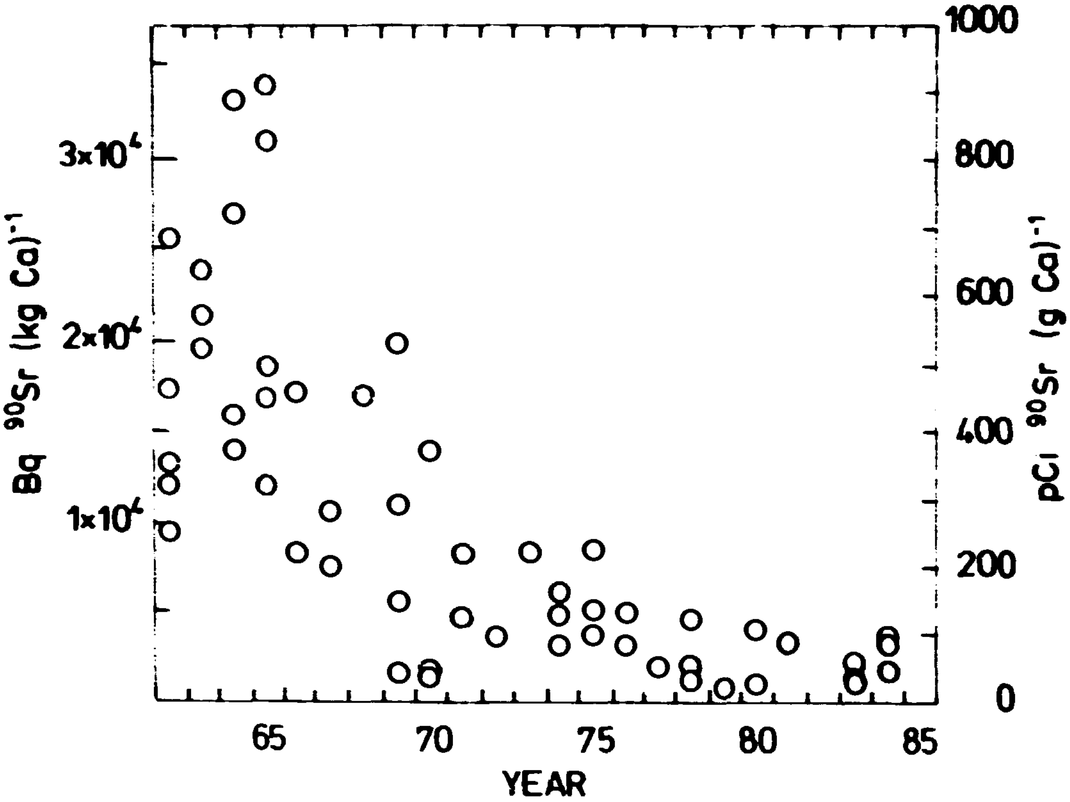


Fig. 2.2.4.1. Strontium-90 (Bq (kg Ca)$^{-1}$)) in lamb bone collected in the Faroes, 1962-1984.

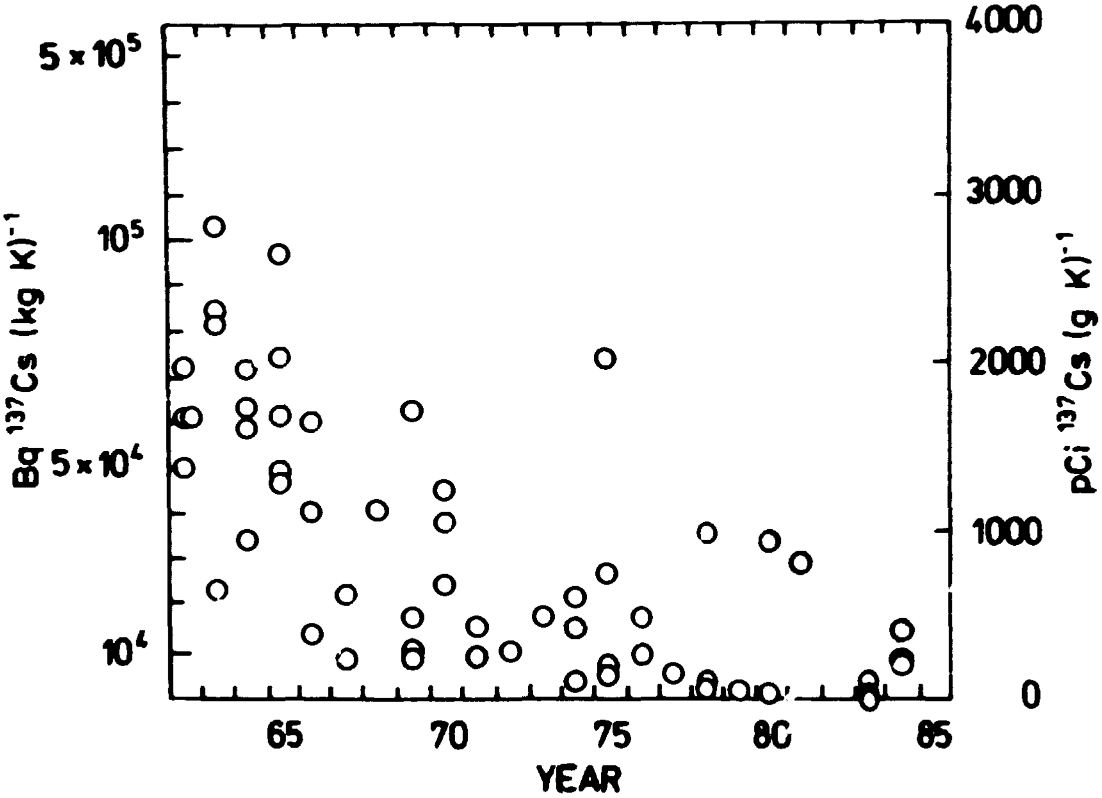


Fig. 2.2.4.2. Cesium-137 (Bq (kg K)$^{-1}$) in lamb meat collected in the Faroes, 1962-1984.

2.2.5. Strontium-90 and Cesium-137 in Faroese sea animals

Table 2.2.5.1 shows the ^{137}Cs levels in fish collected in 1984 in the Faroes. The mean levels in Gadus aeglefinus and Gadus callarias were 0.29 Bq ^{137}Cs kg^{-1} and 0.001 Bq ^{90}Sr kg^{-1}.

Whale meat from August 1984 contained 0.046 Bq ^{90}Sr kg^{-1} and 0.09 (A) Bq ^{137}Cs kg^{-1} (83 (A) Bq ^{137}Cs (kg K)$^{-1}$).

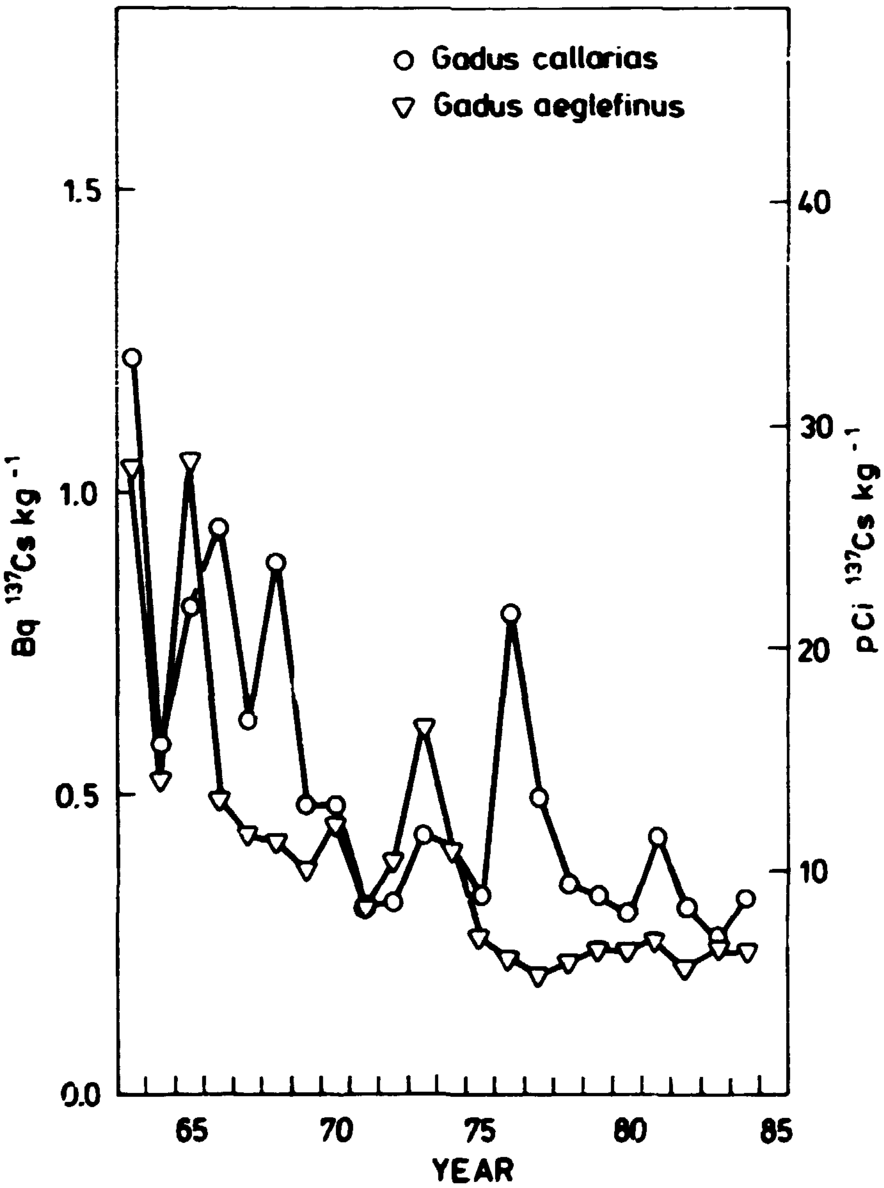


Fig. 2.2.5.1. Cesium-137 levels in meat of cod (Gadus callarias) and Haddock (Gadus aeglefinus) collected in the Faroes, 1962-1984.

Table 2.2.5.1. Strontium-90 and Cesium-137 in fish flesh from the Faroes in 1984

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 flesh			0.30	82
June	- " -	- " -			0.44	115
Sept	- " -	- " -	0.001 B	12 B	0.29	71
Dec	- " -	- " -			0.29	73
March	Gadus aeglefinus	Haddock flesh			0.29	77
Sept	- " -	- " -	B.D.L.	B.D.L.	0.24	62
Dec	- " -	- " -			0.199	55

2.2.6. Strontium-90 and Tritium in Faroese drinking water

Drinking-water samples were collected as previously but the samples were combined before the analysis as shown in Table 2.2.6.1. As in previous years, drinking water from Thorshavn contained more ^{90}Sr than that from Klaksvig and Tværå (cf. the explanation in Risø Report No. 181[1]). The mean level in 1984 was 3.9 Bq ^{90}Sr m^{-3} (0.11 pCi l^{-1}), i.e. lower than in 1983.

Figure 2.2.6.1 shows the annual mean levels of ^{90}Sr in drinking water from the three locations since 1962.

Table 2.2.6.1. Strontium-90 in drinking water from the Faroes in 1984 (Unit: Bq m^{-3})

	Thorshavn	Klaksvig	Tværå
Jan-June	(7.3)	1.19	4.7
July-Dec	5.5	0.80	4.0
1984	6.4	1.00	4.4

Figures in brackets were calculated from VAR3[12]

Table 2.2.6.2. Tritium in drinking water from the Faroes in 1984 (Unit: kBq m^{-3})

	Thorshavn	Klaksvig	Tværå
Jan-June	B.D.L.	B.D.L.	2.5±0.7
July-Dec	B.D.L.		

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

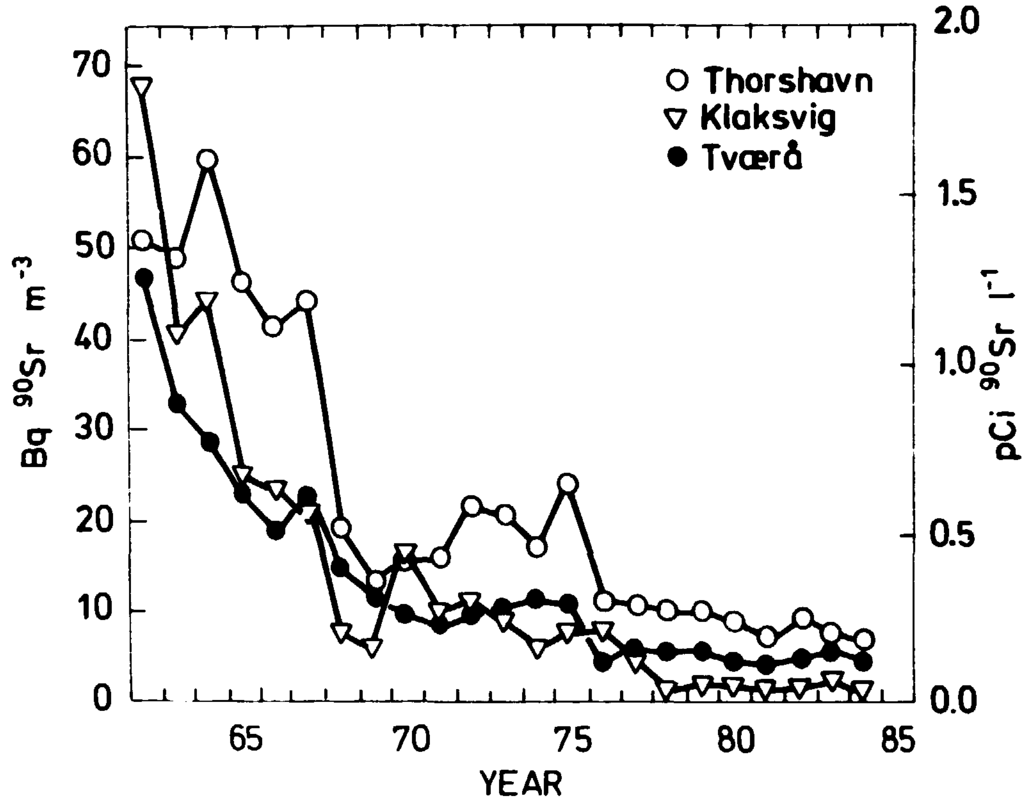


Fig. 2.2.6.1. Strontium-90 in drinking water from the Faroes, 1962-1984.

2.2.7. Strontium-90 and Cesium-137 in miscellaneous Faroese samples

2.2.7.1. Faroese soil

No samples in 1984.

2.2.7.2. Faroese sea water

Cf. Chapter 4, Fig. 2.2.7.2 and Table 2.2.7.2.

2.2.7.3. Faroese sea plants

Table 2.2.7.3. shows the ^{90}Sr and ^{137}Cs contents in Laminaria and Alaria esculenta in 1984.

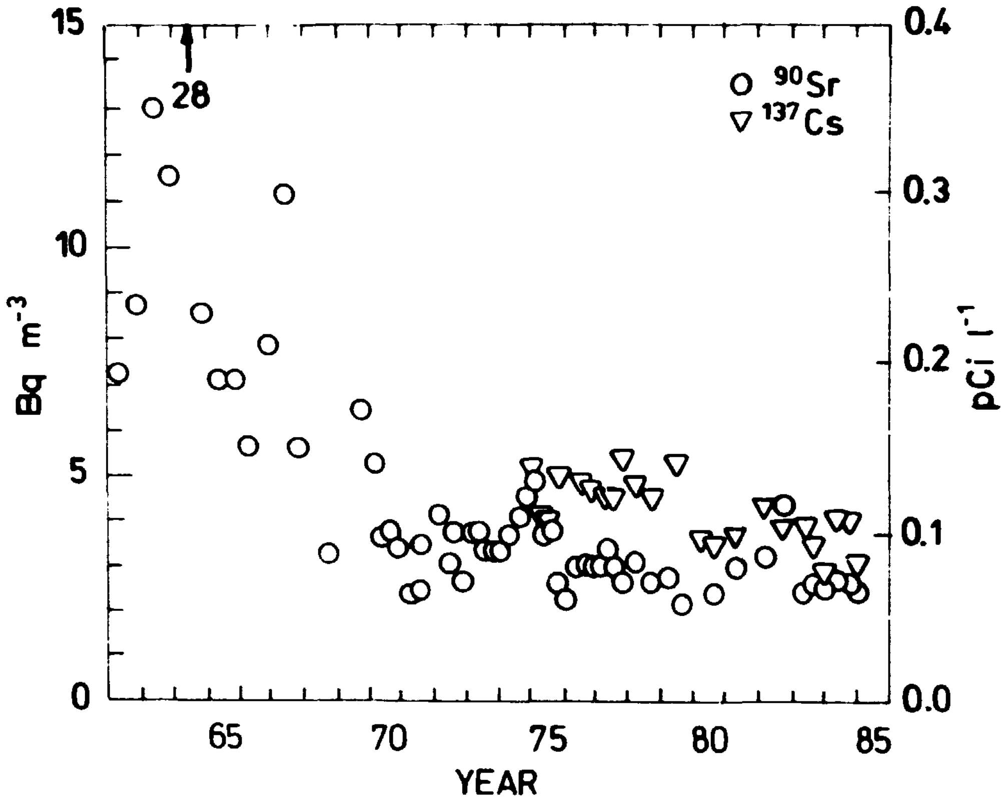


Fig. 2.2.7.2. Strontium-90 and Cesium-137 in Faroese sea water 1962-1984.

Table 2.2.7.2. Strontium-90, Cesium-137 and Tritium in surface sea water from the Faroes in 1984

Sampling month	Bq ^{90}Sr m^{-3}	Bq ^{137}Cs m^{-3}	kBq ^{3}H m^{-3}	Salinity o/oo
April	2.7	4.1	B.D.L.	35.0
August	2.6	4.0		35.0
December	2.4	3.1		34.0
1984	2.6	3.7		34.7

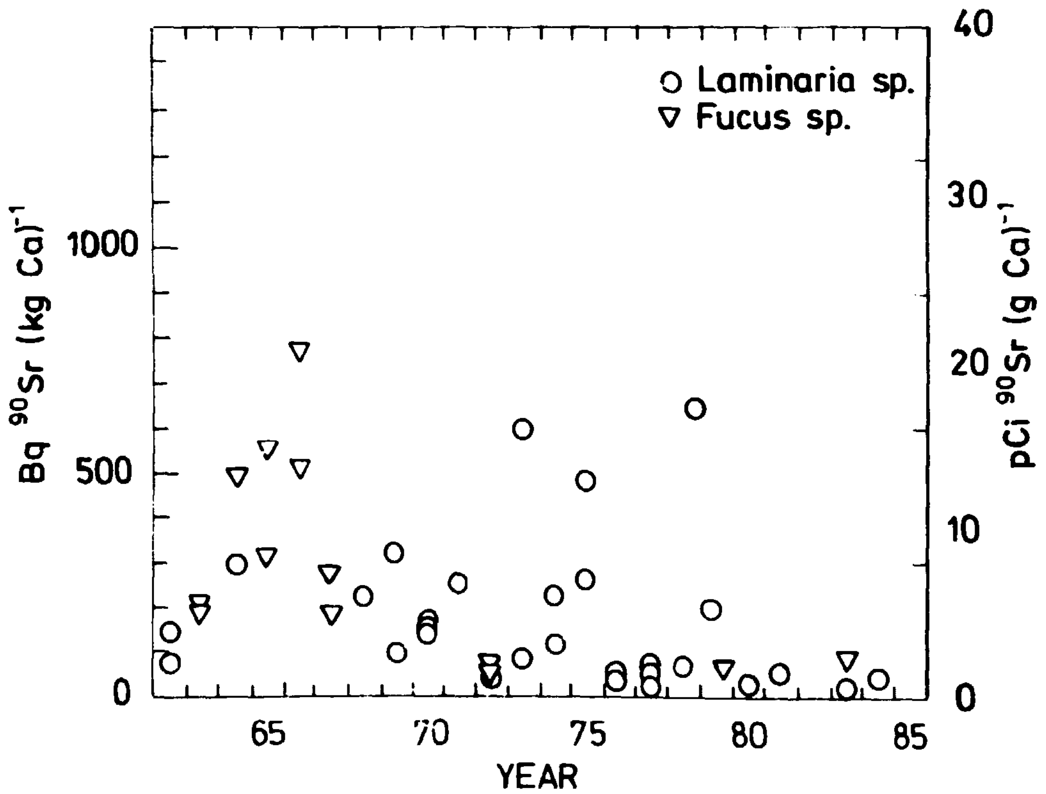


Fig. 2.2.7.3. Strontium-90 (Bq (kg Ca)$^{-1}$) in sea plants collected at Thorshavn, 1962-1984.

Table 2.2.7.3. Radionuclides in Faroese seaweed collected in 1984

Species	Date	Bq ^{90}Sr kg^{-1} dry	Bq ^{90}Sr (kg Ca)$^{-1}$	Bq ^{137}Cs kg^{-1} dry	Bq ^{137}Cs (kg K)$^{-1}$
Laminaria	April	0.68 A	50 A	0.78 A	11.0 A
- " -	Aug	0.83	59	1.16	18.3
Alaria esculenta	April	0.53	50	0.53 A	8.6 A
- " -	Aug	0.66	40	0.42 B	10.2 B

2.2.7.4. Faroese vegetables

Two samples of potatoes were analysed in 1984. The mean content was 0.46 Bq ^{90}Sr kg^{-1} (17000 Bq ^{90}Sr $(kg\ Ca)^{-1}$) and 3.7 Bq ^{137}Cs kg^{-1} (990 Bq ^{137}Cs $(kg\ K)^{-1}$).

Table 2.2.7.4. Radionuclides in Faroese potatoes collected in November 1984

Location	Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr $(kg\ Ca)^{-1}$	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs $(kg\ K)^{-1}$
Thorshavn	0.54	16200	3.1	810
Klaksvig	0.38	17800	4.2	1170

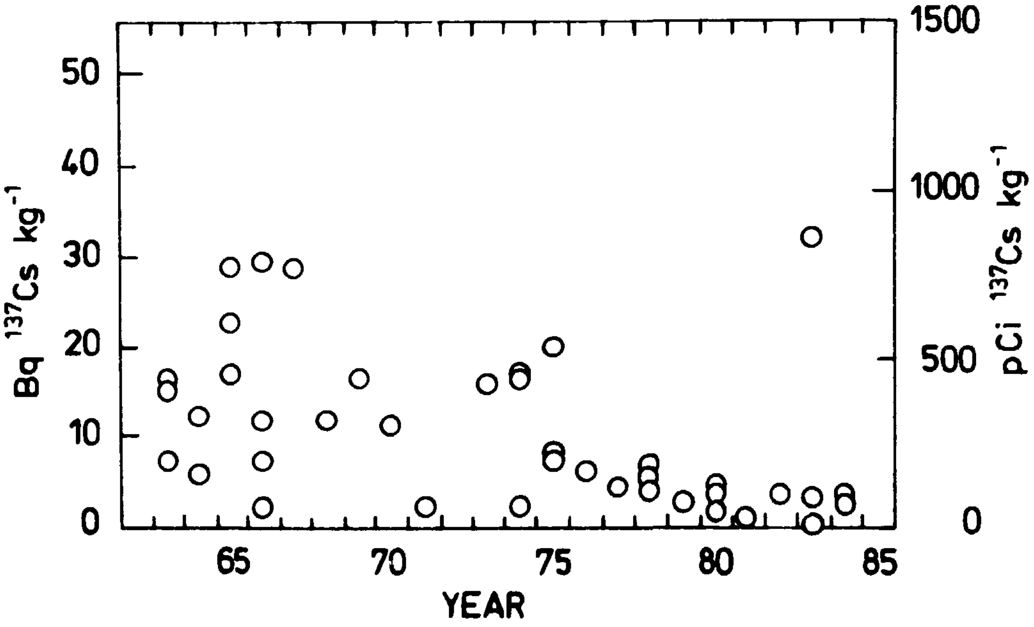


Fig. 2.2.7.4.1. Cesium-137 in Faroese potatoes, 1962-1984.

