Environmental radioactivity in Denmark in 1969

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by A. Aarkrog and J. Lippert

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Environmental Radioactivity in Denmark in 1969

by

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Research Establishment Risö
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Abstract

The present report deals with the measurement of fall-out radioactivity in Denmark in 1969. Sr-90 was determined in samples from all over the country of precipitation, soil, ground water, sea water, grass, dried milk, fresh milk, grain, bread, potatoes, vegetables, fruit, total diet, drinking water, and human bone. Furthermore Sr-90 was determined in local samples of air, rain water, grass, sea plants, fish, meat, and human milk. Cs-137 was determined in milk, grain products, potatoes, vegetables, fruit, total diet, meat, and human milk samples, and Cs-137 was measured by whole-body counting in persons from a control group at Risö. Estimates of the mean contents of radiostrontium and radiocaesium in the human diet in Denmark in 1969 are given. The γ-background was measured regularly at locations around Risö, at ten of the State experimental farms and in an area in Zealand, one in Jutland where future nuclear power plants might be located and along the shores of the Great Belt. Finally the report includes, as previously, regular surveys of environmental samples from the Risö area.

[illegible]
[illegible]

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CONTENTS

ABBREVIATIONS AND UNITS

FP	Fission products
pCi	picocurie, 10^{-12} Ci, μμCi
nCi	nanocurie, 10^{-9} Ci, mμCi
mCi	millicurie, 10^{-3} Ci
MPC	maximum permissible concentration
c/min	counts per minute
d/min	disintegrations per minute
c/h	counts per hour
μR	micro-roentgen, 10^{-6} roentgen
S. U.	pCi Sr-90/g Ca.
O. R.	observed ratio
M. U.	pCi Cs-137/g K.
V	vertebrae
m	male
f	female
n Sr	natural (stable) Sr
eqv. μg	equivalents g uranium: activity as from 1 μg U(~90 d/h)
eqv. mg KCl	equivalents mg KCl: activity as from 1 mg KCl (~0.88 d/min)
S. D.	standard deviation: $\sqrt{\frac{\Sigma(x-x_1)^2}{(n-1)}}$
S. E.	standard error: $\sqrt{\frac{\Sigma(x-x_1)^2}{n(n-1)}}$
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: $\Sigma(x-x_1)^2$
f	degrees of freedom
s^2	the variance
v^2	the ratio between the variance in question and the residual variance
P	probability fractile of the distribution in question
η	coefficient of variation

Samples:

H:	sea water
J:	soil
L:	air
B:	bed soil
Å:	eel
PG:	grass
PH:	sea plants
D:	drain water
S:	waste water
R:	precipitation
M:	milk

1. INTRODUCTION

1.1.

The present report is the thirteenth of a series of periodical reports (cf. ref. 1) dealing with measurements of radioactivity in Denmark.

The programme is nearly unchanged as compared with 1968. Drinking water and sea water were collected only in June. Virumgård was in the grain and potato sampling replaced by Ledreborg. In the dried-milk programme Kalundborg was replaced by Ringsted, and instead of dried milk from Nakskov fresh milk was sampled from three dairies on Lolland, Falster and Mön.

1.2.

The methods of radiochemical analysis[2-4] and the statistical treatment of the results[5] are still based on the principles established in previous reports[1].

1.3.

The report does not include detailed tables of the total β measurements from the environmental control of the Risö site. These tables are available in the form of microcards at the library of the Danish Atomic Energy Commission at Risö.

1.4.

The report contains no information as regards sample collection and analysis except in the cases where these procedures have been altered.

1.5.

In 1969 the personnel of the Environmental Control Section of the Health Physics Department consisted of one chemist, ten laboratory technicians, two men for sample collection, and two women for washing-up. As in the previous years, important assistance was obtained from the Section for Electronics Development, not only in the maintenance of the counting equipment, but also in the interpretation of the γ-spectra.

1.6.

The composition of the Danish average diet used in this report is identical with that proposed in 1962 by the nutritional consultant to the Atomic Energy Commission, Professor E. Hoff-Jørgensen, Ph.D.

2. ORGANIZATION AND FACILITIES

Only minor alterations have taken place in the sample collection, preparation, analysis, and counting[1, 6-8] as compared with the previous years.

3. RISÖ ENVIRONMENTAL MONITORING IN 1969

3.1. Gross β activity

3.1.1. Sea Water

Fig. 3.1.1.1 shows the sample locations in Roskilde Fjord. Fig. 3.1.1.2 shows the control chart for H I. The yearly mean for H I in 1969 was 53 eqv. mg KCl/2.5 g (in 1968: 57), for H III-VI: 52 eqv. mg KCl/2.5 g (in 1968: 57) and for H VII-X: 53 eqv. mg KCl/2.5 g (in 1968: 56). Fig. 3.1.1.3 shows the mean levels of radioactivity in sea salt since 1957.

