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ENVIRONMENTAL RADIOACTIVITY IN THE FAROES IN 1981

A. Aarkrog, H. Dahlgaard, L. Hallstadius*, E. Holm*,
and J. Lippert

*University of Lund, Sweden

Abstract. Measurements of fallout radioactivity in the Faroes in 1981 are presented. Strontium-90 (and ^{137}Cs in most cases) was determined in regularly collected samples of precipitation, grass, milk, fish, sea water, bread and drinking water. In addition, analyses were made of spot samples of lamb, sea birds, potatoes, sea plants, vegetables, eggs, and human bone. Estimates are given of the mean contents of ^{90}Sr and ^{137}Cs in the human diet in the Faroes in 1981. In Appendix the results from samplings of sea water and biota along the Icelandic and the Norwegian coasts are given.

INIS Descriptors

[0] DIET, ENVIRONMENT, EXPERIMENTAL DATA, FAROE ISLANDS, FISHES, FOOD, FOOD CHAINS, GLOBAL FALLOUT, MILK, PLANTS, RADIOACTIVITY, SEA WATER, SHEEP, TABLES
[1] ATMOSPHERIC PRECIPITATIONS, BONE TISSUES, DRINKING WATER, MAN, STRONTIUM 90
[2] CESIUM 137
[3] PLUTONIUM

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CONTENTS

ABBREVIATIONS AND UNITS

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

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

T: tera: 10^{12}
G: giga: 10^{9}
M: mega: 10^{6}
m: milli: 10^{-3}
μ: mikro: 10^{-6}
n: nano: 10^{-9}
p: pico: 10^{-12}
f: femto: 10^{-15}
a: atto: 10^{-18}

cap: caput: (per individual)
TNT: trinitrotoluol; 1 Mt TNT: nuclear explosives equivalent to 10^{9} kg TNT.

cpm: counts per minute
dpm: disintegrations per minute
OR: observed ratio
CF: concentration factor
FP: fission products
μR: micro-roentgen, 10^{-6} roentgen
S.U.: pCi ^{90}Sr (g Ca)$^{-1}$
O.R.: observed ratio
M.U.: pCi ^{137}Cs (g K)$^{-1}$

V: vertebrae

m: male

f: female

nSr: natural (stable) Sr

eqv. mg KCl: equivalents mg KCl: activity as from 1 mg KCl (~ 0.88 dpm)

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

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

U.C.L.: upper control level

L.C.L.: lower control level

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

f: degrees of freedom

s^2: variance

v^2: ratio 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

A: relative standard deviation 20-33%

B: relative standard deviation >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. INTRODUCTION

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 1981. Samples of human bone were obtained in 1981 from Dronning Alexandrine's Hospital in Thorshavn.

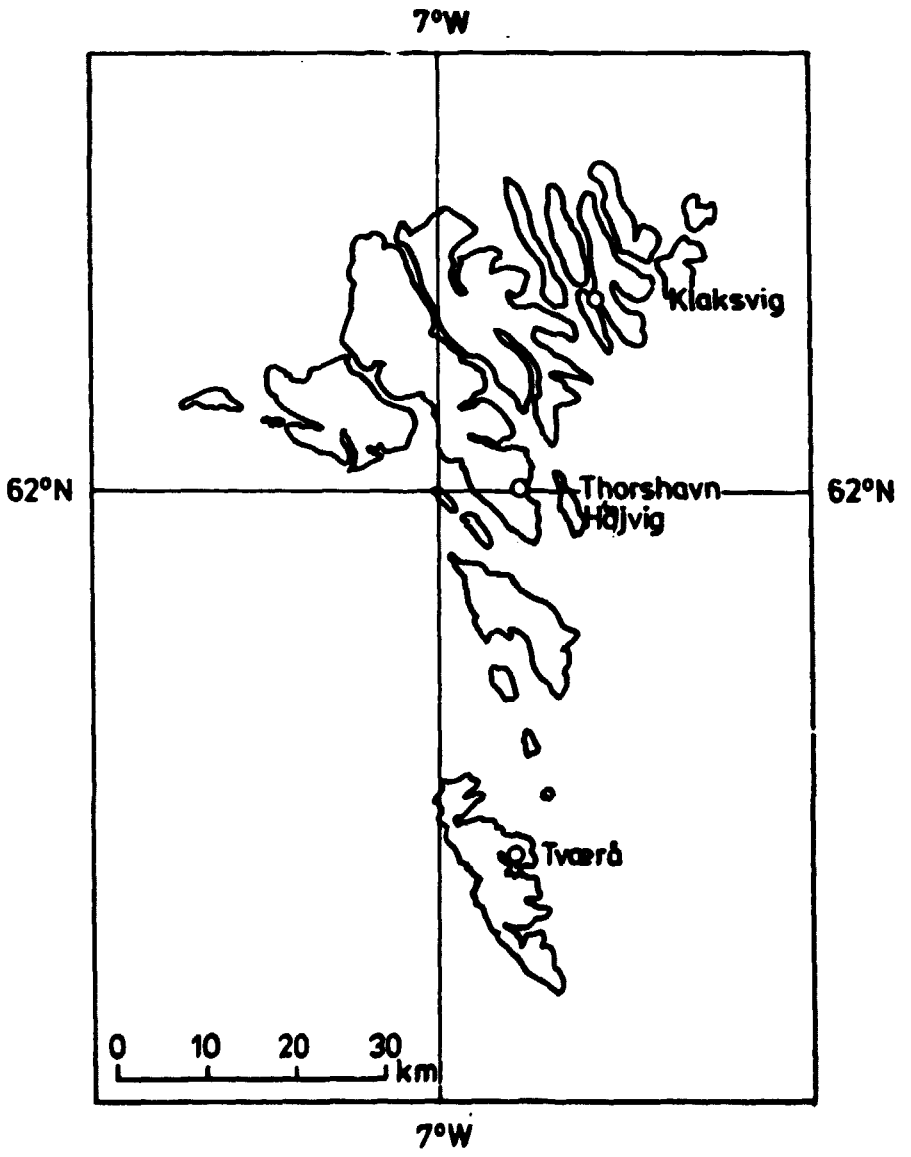

Fig. 1. The Faroese Islands.

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 and 448[1].

1.3.

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

1.4.

The present investigation was carried out together with corresponding examinations of fallout levels in Denmark and Greenland, described in Risø Reports Nos. 469[2] and 471[3], respectively.

2. RESULTS AND DISCUSSION

2.1. Strontium-90 in precipitation

Table 2.1 shows the ^{90}Sr content in precipitation collected at Højvig (near Thorshavn) and Klaksvig in 1981. The amount of fall-out at Klaksvig was a factor of 1.2 greater than that found at Højvig.

The ^{90}Sr fallout in 1981 was approximately 2.1 times of the 1980 levels in the Faroes. In Denmark the 1981 levels were 3.0 times the 1980 levels[2].

Table 2.1. Strontium-90 in precipitation in the Faroes in 1981 (sampling area = 0.02 m^2)

	Höjvig		Klaksvig	
	Bq m^{-3}	Bq m^{-2}	Bq m^{-3}	Bq m^{-2}
Jan-Feb	15.5	4.2	14.2	6.8
March-April	26	4.3	52	2.0
May-June	39	6.4	31	9.9
July-Aug	28	3.0	28	3.5
Sept-Oct	10.7	3.3	4.3	2.4
Nov-Dec	5.9	1.32	4.4	2.1
1981	18.6	Σ 23 Σ_m 1.236	13.5	Σ 27 Σ_m 2.004
1981	0.50 pCi l^{-1}	Σ 0.62 mCi km^{-2}	0.36 pCi l^{-1}	Σ 0.72 mCi km^{-2}

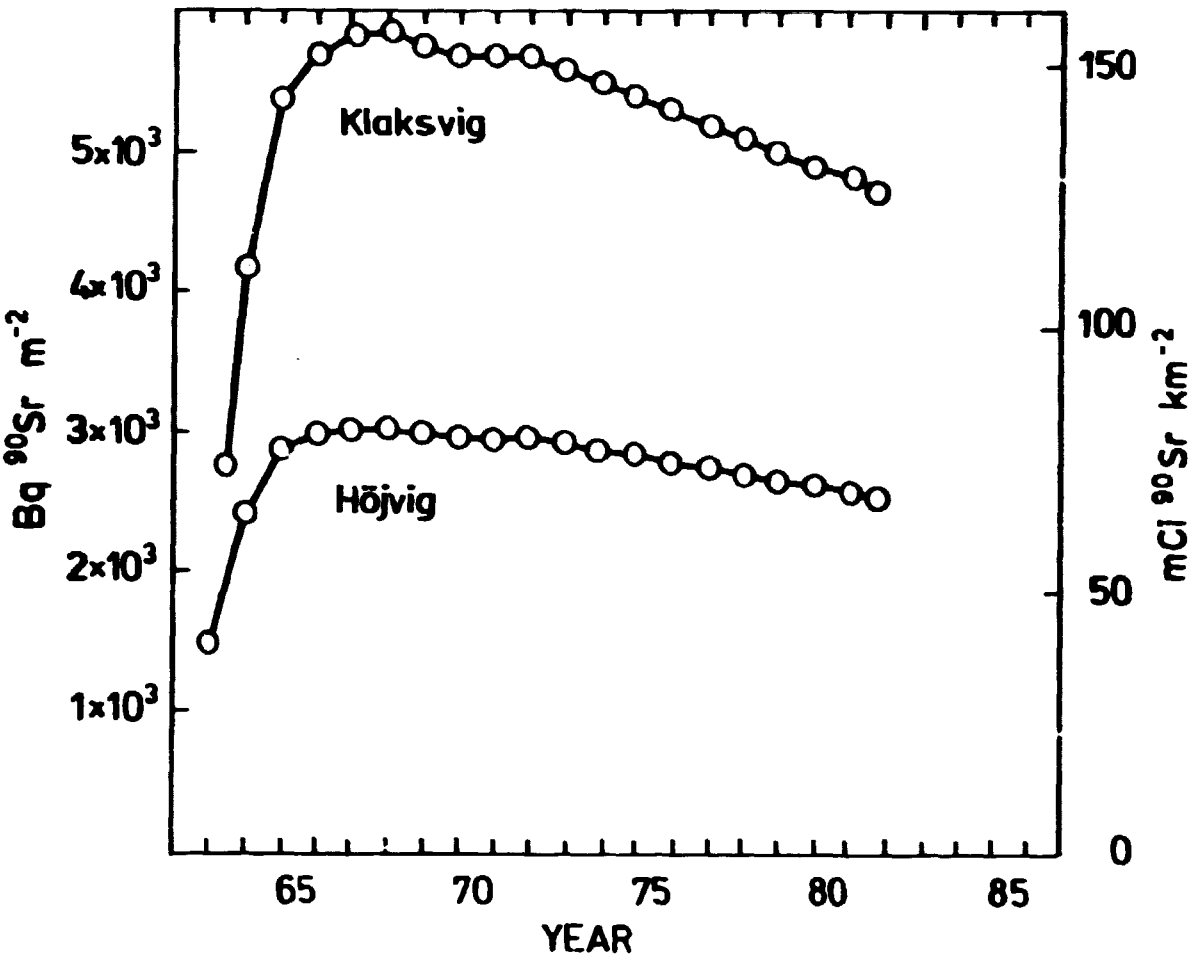

Fig. 2.1. Accumulated ^{90}Sr at Klaksvig and Højvig calculated from precipitation measurements since 1962. The accumulated fallout by 1962 was estimated from the Danish fallout data (cf. Risø Report No. 403[2], Appendix D) and from the ratio between the ^{90}Sr fallout at the Faroese stations and the fallout in Denmark in the period 1962-1974.

2.2. Strontium-90 and Cesium-137 in grass

Grass samples were collected near Thorshavn in 1981. Table 2.2 shows the results. The 1981 ^{137}Cs mean level in grass was 2.1 times the 1980 level. As compared with Danish grass in 1981[2] we found the ^{90}Sr level in the Faroese grass to be higher by a factor of approximately 10 in the summer months.

Table 2.2. Strontium-90 and Cesium-137 in grass from Thorshavn 1981

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	4.5	6300	6.9	1820	1.5
August	6.9	11400	19.5	8600	2.8

2.3. Strontium-90 and Cesium-137 in milk

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

Table 2.3.1 shows the results and Tables 2.3.2, 2.3.3 and 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 in previous years, the variation between locations was significant for ^{137}Cs as well as for ^{90}Sr. The highest levels were found in the milk from Tvørå.

Figure 2.3.1 shows the quarterly Bq ^{90}Sr (kg Ca)$^{-1}$ values and Fig. 2.3.2 the quarterly Bq ^{137}Cs m^{-3} levels since 1962. The annual mean values for 1981 were 250 Bq ^{90}Sr (kg Ca)$^{-1}$ (6.6 S.U.) and 5100 Bq ^{137}Cs m^{-3} (138 pCi ^{137}Cs l^{-1}), i.e. the ^{90}Sr levels in 1981 were 89% of the 1980 concentration, while the ^{137}Cs levels were approximately 119% of the 1980 mean levels. In Danish milk the ^{90}Sr concentration did not change from 1980 to 1981, but the ^{137}Cs 1981 level was 120% of the 1980 content.

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. 2.3.3. The mean ratio in 1981 for the three locations was 12.5±0.6 (1 S.E.) during the grazing period (May-October), and in the winter time it was 12.8±0.6.

Figure 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 Danish milk have shown a slight tendency to decrease through the years.

Table 2.3.1. Strontium-90 and Cesium-137 in milk from the Faroes in 1981

Month	Thorshavn			Klaksvig			Tvarå			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	169	2300	1320	230	5200	2900	220	5300	3000	210	4300	2400
Feb	118	2200	1510	220	5200	3100	250	5200	3500	195	4200	2700
March	183	2300	1440	137	2200	1410	210	5900	3700	175	3500	2200
April	166	2100	1230	200	6200	3500	250	5900	3900	210	4700	2900
May	180	2400	1450	220	5700	3300	300	6000	3500	240	4700	2800
June	184	2100	1580	190	5200	3600	340	7600	4900	240	5000	3400
July	260	2500	1600	230	6200	3400	430	9100	5200	310	5900	3400
Aug	280	4300	2800	360	5500	3600	490	12000	6900	380	7300	4400
Sept	270	3900	2300	270	6600	4100	400	12800	7800	320	7800	4700
Oct	210	2400	1530	290	7000	4100	350	6700	4600	280	5400	3400
Nov	200	2500	1630	168	4700	3000	210	6100	3600	192	4400	2700
Dec	220	2100	1380	220	4600	2900	230	3900	[illegible]	220	3500	2400
Mean	200	2600	1600	230	5400	3200	310	7200	4400	250	5100	3100
Mean (pCi)	5.5 S.U.	70 pCi ^{137}Cs l^{-1}	45 M.U.	6.2 S.U.	145 pCi ^{137}Cs l^{-1}	88 M.U.	8.3 S.U.	195 pCi ^{137}Cs l^{-1}	120 M.U.	6.6 S.U.	138 pCi ^{137}Cs l^{-1}	86 M.U.