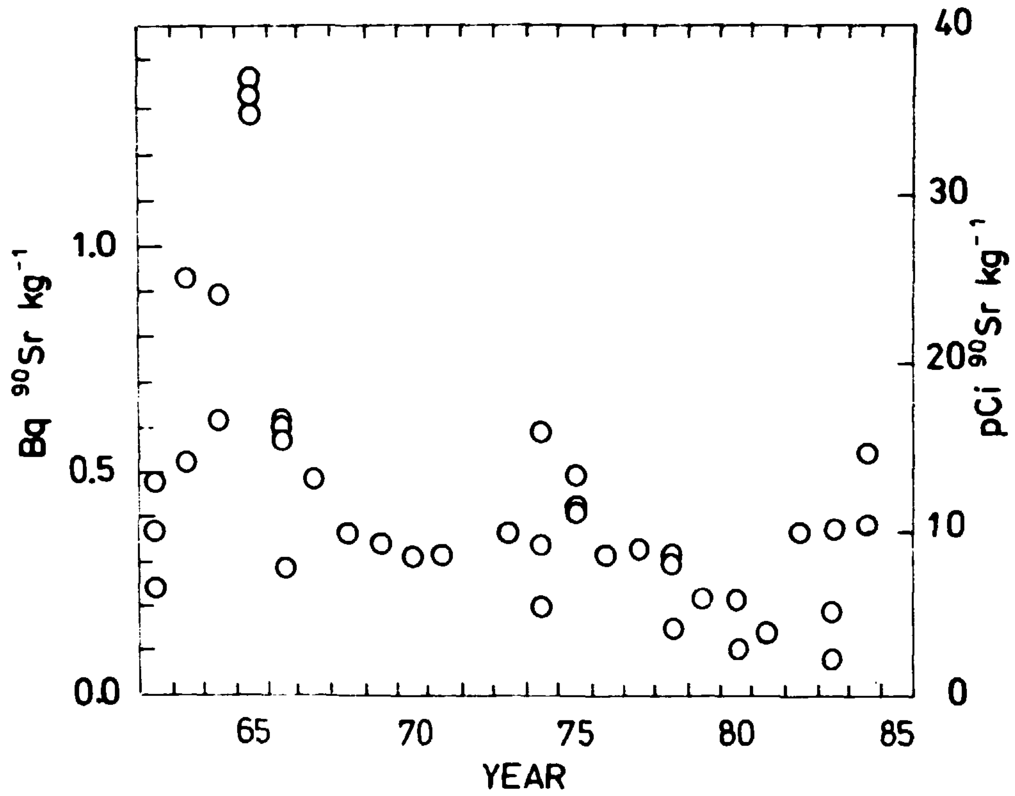


Fig. 2.2.7.4.2. Strontium-90 in Faroese potatoes, 1962-1984.

2.2.7.5. Faroese bread

Rye bread and white bread were collected at Thorshavn in June. The levels in white bread were 0.14 Bq ^{90}Sr kg^{-1} and 0.04 Bq ^{137}Cs kg^{-1}. The rye bread collected in 1984 contained 0.35 Bq ^{90}Sr kg^{-1} and 0.07 Bq ^{137}Cs kg^{-1}. The bread levels were similar to those in 1983.

The ^{137}Cs and ^{90}Sr (kg^{-1}) levels in Faroese rye bread in 1984 were similar to the corresponding Danish[3]).

Table 2.2.7.5. Strontium-90 and Cesium-137 in Faroese bread in June 1984

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	0.138	63	0.04 A	26 A
Rye bread	0.35	101	0.07 A	30 A

2.2.7.6. Faroese eggs

Eggs were collected from Thorshavn in June 1984. The levels of hens eggs were 0.021 Bq ^{90}Sr kg^{-1} (35 Bq (kg Ca)$^{-1}$ and < 0.04 Bq ^{137}Cs kg^{-1}.

2.2.8. Humans from the Faroes

2.2.8.1. Strontium-90 in human bone

In 1984 three human bone samples were obtained from Dronning Alexandrine's Hospital in Thorshavn. Table 2.2.8.1 shows the results.

The mean content of femur samples was 59 Bq ^{90}Sr (kg Ca)$^{-1}$ (1.6 pCi ^{90}Sr (g Ca)$^{-1}$).

Compared to Danish vertebrae in 1984[2)] the Faroese samples of femur contained approximately 2 times as much ^{90}Sr.

Table 2.2.8.1. Strontium-90 in human bone collected in the Faroes in 1984

Age	Bone type		Sex	Bq ^{90}Sr (kg Ca)$^{-1}$
82 years	Femur	Amputation	F	77
84 years	Femur	- " -	F	48
87 years	Femur	- " -	M	52
*41 years			M	44

*From Norway.

2.3. Estimate of the mean contents of ^{90}Sr and ^{137}Cs in the Faroese human diet in 1984

2.3.1. Annual quantities

The annual quantities are still based on the estimate made by the late Professor E. Hoff-Jørgensen, Ph.D., in 1962[1] 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 assumed to be of local origin, and 25% comes from Denmark. Hence the ^{90}Sr content in milk consumed in the Faroes in 1984 was 1.2×(0.75×0.159 + 0.25×0.080) = 0.167 Bq ^{90}Sr kg^{-1}, and the ^{137}Cs content was 0.75×4.1 + 0.25×0.085 = 3.10 Bq ^{137}Cs kg^{-1} (cf. 2.2.3 and Ref. 3). 1 kg milk contains 1.2 g Ca.

2.3.3. Cheese

Nearly all cheese consumed in the Faroes is of Danish origin, and the Danish figures from ref. 3 were used: 0.68 Bq ^{90}Sr kg^{-1} and 0.061 Bq ^{137}Cs kg^{-1}.

2.3.4. Grain products

As most grain products are imported from Denmark, the Danish figures for 1984[3] 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 concentration of ^{90}Sr in grain products consumed in the Faroes in 1984 is 0.24 Bq ^{90}Sr kg^{-1} and 0.094 Bq ^{137}Cs kg^{-1}.

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. 0.46 Bq ^{90}Sr kg-1 and 3.7 Bq 137Cs kg-1.

2.3.6. Other vegetables and fruit

As the amount of vegetables and fruit grown in the Faroes is limited, the Danish figures from 1984[3)] were used. Thus the mean contents in vegetables other than potatoes were 0.31 Bq ^{90}Sr kg^{-1} and 0.052 Bq ^{137}Cs kg^{-1}, and the mean contents in fruit were 0.050 Bq ^{90}Sr kg^{-1} and 0.014 Bq ^{137}Cs kg^{-1}.

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 1984, i.e. 0.12 Bq ^{90}Sr kg^{-1} and 39 Bq ^{137}Cs kg^{-1}. Whale meat contained 0.046 Bq ^{90}Sr kg^{-1} and 0.09 Bq ^{137}Cs kg^{-1}, sea birds contained 0.003 Bq ^{90}Sr kg^{-1} and 0.31 Bq ^{137}Cs kg^{-1}, and eggs (cf. 2.2.4 and 2.2.7.6): 0.021 Bq ^{90}Sr kg^{-1} and 0.04 Bq ^{137}Cs kg^{-1}. Hence we estimate the mean content of ^{90}Sr in meat and eggs consumed in 1984 to be

$$0.50 \cdot 0.12 + 0.25 \cdot 0.046 + 0.25 \cdot \left(\frac{0.003+0.021}{2}\right) = 0.075 \text{ Bq } ^{90}\text{Sr kg}^{-1}$$

and the ^{137}Cs content to be

$$0.50 \cdot 39 + 0.25 \cdot 0.09 + 0.25 \cdot \left(\frac{0.31+0.04}{2}\right) = 19.57 \text{ Bq } ^{137}\text{Cs kg}^{-1}.$$

2.3.8. Fish

All fish consumed in the Faroes is of local origin, and the mean contents in fish, obtained from subsection 2.2.5, were 0.001 Bq ^{90}Sr kg^{-1} and 0.29 Bq ^{137}Cs kg^{-1}.

2.3.9. Coffee and tea

The Danish figures for 1984[3)] were used, i.e. 1.23 Bq ^{90}Sr kg^{-1} and 1.53 Bq ^{137}Cs kg^{-1}.

2.3.10. Drinking water

The mean value found in Table 2.2.6.1 was used, i.e. 0.0039 Bq ^{90}Sr kg^{-1}. The ^{137}Cs content was estimated to be approximately one fourth (the ratio found in New York tap water in 1964[4]) of the ^{90}Sr content, i.e. 0.001 Bq ^{137}Cs kg^{-1}.

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

Table 2.3.1. Estimate of the mean content of ^{90}Sr in the human diet in the Faroe Islands in 1984

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	0.167	24.38	21.9
Cheese	7.3	0.68	4.96	4.4
Grain products	80	0.24	19.20	17.2
Potatoes	91	0.46	41.86	37.6
Vegetables	20	0.31	6.20	5.6
Fruit	18	0.050	0.90	0.8
Meat and eggs	37	0.075	2.78	2.5
Fish	91	0.001	0.09	0.1
Coffee and tea	7.3	1.23	8.98	8.0
Drinking water	548	0.0039	2.14	1.9
Total			111.49	

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 186 (5.0 pCi ^{90}Sr $(g\ Ca)^{-1}$).

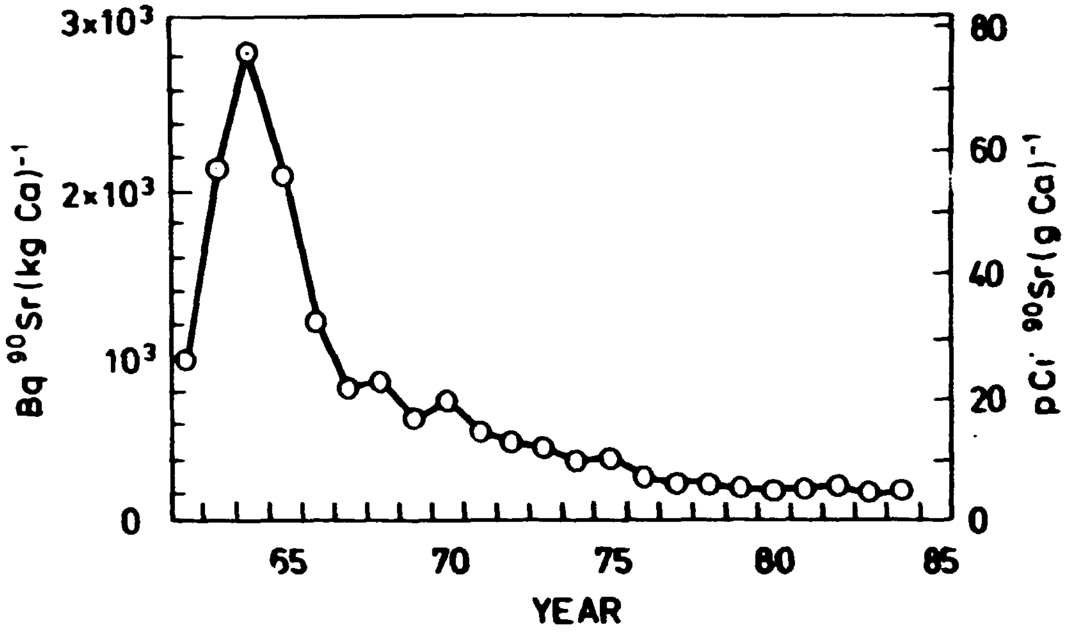


Fig. 2.3.1. Strontium-90 in Faroese diet, 1962-1984.

Table 2.3.2. Estimate of the mean content of ^{137}Cs in the human diet in the Faroe Islands in 1984

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	3.10	452.6	29.0
Cheese	7.3	0.061	0.4	0
Grain products	80	0.094	7.5	0.5
Potatoes	91	3.7	336.7	21.6
Vegetables	20	0.052	1.0	0.1
Fruit	18	0.014	0.3	0
Meat and eggs	37	19.57	724.1	46.4
Fish	91	0.29	26.4	1.7
Coffee and tea	7.3	1.53	11.2	0.7
Drinking water	548	0.001	0.5	0
Total			1560.7	

The mean annual intake of potassium is estimated to be approx. 1.2 kg. Hence the ratio: Bq ^{137}Cs (kg K)$^{-1}$ becomes 1301 (35.1 pCi ^{137}Cs (g K)$^{-1}$).

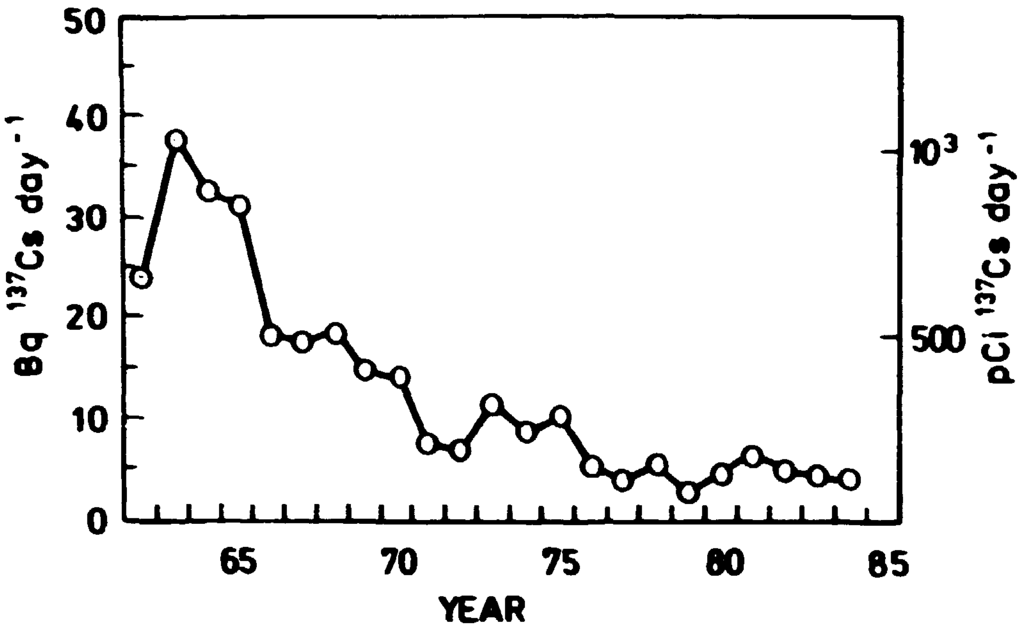


Fig. 2.3.2. Cesium-137 in Faroese diet, 1962-1984.

2.3.11. Discussion

Figures 2.3.1 and 2.3.2 show the Faroese diet levels since 1962.

The 1984 ^{90}Sr level in the total Faroese diet was 115% of the 1983 concentration, and the ^{137}Cs level was 89% of that observed in 1983.

The main contributors to the ^{90}Sr content in the Faroese diet were milk products, cereals and potatoes, which together accounted for approximately 80% of the total ^{90}Sr content in the diet in 1984. As regards ^{137}Cs, potatoes, milk products and meat (lamb) were the most important contributors. In 1984, 97% of the total ^{137}Cs content in the diet originated from these products.

The Faroese mean diet contained 1.6 times as much ^{90}Sr and approximately 18 times as much ^{137}Cs as the Danish diet in 1984[3].

As earlier[1] mentioned, the year-to-year variations in the ^{137}Cs estimates for Faroese diet are markedly influenced by the mutton and potato samples obtained for analysis.

2.4. Conclusion

2.4.1.

The ^{90}Sr fallout rate in the Faroes in 1984 was approximately 4 Bq ^{90}Sr m^{-2} (0.1 mCi km^{-2}). The accumulated fallout by the end of 1984 was estimated at approximately 3500 Bq ^{90}Sr m^{-2} (94 mCi km^{-2}) (the mean at Thorshavn and Klaksvig).

2.4.2.

The mean level of ^{90}Sr in Faroese milk was 159 Bq (kg Ca)$^{-1}$ (4.3 pCi (g Ca)$^{-1}$). The ^{137}Cs concentration was 4100 Bq ^{137}Cs m^{-3} (111 pCi l^{-1}).

Lamb contained 39 Bq ^{137}Cs kg^{-1} (1050 pCi kg^{-1}) in 1984. Fish showed a mean level of 0.29 Bq ^{137}Cs kg^{-1} (7.8 pCi kg^{-1}).

The mean content of ^{90}Sr in drinking water was 3.9 Bq m^{-3} (0.11 pCi l^{-1}).

The mean daily pro capite intakes resulting from the Faroese diet in 1984 were estimated at 0.31 Bq ^{90}Sr (8.2 pCi d^{-1}) and 4.3 Bq ^{137}Cs (115 pCi d^{-1}).

2.4.3.

From the measurements on Faroese human bones (only femur), the Faroese bone level in 1984 was estimated at 59 Bq ^{90}Sr (kg Ca)$^{-1}$ (1.6 pCi (g Ca)$^{-1}$).

The mean content of ^{137}Cs in the Faroese adult was estimated at approximately 3900 Bq ^{137}Cs (kg K)$^{-1}$ (105 pCi (g K)$^{-1}$). This estimate is based on the diet estimate.

APPENDIX 2A

Predictions and observations of ^{90}Sr and ^{137}Cs in Faroese samples in 1984

The models used for the predictions shown in Table 2A were based on data collected 1962-1976[5]. If the predictions for previous years 1977-1982[1] were considered too, we conclude that the model for ^{90}Sr in milk overestimates the level and so do the model for ^{137}Cs in milk from Tværå. The following models underestimate the concentrations: ^{90}Sr in cod fish and ^{137}Cs in milk from Klaksvig.

Table 2A. Comparison between observed and predicted ^{90}Sr and ^{137}Cs concentrations in Faroese samples collected in 1984

Sample	Unit	Observed ±1 S.E.	Number of samples	Predicted	Obs./pre. ±1 S.E.	Model in ref. 5
Drinking water, Thorshavn	Bq ^{90}Sr m^{-3}	6.4	1	10.7	0.60	C.1.4.1 No. 9
- " - , Klaksvig	- " -	1.0 ±0.2	2	2.4	0.42±0.08	- " - No. 10
- " - , Tværå	- " -	4.4 ±0.4	2	2.8	1.57±0.14	- " - No. 11
Sea water	- " -	2.6 ±0.09	3	2.1	1.24±0.04	C.1.5.1 No. 3
Rye bread	Bq ^{90}Sr kg^{-1}	0.35	1	0.32	1.09	C.2.3.1 No. 6
White bread	- " -	0.14	1	0.12	1.17	- " - No. 7
Rye bread	Bq ^{137}Cs kg^{-1}	0.07	1	0.07	1.00	- " - No. 8
White bread	- " -	0.04	1	0.024	1.67	- " - No. 9
Grass	Bq ^{90}Sr $(kg\ Ca)^{-1}$	4400	1	5600	0.79	C.2.4.1 No. 4
- " -	Bq ^{137}Cs $(kg\ K)^{-1}$	2800 ±900	2	560	5.00±1.61	C.2.4.2 No. 3
Potatoes	Bq ^{90}Sr kg^{-1}	0.46 ±0.08	2	0.21	2.19±0.38	C.2.5.1 No. 11
- " -	Bq ^{137}Cs kg^{-1}	3.6 ±0.6	2	1.5	2.40±0.40	C.2.5.3 No. 8
Milk	Bq ^{90}Sr $(kg\ Ca)^{-1}$	159 ±7	12	315	0.50±0.02	C.3.3.1 No. 1
Milk Thorshavn	Bq ^{137}Cs m^{-3}	1680 ±180	12	1060	1.59±0.17	C.3.3.2 No. 7
Milk Klaksvig	- " -	6600 ±430	12	2200	3.00±0.20	- " - No. 9
Milk Tværå	- " -	3900 ±330	12	9200	0.42±0.04	- " - No. 11
Cod fish	Bq ^{90}Sr $(kg\ Ca)^{-1}$	13	1	24	0.54	C.3.5.1 No. 3
- " -	Bq ^{137}Cs kg^{-1}	0.29 ±0.03	7	0.21	1.38±0.14	C.3.5.2 No. 2
Lamb meat	Bq ^{90}Sr $(kg\ Ca)^{-1}$	1560 ± 460	3	1320	1.18±0.35	C.3.4.1 No. 5
- " -	Bq ^{137}Cs $(kg\ K)^{-1}$	12900 ± 1850	3	3500	3.69±0.53	C.3.4.2 No. 5
Lamb bone	Bq ^{90}Sr $(kg\ Ca)^{-1}$	2600 ± 470	3	2200	1.18±0.21	C.3.4.3 No. 1
Whale	Bq ^{90}Sr kg^{-1}	0.046	1	0.014	3.29	C.3.6.1 No. 3
- " -	Bq ^{137}Cs kg^{-1}	0.09	1	0.38	0.24	C.3.6.2 No. 2
Sea birds	- " -	0.31	1	0.06	5.17	C.3.6.2 No. 8

3. ENVIRONMENTAL RADIOACTIVITY IN GREENLAND IN 1984

3.1. Introduction

3.1.1.

In 1984 the sampling programme was similar to that used in previous years but for a few minor modifications.

3.1.2.

As hitherto, samples were collected through the local district physicians and the head of the telestations. However, we have also obtained samples collected by the Greenland Fisheries and Environmental Research Institute.

3.1.3.

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

3.1.4.

The environmental studies in Greenland were carried out together with corresponding investigations in Denmark (cf. Risø Report No. 527[3]) 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 ref. 2.

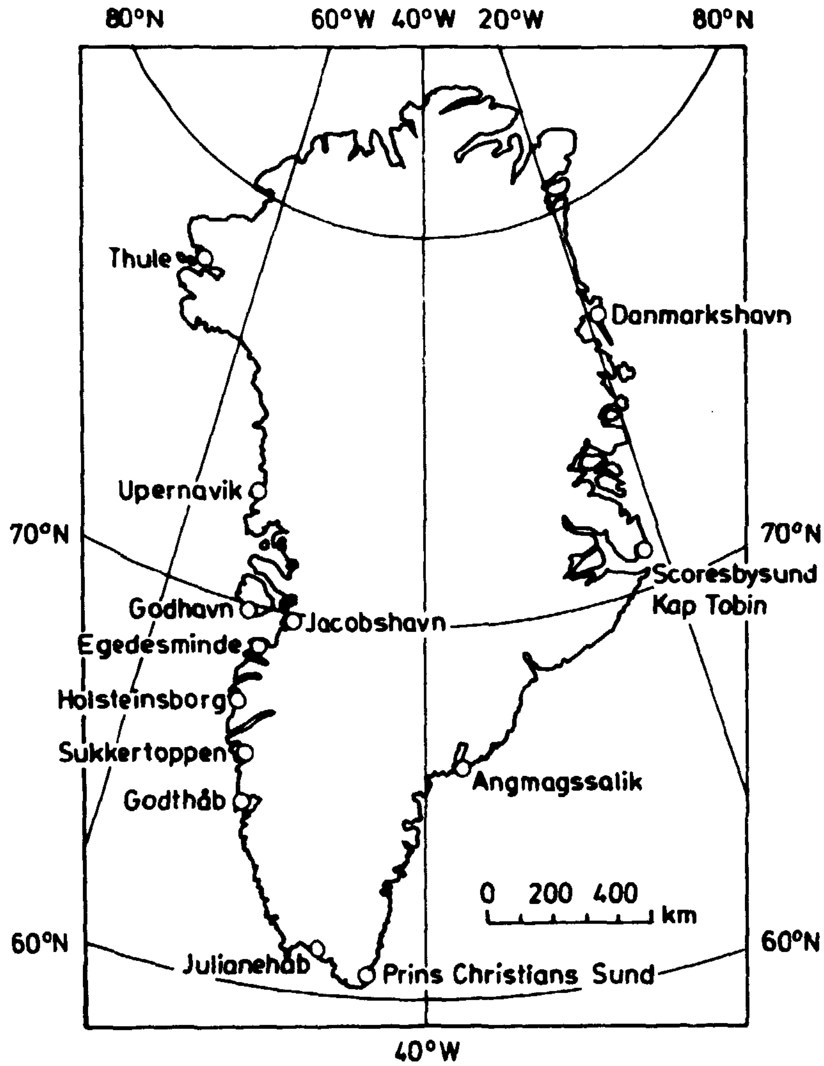


Fig. 3.1. Greenland

3.2. Results and discussion

3.2.1. Strontium-90 in Greenland precipitation

Table 3.2.1.1 shows the results of the measurements.

The ^{90}Sr fallout in 1984 at the Greenland stations were generally lower as compared with 1983. In Denmark[3)] and the Faroes (cf. 2.2.1) the fallout in 1984 was approximately 80% of that in 1983.

Figure 3.2.1 shows the accumulated ^{90}Sr at the various stations in Greenland, since measurements began in 1962.

