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Environmental Radioactivity in Greenland in 1979

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ENVIRONMENTAL RADIOACTIVITY IN GREENLAND IN 1979

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Abstract. Measurements of fallout radioactivity in Greenland in 1979 are reported. Strontium-90 (and Cesium-137 in most cases) was determined in samples of precipitation, sea water, vegetation, animals, and drinking water. Estimates are given of the mean contents of ^{90}Sr and ^{137}Cs in the human diet in Greenland in 1979. Provisional results of the $^{239,240}Pu$ and ^{241}Am measurements on samples from the expedition to Thule in August 1979 are presented.

INIS Descriptors

[0] DEER, DIET, ENVIRONMENT, EXPERIMENTAL DATA, FISHES, FOOD CHAINS, GLOBAL FALLOUT, GRAPHS, GREENLAND, PLANTS, RADIOACTIVITY, SEAWATER, SHEEP, TABLES

[1] ATMOSPHERIC PRECIPITATIONS, DRINKING WATER, STRONTIUM 90

[2] CESIUM 137

[3] ALGAE, AMERICIUM 241, PLUTONIUM 239, PLUTONIUM 240, SEDIMENTS

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ABBREVIATIONS AND UNITS

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

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

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

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%)

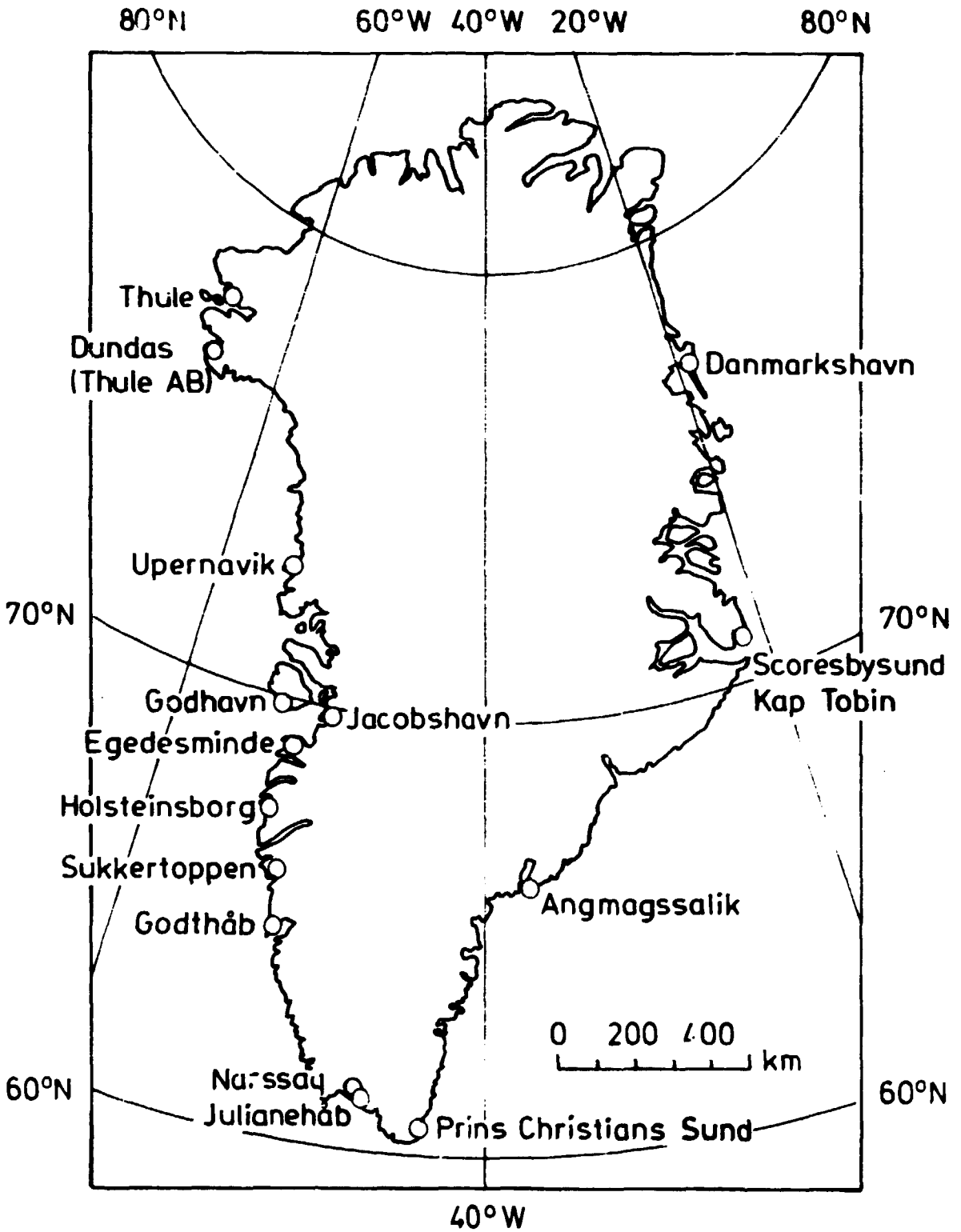

Fig. 1. Greenland.

1. INTRODUCTION

1.1.

In 1979 the sampling programme was similar to that used in previous years but for a few minor modifications.

1.2.

As hitherto, samples were collected through the local district physicians and the head of the telestations.

1.3.

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

1.4.

The environmental studies in Greenland were carried out together with corresponding investigations in Denmark (cf. Risø Report No. 421[2]) and in the Faroes (cf. Risø Report No. 422[3]).

1.5.

The present report does not repeat information concerning sample collection and analysis already given in ref. 1.

1.6.

As an appendix to this report we have as uncommented tables given provisional results of our investigations of transuranics (Pu and Am) and ^{137}Cs at Thule in August 1979. The expedition to Thule in 1979 was supported by the Commission of the European Communities with funds from its Radiation Protection programme.

2. RESULTS AND DISCUSSION

2.1. Strontium-90 in precipitation

Table 2.1.1 shows the results of the measurements.

The ^{90}Sr levels in 1979 at the Greenland stations were 0.46±0.19 (1 SD) times the 1978 figures. In Denmark[2] and the Faroes[3] the fallout levels decreased similarly from 1978 to 1979.

Fig. 2.1 shows the accumulated ^{90}Sr at the various stations in Greenland, since measurements began in 1962.

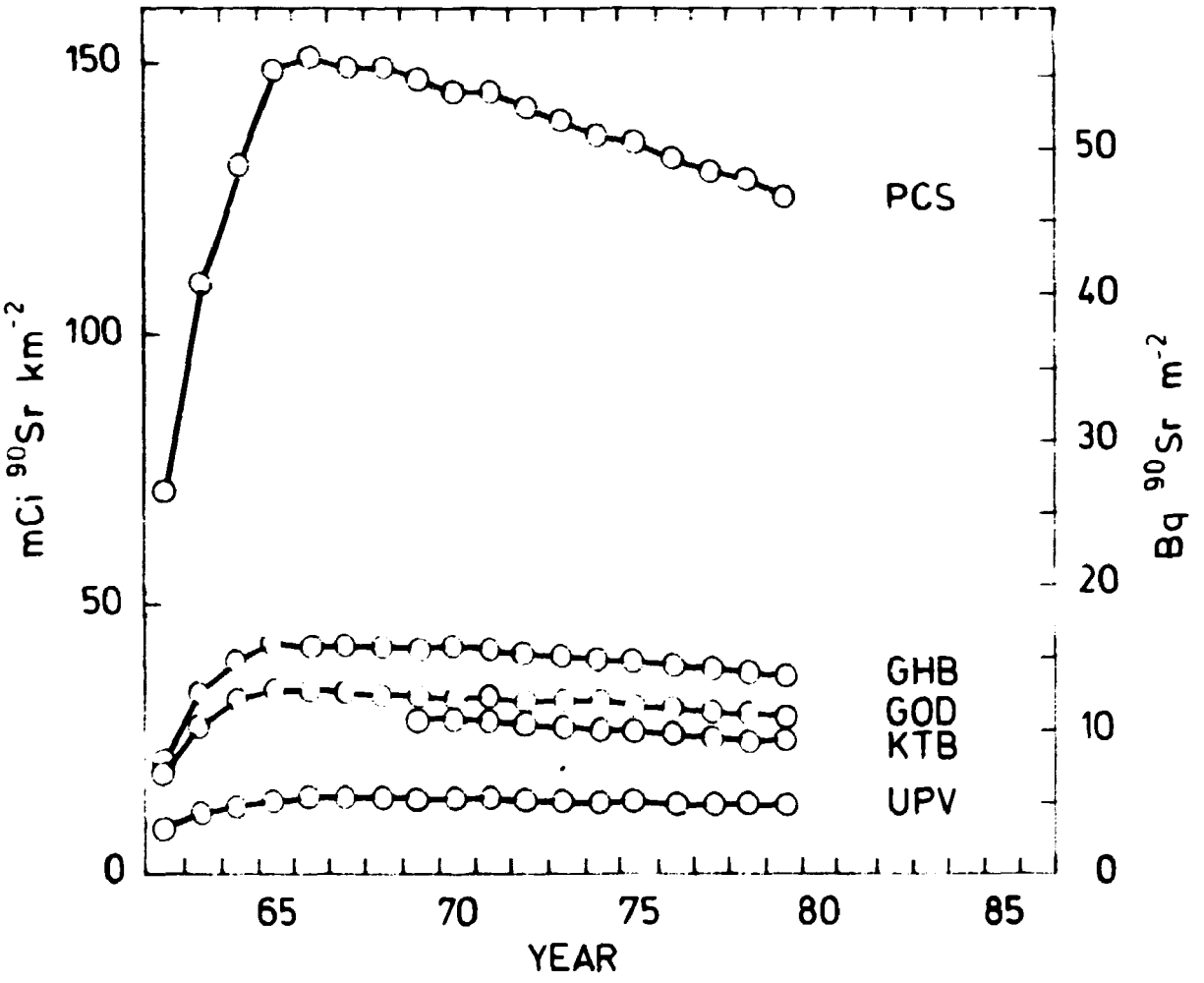

Fig. 2.1. Accumulated ^{90}Sr at Prins Chr. Sund, Godthåb, Godhavn, Kap Tobin and Upernavik calculated from precipitation measurements since 1962. The accumulated fallout by 1962 was estimated from the Danish data (cf. Risø Report No. 403[2], Appendix D) and from the ratio between the ^{90}Sr fallout at the Greenland stations and the fallout in Denmark in the period 1962-1974.