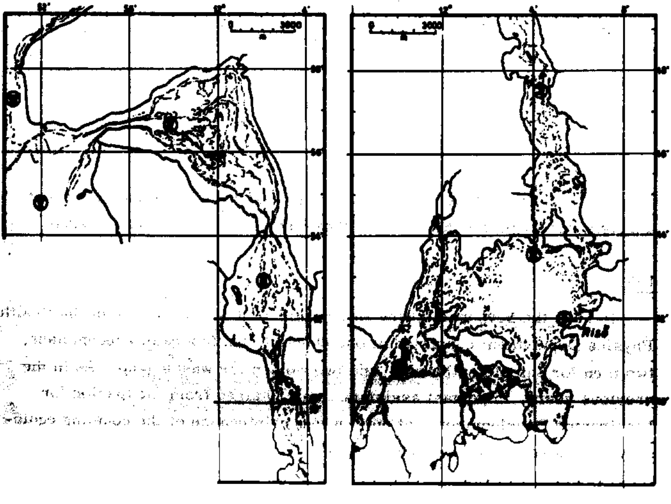


Fig. 3.1.1.1. Roskilde Fjord.

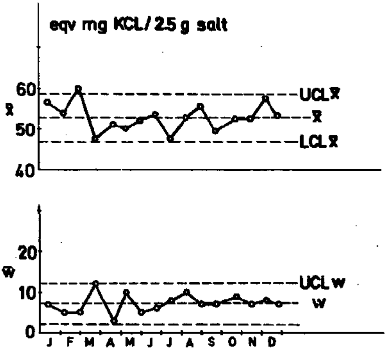


Fig. 3.1.1.2. Control chart for HI, 1969.

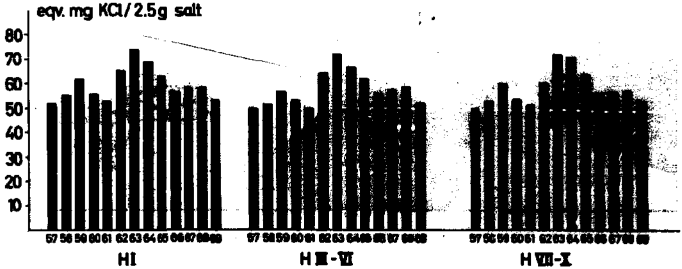


Fig. 3.1.1.3. Mean radioactivity in sea water, 1957-69.

3.1.2. Soil

Figs. 3.1.2.1 and 3.1.2.2 (the coloured map) show the sample locations for land samples in the environment of Risø.

The yearly mean for J I in [illegible] was [illegible] eqv. mg KCl/[illegible]0 g soil (in 1968: 138), for J II-III: 127 eqv. [illegible] (in [illegible]) and for J IV-V: 127 eqv. mg KCl/3.0 g (in [illegible]) [illegible] .1.2.3 [illegible] levels of radioactivity in soil [illegible] a significant variation between [illegible] locations (P [illegible] not [illegible] een days was significant for J I [illegible] (P > 99.95%) and not significant for J IV-V. The relative residual error of the soil activity determinations [illegible].

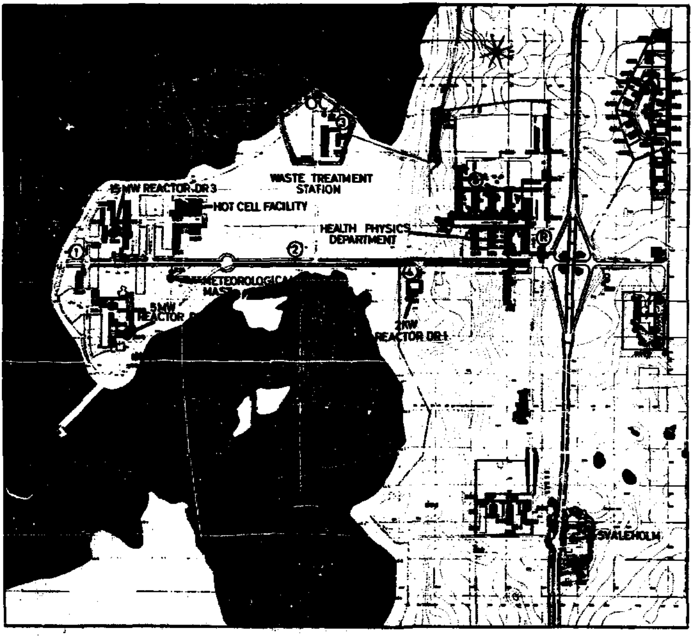


Fig. 3.1.2.1. The Risö Research Establishment.