Table 3.2.1.1. Strontium-90 in precipitation in Greenland in 1984. (Sampling area: 0.02 m^2)

Location m precipitation	Unit	Jan-March	April-June	July-Sept	Oct-Dec	1984
Upernavik	Bq m^{-3}	5.9		15.4		11.2
Σ 0.196	Bq m^{-2}	0.51		1.68		2.19
Godthåb	Bq m^{-3}	8.2 A	4.2 B	0.8 B	1.9 B	2.6
Σ 0.771	Bq m^{-2}	0.77 A	0.55 B	0.28 B	0.28	1.98
Prins Chr. Sund	Bq m^{-3}	(4.5)	14.1	1.21 A	1.24	(2.1)
Σ (0.977)	Bq m^{-2}	(0.71)	0.33	0.45 A	0.53	(2.0)
Scoresbysund	Bq m^{-3}	0.8 B	1.93 A	0.9 B	0.7 B	1.0
Σ 1.042	Bq m^{-2}	0.30 B	0.39 A	0.14 B	0.24 B	1.07
Danmarkshavn	Bq m^{-3}	7.6	11.5 A	4.7	3.0 B	5.9
Σ 0.214	Bq m^{-2}	0.46	0.31 A	0.33	0.17 B	1.27

Figures in brackets were calculated from VAR3[12]

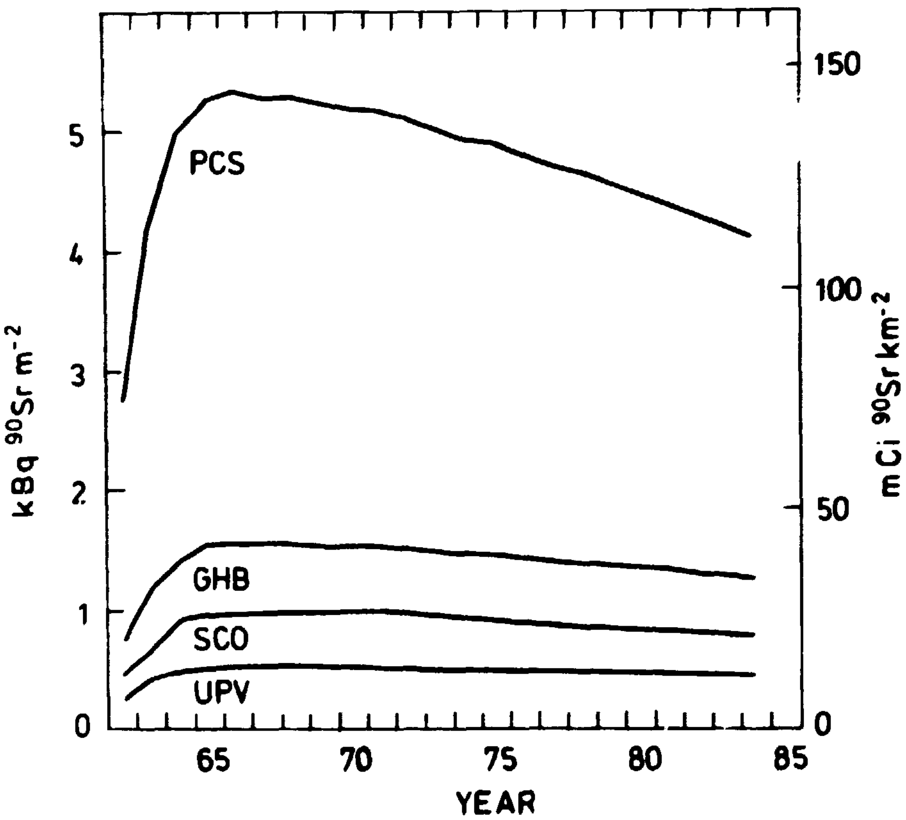


Fig. 3.2.1. Accumulated ^{90}Sr at Prins Chr. Sund, Godthåb, Scoresbysund (Kap Tobin) and Upernavik calculated from precipitation measurements since 1962. The accumulated fallout by 1962 was estimated from the Danish data (cf. Risø Report No. 509[3], Appendix D) and from the ratio between the ^{90}Sr fallout at the Greenland stations and the fallout in Denmark in the period 1962-1984.

Table 3.2.1.2. Fallout rates and accumulated fallout (Bq m^{-2}) in Greenland 1950-1984

	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	24.36	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	29.8[illegible]	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	27.37	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	18.63	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.[illegible]
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	3.15	838.28	7.03	4467.21	4.74	1349.89	3.70	477.41
1981	5.51	823.86	34.04	4394.94	12.95	1330.65	5.55	471.55
1982	2.41	806.75	6.36	4297.35	2.63	1301.79	1.55	461.93
1983	1.44	[illegible].10	(12.4)	(4207.96)	3.65	1274.60	1.88	452.86
1984	1.07	771.51	(2.02)	(4110.55)	1.98	1246.43	2.19	444.30

3.2.2. Radionuclides in Greenland sea water

The detailed results are shown in Chapter 4. Table 3.2.2 shows the samplings carried out from land by local people in 1984. The high ^{90}Sr value from Prins Christians Sund was unaccountable. Further sea water data are shown in Chapter 4 of this report.

Table 3.2.2. Radionuclides in surface sea water collected in Greenland in July-August 1984

Location	Bq ^{90}Sr m^{-3}	Bq ^{137}Cs m^{-3}	Salinity in o/oo
Danmarkshavn	5.51	5.81	29.0
Prins Chr.Sund	9.14	6.40	26.5
Upernavik	3.46	3.45	30.4

3.2.3. Strontium-90 and Cesium-137 in Greenland terrestrial animals

Reindeer samples were obtained from Greenland in 1984. The mean levels in reindeer meat were 0.91 Bq ^{90}Sr kg^{-1} and 98 Bq ^{137}Cs kg^{-1}.

The levels in reindeer were higher than those observed in lamb.

Table 3.2.3.1. Cesium-137 in reindeer meat collected in Greenland in 1984

Location		Month	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs $(kg\ K)^{-1}$
Holsteinsborg		March	75	23000
- " -	I	July	22	5900
- " -	II	-"-	24	6700
Sukkertoppen	I	Winter	149	48000
- " -	II	-"-	229	71000
- " -	III	-"-	190	61000
- " -	IV	-"-	146	49000
K.G.H.	I		25	6400
- " -	II		24	7000
Mean			98	31000
Median			75	23000

Table 3.2.3.2. Strontium-90 in reindeer samples collected in Greenland in 1984

Location		Month	Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr $(kg\ Ca)^{-1}$
Holsteinsborg		March	0.33 (1780)	2600
- " -	I	July	0.11 (840)	800
- " -	II	-"-	0.72 (1360)	2200
Sukkertoppen	I	Winter	1.81 (5400)	3600
- " -	II	-"-	1.15 (4100)	2800
- " -	III	-"-	0.75 (4300)	7200
- " -	IV	-"-	1.35 (5200)	6900
K.G.H.	I		0.55 (1200)	2000
- " -	II		1.44 (1270)	4000
Mean			0.91 (2800)	3600
Median			0.75 (1780)	2800

Bone levels are shown in brackets.

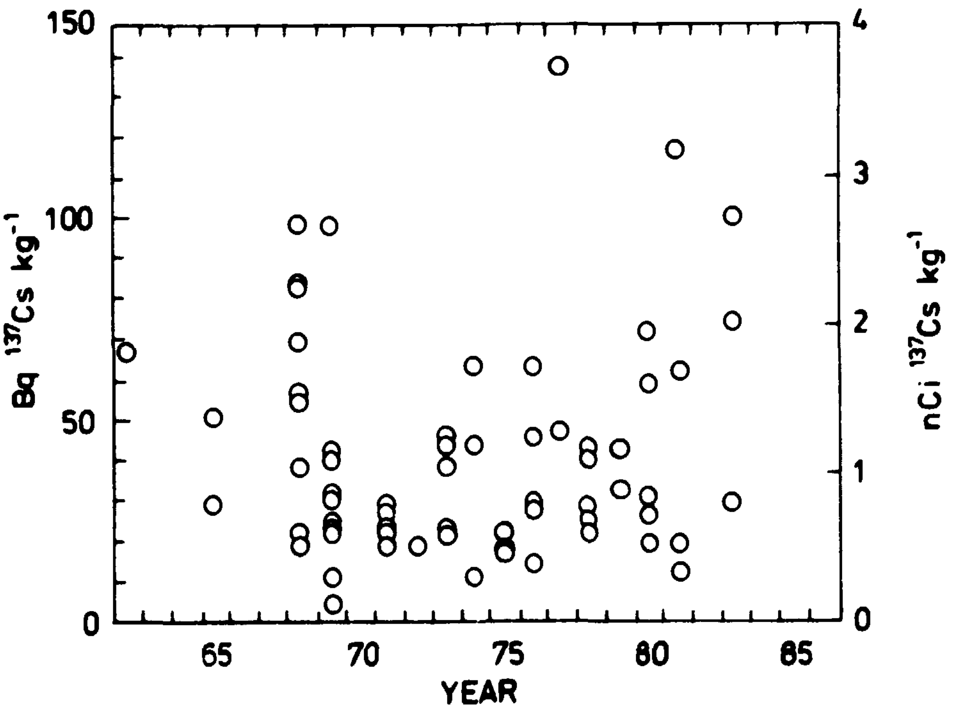


Fig. 3.2.3. Cesium-137 in Greenlandic mutton, 1962-1984.

3.2.4. Strontium-90 and Cesium-137 in Greenland sea animals

The results are shown in Tables 3.2.4.1 and 3.2.4.2. It appears that we only got one fish sample in 1984, a trout, which is not very typical for the fish caught at Greenland. We shall therefore use the fish data from 1983 in our calculation of diet intakes in 1984.

Table 3.2.4.1. Cesium-137 in sea animals collected in Greenland in 1984

Species	Location	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs $(kg\ K)^{-1}$
Seal I	Sukkertoppen	0.53	178
" II	- " -	0.79	300
Whale I	- " -	0.44	210
" II	- " -	0.64	240
"	Holsteinsborg	0.56	210
Shrimps	Jacobshavn	0.07	76
Trout	Holsteinsborg	0.82	290

Table 3.2.4.2. Strontium-90 in sea animals collected in Greenland in 1984

Species	Location	Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr $(kg\ Ca)^{-1}$	
Seal I	Sukkertoppen	-	-	(11.2)
" II	- " -	0.016	240	(6.6)
Whale I	- " -	0.012	210	
" II	- " -	0.014 B	500 B	
"	Holsteinsborg	0.011 A	73 A	
Shrimps	Jacobshavn	0.044	91	
Trout	Holsteinsborg	0.064	1800	

Bone levels are shown in brackets.

Whale meat contained 0.012 Bq ^{90}Sr kg^{-1}, and 0.55 Bq ^{137}Cs kg^{-1}, and seal meat 0.016 Bq ^{90}Sr kg^{-1} and 0.66 Bq ^{137}Cs kg^{-1}. Fig. 3.2.4 shows that the ^{137}Cs levels in seals and whales from Greenland decay with an effective half-life of 8-9 years. This is in agreement with the effective half-life of ^{90}Sr and ^{137}Cs observed in the surface waters of the North Atlantic ocean[21].

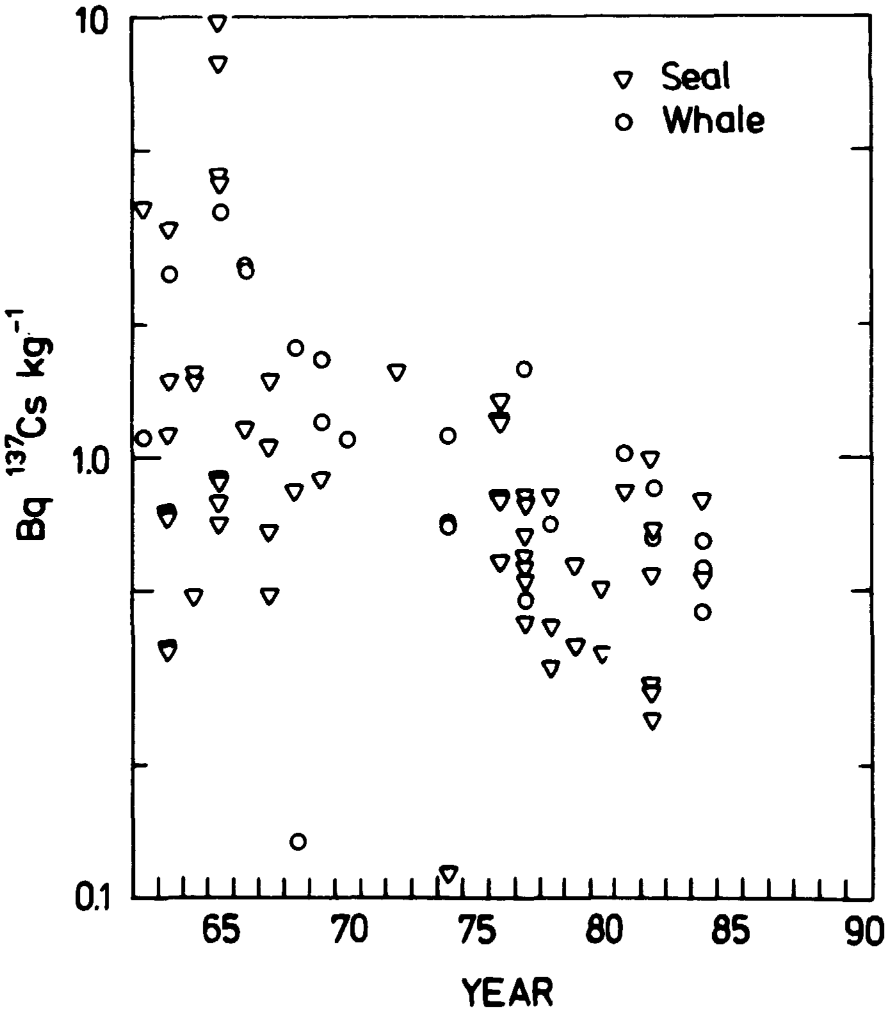


Fig. 3.2.4. Cesium-137 in seal- and whale meat from Greenland 1962-1984.

3.2.5. Radionuclides in Greenland vegetation

Samples of lichens and other terrestrial vegetation were obtained from Prins Christians Sund in 1984 (Tables 3.2.5.1 and 3.2.5.2). The ^{90}Sr and ^{137}Cs were similar to those seen previously (cf. Fig. 3.2.5).

Table 3.2.5.1. Cesium-137 and other γ-emitters in vegetation (dry weight) collected in Prins Chr. Sund in Greenland in the summer 1984.

Sample	Bq ^{137}Cs kg^{-1}	Bq ^{60}Co kg^{-1}	Bq ^{144}Ce kg^{-1}	Bq ^{207}Bi kg^{-1}	g K kg^{-1}
Cetraria nivalis I	315	0.18 B	6.5 A	0.52	4.9
- " - - " - II	510	0.39 A	5.2 B	0.74	11.3
Grey lichen	134	0.15 B	-	0.19 B	13.2
Lichen	1140	-	-	-	55
Crowberry twigs	198	-	-	-	14.1

Table 3.2.5.2. Strontium-90 in vegetation (dry weight) collected in Prins Chr. Sund in Greenland in the summer 1984.

Sample	Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr (kg Ca)$^{-1}$
Cetraria nivalis I	79	35000
- " - - " - II	256	350000
Lichen	138	100000
Crowberry twigs	0.06 B	44

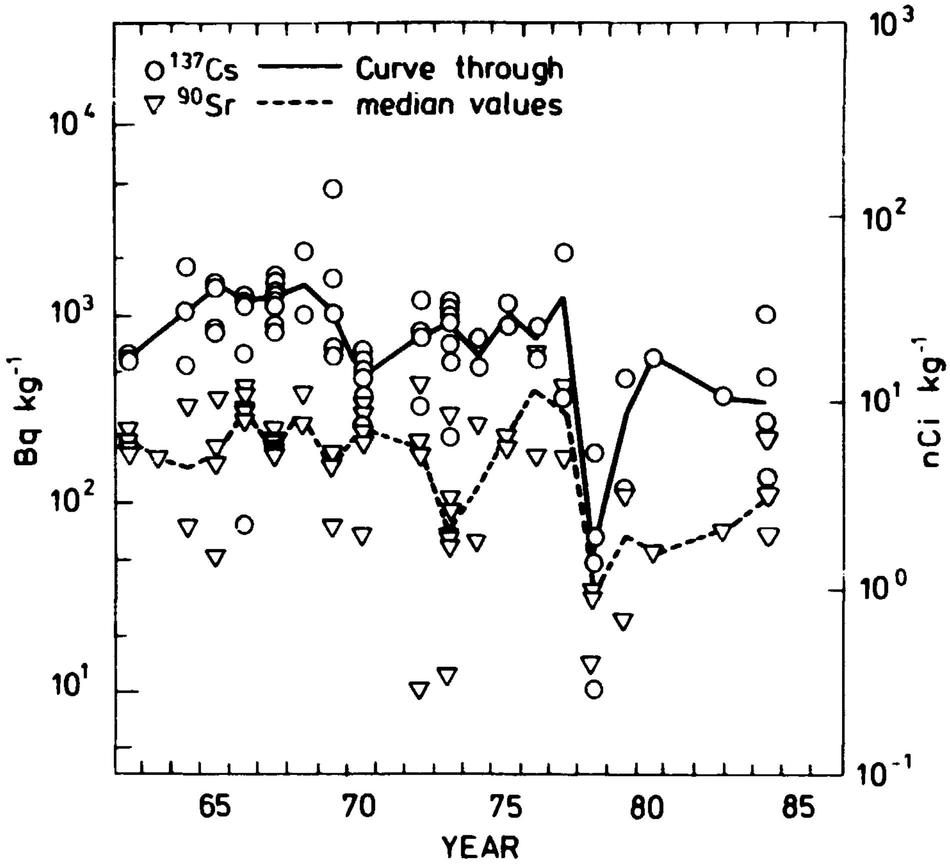


Fig. 3.2.5. Cesium-137 and Strontium-90 in lichen (fresh weight) collected along the Greenlandic coast, 1962-1984.

The contents of ^{207}Bi and ^{60}Co were similar to that found in samples collected at Narssaq in 1979 (if the data all were decay-corrected back to 1961)[20].

Data on seaweed samples are shown in Chapter 4 of this report.

3.2.6. Strontium-90 and Tritium in Greenland drinking water

Quarterly samples of drinking water were collected from a number of locations in Greenland. Table 3.2.6.1 shows the results from 1984, and Fig. 3.2.6 the geometric annual means of all samples for the period 1962-1984.

As in previous years, we found it most expedient to choose the geometric mean of all figures, i.e. 16 Bq ^{90}Sr m^{-3} (0.42 pCi

l^{-1}) as representative of the mean level of ^{90}Sr in Greenland drinking water in 1984, this level was higher than that observed in 1983 (Fig. 3.2.6). The levels in drinking water are still surprisingly high as compared to present rain concentrations (cf. Table 3.2.1.1). We have suggested that evaporation from the drinking water reservoirs was responsible for the higher ^{90}Sr levels. Tritium measurements show (Table 3.2.6.2) that the Greenland drinking water shows similar tritium levels as rain from Denmark[3], hence evaporation seems to be a possible explanation. The high ^{90}Sr levels may, however, also be due to extraction of old deposited ^{90}Sr activity from the soil by the water collected for drinking. This would also be compatible with "normal" tritium concentrations.

Table 3.2.6.1. Strontium-90 in drinking water collected in Greenland in 1984. (Unit: Bq m^{-3})

Location	Jan-March	April-June	July-Sept	Oct-Dec
Danmarkshavn	44	17	9	98
Scoresbysund	9	16	11	9
Prins Chr.Sund		21	21	30
Godthåb		10	7	
Upernavik		12	7	

Table 3.2.6.2. Tritium in drinking water collected in Greenland in 1984. (Unit: kBq m^{-3})

Location	Jan-March	April-June	Oct-Dec
Danmarkshavn	3		
Scorebysund	2		
Prins Chr.Sund		1	0
Godthåb		2	
Upernavik		3	

An empirically found tritium background of 1.2 kBq has been subtracted from all results (cf. the discussion in Risø-R-509, Chapter 7)[3].

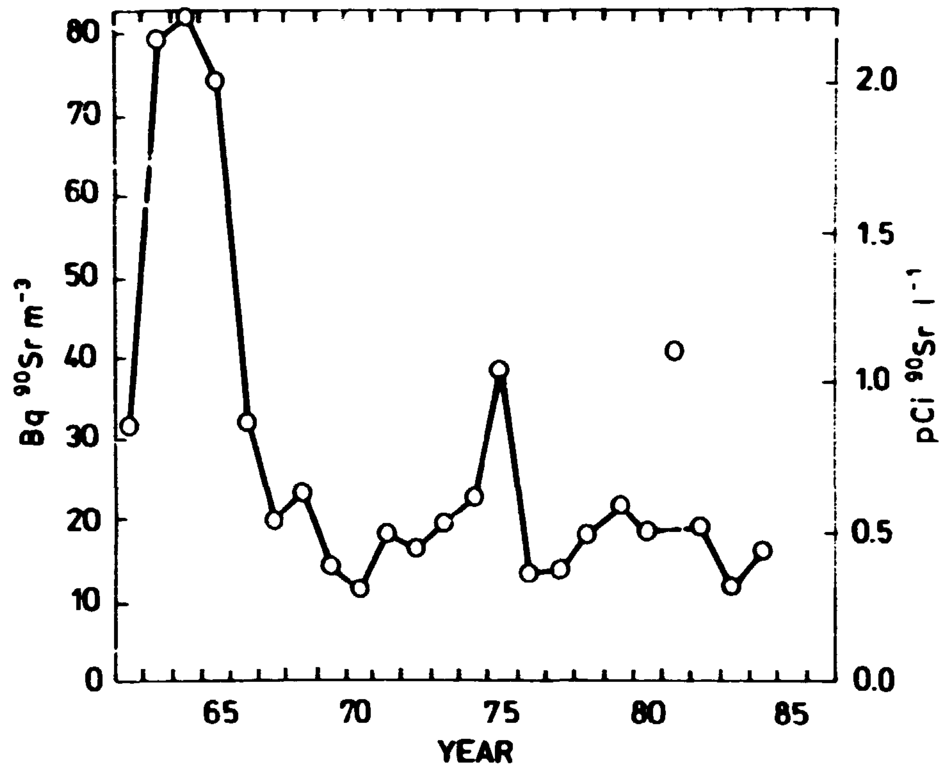


Fig. 3.2.6. Strontium-90 in Greenlandic drinking water (Geometric mean), 1962-1984.

3.3. Estimate of the mean contents of ^{90}Sr and ^{137}Cs in the human diet in Greenland in 1984

3.3.1. The annual quantities

The estimate of the daily pro capite intake of the different foods in Greenland is still based on the fiqures given in 1962 by the late Professor E. Hoff-Jørqensen, Ph.D., in Risø Report No. 65[2].

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 1984 was 0.096 Bq ^{90}Sr kg^{-1} and 0.085 Bq ^{137}Cs kg^{-1} [3].

Cheese was also imported from Denmark and contained 0.68 Bq ^{90}Sr kg^{-1} and 0.061 Bq ^{137}Cs kg^{-1}.

3.3.3. Grain products

All grain was imported from Denmark. It is assumed that only grain from the harvest of 1983 was consumed in Greenland during 1984. The daily pro capite consumption was: rye flour (100% extraction): 80 g, wheat flour (75% extraction): 110 g, rye flour (70% extraction): 20 g, biscuits (rye, 100% extraction): 27 g, and grits: 25 g. The content of ^{90}Sr in these five products was 0.47, 0.10, 0.09, 0.36 and 0.29 Bq kg^{-1}, respectively. Hence the mean content of ^{90}Sr in grain products was 0.26 Bq kg^{-1}. The content of ^{137}Cs in the five products was 0.12, 0.034, 0.06, 0.09 and 0.10 Bq kg^{-1}. Hence the mean content of ^{137}Cs in grain products was 0.07 Bq kg^{-1}.

The activity levels in rye flour (100% extraction), wheat flour (75% extraction), and grits were all taken from Tables 5.9.1 and 5.9.2 in Risø Report No. 509[3]. The ^{90}Sr level in rye flour (70% extraction) was calculated analogously with the level in wheat flour (75% extraction), i.e. as one-fifth of the whole-grain activity. The ^{137}Cs content in rye flour (70% extraction) was calculated as one half of the whole-grain level in rye in analogy with the ratio between ^{137}Cs in whole wheat grain and in wheat flour (75% extraction)[3]. The ^{90}Sr and ^{137}Cs contents in biscuits were calculated by dividing the levels of the rye flour (100% extraction) by 1.35, since 1 kg flour yields 1.35 kg bread[3].

3.3.4. Potatoes, other vegetables, and fruit

The Danish mean levels for 1984 were used[3] since the local production is insignificant compared with imports from Denmark.