Table 2.3.2. Analysis of variance of ln Bq ^{90}Sr (kg Ca)$^{-1}$ in Faroese milk in 1981 (from Table 2.3.1)

Variation	SSD	f	s^2	v^2	P
Between months	1.800	11	0.164	6.263	> 99.95%
Between locations	1.000	2	0.500	19.127	> 99.95%
Remainder	0.575	22	0.026		

Table 2.3.3. Analysis of variance of ln Bq ^{137}Cs (kg K)$^{-1}$ in Faroese milk in 1981 (from Table 2.3.1)

Variation	SSD	f	s^2	v^2	P
Between months	1.795	11	0.163	4.520	> 99.5%
Between locations	6.200	2	3.100	85.862	> 99.95%
Remainder	0.794	22	0.036		

Table 2.3.4. Analysis of variance of ln Bq ^{137}Cs m^{-3} in Faroese milk in 1981 (from Table 2.3.1)

Variation	SSD	f	s^2	v^2	P
Between months	1.874	11	0.170	3.621	> 99.5%
Between locations	6.457	2	3.228	68.627	> 99.95%
Remainder	1.035	22	0.047		

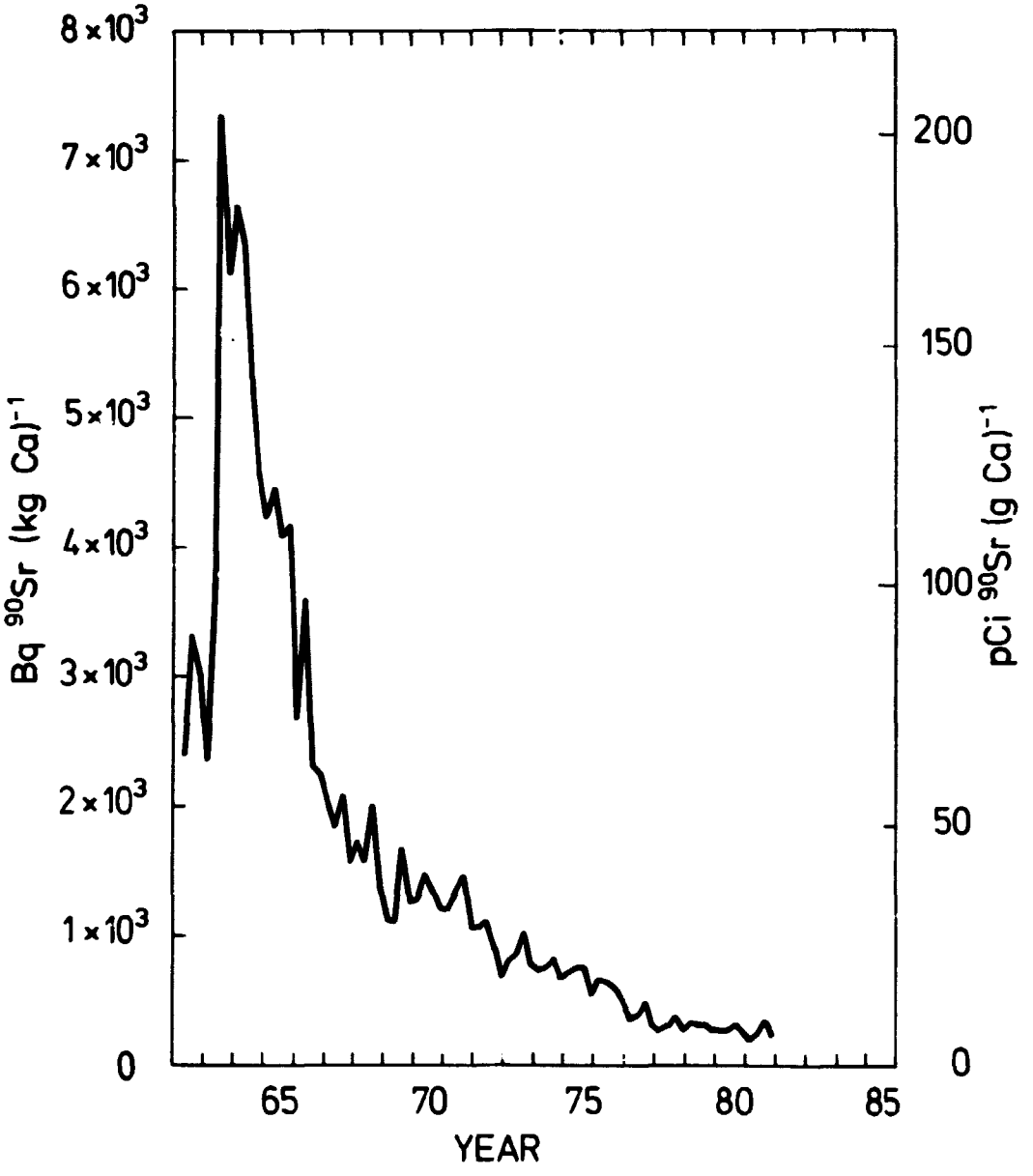

Fig. 2.3.1. Strontium-90 in Faroese milk, 1962-1981.

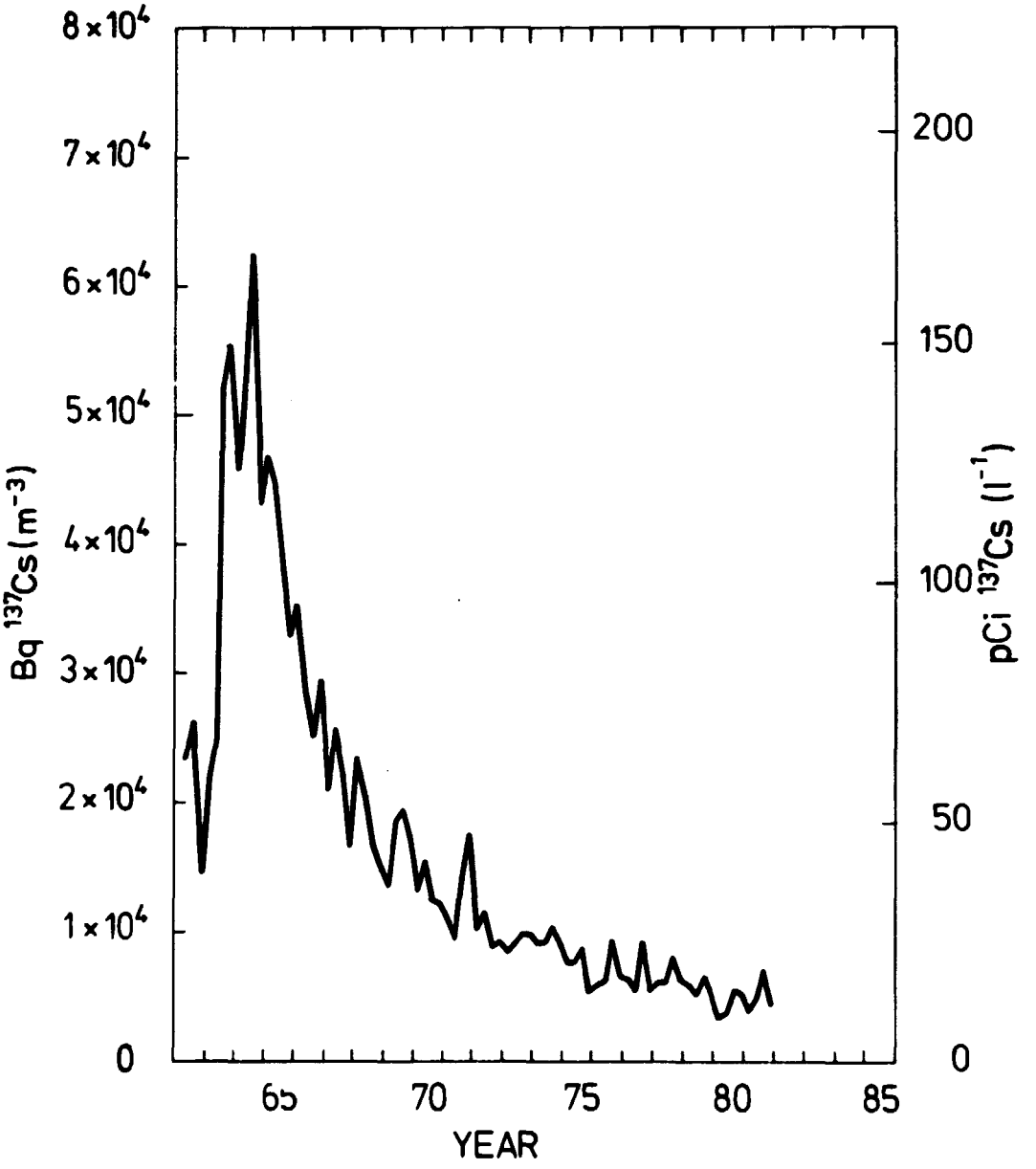

Fig. 2.3.2. Cesium-137 in Faroese milk, 1962-1981.

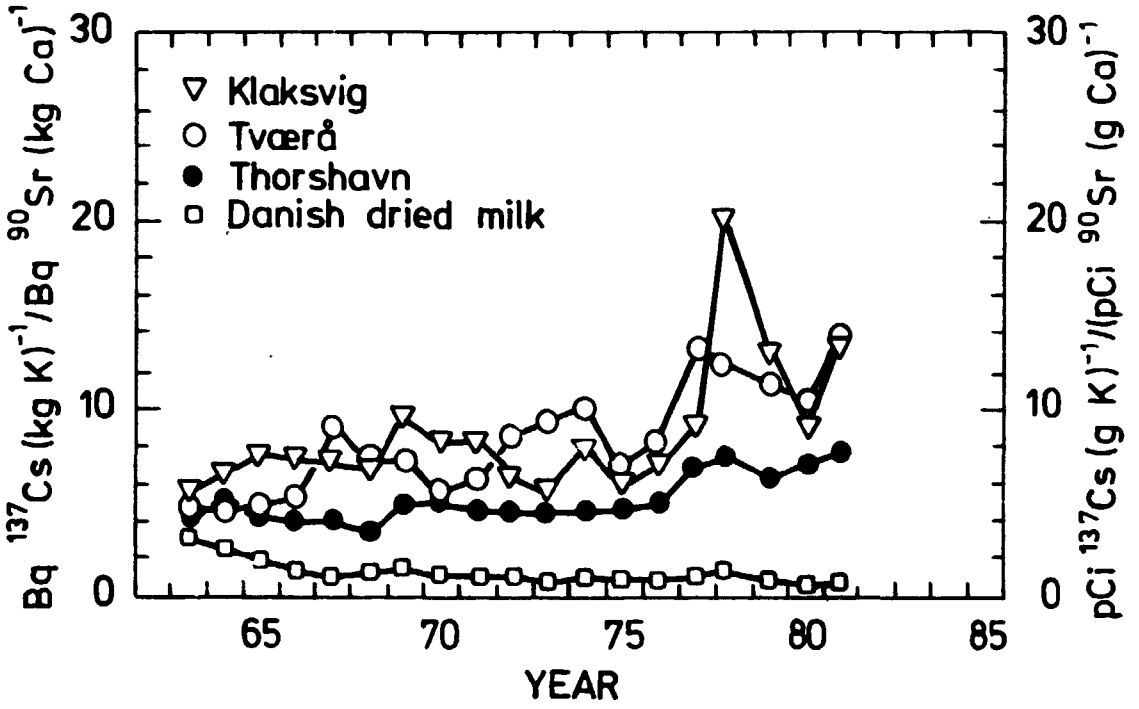

Fig. 2.3.3. $\frac{\text{M.U.}}{\text{S.U.}}$ ratios in Faroese and Danish milk, 1963-1981.

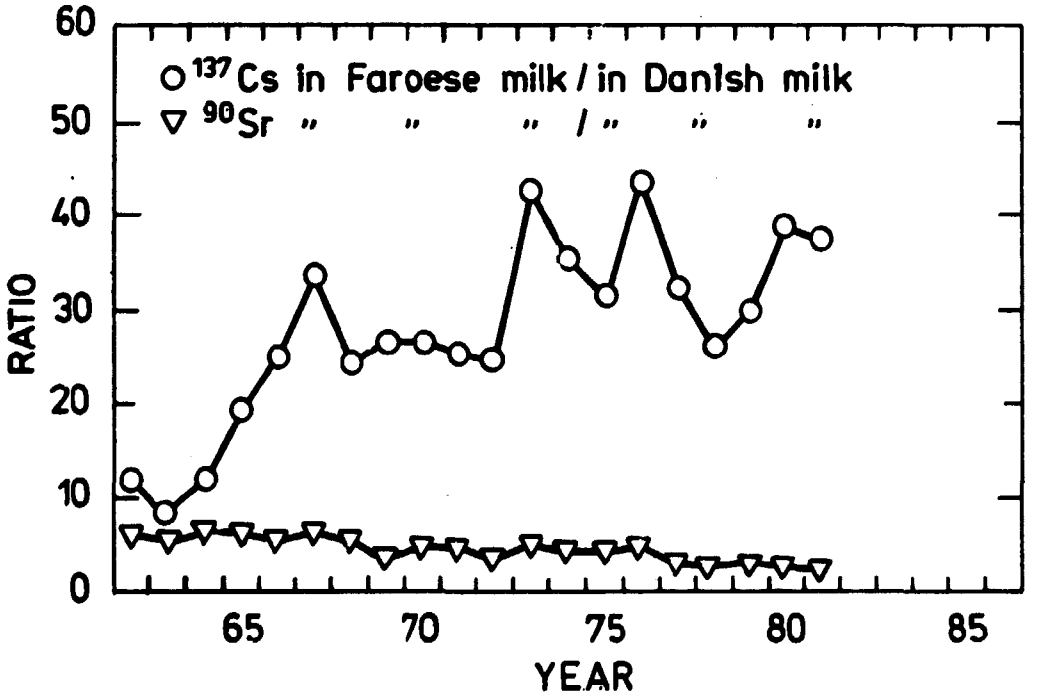

Fig. 2.3.4. A comparison between Faroese and Danish milk levels, 1962-1981.

2.4. Strontium-90 and Cesium-137 in terrestrial animals

The 1981 levels in one sample of mutton were 0.32 Bq ^{90}Sr kg^{-1}, 97 Bq ^{137}Cs kg^{-1}, 3300 Bq ^{90}Sr (kg Ca)$^{-1}$ and 30 000 Bq ^{137}Cs (kg K)$^{-1}$. The bone level was 3300 Bq ^{90}Sr (kg Ca)$^{-1}$.

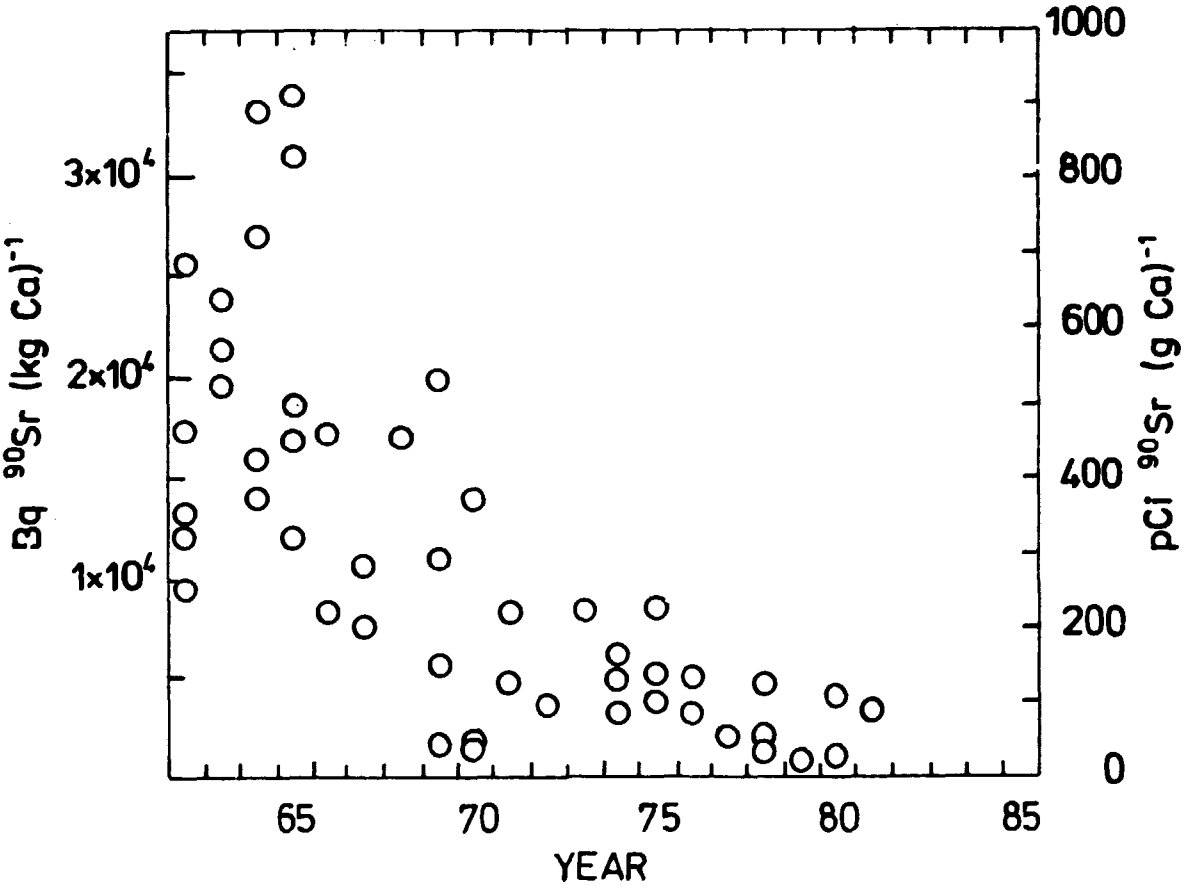

Fig. 2.4.1. Strontium-90 (Bq (kg Ca)$^{-1}$) in lamb bone collected in the Faroes, 1962-1981.