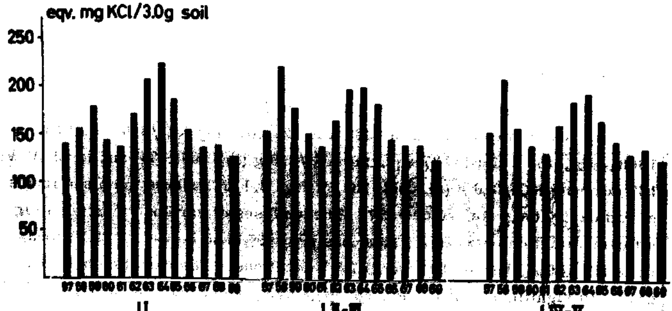


Fig. 3.1.2.2. Mean radioactivity in soil, 1957-69.

3.1.3. Air

Fig. 3.1.3.1 shows the diagram for FP activity in air samples in 1969. The mean value for the year was 0.27 eqv. mg KCl/m^3 as compared with 0.20 eqv. mg KCl/m^3 in 1968.

Fig. 3.1.3.2 shows the mean FP levels in air since 1957.

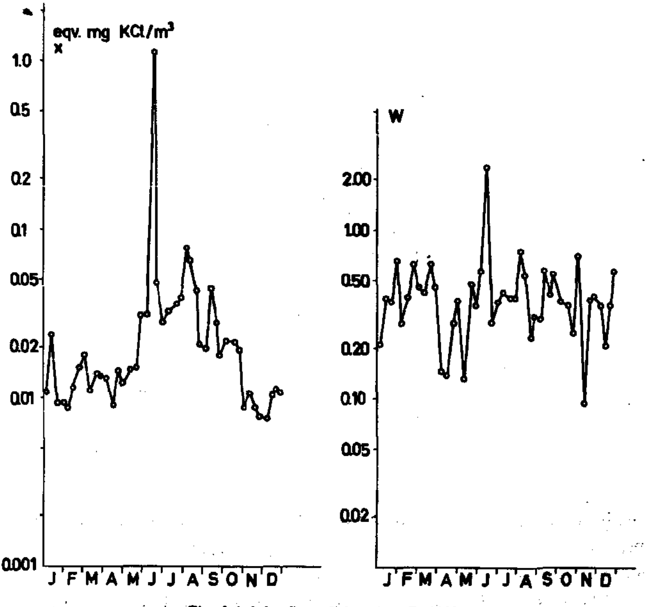


Fig. 3.1.3.1. Control chart for LF, 1969.

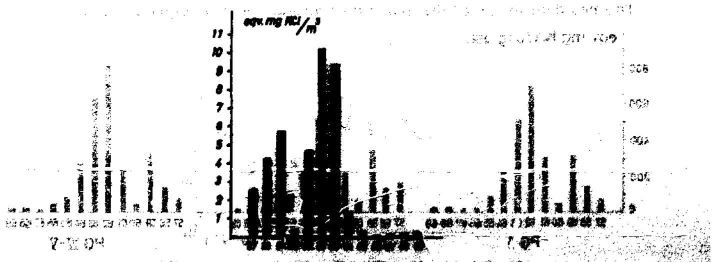


Fig. 3.1.3.2. Mean radioactivity in air, 1957-69.

3.1.4. Bed Soil from the Fjord

The mean activity in bed soil B I was 136 eqv. mg KCl/3.0 g ash in 1969 as compared with 151 eqv. mg KCl/3.0 g in 1968. Fig. 3.1.4.1 shows the mean levels for B I since 1957.

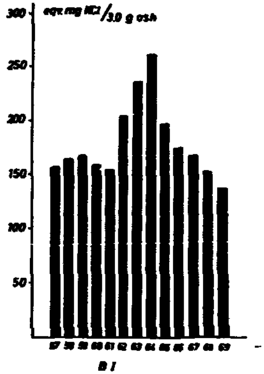


Fig. 3.1.4.1. Mean radioactivity in bed soil, 1957-69.

3.1.5. Fish

No fish samples from Roskilde Fjord were measured in 1969.

3.1.6. Grass

The mean values were in 1969 for PG I: 23 eqv. mg KCl/0.1 g grass ash (in 1968: 28), for PG II-III: 22 eqv. mg KCl/0.1 g (in 1968: 20) and for PG IV-V: 21 eqv. mg KCl/0.1 g (in 1968: 22). Fig. 3.1.6.1 shows the mean activities in grass ash since 1957.

