Environmental Radioactivity in Greenland in 1965

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A. Aarkrog and J. Lippert

The Danish Atomic Energy Commission
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Health Physics Department

Abstract

The present report deals with the measurement of fall-out radioactivity in Greenland in 1965.

Sr-90 (and Cs-137 in most instances) was determined in samples of precipitation, soil, sea water, vegetation, animals, and drinking water.

Estimates of the mean contents of Sr-90 and Cs-137 in the human diet in Greenland in 1965 are given.

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Our thanks are furthermore due to the district physicians, the telestations, GTO, and all other persons and institutions in Greenland who have contributed by collecting samples.

The collection of sea water from the Godthåbs Fjord would have been impossible without the kind co-operation of Mr. Jacob Mortensen.

Finally we thank Mr. Flemming Steenbuch, who has helped with the correction of the language in this report.

ABBREVIATIONS AND UNITS

FP	fission products
pCi	picocurie, 10^{-12} Ci, μμCi
nCi	nanocurie, 10^{-9} Ci, mμCi
mCi	millicurie, 10^{-3} Ci
S. U.	pCi Sr-90/g Ca ("Sunshine unit")
M. U.	pCi Cs-137/g K ("Moonshine unit")
nSr	natural (stable) Sr
S. D.	standard deviation $\sqrt{\frac{\Sigma (x-x_i)^2}{(n-1)}}$
S. E.	standard error $\sqrt{\frac{\Sigma (x-x_i)^2}{n(n-1)}}$
S. S. D.	sum of squares of deviation $\Sigma (x-x_i)^2$
f	degrees of freedom
s^2	the variance
v^2	the ratio between the variance in question and the residual variance
P	the probability fractile of the distribution in question
η	coefficient of variation.

1. INTRODUCTION

1.1.

In 1965 the sampling programme from the previous years[1, 2, 3] was used with only a few modifications.

1.2.

As hitherto, the samples were collected through the local district physicians and the leaders of the meteorological stations. However, it was not possible in 1965 to obtain all samples scheduled in the programme.

1.3.

The mean diet in Greenland was unchanged as compared with 1962, i.e., it was still in accordance with the estimate given by Professor E. Hoff-Jørgensen, Ph. D., nutritional consultant to the Danish Atomic Energy Commission.

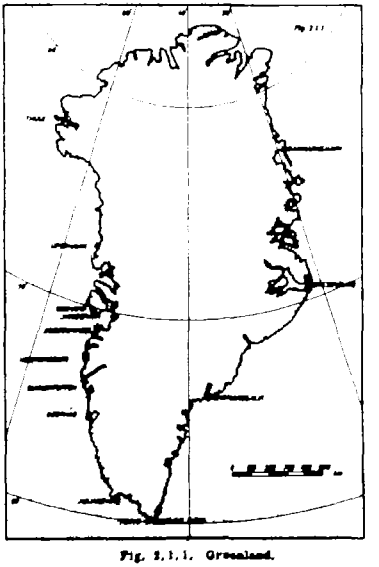

Fig. 1.1.1. Greenland.

1.4.

The environmental studies in Greenland were carried out along with corresponding investigations in Denmark (cf. Risö Report No. 130) and in the Faroes (cf. Risö Report No. 131[5]).

1.5.

The present report will not repeat information concerning sample collecting and analysis already given in Risö Reports No. 65[1], No. 87[2] and No. 109[3].

2. RESULTS AND DISCUSSION

2.1. Sr-90 in Precipitation

Table 2.1.1 shows the results of the measurements and tables 2.1.2 and 2.1.3 the analyses of variance of the pCi Sr-90/l and the mCi Sr-90/km^2 figures respectively. The missing values from Upernavik, Godhavn and Prins Christians Sund were estimated by means of the least squares method.

The total fall-out levels in 1965 at the four stations (Upernavik, Godhavn, Godthåb, and Prins Christians Sund) were 22, 55, 64, and 80% respectively of the 1964 figures. The specific activity was on the average nearly a factor of two lower in 1965 than in 1964. In Denmark[4] and the Faroes[5] the specific activity decreased by a factor of three from 1964 to 1965.