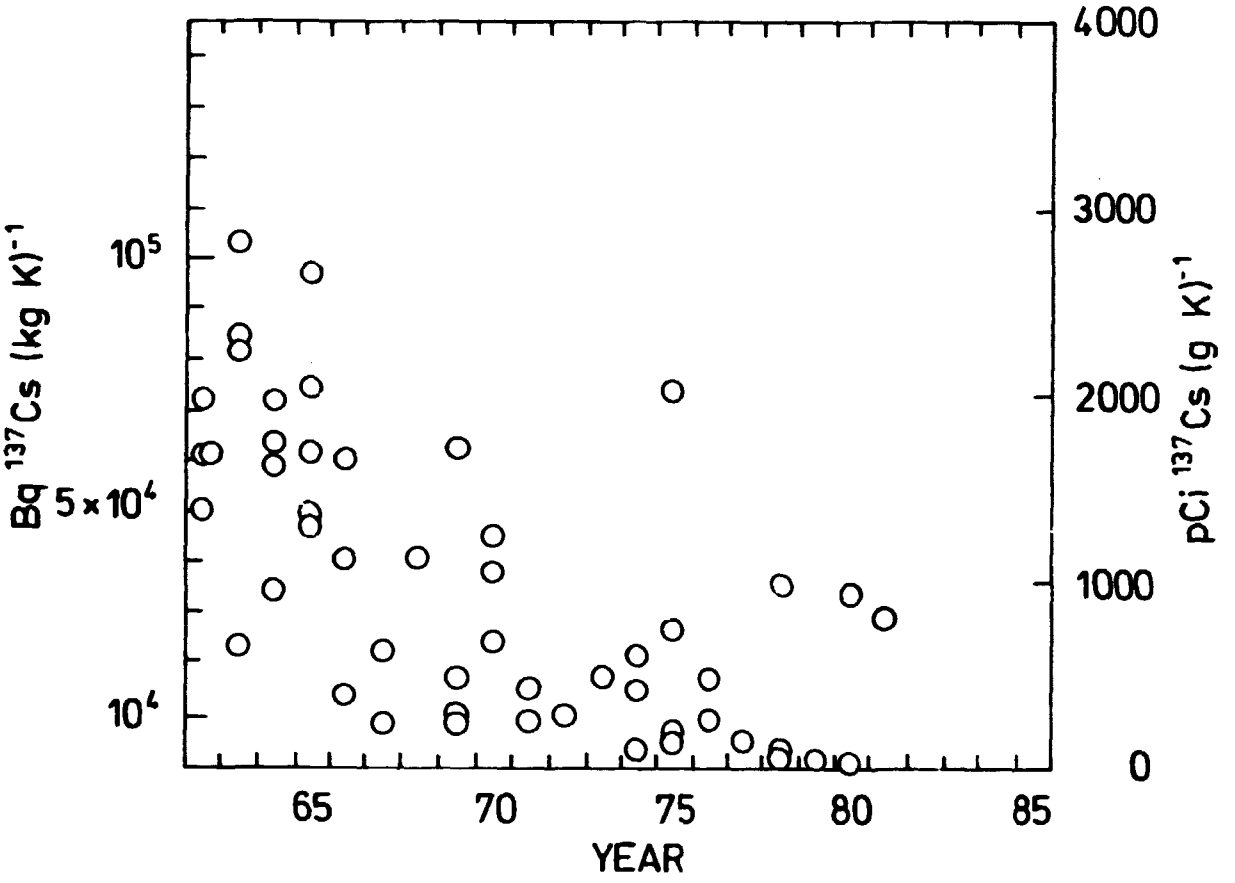

Fig. 2.4.2. Cesium-137 (Bq (kg K)$^{-1}$) in lamb meat collected in the Faroes, 1962-1981.

2.5. Strontium-90 and Cesium-137 in sea animals

Table 2.5.1 shows the ^{137}Cs levels in fish collected in 1981 in the Faroes. The mean levels in Gadus aeglefinus and Gadus callarias were 0.34 Bq ^{137}Cs kg^{-1} and 0.031 Bq ^{90}Sr kg^{-1}.

Table 2.5.1. Strontium-90 and Cesium-137 in fish flesh from the Faroes in 1981

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)$^{-1}$
Jan	Gadus callarias	Cod flesh	0.022	220	0.31	86
March	- " -	- " -	0.032	340	0.31	90
Sept	- " -	- " -	0.036	330	0.22	60
Dec	- " -	- " -	0.031	310	0.89	240
Jan	Gadus aeglefinus	Haddock flesh	0.034	240	0.32	85
March	- " -	- " -	0.023	200	0.23	70
Sept	- " -	- " -	0.051	520	0.33	89
Dec	- " -	- " -	0.0170	122	0.141	45

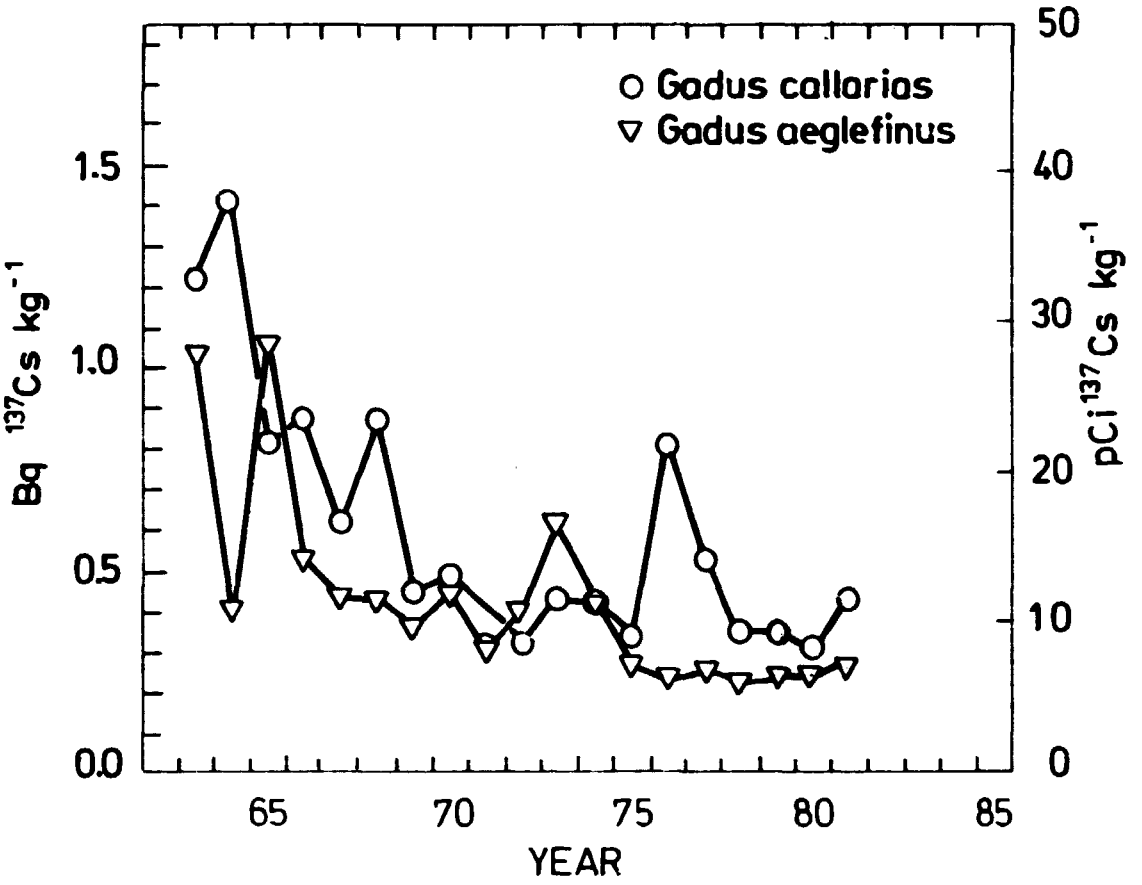

Fig. 2.5.1. Cesium-137 levels in meat of cod (Gadus callarias) and Haddock (Gadus aeglefinus) collected in the Faroes, 1962-1981).

2.6. Strontium-90 in drinking water

Drinking-water samples were collected as previously but the samples were combined before the analysis as shown in Table 2.6.1. As in previous years, drinking water from Thorshavn contained more ^{90}Sr than that from Tværå (cf. the explanation in Risø Report No. 181[1]). The mean level in 1981 was 4.4 Bq ^{90}Sr m^{-3} (0.12 pCi l^{-1}), i.e. a little lower than in 1980.

Table 2.6.1. Strontium-90 in drinking water from the Faroes in 1981 (Unit: Bq m^{-3})

	Thorshavn	Klaksvig	Tværå
Jan-June	9.2	1.90	4.5
July-Nov	5.5	1.30	4.0
1981	7.4	1.60	4.2

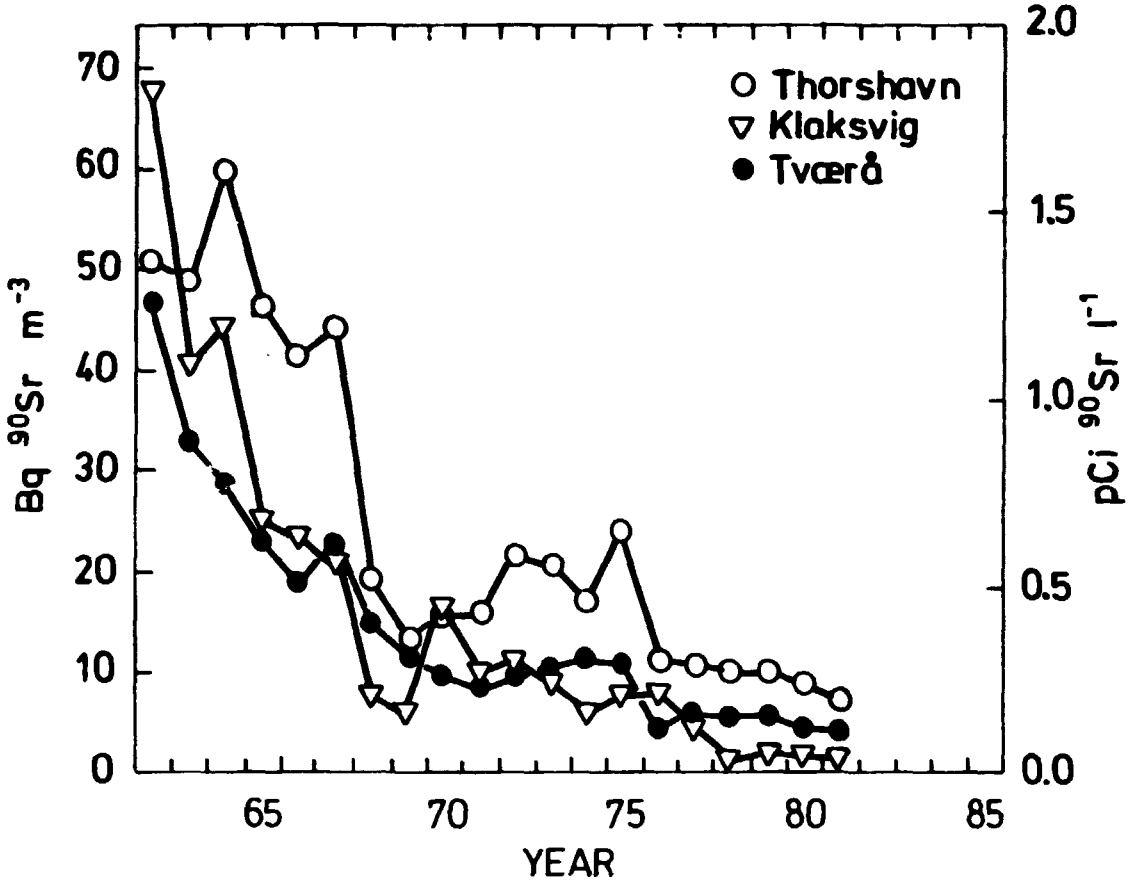

Fig. 2.6.1. Strontium-90 in drinking water from the Faroes, 1962-1981.

Figure 2.6.1 shows the annual mean levels of ^{90}Sr in drinking water from the three locations since 1962.

The tritium concentrations in Faroese drinking water (Table 2.6.2) did not follow the ^{90}Sr levels. The mean tritium level in 1981 was 3.9±1.1 (1 S.D.) kBq m^{-3}, this is approximately 3/4 of the 1980 level.

Table 2.6.2. Tritium in drinking water from the Faroes in 1981. (Unit: kBq m^{-3})

	Thorshavn	Klaksvig	Tværå
Jan-March	3.1±0.2	3.0±0.4	4.1±0.4
July-Sept	5.2±1.5	5.0±0.2	2.8±0.5

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

2.7. Strontium-90 and Cesium-137 in miscellaneous samples

2.7.1. Soil

In June we collected 3 soil cores (6.5 cm in diameter) at Höyvik. The samples were analysed for ^{137}Cs and potassium. The two locations: F 13 and F 14 gave similar results down to 50 cm. The accumulated ^{137}Cs level in these cores was 4400 Bq m^{-2} or 118 mCi ^{137}Cs km^{-2}. If the $^{137}Cs/^{90}Sr$ ratio in fallout is 1.6 the calculated ^{90}Sr fallout in these samples would have been 2750 Bq m^{-2} (or 74 mCi km^{-2}). The third location (F 15) showed 50% higher ^{137}Cs levels than the two others. In 1967[1] we collected soil samples in the same area. At that time the accumulated fallout down to 50 cm was measured to 8180 Bq ^{137}Cs m^{-2} or 221 mCi km^{-2}. If we correct for decay and for new fallout since 1967 we would expect a level in 1981 similar to that found at F 15. We believe that this location has received some run off which makes the measured soil levels higher than that expected.

Figure 2.7.1. shows the distribution of the ^{137}Cs activity at Höyvik as a function of depth in 1967 and 1981. Although the levels have decreased since 1967 it is remarkable that the distribution is nearly unchanged. Approximately 90% of the activity in the 50-cm layer is found in the upper 20-cm layer.