The Danish mean levels were: in potatoes 0.048 Bq ^{90}Sr kg^{-1} and 0.043 Bq ^{137}Cs kg^{-1}, in other vegetables 0.31 Bq ^{90}Sr kg^{-1} and 0.05 Bq ^{137}Cs kg^{-1}, and in fruit 0.05 Bq ^{90}Sr kg^{-1} and 0.014 Bq 137Cs kg-1.

3.3.5. Meat

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

The activities in lamb were estimated from the 1983 data[2]. Reindeer, seal and whale were estimated from 3.2.3. The levels of sea birds and eggs were taken from the 1978 analyses[2]. Hence the mean levels in Greenland meat from 1984 were 0.08 Bq ^{90}Sr kg^{-1} and 12.3 Bq ^{137}Cs kg^{-1}.

(^{90}Sr: $0.1\times0.23 + 0.05\times0.91 + 0.6\times0.016 + 0.05\times0.012 + 0.2\times0.007 = 0.08$ Bq kg^{-1})

(^{137}Cs: $0.1\times68.7 + 0.05\times98 + 0.6\times0.66 + 0.05\times0.55 + 0.2\times0.35 = 12.3$ Bq kg^{-1})

3.3.6. Fish

All fish consumed was of local origin, and the mean levels from 1983 (cod and salmon meat) were used, i.e. 0.015 Bq ^{90}Sr kg^{-1} and 0.28 Bq ^{137}Cs kg^{-1}.

3.3.7. Coffee and tea

The Danish figures for 1984[3] were used for coffee and tea, i.e. 1.23 Bq ^{90}Sr kg^{-1} and 1.53 Bq ^{137}Cs kg^{-1}.

3.3.8. Drinking water

The geometric mean calculated in 3.2.6 was used as the mean level of ^{90}Sr in drinking water, i.e. 16 Bq ^{90}Sr m^{-3}. The ^{137}Cs content was as previously[2] estimated at 1/4 of the ^{90}Sr content, i.e. approximately 4 Bq ^{137}Cs m^{-3}.

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

3.3.9. Discussion

The most important ^{90}Sr source in the Greenland diet is still grain products, which contribute 40% of the total ^{90}Sr content in the diet. Approximately 75% of the ^{90}Sr in the food consumed in Greenland in 1984 originated from imported (Danish) food.

Meat is still the most important ^{137}Cs source in the Greenland diet, contributing 90% of the total content in 1984. Approximately 95% of the ^{137}Cs in the Greenland diet in 1984 came from local products.

The ^{90}Sr contents in the total diet in 1984 was approximately 70% of the 1983 level.

The ^{137}Cs level was 105% of that found in 1983. As earlier discussed[2] the great variations from year to year are primarily due to the variations in the ^{137}Cs levels in the meat samples obtained.

To estimate the maximum pro capite intakes of ^{90}Sr and ^{137}Cs in Greenland in 1984 we assume[2] that the only grain product consumed by a person is dark rye bread, and that he only eats reindeer meat. His daily intake of ^{90}Sr is thus 0.33 Bq and his ^{137}Cs intake 12.4 Bq day^{-1} (using the quantities in Tables 3.3.1 and 3.3.2). At the lower limit we can imagine a person eating white bread and seal and drinking water with hardly any activity (e.g. water formed by the melting of old ice). In this case the daily intakes are 0.12 Bq ^{90}Sr and 0.25 Bq ^{137}Cs. Hence the ratios between the levels in the maximum and minimum diets become 3 for ^{90}Sr and 50 for ^{137}Cs.

The ^{90}Sr content of the Greenland diet in 1984 was 87% of the estimated Danish mean content[3], and 55% of the Faroese level[1]. The ^{137}Cs level in the total diet in Greenland was 7.4 times that of the Danish diet and 40% of the Faroese diet level.

Table 3.3.1. Estimate of the mean content of ^{90}Sr in the human diet in Greenland in 1984

Type of food	Annual quantity in kg	Bq ^{90}Sr per kg	Total Bq ^{90}Sr	Percentage of total Bq ^{90}Sr in food
Milk and cream	78	0.096	7.49	12.2
Cheese	2.5	0.68	1.70	2.8
Grain products	95.6	0.26	24.86	40.5
Potatoes	32.8	0.048	1.57	2.6
Vegetables	5.5	0.31	1.71	2.8
Fruit	13.5	0.05	0.68	1.1
Meat and eggs	45.6	0.08	3.65	6.0
Fish	127.6	0.015	1.91	3.1
Coffee and tea	7.3	1.23	8.98	14.6
Drinking water	548	0.016	8.77	14.3
Total			61.32	

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 1984 was 110 Bq ^{90}Sr (kg Ca)$^{-1}$ or 3.0 pCi ^{90}Sr (g Ca)$^{-1}$ and the daily intake was 0.17 Bq ^{90}Sr or 4.5 pCi ^{90}Sr.

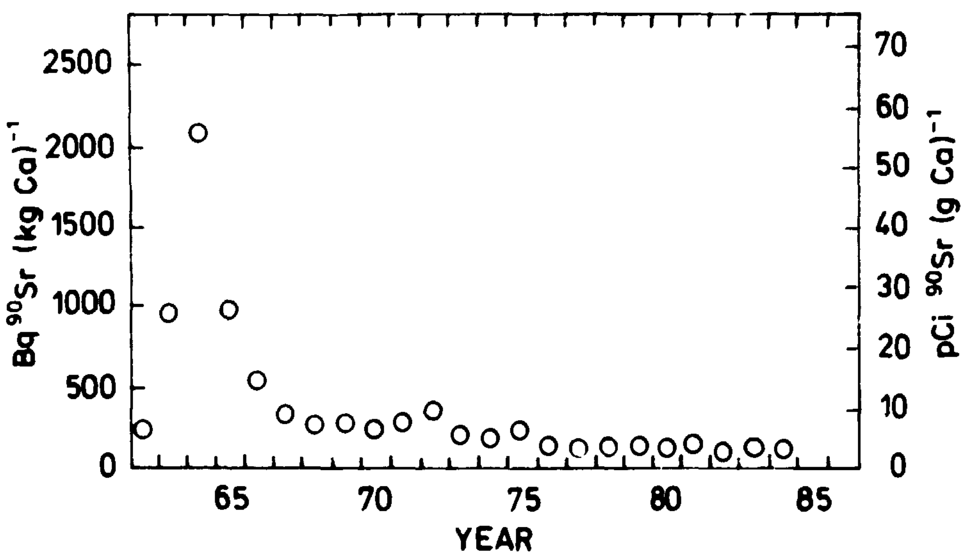


Fig. 3.3.1. Strontium-90 in Greenlandic diet, 1962-1984.

Table 3.3.2. Estimate of the mean content of ^{137}Cs in the human diet in Greenland in 1984

Type of food	Annual quantity in kg	Bq ^{137}Cs per kg	Total Bq ^{137}Cs	Percentage of total Bq ^{137}Cs in food
Milk and cream	78	0.085	6.63	1.1
Cheese	2.5	0.061	0.15	0.0
Grain products	95.6	0.07	6.69	1.1
Potatoes	32.8	0.043	1.41	0.2
Vegetables	5.5	0.05	0.28	0.0
Fruit	13.5	0.014	0.19	0.0
Meat and eggs	45.6	12.3	560.88	89.7
Fish	127.6	0.28	35.73	5.7
Coffee and tea	7.3	1.53	11.17	1.8
Drinking water	548	0.004	2.19	0.4
Total			625.32	

The mean annual potassium intake is estimated to be approx. 1.2 kg. Hence the $^{137}Cs/K$ ratio becomes 521 Bq ^{137}Cs (kg K)$^{-1}$ or 14.1 pCi ^{137}Cs (g K)$^{-1}$. The daily intake in 1984 from food was 1.71 Bq ^{137}Cs or 46 pCi ^{137}Cs.

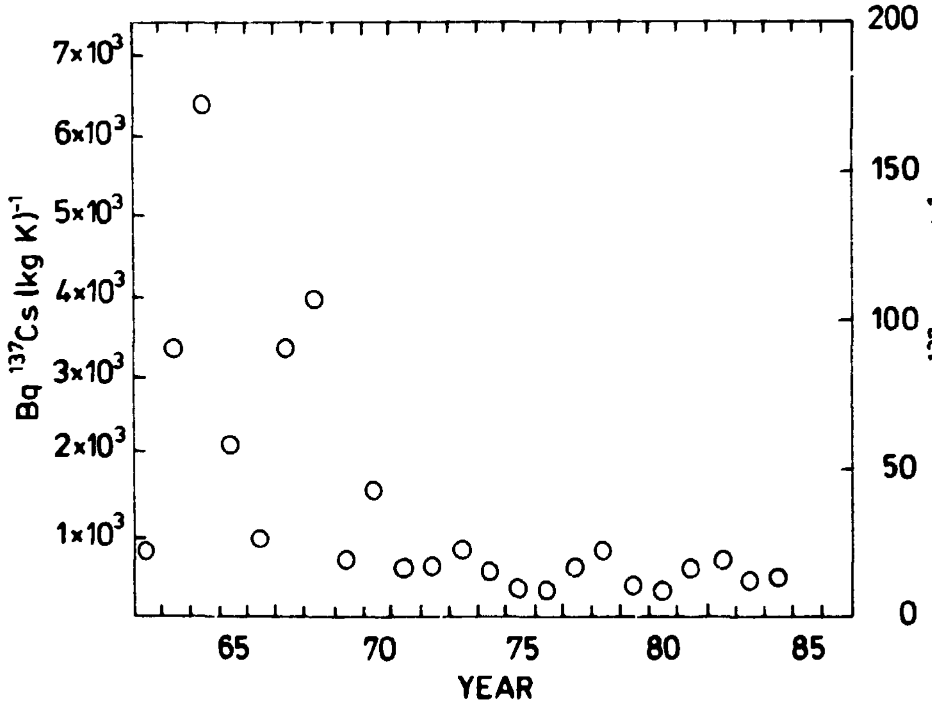


Fig. 3.3.2. Cesium-137 in Greenlandic diet, 1962-1984.

3.4. Conclusion

3.4.1.

The ^{90}Sr fallout rates in 1984 were the following: Prins Chr. Sund: approximately 2.0 Bq ^{90}Sr m^{-2}; Godthåb: 2.0; Scoresby Sund: 1.1; Upernavik: 2.2 and Danmarkshavn: 1.3. The accumulated fallout levels by the end of 1984 were estimated at approximately 1250 Bq ^{90}Sr m^{-2} at Godthåb, 4100 at Prins Chr. Sund, and 440 at Upernavik.

3.4.2.

The food consumed in Greenland in 1984 contained on the average 110 Bq ^{90}Sr (kg Ca)$^{-1}$, and the daily mean intake of ^{137}Cs was estimated at 1.73 Bq. The most important ^{90}Sr contributor to the diet were grain products accounting for approximately 40% of the total ^{90}Sr content of the diet. Cesium-137 originated mainly from meat (reindeer and lamb) and fish, contributing approximately 95% of the total ^{137}Cs content of the diet.

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[4], however, that the 1984 ^{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 30 Bq ^{90}Sr (kg Ca)$^{-1}$ (vertebrae). From diet measurements the ^{137}Cs content in Greenlanders was estimated at 1500 Bq ^{137}Cs (kg K)$^{-1}$.

4. MARINE ENVIRONMENTAL RADIOACTIVITY IN THE NORTH ATLANTIC REGION

4.1. The CSS Baffin cruise* to Thule in July-Aug 1984

4.1 1. Sea water

During the cruise from Sct. Johns on Newfoundland to Thule in NW-Greenland we collected daily seawater samples from the fire hose on board the ship. In order to avoid old rusty water in the samples, the water ran continuously during the cruise. Each day we took two 1800 l samples and one 50 l sample. The big samples were collected in our tanks placed on the fordeck; one sample was used for radiocesium and the other one for transuranics. The 50 l sample was used for ^{90}Sr, and ^{137}Cs, and salinity. The radiocesium in the big tank was collected by 100 g or 200 g AMP. The transuranics were collected by a hydroxide precipitation after addition of ^{242}Pu and ^{243}Am spikes. The yield of the AMP precipitation was found from the determination of ^{137}Cs in the 45 l sample, where we used ^{134}Cs as yield determinant. The radiocesium activity from the 1800 l samples were further concentrated by a Cs_2PtCl_6 precipitation in order to determine ^{134}Cs[11]. The counting time for these precipitates was usually 1 week.

The results are shown in Tables 4.1.1.1-4.1.1.4 and in Figs. 4.1.1.1, and 4.1.1.2.

Between 60° and 66°N the ^{137}Cs as well as the ^{90}Sr levels were enhanced. It was in the same region that we observed ^{134}Cs. Hence we see a signal from Sellafield along the Greenland west coast in August 1984. If we calculate the transfer factors from Sellafield to West Greenland waters we find between 60° and 66°N: 0.9 Bq m^{-3} per PBq a^{-1} discharged from Sellafield and between 60° and 72°N the transfer factor for radiocesium is 0.4.

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*Scientific leader: Dr. John Norton Smith, Bedford Institute of Oceanography.

Table 4.1.1.1. Radionuclides in surface sea water collected from Newfoundland to Thule in July-August 1984

Position N	Position W	Can No.	Date	Salinity o/oo	Temp. ^{o}C	^{90}Sr Bq m^{-3}	^{134}Cs Bq m^{-3}	^{137}Cs Bq m^{-3}	$^{239,240}Pu$ mBq m^{-3}	^{238}Pu / $^{239,240}Pu$	^{241}Am / $^{239,240}Pu$	Remarks
54°12'	55°13'	1101-02	July 31	30.7	7.4	4.0	<0.01	5.3	9.5	-	0.084	
57°18'	54°40'	1104-05	Aug 1	33.9	8.5	3.3	-	5.1	-	-	-	
60°42'	54°11'	1111-12	Aug 2	31.8	7.7	3.2	0.056	5.1	7.9±0.4	0.06±0.04	0.12±0.01	Pu determination on 200 l and 1800 l (± 1 S.E.)
61°16'	54°02'	- " -	Aug 2	31.8	7.7	-	-	-	2.3	0.060	0.49	2500 l water filtered
63°29'	53°38'	1116-17	Aug 3	32.0	1.9	4.2	-	5.9	-	-	-	
64°26'	54°17'	1121	Aug 3	32.3	3.0	3.7	0.034	6.6	-		-	
65°56'	54°31'	1124	Aug 3	33.3	3.6	3.5	0.052	6.8	-	-	-	
68°13'	57°09'	1133	Aug 4	32.6	3.5	3.0	0.014	4.7	-	-	-	Combined ^{134}Cs determination gave 0.017
69°38'	58°09'	1134	Aug 4	31.6	2	2.7	0.023	4.8	8.0	0.052	0.079	
71°48'	59°13'	1140	Aug 5	31.3	3.0	3.1	0.028	4.7	-	-	-	
74°32'	66°25'	1145-46	Aug 6	32.5	5.3	4.3	-	4.1	7.1	0.053	0.091	
74°32'	66°25'	- " -	Aug 6	-	-	-	-	-	1.66	0.129	-	2700 l water filtered
76°15'	69°51'	1161	Aug 7	-	2.3	-	-	-	6.7	0.21	0.113	
76°10'	70°48'	1433	Aug 11	32.0	-	-	-	-	7.5	0.031	0.096	

Table 4.1.1.2. Radionuclides in sea water collected at various depths in the Baffin Bay 74°32'N 66°25'W, August 6 1984

Can No.	Depth in m	Salinity o/oo	^{90}Sr Bq m^{-3}	^{137}Cs Bq m^{-3}
1158	19	33.2	4.1	3.0
1150	100	33.5	3.3	4.2
1155	500	34.5	2.5	2.1
1154	1000	34.5	0.40	0.83
1151	1500	34.5	0.64	<1.4
1152	1765	34.5	0.39	<0.6

Table 4.1.1.3. Radionuclides in sea water from the Thule area; point of impact location V (cf. Fig. 4.1.2). Position 76°31'3N 69°17'4W. August 10 1984

Can No.	Salinity o/oo	Depth in m	^{90}Sr Bq m^{-3}	^{137}Cs Bq m^{-3}	$^{239,240}Pu$ mBq m^{-3}	$\frac{^{238}Pu}{^{239,240}Pu}$	$\frac{^{241}Am}{^{239,240}Pu}$	Remarks	Sample
1361	31.5	7-8	3.4	4.0	8.8	0.042	0.066	1800 l	total water
"	"	"	-	-	3.3	0.019	0.22	1800 l filtered	filter
1365	33.7	185	-	-	51	0.023	0.070	200 l	total water
1367	33.7	"	-	-	34	0.026	0.100	200 l filtered	filter

Table 4.1.1.4. Radionuclides in sea water collected at various depths south of Thule 76°10'N 70°48'W, August 11 1984

Can No.	Depth in m	Salinity o/oo	^{90}Sr Bq m^{-3}	^{137}Cs Bq m^{-3}	$^{239,240}Pu$ mBq m^{-3}	$\frac{^{238}Pu}{^{239,240}Pu}$
1432	58	34.0	3.2	4.5		
1430	250	34.1	2.6	2.9		
1415	615	34.5	1.27	1.8	17	0.053

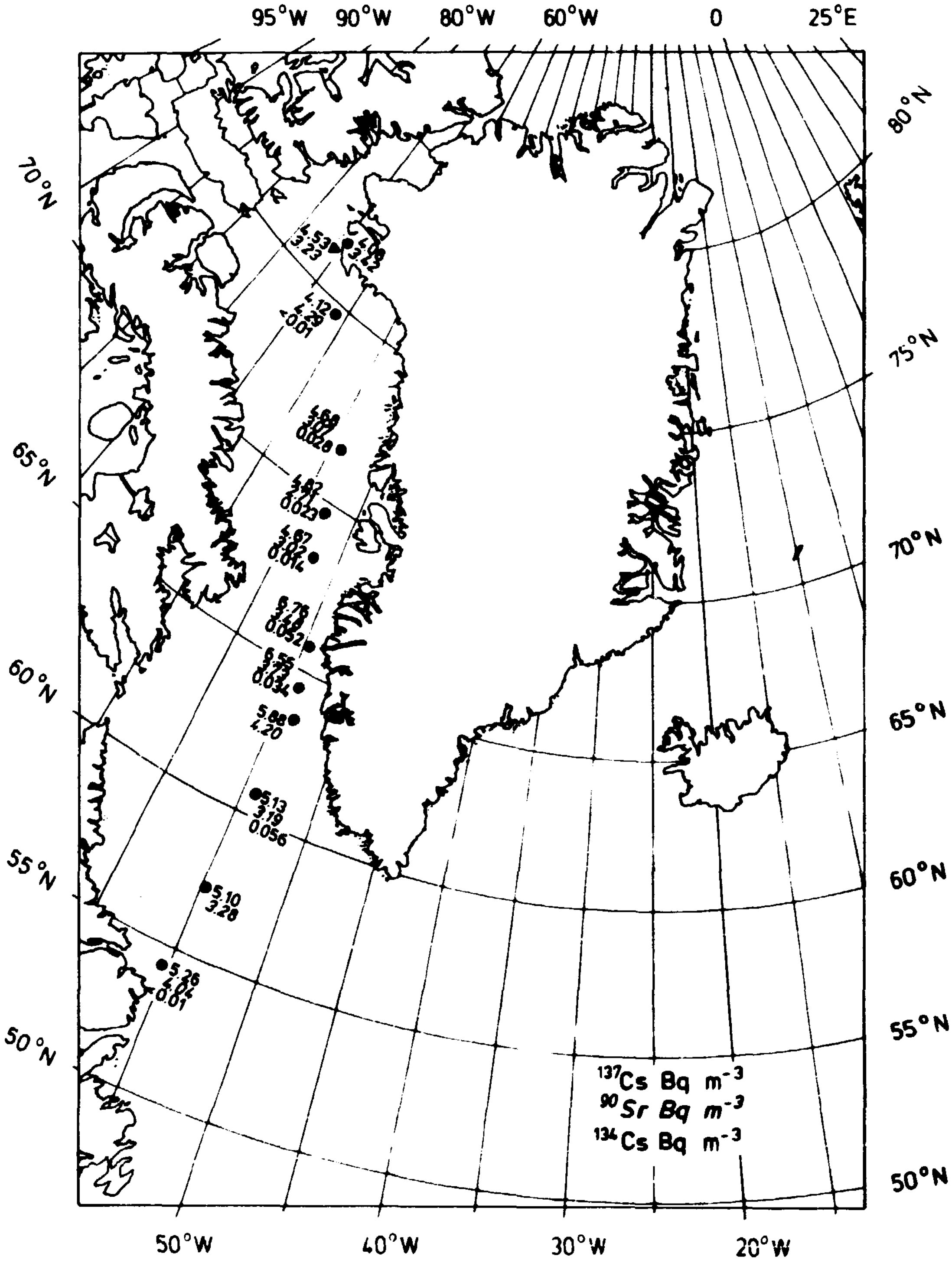

Fig. 4.1.1.1. Radiocesium and ^{90}Sr in surface water collected during the CSS Baffin cruise from Newfoundland to Thule in August 1984.
● surface (7-8 m); ▲: 58 m.

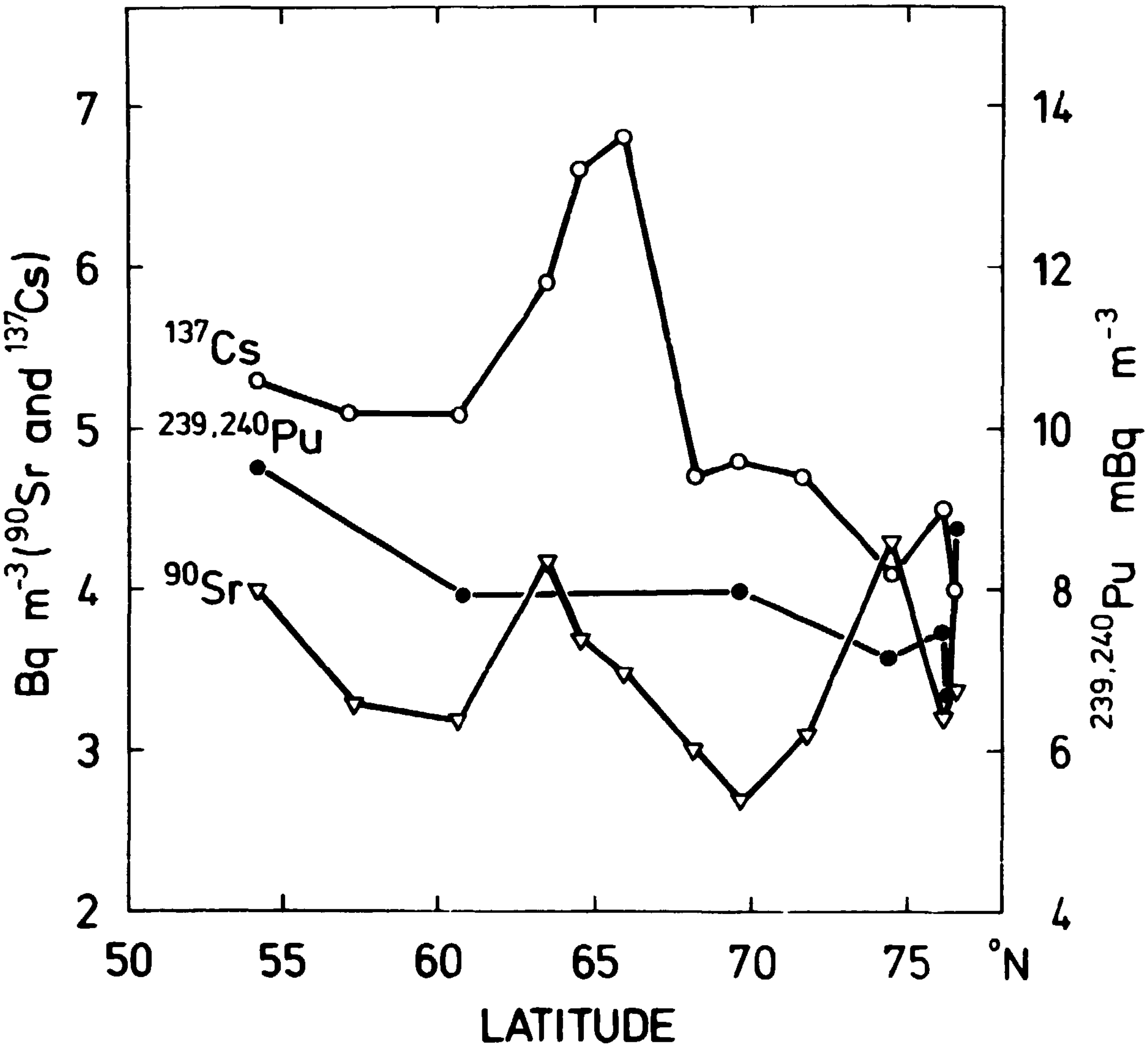

Fig. 4.1.1.2. Radionuclides in surface water collected from Newfoundland to Thule in August 1984 (along 55°-70°W). The abscissa shows the latitude of the samples.