Fig. 2.1.2 shows the quarterly Sr-90 fall-out at Upernavik, Godhavn, Godthåb, and Prins Christians Sund in the years 1962-65. The decreasing

Table 2.1.1

Sr-90 in Precipitation Collected in Greenland in 1965

Location (cf. fig. 2.1.1)	Unit	Jan.- Mar.	Apr.- June	July- Sep.	Oct.- Dec.	1965
Upernavik	pCi Sr-90/l	1.97	31.0	12.1	-	-
	mCi Sr-90/km^2	0.39	0.26	0.15	-	~1
Godhavn	pCi Sr-90/l	16.6	19.4	3.25	-	-
	mCi Sr-90/km^2	1.74	0.19	0.25	-	~3
Godthåb 600 mm in 1965	pCi Sr-90/l	7.57	14.2	5.10	3.23	7.5
	mCi Sr-90/km^2	0.76	2.13	1.28	0.32	4.5
Prins Christians Sund 3736 mm in 1965	pCi Sr-90/l	8.86	8.50	0.75	-	-
	mCi Sr-90/km^2	10.5	8.1	0.57	-	~20
The relative error of the Sr-90 determinations was approx. 15%.						

Table 2.1.2

Analysis of Variance of ln pCi Sr-90/l Precipitation
(from table 2.1.1)

Variation	n/16 SSD	f	s^2	v^2	P
Between locations	3.8249	3	1.3083	3.35	> 90%
Between months	7.5924	5	2.5308	6.48	> 95%
Remainder	2.3429	6	0.3904		
Total	13.8602	12			
η = 0.70					

Table 2.1.3

Analysis of Variance of ln mCi Sr-90/km^2
(from table 2.1.1)

Variation	n/16 SSD	f	s^2	v^2	P
Between locations	15.2186	3	5.0781	8.07	> 97.5%
Between months	10.0773	3	3.3581	5.35	> 90%
Remainder	3.7584	6	0.6280		
Total	29.0541				
η = 0.84					

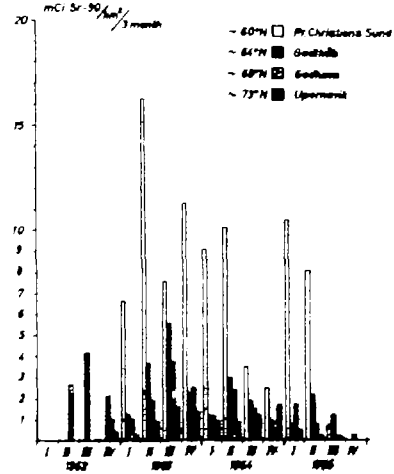

Fig. 2.1.2. Quarterly Sr-90 fall-out in Greenland, 1962-65.

fall-out with increasing latitude is mainly due to the decreasing amounts of precipitation as we go from Prins Christians Sund in the south to Upernavik in the north. The annual amounts of precipitation are an order of magnitude greater at Prins Christians Sund than at Upernavik, and so is the mean fall-out of Sr-90.

2.2. Sr-90 in Sea Water

As in the previous years, sea water was sampled from a number of locations along the coast of Greenland. Other samples were collected from the Godthåb Fjord by M/S "Adolf Jensen" in April and November. The purpose of the latter sampling was to see whether the activity varied from head to mouth of the fjord and to investigate whether there was any difference between the water samples collected in the spring and in the autumn. Furthermore we wanted to compare the levels in the coastal water with those in the open sea. Table 2.2.2 shows the results.

It was not possible to see any systematic variation in the activity in the Godthåb Fjord, either between locations or between sampling months. Nor did salinity have any influence on the activity. As regards the samples collected from the coast, the April sample was equal to the fjord samples, whereas the July-August sample was a factor of two higher, evidently because of contamination with fresh water (salinity 16.2 o/oo). Fig. 2.2 shows

Table 2.2.2

Sr-90 in Sea Water around Greenland in 1965

Location	Sampling month	Position North	Position West	pCi Sr-90/l	pCi Sr-90/g Ca	Salinity in o/oo	Sample depth in m	Location depth in m	mg Sr/g Ca
Godthåb I*	Apr.	64°25'	50°21'	0.31	0.77	30.6	0	220	15
Godthåb II*	"	64°27'	50°49'	0.38	0.93	30.5	0	360	16
Godthåb III*	"	64°15'	51°06'	0.35	0.83	31.8	0	430	16
Godthåb IV*	"	64°14'	51°34'	0.32	1.00	31.6	0	490	16
Godthåb V*	"	64°07'	51°53'	0.30	0.73	30.8	0	330	16
Godthåb	"	-	-	0.35	0.80	33.2	0	-	18
Godthåb	July-Aug.	-	-	0.71	2.31	16.2	0	-	15
Thule	"	-	-	0.29	0.70	29.0	0	-	16
Prins Chr. Sund	"	-	-	0.24	0.57	31.2	0	-	15
Angmagssalik	"	-	-	0.24	0.57	31.2	0	-	15
Godthåb I*	Nov.	64°27'	50°42'	0.34	0.81	30.9	0	220	16
Godthåb II*	"	64°35'	51°03'	0.32	0.82	29.6	0	370	16
Godthåb IV*	"	64°22'	51°37'	0.32	0.81	30.0	0	390	16
Godthåb V*	"	64°08'	51°53'	0.30	0.78	31.0	0	330	16

* Samples collected from the fishing boat "Adolf Jensen" in the Godthåb Fjord.
The estimated error of the Sr-90 analyses was approx. 15%.