Table 2.7.1. Cesium-137 in soil collected at Höjvig at 3 locations, June 15, 1981

Depth in cm	F 13		F 15		F 14		F 13	F 15	F 14
	Bq kg^{-1} dry w.	Bq m^{-2}	Bq kg^{-1} dry w.	Bq m^{-2}	Bq kg^{-1} dry w.	Bq m^{-2}	g K kg^{-1} dry w.		
0-10	128	2910	142	4320	-	-	1.21	1.43	-
10-20	27	870	45	1530	-	-	1.37	0.86	-
20-30	7.7	260	16	470	-	-	0.87	0.94	-
30-40	2.8	88	13	330	-	-	0.61	0.58	-
40-50	2.2	68	8.7	220	-	-	0.57	0.27	-
Σ 0-50		4196		6670	74	4560			1.04
50-70	2.4	138	7.1	320			0.72	0.62	
70-80	2.6	62	5.4	85			0.64	0.55	
Σ 50-80		200		405					

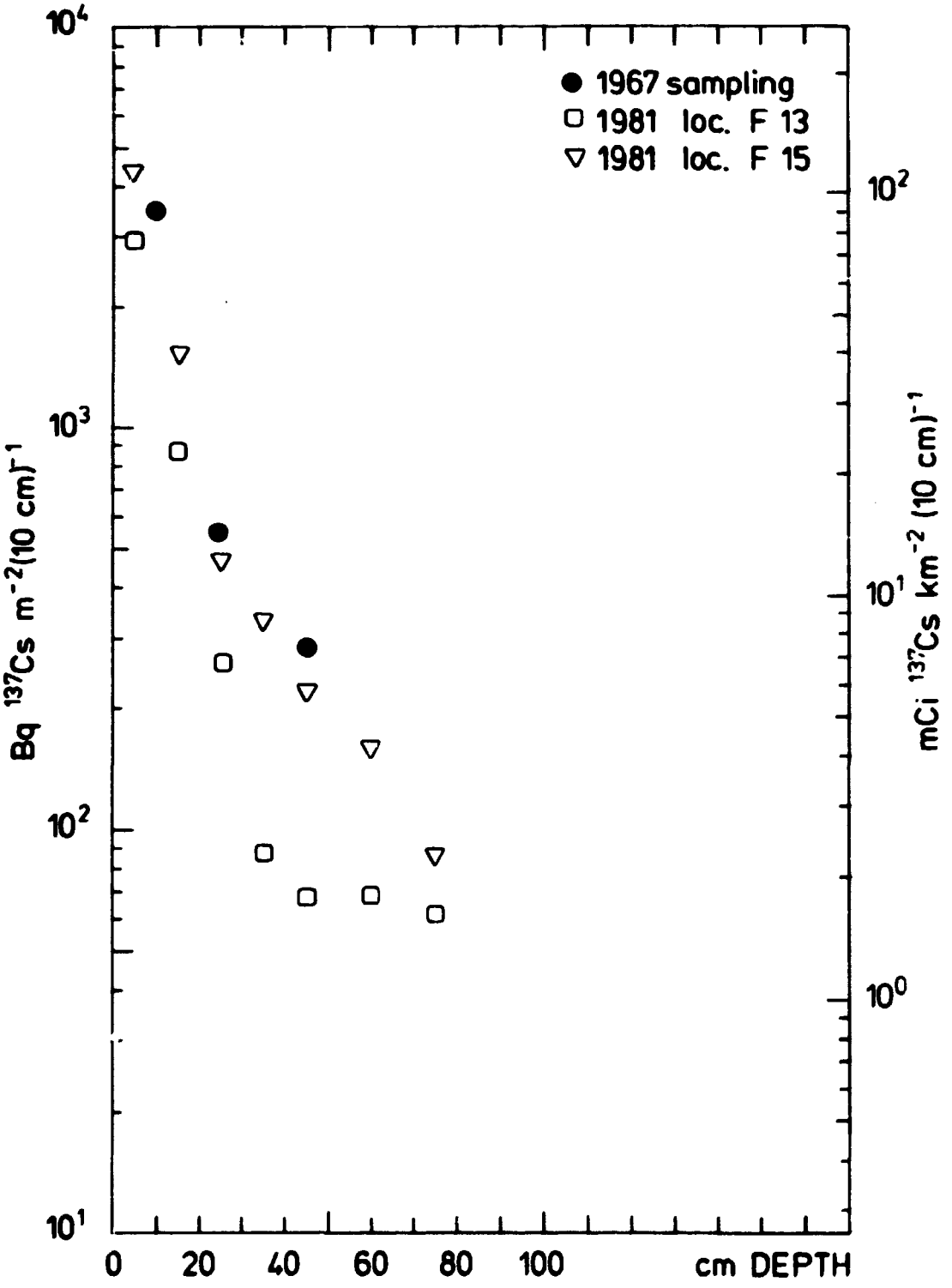

Fig. 2.7.1. Cesium-137 in Faroese soil samples collected in 1967 and 1981.

From earlier years' observations we estimate the accumulated fallout at Thorshavn to be 2540 Bq ^{90}Sr m^{-2} and that at Klaksvig to be 4710 Bq ^{90}Sr m^{-2} (cf. Fig. 2.1).

2.7.2. Sea water

Surface sea water was collected near Thorshavn on four occasions in 1981. The ^{90}Sr mean level was 3.0 Bq ^{90}Sr m^{-3} and 3.4 Bq ^{137}Cs m^{-3}.

Table 2.7.2.1. Strontium-90 and Cesium-137 in surface sea water from the Faroes in 1981

Sampling month	Bq ^{90}Sr m^{-3}	Bq ^{137}Cs m^{-3}	Salinity o/oo
March	3.0	3.5	35.2
April	3.1	3.3	35.3
August	3.3	3.1	[illegible].0
December	2.7	3.6	35.0

Figure 2.7.2 shows the ^{90}Sr levels since 1962.

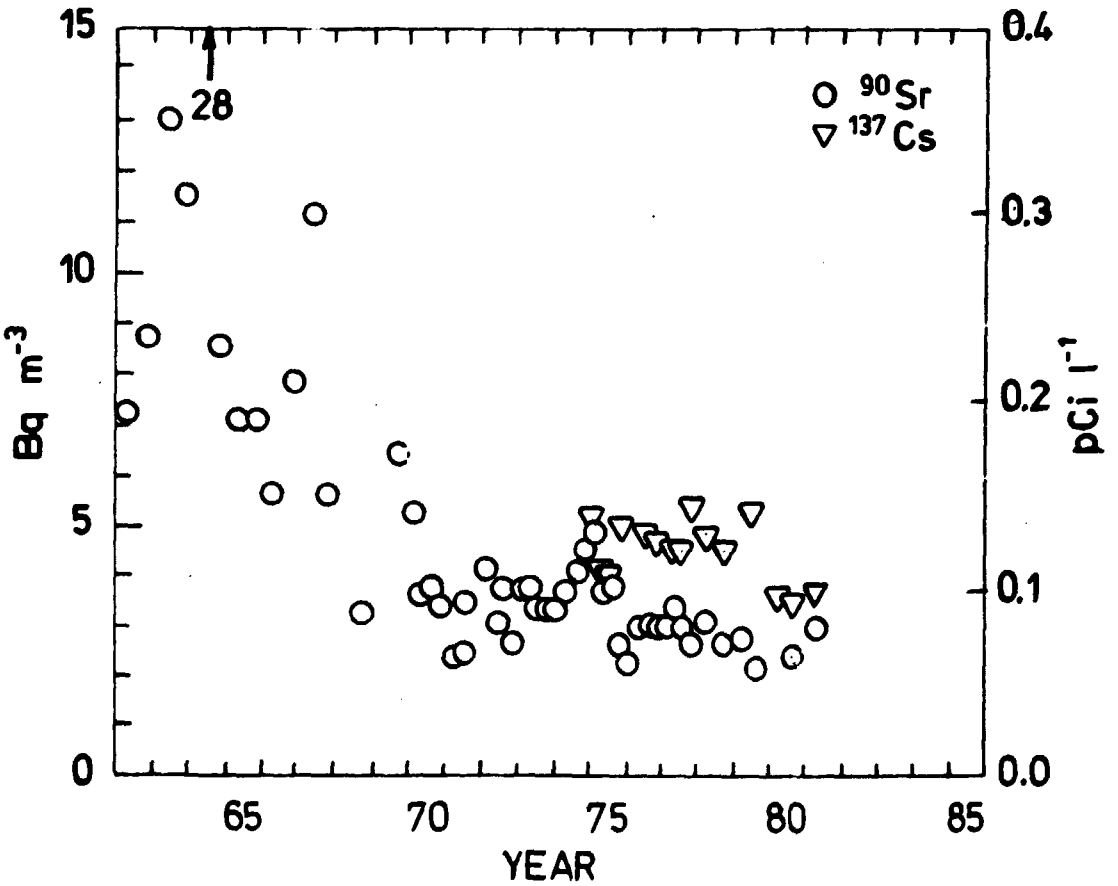

Fig. 2.7.2. Strontium-90 and Cesium-137 in Faroese sea water, 1962-1981.

The $^{137}Cs/^{90}Sr$ ratio was 1.13±0.17 (1 S.D.), i.e. probably less than expected in ocean water.

Tritium was measured in Faroese sea water collected in 1981 (Table 2.7.2.2).

Table 2.7.2.2. Tritium in surface sea water from the Faroes in 1981

Month	kBq ^{3}H m^{-3} ±1 S.E.	Salinity o/oo
March	1.48±0.37	35.2
April	1.66±0.56	35.3
August	0.92±0.18	35.0
December	1.85±0.37	35.0

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

The mean concentration (±1 S.D.) was 1.48±0.40 kBq ^{3}H m^{-3}. This is lower than in 1980 where we found 4.35±0.35 (N = 1). In North Sea water the tritium concentrations varied between 0.4 and 3.3 kBq m^{-3}.

2.7.3. Sea plants

Two samples of Laminaria were analysed in 1981. They contained 3.2 Bq ^{90}Sr kg^{-1} ash (47 Bq ^{90}Sr (kg Ca)$^{-1}$) and 3.4 Bq ^{137}Cs kg^{-1} ash (17 Bq ^{137}Cs (kg K)$^{-1}$). Table 2.7.3.2 shows the results of our own sampling in the Faroes in June 1981.

Table 2.7.3.1. Strontium-90 and Cesium-137 in sea plants from the Faroes in 1981

Species	Sampling month	Bq ^{90}Sr (kg ash)$^{-1}$	Bq ^{90}Sr (kg Ca)$^{-1}$	Bq ^{137}Cs (kg ash)$^{-1}$	Bq ^{137}Cs (kg K)$^{-1}$
Laminaria hyperborea	April	4.3	62	4.0	10.6
Laminaria saccharina	August	2.1	32	2.8	15.9
Rhodomenia palmata	August	1.24	53	5.1	27

Table 2.2.1.2. Radionuclides in Faroese sea plants collected in June 1981. (Units: Bq kg^{-1} dry weight)

Location	Station No.	Species	^{7}Be	^{40}K kg K kg^{-1}	^{54}Mn	^{95}Zr	^{95}Nb	^{106}Ru	^{125}Sb	^{137}Cs	^{141}Ce	^{144}Ce	^{226}Ra	^{239,240}Pu	^{238}Pu / ^{239,240}Pu	^{241}Am / ^{239,240}Pu	dry weight / fresh weight	
Borgvik 62°03'N 6°45'W	F11	Fucus spiralis	39 (5)	0.032 (0.4)	1.4 (9)	10 (3)	29 (1)	14 (7)		1.01 (10)	4.8 (13)	25 (2)	1.5 (8)	0.31 (5)			0.16	
" " "	F10	Laminaria digitata		0.071 (0.3)		7.2 (6)	16 (3)			0.63 (10)	4 (17)	26 (3)	2.1 (5)	0.050 (8)			0.24	
Oyney 62°20'N 6°56'W	F17	Fucus distichus		0.042 (0.3)	3.4 (5)	24 (10)	56 (4)	19 (7)	3.0 (11)	1.11 (8)		44 (2)	2.6 (5)	0.076 (4)	0.04		0.17	
" " "	F16	Laminaria digitata		0.092 (0.2)		15 (31)	33 (12)			0.08 (16)		35 (3)	2.3 (7)	0.049 (6)			0.16	
Skyvanoy-Eysturoy 62°13'N 7°00'W	F18	Ascophyllum nodosum		0.023 (0.5)	0.53 (31)	16 (21)	31 (9)	7 (15)		0.63 (12)		11 (7)	1.5 (7)	0.169 (10)		0.08	0.20	

In brackets: rel. S.D. in % due to counting.

Table 2.7.3.2 compared with Table C.1 in Appendix C shows that the concentration ratio: $\frac{\text{Bq kg}^{-1} \text{ dry w. Fucus}}{\text{Bq l}^{-1} \text{ sea water}}$ is 300 for ^{137}Cs and $(0.4 - 1.0) \cdot 10^4$ for Pu. The ratios for laminaria were 200 and $0.3 \cdot 10^4$, respectively. In Danish waters[2] the concentration ratio for ^{137}Cs in Fucus varied between 200 and 700 showing an increase with decreasing salinity. In the case of Pu, Danish waters[2] showed concentration factors to fucoids at $(1-3) \cdot 10^4$. The concentration ratios in Faroese waters were similar to those in high-salinity Danish waters (cf. also Appendix C).

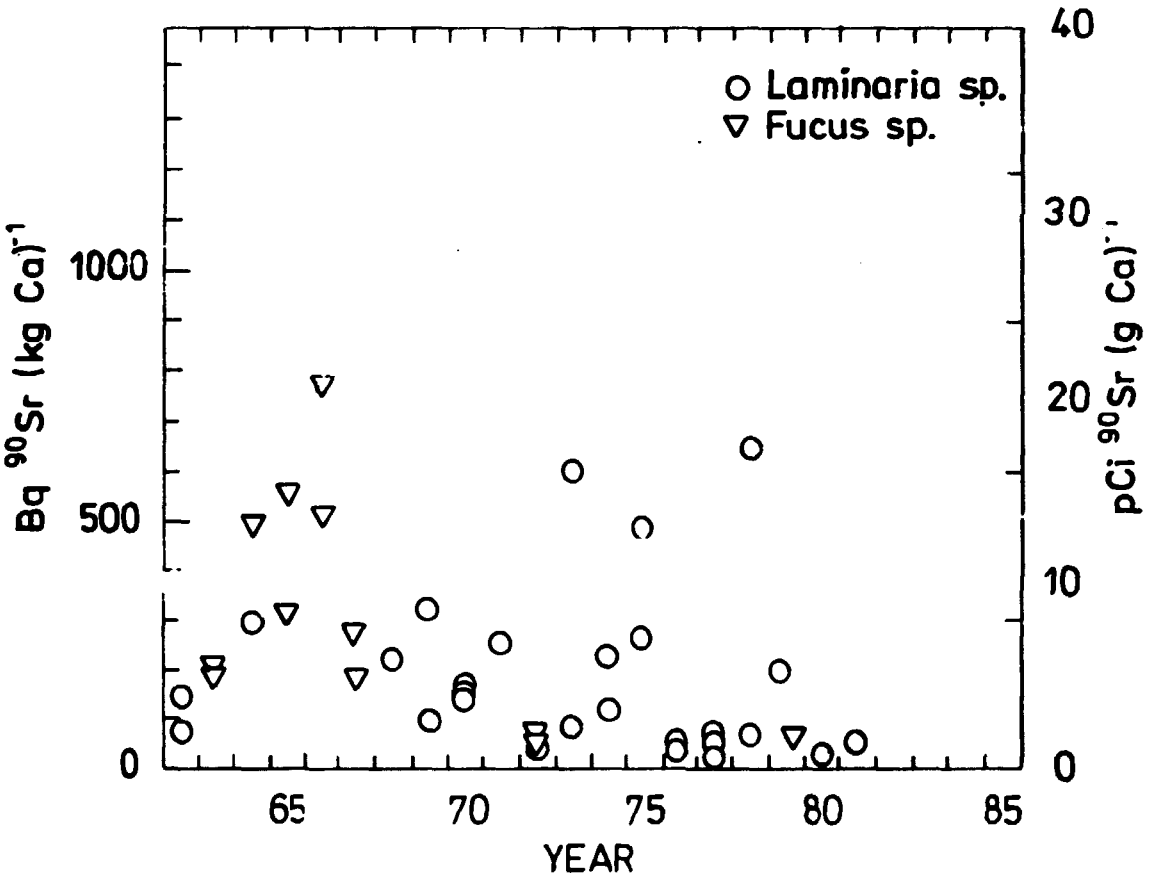

Fig. 2.7.3. Strontium-90 (Bq (kg Ca)$^{-1}$) in sea plants collected at Thorshavn, 1962-1981.

2.7.4. Vegetables

One sample of potatoes was analysed in 1981. It contained 0.141 Bq ^{90}Sr kg^{-1} (3100 Bq ^{90}Sr (kg Ca)$^{-1}$) and 0.89 Bq ^{137}Cs kg^{-1} (200 Bq ^{137}Cs (kg K)$^{-1}$). Both levels were lower than those observed in 1980.

