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Environmental radioactivity in the Faroes in 1976

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Environmental Radioactivity in the Faroes in 1976

by A. Aakrog and J. Lippert

July 1977

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INS Descriptors

- [0] DIET**
 - ENVIRONMENT**
 - FAEROE ISLANDS**
 - FISHES**
 - FOOD**
 - FOOD CHAINS**
 - GLOBAL FALLOUT**
 - MILK**
 - PLANTS**
 - RADIOACTIVITY**
 - SEAWATER**
 - SHEEP**
- [1] ATMOSPHERIC PRECIPITATIONS**
 - BONE TISSUES**
 - DRINKING WATER**
 - MAN**
 - STRONTIUM 90**
- [2] CESIUM 137**

Environmental Radioactivity in the Faroes in 1976

by

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Health Physics Department

Abstract

Measurements of fall-out radioactivity in the Faroes in 1976 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 1976.

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ABBREVIATIONS AND UNITS

PP	fission products
pCi	picocurie, 10^{-12} Ci $\mu\mu$ Ci
nCi	nanocurie, 10^{-9} Ci, $m\mu$ Ci
mCi	millicurie, 10^{-3} Ci
MPC	maximum permissible concentration
S.U.	pCi $^{90}\text{Sr/g Ca}$
O.R.	observed ratio
M.U.	pCi $^{137}\text{Cs/g K}$
nSr	natural (stable) Sr
S.D.	standard deviation, $\sqrt{\frac{\sum (\bar{x}-x_i)^2}{(n-1)}}$
S.E.	standard error, $\sqrt{\frac{\sum (\bar{x}-x_i)^2}{n(n-1)}}$
S.S.D.	sum of squares of deviations, $\sum (\bar{x}-x_i)^2$
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
\bar{x}	mean values
Σ	sum
η	coefficient of variation, relative standard deviation: $\frac{SD}{\bar{x}}$
A:	η : 20-33% (due to counting)
B:	η : >33% (due to counting)
B.D.L.	below detection limit

1. INTRODUCTION

1.1.

The fall-out programme for the Faroes, which was initiated in 1962¹⁾ in close co-operation with the National Health Service and the chief physician of the Faroes, was continued in 1976. Samples of human bone were obtained in 1976 from Dronning Alexandrine's Hospital in Thorshavn.

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 and 346¹⁾.

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 fall-out levels in Denmark and Greenland, described in Risø Reports Nos. 361²⁾ and 363³⁾ respectively.

2. RESULTS AND DISCUSSION

2.1. Strontium-90 in Precipitation

Table 2.1 shows the ^{90}Sr content in precipitation collected at Høyvig (near Thorshavn) and Klaksvig in 1976. The amount of precipitation at Klaksvig was a factor of 1.6 greater than that found at Høyvig, and the amount of fall-out at Klaksvig was 2.4 times that measured at Høyvig.

The mean activity of ^{90}Sr in precipitation in 1976 was approx. one third of the 1975 levels in the Faroes. This was in agreement with the fall-out observations in Denmark in 1976²⁾.

Table 2.1

Strontium-90 in precipitation in the Faroes in 1976

Month	Høyvig		Klaksvig	
	pCi ^{90}Sr l ⁻¹	mCi ^{90}Sr km ⁻²	pCi ^{90}Sr l ⁻¹	mCi ^{90}Sr km ⁻²
Jan.	0.007 B	0.001 B	1.27	0.095
Feb.	0.149	0.008	0.38 A	0.020 A
March	0.25 B	0.017 B	0.23	0.052
April	0.41	0.029	0.53 B	0.022 B
May	0.17 A	0.014 A	0.20 A	0.034 A
June	0.71	0.044	0.34 A	0.017 A
July	0.41 B	0.029 B	0.42 B	0.021 B
Aug.	0.69	0.010	0.31 A	0.040 A
Sep.	0.36 A	0.018 A	0.71	0.029
Oct.	0.21 A	0.035 A	0.17 A	0.046 A
Nov.	0.16 A	0.25 A	0.69	0.117
Dec.	0.151	0.010	0.37	0.091
1976	\bar{x} 0.25	\bar{x} 0.240 Σ mm 954	\bar{x} 0.38	\bar{x} 0.584 Σ mm 1522

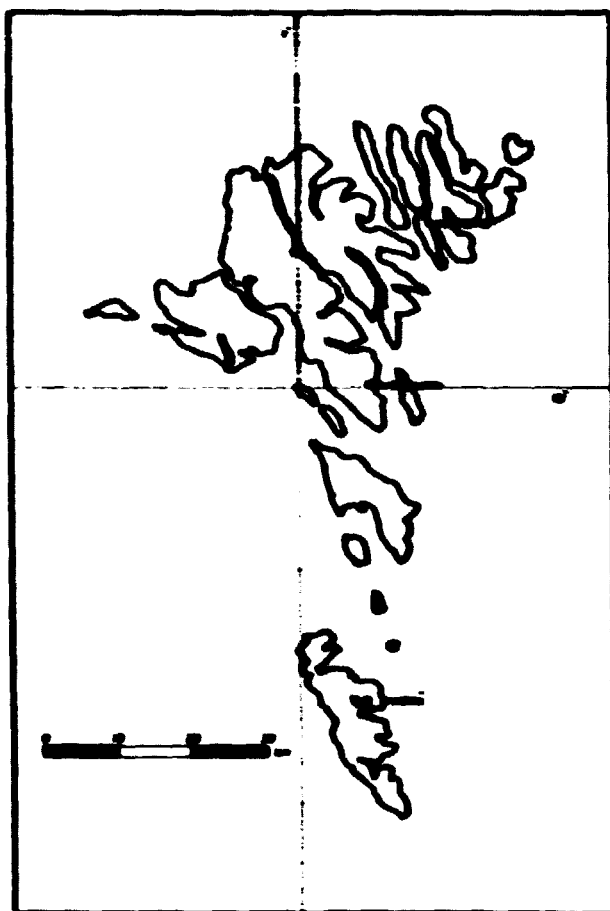


Fig. 2.1.1. The Faroes.

2.2. Strontium-90 and Caesium-137 in Grass

Grass samples were collected near Thorshavn in 1976. Table 2.2 shows the results. The S.U. content of the grass in July was at 51 S.U., and the mean S.U. in milk during June-September was 12.8 S.U. at Thorshavn (cf. 2.3), i.e., the observed ratio between the S.U. in milk and in grass was 0.25 (mean 1965-75: 0.10 ± 0.01). The 1976 S.U. levels in grass were 0.4 times the 1975 levels. As compared with Danish grass in 1976²⁾, we found the S.U. levels in the Faroese grass to be higher by a factor of approx. 2 in the summer months. This was lower than in previous years and together with the high observed ratio between ⁹⁰Sr in milk and grass, it may indicate that the grass sample was atypical with respect to ⁹⁰Sr content.

The mean ratio between ¹³⁷Cs and ⁹⁰Sr in the grass (pCi/g ash) was 2.4 in 1976. (Mean 1965-75: 2.3 ± 0.2).

Table 2.2

Strontium-90 and Caesium-137 in grass from Thorshavn 1976

Month	pCi ⁹⁰ Sr (g ash) ⁻¹	pCi ⁹⁰ Sr (g Cal) ⁻¹	pCi ¹³⁷ Cs (g ash) ⁻¹	¹³⁷ Cs/ ⁹⁰ Sr
March	3.7	81	3.6	0.97
July	3.3	51	12.4	3.76

2.3. Strontium-90 and Caesium-137 in Milk

As in previous years¹⁾, weekly samples of fresh milk were obtained from Thorshavn, Klaksvig, and Tværå. Strontium-90 and ¹³⁷Cs 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 S.U., M.U., and pCi ¹³⁷Cs/l figures respectively. The variation between months was probably significant. As also observed in previous years, the variation between locations was significant. The highest ¹³⁷Cs and ⁹⁰Sr levels were found in the milk from Tværå and the lowest in the Thorshavn milk.