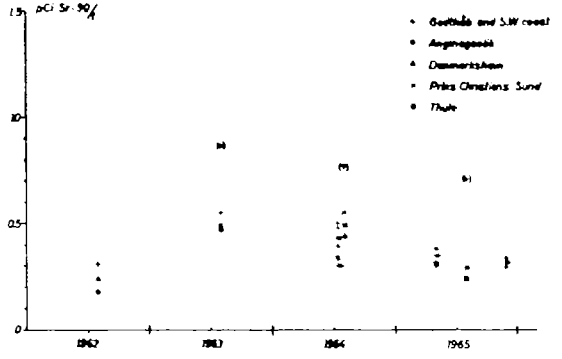

Fig. 2.2. Sr-90 in Greenland sea water, 1962-65.

the Sr-90 levels in Greenland water collected in the period 1962-65. The three points in brackets represent samples presumably contaminated with fresh water. The figure shows a maximum in 1963-64. The 1965 levels are a little higher than the 1962 levels and definitely higher than the Faroese 1965 levels[5], which were below 0.2 pCi Sr-90/l.

2.3. Sr-90 and Cs-137 in Terrestrial Animals

Samples of reindeer were collected in the spring and the autumn from the west coast of Greenland. Table 2.3.1 shows the results. As in previous

Table 2.3.1

Sr-90 and Cs-137 in Reindeer and Sheep Samples Collected in Greenland in 1965

Location	Sampling month	Species	Sample	pCi Sr-90/kg	pCi Sr-90/g Ca	nCi Cs-137/kg	pCi Cs-137/g K
Egedesminde	Mar.	Reindeer	Meat	39.8	424	7.8	2900
			Bone	-	420	-	-
	Sep.	Reindeer	Meat	34.7	221	2.4	700
			Bone	-	340	-	-
Godthåb	Aug.-Sep.	Reindeer	Meat	8.6	57	1.4	420
			Bone	-	161	-	-
	Aug.	Sheep	Meat	I 6.5 II 6.5	I 65 II 47	1.4 0.8	500 380
	Aug.	Sheep	Bone	I - II -	I 128 II 107	-	
Sukkertoppen	Autumn	Reindeer	Meat	82.1	782	0.9	270
			Bone	-	199	-	-
The relative error of the analyses was approx. 10%.							

years, the variation between the samples was considerable. The geometric means of the samples were 28.8 pCi Sr-90/kg meat (η = 0.87) and 2.2 nCi Cs-137/kg (η = 1.21). Fig. 2.3 shows the geometric means of Sr-90 in bone and Cs-137 in meat of reindeer from Greenland collected in the period 1961-65. There seems to be a decrease in the levels during 1965. Although the material is very limited and the coefficients of variation are rather high, we find the same seasonal tendency as that found in Cs-137 measurements on reindeer from Lapland[6], i.e. higher levels in the spring samples than in the autumn samples, on account of a greater consumption of lichen in winter than in summer. The S.U. level in bone does not show a similar seasonal variation; however, the annual trend in the Sr-90 concentrations is similar to that

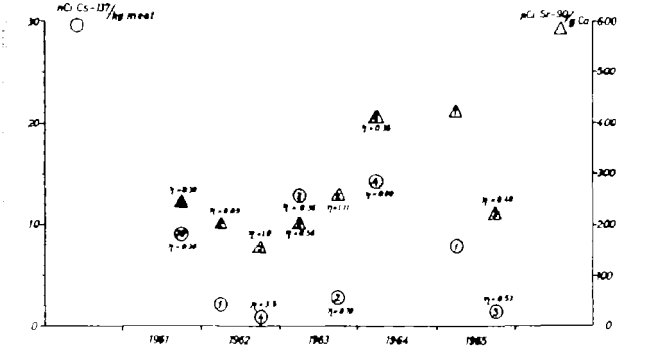

Fig. 2.3. Cs-137 in meat and Sr-90 in bone at reindeer from Greenland. (The figures in the circles and triangles are the numbers of samples included in the geometric mean; η is the coefficient of variation.)