Table 2.1.1.A. Strontium-90 in precipitation in Greenland in 1979

Location	Unit	Jan-March	April-June	July-Sept	Oct-Dec	1979
Upernavik	pCi l^{-1}	—— 0.65 ——		(0.59)	0.42	(0.55)
Σ 182[265] mm	mCi km^{-2}	—— 0.0162 ——		(0.063)	0.021	(0.100)
Godhavn	pCi l^{-1}	0.38	0.44	0.33	(0.20)	(0.35)
Σ 631[499] mm	mCi km^{-2}	0.057	0.052	0.096	(0.014)	(0.219)
Godthåb	pCi l^{-1}	0.42	0.37	0.30	(0.19)	(0.34)
Σ 778[784] mm	mCi km^{-2}	0.079	0.114	0.058	(0.017)	(0.268)
Prins Chr. Sund	pCi l^{-1}	0.102	0.38	0.163	0.120	0.18
Σ 1578[1809] mm	mCi km^{-2}	0.049	0.132	0.049	0.054	0.284
Kap Tobin	pCi l^{-1}	0.27	(0.40)	0.25	0.124	(0.27)
Σ 382[476] mm	mCi km^{-2}	0.0134	(0.017)	0.020	0.026	(0.076)
Danmarkshavn	pCi l^{-1}	0.66	1.29	—— 0.39 ——		0.50
Σ 202[223] mm	mCi km^{-2}	0.042	0.006	—— 0.052 ——		0.100

The missing amount of precipitation was kindly supplied by Mr. Gunnar Nielsen, Danish Meteorological Institute. Figures in parenthesis were estimated from VAR 3 due to missing samples. The annual amount of precipitation at the six locations according to Danish Meteorological Institute were shown in brackets.

Table 2.1.1.B. *Strontium-90 in precipitation in Greenland in 1979*

Location	*Unit*	*Jan-March*	*April-June*	*July-Sept*	*Oct-Dec*	*1979*
Upernavik	Bq m^{-3}	—— 24 ——		(22)	15.5	(20)
Σ 0.182[0.265] m	Bq m^{-2}	—— 0.60 ——		(2.3)	0.78	(1.37)
Godhavn	Bq m^{-3}	14.1	16.4	12.3	(7.4)	(13.0)
Σ 0.631[0.499] m	Bq m^{-2}	2.1	1.92	3.6	(0.52)	(8.1)
Godthåb	Bq m^{-3}	15.4	13.8	11.0	(7.0)	(12.6)
Σ 0.778[0.784] m	Bq m^{-2}	2.9	4.2	2.1	(0.63)	(9.9)
Prins Chr. Sund	Bq m^{-3}	3.8	14.0	6.0	4.4	6.7
Σ 1.578[1.809] m	Bq m^{-2}	1.8	4.9	1.8	2.0	10.5
Kap Tobin	Bq m^{-3}	9.9	(14.8)	9.2	4.6	(10.0)
Σ 0.382[0.476] m	Bq m^{-2}	0.50	(0.63)	0.74	0.98	(2.8)
Danmarkshavn	Bq m^{-3}	24	48	—— 14.5 ——		18.5
Σ 0.202[0.223] m	Bq m^{-2}	1.56	0.23	—— 1.9 ——		3.7

The missing amount of precipitation was kindly supplied by Mr. Gunnar Nielsen Danish Meteorological Institute. Figures in parenthesis were estimated from VAR 3 due to missing samples. The annual amount of precipitation at the six locations according to Danish Meteorological Institute were shown in bracket

2.2. Strontium-90 in sea water

Six samples of surface water were obtained in August 1979. The sample from Thule was a double sample. Table 2.2 shows the results. The ^{90}Sr level was comparable with those of the previous years. The $^{137}Cs/^{90}Sr$ mean ratio was 1.4 (1 SD), i.e. there was no indication of any surplus ^{137}Cs in Greenland waters in the 1979 samples.

The concentrations in the East Greenland waters were as usual higher than the levels along the west coast of Greenland.

Table 2.2.A. Strontium-90 and Cesium-137 in sea water from Greenland in 1979

Location	pCi ^{90}Sr l^{-1}	pCi ^{137}Cs l^{-1}	Salinity o/oo
76°30'N 69°15'W Thule	0.074	0.100	32.0
- " -	0.077	0.118	
Godhavn	0.072	0.114	34.2
Prins Chr. Sund	0.156	0.152	32.3
Danmarkshavn	-	0.190	29.1
Angmagssalik		0.177	31.6
Godthåb		0.122	32.8
Mean	0.10	0.14	

Table 2.2.B. Strontium-90 and Cesium-137 in sea water from Greenland in 1979

Location	Bq ^{90}Sr m^{-3}	Bq ^{137}Cs m^{-3}	Salinity o/oo
76°30'N 69°15'W Thule	2.7	3.7	32.0
-"-	2.8	4.4	
Godhavn	2.7	4.2	34.2
Prins Chr. Sund	2.8	5.6	32.3
Danmarkshavn	-	7.0	29.1
Angmagssalik		6.5	31.6
Godthåb		4.5	32.8
Mean	3.7	5.2	

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

Two samples of lamb were received from Narssaq (SW-Greenland) in 1979. The mean levels were 7.5 pCi $^{90}Sr\ kg^{-1}$ meat and 1.03 nCi $^{137}Cs\ kg^{-1}$. The lamb bones contained 137 pCi ^{90}Sr (g Ca)$^{-1}$.

Table 2.3.A. Strontium-90 and Cesium-137 in terrestrial animals collected in Greenland in 1979

Date	Location	Sample type		pCi $^{90}Sr\ kg^{-1}$	pCi ^{90}Sr (g Ca)$^{-1}$	pCi $^{137}Cs\ kg^{-1}$	pCi ^{137}Cs (g K)$^{-1}$
June	Narssaq	Lamb	meat I	9.4	170	1160	326
		"	bone I	-	177	-	-
		Lamb	meat V	5.6	105	890	268
		"	bone V	-	97	-	-
Autumn	Holsteinsborg	Reindeer	meat I	1.9	23	695	171
		"	bone I	-	35	-	-
		Reindeer	meat II	2.0	23	606	154
		"	bone II	-	16	-	-
Aug	Scoresbysund	Muskox	meat I	6.9	52	84	32
		"	bone I	-	38	-	-
		Muskox	meat VI	17.3	75	127	37
		"	bone II	-	46	-	-

Table 2.3.B. Strontium-90 and Cesium-137 in terrestrial animals collected in Greenland in 1979

Date	Location	Sample type		Bq $^{90}Sr\ kg^{-1}$	Bq ^{90}Sr (kg Ca)$^{-1}$	Bq $^{137}Cs\ kg^{-1}$	Bq ^{137}Cs (kg K)$^{-1}$
June	Narssaq	Lamb	meat I	0.35	$6.3 \cdot 10^3$	43	$12.1 \cdot 10^3$
		"	bone I	-	$6.5 \cdot 10^3$	-	-
		Lamb	meat V	0.21	$3.9 \cdot 10^3$	33	$9.9 \cdot 10^3$
		"	bone V	-	$3.6 \cdot 10^3$	-	-
Autumn	Holsteinsborg	Reindeer	meat I	0.07	$0.86 \cdot 10^3$	26	$6.3 \cdot 10^3$
		"	bone I	-	$1.30 \cdot 10^3$	-	-
		Reindeer	meat II	0.07	$0.86 \cdot 10^3$	22	$5.9 \cdot 10^3$
		"	bone II	-	$1.33 \cdot 10^3$	-	-
August	Scoresbysund	Muskox	meat I	0.26	$1.92 \cdot 10^3$	3.2	$1.18 \cdot 10^3$
		"	bone I	-	$1.41 \cdot 10^3$	-	-
		Muskox	meat II	0.64	$2.8 \cdot 10^3$	4.7	$1.37 \cdot 10^3$
		"	bone II	-	$1.68 \cdot 10^3$	-	-

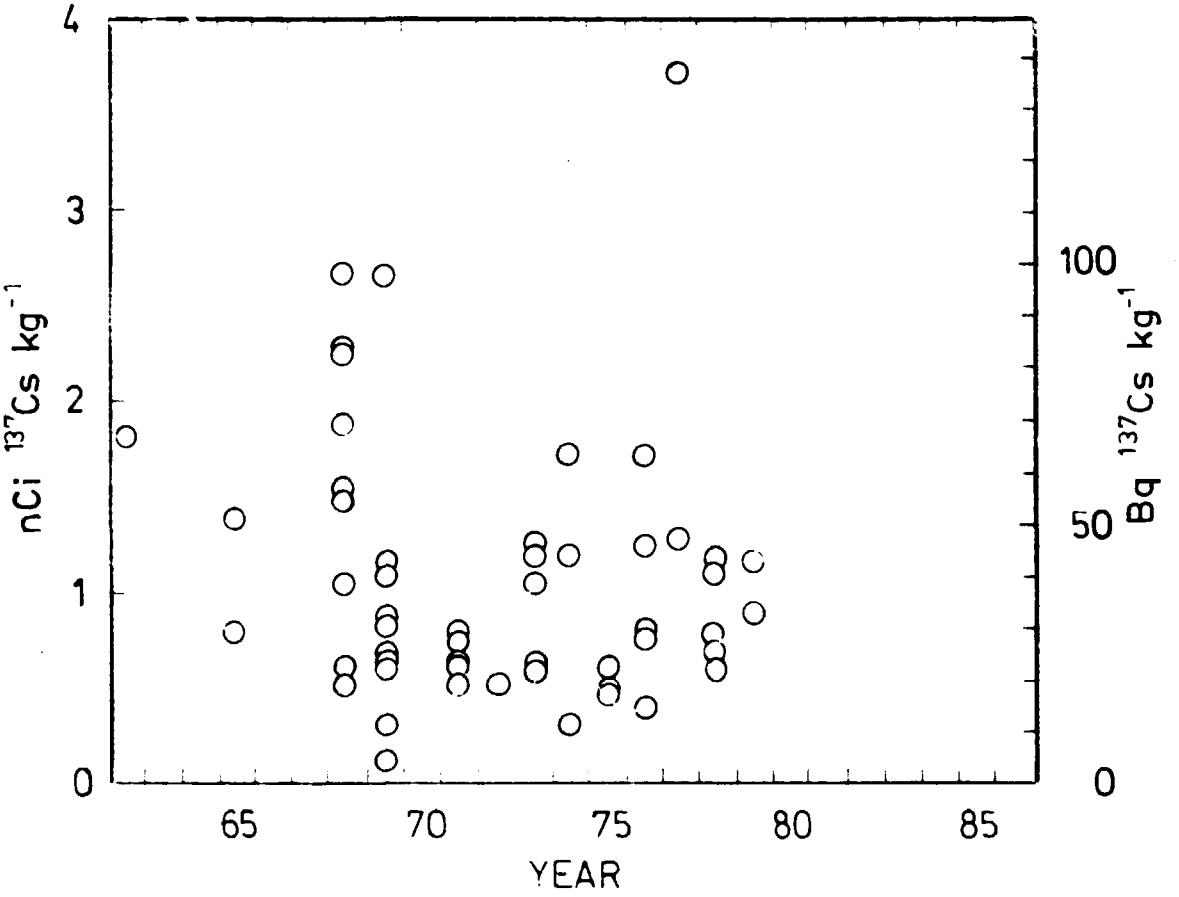

Fig. 2.3.1. Cesium-137 in mutton, 1962-1979.