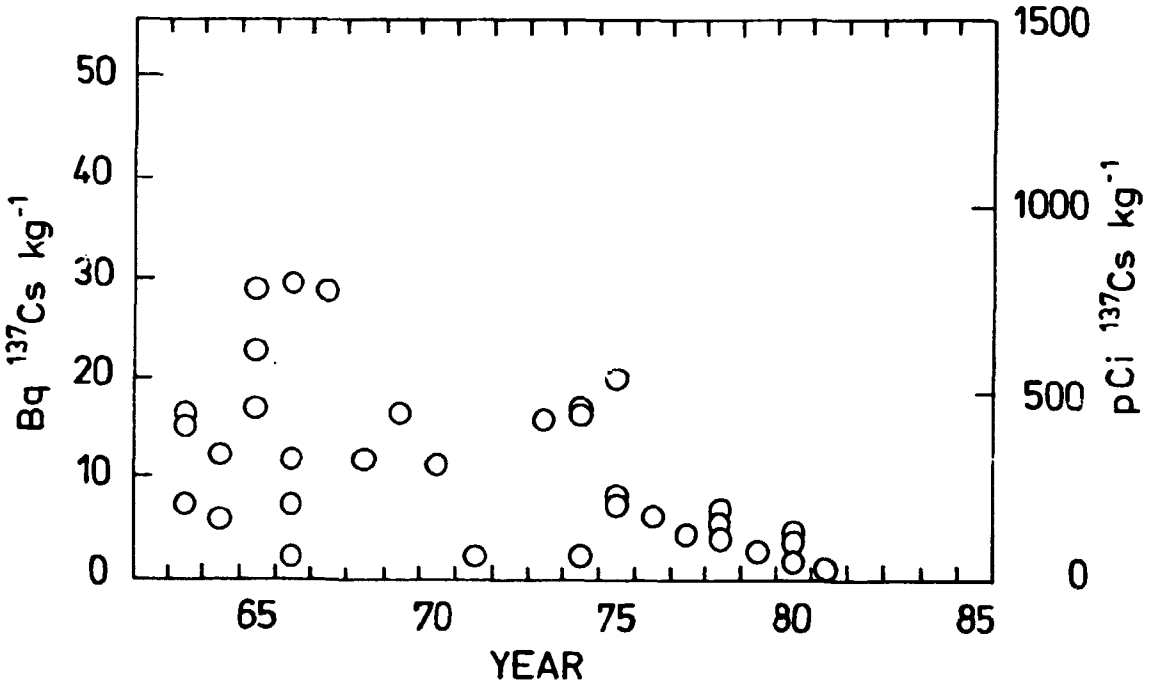

Fig. 2.7.4.1. Cesium-137 in Faroese potatoes, 1962-1981.

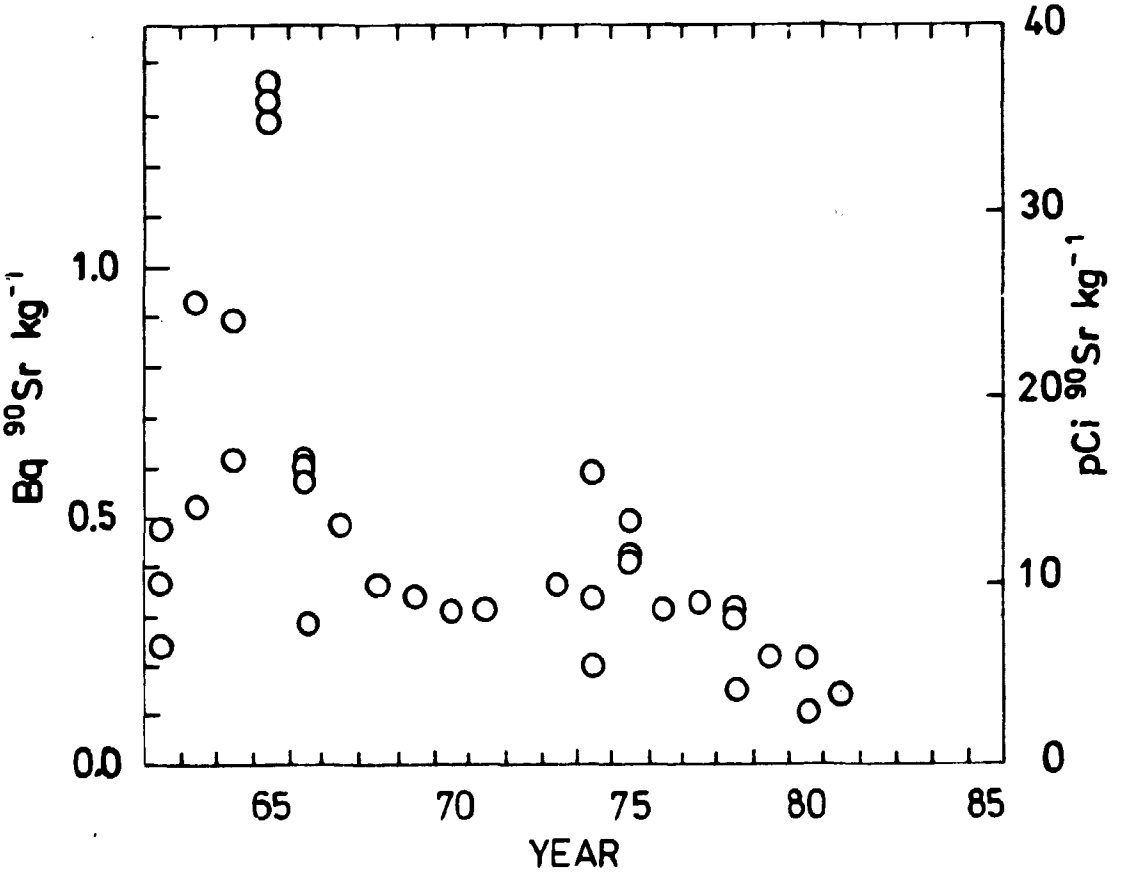

Fig. 2.7.4.2. Strontium-90 in Faroese potatoes, 1962-1981.

2.7.5. Bread

Rye bread and white bread were collected at Thorshavn in June. The levels in white bread were 0.19 Bq ^{90}Sr kg^{-1} and 0.10 Bq ^{137}Cs kg^{-1}. The rye bread collected in 1981 contained 0.37 Bq ^{90}Sr kg^{-1} and 0.25 Bq ^{137}Cs kg^{-1}, i.e. the bread levels were higher than the 1980 levels.

Table 2.7.5. Strontium-90 and Cesium-137 in Faroese bread in June 1981

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	0.192	560	0.100	57
Rye bread	0.37	280	0.25	114

The ^{137}Cs and ^{90}Sr (kg^{-1}) levels in Faroese bread were generally lower than the corresponding Danish[2].

2.7.6. Eggs

Eggs were collected from Thorshavn in June 1981. The levels of hens eggs were 0.030 Bq ^{90}Sr kg^{-1} (92 Bq (kg Ca)$^{-1}$ and < 0.04 Bq ^{137}Cs kg^{-1}.

2.8. Humans

2.8.1. Strontium-90 in human bone

In 1981 seven human bone samples representing 9 individuals from Dronning Alexandrine's Hospital in Thorshavn were analysed. Table 2.8.1 shows the results.

The mean level in bone of newborn infants was 95 Bq ^{90}Sr (kg Ca)$^{-1}$ (2.6 pCi ^{90}Sr (g Ca)$^{-1}$).

The adult bone samples were all femur and the mean content was 62 Bq ^{90}Sr (kg Ca)$^{-1}$ (1.7 pCi ^{90}Sr (g Ca)$^{-1}$).

The bone levels in 1981 were in general higher than those observed in 1980. Compared to Danish bones in 1981[2] the Faroese bones contained approximately two times as much ^{90}Sr.

Table 2.8.1. Strontium-90 in human bone collected in the Faroes in 1981

Age	Bone type		Sex	Bq ^{90}Sr (kg Ca)$^{-1}$	S.U.
0	Vertebrae		M	92 B	2.5
0	Vertebrae		M	98 A	2.6
61 years	Femur	Amputation	F	59	1.60
79 years	Femur	- " -	F	59	1.59
82 years	Femur	- " -	M	78	2.11
82 years	Femur	- " -	F	75	2.03
86 years	Femur	- " -	M	38	1.03

3. ESTIMATE OF THE MEAN CONTENTS OF ^{90}Sr AND ^{137}Cs IN THE HUMAN DIET

3.1. Annual quantities

The annual quantities are still based on the estimate made by Professor E. Hoff-Jørgensen, Ph.D., in 1962[1] assuming a daily per caput intake of approximately 3000 calories (12.6 MJ).

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 1981 was $1.2 \cdot (0.75 \cdot 0.25 + 0.25 \cdot 0.108) = 0.290$ Bq ^{90}Sr kg^{-1}, and the ^{137}Cs content was $0.75 \cdot 5.1 + 0.25 \cdot 0.134 = 3.86$ Bq ^{137}Cs kg^{-1} (cf. 2.3 and ref. 2). 1 kg milk contains 1.2 g Ca.

3.3. Cheese

Nearly all cheese consumed in the Faroes is of Danish origin, and the Danish figures from ref. 2 were used: 0.92 Bq ^{90}Sr kg^{-1} and 0.10 Bq ^{137}Cs kg^{-1}.

3.4. Grain products

As most grain products are imported from Denmark, the Danish figures for 1981[2] 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 1981 is 0.42 Bq ^{90}Sr kg^{-1} and 0.33 Bq ^{137}Cs kg^{-1}.

3.5. Potatoes

All potatoes consumed in the Faroes are assumed to be of local origin. The values from Table 2.7.4 were used, i.e. 0.14 Bq ^{90}Sr kg^{-1} and 0.89 Bq ^{137}Cs kg^{-1}.

3.6. Other vegetables and fruit

As the amount of vegetables and fruit grown in the Faroes is limited, the Danish figures from 1981[2)] were used. Thus the mean contents in vegetables other than potatoes were 0.38 Bq ^{90}Sr kg^{-1} and 0.086 Bq ^{137}Cs kg^{-1}, and the mean contents in fruit were 0.044 Bq ^{90}Sr kg^{-1} and 0.09 Bq ^{137}Cs kg^{-1}.

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.

The mutton contained 0.32 Bq ^{90}Sr kg^{-1} and 97 Bq ^{137}Cs kg^{-1} (cf. 2.4). Whale meat from 1980 contained 0.04 Bq ^{90}Sr kg^{-1} and 0.19 Bq ^{137}Cs kg^{-1}, sea birds from 1979 and eggs from 1981 (cf. 2.7.6): 0.007 Bq ^{90}Sr kg^{-1} and 0.030 Bq ^{90}Sr kg^{-1}, and 0.27 and ~ 0.04 Bq ^{137}Cs kg^{-1} respectively.

Hence we estimate the mean content of ^{90}Sr in meat and eggs consumed in 1981 to be

$$0.50 \cdot 0.32 + 0.25 \cdot 0.04 + 0.25 \cdot \left(\frac{0.007+0.030}{2}\right) = 0.175 \text{ Bq } ^{90}Sr \text{ } kg^{-1}$$

and the ^{137}Cs content to be

$$0.50 \cdot 97 + 0.25 \cdot 0.19 + 0.25 \cdot \left(\frac{0.27+0.04}{2}\right) = 48.6 \text{ Bq } ^{137}Cs \text{ } kg^{-1}.$$

3.8. Fish

All fish consumed in the Faroes is of local origin, and the mean contents in fish, obtained from subsection 2.5, were 0.031 Bq ^{90}Sr kg^{-1} and 0.34 Bq ^{137}Cs kg^{-1}.

3.9. Coffee and tea

The Danish figures for 1981[2] were used, i.e. 0.66 Bq ^{90}Sr kg^{-1} and 2.21 Bq ^{137}Cs kg^{-1}.

3.10. Drinking water

The mean value found in Table 2.6.1 was used, i.e. 0.0044 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 3.1 and 3.2 show the diet estimates of ^{90}Sr and ^{137}Cs respectively.

Table 3.1. Estimate of the mean content of ^{90}Sr in the human diet in the Faroe Islands in 1981

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	0.29	42.34	35.2
Cheese	7.3	0.92	6.72	5.6
Grain products	80	0.42	33.60	27.9
Potatoes	91	0.14	12.74	10.6
Vegetables	20	0.38	7.60	6.3
Fruit	18	0.044	0.79	0.7
Meat and eggs	37	0.175	6.48	5.4
Fish	91	0.031	2.82	2.3
Coffee and tea	7.3	0.66	4.82	4.0
Drinking water	548	0.0044	2.41	2.0
Total			120.32	

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 200 (5.4 pCi ^{90}Sr (g Ca)$^{-1}$).

Table 3.2. Estimate of the mean content of ^{137}Cs in the human diet in the Faroe Islands in 1981

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	3.86	563.6	22.4
Cheese	7.3	0.10	0.7	0
Grain products	80	0.33	26.4	1.1
Potatoes	91	0.89	81.0	3.2
Vegetables	20	0.086	1.7	0.1
Fruit	18	0.09	1.6	0.1
Meat and eggs	37	48.6	1798.2	71.3
Fish	91	0.34	30.9	1.2
Coffee and tea	7.3	2.21	16.1	0.6
Drinking water	548	0.001	0.5	0
Total			2520.7	

The mean annual intake of potassium is estimated to be approx. 1.2 kg. Hence the ratio: Bq ^{137}Cs $(kg\ K)^{-1}$ becomes 2100 (56.7 pCi ^{137}Cs $(g\ K)^{-1}$).

3.11. Discussion

Figures 3.1 and 3.2 show the Faroese diet levels since 1962.

The 1981 ^{90}Sr level in the total diet was nearly equal to the 1980 concentration, but the ^{137}Cs level was 44% higher than that observed in 1980.

The main contributors to the ^{90}Sr content in the Faroese diet were milk products, cereals and potatoes, which together accounted for approximately 79% of the total ^{90}Sr content in the diet in 1981. As regards ^{137}Cs, milk products, meat (lamb) and potatoes were the most important contributors. In 1981, 97% of the total ^{137}Cs content in the diet originated from these products.

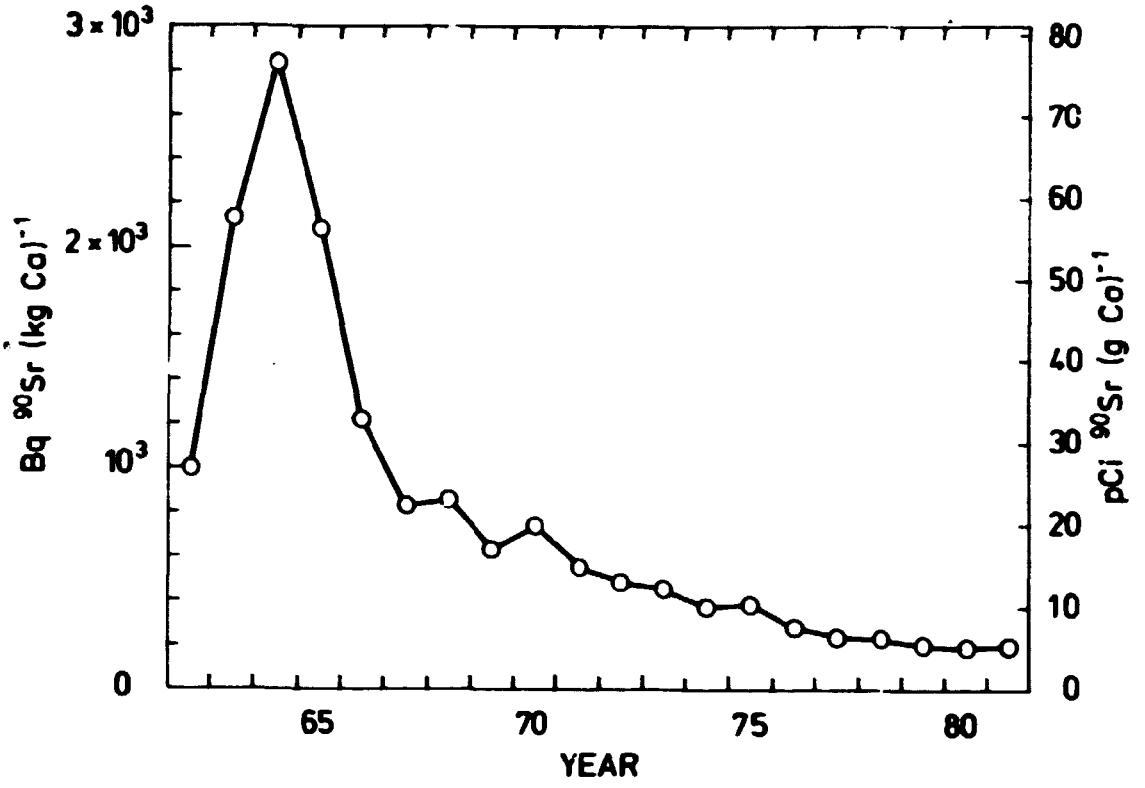

Fig. 3.1. Strontium-90 in Faroese diet, 1962-1981.