Figure 2.3.1 shows the quarterly S.U. values and fig.2.3.2 the quarterly pCi ¹³⁷Cs/l levels since 1962. The annual mean values for 1976 were 16 S.U. (~ 20 pCi ⁹⁰Sr/l) and 115 M.U., or 189 pCi ¹³⁷Cs/l, i.e. the ⁹⁰Sr levels in 1976 were a little lower than the 1975 mean levels, the ¹³⁷Cs levels were nearly unchanged.

Table 2.3.1

Strontium-90 and Caesium-137 in milk from the Faroes in 1976

Month	Thorshavn			Klaksvig			Tværå			Mean		
	S.U.	pCi ¹³⁷ Cs l ⁻¹	M.U.	S.U.	pCi ¹³⁷ Cs l ⁻¹	M.U.	S.U.	pCi ¹³⁷ Cs l ⁻¹	M.U.	S.U.	pCi ¹³⁷ Cs l ⁻¹	M.U.
Jan.	14.2	85	48	19.4	214	138	17.6	164	99	17.9	155	95
Feb.	19.9	105	63	22.6	168	111	21.0	219	140	21.2	164	105
March	13.0	72	52	19.0	170	114	14.0	242	143	15.4	161	103
April	12.6	82	50	18.2	189	117	22.8	219	130	17.8	163	99
May	12.0	89	52	11.5	173	99	19.2	197	117	14.2	153	89
June	12.4	87	50	23.4	159	96	25.9	124	195	20.6	190	114
July	15.5	178	100	17.0	225	134	30.6	401	233	21.3	268	156
Aug.	12.4	146	87	13.2	188	112	21.8	421	257	15.8	252	152
Sep.	11.0	180	114	10.5	196	134	14.4	309	173	12.0	228	141
Oct.	18.0	125	81	12.6	167	103	20.5	346	199	17.0	213	128
Nov.	10.9	84	51	16.1	265	162	12.7	208	130	13.3	186	114
Dec.	10.7	89	52	9.6	81	48	12.6	249	140	11.3	140	80
Mean	13.6	110	67	16.1	183	114	19.6	275	143	16.4	189	115

Table 2.3.2

Analysis of variance of $\ln \text{pCi } ^{90}\text{Sr (g Ca)}^{-1}$ in Faroese milk in 1976
(from table 2.3.1)

Variation	SSD	f	s ²	v ²	P
Betw. months	1.463	11	0.133	3.454	> 99%
Betw. locations	0.781	2	0.390	10.140	> 99.9%
Remainder	0.847	22	0.038		

Table 2.3.3

Analysis of variance of $\ln \text{pCi } ^{137}\text{Cs (g K)}^{-1}$ in Faroese milk in 1976
(from table 2.3.1)

Variation	SSD	f	s ²	v ²	P
Betw. months	1.702	11	0.155	2.446	> 95%
Betw. locations	5.220	2	2.610	41.258	> 99.95%
Remainder	1.392	22	0.063		

Table 2.3.4

Analysis of variance of $\ln \text{pCi } ^{137}\text{Cs l}^{-1}$ in Faroese milk in 1976
(from table 2.3.1)

Variation	SSD	f	s ²	v ²	P
Betw. months	1.663	11	0.151	2.444	> 95%
Betw. locations	5.340	2	2.670	43.772	> 99.95%
Remainder	1.361	22	0.062		

The annual mean values of the M.U./S.U. ratio in Faroese milk are shown in fig. 2.3.3.

The mean M.U./S.U. ratio in 1976 was 8.0 ± 0.9 during the grazing period (May-October), and in the winter time it was 6.4 ± 0.6 . The ¹³⁷Cs content was thus probably relatively higher in the summer milk, due to unusual high M.U./S.U. ratios in the milk from August and September.

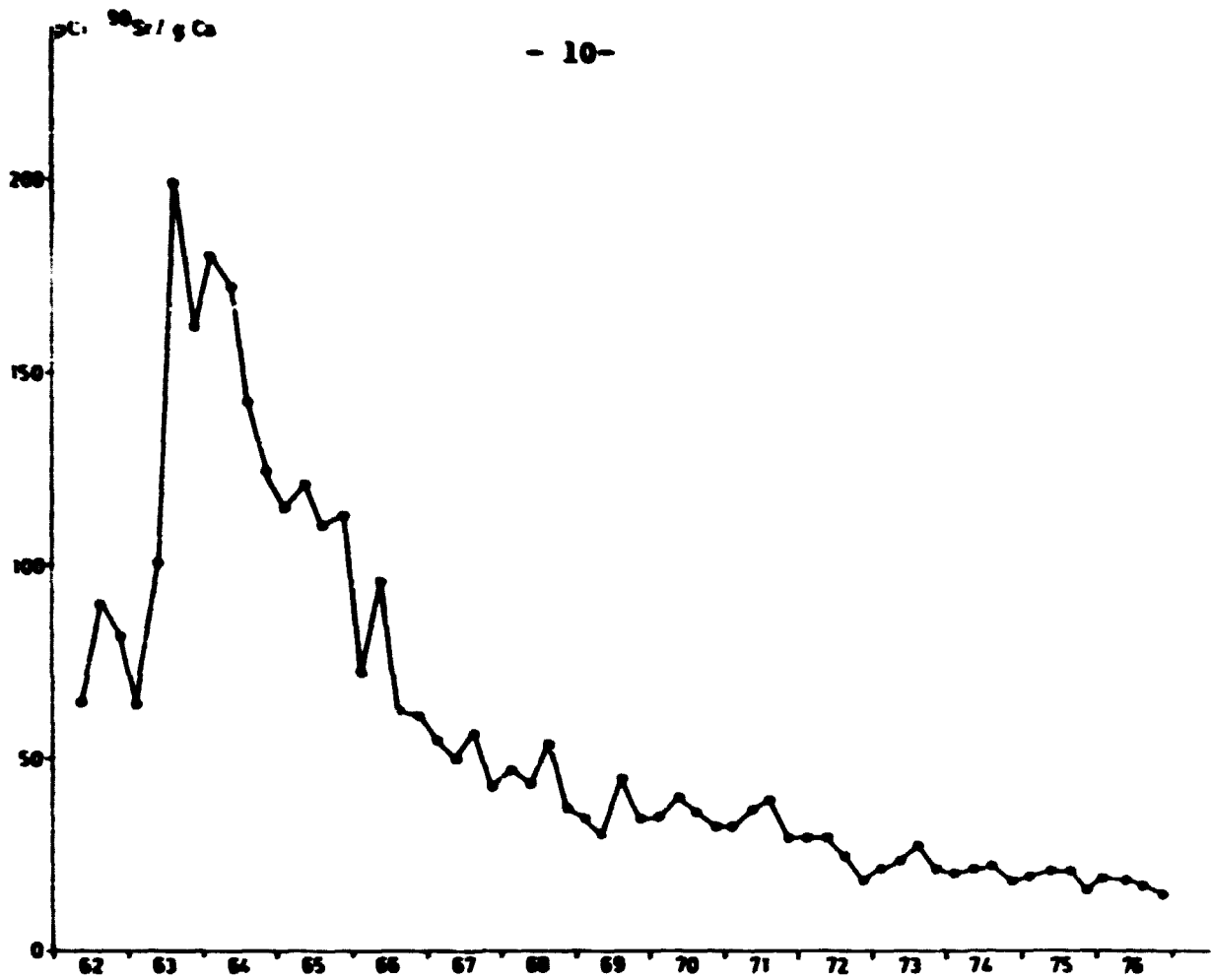


Fig. 2.3.1. Strontium-90 in Faroese milk, 1962-76.