Two samples of reindeer from Holsteinsborg showed mean levels of 2 pCi ^{90}Sr kg^{-1} meat, 0.65 nCi ^{137}Cs kg^{-1} meat and in bone: 36 pCi ^{90}Sr (g Ca)$^{-1}$.

Muskox from Scoresbysund contained 12 pCi ^{90}Sr kg^{-1} meat and 106 pCi ^{137}Cs kg^{-1}. Bones showed a mean level of 39 pCi ^{90}Sr (g Ca)$^{-1}$. The median levels in muskox meat during 1964-1973[1)] were 140 pCi ^{137}Cs kg^{-1} and 8 pCi ^{90}Sr kg^{-1}, and in bone 60 pCi ^{90}Sr (g Ca)$^{-1}$.

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

The Fishery Investigations of Greenland (GFU) collected in June a large number of marine samples at Narssaq in SW-Greenland in connection with a preoperational survey around the depo.its of uranium in Kvanefjeld. These samples are analysed for radium isotopes at Risø and have furthermore been measured for ^{137}Cs

and ^{90}Sr. Table 2.4.1 shows the results. The ^{137}Cs (g K)$^{-1}$ level in fish was 2-3 times that in shrimps and mussels. The mean levels in fish meat were: 0.2 pCi ^{90}Sr kg^{-1}, 19 pCi ^{137}Cs kg^{-1}, and seal contained 0.8 pCi ^{90}Sr kg^{-1} meat and 13 pCi ^{137}Cs kg^{-1}. Shrimps contained 0.4 pCi ^{90}Sr kg^{-1} flesh and 5 pCi ^{137}Cs kg^{-1}, and mussels 2.5 pCi ^{90}Sr kg^{-1} flesh and 4 pCi ^{137}Cs kg^{-1}.

Table 2.4.1.A. Cesium-137 and Strontium-90 in marine animals collected by GFU in June 1979 at Narssaq, SW-Greenland

Species	pCi ^{137}Cs kg^{-1}	pCi ^{137}Cs (g K)$^{-1}$	pCi ^{90}Sr kg^{-1}
Etmopterus spinax (shark)	11.6	5.6	-
Reinhardtius hippoglossoides (halibut)	23	6.0	0.089
- " - - " -	9.6	3.2	-
Gadus morhua (cod)	55	12.1	0.116
- " - "	17.3	3.8	-
Gadus ogac (polar cod) (total)	17.6	5.1	2.7
Anarhichas lupus (cat fish)	13.6	4.3	-
Mean ±1 S.D.	21±16	5.7±3.0	
Median	17.3	5.1	
Shrimps flesh	4.6	2.0	0.38
"	9.4	3.0	-
shells	4.1	2.0	-
"	3.4	1.6	-
"	3.6	1.6	-
heads	7.8	3.6	-
Mussels flesh (2-4.5 cm)	< 5.6	< 3	-
" (4.5-5.5 cm)	6.0 (A)	4.2	-
" (5.5-7.5 cm)	< 2.6	< 2	-
Mussels flesh I	2.9	2	2.5
flesh II	1.9	1.2	-
Mussels shells (5 samples)	B.D.L.	B.D.L.	-

Fish bone did not contain measurable amounts of ^{137}Cs. The ^{90}Sr level in bones from cod and halibut was 0.09 pCi ^{90}Sr (g Ca)$^{-1}$. Shells from mussels contained 0.17 pCi ^{90}Sr (g Ca)$^{-1}$.

Table 2.4.1.B. Cesium-137 and Strontium-90 in marine animals collected by GFU in June 1979 at Narssaq, SW-Greenland

Species	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs (kg K)$^{-1}$	Bq ^{90}Sr kg^{-1}
Etmopterus spinax (shark)	0.43	210	
Reinhardtius hippoglossoides (halibut)	0.85	220	0.003
- " - - " -	0.36	118	
Gadus morhua (cod)	2.04	450	0.004
- " - "	0.64	140	
Gadus ogac (polar cod, total)	0.65	190	0.10
Anarhichas lupus (cat fish)	0.50	160	
Mean ±1 S.D.	0.78±0.58		
Median	0.64		
Shrimps flesh	0.17	74	0.014
"	0.35	111	
shells	0.15	74	
"	0.13	59	
"	0.13	59	
heads	0.29	133	
Mussels flesh (2-4.5 cm)	< 0.2	< 110	
" (4.5-5.5 cm)	0.22	155	
" (5.5-7.5 cm)	< 0.1	< 70	
flesh I	0.11	74	0.09
flesh II	0.07	44	
shells (5 samples)	B.D.L.	B.D.L.	

The mean ^{90}Sr level in bones from cod and halibut was 3.3 Bq ^{90}Sr (kg Ca)$^{-1}$. Shells from mussels contained 6.3 Bq ^{90}Sr (kg Ca)$^{-1}$.

Table 2.4.2.A. Strontium-90 and Cesium-137 in sea animals collected in Greenland in 1979

Date	Location	Sample		pCi ^{90}Sr kg^{-1}	pCi ^{90}Sr (g Ca)$^{-1}$	pCi ^{137}Cs kg^{-1}	pCi ^{137}Cs (g K)$^{-1}$
Autumn	Holsteinsborg	Salmon	meat	0.44	1.18	7.9	2.2
			bone	-	0.71	-	-
Aug	Jacobshavn	Seal	meat	1.37	27	10.0	3.8
			bone	-	0.033	-	-
Aug	Scoresbysund	Seal	meat	0.23	3.8	15.5	5.1
			bone	-	0.081	-	-

Table 2.4.2.B. Stronium-90 and Cesium-137 in sea animals collected in Greenland in 1979

Date	*Location*	*Sample*		*Bq ^{90}Sr kg^{-1}*	*Bq ^{90}Sr (kg Ca)$^{-1}$*	*Bq ^{137}Cs kg^{-1}*	*Bq ^{137}Cs (kg K)$^{-1}$*
Autumn	*Holsteinsborg*	*Salmon*	*meat*	*0.016*	*44*	*0.29*	*81*
			bone	-	*26*	-	-
Aug	*Jacobshavn*	*Seal*	*meat*	*0.051*	*1000*	*0.37*	*140*
			bone	-	*1.22*	-	-
Aug	*Scoresbysund*	*Seal*	*meat*	*0.009*	*140*	*0.57*	*190*
			bone	-	*3.0*	-	-

2.5. Strontium-90 and Cesium-137 in vegetation

Lichen, moss, grass, crowberry and seaweed were collected along the Greenland coast during the summer. In connection with the preoperational survey at Narssaq (cf. 2.4) several samples were obtained from this part of Greenland. Tables 2.5.1 and 2.5.2 show the results.

The ^{90}Sr and ^{137}Cs levels in lichen compared with those from previous years are shown in Fig. 2.5. As mentioned in Risø Report No. 405[1)] the decrease observed in 1978 was probably due to the lack of samples from the west coast that year.

In Narssaq the lichens contained two times more ^{137}Cs and three times more ^{90}Sr per m^2 than lichen collected at Danmarkshavn in

Table 2.5.1.A. Strontium-90 and Cesium-137 in terrestrial vegetation samples collected in Greenland in 1979

Location	Species	Sampling time	pCi ^{90}Sr kg^{-1}	pCi ^{90}Sr (g Ca)$^{-1}$	pCi ^{137}Cs kg^{-1}	pCi ^{137}Cs (g K)$^{-1}$
Narssaq	Lichen	June	3200*	730	3300*	1980
Prins Chr. Sund	"	Oct	670	460	13100	2600
Narssaq	Moss	June	-	3000	13700	5400
"	"	"	-	-	5400	3900
" st. 14	" top	"	-	-	5300	8000
" st. 14	" bottom	"	-	-	623	480
Prins Chr. Sund	"	Sept	410	700	2700	230
Scoresbysund	"	Sept	2600	610	10900	1940
Scoresbysund	Grass	Sept	-	93	65	10.5
Prins Chr. Sund	Crowberry (plant)	Sept	770	580	1650	400
Prins Chr. Sund	Sphagnum	Sept	1290	310	4600	380

*12.6 nCi ^{137}Cs m^{-2} and 12.2 nCi ^{90}Sr m^{-2}.

Table 2.5.1.B. Strontium-90 and Cesium-137 in terrestrial vegetation collected in Greenland in 1979

Location	Species	Sampling time	Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr (kg Ca)$^{-1}$	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs (kg K)$^{-1}$
Narssaq	Lichen	June 28	118	27 $\times 10^3$	122	73 $\times 10^3$
Prins Chr. Sund	"	Oct	25	17 $\times 10^3$	485	96 $\times 10^3$
Narssaq	Moss	June 23	-	111 $\times 10^3$	510	200 $\times 10^3$
"	"	June	-	-	200	144 $\times 10^3$
" st. 14	" top	"	-	-	196	296 $\times 10^3$
" st. 14	" bottom	"	-	-	23	18 $\times 10^3$
Prins Chr. Sund	Moss	Sept	15	26 $\times 10^3$	100	8.5 $\times 10^3$
Scoresbysund	Moss	"	96	23 $\times 10^3$	400	72 $\times 10^3$
Scoresbysund	Grass	Sept	-	3.4$\times 10^3$	2.4	0.39$\times 10^3$
Prins Chr. Sund	Crowberry (plant)	Sept	28	21 $\times 10^3$	61	14.8 $\times 10^3$
Prins Chr. Sund	Sphagnum	Sept	48	11.5$\times 10^3$	170	14.1 $\times 10^3$

1978[1]. The precipitation at Narssaq is more than five times higher than that at Danmarkshavn; this great difference is thus not reflected in the lichen levels. This may have several causes. Firstly, the greater amounts of rain at Narssaq may wash off some of the deposit on the lichen. Secondly, dry deposition may play a relatively greater role at Danmarkshavn, and thirdly, in the colder climate at Danmarkshavn the lichen will grow more slowly and this will enhance the accumulation of activity in the lichen relative to that from Narssaq.