Table 2.3.2

Cs-137 and Sr-90 in Musk Ox Samples from Scoresbysund Collected in December 1964

Sample No.	Sample	pCi Cs-137/kg	pCi Cs-137/g K	pCi Sr-90/kg	pCi Sr-90/g Ca
I	Meat	67	30	2.5	-
II	Meat	270	103	6.7	-
III	Meat	93	109	14.9	-
IV	Meat	37	165	45.1	-
	Bone	-	-	-	56
V	Meat	206	84	13.1	-
	Bone	-	-	-	41
The relative error of the analyses was approx. 15%.					

found for Cs-137. All samples were collected in Greenland except the 1961 samples[7], which were purchased in shops in Copenhagen. As compared with reindeer from Lapland[6], the Greenland samples were lower in Cs-137 content. Two samples of mutton were obtained from Godthåb in August (cf. table 2.3.1). The mean levels of the meat were 6.5 pCi Sr-90/kg and 1.1 nCi Cs-137/kg, i.e., as regards Cs-137, close to the reindeer concentrations found in the autumn.

In December 1964 we received five samples of musk ox from Scoresby Sund[3]. The Sr-90 levels in the meat were not published in the 1964 report. Table 2.3.2 shows these and the Cs-137 figures published earlier. The arithmetic mean was 16.5, the geometric mean 10.8 (η = 1.4) and the median 13.1 pCi Sr-90/kg meat.

2.4. Sr-90 and Cs-137 in Sea Animals

Table 2.4.1

Sr-90 and Cs-137 in Seal Samples Collected in Greenland in 1965

Location	Sampling month	Sample	pCi Sr-90/kg	pCi Sr-90/g Ca	pCi Cs-137/kg	pCi Cs-137/g K
Thule	Summer	Meat	0.36	5.7	24	8.8
		Bone	-	0.11	-	-
Thule	Summer	Meat	0.79	7.6	21	9.8
		Bone	-	0.15	-	-
Scoresbysund	Summer	Meat	0.73	18.8	113	39.2
		Bone	-	0.13	-	-
"	"	Meat	1.21	-	266	102.0
		Bone	-	0.15	-	-
"	"	Meat	1.48	32.4	211	76.0
		Bone	-	0.12	-	-
"	"	Meat	2.82	58.6	118	42.5
		Bone	-	0.19	-	-
Upernavik	"	Meat	0.55	4.0	19	10.2
		Bone	-	0.12	-	-
"	"	Meat	0.61	6.1	24	10.6
		Bone	-	0.55	-	-
Jacobshavn	"	Meat	0.51	8.9	-	-
		Bone	-	0.13	-	-
Egedesminde	July-Aug.	Meat*	0.88	3.4	86	37.5
Mean	1965	Meat	0.68	10.1	99	37.5
		Bone	-	0.18	-	-

* A whale (Balaenoptera acutorostrata).
The relative error of the analyses was approx. 20%.

Table 2.4.1 shows the levels in seals (Phoca foetida) and a single piked whale (Balaenoptera acutorostrata) collected along the coast of Greenland during the summer of 1965. The geometric mean levels in the meat were 0.70 pCi Sr-90/kg ($\bar{x}$ = 0.82) and 63 pCi Cs-137/kg ($\bar{x}$ = 1.4). It is remarkable that the samples from Scoresby Sund show 5-10 times higher Cs-137 concentrations than the west coast samples.

In table 2.4.2 the results of the measurements on sea birds collected at Prins Christians Sund and Thule are shown.

Table 2.4.2

Sr-90 and Cs-137 in Sea Birds Collected around Greenland in 1965

Location	Month	Species	Sample type	pCi Sr-90/kg	pCi Sr-90/g Ca	pCi Cs-137/kg	pCi Cs-137/g K
Prins Chr. Sund	Nov.-Dec.	Somateria mollissima	Meat	0.36	-	62	33
			Bone	-	0.57	-	-
Thule	June-July	Somateria mollissima	Meat	0.58		< 52	< 17
			Bone	-	0.24	-	-
		Uria aalge	Meat	0.28		17	6
			Bone	-	0.49	-	-

The estimated error of the results was approx. 20%.