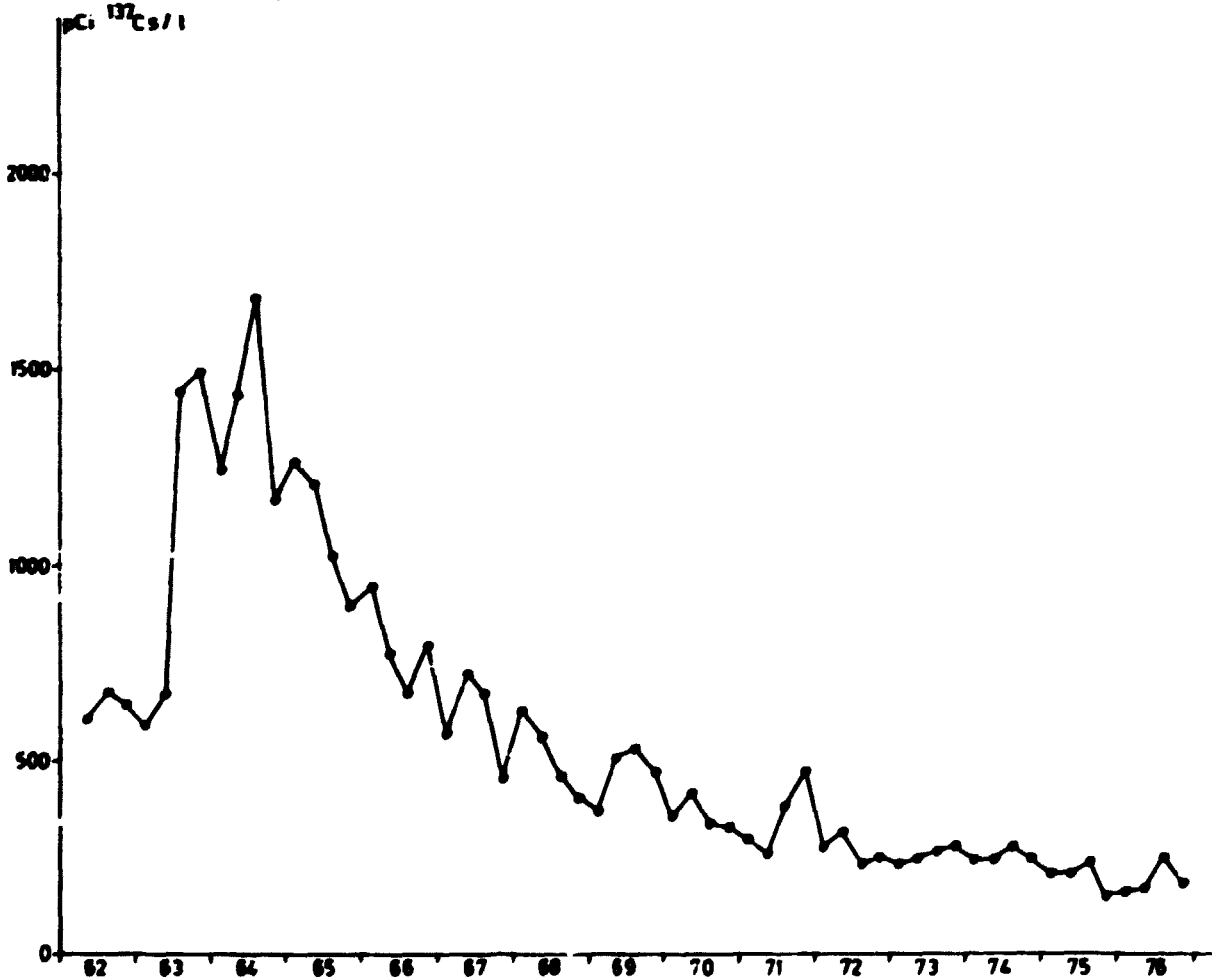


Fig. 2.3.2. Caesium-137 in Faroese milk, 1962-76.

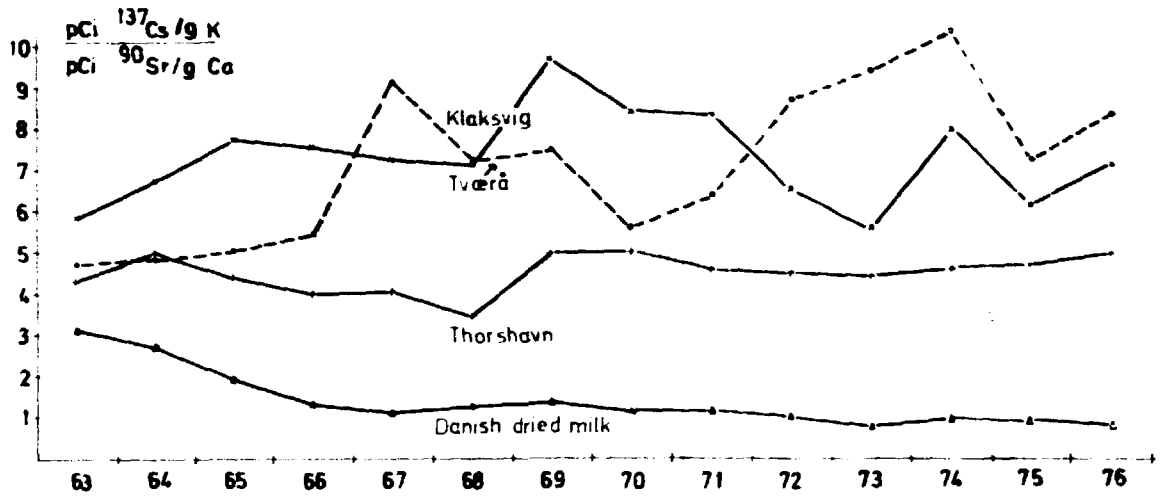


Fig. 2.3.3. $\frac{\text{M.U.}}{\text{S.U.}}$ ratios in Faroese and Danish milk, 1963-76.