One of the moss samples from Narssaq was divided into an upper fresh part and a lower part consisting of decayed plant material ("jelly"). The fresh part contained 8.5 times more ^{137}Cs and half as much potassium as the old material. Similar observations have been made in lichens[5].

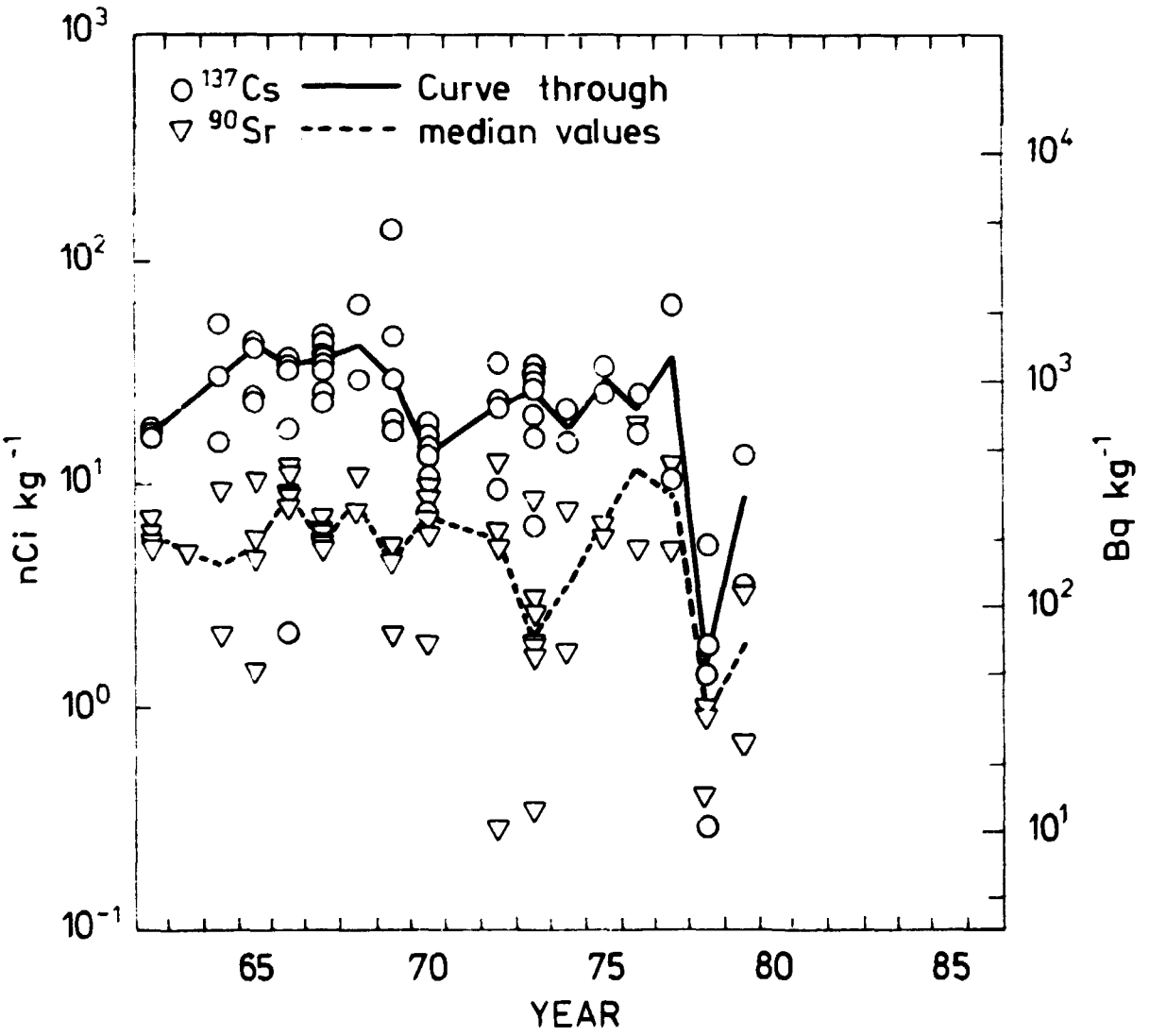

Fig. 2.5. Cesium-137 and Strontium-90 in lichen (fresh weight) collected along the Greenlandic coast, 1962-1979.

Table 2.5.2.A. Strontium-90, Cesium-137 and Cerium-144 in marine vegetation samples collected in Greenland in 1979

Location	Species	Sampling time	pCi ^{90}Sr kg^{-1}	pCi ^{90}Sr (g Ca)$^{-1}$	pCi ^{137}Cs kg^{-1}	pCi ^{137}Cs (g K)$^{-1}$	pCi ^{144}Ce kg^{-1}
Narssaq	Focus vesiculosus (wet)*	June 21	13.7	2.3	5.1	0.86	118
"	- " -	June 24	-	-	2.9	0.72	58
"	- " -	June 26	-	-	4.7	1.14	64
"	- " -	June 27	-	-	7.1	1.34	120
"	Ascophyllum nodusum (wet)**	June 19	1.29	1.31	4.4	0.86	34
"	- " -	June 26	-	-	3.7	0.78	41
"	Plankton (wet)	June 20	-	-	< 3.1	< 2	< 50
"	- " -	June 20	-	-	< 3.5	< 4	< 58
Prins Chr.Sund	Fucus vesiculosus (wet)	Sept	0.56	1.85	5.8	0.94	-
Scoresbysund	Fucus sp (wet)	"	3.59	3.0	8.0	1.77	46

*Dry matter content 21.9%. **Dry matter content 20.7%.

Table 2.5.2.6. Strontium-90, Cesium-137 and Cerium-144 in marine vegetation samples collected in Greenland in 1979

Location	Species	Sampling time	Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr (kg Ca)$^{-1}$	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs (kg K)$^{-1}$	Bq ^{144}Ce kg^{-1}
Narssaq	Fucus vesiculosus (wet)*	June 21	0.51	85	0.189	32	4.4
"	- " -	June 24	-	-	0.107	27	2.1
"	- " -	June 26	-	-	0.174	42	2.4
"	- " -	June 27	-	-	0.26	50	4.4
"	Ascophyllum nodusum (wet)**	June 19	0.048	48	0.163	32	1.25
"	- " -	June 26	-	-	0.137	29	1.52
"	Plankton (wet)	June 20	-	-	< 0.1	< 70	< 1.8
"	- " -	June 20	-	-	< 0.1	< 150	< 2.1
Prins Chr.Sund	Fucus vesiculosus (wet)	Sept	0.021	68	0.22	35	-
Scoresbysund	Fucus sp (wet)	Sept	0.133	111	0.30	65	1.70

*Dry matter content 21.9%. **Dry matter content 20.7%.

The mean level of ^{137}Cs in fucoids collected in Greenland in 1979 was 5.2±1.7 (1 SD) pCi ^{137}Cs kg^{-1} (wet weight). The mean level in sea water was 0.14±0.04 (1 SD) pCi ^{137}Cs l^{-1}. Hence the observed ratio between ^{137}Cs concentrations in fucoids and water becomes 37±16 (1 SD). In Danish waters we observed in 1979[2] a mean ratio of approx. 25 for salinities greater than 20 o/oo and of approx. 40 for salinities below 20 o/oo.

The geometric mean levels in moss and lichen were 1.2 nCi ^{90}Sr kg^{-1} and 6.5 nCi ^{137}Cs kg^{-1}.

Cerium-144 was determined in fucoids because in 1978[1] we observed relatively high levels of this radionuclide in some samples from the east coast of Greenland. The levels found in 1979 was an order of magnitude lower than those observed in 1978. However, the $^{144}Ce/^{137}Cs$ ratios were nearly unchanged from 1978 to 1979. We conclude that the contamination of fucoids from 1978 have been ten times higher than that observed in 1979. We can offer no evident explanation for this phenomenon. Melting of old contaminated ice originating from locations close to test explosion sites could perhaps be a source of this surplus activity observed in 1978.

Plankton from Narssaq showed ^{137}Cs and ^{144}Ce levels similar to those found in flucoids.

2.6. Strontium-90 in drinking water

Quarterly samples of drinking water were collected from a number of locations in Greenland. Table 2.6 shows the results from 1979, and Fig. 2.6 the geometric annual means of all samples for the period 1962-1979.

As in previous years, we found it most expedient to choose the geometric mean of all figures, i.e. 0.59 pCi ^{90}Sr l^{-1}, as representative of the mean level of ^{90}Sr in Greenland drinking water in 1979, this level was not significantly different from that observed in recent years (Fig. 2.6). Some of the levels (e.g. those from Prins Chr.sund) are surprisingly high as com-

Table 2.6.A. Strontium-90 in drinking water collected in Greenland in 1979 (Unit: pCi $^{90}Sr\ l^{-1}$)

Location	Jan-March	April-June	July-Sept	Oct-Dec
Danmarkshavn		0.88	0.30	1.61
Scoresbysund	1.04	0.21		
Prins Chr. Sund	1.51	0.89	4.06	3.60
Godthåb		0.47		0.44
Upernavik				0.005 B

Table 2.6.B. Strontium-90 in drinking water collected in Greenland in 1979 (Unit: Bq $^{90}Sr\ m^{-3}$)

Location	*Jan-March*	*April-June*	*July-Sept*	*Oct-Dec*
Danmarkshavn		*33*	*11*	*60*
Scoresbysund	*38*	*7.8*		
Prins Chr. Sund	*56*	*33*	*150*	*130*
Godthåb		*17*		*16*
Upernavik				*0.2 B*

pared to present rain water concentrations (cf. Table 2.1.1). We assume that evaporation from the drinking water reservoirs is responsible for the higher ^{90}Sr levels. Tritium measurements have shown[2] that the drinking water has the same tritium content as rain water at Prins Chr.sund, hence evaporation seems to be a likely explanation.