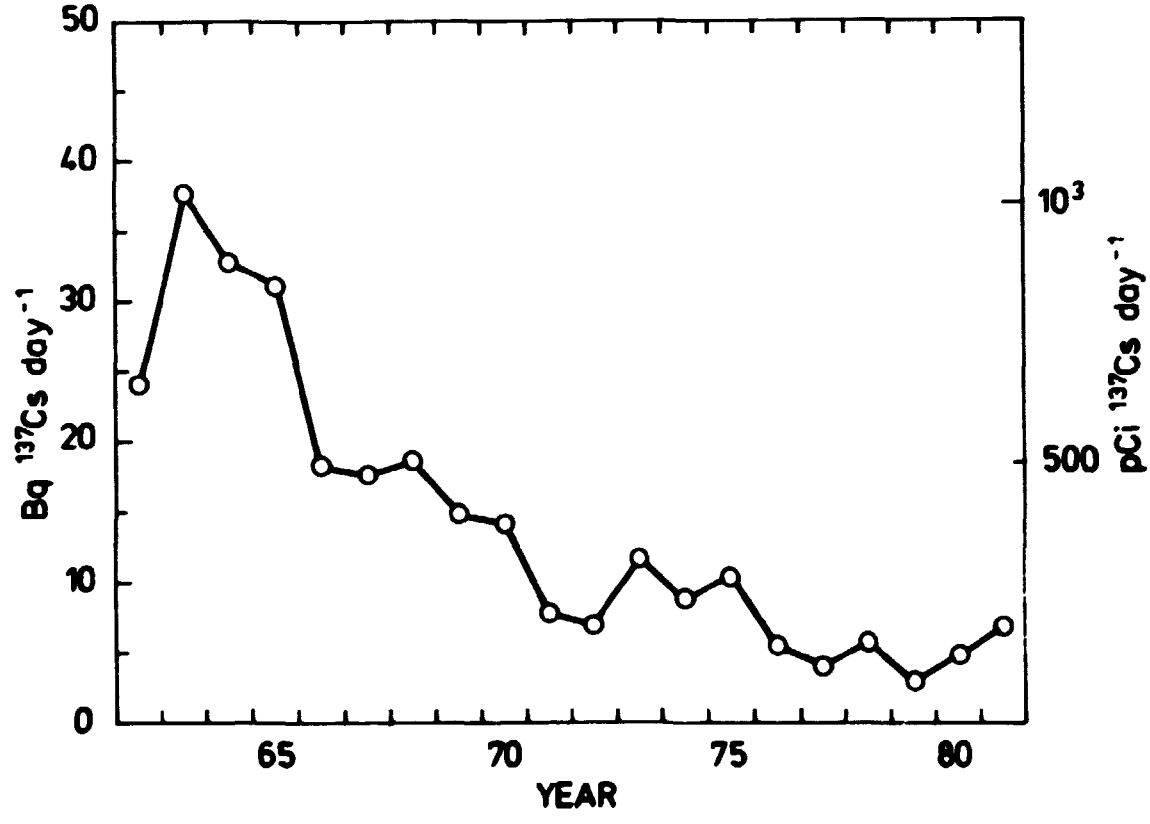

Fig. 3.2. Cesium-137 in Faroese diet, 1962-1981.

The Faroese mean diet contained 1.3 times as much ^{90}Sr and approximately 16 times as much ^{137}Cs as the Danish diet in 1981[2].

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

4. CONCLUSION

4.1.

The ^{90}Sr fallout rate in the Faroes in 1981 was approximately 25 Bq ^{90}Sr m^{-2} (0.67 mCi km^{-2}). The accumulated fallout by the end of 1981 was estimated at approximately 3600 Bq ^{90}Sr m^{-2} (98 mCi km^{-2}) (the mean at Thorshavn and Klaksvig).

4.2.

The mean level of ^{90}Sr in Faroese milk was 250 Bq $(kg\ Ca)^{-1}$ (6.6 pCi $(g\ Ca)^{-1}$). The ^{137}Cs concentration was 5100 Bq ^{137}Cs m^{-3} (138 pCi l^{-1}).

Mutton contained 0.32 Bq ^{90}Sr kg^{-1} (8.6 pCi kg^{-1}) and 97 Bq ^{137}Cs kg^{-1} (2.6 nCi kg^{-1}). Fish showed a mean level of 0.34 Bq ^{137}Cs kg^{-1} (9.2 pCi kg^{-1}).

The mean content of ^{90}Sr in drinking water was 4.4 Bq m^{-3} (0.12 pCi l^{-1}).

The mean daily per caput intakes resulting from the Faroese diet in 1981 were estimated at 0.33 Bq ^{90}Sr (8.9 pCi d^{-1}) and 6.9 Bq ^{137}Cs (186 pCi d^{-1}).

4.3.

From the measurements on Faroese human bones, the Faroese bone level in 1981 was estimated at 70 Bq ^{90}Sr $(kg\ Ca)^{-1}$ (2 pCi $(g\ Ca)^{-1}$).

The mean content of ^{137}Cs in the Faroese adult was estimated at approximately 6000 Bq ^{137}Cs $(kg\ K)^{-1}$ (160 pCi $(g\ K)^{-1}$). This estimate is based on the diet estimate.

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APPENDIX A

The models used for the predictions shown in Table A were based on data collected 1962-1976[6]. If the predictions for previous years 1977-1980[1] were considered too, we conclude that the model for ^{90}Sr in milk overestimates the level and so do the models: for ^{90}Sr in drinking water from Klaksvig, for ^{137}Cs in milk from Tvørå and for ^{137}Cs in potatoes. The following models underestimate the concentrations: ^{90}Sr in cod fish, ^{90}Sr in newborn bone, and probably also ^{137}Cs in milk from Klaksvig.

Table A. Comparison between observed and predicted ^{90}Sr and ^{137}Cs concentrations in Faroese samples collected in 1981

Sample	Unit	Observed ±1 S.E.	Number of samples	Predicted	Obs./pre. ±1 S.E.	Model in ref. 6
Drinking water, Thorshavn	Bq ^{90}Sr m^{-3}	7.4 ±1.8	2	17.4	0.42±0.10	C.1.4.1 No. 9
- " - , Klaksvig	- " -	1.6 ±0.3	2	3.2	0.50±0.09	- " - No. 10
- " - , Tvørå	- " -	4.2 ±0.3	2	4.8	0.88±0.06	- " - No. 11
Sea water	- " -	3.0 ±0.13	4	2.5	1.20±0.05	C.1.5.1 No. 3
Rye bread	Bq ^{90}Sr kg^{-1}	0.37	1	0.78	0.45	C.2.3.1 No. 6
White bread	- " -	0.27	1	0.19	1.42	- " - No. 7
Rye bread	Bq ^{137}Cs kg^{-1}	0.25	1	0.49	0.51	- " - No. 8
White bread	- " -	0.10	1	0.19	0.53	- " - No. 9
Grass	Bq ^{90}Sr (kg Ca)$^{-1}$	8850 ±2550	2	9350	0.95±0.27	C.2.4.1 No. 4
- " -	Bq ^{137}Cs (kg K)$^{-1}$	5200 ±3400	2	2275	2.29±1.50	C.2.4.2 No. 3
Potatoes	Bq ^{90}Sr kg^{-1}	0.14	1	0.23	0.61	C.2.5.1 No. 11
- " -	Bq ^{137}Cs kg^{-1}	0.9	1	7.0	0.13	C.2.5.3 No. 8
Brown algae	Bq ^{90}Sr (kg Ca)$^{-1}$	47 ±15	2	116	0.40±0.13	C.2.7.1 No. 5
Milk	- " -	250 ±18	12	435	0.57±0.04	C.3.3.1 No. 1
Milk Thorshavn	Bq ^{137}Cs m^{-3}	2370 ±265	12	2620	0.90±0.10	C.3.3.2 No. 7
Milk Klaksvig	- " -	5500 ±240	12	2700	2.04±0.08	- " - No. 9
Milk Tvørå	- " -	6900 ±860	12	12650	0.55±0.07	- " - No. 11
Mutton	Bq ^{90}Sr (kg Ca)$^{-1}$	3200	1	2000	1.60	C.3.4.1 No. 5
- " -	Bq ^{137}Cs (kg K)$^{-1}$	30000	1	6000	5.00	C.3.4.2 No. 5
Sheep bone	Bq ^{90}Sr (kg Ca)$^{-1}$	3300	1	2820	1.17	C.3.4.3 No. 1
Cod fish	- " -	220 ±40	8	30	7.3 ±1.3	C.3.5.1 No. 3
- " -	Bq ^{137}Cs kg^{-1}	0.34 ±0.08	8	0.24	1.42±0.34	C.3.5.2 No. 2
Newborn bone	Bq ^{90}Sr (kg Ca)$^{-1}$	95 ±3	2	9.5	10 ±0.3	C.4.3.1 No. 15

APPENDIX B

Algae from West Norway

In 1980, Gordon Christensen, of the Institute of Energy Technology, and T. Bertelsen, of the Norwegian Institute of Radiation Hygiene, sampled algae along the entire Norwegian coastline. A number of these samples have in an intercalibration effort been analysed at Risø. The results of the plutonium determinations are shown in Table B.1.

Risø participated at two of the Norwegian locations, Bud and Vågsøy, and made supplementary samplings there (cf. Figs. B.1 and B.2). Table B.2 shows the Pu determinations of these samples.

Table B.1. Plutonium-239,240 in Fucus vesiculosus collected along the Norwegian Westcoast in August-September 1980

Location (position)	Sample No.	Date	mBq kg^{-1} dry w.	rel. S.D. in %	wet weight / dry weight
Jacobselv (70°N, 31°E)	1-2	Aug 11	184	9	4.9
Hammerfest (71°N, 24°E)	4A-3	Aug 14	270	6	3.4
Vestvågøy (68°N, 14°E)	6-4	Aug 20	140	9	3.8
Kvaløya (65°N, 12°E)	7B-2	Aug 23	110	12	3.6
Lista (58°N, 7°E)	11-3	Sept 14	132	10	4.2
Tromøya (58°30'N, 9°E)	12-1	Sept 15	89	11	3.9
Tjøme (59°N, 10°E)	13-4	Sept 15	75	9	4.6
Hvaler (59°N, 11°E)	14-6	Sept 26	86	14	5.8

Table B.2. Plutonium-239,240 in sea plants collected in September 1980 at Bud, W-Norway (62°N, 6°E)

Sample No.	Species	mBq kg^{-1} dry w.	rel. S.D. %
Vågsøy 2	Fucus vesiculosus	81	11
Bud 3	Laminaria digitata	112	7
Bud 6	Fucus vesiculosus	100	13
Bud 7	Pelvetia	84	14
Bud 16	Pelvetia	67	20
Bud 17	Fucus spiralis	98	18
Bud 18	Fucus vesiculosus	87	15
Bud 19	Ascophyllum nodosum	110	8
Bud 20	Fucus serratus	153	7

The plutonium concentrations in Fucus vesiculosus showed a decreasing tendency from north to south. A single location: Lista at the southwest corner of Norway did not follow the general pattern. Whether or not this was due to a contribution of plutonium from Windscale at this location is unclear. If the plutonium results are compared with those of Christensen[7] on the same samples, the mean ratio of ours to Christensen's is 1.18±0.27 (1 S.D., N = 8). The relative standard deviations of double Pu determinations carried out by the two laboratories were thus 23%. These are the same deviations as found earlier in Nordic Pu-intercomparison runs[8] on seaweed and sediments.

The relative SD at a single location: Bud (Table B2) between the 9 samples obtained at this location was 27%. The 9 samples represented 6 different species. The local variation along the entire coastline of Fucus vesiculosus alone was 48%, if we use the data in Table B.1.

The mean of all seaweed samples in Tables B1 and B2 was 116 mBq $^{239,240}Pu$ kg^{-1} dry weight (1 SD: 50, N = 17). The corresponding fresh weight concentration was 25 mBq kg^{-1} if the mean ratio of fresh to dry weight was 4.6 as found by Christensen in 1980[7]. The mean of the 15 samples analysed by Christensen was 26 mBq kg^{-1} wet weight (1 S.D.:11).

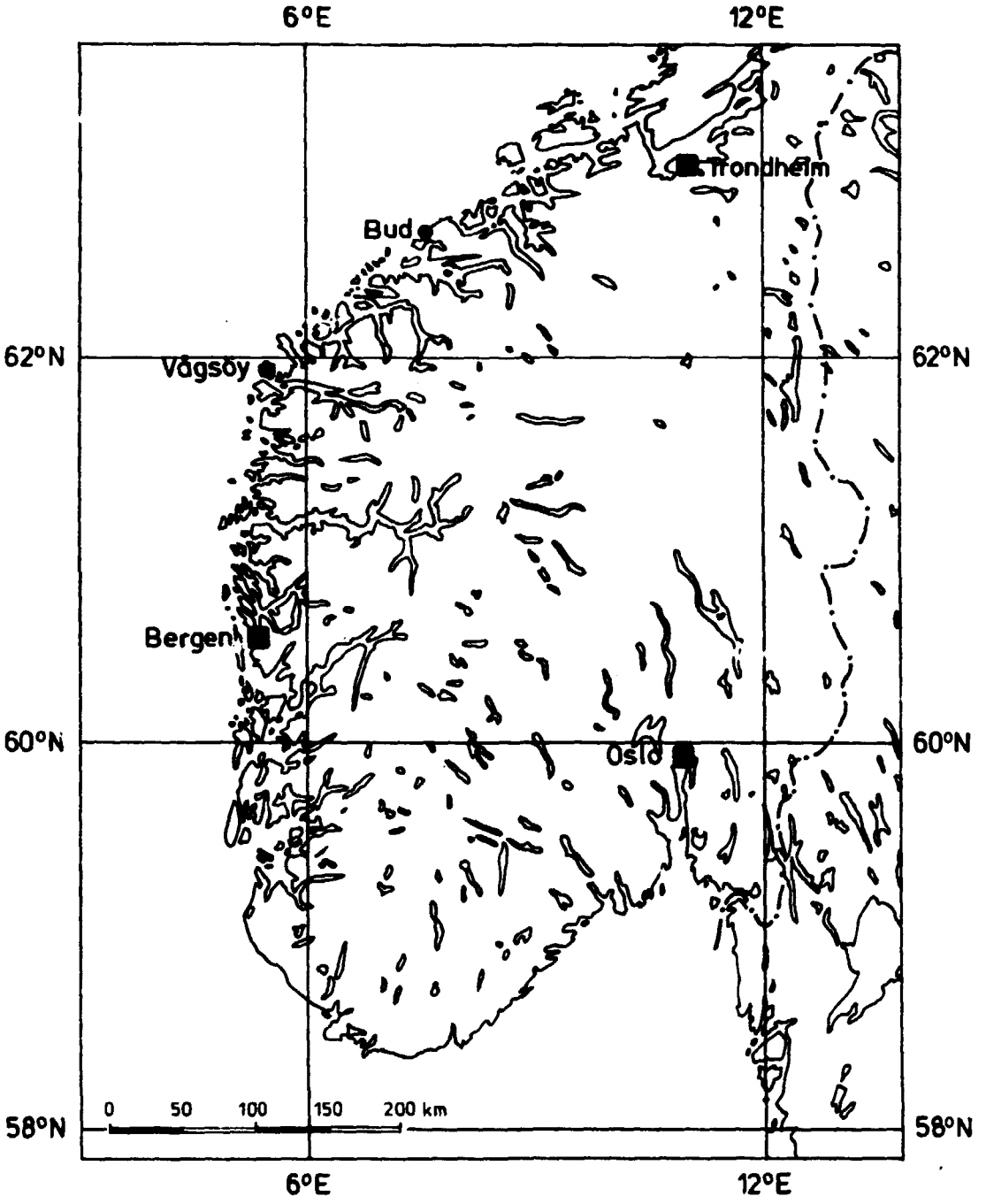

Fig. B.1. Sampling locations in West-Norway, Bud and Vågsøy, 1980.