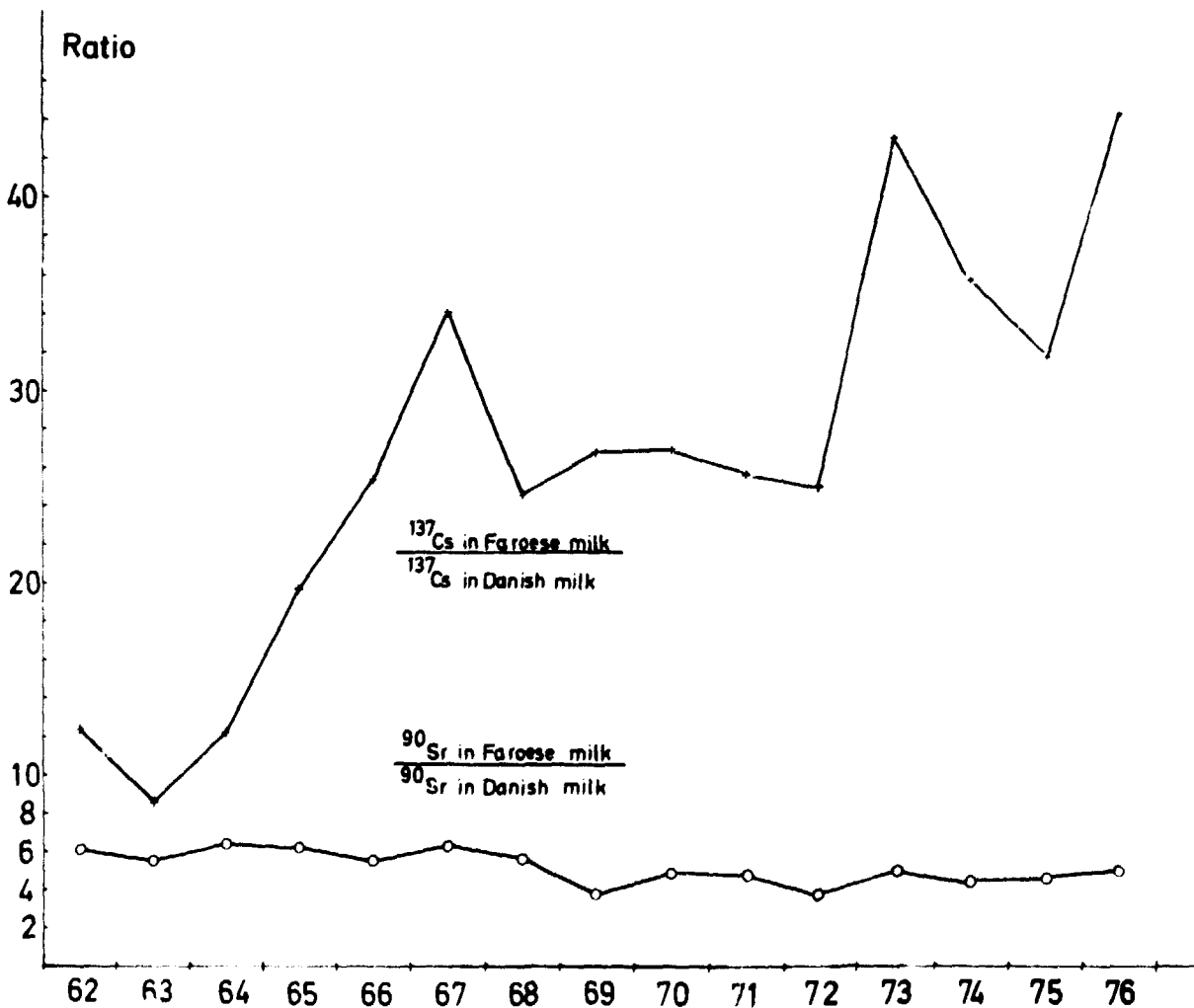


Fig. 2.3.4. A comparison between Faroese and Danish milk levels, 1962-76.

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 soil uptake plays an important role for the ^{137}Cs levels in the Faroes, because the ratio between ^{137}Cs in Faroese and Danish milk increases with time. The ratios between the ^{90}Sr levels in Faroese and Danish milk have shown a slight tendency to decrease through the years.

2.4. Strontium-90 and Caesium-137 in Terrestrial Animals

The mean levels for lamb meat and mutton were 8.7 pCi $^{90}\text{Sr}/\text{kg}$, or 118 S.U., and 0.79 nCi $^{137}\text{Cs}/\text{kg}$, or 320 M.U. The bone level was 97 pCi $^{90}\text{Sr}/\text{g Ca}$. As compared with 1975, the mean levels were lower in 1976.

Table 2.4

Strontium-90 and Caesium-137 in lamb and sheep samples from the Faroes in October 1976

Location	Sample type	pCi $^{90}\text{Sr kg}^{-1}$	pCi $^{90}\text{Sr (g Ca)}^{-1}$	pCi $^{137}\text{Cs kg}^{-1}$	pCi $^{137}\text{Cs (g K)}^{-1}$
Høyvik	Mutton	7.8	122	1120	430
Høyvik	Sheep bone	-	119	-	-
The Faroes	Lamb meat	9.6	114	460	210
The Faroes	Lamb bone	-	75	-	-

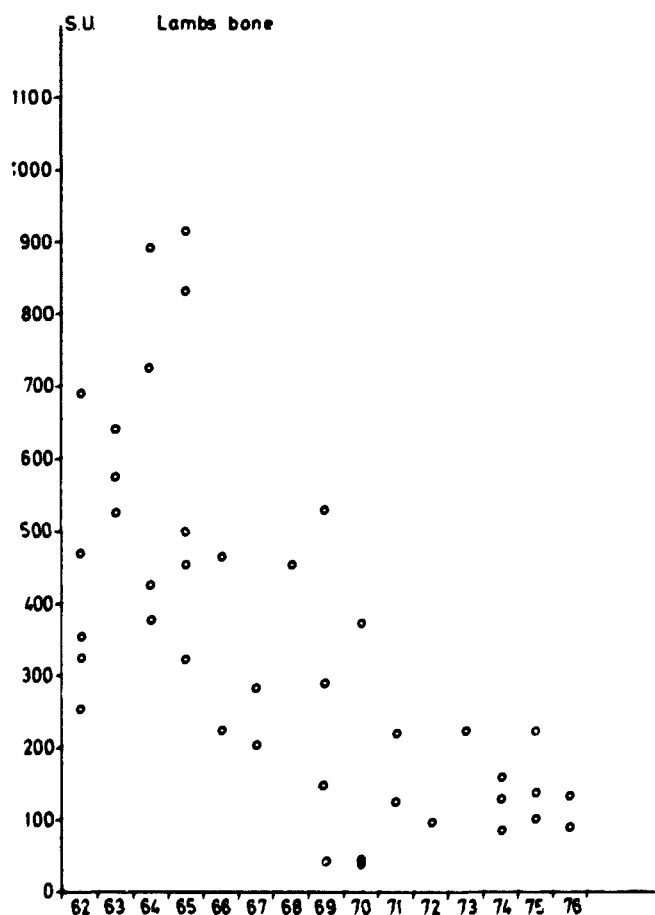


Fig. 2.4.1. S.U. in lamb bone collected in the Faroes, 1962-76.

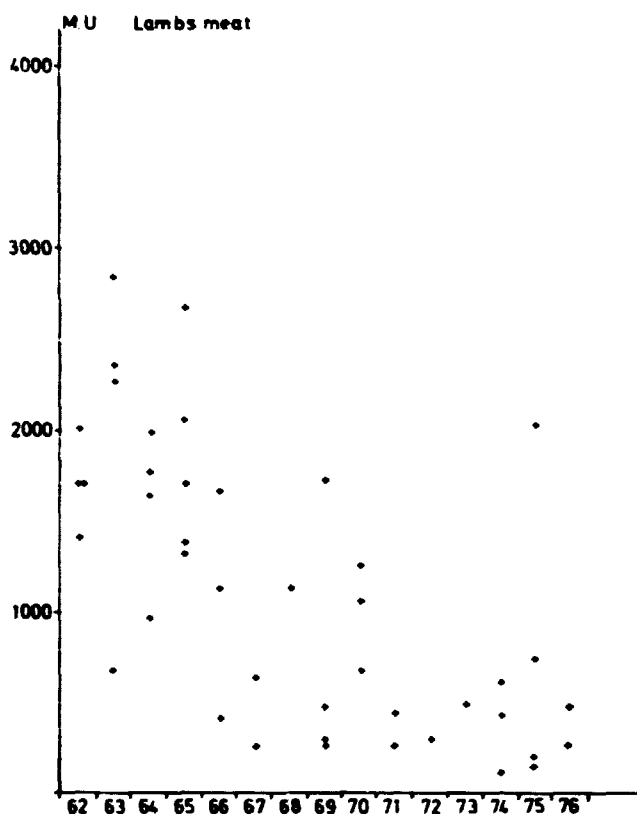


Fig. 2.4.2. M.U. in lamb meat collected in the Faroes 1962-76.

2.5. Strontium-90 and Caesium-137 in Sea Animals

Table 2.5.1 shows the ^{90}Sr and ^{137}Cs levels in fish collected in 1976 in the Faroes. The mean levels in *Gadus aeglefinus* and *Gadus callarias* were 0.16 pCi $^{90}\text{Sr}/\text{kg}$ and 14 pCi $^{137}\text{Cs}/\text{kg}$ (S.E.: 7) if we excluded the outlier the mean was 7 pCi $^{137}\text{Cs}/\text{kg}$ (S.E.: 0.8).