Table 2.4.3

Sr-90 and Cs-137 in Fish and Shrimps Collected around Greenland in 1965

Location	Sampling month	Species	Sample type	pCi Sr-90/kg	pCi Sr-90/g Ca	mg Sr/g Ca	pCi Cs-137/kg	pCi Cs-137/g K
Godthab	Summer	Salmo salar	Meat	0.93	1.41	3.5	37	8.1
			Bone		0.14	2.9		
Godthab	Oct.	Salmo salar	Meat	3.00	0.85	5.2	26	8.9
			Bone		0.53	2.5		
Godthab	Oct.	Salmo salar	Meat	1.15	0.91	4.5	20	6.0
			Bone		0.58	2.9		
Jakobshavn	Summer	Reinhardtius hippoglossoides	Meat	0.34	0.36	5.5	18	5.9
			Bone		0.18	5.0		
Egedesminde	June	Mallotus villosus	Total	0.40	0.16	5.1	-	-
Jakobshavn	Oct.	Shrimps	Total	2.78	2.15	12.9	14	10.3
Mean			Bone		0.35	3.9		
S.D.			Bone		0.23	1.1		

The relative analytical error of the determinations was approx. 20%.

Table 2.4.3 presents the results of Sr-90 and Cs-137 determinations in fish and shrimps. The geometric means of the meat were 1.0 pCi Sr-90/kg (η = 1.2) and 22 pCi Cs-137/kg (η = 0.38). The stable mg Sr/g Ca ratio of the bones was equal to that found in 1964[3], and the observed ratio between mg Sr/g Ca in fish bone and in sea water (the Godthåb Fjord, cf. table 2.2) was 0.21. Shrimps showed, as in 1964, a surprisingly large stable-strontium to calcium ratio (12 mg Sr/g Ca).

2.5. Sr-90 and Cs-137 in Vegetation

Grass was collected from four stations along the west coast during the summer. Table 2.5.1 shows the results. The geometric mean levels were 1.3 nCi Sr-90/kg dry weight (η = 1.7) and 2.7 nCi Cs-137/kg (η = 1.05). The concentrations were definitely lower than in 1964.

Table 2.5.1

Sr-90, Cs-137 and Mn-54 in Grass and Hay Samples Collected in Greenland in 1965

Location	Month	nCi Sr-90/kg	pCi Sr-90/g Ca	nCi Cs-137/kg	pCi Cs-137/g K	nCi Mn-54/kg
Egedesminde	Aug.	I 2.87	800	3.0	400	-
	Aug.	II 2.98	600	3.2	200	-
Julianehåb	June	0.53	80	1.5	50	-
	Sep.	1.47	300	0.7	20	-
Godthåb	July	0.18	60	4.3	500	-
Sukkertoppen	July	3.50	2190	8.6	1500	1.7
The relative error of the measurements was approx. 15%.						

Table 2.5.2

Sr-90 and Cs-137 in Miscellaneous Terrestrial Vegetation Samples Collected in Greenland in 1965

Location	Months	Sample type	nCi Sr-90/kg	pCi Sr-90/g Ca	mg Sr/g Ca	nCi Cs-137/kg	pCi Cs-137/g K
Sukkertoppen	July	Lichen	5.86	1400	8.5	40.5	-
	Autumn	Bilberry	0.940	700	7.2	0.90	350
Egedesminde	Aug.	Lichen	1.43	3800	9.3	44.0	35,500
	"	Lichen	4.62	1800	8.9	43.0	29,800
	"	Lichen	-	-	-	23.6	24,300
	"	Lichen	10.05	2100	7.3	23.8	18,500
Godthåb	Autumn	Berries	0.092	1000	-	0.84	90
	Nov.	Willow buds	3.38	1300	-	1.5	400
The relative error of the measurements was approx. 15%.							

Table 2.5.2 shows the activity contents in miscellaneous terrestrial vegetation collected in the summer and the autumn at the west coast. The geometric mean levels in lichen were 4.4 nCi Sr-90/kg ($\bar{x}$ = 0.97) and 33.6 nCi Cs-137/kg ($\bar{x}$ = 0.33). As previously, lichen contained more Sr-90 and especially Cs-137 than grass. It was not possible to observe any difference between the 1965 and 1964 lichen levels.

2.6. Radiostrontium in Drinking Water

Quarterly samples of drinking water were as previously collected from a number of locations in Greenland. Table 2.6 shows the results from

Table 2.6

Sr-90 in Drinking Water Collected in Greenland in 1965

Location	Jan. - Mar.	Apr. - June	July - Sep.	Oct. - Dec.
	pCi Sr-90/l	pCi Sr-90/l	pCi Sr-90/l	pCi Sr-90/l
Godhavn	0.36	0.87	-	-
Godthåb	-	2.76	-	1.12
Prins Chr. Sund	16.3	1.14	1.50	-
Scoresbysund	0.81	-	-	-
Danmarkshavn	-	-	1.86	4.94

The relative analytical error of the Sr-90 determinations was approx. 15%.