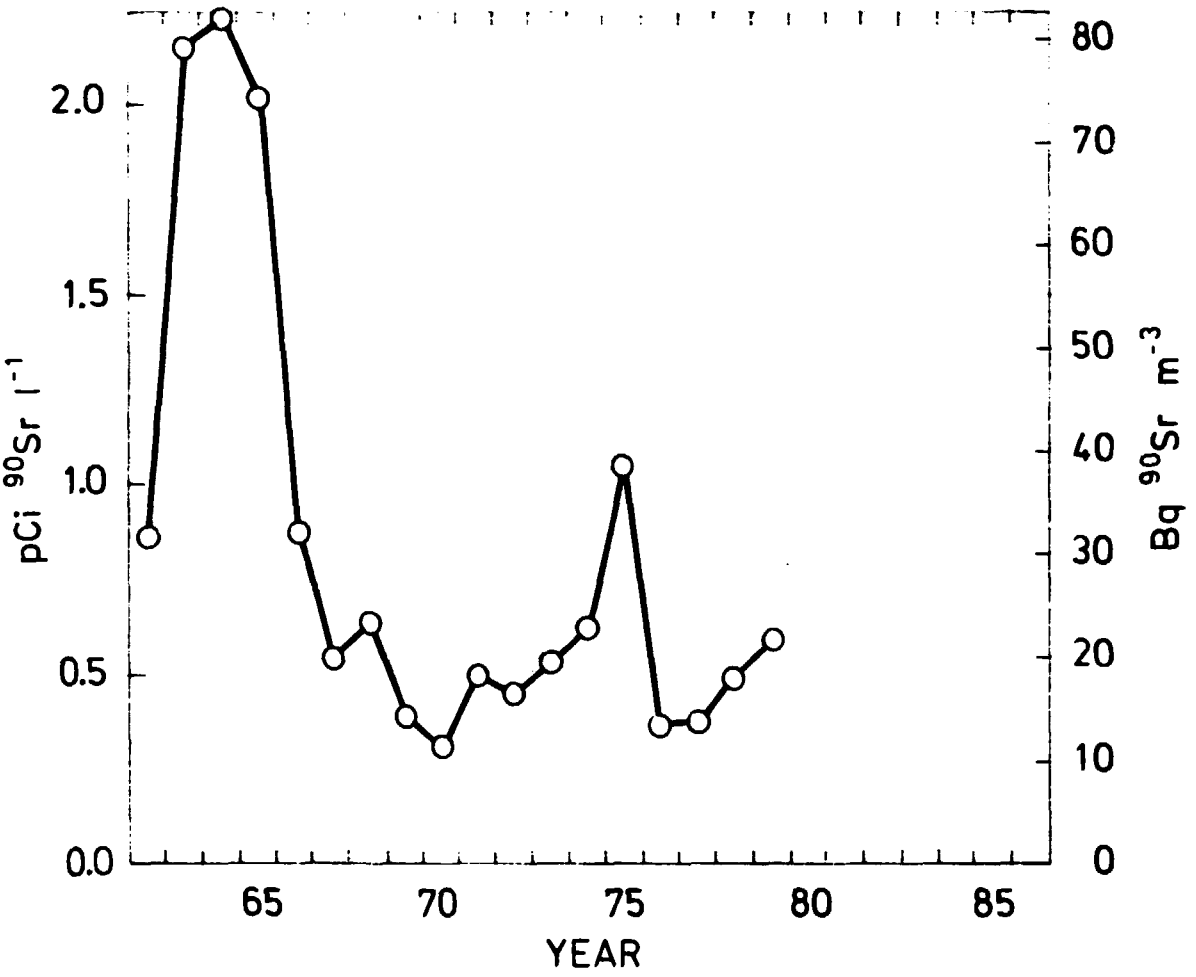

Fig. 2.6. Strontium-90 in Greenlandic drinking water (Geometric mean), 1962-1979.

3. ESTIMATE OF THE MEAN CONTENTS OF ^{90}Sr AND ^{137}Cs IN THE HUMAN DIET IN GREENLAND IN 1979

3.1. The annual quantities

The estimate of the daily per capita intake of the different foods in Greenland is still based on the figures given in 1962 by Professor E. Hoff-Jørgensen, Ph.D., in Risø Report No. 65[1].

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 1979 was 3.5 pCi ^{90}Sr kg^{-1} and 4.8 pCi ^{137}Cs kg^{-1} [2].

Cheese was also imported from Denmark and contained 24.6 pCi ^{90}Sr kg^{-1} and 3.5 pCi ^{137}Cs kg^{-1}.

3.3. Grain products

All grain was imported from Denmark. It is assumed that only grain from the harvest of 1978 was consumed in Greenland during 1979. The daily per capita 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 23, 5.0, 4.6, 17.0 and 8.0 pCi kg^{-1} respectively. Hence the mean content of ^{90}Sr in grain products was 12.0 pCi kg^{-1}. The content of ^{137}Cs in the five products was 40, 10.0, 20, 30 and 10.4 pCi kg^{-1}. Hence the mean content of ^{137}Cs in grain products was 21.4 pCi 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. 403[2]. 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)[2]. 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[2].

3.4. Potatoes, other vegetables, and fruit

The Danish mean levels for 1979 were used[2] since the local production is insignificant compared with imports from Denmark.

The Danish mean levels were: in potatoes 2.0 pCi ^{90}Sr kg^{-1} and 2.1 pCi ^{137}Cs kg^{-1}, in other vegetables 6.9 pCi ^{90}Sr kg^{-1} and 1.7 pCi ^{137}Cs kg^{-1}, and in fruit 1.5 pCi ^{90}Sr kg^{-1} and 1.7 pCi ^{137}Cs kg^{-1}.

3.5. Meat

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

The activity in reindeer and lamb was estimated from 2.3. Activity in seals was estimated from 2.4. The levels of whales, sea birds and eggs were taken from the 1978 analyses[1]. Hence the mean levels in Greenland meat from 1979 were 1.4 pCi ^{90}Sr kg^{-1} and 146 pCi ^{137}Cs kg^{-1}.

(^{90}Sr: $0.1 \times 7.5 + 0.05 \times 1.95 + 0.6 \times 0.8 + 0.05 \times 0.035 + 0.2 \times 0.19$
$= 1.37$ pCi kg^{-1})

(^{137}Cs: $0.1 \times 1025 + 0.05 \times 650 + 0.6 \times 12.75 + 0.05 \times 19 + 0.2 \times 9.5$
$= 145.5$ pCi kg^{-1})

3.6. Fish

All fish consumed was of local origin, and the mean levels from 2.4 were used, i.e. 0.2 pCi ^{90}Sr kg^{-1} and 19 pCi ^{137}Cs kg^{-1}.

3.7. Coffee and tea

The Danish figures for 1979[2] were used for coffee and tea, i.e. 29 pCi ^{90}Sr kg^{-1} and 71 pCi ^{137}Cs kg^{-1}.

3.8. Drinking water

The geometric mean calculated in 2.6 was used as the mean level of ^{90}Sr in drinking water, i.e. 0.59 pCi ^{90}Sr l^{-1}. The ^{137}Cs content was as previously[1] estimated at 1/4 of the ^{90}Sr content, i.e. approx. 0.1 pCi ^{137}Cs l^{-1}.

Table 3.1. Estimate of the mean content of ^{90}Sr in the human diet in Greenland in 1979

Type of food	Annual quantity in kg	pCi ^{90}Sr per kg	Total pCi ^{90}Sr	Percentage of total pCi ^{90}Sr in food
Milk and cream	78	3.5	273	12.2
Cheese	2.5	24.6	62	2.8
Grain products	95.6	12.0	1147	51.4
Potatoes	32.8	2.0	66	3.0
Vegetables	5.5	6.9	38	1.7
Fruit	13.5	1.5	20	0.9
Meat and eggs	45.6	1.4	64	2.9
Fish	127.6	0.2	26	1.2
Coffee and tea	7.3	29	212	9.5
Drinking water	548	0.59	323	14.4
Total			2231	100.0

The mean annual calcium intake is estimated to be 560 g (approx. 200-250 g creta praeparata). Hence the ^{90}Sr (g Ca)$^{-1}$ ratio in Greenland total diet in 1979 was 4.0 S.U. and the daily intake 6.1 pCi ^{90}Sr.

Table 3.2. Estimate of the mean content of ^{137}Cs in the human diet in Greenland in 1979

Type of food	Annual quantity in kg	pCi ^{137}Cs per kg	Total pCi ^{137}Cs	Percentage of total pCi ^{137}Cs in food
Milk and cream	78	4.8	374	3.1
Cheese	2.5	3.5	9	0.1
Grain products	95.6	21.4	2045	16.8
Potatoes	32.8	2.1	69	0.6
Vegetables	5.5	1.7	9	0.1
Fruit	13.5	1.7	23	0.2
Meat and eggs	45.6	146	6658	54.6
Fish	127.6	19	2424	19.9
Coffee and tea	7.3	71	518	4.2
Drinking water	548	0.1	55	0.4
Total			12184	100.0

The mean annual potassium intake is estimated to be approx. 1200 g. Hence the ^{137}Cs $(g\ K)^{-1}$ ratio becomes 10 pCi ^{137}Cs $(g\ K)^{-1}$. The daily intake in 1979 from food was 33 pCi ^{137}Cs.

Tables 3.1 and 3.2 show the diet estimates of ^{90}Sr and ^{137}Cs respectively.

3.9. Discussion

The most important ^{90}Sr source in the Greenland diet is still grain products, which contribute 51% of the total ^{90}Sr content in the diet. Milk products came next in importance, contributing 15%. Approx. 80% of the ^{90}Sr in the food consumed in Greenland in 1979 originated from imported Danish food.

Meat is still the most important ^{137}Cs source in the Greenland diet, contributing 55% of the total content in 1979. Approx. 75% of the ^{137}Cs in the Greenland diet in 1979 came from local products.