The analysis of variance revealed no significant variations between locations. The variation between days was highly significant (P ⟩ 99.95%). The residual error of the grass determinations was approx. 22%.

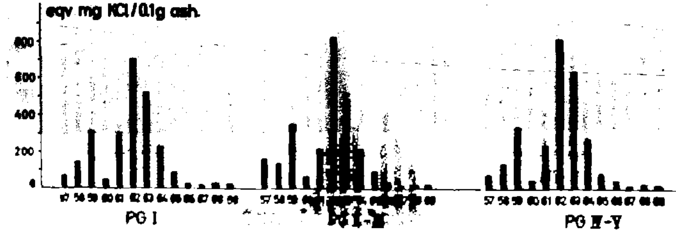


Fig. 3.1.6.1. Mean FP-radioactivity in grass ash, 1957-69.

3.1.7. Sea Plants

The mean FP level in 1969 in Fucus vesicolosus (PH I) was 1 eqv. mg KCl/0.1 g ash (2.5 in 1968), and in Zostera marina (PH III and PH IX) we found 0 eqv. mg KCl/0.1 g ash (5 in 1968). Fig. 3.1.7.1 shows the mean FP radioactivity levels in sea plants since 1958.

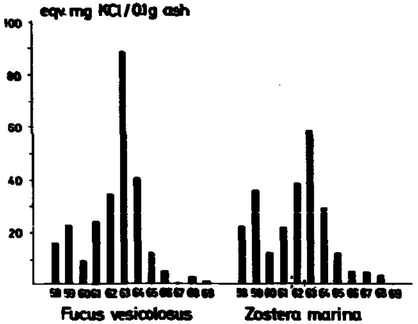


Fig. 3.1.7.1. Mean FP-radioactivity in sea plants, 1958-69.

3.1.8. Fresh Water

Fig. 3.1.8.1 contains the control charts for S (cf. fig. 3.1.2.2). The yearly means for D I, D II, D IV, and S in 1969 were 61 eqv. mg KCl/1 (1968: 38), 25 eqv. mg KCl/1 (1968: 33), 33 eqv. mg KCl/1 (1968: 32), and 56 eqv. mg KCl/1 (1968: 35) respectively. Fig. 3.1.8.2 shows the activity in drainage water (D) and sewage water (S). The surplus activity in sewage water was due to minor amounts of S-35 released in Sept.-Oct. from the Waste Treatment Station (cf. fig. 3.1.8.1).

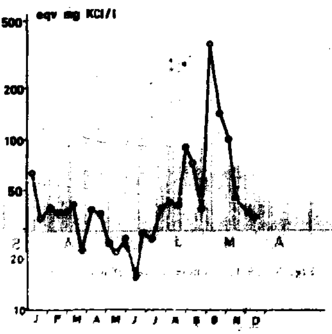


Fig. 3.1.8.1. Control chart for S, 1969.

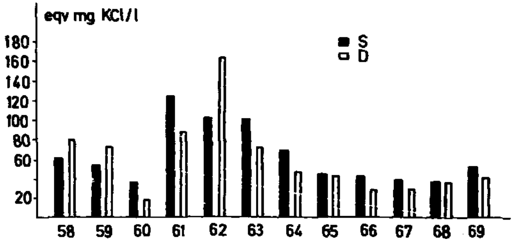


Fig. 3.1.8.2. Mean radioactivity in fresh water, 1958-69.

3.1.9. Rain Water

Figs. 3.1.9.1 and 3.1.9.2 show the specific FP level in and the total fall-out from rain water collected daily at Risö in 1969. The total fall-out in 1969 was measured at $0.053 \cdot 10^6$ eqv. mg KCl/m^2, and the annual mean concentration in rain water at Risö was 134 eqv. mg KCl/l. In 1968 the corresponding figures were $0.048 \cdot 10^6$ and 134 respectively.

Fig. 3.1.9.3 shows the specific activity in rain water since 1957.

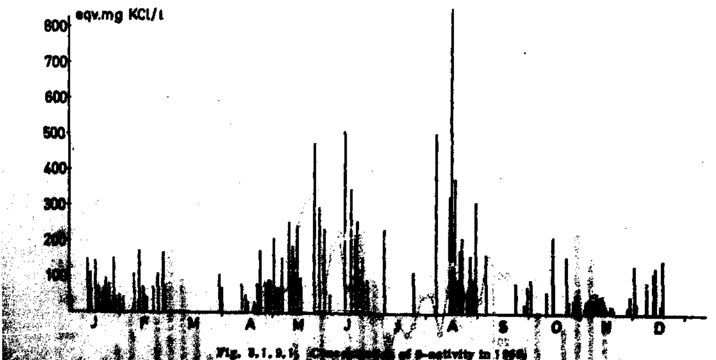


Fig. 3.1.9.1. Concentration of β-activity in 1969.