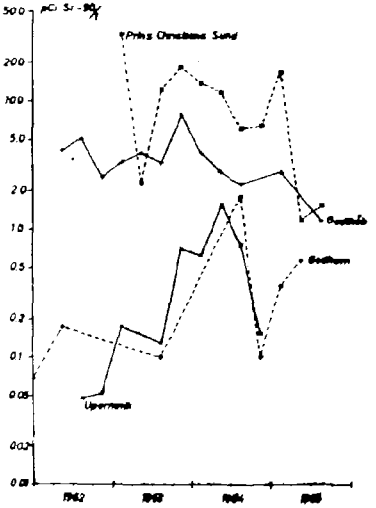

Fig. 2.6. Sr-90 in Greenland drinking water, 1962-65.

1965 and fig. 2.6 the results from four of the locations for the period 1962-65.

As the material from 1965 is very incomplete, we have found it most expedient to choose the geometric mean of the figures, i.e. 2.2 pCi Sr-90/l ($\bar{x}$ = 1.7), as representative of the mean level of Sr-90 in Greenland drinking water in 1965.

2.7. Miscellaneous

2.7.1. Sr-90 in soil

A soil sample taken in September at Prins Christians Sund to a depth of 10 cm was analysed for Sr-90. The specific activity was 3,320 pCi Sr-90/kg dry weight, and the accumulated fall-out down to 10 cm was estimated at 73 mCi Sr. 90/km^2. At Thorshavn in the Faroes[5] we found that more than 30% of the total fall-out was below 10 cm depth. As the soil at Prins Christians Sund is similar to that at Thorshavn, we estimate the total accumulated fall-out at Prins Christians Sund by September 1965 to be at least 110 mCi Sr-90/km^2. In 1963-65 the fall-out rate at Prins Christians Sund was 87/34 = 2.56 times that in Denmark, and as the accumulated fall-out in Denmark[4] by September 1965 was 55 mCi Sr-90/km^2, the estimated accumulated fall-out at Prins Christians Sund should be approx. 140 mCi Sr-90/km^2.

Table 2.7.2

Sr-90 in Sea Plants Collected in Greenland in 1965

Location	Month	Species	pCi Sr-90/g Ca	mg Sr-90/g Ca	pCi Ca-137/g K
Godthåb	July	Fucus sp.	4.0	42.0	32
Thule	Sep.	Fucus serratus	1.2	37.5	-
Thule	Sep.	Laminaria sp.	0.7	48.2	13

The relative analytical error was estimated at 15%.

2.7.2. Sr-90 in sea plants

The Sr-90 contents of the sea plants collected in 1965 were lower than those found in 1964[3]. The CR between mg Sr/g Ca in sea plants and sea water (cf. table 2.2) varied between 2 and 3 and the CR between S.U. in these samples between 1 and 5.

3. ESTIMATE OF THE MEAN CONTENTS OF Sr-90 AND Cs-137 IN THE HUMAN DIET IN GREENLAND IN 1965

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 by Professor E. Hoff-Jørgensen, Ph. D., in Risö 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 1965 was 20.8 pCi Sr-90/kg and 55 pCi Cs-137/kg[4].

The cheese was also imported from Denmark and contained 147.9 pCi Sr-90/kg and 40 pCi Cs-137/kg.

3.3. Grain Products

All grain was imported from Denmark. It is assumed that only grain from the harvest of 1964 was consumed in Greenland during 1965. 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 Sr-90 in these five products was 252 pCi/kg, 27.4 pCi/kg, 50 pCi/kg, 187 pCi/kg, and 56 pCi/kg respectively. Hence the mean content of Sr-90 in grain products was 117 pCi/kg. The content of Cs-137 in the five products was 958 pCi/kg, 189 pCi/kg, 479 pCi/kg, 709 pCi/kg, and 329 pCi/kg. Hence the mean content of Cs-137 in grain products was 513 pCi/kg.

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 Risö Report No. 107[3]. The Sr-90 level in rye flour (70% extraction) was calculated by analogy with the level in wheat flour (75% extraction), i.e. as one fifth of the whole-grain activity. The Cs-137 content in rye flour (70% extraction) was calculated as one half of the whole-grain level in rye, i.e. the ratio between Cs-137 in whole wheat grain and in wheat flour (75% extraction)[4]. The Sr-90 and Cs-137 contents in biscuits were calculated by division of the levels of the rye flour (100% extraction) by 1.35, since 1 kg flour yeilds 1.35 kg bread[4].