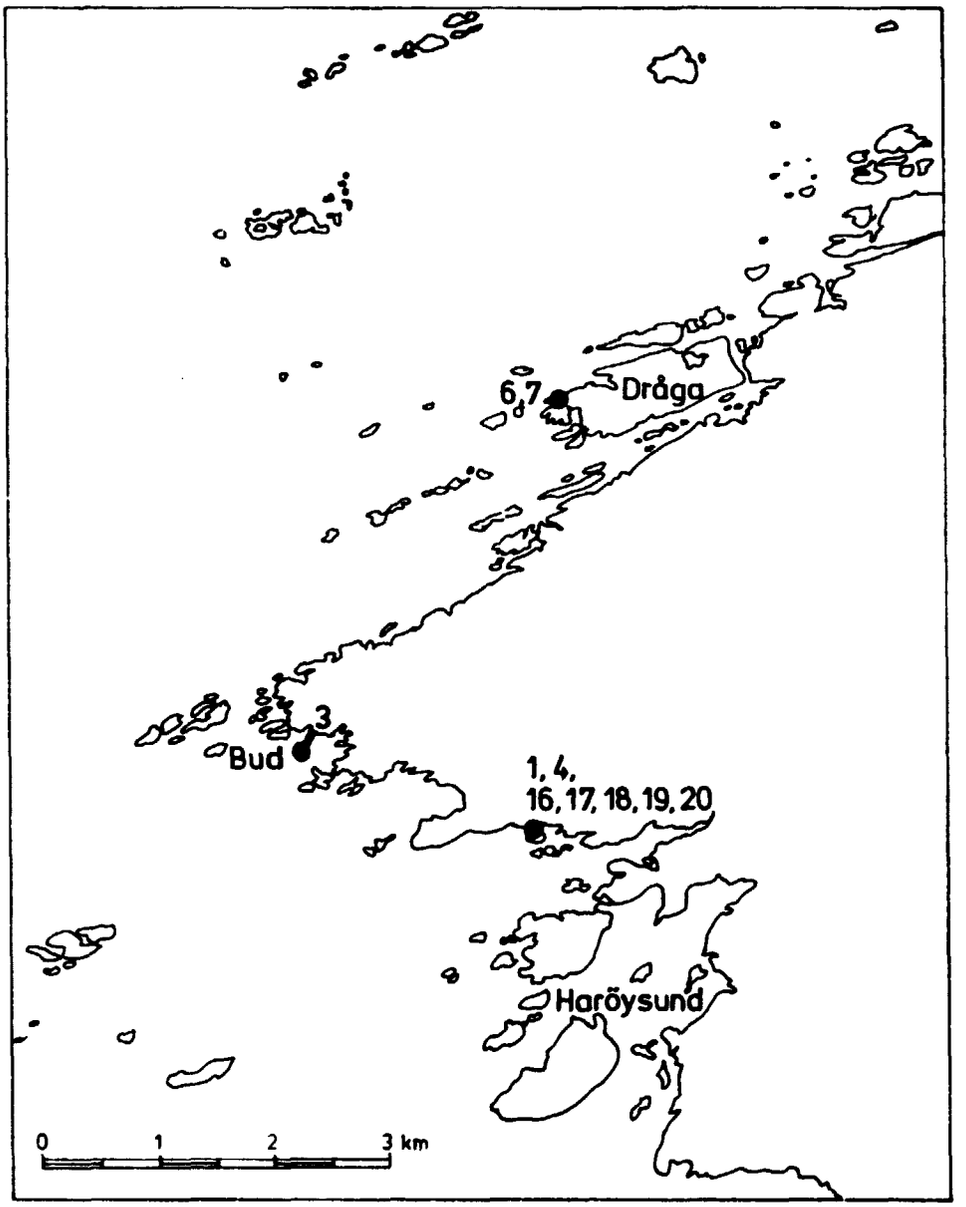

Fig. B.2. Sampling locations in the Bud area, West Norway, 1980. Sample numbers are indicated.

Appendix C

Sea water and biota collected in Iceland and on the Bergen-Faroe Islands-Iceland route in June-July 1981

Surface sea water was collected from M/S "Smyril" on its way from Norway to Iceland and back again 18 days later. Table C.1 and Figs. C.1 and C.2 show the ^{137}Cs and $^{239,240}Pu$ concentrations, respectively. Between the Faroes and Norway the samples were collected twice at nearly the same locations. The upper figures are the concentrations found on the way out and the lower ones on the way back to Norway. It is evident that the ^{137}Cs concentrations, in particular, reproduce convincingly.

Close to the Norwegian coast the surface water contained ^{137}Cs levels which were nearly 30 times higher than in the open Atlantic Ocean. The presence of ^{134}Cs suggested that the activity came from Sellafield. The concentrations decreased rapidly on moving westwards. At Iceland the lowest concentrations were found on the west coast (cesium-137 levels there were nearly 30% lower than those observed at the Faroe Islands. A single water sample collected east of Iceland (S 57) contained more ^{137}Cs than expected. This sample may have been contaminated because the ship had just arrived from Scottish waters when this sample was collected.

The $^{239,240}Pu$ concentrations were also lower in the waters around Iceland than between Norway and the Faroes, but the difference was less marked than for ^{137}Cs, and the presence of any surplus plutonium originating from Sellafield was not demonstrated in these samples. On the average the ^{241}Am concentration was 20% of the plutonium activity. A few samples were analysed for particulate Pu and Am (Table C.1 shows the results).

Table C.1. Radiocesium, plutonium and americium in surface sea water collected in June-July 1981 between Norway, The Faroe Islands and Iceland. (Unit: Bq m^{-3})

Latitude N	Longitude	No. & Location	Date	^{137}Cs	$^{134}Cs/^{137}Cs$	$^{239,240}Pu$	$^{241}Am/^{239,240}Pu$	% particulate activity Pu	% particulate activity Am	Salinity in ‰
60°45'	4°41'E	S1	June 13	91 (1%)	0.039 (8%)	0.019 (16%)	0.4 (31%)			31.74
61°06'	2°00'E	S2	June 13	57 (1%)	0.049 (10%)	0.014 (16%)	0.3 (20%)			34.75
61°19'	0°45'E	S3	June 13	5.4 (6%)	-	0.021 (27%)	0.2 (46%)			35.21
61°30'	1°22'W	S4	June 14	3.8 (9%)	-	0.017 (11%)	0.15 (31%)			35.21
61°40'	3°23'W	S5	June 14	4.2 (8%)	-	0.017 (15%)	0.3 (31%)			35.21
61°51'	5°20'W	S6	June 14	3.5 (10%)	-	0.017 (26%)	0.15 (39%)			35.21
62°02'	6°45'W	F7-9 Hoyvik	June 14	3.55 (3%)	-	0.020 (11%)	0.17 (25%)	13	30	33.54
64°40'	14°25'W	I20 Krossanesss	June 17			0.017 (13%)	0.3 (20%)			30.30
63°50'	22°27'W	I22-24 Grindavik	June 19	2.77 (4%)	-	0.010 (79%)	0.2 (44%)	9	15	32.36
66°07'	23°06'W	I27,35,36 Hnifsdalur	June 22	2.92 (4%)	-	0.014 (11%)	0.1 (51%)	6	4	34.10
66°09'	18°55'W	I37,I38 Siglufjordur	June 24	3.19 (3%)	-	0.010 (14%)	0.15 (43%)			32.55
66°28'	15°55'W	I48,I49 Raufarhöfn	June 26	3.18 (4%)	-	0.010 (12%)	0.1 (100%)			31.21
65°10'	13°43'W	I53,I54 Hrskaup-staðhur	June 28	3.19 (4%)	-	0.010 (12%)	- -			28.58
65°03'	12°57'W	S57	July 1	5.5 (4%)	-	0.010 (23%)	0.2 (46%)			34.03
63°43'	9°52'W	S58	July 1	3.3 (8%)	-	0.012 (19%)	0.2 (63%)			35.21
62°53'	8°08'W	S59	July 1	3.2 (9%)	-	0.014 (16%)	0.2 (47%)			34.97
61°59'	6°02'W	S60	July 1	3.4 (10%)	-	0.026 (34%)	0.1 (44%)			34.96
61°44'	3°47'W	S61	July 2	4.0 (9%)	-	0.009 (17%)	0.2 (43%)			35.09
61°30'	1°31'W	S62	July 2	3.9 (8%)	-	0.010 (21%)	0.2 (40%)			35.09
61°20'	0°42'E	S63	July 2	5.7 (7%)	-	0.016 (16%)	0.2 (4'%)			35.09
61°00'	2°55'E	S64	July 2	50 (1%)	0.056 (12%)	0.025 (25%)	0.1 (56%)			33.87
60°45'	4°36'E	S65	July 2	83 (1%)	0.041 (7%)	0.014 (16%)	0.2 (30%)			31.74

In brackets relative S.D. due to counting error.

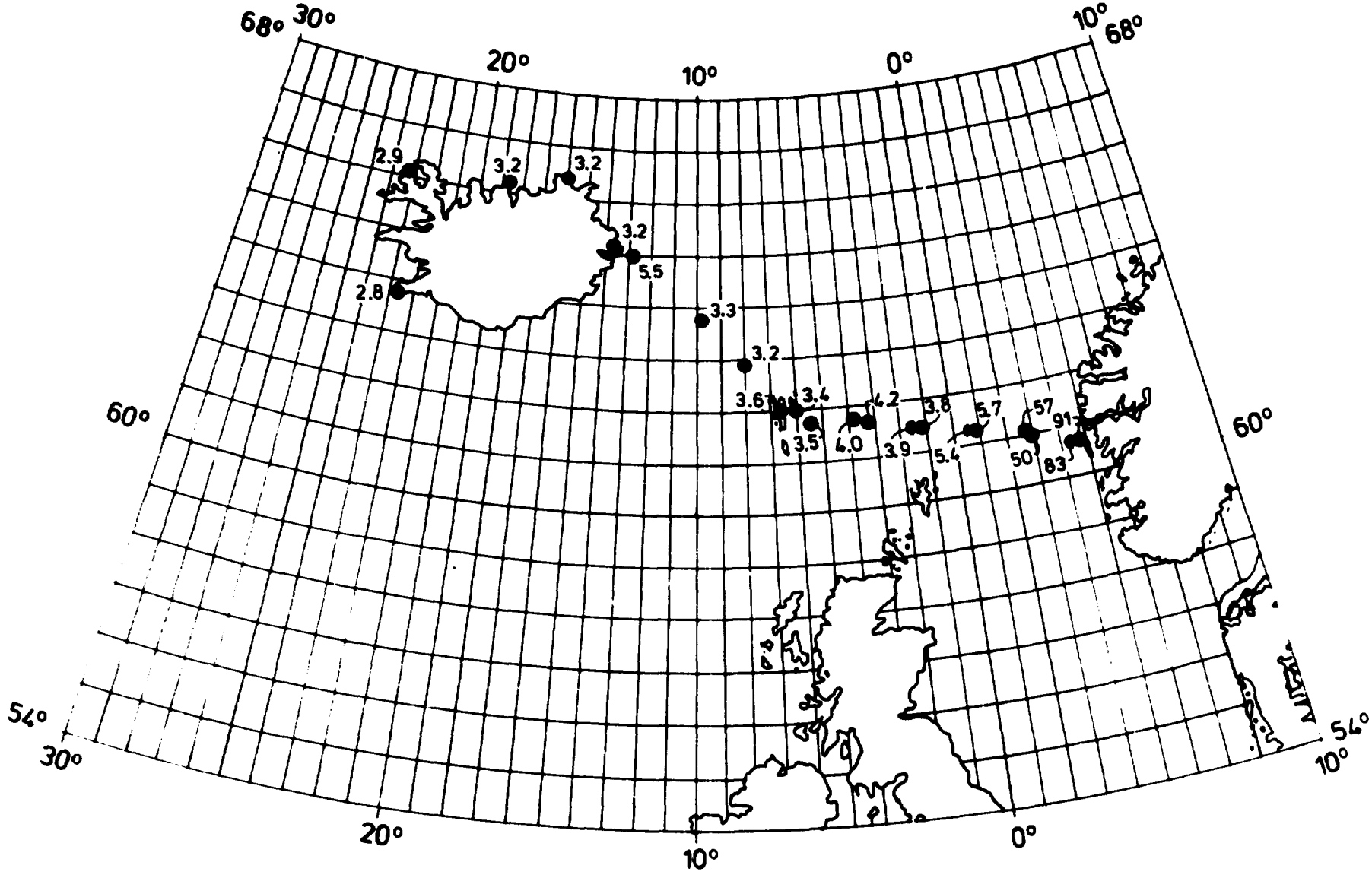

Fig. C.1. Cesium-137 in surface sea water collected June-July 1981. (Unit: Bq m^{-3}).

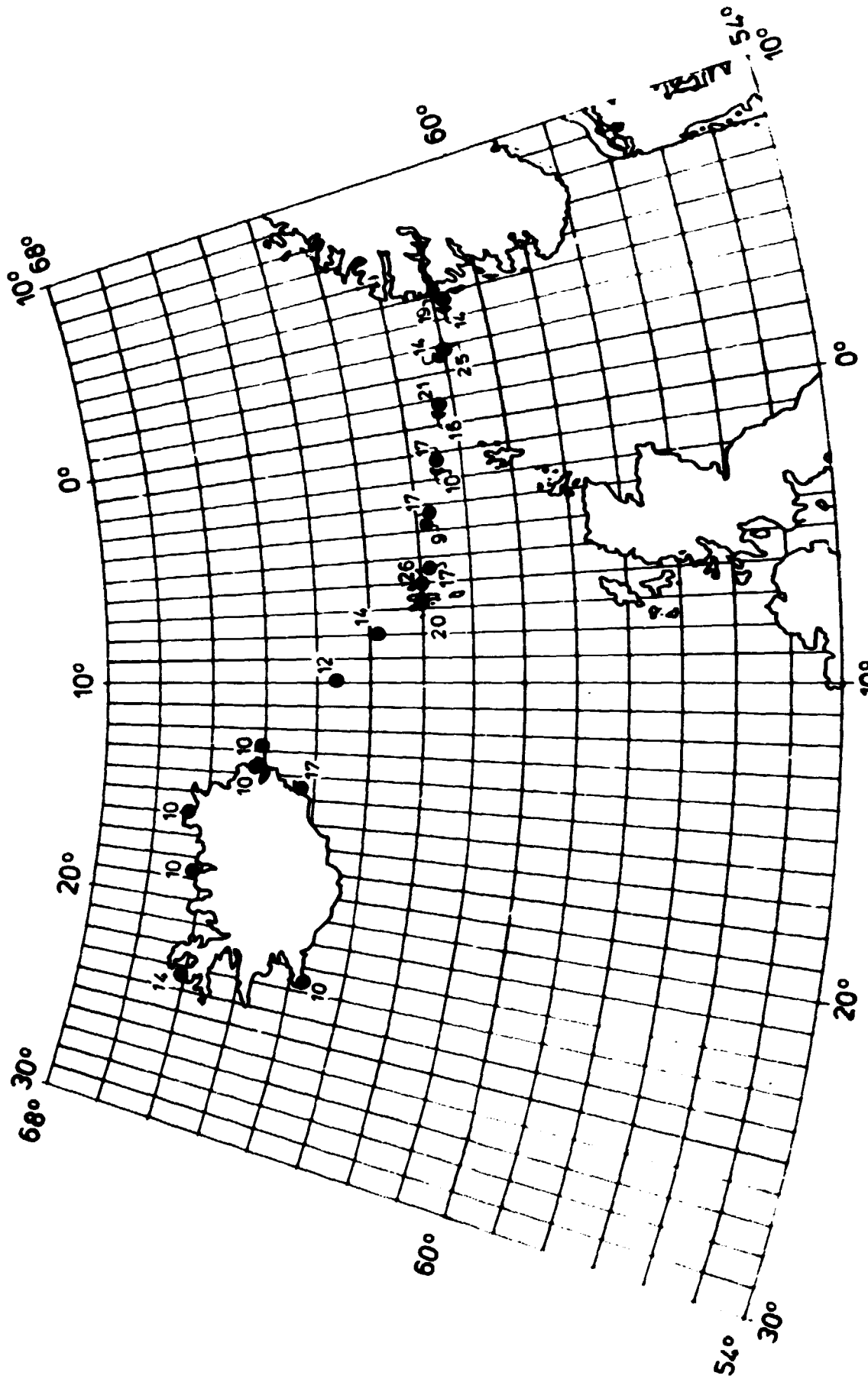

Fig. C.2. Plutonium-239,240 in surface sea water collected June-July 1981. (Unit: mBq m^{-3}).