The increase observed in the ^{90}Sr levels in the northern part of Baffin Bay is somewhat surprising. Table 4.1.1.2 shows that the enhanced ^{90}Sr also is seen at 19 m depths. First at 100 meters the ^{90}Sr level approaches what we would have expected to see in surface water. The surface samples may have contained run-off enriched with ^{90}Sr relative to ^{137}Cs, but the salinities do not suggest any significant contribution of fresh water in the two upper layer samples from Baffin Bay.

The plutonium concentrations in surface water from Newfoundland to Thule varied between 6.7 and 9.5 mBq $^{239,240}Pu$ m^{-3}. The $^{241}Am/^{239,240}Pu$ mean ratio was 0.097±0.016 (N=6,±1 S.D.). The $^{238}Pu/^{239,240}Pu$ ratio varied between 0.03 and 0.06. An outlier showed a ratio of 0.21. Three surface samples were analysed for particulate Pu and Am activity. We found that 23-38% of the $^{239,240}Pu$ and nearly 100% of the ^{241}Am were particulates.

The surface concentrations of $^{239,240}Pu$ in Thule sea water were not significantly different from those found in water distant from Thule at this cruise. Compared with 1979[16])the sea water levels at Thule had decreased by a factor of two. As in 1979 we found that the surplus $^{239,240}Pu$ activity seen in bottom water over the point of impact is contained mainly in particulates (Table 4.1.1.2). There may be a small contribution of accident Pu in the filtered seawater. Compared with the filtered surface water, the bottom water filtrated contained Pu levels 3 times higer. However, bottom water (unfiltered) collected at 615 metres (Table 4.1.1.4) south of Thule contained 17 mBq $^{239,240}Pu$ m^{-3}, i.e. the same as the filtrate of the bottom water from the point of impact (51-34 = 17) (Table 4.1.1.2). If we compare the $^{241}Am/^{239,240}Pu$ mean ratio found at Thule (point of impact, station V) in bottom and surface total water with that found in the samples of total water in Table 4.1.1.1, i.e. outside Thule, the Thule ratio is probably lower (P ~ 95%). This may indicate a small contribution of nonfallout transuranics in the water at Thule. But we are most inclined to stick to our conclusion from 1979[16]) that we can see no accident-derived Pu in solution in the sea water at Thule (cf. also 4.1.3).

4.1.2. Sediments

The measurements on the sediment samples collected at Thule in August 1984 are not completed, but Tables 4.1.2.1-4.1.2.16 show the results obtained hitherto. The tables are arranged after increasing distance from the point of impact (cf. Fig. 4.1.2).

As observed earlier[16] the ^{137}Cs levels (Bq m^{-2}) were in general higher close to the point of impact than farther away. This was due to the higher sedimentation in the proximity of the point of impact.

From the $^{239,240}Pu$ results obtained until now we may calculate the distance relation from the point of impact:

$$\text{Bq } ^{239,240}\text{Pu m}^{-2} = 8500 \, e^{-0.2 \text{ km}}$$

This relation is within the range (95% confidence limits) given for the data from 1974 and 1979[16]. At location 76°10'N, 70°48'W (55.9 km from the point of impact) (see Table 4.1.2.16) the fallout background was 23.4 Bq $^{239,240}Pu$ m^{-2}. This is two times lower than the background estimated in 1979[16]. However, the ^{137}Cs background was 1.5 times that estimated in 1979 for a similar distance. This may imply that the estimated $^{239,240}Pu/^{137}Cs$ ratio in fallout of 0.36±0.17 (1 S.D.) estimated in 1979 has been too high.

Table 4.1.2.1. Radionuclides in marine sediments collected with a 145 cm^2 corer at Thule in August 1984. Location: South of J (cf. Fig. 4.1.2) ('325). Position: 76°31'N 69°27'W. Depth: 150 m. Distance from point of impact: 4.2 km

Depth in cm	$^{239,240}Pu$ Bq kg^{-1}	$^{239,240}Pu$ Bq m^{-2}	^{137}Cs Bq kg^{-1}	^{137}Cs Bq m^{-2}	^{241}Am Bq m^{-2}	$\frac{^{239,240}Pu}{^{137}Cs}$	$\frac{^{241}Am}{^{239,240}Pu}$	$\frac{^{238}Pu}{^{239,240}Pu}$	Total g
0-3	23.9	380	4.0	63	37	5 98	0.097	0.023	230
3-6	54.5	1160	4.2	88	134	12.98	0.116	0.017	308
6-9	30.4	900	4.4	128	90	6.91	0.099	0.012	428
9-12			2.4	68					411
Σ				347					

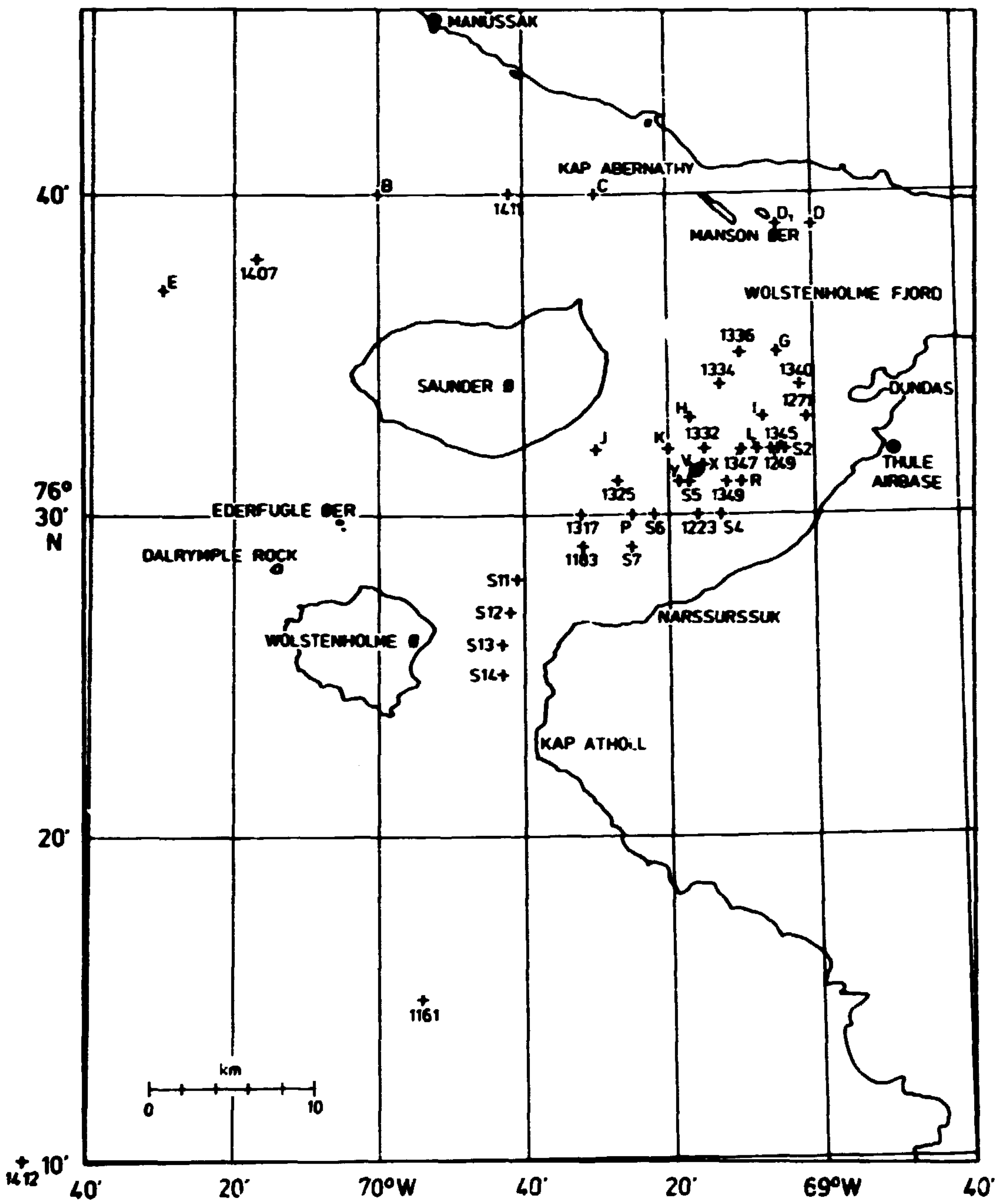

Fig. 4.1.2. Sampling locations at Thule in August 1984.

Table 4.1.2.2. Radionuclides in marine sediments collected with a 145 cm^2 corer at Thule in August 1984. Location: North of S2 (cf. Fig. 4.1.2) (1345). Position: 76°32'N 69°05'W. Depth: 220 m. Distance from point of impact: 5.5 km

Depth in cm	$^{239,240}Pu$ Bq kg^{-1}	$^{239,240}Pu$ Bq m^{-2}	^{137}Cs Bq kg^{-1}	^{137}Cs Bq m^{-2}	^{241}Am Bq m^{-2}	$\frac{^{239,240}Pu}{^{137}Cs}$	$\frac{^{241}Am}{^{239,240}Pu}$	$\frac{^{238}Pu}{^{239,240}Pu}$	Total g
0-3			13.4	82					89
3-6			15.8	225					207
6-9			17.2	285					241
9-12			13.4	220					239
12-15			4.9	96					286
15-18			1.0	20					288
18-20			3.3	35					155
Σ				963					

Table 4.1.2.3. Radionuclides in marine sediments collected with a 145 cm^2 corer at Thule in August 1984. Location: J (cf. Fig. 4.1.2) (1305). Position: 76°32'N 69°30'W. Depth: 100 m. Distance from point of impact: 5.6 km

Depth in cm	$^{239,240}Pu$ Bq kg^{-1}	$^{239,240}Pu$ Bq m^{-2}	^{137}Cs Bq kg^{-1}	^{137}Cs Bq m^{-2}	^{241}Am Bq m^{-2}	$\frac{^{239,240}Pu}{^{137}Cs}$	$\frac{^{241}Am}{^{239,240}Pu}$	$\frac{^{238}Pu}{^{239,240}Pu}$	Total g
0-3	12.9	300	4.5	105	32	2.87	0.137	0.011	336
3-6	24.8	800	3.6	115	68	6.89	0.085	0.026	468
6-9	3.4	124	1.5	56	14.6	2.27	0.118	0.041	523
Σ		1224		276	115				

Table 4.1.2.4. Radionuclides in marine sediments collected with a 145 cm^2 corer at Thule in August 1984. Location: Between O & P (cf. Fig. 4.1.2) (1317). Position: 76°30'N 69°32'W. Depth: 176 m. Distance from point of impact: 6.8 km

Depth in cm	$^{239,240}Pu$ Bq kg^{-1}	$^{239,240}Pu$ Bq m^{-2}	^{137}Cs Bq kg^{-1}	^{137}Cs Bq m^{-2}	^{241}Am Bq m^{-2}	$\frac{^{239,240}Pu}{^{137}Cs}$	$\frac{^{241}Am}{^{239,240}Pu}$	$\frac{^{238}Pu}{^{239,240}Pu}$	Total g
0-3	32.0	105	8.8	29	10	3.64	0.090	0.012	48
3-6	15.1	306	4.5	91	31	3.36	0.100	0.013	295
6-9	4.3	144	1.3	44	18	3.30	0.126	0.027	487
9-12			1.2	27					339
Σ				191					

Table 4.1.2.5. Radionuclides in marine sediments collected with a 145 cm^2 corer at Thule in August 1984. Location: West of G (cf. Fig. 4.1.2) (1336). Position: 76°35'N 69°10'W. Depth: 190 m. Distance from point of impact: 7.6 km

Depth in cm	$^{239,240}Pu$ Bq kg^{-1}	Bq m^{-2}	^{137}Cs Bq kg^{-1}	Bq m^{-2}	^{241}Am Bq m^{-2}	$\frac{^{239,240}Pu}{^{137}Cs}$	$\frac{^{241}Am}{^{239,240}Pu}$	$\frac{^{238}Pu}{^{239,240}Pu}$	Total g
0-3	116	900	17.9	92		9.7		0.015	112
3-6	114	2060	12.7	228		9.0		0.016	261
6-9	40	725	9.2	167		4.3		0.017	264
9-12	25	475	5.0	111		4.3		0.014	274
12-15			3.0	73					285
15-18	10	210	2.7	56		3.7		0.012	299
Σ				727					

Table 4.1.2.6. Radionuclides in marine sediments collected with a 145 cm^2 corer at Thule in August 1984. Location: North of S9 (cf. Fig. 4.1.2) (1103). Position: 76°29'N 69°32'W. Depth: 244 m. Distance from point of impact: 7.6 km

Depth in cm	$^{239,240}Pu$ Bq kg^{-1}	Bq m^{-2}	^{137}Cs Bq kg^{-1}	Bq m^{-2}	^{241}Am Bq m^{-2}	$\frac{^{239,240}Pu}{^{137}Cs}$	$\frac{^{241}Am}{^{239,240}Pu}$	$\frac{^{238}Pu}{^{239,240}Pu}$	Total g
0-3	35.5	673	9.4	177		3.78		0.015	275
3-6	44.5	1047	9.2	217		4.84			341
6-9	3.24	95	2.0	60		1.62		0.012	424
9-12	0.73	19	<1	<30		>0.73		0.043	384
Σ		1834		~480		ΣPu/ΣCs: 3.82			

Table 4.1.2.7. Radionuclides in marine sediments collected with a 145 cm^2 corer at Thule in August 1984. Location: South of S1 (cf. Fig. 4.1.2) (1271). Position: 76°33'N 69°01'W. Depth: 227 m. Distance from point of impact: 7.8 km

Depth in cm	$^{239,240}Pu$ Bq kg^{-1}	Bq m^{-2}	^{137}Cs Bq kg^{-1}	Bq m^{-2}	^{241}Am Bq m^{-2}	$\frac{^{239,240}Pu}{^{137}Cs}$	$\frac{^{241}Am}{^{239,240}Pu}$	$\frac{^{238}Pu}{^{239,240}Pu}$	Total g
0-3			14.2	112					115
3-6			17.3	290					251
6-9			20.6	381					268
9-12			15.7	274					253
12-15			4.9	83					248
Σ				1148					

Table 4.1.2.8. Radionuclides in marine sediments collected with a 145 cm^2 corer at Thule in August 1984. Location: Between G&S1 (cf. Fig. 4.1.2) (1340). Position: 76°34'N 69°02'W. Depth: 168 m. Distance from point of impact: 8.1 km

Depth in cm	$^{239,240}Pu$ Bq kg^{-1}	$^{239,240}Pu$ Bq m^{-2}	^{137}Cs Bq kg^{-1}	^{137}Cs Bq m^{-2}	^{241}Am Bq m^{-2}	$\frac{^{239,240}Pu}{^{137}Cs}$	$\frac{^{241}Am}{^{239,240}Pu}$	$\frac{^{238}Pu}{^{239,240}Pu}$	Total g
0-3	42.6	530	11.7	146		3.6		0.017	181
3-6	5.5	88	5.7	92		0.96		0.011	234
6-9	1.43	25	1.45	25		1.00		-	252
9-12	0.70	6	1.44	12		0.50		-	120
Σ		649		275					

Table 4.1.2.9. Radionuclides in marine sediments collected with a 145 cm^2 corer at Thule in August 1984. Location: G (cf. Fig. 4.1.2) (1282). Position: 76°35'N 69°05'W. Depth: 187 m. Distance from point of impact: 8.7 km

Depth in cm	$^{239,240}Pu$ Bq kg^{-1}	$^{239,240}Pu$ Bq m^{-2}	^{137}Cs Bq kg^{-1}	^{137}Cs Bq m^{-2}	^{241}Am Bq m^{-2}	$\frac{^{239,240}Pu}{^{137}Cs}$	$\frac{^{241}Am}{^{239,240}Pu}$	$\frac{^{238}Pu}{^{239,240}Pu}$	Total g
0-3	42	450	13.1	139		3.2			154
3-6	33	540	10.9	176		3.0			235
6-9	27	510	2.8	52		9.6			272
9-12	1.2	25	<0.9	<20		>1.3			303
12-15	0.15	4	<0.9	<25		>0.2			396
Σ		1529		<412					

Table 4.1.2.10. Radionuclides in marine sediments collected with a 145 cm^2 corer at Thule in August 1984. Location: S11 (cf. Fig. 4.1.2) (1181). Position: 76°28'N 69°41'W. Depth: 285 m. Distance from point of impact: 11.9 km

Depth in cm	$^{239,240}Pu$ Bq kg^{-1}	$^{239,240}Pu$ Bq m^{-2}	^{137}Cs Bq kg^{-1}	^{137}Cs Bq m^{-2}	^{241}Am Bq m^{-2}	$\frac{^{239,240}Pu}{^{137}Cs}$	$\frac{^{241}Am}{^{239,240}Pu}$	$\frac{^{238}Pu}{^{239,240}Pu}$	Total g
0-3	5.64	62	4.2	46		1.34		0.033	159
3-6	5.72	163	4.5	127		1.27		0.016	414
6-9	7.21	195	4.7	128		1.53		0.017	393
Σ		420		301		ΣPu/ΣCs:1.40			

Table 4.1.2.11. Radionuclides in marine sediments collected with a 145 cm^2 corer at Thule in August 1984. Location: S12 (cf. Fig. 4.1.2) (1177). Position: 76°27'N 69°42'W. Depth: 285 m. Distance from p nt of impact: 13.3 km

Depth in cm	$^{239,240}Pu$ Bq kg^{-1}	Bq m^{-2}	^{137}Cs Bq kg^{-1}	Bq m^{-2}	^{241}Am Bq m^{-2}	$\frac{^{239,240}Pu}{^{137}Cs}$	$\frac{^{241}Am}{^{239,240}Pu}$	$\frac{^{238}Pu}{^{239,240}Pu}$	Total g
0-3	18.8	80	5.1	22		3.69		0.018	62
3-6	13.2	342	5.0	129		2.64		0.019	376
6-9	43.5	1539	5.2	182		8.37		0.011	513
Σ		1961		333		ΣPu/ΣCs:5.89			

Table 4.1.2.12. Radionuclides in marine sediments collected with a 145 cm^2 corer at Thule in August 1984. Location: S13 (cf. Fig. 4.1.2) (1170). Position: 76°26'N 69°43'W. Depth: 300 m. Distance from point of impact: 14.8 km

Depth in cm	$^{239,240}Pu$ Bq kg^{-1}	Bq m^{-2}	^{137}Cs Bq kg^{-1}	Bq m^{-2}	^{241}Am Bq m^{-2}	$\frac{^{239,240}Pu}{^{137}Cs}$	$\frac{^{241}Am}{^{239,240}Pu}$	$\frac{^{238}Pu}{^{239,240}Pu}$	Total g
0-3	20.4	180	5.2	46		3.92		0.019	128
3-6	4.3	149	3.8	131		1.13		0.030	504
6-9	4.0	82	4.2	86		0.95		0.025	296
Σ		411		263		ΣPu/ΣCs:1.56			

Table 4.1.2.13. Radionuclides in marine sediments collected with a 145 cm^2 corer at Thule in August 1984. Location: D (cf. Fig. 4.1.2) (1402). Position: 76°39'N 69°00'W. Depth: 85 m. Distance from point of impact: 16.1 km

Depth in cm	$^{239,240}Pu$ Bq kg^{-1}	Bq m^{-2}	^{137}Cs Bq kg^{-1}	Bq m^{-2}	^{241}Am Bq m^{-2}	$\frac{^{239,240}Pu}{^{137}Cs}$	$\frac{^{241}Am}{^{239,240}Pu}$	$\frac{^{238}Pu}{^{239,240}Pu}$	Total g
0-3	3.8	62	3.0	49		1.27			240
3-6			1.7	36					308
6-9	0.22	5.1	0.7 B	16		0.3			330
9-12	0.14	12.5	0.9 B	27		0.15			455
12-15	0.36	11.7	1.0 B	32		0.4			467
15-18	0.091	3.8	0.4 B	17		0.2			604
Σ				178					

Table 4.1.2.14. Radionuclides in marine sediments collected with a 145 cm^2 corer at Thule in August 1984. Location: S14 (cf. Fig. 4.1.2) (1169). Position: 76°25'N 69°43'W. Depth: 250 m. Distance from point of impact: 16.1 km

Depth in cm	$^{239,240}Pu$ Bq kg^{-1}	Bq m^{-2}	^{137}Cs Bq kg^{-1}	Bq m^{-2}	^{241}Am Bq m^{-2}	$\frac{^{239,240}Pu}{^{137}Cs}$	$\frac{^{241}Am}{^{239,240}Pu}$	$\frac{^{238}Pu}{^{239,240}Pu}$	Total g
0-3	12.8	142	5.5	61		2.33		0.007	161
3-6	2.5	75	2.3	70		1.09		0.042	435
6-9	1.62	38	1.4	33		1.16		-	343
Σ		255		164		ΣPu/ΣCs:1.56			

Table 4.1.2.15. Radionuclides in marine sediments collected with a 145 cm^2 corer at Thule in August 1984. Location: C (cf. Fig. 4.1.2) (1404). Position: 76°40'N 69°30'W. Depth: 110 m. Distance from point of impact: 17.0 km

Depth in cm	$^{239,240}Pu$ Bq kg^{-1}	Bq m^{-2}	^{137}Cs Bq kg^{-1}	Bq m^{-2}	^{241}Am Bq m^{-2}	$\frac{^{239,240}Pu}{^{137}Cs}$	$\frac{^{241}Am}{^{239,240}Pu}$	$\frac{^{238}Pu}{^{239,240}Pu}$	Total g
0-3	36	470	9.8	130		3.7			192
3-6	4.9	97	6.5	130		0.75			289
6-9	1.7	32	3.6	68		0.47			275
9-12	0.17	3	<0.9	<18		>0.2			292
Σ		602		<346					

Table 4.1.2.16. Radionuclides in marine sediments collected with a 145 cm^2 corer at Thule in August 1984. Location: SW. Kap Atholl (cf. Fig. 4.1.2) (1412). Position: 76°10'N 70°48'W. Depth: 625 m. Distance from point of impact: 55.9 km

Depth in cm	$^{239,240}Pu$ Bq kg^{-1}	Bq m^{-2}	^{137}Cs Bq kg^{-1}	Bq m^{-2}	^{241}Am Bq m^{-2}	$\frac{^{239,240}Pu}{^{137}Cs}$	$\frac{^{241}Am}{^{239,240}Pu}$	$\frac{^{238}Pu}{^{239,240}Pu}$	Total g
0-3	1.24	10.3	6.3	52		0.20			120
3-6	0.50	5.9	4.2	49		0.12			170
6-9	0.21	2.9	2.9	39		0.07			199
9-12	0.17	2.5	1.4	21		0.12			214
12-15	0.107	1.8	1.2	20		0.09			241
Σ		23.4		181		ΣPu/ΣCs:0.13			

4.1.3. Seaplants

The ^{239,240}Pu concentrations (Bq kg^{-1} dry weight) in Fucus and Laminaria from Thule (Table 4.1) were similar to those observed in 1979 (0.40±0.16 (1 S.D.) and 0.18±0.10, respectively)[16]. As the sea water concentrations were lower in 1984 than in 1979 (cf. 4.1.1) the observed concentration factors between water and seaplants rose in 1984. Compared with Fucus from Grise Fjord at Ellesmere Island the Thule samples did not show enhanced levels and we thus see no indication of accident-derived Pu in the Thule seaweed.

The most interesting observation is the enhanced ^{99}Tc in the two Fucus samples from Thule. Compared with 1979[10] we notice an increase by a factor of four, and compared with Grise Fjord the Thule samples contained 2-3 times more ^{99}Tc. We conclude that the West Greenland Current has transported Sellafield ^{99}Tc up to Thule since 1979, but no surplus ^{99}Tc has yet shown up on the Canadian coast.

The ^{90}Sr concentration in the Fucus sample from Grise Fjord was higher than expected when we compare it with the other locations and radionuclides.

Alaria esculenta does not concentrate Pu, Am, Tc as efficiently as Fucus.