3.4. Potatoes, Other Vegetables and Fruit

The Danish mean levels for 1965 were used [4] as the local production is insignificant as compared with the import from Denmark.

The Danish mean levels were: in potatoes 3.7 pCi Sr-90/kg and 22 pCi Cs-137/kg, in other vegetables 13.8 pCi Sr-90/kg and 14 pCi Cs-137/kg, and in fruit 4.6 pCi Sr-90/kg and 35 pCi Cs-137/kg.

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 mutton was 6.5 pCi Sr-90/kg and 1.1 nCi Cs-137/kg. In reindeer the levels were 28.8 pCi Sr-90/kg and 2.2 nCi Cs-137/kg (cf. table 2.3.1). Seals and whales were estimated from table 2.4.1 to have contained 0.7 pCi Sr-90/kg and 63 pCi Cs-137/kg, and sea birds and eggs were estimated from table 2.4.2 to have contained 0.4 pCi Sr-90/kg and 0.05 nCi Cs-137/kg. Hence the mean levels in Greenland meat from 1965 were 26 pCi Sr-90/kg and 0.27 nCi Cs-137/kg.

3.6. Fish

All fish consumed was of local origin, and the mean levels were obtained from table 2.4.3, i.e. 1.0 pCi Sr-90/kg and 22 pCi Cs-137/kg.

3.7. Coffee and Tea

The Danish figures for 1965 [4] were used for coffee and tea, i.e. 21.6 pCi Sr-90/kg and 77 pCi Cs-137/kg.

3.8. Drinking Water

The geometric mean calculated in 2.6 was used as the mean level of Sr-90 in drinking water, i.e. 2.2 pCi Sr-90/l. The Cs-137 content was estimated to be 1/4 of the Sr-90 content (the ratio found in New York tap water in 1964 [8]), i.e. approx. 0.5 pCi Cs-137/l.

Tables 3.1 and 3.2 show the estimates of Sr-90 and Cs-137 respectively.

3.9. Discussion

The most important Sr-90 source in the diet in Greenland was grain products, which contributed 74.3% of the total Sr-90 content of the diet. Milk and drinking water came second in importance, contributing 10.8 and

Table 3.1

Estimate of the Mean Content of Sr-90 in the Human Diet in Greenland in 1965

Type of food	Annual quantity in kg	pCi Sr-90/kg	Total pCi Sr-90	Percentage of total Sr-90 in food
Milk and cream	78	20.8	1,622	10.8
Cheese	2.5	147.9	370	2.5
Grain products	95.6	117	11,185	74.3
Potatoes	32.8	3.7	121	0.8
Other vegetables	5.5	13.8	76	0.5
Fruit	13.5	4.6	62	0.4
Meat	45.6	2.6	119	0.8
Eggs				
Fish	127.8	1.0	128	0.9
Coffee and tea	7.3	21.6	158	1.0
Drinking water	548	2.2	1,206	8.0
Total			15,047	

The mean annual intake of calcium is estimated to be 560 g (approx. 200-250 g Ca/l as praeparata). Hence the Sr-90/Ca ratio in Greenland total diet in 1965 was 26.9 S.U. The daily intake in 1965 from food was 41.2 pCi Sr-90.

8.0% respectively. As in 1964, approx. 90% of the Sr-90 in the food consumed in Greenland in 1965 came from imported Danish food.

Cereals were also the most important Cs-137 source in the Greenland diet in 1965, contributing 69.4% of the total Cs-137 content. Meat contributed 17.4% and was thus next in importance. Approx. 1/5 of the Cs-137 in the Greenland diet in 1965 came from local products.

As compared with the 1964 figures[3], the Sr-90 content in the total diet was smaller by a factor of two and the Cs-137 level lower by a factor of three. It is especially the lower concentrations in meat that were responsible for the rapid decrease in the Cs-137 content of the diet. The lowering of the mean concentrations from 1964 to 1965 is further due to the application of geometric instead of arithmetic means.