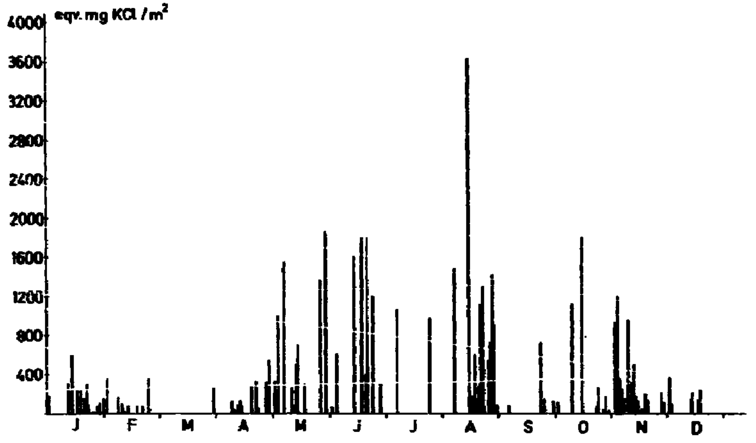


Fig. 3.1.9.2. Total fall-out from precipitation in 1968.

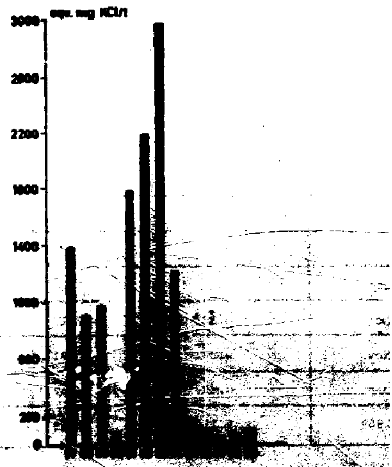


Fig. 3.1.9.3. Specific activity in precipitation, [illegible]

3.2. Radiochemical β Analysis

3.2.1. Air

Table 3.2.1 shows the Sr-90 and Sr-89 levels in air collected at Risö in 1969. Two collections were made, one with the daily air sampler furnished with paper filters (cf. 3.1.1) and one with the half-weekly air sampler furnished with glass-fibre filters (cf. 3.3).

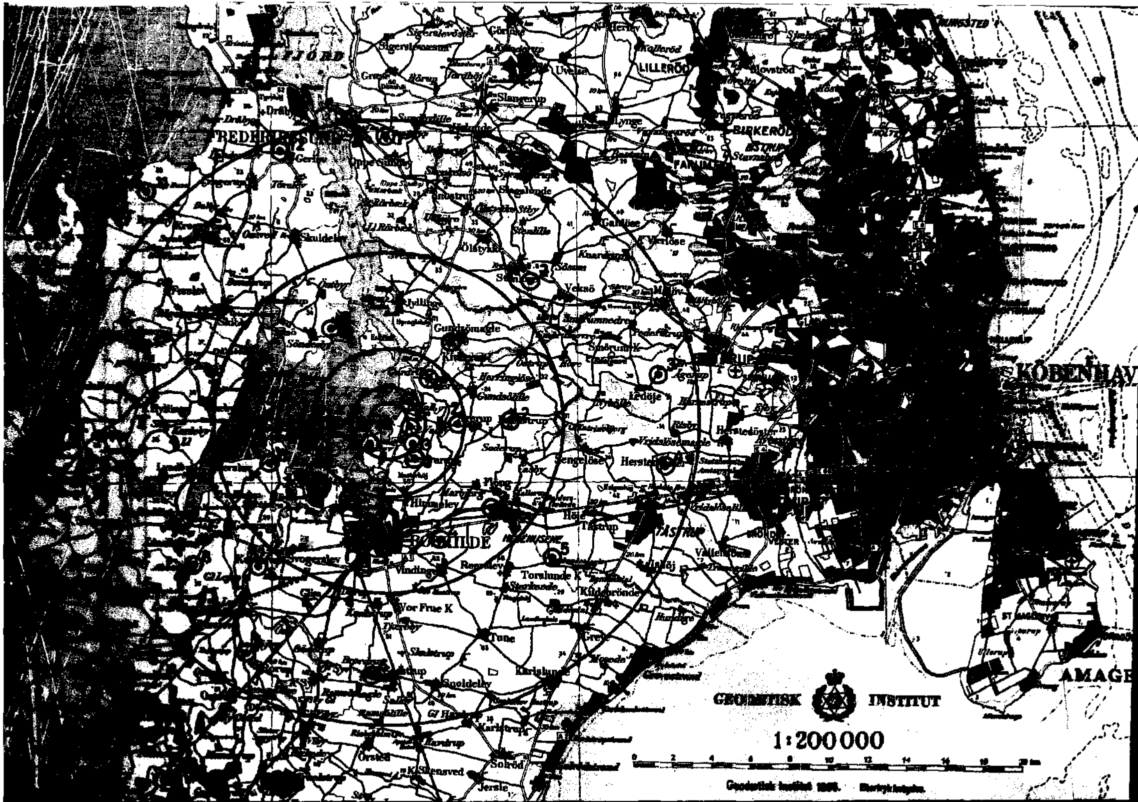
The mean activity level for 1969 found from the two collections was 1.4 ± 0.2 pCi Sr-90/$10^3 m^3$, i.e. equal to the level in 1968. The mean peak activity of the two collections in 1969 was measured in July-August to be 2.3 pCi Sr-90/$10^3 m^3$. Sr-89 from the Chinese tests was detectable throughout the year.