Table 2.5.1

Strontium-90 and Caesium-137 in fish from the Faroes in 1976

Sampling months	Species	Sample type	pCi $^{90}\text{Sr} \text{ kg}^{-1}$	pCi $^{90}\text{Sr} (\text{g Ca})^{-1}$	pCi $^{137}\text{Cs} \text{ kg}^{-1}$	pCi $^{137}\text{Cs} (\text{g K})^{-1}$
Jan.	<i>Gadus aeglefinus</i>	Meat	0.22	0.53	8.6	
March	" "	Meat			7.0	
July	" "	Meat			3.7	
Oct.	" "	Meat			7.6	
Nov.	" "	Meat			4.7	
Jan.	<i>Gadus callarias</i>	Meat	0.11	0.71	78	
March	" "	Meat			4.4	
July	" "	Meat			7.9	
Oct.	" "	Meat			6.6	
Nov.	" "	Meat			11.7	
	<i>Salmo iridius</i>	Meat	5.9	5.6	12.2	3.4
	<i>Salmo iridius</i>	Bone	-	5.0	-	-

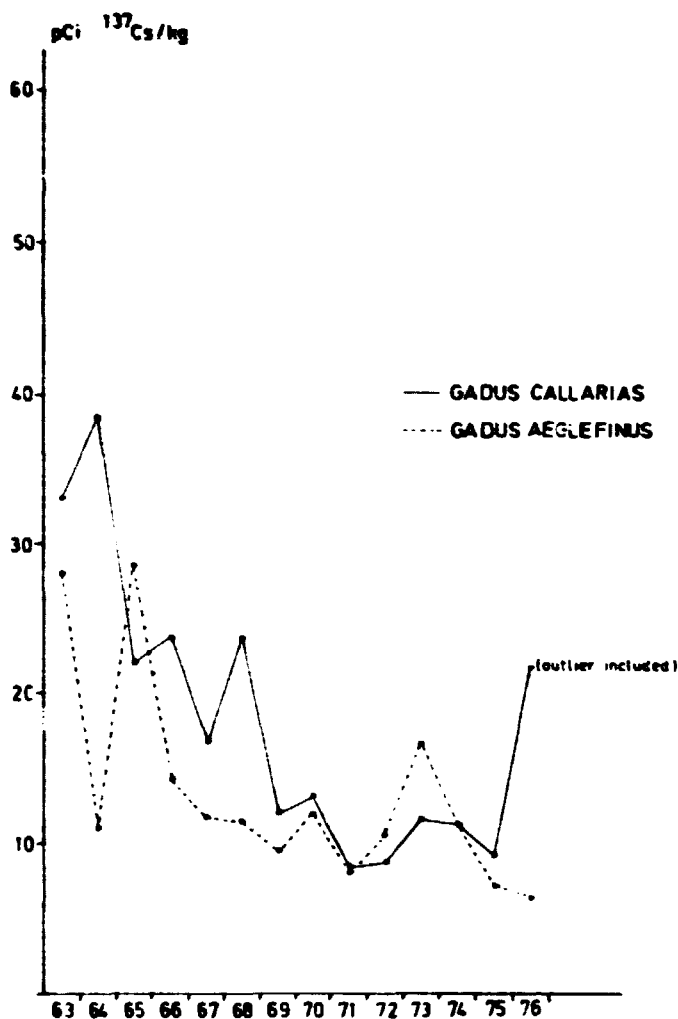


Fig. 2.5.1. Caesium-137 levels in meat of Cod and Haddock collected in the Faroes, 1962-76.

2.6. Strontium-90 in Drinking Water

Drinking-water samples were collected as previously but the sample were combined before the analysis as shown in the table¹⁾. Table 2.6.1 shows the results. As in previous years, drinking water from Thorshavn contained more ⁹⁰Sr than that from Tvørá (cf. the explanation in Risø Report No. 181¹⁾).

Figure 2.6.1 shows the bimonthly mean levels of ⁹⁰Sr in drinking water from the three locations since 1962.

The mean level in 1976 was 0.21 pCi ⁹⁰Sr/l, i.e. approx. half of the 1975 level.

Table 2.6.1

Strontium-90 in drinking water from the Faroes in 1976

pCi $^{90}\text{Sr l}^{-1}$

	Thorshavn	Klaksvig	Tværå
Jan.-June	0.34	0.26	0.143
July-Dec.	0.23	0.154	0.098
1976	0.29	0.21	0.121

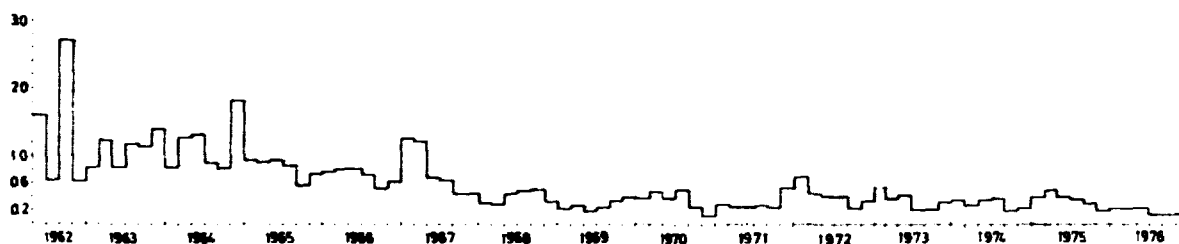


Fig. 2.6.1. Strontium-90 in drinking water, 1962-76 (mean of Thorshavn, Klaksvig and Tværå).

2.7. Strontium-90 and Caesium-137 in Miscellaneous Samples

2.7.1. Soil

No soil samples were collected in 1976 from the Faroes. From earlier years observations we estimate the accumulated fall-out at Thorshavn to be 63 mCi $^{90}\text{Sr}/\text{km}^2$ and that at Klaksvig to be 126 mCi $^{90}\text{Sr}/\text{km}^2$.

2.7.2. Sea Water

Surface sea water was collected near Thorshavn on four occasions in 1976. The ^{90}Sr mean level was 0.075 pCi $^{90}\text{Sr}/\text{l}$. (1 S.E.: 0.005).

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

The samples were also analysed for ^{137}Cs . The mean was 0.22 ± 0.06 pCi $^{137}\text{Cs}/\text{l}$. The $^{137}\text{Cs}/^{90}\text{Sr}$ ratio was: 3.0 ± 0.9 . North Sea water collected in 1976 showed a mean ratio of 2.7 ± 0.3 (cf. Risø Report No. 261²). We assume the enhanced ^{137}Cs levels to originate from Windscale.

Table 2.7.2

Strontium-90 and Caesium-137 in sea water from the Faroes in 1976

Sampling month	^{90}Sr pCi l ⁻¹	^{137}Cs pCi l ⁻¹	Salinity o/oo
March	0.06	0.30 A	34.7
June	0.08	0.33	34.6
Aug.	0.08	0.15 B	34.7
Nov.	0.08	0.08 B	34.6

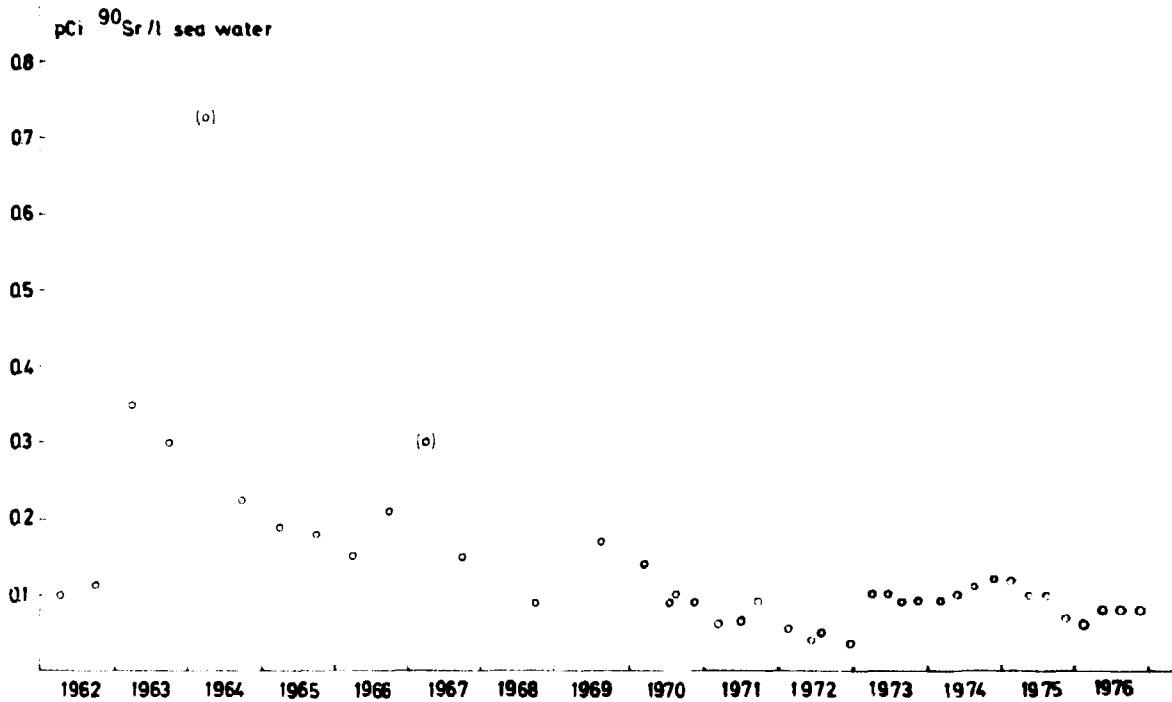


Fig. 2.7.2. Strontium-90 in Faroese sea water 1962-76.