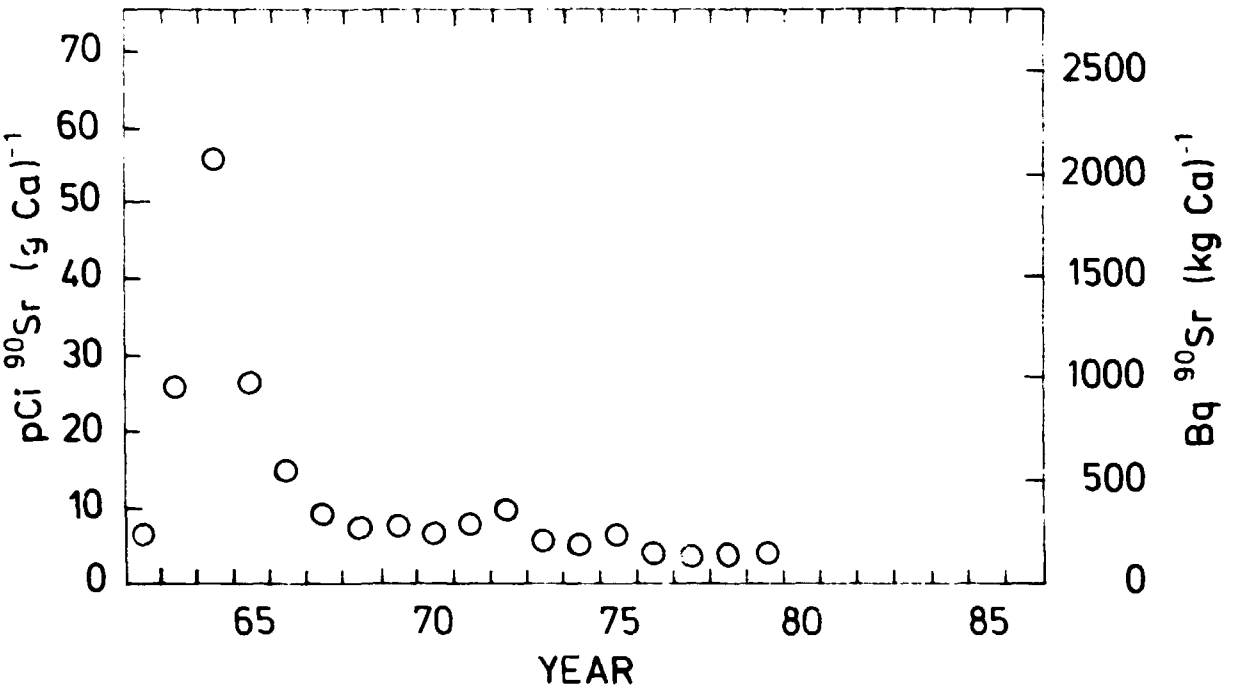

Fig. 3.1. Strontium-90 in Greenlandic diet, 1962-1979.

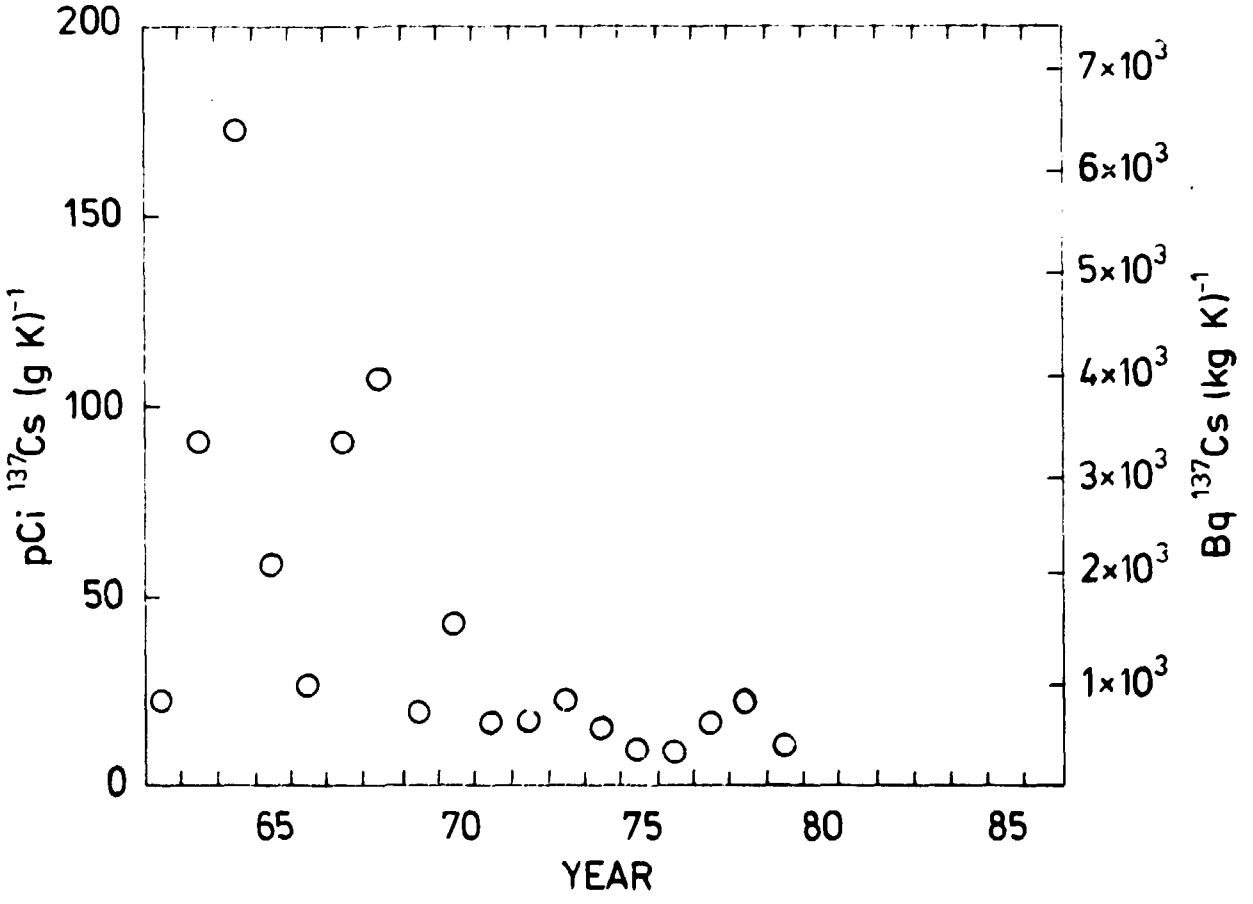

Fig. 3.2. Cesium-137 in Greenlandic diet, 1962-1979.

As compared with the 1978 figures, the ^{90}Sr contents in the total diet in 1979 was 6% lower than the 1978 level.

The ^{137}Cs level was 46% of the level found in 1978. As earlier discussed[1] 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 per capita intakes of ^{90}Sr and ^{137}Cs in Greenland in 1979 we assume[1] that the only grain product consumed by a person is dark rye bread, and that he only eats lamb meat. His daily intake of ^{90}Sr is thus 9.8 pCi (6.4 S.U.) and his ^{137}Cs intake 148 pCi day^{-1} (using the quantities in Tables 3.1 and 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. wated formed by the melting of old ice). In this case the daily intakes are 3.3 pCi ^{90}Sr (2.1 S.U.) and 13.6 pCi ^{137}Cs. Hence the ratios between the levels in the maximum and minimum diets become 3 for ^{90}Sr and 11 for ^{137}Cs.

The ^{90}Sr content of the Greenland diet in 1979 was 89% of the estimated Danish mean content[2], and 70% of the Faroese level[3]. The ^{137}Cs level in the total diet in Greenland was 2.4 times that of the Danish diet and 43% of the Faroese diet level.

4. CONCLUSION

4.1.

The ^{90}Sr fallout rates in 1979 were the following: Godhavn: approx. 0.2 mCi ^{90}Sr km^{-2}; Godthåb: 0.3 mCi ^{90}Sr km^{-2}; Prins Christians Sund: approx. 0.3 mCi ^{90}Sr km^{-2}; Upernavik: 0.1 mCi ^{90}Sr km^{-2}. The accumulated fallout levels by the end of 1979 were estimated at approx. 28 mCi ^{90}Sr km^{-2} at Godhavn, 36 mCi ^{90}Sr km^{-2} at Godthåb, 126 mCi ^{90}Sr km^{-2} at Prins Christians Sund, and 12 mCi ^{90}Sr km^{-2} at Upernavik.

4.2.

The food consumed in Greenland in 1979 contained on the average 4.0 pCi ^{90}Sr $(g\ Ca)^{-1}$, and the daily mean intake of ^{137}Cs was estimated at 33 pCi. The most important ^{90}Sr contributors to the diet were grain products and milk products, together accounting for approx. 80% of the total ^{90}Sr content of the diet. Cesium-137 originated mainly from meat (reindeer and lamb) and fish, contributing 75% of the total ^{137}Cs content of the diet.

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 1979 ^{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 approx. 1 S.U. (vertebrae). From diet measurements the ^{137}Cs content in Greenlanders was estimated at 30 pCi ^{137}Cs $(g\ K)^{-1}$.

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APPENDIX A

Provisional results from the August 1979 Thule expedition.
The expedition to Thule in 1979 was supported by the Commission of the European Communities with funds from its Radiation protection programme.

Table A.1. Plutonium and Americium in marine sediments collected with a 145 cm^2 corer in Thule, August 1979

Position	Unit	Depth section in cm					
A		0-3	3-6	6-9	9-12	12-15	15-18
76°45'N 70°45'W	pCi $^{239,240}Pu$ kg^{-1}	32	26	169			
		61	39	22			
	nCi $^{239,240}Pu$ m^{-2}	0.28	0.48	4.41			
		0.52	0.72	0.58			
	$^{238}Pu/^{239,240}Pu$	0.053	-	0.020			
		0.044	-				
	$^{241}Am/^{239,240}Pu$	0.26	0.27				
		0.32					
	$^{239,240}Pu/^{137}Cs$	0.29	0.25	1.96			
		0.54	0.37	0.25			

No samples were obtained below 9 cm.

Table A.2. Plutonium and Americium in marine sediments collected with a 145 cm^2 corer in Thule, August 1979

Position	Unit	Depth section in cm					
B		0-3	3-6	6-9	9-12	12-15	15-18
$76^{o}40'N$ $70^{o}00'W$	pCi $^{239,240}Pu$ kg^{-1}	58	4.7	3.3			
		122	11	2.3			
	nCi $^{239,240}Pu$ m^{-2}	0.62	0.10	0.084			
		1.31	0.24	0.059			
	$^{238}Pu/^{239,240}Pu$	-	-	-			
		-	-	-			
	$^{241}Am/^{239,240}Pu$						
	$^{239,240}Pu/^{137}Cs$	0.41	0.09	B.D.L.			
		0.86	0.22	B.D.L.			