Fig. 3.2.1.1 shows the Sr-90 levels in air since 1957.

Table 3.2.1

Sr-90 (and Sr-89) in air collected at Risö in 1969, pCi Sr-90/$10^3 m^3$

Month	Daily air filters (paper filters)	Monthly air filters (glass-fibre filters)	Sr-89/Sr-90 mean ratio
Jan.	0.85	0.81	2.5
Feb	1.23	1.02	0.3
Mar.	1.22	1.86	2.0
Apr.	0.78	1.19	1.6
May	0.91	1.45	5.6
June	1.55	2.84	6.7
July	1.39	2.98	3.8
Aug.	2.72	3.39	2.7
Sep.	1.27	2.03	3.4
Oct.	0.88	1.12	2.6
Nov.	0.37	0.81	0.8
Dec.	0.58	0.62	1.8
1969	1.15	1.59	-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Gundsømagle
Jyllinge
Skuldelev
Sengeløse
Herstedøster
Hedehusene
Tune
Karlslunde
Solrød
Jersie
Vor Frue K
Snoldelev
Toralunde K
Kildebrønde
Himmelev
Vindinge
Ølstykke
Veksø
Gerlev
Tørslev
Svogerslev
Sigerslevøster
Vallensbæk
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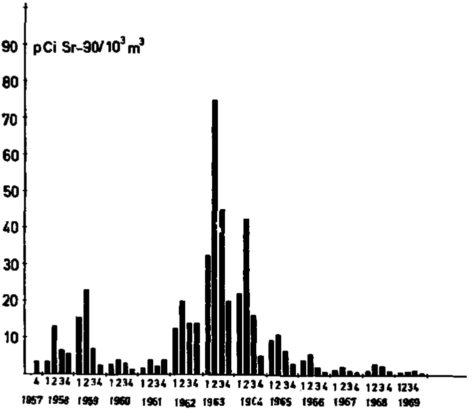


Fig. 3.2.1.1. Sr-90 in air, 1957-69.

3.2.2. Grass

Table 3.2.2 shows the Sr-90 content in grass ash from Zealand in 1969. The mean Sr-90 activity was 3.2 pCi Sr-90/g ash or 54 S.U. as compared with 4.1 pCi/g ash or 72 S.U. in 1968, i.e. the 1969 level was three fourths of the 1968 level. Fig. 3.2.2.1 shows the Sr-90 levels in grass since 1957.

Table 3.2.2

Sr-90 in grass from Zealand, 1969

Month	pCi Sr-90/g ash	pCi Sr-90/g Ca
Jan. - Mar.	3.80 ± 0.42	77 ± 8
Apr. - June	2.64 ± 0.50	57 ± 10
July - Sep.	4.31 ± 0.39	55 ± 4
Oct. - Dec.	2.07	28
1969	3.20	54
The error term is the S.E. of double determinations		

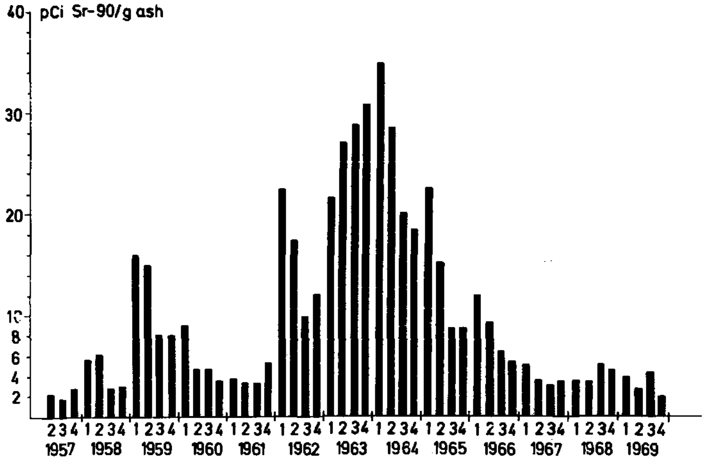


Fig. 3.2.2.1. Sr-90 in grass ash, 1957-68.