2.7.3. Sea Plants

Three samples of fucus were obtained in 1976. Table 2.7.3 shows the ^{90}Sr and the ^{137}Cs determinations.

Table 2.7.3

Strontium-90 and Caesium-137 in sea plants from the Faroes in 1976

Sampling month	Species	pCi ^{90}Sr (g ash) ⁻¹	pCi ^{90}Sr (g Ca) ⁻¹	pCi ^{137}Cs (g ash) ⁻¹	pCi ^{137}Cs (g K) ⁻¹
June	<i>Fucus vesiculosus</i>	0.086	1.15	0.24 B	1.16 B
July I	<i>Fucus vesiculosus</i>	0.060 A	0.78 A	0.10 B	0.45 B
July II	<i>Fucus vesiculosus</i>	0.064	1.21	B.D.L.	B.D.L.

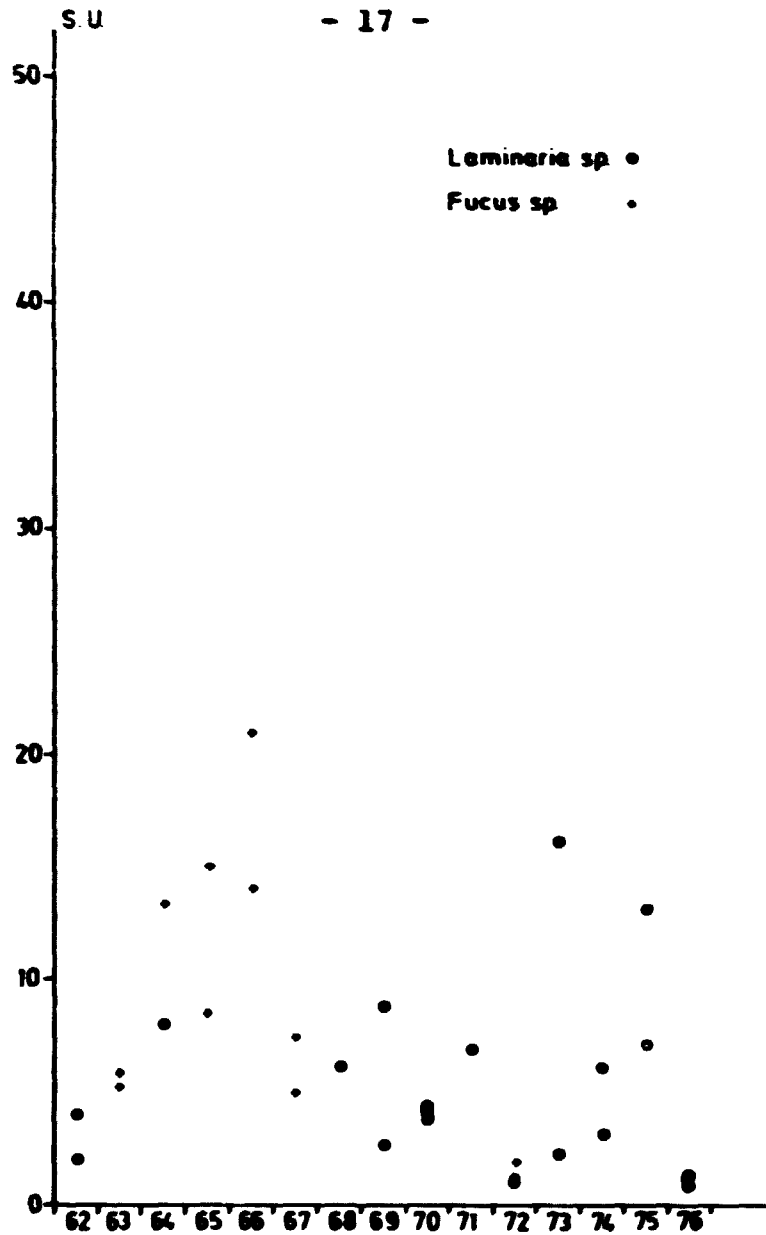


Fig. 2.7.3. S.U. in seaplants collected at Thorshavn 1962-76.

2.7.4. Vegetables

Table 2.7.4 shows the results of the ^{90}Sr and ^{137}Cs determinations.

The levels in potatoes were lower than those observed in 1975.

Table 2.7.4

Strontium-90 and Caesium-137 in vegetable, fruits and potatoes from the Faroes in 1976

Sampling month	Species	pCi ^{90}Sr kg $^{-1}$	pCi ^{90}Sr (g Ca) $^{-1}$	pCi ^{137}Cs kg $^{-1}$	pCi ^{137}Cs (g K) $^{-1}$
July	Carrot	16.7	79	8.5 A	3.5 A
July	Cabbage	5.4	15.4	5.8 A	1.7 A
Oct.	Potatoes	7.1	141	170	41

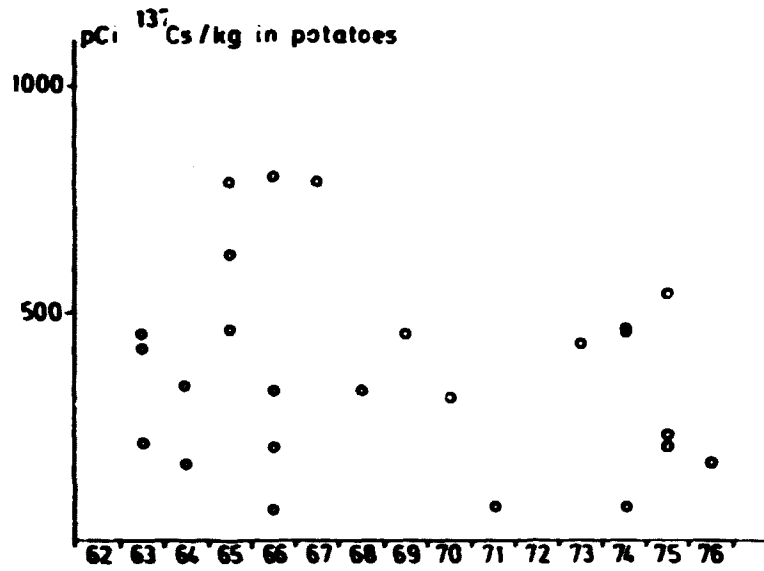


Fig. 2.7.4.1. Caesium-137 in Faroese potatoes collected, 1962-76.