No samples were obtained below 9 cm.

Table A.3. Plutonium and Americium in marine sediments collected with a 145 cm^2 corer in Thule, August 1979

Position	Unit	Depth section in cm					
C(I)		0-3	3-6	6-9	9-12	12-15	15-18
$76^{o}40'N$ $69^{o}30'W$	pCi $^{239,240}Pu$ kg^{-1}	2069	474	387	95	41	10
		668	295	206	70	28	13
	nCi $^{239,240}Pu$ m^{-2}	28.9	10.4	8.4	2.2	1.02	0.24
		9.3	6.5	4.5	1.6	0.70	0.31
	$^{238}Pu/^{239,240}Pu$	0.016	0.018	0.020	0.021		
		0.016	0.016	0.024	0.036		
	$^{241}Am/^{239,240}Pu$	0.10	0.12	0.16			
	$^{239,240}Pu/^{137}Cs$	6.10	1.57	1.93	0.82	0.97	B.D.L.
		1.97	0.98	1.02	0.60	0.66	B.D.L.

Table A.4. Plutonium and Americium in marine sediments collected with a 145 cm^2 corer in Thule, August 1979

Position	Unit	Depth section in cm					
C(II)		0-3	3-6	6-9	9-12	12-15	15-18
$76^{o}40'N$ $69^{o}30'W$	pCi $^{239,240}Pu$ kg^{-1}	1656	484	51	8.9	4.8	5.1
		1600	195	45	3.9	7.3	3.0
	nCi $^{239,240}Pu$ m^{-2}	21.2	9.6	0.95	0.19	0.11	0.10
		20.5	3.9	0.84	0.083	0.17	0.061
	$^{238}Pu/^{239,240}Pu$	0.018	0.021	0.043	-	-	-
		0.013	0.024	0.027	-	-	-
	$^{241}Am/^{239,240}Pu$						
	$^{239,240}Pu/^{137}Cs$	4.71	2.30	0.63	0.34	B.D.L.	B.D.L.
		4.55	0.93	0.55	0.15	B.D.L.	B.D.L.

Table A.5. Plutonium and Americium in marine sediments collected with a 145 cm^2 corer in Thule, August 1979

Position	Unit	Depth section in cm					
D		0-3	3-6	6-9	9-12	12-15	15-18
$76^{o}39'N$ $69^{o}00'W$	pCi $^{239,240}Pu$ kg^{-1}	147	8113	4.0	0.80	0.3	
		144	25	3.3			
	nCi $^{239,240}Pu$ m^{-2}	2.11	198	0.092	0.023		
		2.07	0.64	0.078			
	$^{238}Pu/^{239,240}Pu$	0.018	0.014				
	$^{241}Am/^{239,240}Pu$	0.17	0.10	0.25			
	$^{239,240}Pu/^{137}Cs$	0.53	88.5	0.17	B.D.L.	B.D.L.	
		0.53	0.27	0.14			

No samples were obtained b low 15 cm.

Table A.6. Plutonium and Americium in marine sediments collected with a 145 cm^2 corer in Thule, August 1979

Position	Unit	Depth section in cm					
E		0-3	3-6	6-9	9-12	12-15	15-18
$76^{o}37'N$ $70^{o}30'W$	pCi $^{239,240}Pu$ kg^{-1}	18.9	8.7	2.7	B.D.L.		
		36	8.7	2.4	B.D.L.		
	*)	28	13.4	5.4	3.9		
	nCi $^{239,240}Pu$ m^{-2}	0.53	0.29	0.083			
		1.02	0.29	0.074			
	*)	0.79	0.45	0.17			
	$^{238}Pu/^{239,240}Pu$	-	-	-			
		-	-	-			
	$^{241}Am/^{239,240}Pu$	0.16	0.17				
	*)	0.37	0.17				
	$^{239,240}Pu/^{137}Cs$	0.29	0.16	B.D.L.	B.D.L.		
		0.55	0.17	B.D.L.	B.D.L.		

*) Determinations carried out by Elis Holm, Lund, Sweden.

No samples were obtained below 12 cm.

Table A.7. Plutonium and Americium in marine sediments collected with a 145 cm^2 corer in Thule, August 1979

Position	Unit	Depth section in cm					
G		0-3	3-6	6-9	9-12	12-15	15-18
$76^{o}35'N$ $69^{o}05'W$	pCi $^{239,240}Pu$ kg^{-1}	1141	637	135	86	33	3.7
		1789	491	89	76	24	9.0
		898	424	88	68	19	2.9
	*)	1780	853	-	112	14	10
	nCi $^{239,240}Pu$ m^{-2}	9.7	9.4	2.30	1.68	0.63	0.085
		15.1	7.3	1.51	1.48	0.46	0.209
		7.6	6.3	1.50	1.32	0.36	0.067
	*)	15.0	12.7	-	2.18	0.27	0.23
	$^{238}Pu/^{239,240}Pu$	0.014	0.017	0.040	0.016	0.036	
		-	-	-			
		0.022	0.025	0.041			
	*)	0.017	0.018	-	0.044		
	$^{241}Am/^{239,240}Pu$	0.12	0.12	0.16	0.10		
		0.13	0.12	0.17	0.12		
	*)	0.12	0.11	-	0.23	0.14	0.17
	$^{239,240}Pu/^{137}Cs$	3.46	2.35	1.48	3.66	3.15	B.D.L.
		5.39	1.81	0.97	3.22	2.29	B.D.L.
		2.70	1.57	0.96	2.87	1.80	B.D.L.

*) Determinations carried out by Elis Holm, Lund, Sweden.

Table A.8. Plutonium and Americium in marine sediments collected with a 145 cm^2 corer in Thule, August 1979

Position	Unit	Depth section in cm					
H		0-3	3-6	6-9	9-12	12-15	15-18
$76^{o}33'N$ $69^{o}17'W$	pCi $^{239,240}Pu$ kg^{-1}	3772	1272	2962	2170	4184	
	nCi $^{239,240}Pu$ m^{-2}	70	28.1	63.5	55.7	90	
	$^{238}Pu/^{239,240}Pu$	0.018	0.017	0.014	0.014	0.012	
	$^{241}Am/^{239,240}Pu$	0.11	0.096	0.11	0.091		
	$^{239,240}Pu/^{137}Cs$	15.02	5.89	10.23	10.02	21.09	

No samples were obtained below 15 cm.

Table A.9. Plutonium and Americium in marine sediments collected with a 145 cm^2 corer in Thule, August 1979

Position	Unit	Depth section in cm					
I		0-3	3-6	6-9	9-12	12-15	15-18
$76^{o}33'N$ $69^{o}07'W$	pCi $^{239,240}Pu$ kg^{-1}	754	6258	34	4.4	1.76	12.4 (s cc
		7556	581	50	5.5	13	2.2
	nCi $^{239,240}Pu$ m^{-2}	12.1	197	0.99	0.14	0.06	
		121	18.3	1.46	0.18	0.44	
	$^{238}Pu/^{239,240}Pu$	0.017	0.012	0.029			
		0.0095	0.0036				
	$^{241}Am/^{239,240}Pu$	0.080	0.077	0.14			
	$^{239,240}Pu/^{137}Cs$	2.03	27.20	0.58	0.15	B.D.L.	0.87
		20.38	2.52	0.86	0.19	B.D.L.	0.16

Table A.10. Plutonium and Americium in marine sediments collected with a 145 cm^2 corer in Thule, August 1979

Position	Unit	Depth section in cm					
J		0-3	3-6	6-9	9-12	12-15	15-18
76°32'N 69°30'W	pCi $^{239,240}Pu\ kg^{-1}$	213	238	901			
	nCi $^{239,240}Pu\ m^{-2}$	4.5	7.5	33.3			
	$^{238}Pu/^{239,240}Pu$	0.022	0.022	0.012			
	$^{241}Am/^{239,240}Pu$	0.11	0.080	0.084			
	$^{239,240}Pu/^{137}Cs$	2.23	1.94	9.45			

No samples were obtained below 9 cm.

Table A.11. Plutonium and Americium in marine sediments collected with a 145 cm^2 corer in Thule, August 1979

Position	Unit	Depth section in cm					
K		0-3	3-6	6-9	9-12	12-15	15-18
76°32'N 69°20'W	pCi $^{239,240}Pu\ kg^{-1}$	2114	1491	1740	3626	786	
		2797	2090	728	616	885	
	nCi $^{239,240}Pu\ m^{-2}$	28.0	34.8	44.6	100.9	13.5	
		37.0	48.8	18.7	17.1	15.2	
	$^{238}Pu/^{239,240}Pu$	0.015	0.019	0.013	0.012	0.018	
		0.030	0.012	0.015	0.015	0.023	
	$^{241}Am/^{239,240}Pu$	0.11	0.098	0.069	0.062	0.11	
	$^{239,240}Pu/^{137}Cs$	9.38	9.56	23.80	69.97	7.63	
		12.41	13.40	9.96	11.89	8.59	

No samples were obtained below 15 cm.

Table A.12. Plutonium and Americium in marine sediments collected with a 145 cm^2 corer in Thule, August 1979

Position	Unit	Depth section in cm					
L		0-3	3-6	6-9	9-12	12-13.5	15-18
$76^{o}32'N$ $69^{c}10'W$	pCi $^{239,240}Pu$ kg^{-1}	6327	372	182	27	373 (surf.cont.)	
		1122	1470	234	32		
	nCi $^{239,240}Pu$ m^{-2}	196	11.5	5.5	0.92	-	
		35	45.4	7.1	1.10		
	$^{238}Pu/^{239,240}Pu$	0.013	0.014	0.023	0.033	0.020	
		0.031	0.013	0.022			
	$^{241}Am/^{239,240}Pu$	0.083	0.12	0.12	(0.070)	0.12	
		0.13	0.074	0.11	0.091		
	$^{239,240}Pu/^{137}Cs$	28.6	3.25	4.75	B.D.L.	26.0	
		5.04	12.84	6.11	B.D.L.		

No samples were obtained below 13.5 cm.