3.2.3. Sea Plants

Table 3.2.3 shows the Sr-90 content in sea plants collected from Roskilde Fjord in 1969.

The level in Fucus vesicolosus was 5 S.U. in 1969 as compared with

Table 3.2.3

Sr-90 in sea plants from Roskilde Fjord, 1969

Sampling period	Location	Species	pCi Sr-90/g Ca	pCi Sr-90/g ash
Jan.-June	I	Fucus vesicolosus	7.7 ± 1.6	0.96 ± 0.05
	III	Zostera marina	1.7	0.11
	IX	- " -	2.35 ± 0.15	0.17 ± 0.04
July-Sep.	I	Fucus vesicolosus	1.8	0.19
	III	Zostera marina	2.5 ± 0.6	0.16 ± 0.02
	IX	- " -	3.5	0.22
1969	I	Fucus vesicolosus	4.8	0.58
	III and IX	Zostera marina	2.5	0.16

The error term is the S.E. of the mean of two samplings carried out within two months of each other.

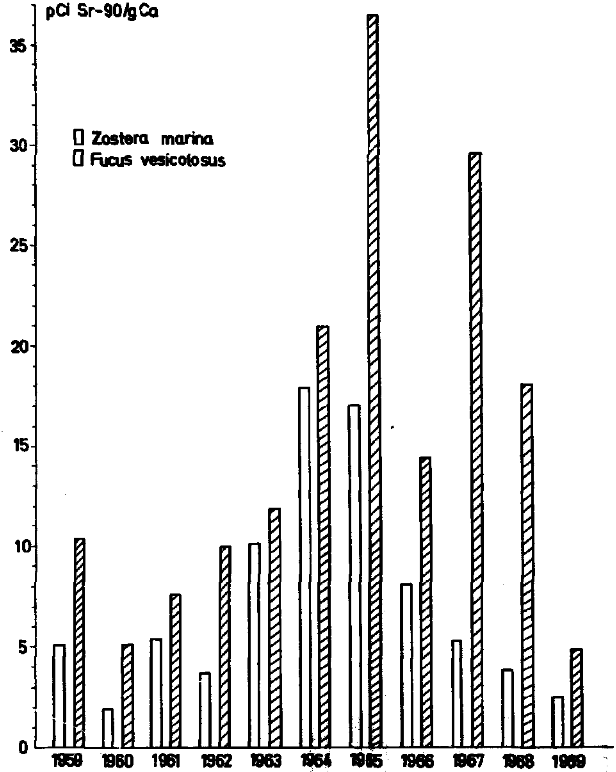


Fig. 3.2.3. Sr-90 in sea plants, 1959-69.

18 S. U. in 1968, and in Zostera marina the 1969 mean content was 2.5 S. U. as compared with 4 S. U. in 1968.

Fig. 3.2.3 shows the S. U. levels in sea plants since 1959. It is evident that Fucus vesicolosus contains more Sr-90 per g calcium than Zostera marina.

3.2.4. Rain Water

Table 3.2.4.1 shows the radiostrontium level in rain water collected at Risö in 1969. The total Sr-90 fall-out in 1969 was 0.82 mCi Sr-90/km^2 (429 mm precipitation), and the mean concentration in the rain water was 1.9 pCi Sr-90/l. In 1968 we measured 0.99 mCi Sr-90/km^2 (552 mm precipitation) and 1.8 pCi Sr-90/l, i.e. the 1969 levels were nearly equal to those of 1968.

Fig. 3.2.4.1 shows the Sr-90 levels in rain water since 1959.

At five sampling locations (1-5) in zone I (cf. fig. 3.1.2.1) ion-exchange columns collected monthly samples of precipitation along with the bottle collectors. The columns have been described earlier (Risö Report No. 41[1]) and are similar to those used in the U.S.A. by HASL[4]. The purpose of this collection is to compare the efficiency of the ion-exchange columns with that of rain bottles as collectors of fall-out. Table 3.2.4.2 shows the results.