To estimate the maximum per capita intakes of Sr-90 and Cs-137 in Greenland in 1965 we will suppose, as in 1964[3], that the only grain product consumed by a person was dark rye bread, that all his meat came from reindeer, and that his drinking water was rain water with a specific mean activity of 7.5 pCi Sr-90/l and 13 pCi Cs-137/l (cf. table 2.2.1). His daily

Table 3, 2

Estimate of the Mean Content of Cs-137 in the Human Diet in Greenland in 1965

Type of food	Annual quantity in kg	pCi Cs-137/kg	Total pCi Cs-137	Percentage of total Cs-137 in food
Milk and cream	78	55	4,290	6.1
Cheese	2.5	40	100	0.1
Grain products	95.6	513	49,043	69.4
Potatoes	32.8	22	722	1.0
Other vegetables	5.5	14	77	0.1
Fruit	13.5	35	473	0.7
Meat	45.6	270	12,312	17.4
Eggs				
Fish	127.8	22	2,812	4.0
Coffee and tea	7.3	77	562	0.8
Drinking water	548	0.5	274	0.4
Total			70,665	

The mean annual intake of potassium is estimated to be approx. 1000 g. Hence the Cs-137/K ratio becomes 59 M. U. The daily intake in 1965 from food was 194 pCi Cs-137.

intake of Sr-90 would thus be 88 pCi ($\sim$ 57 S. U.) and his Cs-137 intake 0.57 nCi/day (if we use the quantities in tables 3.1 and 3.2). At the lower limit we can imagine someone who ate white bread and seal meat and drank water with hardly any activity (e. g. water formed by the melting of old ice). In this case the daily intakes would be 14 pCi Sr-90 (9 S. U.) and 82 pCi Cs-137.

As compared with the estimated Sr-90 and Cs-137 levels in the Danish[4] and Faroese[5] diets in 1965, the Sr-90 content of the Greenland diet was nearly equal to the Danish mean content, but definitely lower than the Faroese level. The Cs-137 level in the total diet in Greenland was approx. 1/4 and the Sr-90 concentration one half of the level in the Faroes.

4. CONCLUSION

4.1.

The Sr-90 fall-out rates in 1965 were the following: Godhavn: approx. 3 mCi Sr-90/km^2; Godthåb: 4.5 mCi Sr-90/km^2; Prins Christians Sund: approx. 20 mCi Sr-90/km^2, and Upernavik: approx. 1 mCi Sr-90/km^2. The accumulated fall-out levels by the end of 1965 were estimated to be

approx. 30 mCi Sr-90/km^2 at Godhavn, 41 mCi Sr-90/km^2 at Godthåb, 146 mCi Sr-90/km^2 at Prins Christians Sund, and 11 mCi Sr-90/km^2 at Upernavik.

The content of Sr-90 in surface sea water collected along the coasts of Greenland in 1965 varied from 0.24 to 0.71 pCi Sr-90/l.

4.2.

The food consumed in Greenland in 1965 contained on the average 26.9 pCi Sr-90/g Ca, and the daily mean intake of Cs-137 was estimated at 194 pCi. The most important Sr-90 contributors in the diet were grain products, milk products and drinking water, together accounting for more than 90% of the total Sr-90 content of the diet. Cs-137 came mainly from meat and grain products, together contributing nearly 90% of the total Cs-137 content of the diet.

Among the locally produced food components, reindeer meat showed the highest levels, namely up to 52 pCi Sr-90/kg and 7.8 nCi Cs-137/kg. Meat of musk ox collected at Scoresbysund in December 1964 contained from 25 to 45 pCi Sr-90/kg. Fish contained from 0.3 to 3.0 pCi Sr-90/kg and from 0.01 to 0.04 nCi Cs-137/kg. Seal and whale contained approx. 0.7 pCi Sr-90/kg and 0.06 nCi Cs-137/kg.

The levels in the quarterly drinking-water samples varied from 0.4 pCi Sr-90/l, found in water from Godhavn in January-March, to 16.3 pCi Sr-90/l, found in January-March in the drinking water collected at Prins Christians Sund. The mean content in drinking water from Greenland in 1965 was estimated at 2.2 pCi Sr-90/l.

4.3.

Neither Sr-90 analyses on human bone samples nor Cs-137 determinations by whole-body counting have until now been carried out on the population of Greenland. Considering the estimated Sr-90 levels in the diet, it seems probable, however, that the 1965 levels for humans in Greenland were on the average rather similar to those found in Denmark, i.e. the Sr-90 mean levels in human bone in Greenland were approx. 3 S.U. in newborn children, 7 S.U. in infants, 4 S.U. in children and teenagers, and 2.7 S.U. in adults (vertebrae). The Cs-137 whole-body mean content was estimated to be approx. 24 nCi or 170 pCi Cs-137/g K.

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