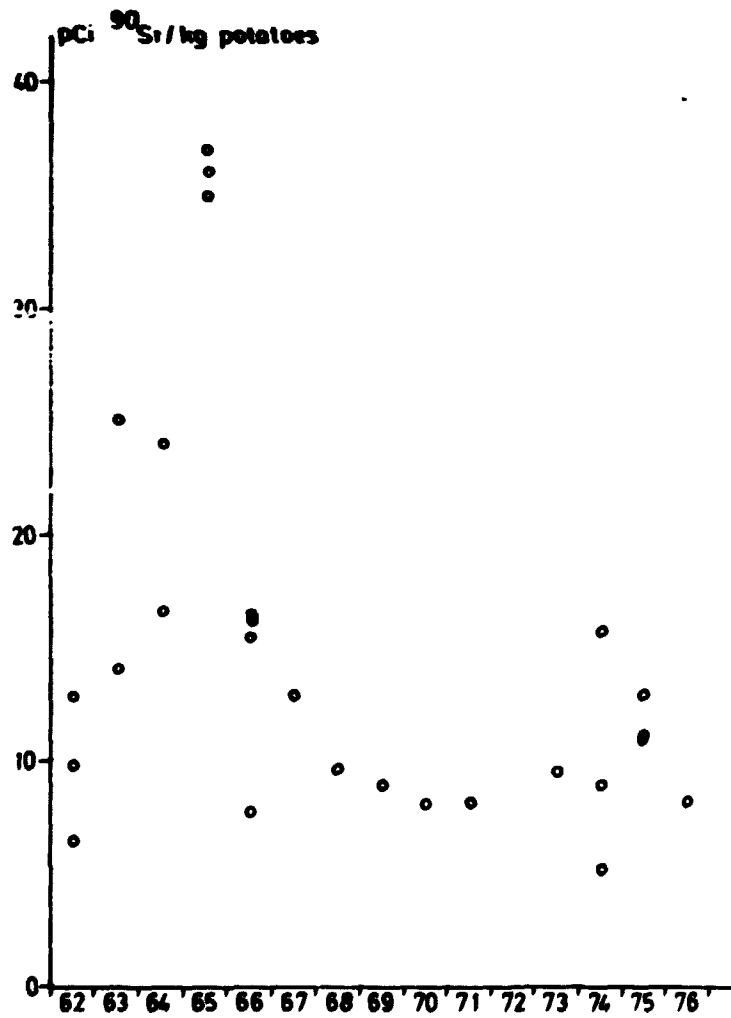


Fig. 2.7.4.2. Strontium-90 in Faroese potatoes collected, 1962-76.

2.7.5. Bread

As in previous years¹⁾, rye bread and white bread were collected at Thorshavn in June and December. The mean levels in white bread were 2.8 pCi ⁹⁰Sr/kg and 5.3 pCi ¹³⁷Cs/kg. The rye bread collected in 1976 contained on the average 11 pCi ⁹⁰Sr/kg and 8 pCi ¹³⁷Cs/kg, i.e. the bread levels were generally lower than the 1975 levels. The ⁹⁰Sr and ¹³⁷Cs levels in Faroese bread were nearly equal to the Danish²⁾.

Table 2.7.5

Strontium-90 and Caesium-137 in Faroese bread in 1976

Month	Sort	pCi ⁹⁰ Sr kg ⁻¹	pCi ⁹⁰ Sr (g Ca) ⁻¹	pCi ¹³⁷ Cs kg ⁻¹	pCi ¹³⁷ Cs (g K) ⁻¹
June	White bread	2.6	2.1	4.0 B	2.7 B
June	Rye bread	13.9	7.5	10.6	4.0
Dec.	White bread	3.0	3.7	6.5	4.3
Dec.	Rye bread	8.8	4.2	5.9	2.5

2.7.6. Eggs

Eggs were collected from Thorshavn in June and December 1976. Table 2.7.6 shows the results. The mean levels of hens eggs were 1.1 pCi ⁹⁰Sr/kg (1.7 S.U.) and 5 pCi ¹³⁷Cs/kg, i.e. lower than last year. The ⁹⁰Sr level in goats cheese was approx. 10 times higher than the ⁹⁰Sr level (S.U.) in cows milk, whereas the ¹³⁷Cs levels were nearly the same in the two products (cf. table 2.3.1).

Table 2.7.6

Strontium-90 and Caesium-137 in eggs and cheese from the Faroes in 1976

Month	Species	pCi ⁹⁰ Sr kg ⁻¹	pCi ⁹⁰ Sr (g Ca) ⁻¹	pCi ¹³⁷ Cs kg ⁻¹	pCi ¹³⁷ Cs (g K) ⁻¹
June	Hens egg	1.33	2.2	3.9 B	2.8 B
June	Ducks egg	1.67	2.3	12.0	8.9
Dec.	Hens egg	0.82 A	1.21 A	6.4 A	5.4 A
June	Goat's cheese	192	165	181	102

2.8. Humans

2.8.1. Strontium-90 in Human Bone

In 1976 eight human bone samples were analysed from Dronning Alexandrine's Hospital in Thorshavn. Table 2.8.1 shows the results.

The mean level in bone of newborn infants was 1.0 pCi $^{90}\text{Sr/g Ca}$, i.e. approx. half that of previous years observations¹⁾.

Table 2.8.1

Strontium-90 in human vertebrae collected
in the Faroes in 1976

Age	Month of death	Sex	pCi $^{90}\text{Sr (g Ca)}^{-1}$
~ 0	~ 4	F	1.16*
~ 0	~ 5	F	0.77**
74 years	5	F	2.17

* 4 samples combined in one analysis
** 3 samples combined in one analysis

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 1962¹⁾ of a daily per capita intake of approx. 3000 calories.

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 1976 was $1.2 \cdot (0.75 \cdot 16.4 + 0.25 \cdot 3.4) = 15.8$ pCi $^{90}\text{Sr}/\text{kg}$, and the ^{137}Cs content was $0.75 \cdot 189 + 0.25 \cdot 4.3 = 143$ pCi $^{137}\text{Cs}/\text{kg}$ (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: 28.9 pCi $^{90}\text{Sr}/\text{kg}$ and 3.1 pCi $^{137}\text{Cs}/\text{kg}$.

3.4. Grain Products

As most grain products are imported from Denmark, the Danish figures for 1976²⁾ 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 1976 is 10.7 pCi $^{90}\text{Sr}/\text{kg}$ and 8.9 pCi $^{137}\text{Cs}/\text{kg}$.

3.5. Potatoes

All potatoes consumed in the Faroes are assumed to be of local origin. The values from table 2.7.4.2 were used, i.e. 7.1 pCi $^{90}\text{Sr}/\text{kg}$ and 170 pCi $^{137}\text{Cs}/\text{kg}$.

3.6. Other Vegetables and Fruit

As the amount of vegetables and fruit grown in the Faroes is limited, the Danish figures from 1976²⁾ were used. Thus the mean contents in vegetables other than potatoes were 6.6 pCi ⁹⁰Sr/kg and 2.8 pCi ¹³⁷Cs/kg, and the mean contents in fruit were 2.3 pCi ⁹⁰Sr/kg and 2.0 pCi ¹³⁷Cs/kg.

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 8.7 pCi ⁹⁰Sr/kg and 0.79 nCi ¹³⁷Cs/kg (cf. 2.4). Whale meat from 1975 contained 0.44 pCi ⁹⁰Sr/kg and 19 pCi ¹³⁷Cs/kg, sea birds from 1975¹⁾ and eggs (cf. 2.7.6): 1.1 pCi ⁹⁰Sr/kg and 1.1 pCi ⁹⁰Sr/kg, and 10 and 5 pCi ¹³⁷Cs/kg respectively.

Hence we estimate the mean content of ⁹⁰Sr in meat and eggs consumed in 1976 to be

$$0.50 \cdot 8.7 + 0.25 \cdot 0.44 + 0.25 \cdot \left(\frac{1.1 + 1.1}{2}\right) = 4.7 \text{ pCi } ^{90}\text{Sr/kg}$$

and the ¹³⁷Cs content to be

$$0.50 \cdot 790 + 0.25 \cdot 19 + 0.25 \cdot 7.5 = 402 \text{ pCi } ^{137}\text{Cs/kg.}$$

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 0.16 pCi ⁹⁰Sr/kg and 14 pCi ¹³⁷Cs/kg.

3.9. Coffee and Tea

The Danish figures for 1976²⁾ were used, i.e. 7.3 pCi ⁹⁰Sr/kg and 36 pCi ¹³⁷Cs/kg.