Table 4.1.3. Seaweed samples collected in Canada and Greenland during the Baffin cruise in July-August 1984. (Unit: Bq kg^{-1} dry weight)

Position N	Position W	Location	Species	Date	^{40}K**	^{90}Sr	^{99}Tc	^{137}Cs	^{239,240}Pu	^{241}Am
48°	53°	Sct. Johns	Fucus ves/dis	July 28	39.5	0.50	0.96	0.79	0.033	0.010
"	"	- " -	Alaria esculenta	- " -	52.1	0.63	0.05B	0.45B	0.057A	0.0046A
76°30'	70°06'	Eiderduck Island	Fucus ves/dis	Aug 11	27.8	0.34	2.58	0.64	0.43	0.038
76°34'	68°48'	Dundas	Fucus ves/dis	- " -	46.7	0.54	2.34	1.07	0.32	0.046
76°30'	70°01'	Bylot Sound	Laminaria sac.	Aug 9	234	0.68	-	0.91B	0.11	0.014
76°11'	82°50'	Grise Fj.	Fucus ves/dis	Aug 13	22.4	1.87	1.02	1.01	0.45	0.104
74°42'	94°55'	Resolute	Fucus distichus*	Aug 16	3.7	-	-	1.82	-	-

* Washed up on beach.

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

4.2. The F/S Polarstern cruise in July 1984 to the Fram Strait

4.2.1. Surface sea water

The transit time of waterborne pollution from Sellafield to Svalbard is approximately five years[11]. The discharges of ^{137}Cs from Sellafield were reduced by a factor of 1.6 from 1978 to 1979[12,13]. Hence we would expect to see a decrease from 1983 to 1984 in the Norwegian Sea beteen Norway and Svalbard. Figure 4.2.1.2 shows that such a decrease did in fact occur in the case of ^{137}Cs, but not so evidently for ^{90}Sr. This was to be expected, because the fallout background of ^{90}Sr is relatively more important than for ^{137}Cs. Hence variations in the Sellafield contributions are more easily obscured for ^{90}Sr.

In the Fram Strait the ^{137}Cs concentrations east of 0^{o} were higher than in 1984, whereas the opposite was the case west of this longitude (Fig. 4.1.2.3). The ^{134}Cs levels around 0^{o} increased from 0.06 in 1983 to 0.10 Bq m^{-3} in 1984 (decay corrected to 1983)[9,10]. Both sets of observations suggest that that radiocesium from Sellafield was transferred from Atlantic to Polar water in the Fram Strait from 1983 to 1984.

The $^{239,240}Pu$ concentrations in the Fram Strait were significantly higher (12.6 ± 1.8 mBq m^{-3}) than those observed in West Greenland waters (7.9 ± 1.0 Bq m^{-3}) (cf. 4.1.1). However, the $^{241}Am/^{239,240}Pu$ ratios did not differ significantly, (0.112 and 0.104, respectively). These observations support earlier conclusions[19] that $^{239,240}Pu$ and ^{241}Am in arctic water nearly exclusively originate from fallout.

Table 4.2.1. Radionuclides in surface sea water collected from N-Norway, via Svalbard to NE-Greenland in in July-Aug 1984. (Unit: Bq m^{-3})

Position N	E or W	Station No.	Date	Salinity o/oo	Temp. °C	^{90}Sr	^{134}Cs	^{137}Cs	$^{239,240}Pu$*	$\frac{^{241}Am}{^{239,240}Pu}$
80°34'	7°16'E	319	July 20	32.4	-1.1	3.6		9.7	14.7	0.044
80°44'	13°00'E	321	July 21	29.6	-1.0	4.5	0.126	8.7	12.2	0.175
80°08'	4°44'E	327	July 23	32.2	1.6	4.0		10.0	14.1	0.178
81°19'	15°22'E	325	July 22	28.4	-1.3	4.1		9.7	13.4	0.094
80°55'	18°35'E	322	July 21	34.0	3.2	4.0	-	10.4	-	-
81°46'	10°42'W	329	July 26	31.9	-0.8	5.6		5.4	12.4	0.140
81°30'	2°03'W	354	July 29	32.4	-1.6	5.2	0.016A	7.4	12.5	0.114
82°16'	8°38'W	333	July 27	32.1	-1.4	5.9		6.1	9.8	0.040
81°54'	11°00'W	331	July 26	32.0	-0.4	7.2	-	6.1	-	-
82°32'	6°16'W	334	July 27	32.3	-1.9	6.2	-	6.1	-	-
82°46'	9°41'W	335	July 28	32.2	-2.0	4.2	-	7.9	-	-
80°42'	4°37'W	359	July 30	32.0	-1.8	7.0	-	6.2	-	-
77°40'	4°56'W	363	Aug 1	31.4	-0.6	5.8	0.015B	7.6	10.0	0.111
77°30'	4°13'W	365	Aug 2	32.1	1.2	4.9	-	8.4	-	-
77°40'	2°30'W	366	Aug 2	31.9	-0.6	4.9	0.074	9.0	14.5	0.112
77°40'	0°32'W	367	Aug 2	34.6	4.1	3.6	-	8.9	-	-
77°40'	2°30'E	371	Aug 3	34.9	3.1	2.9	-	7.2	-	-
77°40'	5°16'E	375	Aug 3	35.0	5.0	2.5	-	7.1	-	-
77°40'	7°34'E	381	Aug 4	35.0	5.6	3.6	-	8.8	-	-
77°40'	9°44'E	383	Aug 4	35.0	5.9	3.7	-	8.7	-	-
77°41'	10°21'E	384	Aug 4	35.3	6.5	4.5	-	10.9	-	-
76°44'	14°40'E	22T	Aug 5	33.2	2.7	4.5	-	10.2	-	-
76°58'	14°36'E	21T	Aug 5	33.0	2.9	4.2	-	9.2	-	-
76°20'	12°58'E	23T	Aug 6	35.0	5.8	4.0	-	11.1	-	-
74°44'	15°05'E	24T	Aug 6	35.1	7.7	4.6	-	13.0	-	-
73°55'	16°00'E	25T	Aug 6	35.1	7.8	5.0	-	14.6	-	-
73°27'	16°29'E	26T	Aug 6	35.2	7.5	4.3	-	10.9	-	-
72°53'	16°52'E	27T	Aug 6	35.1	7.2	5.0	-	15.8	-	-
72°24'	17°28'E	28T	Aug 6	34.9	8.0	4.7	-	15.0	-	-
71°38'	18°19'E	29T	Aug 6	35.2	9.4	5.9	-	21.3	-	-
71°11'	18°38'E	30T	Aug 6	34.8	9.4	7.9	-	35.5	-	-
70°47'	19°06'E	31T	Aug 6	34.5	10.4	9.4	-	33.7	-	-

*Unit: mBq m^{-3}

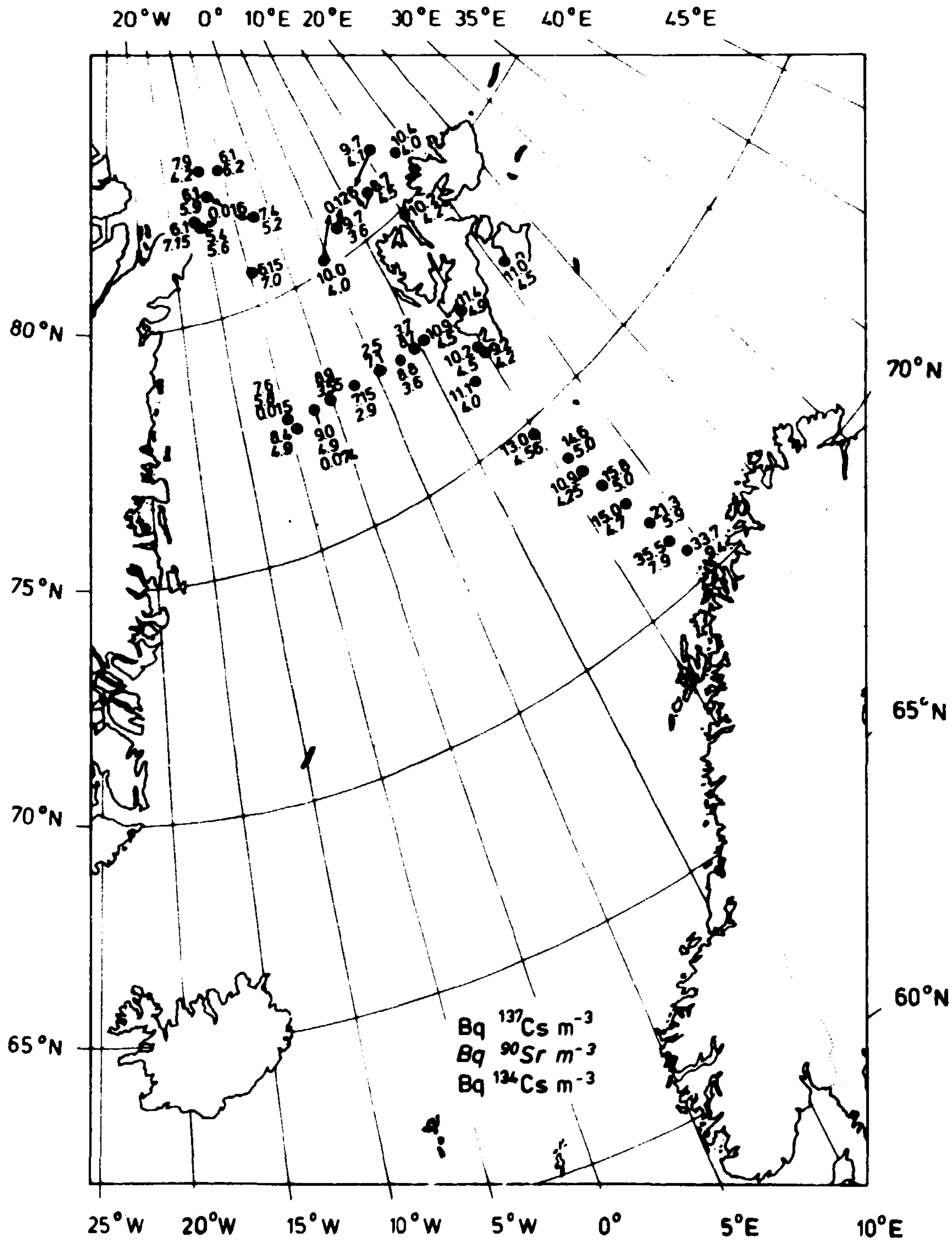

Fig. 4.2.1.1. Radiocesium and ^{90}Sr in surface water collected during the F/S Polarstern cruise from Norway to East Greenland via Svalbard in July-August 1984.

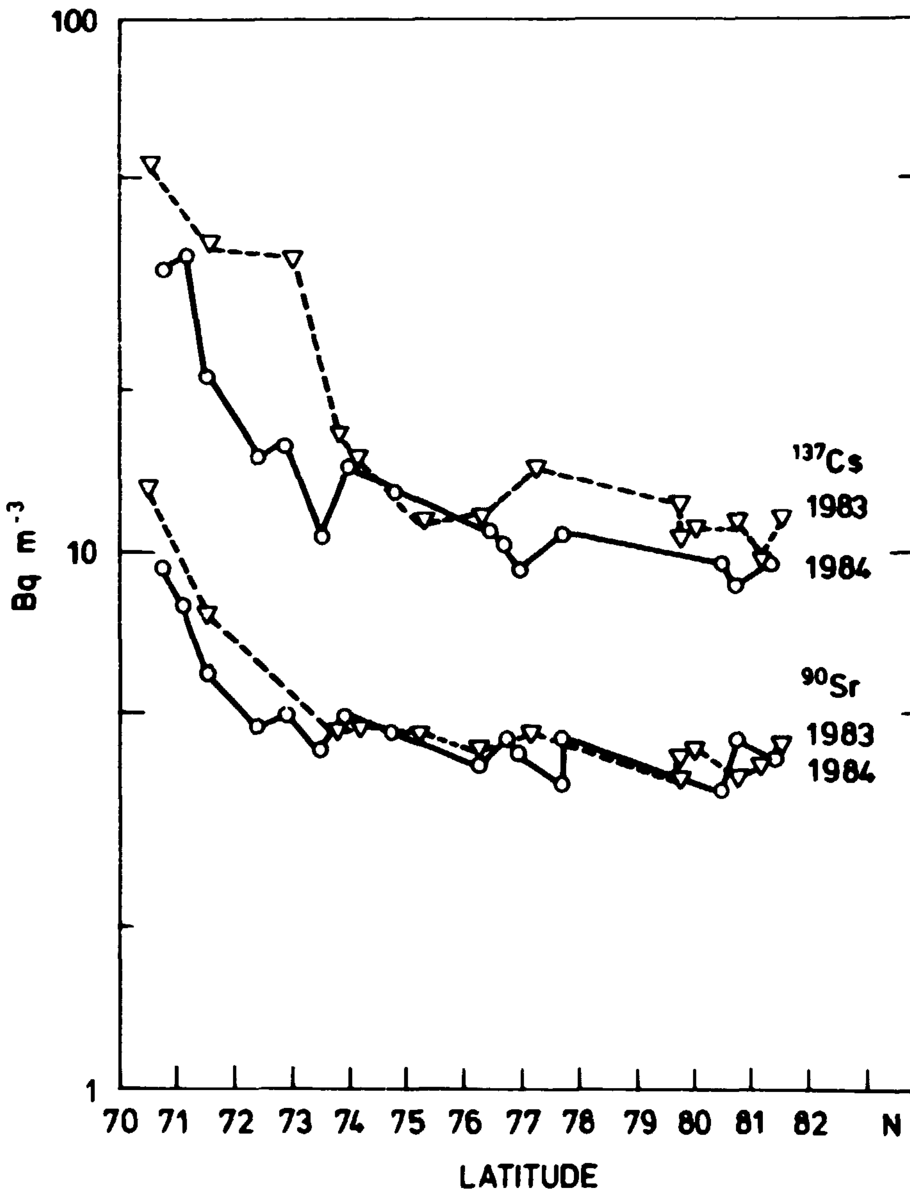

Fig. 4.2.1.2. Cesium-137 and ^{90}Sr in surface water collected between N-Norway and Svalbard in July-August 1983 and 1984. The abscissa shows the latitude of the samples.

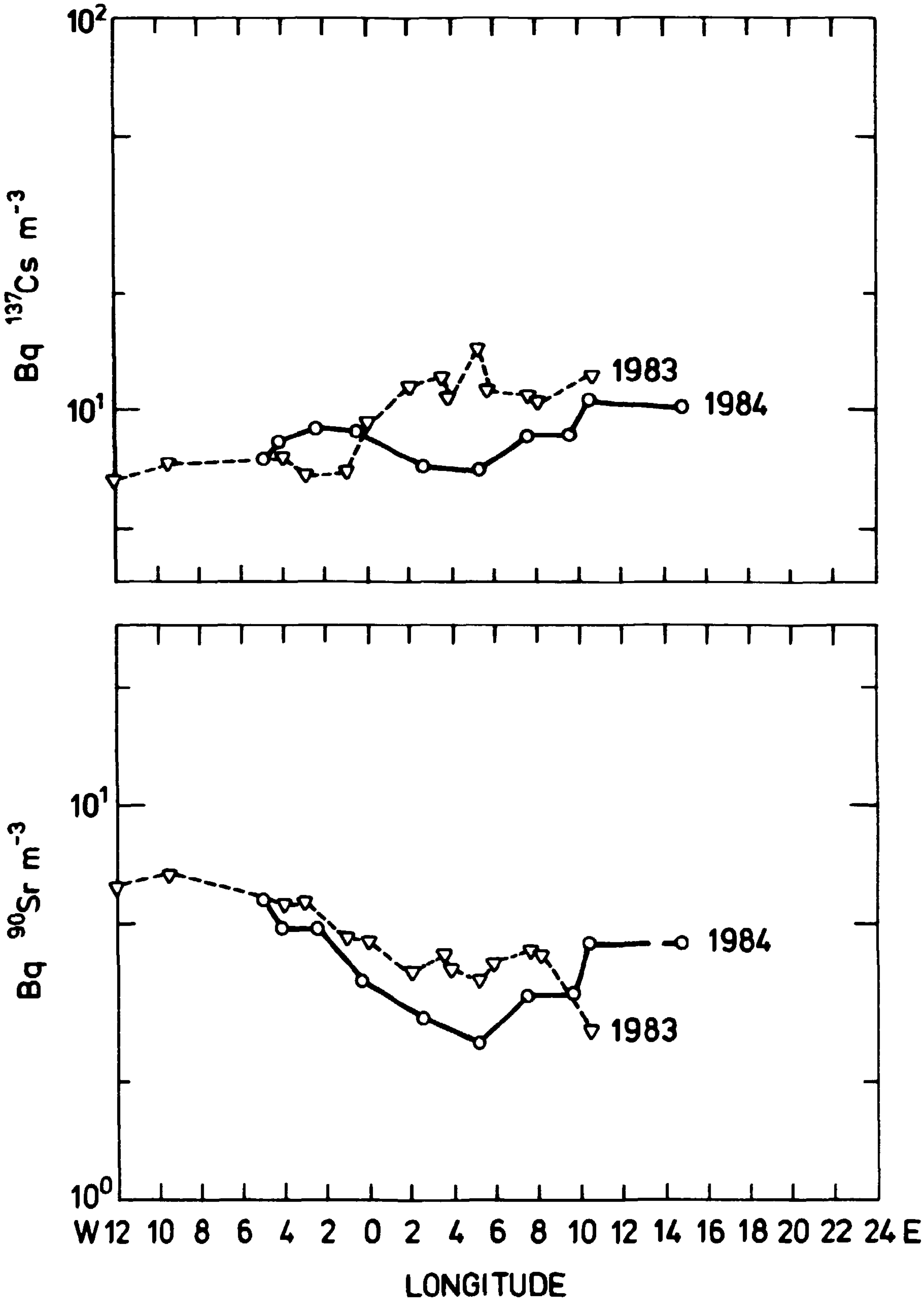

Fig. 4.2.1.3. Cesium-137 and ^{90}Sr in surface water collected in the Fram Strait between Svalbard and East-Greenland in July 1983 (79°-80°N) and in August 1984 (77o-78oN). The abscissa shows the longitude of the samples.

4.3. Samplings by the Greenland Fisheries and Environmental Resarch Institutes

4.3.1. Surface sea water

The systematic sampling of seawater along the Greenland west coast, which began in 1983[9)], was continued in 1984. The ^{90}Sr concentrations have shown a decrease throughout the period, whereas the ^{137}Cs levels have not changed significantly from 1983 to 1984. In the case of ^{137}Cs the summer concentrations have in general been lower than those observed in November. Sr-90 as well as ^{137}Cs have shown decreasing values, northward.

In Table 4.3.1.1 two samples were collected from the same location (Disko Rende) with 5 days between samplings. We observed an increase of 22% in the ^{90}Sr as well as in the ^{137}Cs levels during this short period. This shows how rapidly the concentrations may change along the Greenland west coast.

In Fig. 4.3.1.1 we have plotted some data from the Baffin Cruise (Table 4.1.1.1) along with those from Table 4.3.1.1. The two samplings took place 3-4 weeks apart. We observed that the Baffin samples in general showed the highest levels. We conclude that water enriched with (Sellafield) radiocesium appeared during the last part of July along the Greenland west coast.

The samplings in November 1984 (Table 4.3.1.2 and Fig. 4.3.1.2) were extended to include the south east coast of Greenland. It is evident that the samples collected closest to the east coast showed higher activity levels and lower salinities that those collected farther away from the coast. The coast near samples were collected within the East Greenland Current (EGC), whereas the more easterly samples were from the Irminger Current, which comes from the Atlantic Ocean. The two stations at Kap Farvel (Table 4.3.1.2) are evidently taken outside the EGC.

A coastal sample collected at Prins Christians Sund (Table 3.2.2 and Fig. 4.3.1.2) shows higher levels indicating that we here are in the polar water of the EGC. When we continue up along the Greenland west coast the coast near stations still show the

Table 4.3.1.1. Strontium-90 and Cesium-137 in surface sea water off West Greenland in June-July 1984

Latitude N	Longitude W	Name of location	^{90}Sr Bq m^{-3}	^{137}Cs Bq m^{-3}	Salinity o/oo
64°01'	52°19'	Fylla Bank (Nuuk)	4.1	6.2	33.2
63°55'	53°07'	- " -	5.3	5.8	32.7
63°48'	53°56'	- " -	4.7	5.8	32.7
65°06'	53°00'	Sukkertoppen (Manitsoq)	4.4	4.7	28.7
65°06'	53°59'	- " -	3.7	4.4	32.4
65°06'	54°58'	- " -	3.9	5.7	33.3
66°53'	54°10'	Holsteinborg (Sisimiut)	3.3	3.7	34.0
66°46'	55°36'	- " -	3.2	3.9	34.0
66°41'	56°38'	- " -	4.3	4.9	32.3
67°34'	57°10'	Intermediate station	4.6	3.6	27.3
68°04'	56°00'	Egedesminde (Ausiait)	4.2	3.8	33.4
68°08'	57°17'	- " -	4.4	5.3	32.4
68°54'	55°54'	Disko Rende*	3.6	4.9	33.3
- " -	- " -	- " - **	4.4	6.0	31.8
69°30'	57°10'	Disko Fjord	3.8	4.5	31.8
70°20'	55°10'	Hareø south	3.6	4.0	32.8
70°34'	54°47'	Hareø north	4.6	3.8	28.8
69°42'	51°38'	Arveprinsen	3.7	4.4	29.3
68°55'	52°24'	Skansen-Akunaq	4.6	4.2	28.5

* June 30

**June 5

Table 4.3.1.2. Strontium-90 and Cesium-137 in surface sea water collected around Greenland from the Denmark Strait to the Davis Strait in November 1984

Latitude N	Longitude W	Name of location	^{90}Sr Bq m^{-3}	^{137}Cs Bq m^{-3}	Salinity o/oo	$\frac{^{137}Cs}{^{90}Sr}$
65°53'	30°52'	Dohrn Bank	4.8	6.7	33.1	1.40
65°45'	28°17'	- " -	1.9	2.7	35.3	1.42
63°04'	39°11'	Kap Mösting	4.3	6.7	33.0	1.56
63°38'	40°05'	- " -	2.0	2.15	35.0	1.08
62°10'	41°25'	Kap Steen Bille	3.1	5.9	32.4	1.90
61°56'	40°27'	- " -	1.8	2.5	33.1	1.39
60°57'	42°47'	Kap Discord	3.8	6.0	33.8	1.58
60°48'	41°16'	- " -	1.76	2.5	34.9	1.42
59°15'	44°58'	Kap Farvel	1.62	2.9	33.4	1.79
58°46'	45°50'	- " -	1.9	3.2	34.6	1.68
60°50'	48°45'	Kap Desolation	4.1	6.3	32.6	1.54
60°02'	51°27'	- " -	2.5	4.0	34.5	1.60
61°57'	50°00'	Frederikshåb	3.9	6.5	32.3	1.67
61°26'	53°25'	- " -	3.8	4.6	33.7	1.21
64°01'	52°18'	Fylla Bank	4.1	6.2	32.1	1.51
63°37'	55°30'	- " -	4.1	5.6	32.6	1.37
65°06'	53°00'	Sukkertoppen	4.0	6.0	32.6	1.50
65°06'	55°43'	- " -	4.0	6.3	32.5	1.58
66°52'	54°09'	Holsteinsborg	3.5	5.0	32.4	1.43
66°41'	56°39'	- " -	4.4	6.0	32.2	1.36
69°30'	54°54'	Disco Fjord	3.3	5.6	32.8	1.70
69°30'	58°20'	- " -	2.9	4.6	33.1	1.59

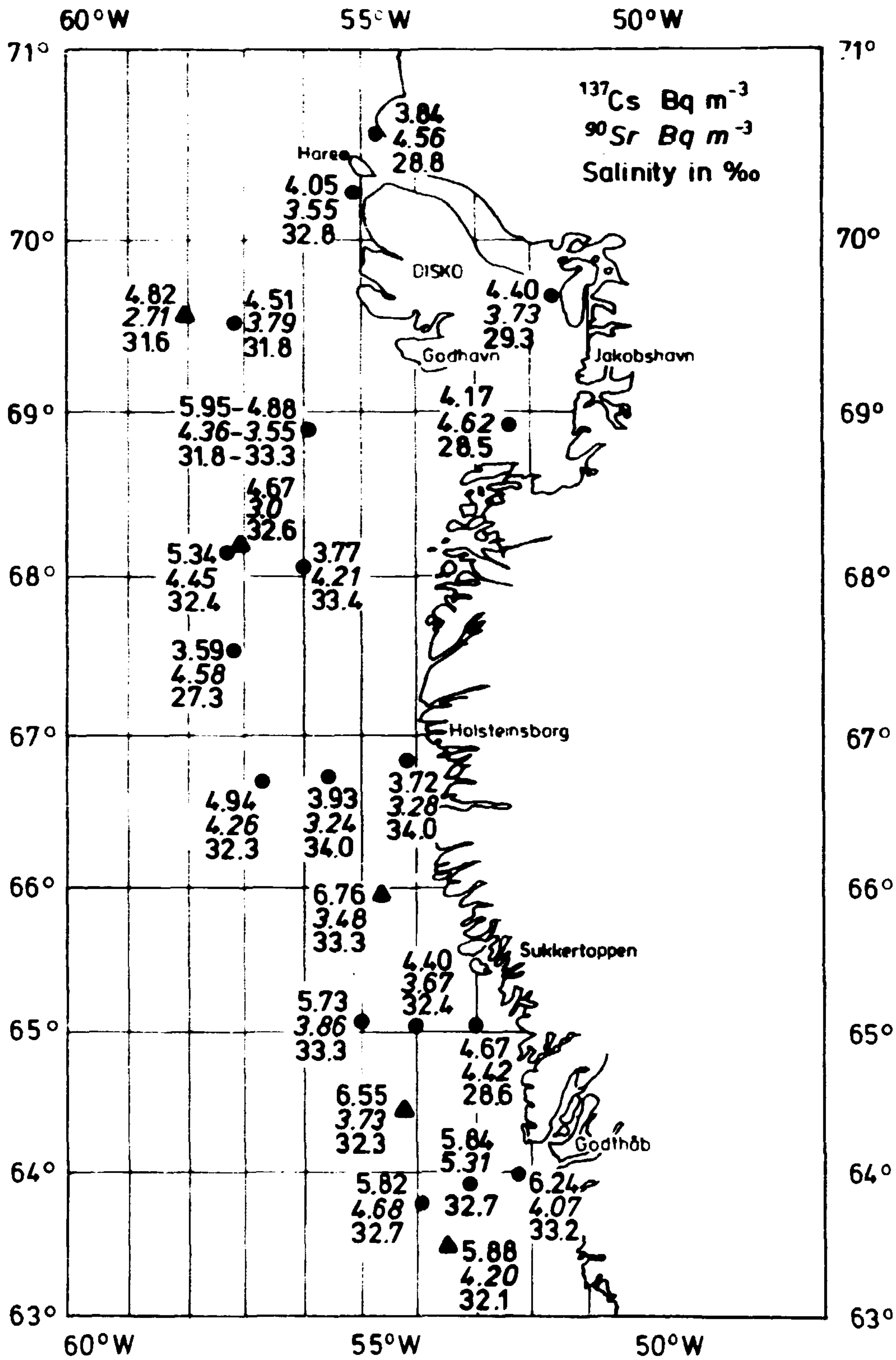

Fig. 4.3.1.1. Cesium-137, ^{90}Sr, and salinity in surface water collected along the Greenland west coast.