Algae were collected at the Faroe Islands (Table 2.7.3.2) and along the Icelandic coastline (Table C.2 and Fig. C.3). Fucus distichus and Fucus vesiculosus were the most frequent species. An anova showed that the radionuclide concentrations in these two species did not differ significantly. The anova also showed that samples in the eastern locations in Iceland had approximately 30% higher concentrations of radionuclides than those from the north and west. (In the anova we included 7 isotopes: ^{54}Mn, ^{95}Nb, ^{106}Ru, ^{137}Cs, ^{144}Ce, ^{226}Ra, and $^{239,240}Pu$, and 3 areas: West: Grindavik, Skalanes, North: Hnifsdalur, Arnarnæs, Siglufjordur, Raufarhöfn and East: Seydisfjordur, Neskaupstadur, Streitishvarf). The interactions among species, nuclides, or locations were not significant.

The radionuclides ^{95}Zr, ^{95}Nb, ^{106}Ru, ^{125}Sb, and ^{144}Ce occurred in the same relative mutual concentrations in fucoids as in air collected in June 1981 at Pisa[2]. This suggests that the contamination of the fucoids with these radionuclides was an adsorption of fallout particles suspended in the water.

Another pathway may have been uptake directly from the air if the plants have been exposed to the atmosphere during low tide. The relative concentrations of ^{54}Mn and $^{239,240}Pu$ compared with the other radionuclides were, respectively, 3-5 times higher in fucoids than in fresh fallout. This suggests that these nuclides were present in the water in dissolved form also, because only if a nuclide is in solution can we expect that the uptake by algae will differ for the various elements. The ratios: $^{95}Zr/^{137}Cs$, $^{95}Nb/^{137}Cs$, $^{106}Ru/^{137}Cs$, $^{125}Sb/^{137}Cs$, and $^{144}Ce/^{137}Cs$ in fucoids were on the average 50% higher than those in air. This suggests that ^{137}Cs has been dissolved from the fallout particles absorbed by the algae in contrast to the other five fallout nuclides. Furthermore, it shows that the concentration factor is lower for ^{137}Cs in solution than for dissolved ^{54}Mn and $^{239,240}Pu$.

Table C.3 shows the concentration ratios for ^{137}Cs and $^{239,240}Pu$ in fucoids. These are slightly lower than, but not significantly different from, those calculated for the Faroe Islands in 2.7.3.

Table C.3. Radionuclides in algae collected around the Icelandic coastline in June-July 1981.
(Unit: Bq kg^{-1} dry weight)

Date	Location (position)	Station No.	Species	^{40}K kg K kg^{-1}	^{54}Mn	^{95}Sr	^{95}Nb	^{106}Ru	^{125}Sb	^{137}Cs	^{144}Ce	^{226}Ra	$^{239,240}Pu$	$\frac{^{241}Am}{^{239,240}Pu}$	$\frac{\text{dry weight}}{\text{fresh weight}}$
June 17	Straitishvarf (64°45'N 16°80'W)	I19	Fucus distichus	0.046 (0.4%)		9 (37%)	15 (15%)			0.60 (10%)	3.8 (25%)	1.4 (10%)	0.034 (7%)		0.13
June 18	Vik (63°25'N 19°00'W)	I21	Fucus distichus	0.041 (0.4%)	0.9 (25%)		30 (14%)	8 (33%)		0.67 (17%)	4.7 (10%)	2.0 (8%)	0.087 (13%)		0.30
June 18	Grindavik (63°50'N 22°27'W)	I25	Fucus vesiculosus	0.034 (0.4%)	0.6 (23%)	8 (28%)	14 (9%)	4.3 (25%)		0.88 (11%)	9.7 (7%)	3.3 (8%)			0.19
June 21	Skalanes (65°30'N 22°30'W)	I26	Fucus vesiculosus	0.030 (0.5%)	0.9 (17%)	32 (11%)	78 (4%)	10.2 (13%)	0.8 (25%)	1.07 (7%)	30 (3%)	3.2 (4%)	0.138 (3%)	0.18	0.22
June 22	Hvalfadalur (66°07'N 23°06'W)	I30	Fucus vesiculosus	0.037 (0.4%)	0.6 (34%)		19 (16%)			0.63 (15%)	12 (6%)	1.0 (9%)	0.079 (13%)		0.20
- " -	- " -	I31	Fucus distichus	0.050 (0.4%)			22 (10%)			0.86 (14%)	11 (8%)	2.0 (8%)	0.020 (7%)		0.16
- " -	- " -	I32	Ascophyllum nodosum	0.023 (0.6%)		8 (25%)	15 (11%)			0.42 (22%)	3 (22%)	1.5 (8%)	0.010 (10%)		0.27
- " -	Arnarnes (66°07'N 23°06'W)	I34	Fucus vesiculosus	0.026 (0.4%)	0.48 (17%)	8.0 (3%)	15 (1%)	2.7 (24%)		0.45 (15%)	5.2 (6%)	1.7 (7%)	0.055 (6%)		0.25
June 24	Siglufjordur (66°09'N 18°55'W)	I40	Fucus distichus	0.036 (0.4%)	0.5 (33%)	17 (11%)	33 (5%)	5 (29%)		0.73 (14%)	10.4 (4%)	1.7 (8%)			0.17
- " -	Siglufjordur pier (66°09'N 18°55'W)	I41	Fucus distichus	0.042 (0.4%)	0.6 (33%)	21 (14%)	41 (5%)	7.8 (13%)		0.78 (13%)	31 (3%)	1.4 (10%)	0.052 (8%)		0.13
June 25	Raufarhöfn (66°28'N 15°55'W)	I42	Fucus distichus	0.020 (1%)		6.5 (4%)	11 (3%)			0.59 (13%)	3.9 (10%)	1.5 (7%)	0.025 (15%)		0.20
- " -	- " -	I44	Fucus vesiculosus	0.039 (0.4%)	0.5 (34%)	5.7 (7%)	14 (5%)	3 (30%)		0.77 (7%)	10.2 (4%)	1.5 (8%)			0.19
- " -	- " -	I45	Fucus distichus	0.046 (0.4%)			12 (16%)			0.65 (17%)	8.7 (10%)	1.7 (10%)	0.024 (9%)		0.17
- " -	- " -	I46	Laminaria digitata	0.044 (0.3%)			16 (12%)			0.81 (12%)	6.3 (13%)	1.6 (10%)	0.0064 (11%)		0.17
- " -	- " -	I47	Laminaria saccharina	0.044 (0.4%)			11 (10%)			0.54 (21%)	8.8 (9%)	1.7 (10%)	0.0051 (13%)		0.17
June 28	Raufarhöfn (65°10'N 13°43'W)	I50	Fucus distichus	0.041 (0.4%)	0.8 (22%)	28 (9%)	58 (3%)	9.7 (13%)		1.29 (9%)	32 (3%)	2.5 (11%)			0.15
- " -	- " -	I51	Fucus vesiculosus	0.034 (0.4%)	0.6 (24%)	15 (14%)	31 (5%)	6.9 (17%)		0.89 (9%)	22 (4%)	1.2 (12%)	0.020 (6%)		0.17
- " -	Seydisfjordur (65°17'N 13°50'W)	I55	Fucus distichus	0.036 (0.4%)	1.0 (15%)	20 (9%)	43 (3%)	8.9 (14%)	0.9 (23%)	1.03 (9%)	33 (4%)	1.8 (8%)			0.12
- " -	- " -	I56	Fucus vesiculosus	0.023 (3%)	1.0 (11%)	21 (2%)	38 (1%)	9.5 (9%)	0.9 (27%)	0.84 (13%)	30 (2%)	1.7 (8%)			0.15

The relative S.D. due to counting is shown in brackets.

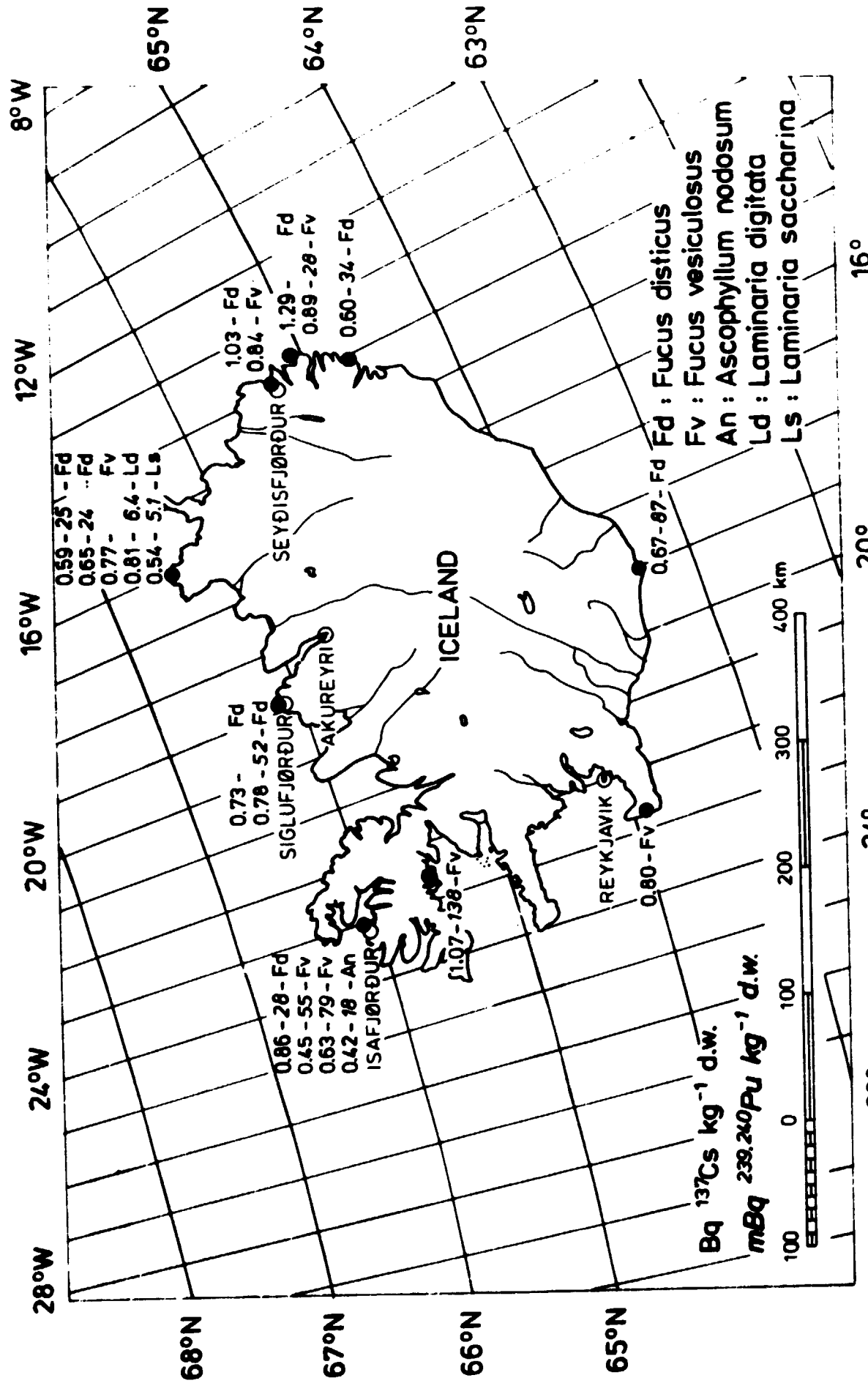

Fig. C.3. Cesium-137 and Plutonium-239,240 in algae collected around Iceland in June 1981.

Mussels were collected at four locations in Iceland and one in the Faroes (Table C.4). The mean ratio between the concentrations of ^{54}Mn, ^{95}Nb, ^{137}Cs, ^{144}Ce, and $^{239,240}Pu$ in fucoids and Mytilus was 2.5 on a dry weight basis. Similar ratios have been found in Danish samples[2]. Ruthenium-106 did not follow the same pattern as the above-mentioned nuclides. The mean concentration of ^{106}Ru was thus nearly the same in Mytilus as in Fucus. The local variation for Mytilus was similar to that of Fucus, i.e. the eastern location showed the highest concentrations (except for Pu).

Table C.3. Concentration ratios (CR) in Icelandic fucoids

			^{137}Cs	$^{239,240}Pu$
Sea water	Bq l^{-1}:	$\bar{x}$:	$3.0^{5} \cdot 10^{-3}$	$0.012 \cdot 10^{-3}$
		SD:	$0.19 \cdot 10^{-3}$	$0.003 \cdot 10^{-3}$
		N:	5	6
Fucoids	Bq kg^{-1} dry w.	$\bar{x}$:	0.79	0.055
		SD:	0.21	0.037
		N:	16	10
CR±1 S.D.			260±70	4600±3300

A single moss sample were collected at Isafjordur (Table C.5). The sample consisted of 19.1 kg dry matter and covered an area of 5 m^2. The accumulated ^{137}Cs fallout in the moss was 2188 Bq m^{-2} or 59 mCi ^{137}Cs km^{-2}. It is interesting to note that radionuclides such as ^{60}Co and ^{207}Bi occur. In order to determine the inhomogeneity of the sample we measured five aliqouts ranging from 169 to 699 g. The mean deposition in these 5 samples was 2490 Bq ^{137}Cs m^{-2} (1 SD: 550 Bq m^{-2}). The mosses of four aliquots of 94 g dry matter each were analysed for $^{239,240}Pu$, ^{238}Pu, and ^{241}Am; the mean values ±1 S.D. were: 9.87±0.20 Bq kg^{-1}, 0.35±0.03 Bq kg^{-1} and 2.34±0.17 Bq kg^{-1}, respectively. In accumulated fallout in 1981, we thus found the $^{238}Pu/^{239,240}Pu$ ratio as 0.035±0.003 and the $^{241}Am/^{239,240}Pu$ ratio, to 0.24±0.002.

Table C.4. Radionuclides in Mytilus edulis collected at the Faroe Islands and Iceland in June 1981. (Unit: Bq kg^{-1} dry matter)

Date	Location (position)	Station No.	^{7}Be	^{40}K kg K kg^{-1}	^{54}Mn	^{95}Zr	^{95}Nb	^{106}Ru	^{125}Sb	^{137}Cs	^{144}Ce	$^{239,240}Pu$	dry weight fresh weight
June 14	Hoyvik 62°02'N 6°45'W	F12	8 (20%)	0.015 (0.8%)	0.3 (35%)	1.8 (20%)	3.0 (8%)	5.3 (10%)		0.34 (30%)	1.8 (12%)	0.026 (9%)	0.17
June 22	Arnanes 66°07'N 23°06'W	I33	7 (21%)	0.015 (0.9%)		3.1 (10%)	6.2 (4%)	5.4 (21%)		0.27 (33%)	4.4 (10%)	0.020 (10%)	0.15
June 24	Siglufjordur 66°09'N 18°55'W	I39	17 (9%)	0.016 (0.7%)	0.4 (28%)	3.5 (7%)	6.3 (3%)	10.2 (9%)	0.5 (39%)	0.33 (27%)	6.4 (8%)	0.023 (12%)	0.15
June 25	Raulerhöfn 66°28'N 15°55'W	I43	6 (26%)	0.016 (0.8%)		1.4 (19%)	3.3 (6%)	4.8 (21%)		0.38 (24%)	4.3 (10%)	0.015 (15%	0.17
June 28	Neskaupstadur 65°10'N 13°43'W	I52	13 (13%)	0.016 (0.7%)	0.4 (26%)	3.6 (7%)	7.2 (3%)	15 (7%)		0.40 (24%)	6.8 (6%)	0.013 (17%)	0.17

The relative S.D. due to counting is shown in brackets.

Table C.5. Radionuclides in moss collected June 22, 1981 at 66°07'N, 23°06'W (Isafjördur) Iceland (I 29)

Nuclide	Bq kg^{-1} fresh w.	Bq m^{-2}	rel. S.D.	
^{7}Be	330	2900	10%	
^{54}Mn	0.57	5.1	3%	
^{60}Co	0.19	1.7	3%	
^{95}Zr	11.1	100	4%	
^{95}Nb	23	210	2%	
^{106}Ru	10	90	5%	
^{125}Sb	4.6	41	2%	
^{137}Cs	242	2190	0.1%	
^{144}Ce	23	210	2%	
^{155}Eu	3.3	30	2%	
^{207}Bi	0.31	2.8	3%	
^{226}Ra	0.17	1.6	15%	
^{238}Pu	0.35	3.2	8%	rel. S.D. determined
$^{239,240}Pu$	9.87	89	2%	from analysis
^{241}Am	2.34	21	7%	of four aliquots

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