3.10. Drinking Water

The mean value found in table 2.6.1 was used, i.e. 0.21 pCi ⁹⁰Sr/l. The ¹³⁷Cs content was estimated to be approx. one fourth (the ratio found in New York tap water in 1964⁴⁾) of the ⁹⁰Sr content, i.e. 0.05 pCi ¹³⁷Cs/l.

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 Faroes in 1976

Type of food	Annual quantity in kg	pCi ^{90}Sr per kg	Total pCi ^{90}Sr	Percentage of total ^{90}Sr in food
Milk and cream	146	15.8	2307	50.7
Cheese	7.3	28.9	211	4.7
Grain products	80	10.7	856	18.8
Potatoes	91	7.1	646	14.2
Vegetables	20	6.6	132	2.9
Fruit	18	2.3	41	0.9
Meat and eggs	37	4.7	174	3.8
Fish	91	0.16	15	0.3
Coffee and tea	7.3	7.3	53	1.2
Drinking water	548	0.21	115	2.5
Total			4550	

The mean annual calcium intake is estimated to be 600 g (approx. 200-250 g of creta praeparata). Hence the pCi ^{90}Sr /g Ca ratio in the total Faroese diet was 7.6 S.U., and the mean daily intake was 12.5 pCi ^{90}Sr .

Table 3.2

Estimate of the mean content of ^{137}Cs in the human diet
in the Faroes in 1976

Type of food	Annual quantity in kg	pCi ^{137}Cs per kg	Total pCi ^{137}Cs	Percentage of total ^{137}Cs in food
Milk and cream	146	143	20878	38.9
Cheese	7.3	3.1	23	0.0
Grain products	80	8.9	712	1.3
Potatoes	91	170	15470	28.9
Vegetables	20	2.8	56	0.1
Fruit	18	2.0	36	0.1
Meat and eggs	37	402	14874	27.7
Fish	91	14	1274	2.4
Coffee and tea	7.3	36	263	0.5
Drinking water	548	0.05	27	0.1
Total			53613	

The mean annual intake of potassium is estimated to be approx. 1200 g. Hence the pCi $^{137}\text{Cs}/\text{g K}$ ratio becomes 45 and the daily intake of ^{137}Cs 147 pCi.

3.11. Discussion

Figure 3 shows the Faroese diet levels since 1962.

The 1976 ^{90}Sr level in the total diet was three quarter of the 1975 concentration, and the ^{137}Cs level was approx. half of that observed in 1975.

The main contributors to the ^{90}Sr content in the Faroese diet were milk products, cereals and potatoes, which together accounted for approx. 9/10 of the total ^{90}Sr content in the diet in 1976. As regards ^{137}Cs , milk products, meat (lamb) and potatoes were the most important contributors. In 1976, 96% of the total ^{137}Cs content in the diet originated from these products.

The Faroese mean diet contained 1.9 times as much ^{90}Sr and approx. 13 times as much ^{137}Cs as the Danish diet in 1976²⁾.

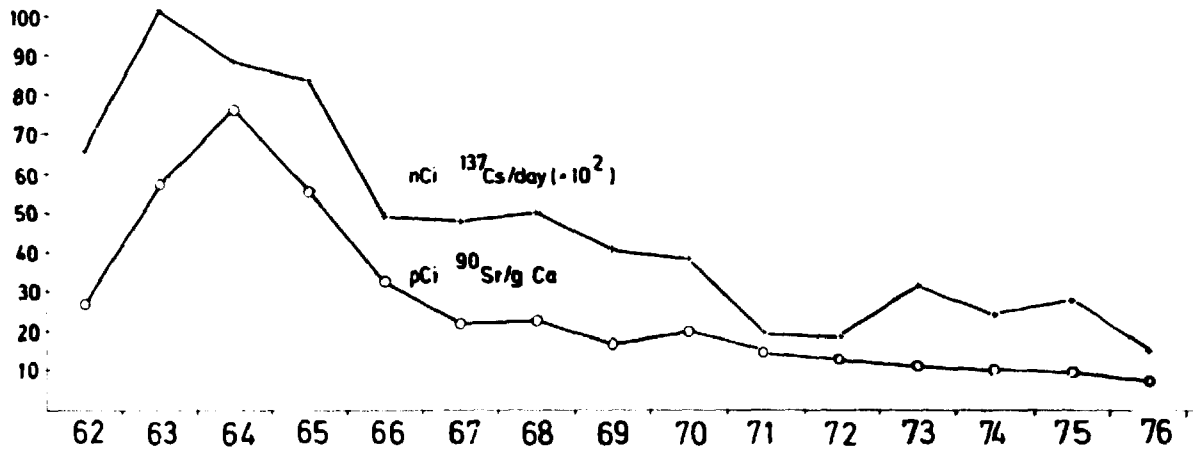


Fig. 3. Strontium-90 and Caesium-137 in Faroese diet, 1962-76.

4. CONCLUSION

4.1.

The ^{90}Sr fall-out rate in the Faroes in 1976 was approx. $0.4 \text{ mCi } ^{90}\text{Sr}/\text{km}^2$. The accumulated fall-out by the end of 1976 was estimated at approx. $94 \text{ mCi } ^{90}\text{Sr}/\text{km}^2$ (the mean at Thorshavn and Klaksvig).

4.2.

The mean level of ^{90}Sr in Faroese milk was 16.4 S.U. or $20 \text{ pCi } ^{90}\text{Sr}/\text{l}$. The ^{137}Cs concentration was $115 \text{ pCi } ^{137}\text{Cs}/\text{g K}$, or $189 \text{ pCi } ^{137}\text{Cs}/\text{l}$.

Lamb contained $8.7 \text{ pCi } ^{90}\text{Sr}/\text{kg}$ and $0.79 \text{ nCi } ^{137}\text{Cs}/\text{kg}$. Fish showed mean levels of $0.16 \text{ pCi } ^{90}\text{Sr}/\text{kg}$ and $14 \text{ pCi } ^{137}\text{Cs}/\text{kg}$.

The mean content of ^{90}Sr in drinking water was $0.21 \text{ pCi}/\text{l}$.

The mean daily per capita intakes resulting from the Faroese diet in 1976 were estimated at $12.5 \text{ pCi } ^{90}\text{Sr}$ (7.6 S.U.) and $147 \text{ pCi } ^{137}\text{Cs}$ ($45 \text{ pCi } ^{137}\text{Cs}/\text{g K}$).

4.3.

From the Faroese and Danish diet estimates and from measurements on Faroese and Danish bones, the Faroese bone levels in 1976 were estimated as follows: in newborn infants: approx. 1.0 S.U.; in small children (1 month - 4 years): approx. 2 S.U. (depending upon the amount of locally produced milk in the diet of the infants); in children and teenagers (5 - 19 years): approx. 2 S.U.; in adult vertebrae: approx. 2 S.U.

The mean content of ^{137}Cs in the Faroese adult was estimated at approx. $25\text{-}50 \text{ pCi } ^{137}\text{Cs}/\text{g K}$. This estimate is based on whole-body measurements of six adults in 1974 and on the diet estimates in 1974, 1975 and 1976.

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REFERENCES

- 1) Environmental Radioactivity in the Faroes 1962-1975. Risø Reports Nos. 64, 86, 108, 131, 155, 181, 202, 221, 246, 266, 292, 306, 324 and 346 (1963-1976).
- 2) A. Aarkrog and J. Lippert, Environmental Radioactivity in Denmark in 1976. Risø Report No. 361 (1977).
- 3) A. Aarkrog and J. Lippert, Environmental Radioactivity in Greenland in 1976. Risø Report No. 363 (1977).
- 4) E.P. Hardy, Jr., and Joseph Rivera, Fallout Program Quarterly Summary Report (March 1, 1965, through June 1, 1965). HASL-161 (1965).
- 5) UNSCEAR, Ionizing Radiation: Levels and Effects. Vol. 1, New York, 1972.