● Samples collected by the Greenland Fisheries and Environmental Research Institute in July 1984.

▲ Samples collected by CSS Baffin in August 1984.

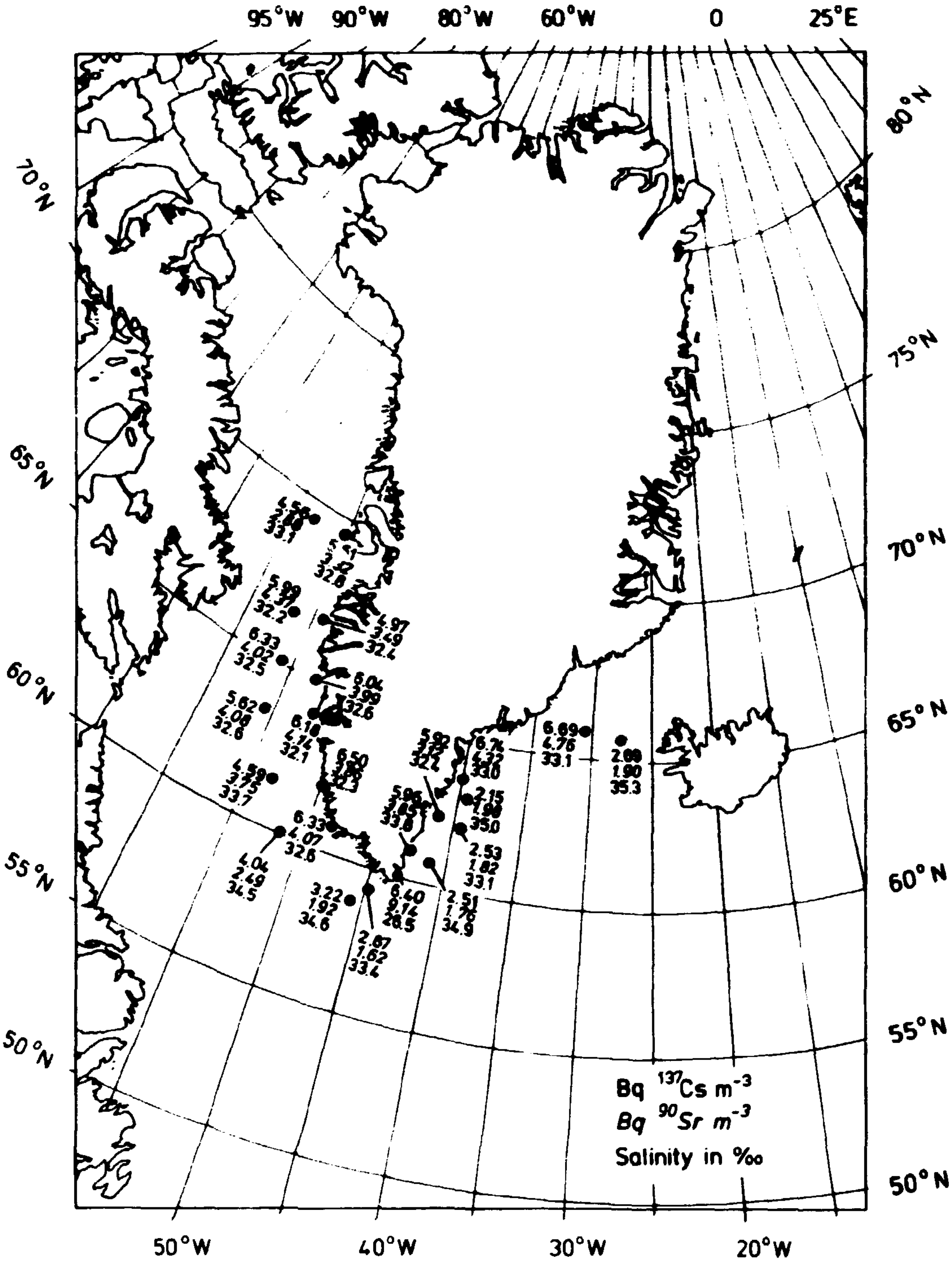

Fig. 4.3.1.2 Cesium-137, ^{90}Sr, and salinity in surface water collected along the Greenland east and west coast by F/S Walter Herwig in November 1984.

highest values up to 65°N, but the difference between eastern and western stations becomes far less pronounced than seen on the east coast. The four coast-near stations on the east coast contained 4.00±0.73 Bq ^{90}Sr m^{-3} (±1 S.D.) and 6.33±0.43 Bq ^{137}Cs m^{-3}. The six coast-near stations along the west coast contained 3.82±0.34 Bq ^{90}Sr m^{-3} and 5.93±0.55 Bq ^{137}Cs m^{-3}. Thus we observe a small decrease in the activities, when we

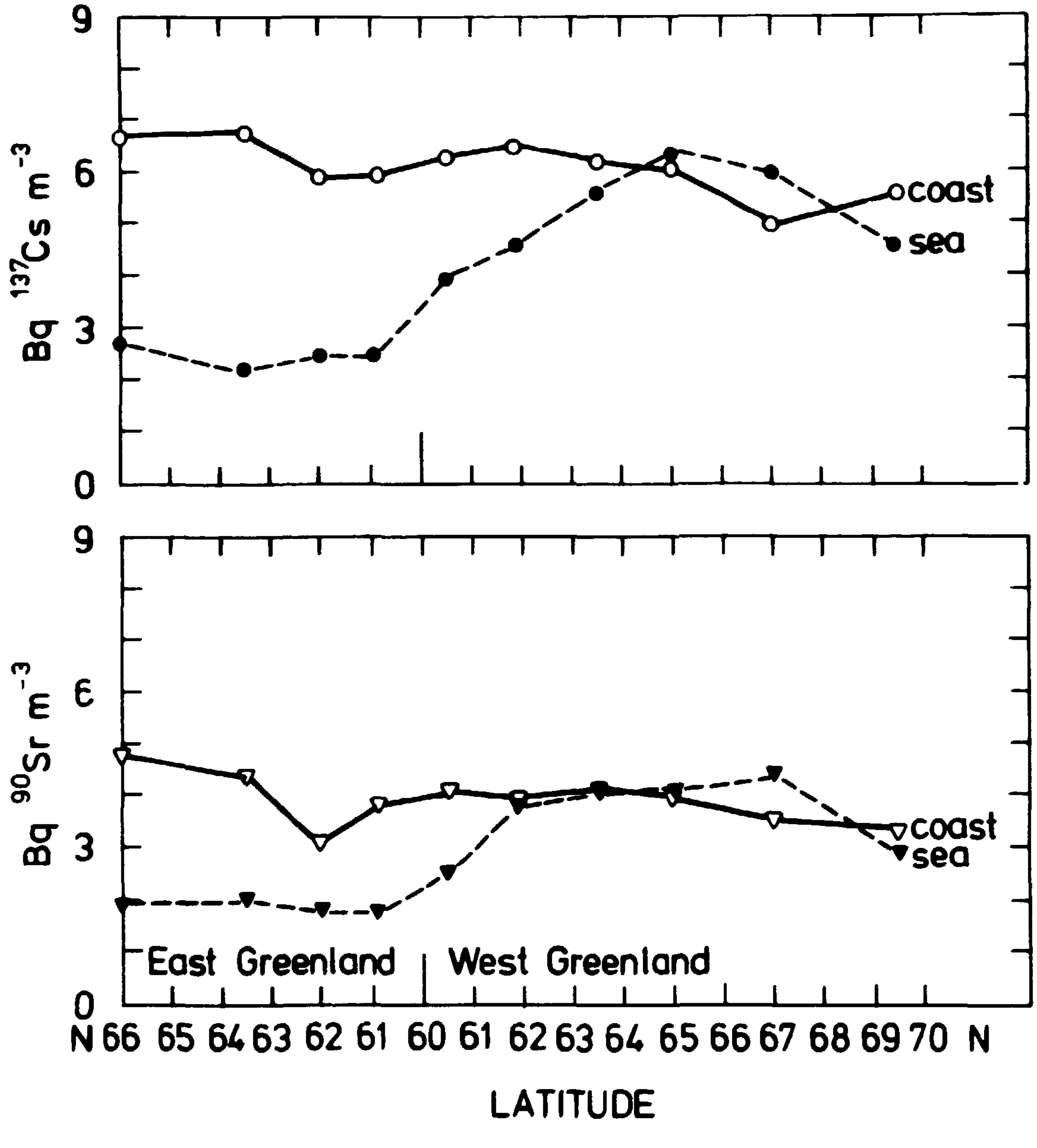

Fig. 4.3.1.3. Cesium-137 and ^{90}Sr in surface water collected in November 1984 from East Greenland around Kap Farvel to West Greenland. The latitudes are indicated on the abscissa.

Coast: Sample location near the coast

Sea: Sample location farther away from the shore (cf. also Fig. 4.3.1.2).

pass from the east to the west coast of Greenland. At the stations farther away from the shore the water on the west coast shows higher activity levels than that on the east coast. This is because the EGC becomes broader, when the current turns into the West Greenland Current after having passed Kap Farvel (see Fig. 4.3.1.3).

4.3.2. Sea plants from the Godthåb Fjord

Strontium-90 and ^{99}Tc were determined in a number of Fucus and Ascophyllum samples collected in the Godthåb Fjord in 1980-1982 (Table 4.3.2.1). An anova (Table 4.3.2.2) showed significant differences between years and between species for ^{99}Tc. Ascophyllum nodosum contained 1.3 times more ^{99}Tc than Fucus vesiculosus/disticus, and 1982 showed levels 1.3 times higher than 1980. This increase in ^{99}Tc on the Greenland west coast have also been seen at other locations[9,10]. In earlier studies[10] Ascophyllum has showed about about 2 times higher levels than Fucus. In the present material the difference was thus less pronounced. Whether this is because the present samples are from arctic rather than from temperate waters is a question yet to be answered.

Table 4.3.2.1. Seaweed samples collected at Godthåb in 1980-82. (Unit: Bq kg^{-1} dry weight)

Species	Year	^{90}Sr	^{99}Tc	Sample number according to Greenland Fisheries and Environmental Research Institute
Fucus vesiculosus	1980		1.10	Z 53 St 1
- " -	1980		1.45	Z 54 St 1
- " -	1980	0.59	1.36	Z 55 St 1
- " -	1980		1.40	Z 56 St 1
- " -	1980		1.23	Z 57 St 1
Ascophyllum nodosum	1980	-	1.95	Z 64 St 1
- " -	1980	-	1.62	Z 65 St 1
- " -	1980	-	2.06	Z 66 St 1
- " -	1980	-	1.95	Z 67 St 1
Fucus disticus	1980	0.43	1.40	Z 58,59,60,61,62 St 1
Fucus vesiculosus	1981	0.77	1.61	X 53,54,55,56,57 St 1
Ascophyllum nodosum	1981	-	1.95	X 63,64,65,66,67 St 1
Fucus disticus	1981	-	1.60	X 58,59,60,61 St 1
Fucus vesiculosus	1982	0.44	1.77	Y 53,54,55,56,57 St 1
Ascophyllum nodosum	1982	-	2.23	Y 63,64,65,66,67 St 1
Fucus disticus	1982	-	1.88	Y 58,59,60,61,62 St 1

Table 4.3.2.2. Anova of ln Bq ^{99}Tc kg^{-1} d.w. in Fucus and Ascophyllum (from Table 4.3.2.1)

Variation	SSD	f	s^2	v^2	P
Between years	0.180	2	0.090	10.03	99.6%
Between species	0.340	1	0.340	37.85	99.9%
Species × years	0.022	2	0.011	1.25	67.2%
Remainder	0.090	10	0.009		

4.3.3. Shrimps, Thule 1984

The shrimp samples from Thule should be seen in context with our plutonium studies in 1984 at Thule (cf. 4.1). The mean level was 0.081∓0.048 Bq $^{239,240}Pu$ kg^{-1} fresh flesh (±1 S.D.; N=10). If a person eats 10 kg of these shrimp annually, he will receive a dose of $0.081 \times 10 \times 0.05/2 \times 10^5 = 0.2$ μSv. However, according to recent studies made by the NRPB[22] the gastrointrestinal absorption of Pu may be higher for diet than the figure used by ICRP, and this may increase the dose by a factor of five, i.e. to 1 μSv. We may compare this dose with that received from naturally occurring ^{210}Po in the shrimps (cf. 4.5.4). We notice that the dose from $^{239,240}Pu$ is half of that from polonium, which again is 1 o/oo of the natural background radiation (including radon in houses).

Figure 4.3.3 shows the median levels of $^{239,240}Pu$ in shrimp flesh collected in Bylot Sound at Thule since the B52 accident in 1968. After a rapid initial drop (1968 - 1970), the activity has leveled off, and from 1970 to 1984 it has been following the power function:

$$\text{Bq } ^{239,240}\text{Pu kg fresh shrimp flesh} = 0.19\ X^{-0.84}$$

where X is the year (1969 = 1 etc.)

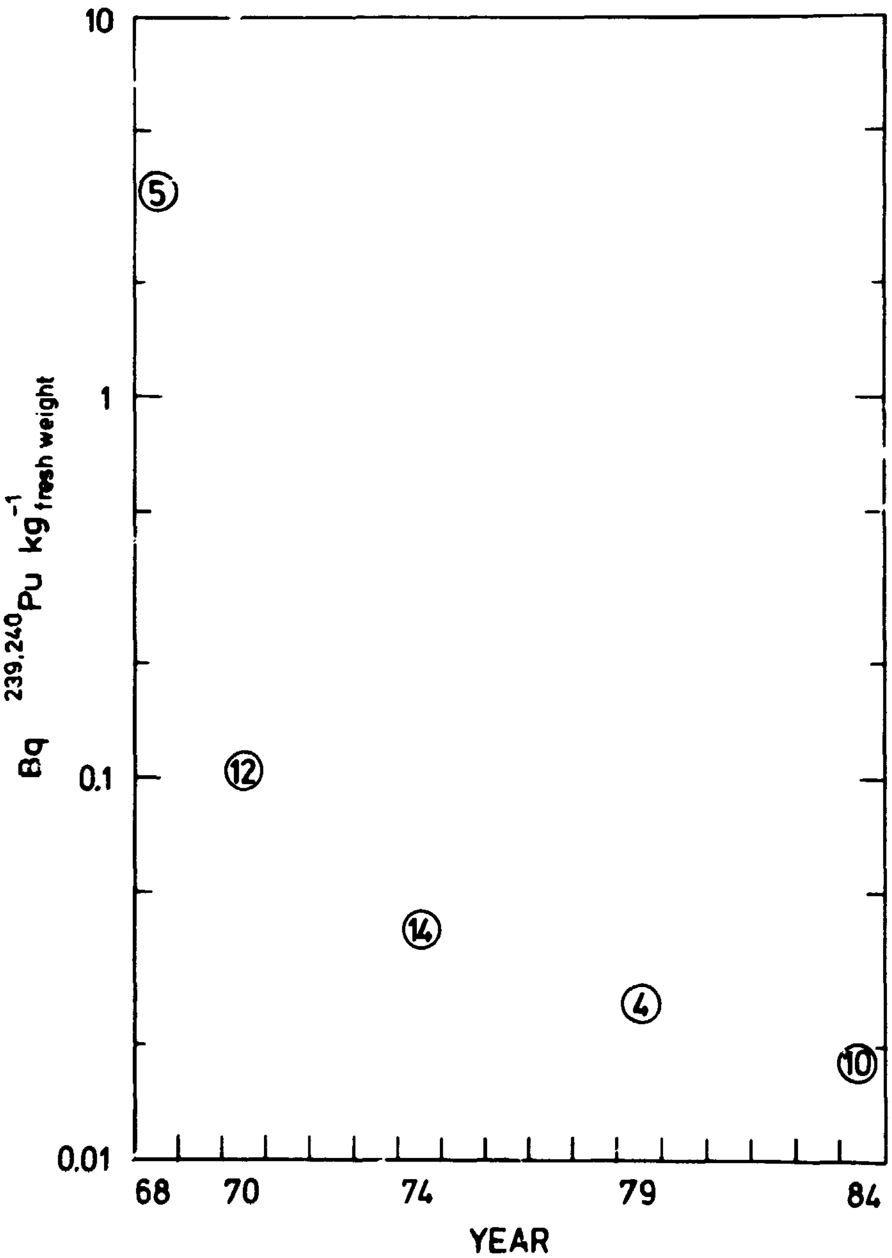

Fig. 4.3.3 Median plutonium levels in shrimp flesh from Thule 1968-1984. The number of samples are shown for each year. In 1970, 1974, and 1979 the flesh levels were calculated from the total animal concentrations by division with six [2,5].

Table 4.3.3. Plutonium 239,240 in shrimps caught in Bylot Sound at Thule in July-August 1984 by the Greenland Fisheries and Environmental Research Institute

Sample No.	Shell length in mm	Number of individuals	Fresh weight of flesh	% dry weight	mBq kg^{-1} fresh weight
84-576	12-13	20	18.4 g	17.5	62
84-577	14-15	20	25.5 g	17.1	6.7 B
84-578	16	15	23.7 g	17.3	9.7 A
84-579	17-19	11	24.2 g	16.8	14.5 A
84-580	9-11	16	8.0 g	12.8	23 B
84-581	12-13	20	17.6 g	16.1	22 B
84-582	14-15	20	25.7 g	16.4	154
84-583	16	19	29.6 g	17.8	490 A
84-584	17-19	20	47.3 g	17.6	14 A
84-585	20-23	14	43.7 g	16.0	12 A
84-586*	15-18	5	13.0 g	12.7	0
84-587*	19-25	9	12.1 g	10.0	0

*Qanaq

4.4. Norwegian samplings

4.4.1. Surface sea water collected at Svalbard in 1984

Three samples were collected from Svalbard in Sept. 1984 (Table 4.4.1). The results agreed with those found in July during the Polarstern cruise (Table 4.2.1 and Fig. 4.2.1.1). Sellafield radiocesium is thus detectable in the coastal waters around Svalbard.

Table 4.4.1. Surface sea water samplings at Svalbard in 1984

Latitude N	Longitude E	Location	Date	Salinity o/oo	Temp. °C	^{90}Sr Bq m^{-3}	^{137}Cs Bq m^{-3}
78°53'	16°00'	Mosselbukta	Sep 8	33.9	2	4.2	10.2
77°44'	14°37'	Bellsund	Sep 22	32.6	3	4.9	11.4
77°39'	21°05'	Russebukta	Sep 18	33.9	3	4.5	11.0

4.4.2. Sea plants from the Norwegian west coast, Svalbard and Jan Mayen

An anova on the data in Table 4.4.2.1 shows a significant variation between years and between locations. 1981 thus showed higher Pu levels for all stations than the other years, and the most southern (Utsira) and most northern (Indre Kiberg) stations showed higher levels than the other ones. We thus see another picture for plutonium than that observed for radiocesium and ^{99}Tc along the Norwegian west coast[10]. The enhanced levels at Utsira may be due to Sellafield, but the increased Pu concentrations seen in the north must have other explanations. We assume that the slower growth of Fucus in the north is tantamount to higher concentration factors for Pu than those seen at more temperate latitudes. The discharges of Pu from Sellafield were reduced by a factor of 2 from 1979 to 1980[12]. This may explain part of the decrease seen in the Norwegian fucus from 1981 to 1982-83, although the transit time from

Table 4.4.2.1. Plutonium and Americium in Fucus vesiculosus collected along the Norwegian west coast 1981-1984

Station No. (cf. Fig. 4.4.2.1)	Location	Unit	1981	1982	1983	1984
3	Indre Kiberg 70°17'N 30°56'E	Bq $^{239,240}Pu$ kg^{-1} dry weight	0.25	0.16	0.195	
		$^{238}Pu/^{239,240}Pu$	0.09	0.13	0.10	
		$^{241}Am/^{239,240}Pu$	0.08			
6	Vestvågøy 68°10'N 13°50'E	Bq $^{239,240}Pu$ kg^{-1} dry weight	0.21 0.19	0.13	0.12	
		$^{238}Pu/^{239,240}Pu$	0.15 0.05	0.18	0.08	
		$^{241}Am/^{239,240}Pu$	0.26	0.09	0.04	
8	Eid 62°38'N 7°38'E	Bq $^{239,240}Pu$ kg^{-1} dry weight	0.21	0.14	0.14	
		$^{238}Pu/^{239,240}Pu$	0.08	0.10	0.07	
		$^{241}Am/^{239,240}Pu$	0.12	0.08	0.15	
10	Utsira 59°19'N 4°54'E	Bq $^{239,240}Pu$ kg^{-1} dry weight	0.26	0.15	0.17	0.07
		$^{238}Pu/^{239,240}Pu$	0.10		0.09	0.03
		$^{241}Am/^{239,240}Pu$	0.07		0.19	

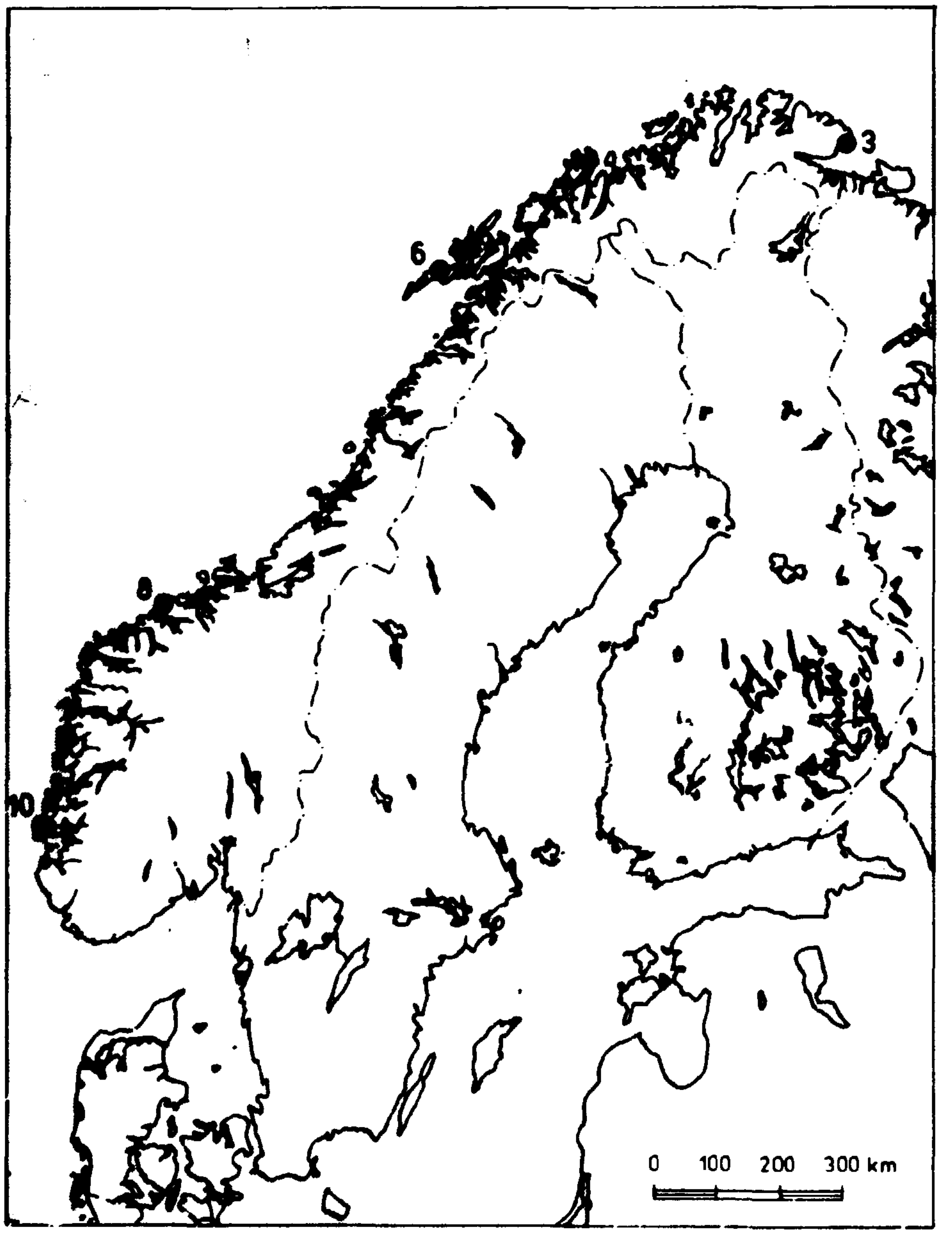

Fig. 4.4.2.1. Sampling locations for seaweed along the Norwegian coast.