Table A.13. Plutonium and Americium in marine sediments collected with a 145 cm^2 corer in Thule, August 1979

Position	Unit	Depth section in cm					
O		0-3	3-6	6-9	9-12	12-15	15-18
$76^{o}30'N$ $69^{o}40'W$	pCi $^{239,240}Pu$ kg^{-1}	1469	2552				
		232	399				
	nCi $^{239,240}Pu$ m^{-2}	31.9	91.9				
		5.0	14.3				
	$^{238}Pu/^{239,240}Pu$	0.017	0.015				
		0.016	0.019				
	$^{241}Am/^{239,240}Pu$	0.13	0.090				
		0.16	0.15				
	$^{239,240}Pu/^{137}Cs$	13.5	23.6				
		2.12	3.7				

No samples were obtained below 6 cm.

Table A.14. Plutonium and Americium in marine sediments collected with a 145 cm^2 corer in Thule, August 1979

Position	Unit	Depth section in cm					
P		0-3	3-6	6-9	9-12	12-15	15-17
76°30'N 69°25'W	pCi $^{239,240}Pu$ kg^{-1}	83447	521	123	67	468	359
		978	619				
	nCi $^{239,240}Pu$ m^{-2}	1390	10.2	2.72	1.41	11.1	5.6
		16	12.2				
	$^{238}Pu/^{239,240}Pu$	0.018	0.014				
		0.015	0.019				
	$^{241}Am/^{239,240}Pu$	0.097	6.11	0.26	0.15	0.096	0.14
		6.12	6.18				
	$^{239,240}Pu/^{137}Cs$	218	1.83	1.42	1.3	6.4	3.4
		2.55	2.17				

Table A.15. Plutonium and Americium in marine sediments collected with a 145 cm^2 corer in Thule, August 1979

Position	Unit	Depth section in cm					
R		0-3	3-6	6-9	9-12	12-15	15-18
76°30'N 69°10'W	pCi $^{239,240}Pu$ kg^{-1}	69	30	9.9			
	nCi $^{239,240}Pu$ m^{-2}	1.76	1.18	0.43			
	$^{238}Pu/^{239,240}Pu$	-	-	-			
	$^{241}Am/^{239,240}Pu$	(0.11)	(0.25)				
	$^{239,240}Pu/^{137}Cs$	1.11	0.70	0.39			

Table A.16. Plutonium and Americium in sea water collected in Thule, August 1979

Position	Unit	Sample depth	Total water	Filtered water (0.45 μ)	Particulate activity
E → M	fCi $^{239,240}Pu$ l^{-1}		0.48	0.40	
$76^{o}37'N$ $70^{o}30'W$	$^{238}Pu/^{239,240}Pu$	Surface			
$76^{o}30'N$ $70^{o}55'W$	$^{241}Am/^{239,240}Pu$				
	fCi $^{239,240}Pu$ l^{-1}		0.54	0.88	0.08
$76^{o}43'N$ $73^{o}00'W$ (Analysed by Elis Holm, Lund)	$^{238}Pu/^{239,240}Pu$	Surface	-	0.023	-
	$^{241}Am/^{239,240}Pu$		0.19	0.13	0.63
	fCi $^{239,240}Pu$ l^{-1}		0.55		
$76^{o}33'N$ $69^{o}35'W$ (Analysed by Elis Holm, Lund)	$^{238}Pu/^{239,240}Pu$	Surface	0.055		
	$^{241}Am/^{239,240}Pu$		0.27		
L	fCi $^{239,240}Pu$ l^{-1}		0.49		
$76^{o}32'N$ $69^{o}10'W$	$^{238}Pu/^{239,240}Pu$	Surface	-		
	$^{241}Am/^{239,240}Pu$		0.063		

Table A.17. Plutonium and Americium in sea water collected in various depths at the point of impact: V: $76^{o}31'N$, $69^{o}18'5W$ in Thule, August 1979

Sample depth in metres	Unit	Total water	Filtered water 0.45 μ	Particulate activity
	fCi $^{239,240}Pu$ l^{-1}		0.31	0.030
Surface	$^{238}Pu/^{239,240}Pu$			
	$^{241}Am/^{239,240}Pu$		0.079	0.28
	fCi $^{239,240}Pu$ l^{-1}	0.57		
50	$^{238}Pu/^{239,240}Pu$			
	$^{241}Am/^{239,240}Pu$			
	fCi $^{239,240}Pu$ l^{-1}	0.42		
100	$^{238}Pu/^{239,240}Pu$			
	$^{241}Am/^{239,240}Pu$			
	fCi $^{239,240}Pu$ l^{-1}	0.53		
150	$^{238}Pu/^{239,240}Pu$			
	$^{241}Am/^{239,240}Pu$	~0.19		
	fCi $^{239,240}Pu$ l^{-1}	1.82	estimated 1.82-1.42 = 0.4	1.42
170	$^{238}Pu/^{239,240}Pu$			
(near bottom)	$^{241}Am/^{239,240}Pu$	0.060		0.12

Table A.18. Plutonium and Americium in brown algae collected at Thule, August 1979

Position	Unit	Species and plant part		
		Fucus total plant	Laminaria leaves	Laminaria stems
76°43'N 73°00'W	pCi $^{239,240}Pu$ kg^{-1} dry	14.6, 16.7*	3.0	3.4
tidal zone	$^{238}Pu/^{239,240}Pu$	0.051*		
	$^{241}Am/^{239,240}Pu$	0.043		
76°43'N 73°00'W	pCi $^{239,240}Pu$ kg^{-1} dry		6.8, 11.3*	4.9, 5.3*
8 m depth	$^{238}Pu/^{239,240}Pu$		0.040*	
	$^{241}Am/^{239,240}Pu$		0.088*	0.13
76°34'N 68°50'W	pCi $^{239,240}Pu$ kg^{-1} dry	7.7, 7.6*		
tidal zone	$^{238}Pu/^{239,240}Pu$			
	$^{241}Am/^{239,240}Pu$			
76°45'N 69°55'N	pCi $^{239,240}Pu$ kg^{-1} dry	7.8	5.7	6.5
tidal zone	$^{238}Pu/^{239,240}Pu$			
	$^{241}Am/^{239,240}Pu$			
76°27'N 69°21'5N	pCi $^{239,240}Pu$ kg^{-1} dry			3.24
5 m depth	$^{238}Pu/^{239,240}Pu$			
	$^{241}Am/^{239,240}Pu$			
76°27'N 69°21'5N	pCi $^{239,240}Pu$ kg^{-1} dry		1.64	2.00
tidal zone	$^{238}Pu/^{239,240}Pu$			
	$^{241}Am/^{239,240}Pu$			

*Samples analysed by Elis Holm, Lund, Sweden.

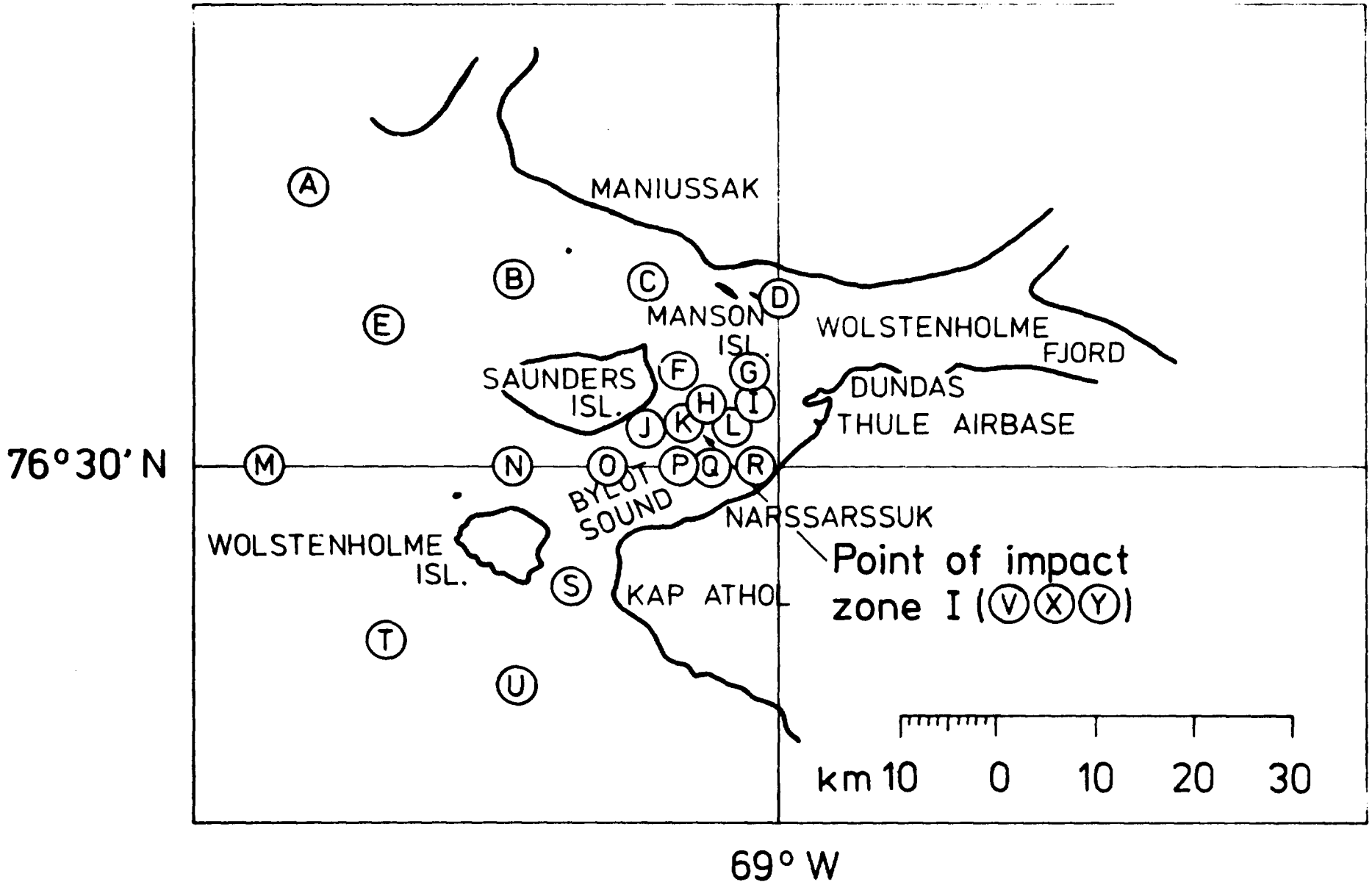

Fig. A.1 The sample locations at Thule.

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