Table 4.4.2.2. Plutonium and Americium in seaweed collected at Svalbard and Jan Mayen in 1983

Station (cf. Fig. 4.4.2.2)	Location	Species	Date of sampling	$^{239,240}Pu$ Bq kg^{-1} d.w.	^{238}Pu / $^{239,240}Pu$	^{241}Am / $^{239,240}Pu$
20-2	Jan Mayen 71°00'N 8°00'W	La.di.	29 Aug	0.047	0.06	
20-3	- " -	La.sa.	29 Aug	0.047	0.12	0.15
23-5	Hinlopen 79°50'N 18°20'E	Al.es.	29 July	0.025	0.14	0.28
23-6	Dickson Fjord 78°46'N 15°00'E	Fu.sp.	5 Aug	0.20	0.04	0.04
23-7	Gråhuken 79°50'N 14°30'E	Al.es.	13 Aug	0.091	0.06	
23-8	Calypsobyen 77°45'N 14°20'E	- " -	16 Aug	0.013		
23-9	Mosselbukta 79°50'N 16°00'E	Fu.sp.	30 Aug	0.831	0.050	0.171
23-10	Kapp Martin 77°45'N 13°45'E	Al.es.	14 Sep	0.052	0.11	0.07

La.di.: Laminaria digitata; La.sa.: Laminaria saccharina; Al.es.: Alaria esculenta; Fu.sp.: Fucus spiralis.

Sellafield to the Norwegian coast then seems one year shorter than usually anticipated[11].

Table 4.4.2.2 shows that Fucus spiralis from Svalbard shows higher Pu levels than the other species and that the levels are similar to or higher than those observed at the northern station (Indre Kiberg) in Norway. The sample from Mosselbukta was in fact as high as one obtained from East Greenland in 1982 at Scoresby Sund[2].

Table 4.4.2.3 shows that ^{60}Co probably was present in Fucus vesiculosus collected at Trondheim in 1984. The source of the ^{60}Co is probably Sellafield or Winfrith in the U.K. or Cap de la Haque in France. From our distance relation for ^{60}Co determined for Fucus collected along the British coastline in 1982[1], we would at a distance corresponding to that from Sellafield to Trondheim (with the current: 2500 km) has expected 0.23 Bq kg^{-1} Fucus vesiculosus in 1984.

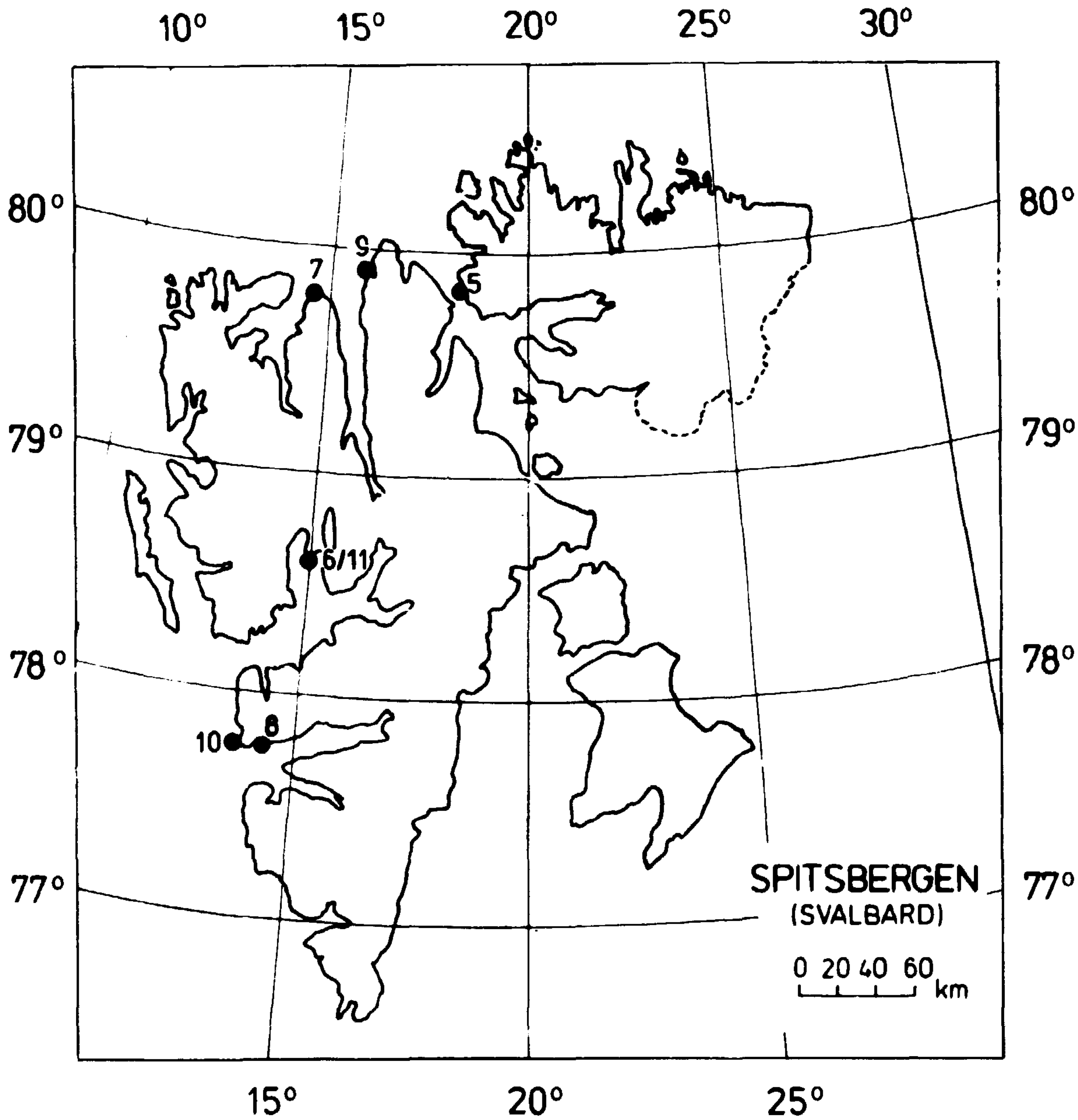

Fig. 4.4.2.2. Sampling locations for seaweed of Svalbard (cf. Table 4.4.2.2).

Table 4.4.2.3. Radionuclides in Fucoids collected in the Trondheim Fjord in 1984

Latitude N	Longitude E	Sampling date	Species	Bq kg^{-1} dry weight ^{60}Co	^{137}Cs
63°35'	09°46'	Aug 13	Fucus vesiculosus	0.26 B	4.45
- " -	- " -	- " -	Fucus serratus		5.57

4.5. Polonium-210 studies

4.5.1. Introduction

If a polonium analysis is carried out on a fresh sample by wet ashing, the ^{210}Po content found may come from ^{210}Po taken up from the environment by the organisms as well as from decay of ^{210}Pb in the organism. We denounce the last source "supported ^{210}Po" and the first "environmental ^{210}Po".

Ashed samples may be measured approximately 3 years after the ashing in order to give ^{210}Po daughter in the samples an opportunity to come into equilibrium with ^{210}Pb. In ashed samples the ^{210}Po thus represents ^{210}Pb only and the analysis does not necessarily tell what the ^{210}Po was in the fresh samples because we have no determination of environmental ^{210}Po.

In the following we will denounce ^{210}Po measured on ashed samples ^{210}Pb. Such samples have been decay corrected to the date of sampling by the half-life of ^{210}Pb. Polonium analysis on fresh or dried samples will be given as ^{210}Po and in this case the results are decay corrected with the half-life of ^{210}Po from the date of analysis. This correction may underestimate the ^{210}Po content if there is a lapse of time between sampling and analysis, provided most of the ^{210}Po is environmental. If all ^{210}Po is supported and there is equilibrium with ^{210}Pb there will be an underestimate arising from the decay of ^{210}Pb only, and this will usually be of minor importance due to the relative long half-life of ^{210}Pb.

4.5.2. Sea plants

The results in Table 4.5.2.1 were all obtained from fresh or dry samples analysed for ^{210}Po after a wet ashing.

Table 4.5.2.1. Polonium-210 in seaweed (fresh or dry) collected in the northern North Atlantic region 1980-1984

Location	Species	Sampling date	Bq kg^{-1} dry weight	Date of analysis
Læsø, Østerby, Denmark	Fucus vesiculosus	Oct 25 1984	6.7	Jan 30, 1985
Hesselø, Denmark	- " -	Oct 30 1984	9.4	- " -
Anholt, Denmark	- " -	Nov 20 1984	11.7	- " -
Godthåb Fjord, Greenland	- " -	Summer 1980	5.3	April 15, 1985
- " -	- " -	- " - - " -	6.0	- " -
- " -	- " -	- " - - " -	5.7	- " -
- " -	- " -	- " - - " -	5.5	- " -
- " -	- " -	- " - - " -	5.9	- " -
- " -	- " -	July 22 1981	16.5	- " -
- " -	- " -	July 27 1982	7.1	April 17, 1985
- " -	Ascophyllum nodosum	Summer 1980	2.5	- " -
- " -	- " -	- " - - " -	2.3	- " -
- " -	- " -	- " - - " -	2.4	- " -
- " -	- " -	- " - - " -	2.8	- " -
- " -	- " -	July 22 1981	4.2	April 25, 1985
- " -	- " -	July 27 1982	2.7	- " -
- " -	Fucus disticus	Summer 1980	5.8	April 17, 1985
- " -	- " -	July 22 1981	15.8	- " -
- " -	- " -	July 27 1982	9.9	- " -
Indre Kiberg, Norway 70°17'N 30°56'E	Fucus vesiculosus	Nov 4 1981	15.1	Aug 19, 1985
- " -	- " -	Oct 24 1982	15.7	- " -
- " -	- " -	Aug 22 1983	12.0	Sept 3, 1985
Vestvågøy, Norway 68°10'N 13°50'E	Fucus vesiculosus	June 2 1981	12.0	- " -
- " -	- " -	Aug 27 1981	13.3	- " -
- " -	- " -	Aug 30 1982	8.1	- " -
- " -	- " -	Aug 29 1983	9.2	Sept 9, 1985

Table 4.5.2.1. (continued)

Location	Species	Sampling date	Bq kg^{-1} dry weight	Date of analysis
Bud, Norway 62°38'N 7°35'E	Fucus vesiculosus	Sept 4 1980	8.1	Sept 9, 1985
- " -	- " -	Aug 17 1981	16.7	- " -
- " -	- " -	Aug 10 1982	9.9	- " -
- " -	- " -	Aug 15 1983	12.7	- " -
Utsira, Norway 59°19'N 4°54'E	Fucus vesiculosus	Sept 29 1981	10.6	- " -
- " -	- " -	June 14 1982	15.0	- " -
- " -	- " -	Aug 8 1983	13.7	Sept 17, 1985
- " -	- " -	May 5 1984	9.7	- " -
Jan Mayer 71°00'N 8°00'W	Laminaria digitata	Sept 29 1983	3.2	- " -
- " -	Laminaria saccharina	- " - - " -	3.3	- " -
Hinlopen, Svalbard 79°50'N 18°20'E	Alaria esculenta	July 29 1983	2.2	- " -
Dickson Fjord, Svalbard 78°46'N 15°00'E	Fucus spiralis	Aug 5 1983	4.3	- " -
Gråhuken, Svalbard 79°50'N 14°30'E	Alaria esculenta	Aug 13 1983	4.4	- " -
Calypsobyen, Svalbard 77°45'N 14°20'E	- " -	Aug 16 1983	5.2	- " -
Mosselbukta, Svalbard 79°50'N 16°00'E	Fucus spiralis	Aug 30 1983	49.4	Sept 25, 1985
Kapp Martin, Svalbard 77°45'N 13°45'E	Alaria esculenta	Sept 14 1983	3.9	- " -

Samples from Greenland and Norway were collected from the same locations over a period of 3-4 years. An anova showed that there was a probably significant variation between years: 1981 showing higher ^{210}Po concentrations than the other years. However, an interaction between years and locations obscured this variation.

Ascophyllum nodosum showed lower concentrations than Fucus vesiculosus/disticus.

As all samples were analysed several months after the collection the results probably reflect the ^{210}Pb rather than the ^{210}Po content of the fresh samples (cf. 4.5.1).

Table 4.5.2.2 was based upon ashed samples only, and the polonium determinations thus represent the ^{210}Pb in the samples. It is interesting to note that the mean content of the samples from the Greenland east coast (Danmarkshavn, Scoresby Sund and Angmagssalik) is 2.5 times higher than that on the west coast (Narsaq, Godthåb, Upernavik, Thule).

Table 4.5.2.2. Lead-210 in seaweed (ash) collected in Greenland 1966-1981

Location	Species	Sampling date		Bq g^{-1} ash*	Date of analysis
Narssaq	As[illegible]m nodos.	June 19,21	1979	0.044 0.083	Feb 27, 1984
-"-	Fucus vesiculosus	June 21,24,26	1979	0.167 0.226 0.190	-"-
Danmarkshavn	Fucus disticus/ves.	Summer	1968	0.81	Mar 12, 1984
Scoresbysund	-"-	Sept	1978	0.34 0.41	-"-
Prins Chr.sund	-"-	Sept	1979	0.151 0.193	-"-
Upernavik	-"-	Summer	1981	0.065	-"-
Godthåb	-"-	Summer	1966	0.309	Mar 25, 1984
-"-	-"-	July	1967	0.101	-"-
Angmagssalik	-"-	Summer	1966	0.222	-"-
-"-	-"-	Sept 17	1968	0.39	-"-
Thule	-"-	Sept 17	1968	0.165	-"-

*The activity per kg dry weight may be estimated from the Bq g^{-1} ash data by multiplication with 260.

4.5.3. Mussels

The Greenland Fisheries and Environmental Research Institute collected mussels (and other biota) at Narssaq in June 1979. The mussels were divided after shell length and analysed in 1984 for ^{210}Po. There is no correlation between mussel size and ^{210}Pb content.

The mean concentration of all samples was 24.7±5.2 Bq ^{210}Pb kg^{-1} fresh weight (±1 S.D.; N = 20). An annual consumption of 10 kg mussel fresh will give an annual dose from ^{210}Po of:

$$10 \times 24.7 \times 0.05/10^5 \text{ Sv} = 0.12 \text{ mSv}$$

assuming that the ^{210}Po content of fresh mussels equals that of ^{210}Pb in the present samples.

Table 4.5.3.1. Lead-210 in mussels (ash) collected in SW Greenland at Narssaq in 1979. (Date of analysis: March 12-14, 1984)

Location	Size	Sampling date	Bq kg^{-1} fresh flesh			Bq kg^{-1} dry matter		
T1	4-5 cm	June 21	29	24		198	163	
"	6-8 cm	- " -	19	18		134	129	
"	4-8 cm	- " -	36	23		279	156	
"	4-6 cm	- " -	23			157		
"	6-7 cm	- " -	23			165		
"	7-8 cm	- " -	25			182		
"	4.5-7 cm	- " -	28			173		
"	7-9 cm	- " -	30			193		
T2	2.5-5 cm	June 24	22			131		
"	5-6 cm	- " -	25			154		
"	6-8.5 cm	- " -	36			212		
"	2-4 cm	- " -	22			162		
"	4.5-5.5 cm	- " -	25			173		
"	2.5-5.5 cm	- " -	21			142		
"	5.5-7.5 cm	- " -	27	17	21	177	121	146

4.5.4. Shrimps

The samples in Table 4.5.4.1 were all freeze dried whereas Table 4.5.4.2 contains ashed samples as well as fresh ones. The ashed samples were analysed after quilibrium between ^{210}Pb and ^{210}Po was attained. These samples thus represents the ^{210}Pb content of the shrimps decay corrected with the half-life of ^{210}Pb to the sampling date. The fresh and the freeze-dried samples will contain ^{210}Pb partly directly accumulated from the environment and partly from decay of ^{210}Pb accumulated in the shrimps.

It is not clear from the tables whether ashed or fresh samples contain most ^{210}Pb. It is evident that there are great variation even between samples collected at the same location at the same time. Table 4.5.3.1 does not suggest any significant difference in the ^{210}Po content bwtween different sizes of the animals. The mean content in shrimps collected at Bylot Sound, Thule was 0.41±0.03 Bq ^{210}Po kg^{-} (±1 S.E., N = 10). If we imagine a person eating 10 kg of these shrimps per year he would receive an annual dose of

$$0.41 \times 10 \cdot 0.5/10^5 = 2 \times 10^{-6} \text{ Sv}$$

or 1 o/oo of the natural background (cf. also 4.3.3).

Table 4.5.4.1. Polonium-210 in shrimps caught in Bylot Sound at Thule in July-August 1984 by the Greenland Fisheries and Environmental Research Institute

Sample No.	Shell length in mm	Number of individuals	Fresh weight of flesh	% dry weight	Bq kg^{-1} fresh flesh
84-576	12-13	20	18.4 g	17.5	0.49
84-577	14-15	20	25.5 g	17.1	0.60
84-578	16	15	23.7 g	17.3	0.40
84-579	17-19	11	24.2 g	16.8	0.43
84-580	9-11	16	8.0 g	12.8	0.39
84-581	12-13	20	17.6 g	16.1	0.35
84-582	14-15	20	25.7 g	16.4	0.40
84-583	16	19	29.6 g	17.8	0.42
84-584	17-19	20	47.3 g	17.5	0.19
84-585	20-23	14	43.7 g	16.0	0.43
84-586*	15-18	5	13.0 g	12.7	0.23
84-587*	19-25	9	12.1 g	10.0	

*Qanaq

Table 4.5.4.2. Lead-210 in shrimps caught at various places in Denmark and Greenland 1968-1984

Location	Sampling date	Bq kg^{-1} fresh weight				Sample type
Danish Straits, Denmark	Oct 1968	0.56				Ashed flesh
Roskilde Fjord, Denmark	July 1984	2.15	1.72	3.13	3.46	Fresh "
Thule st. 42, Greenland	Aug 1968	1.08				Ashed "
- " - st. 44, - " -	Aug 1968	1.88				" "
Jacobshavn, Greenland	Aug 1970	0.40				" "
- " -	Aug 1981	0.40				" "
- " -	Aug 1982	0.17				Fresh "
Discobay, Greenland	July 1971	0.71				Ashed "
Frederikshåb, Greenland	Aug 1971	2.73				" "
Niaqornap, Greenland*	June 1979	1.58	0.37			" "
Narssaq Sound, Greenland*	June 1979	0.76				" "
Skov Fjord, Greenland*	June 1979	0.57				" "
- " -	- " -	1.03				Ashed shells
- " -	- " -	2.97				Ashed heads

*Collected by the Greenland Fisheries and Environmental Research Institute.

4.5.5. Fish

Polonium-210 was determined in fresh fish samples collected from Danish waters (cf. Tables 5.8.2.3-5.8.2.4 in Risø Report No. 527[3]). The mean content in these samples was 0.80±0.31 Bq ^{210}Po kg^{-1} fresh flesh (±1 S.D.;, N = 22). The mean of the ^{210}Pb values in Table 4.5.5 was 0.32±0.36 Bq ^{210}Pb kg^{-1} fresh flesh (±1 S.D., N = 12) (the Uvaq data were not included, because they were based on total fish analysis). From the measurements of the Danish fish samples we concluded[3] that most of the ^{210}Po was environmental. The Greenland values, which were based on ashed samples, may thus underestimate the ^{210}Po content (cf. 4.5.1).

Table 4.5.5. Lead-210 in fish (ash) collected in SW Greenland in 1979

Location	Species	Sampling date	Bq kg^{-1} fresh						Date of analysis
Narssaq	Catfish flesh	June 23	0.29	0.070					Feb 27, 1984
Skov Fjord	- " -	June 26	0.24	0.21	0.21	0.15	0.36	0.16	Mar 13, 1984
Narssaq Sound	Cod flesh	June 28	0.33	0.17	0.25	1.45			- " -
Skov Fjord	Uvaq total fish	June 23*	0.53	0.52	0.44	0.42			Feb 21, 1984
- " -	- " -	- " -	0.60	0.51	0.46	0.44			- " -

*Analysed on 0.1, 0.2, 0.4 and 0.8 g ash in the order given in the table from left to right.

4.5.6. Mammals

Table 4.5.6.1 shows that marine mammals may contain ^{210}Po-^{210}Pb levels similar to those found in terrestrial animals. Furthermore, it is evident that there are great variations within the species. The samples in Table 4.5.6.1 were all fresh, but the analysis was carried out 0.5-1 year after the sampling. We may thus have underestimated the ^{210}Po in the freshly collected samples (cf. 4.5.1).

Table 4.5.6.1. Polonium-210 in mammals (fresh samples) collected in Greenland and the Faroe Islands in 1982-1983

Location	Species	Sampling date	Bq kg^{-1} fresh meat	Date of analysis
Angmagssalik, Greenland	Seal	Summer 1982	3.37	July 20, 1983
Sukkertoppen, Greenland	- " -	Summer 1982	0.45	June 14, 1983
Holsteinsborg, Greenland	Reindeer	Summer 1982	1.44	May 25, 1983
Egedesminde, Greenland	- " -	Summer 1982	0.75	- " -
Thorshavn, The Faroes	Lamb	Dec 12 1983	0.48	June 14, 1984
Klaksvig, The Faroes	- " -	Dec 12 1983	0.46	- " -
Dumin, The Faroes	- " -	Dec 12 1983	0.19	- " -

Table 4.5.6.2. Lead-210 in lamb (ashed samples) collected in Narssaq, SW Greenland in February 1980

Species	Bq kg^{-1} fresh meat	Date of analysis
Lamb 1	0.067 0.061	April 25, 1984
" 2	0.11	May 23, 1984
" 3	0.18	- " -
" 4	0.022	- " -
" 5	0.11	- " -

4.5.7. Polonium-210 diet estimates

In order to get a reliable estimate of the ^{210}Po intake with the diet, it will be necessary to analyse the various food components very shortly after the sampling.

As mussels apparently contain 1-2 orders of magnitude higher ^{210}Po levels than other diet components, the intake of mussels will strongly influence the individual doses from ^{210}Po in the diet.

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