Table 3.2.4.3 shows Sr-90 determined in monthly samples of rain water collected daily in the 1 m^2 rain collector (R) (cf. fig. 3.1.2.1) at Risö. The

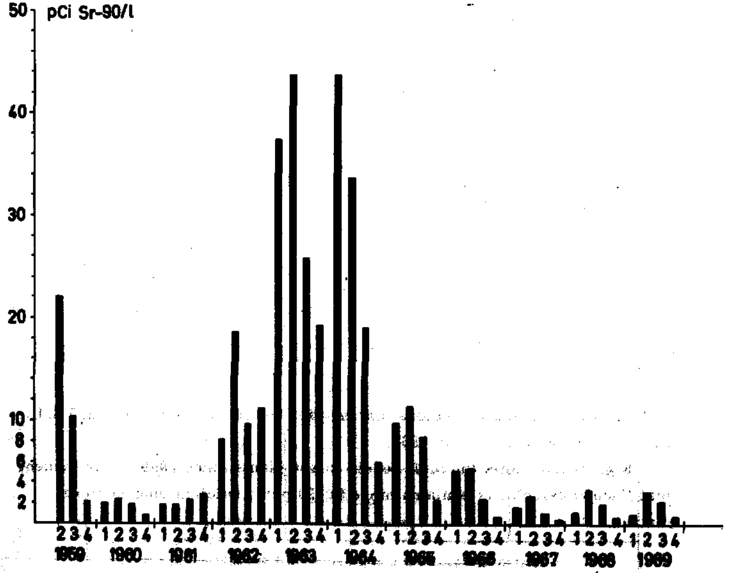


Fig. 3.2.4.1. Sr-90 in precipitation, 1959-69.

Table 3.2.4.1

Sr-90 in monthly samples of rain water collected in rain bottles at Risø in 1969 (sampling area 1232 cm^2)

Month	mm	pCi Sr-90/l	mCi Sr-90/km^2
Jan.	29	1.06	0.031
Feb.	17	0.95	0.016
Mar.	6	1.00	0.006
Apr.	38	1.09	0.041
May	57	3.31	0.189
June	44	4.61	0.203
July	21	3.65	0.077
Aug.	72	2.15	0.155
Sep.	25	0.99	0.025
Oct.	36	0.73	0.026
Nov.	75	0.55	0.041
Dec.	9	0.98	0.009
1969	Σ 429	$\bar{x}$: 1.91	Σ 0.82

$$\bar{x} = \frac{\Sigma \text{mCi/km}^2 \cdot 10^3}{\Sigma \text{mm}} \text{ pCi/l}$$

Table 3.2.4.2

Sr-90 in monthly samples of rain water collected in ion-exchange column collectors at Risø in 1969 (sampling area 2450 cm^2)

Month	mm	pCi Sr-90/l	mCi Sr-90/km^2
Jan.	26	1.68	0.044
Feb.	22	1.45	0.032
Mar.	4	3.60	0.014
Apr.	47	2.27	0.107
May	69	3.33	0.230
June	45	6.13	0.276
July	16	4.02	0.072
Aug.	61	[illegible]	[illegible]
Sep.	26	[illegible]	[illegible]
Oct.	42	0.92	[illegible]
Nov.	67	0.43	[illegible]
Dec.	[illegible]	[illegible]	[illegible]
1969	Σ475	$\bar{x}$: 2.16	Σ 1.[illegible]

Table 3.2.4.3

Sr-90 in monthly samples of rain water collected daily in a 1 m^2 collector at Risö in 1969

Month	mm	pCi Sr-90/l	mCi Sr-90/km^2
Jan.	32	6.65	0.213
Feb.	21	1.34	0.029
Mar.	2	4.52	0.011
Apr.	34	1.88	0.064
May	50	3.5[illegible]	0.180
June	42	1.19	0.049
July	13	0.52	0.007
Aug.	60	3.31	0.199
Sep.	18	1.52	0.027
Oct.	8	0.58	0.005
Nov.	105	0.59	0.062
Dec.	9	1.50	0.013
1969	Σ 394	$\bar{x}$: 2.18	Σ 0.86

Table 3.2.4.4

Analysis of variance of mm precipitation at Risö in 1969 (from tables 3.2.4.1 - 3.2.4.3)

Variation	SSD	f	s^2	v^2	P
Betw. samplers	269.49	2	134.74	2.03	-
Betw. months	22226	11	2020.54	30.51	>99.95%
Remainder	1456.84	22	66.22		
η = 0.23					

Table 3.2.4.5

Analysis of variance of in pCi Sr-90/l precipitation collected at Risö in 1969 (from tables 3.2.4.1 - 3.2.4.3)

Variation	SSD	f	s^2	v^2	P
Betw. samplers	0.5105	2	0.2553	0.70	-
Betw. months	12.2369	11	1.1124	3.04	>97.5%
Remainder	8.0602	22	0.3664		
η = 0.66					

Table 3.2.4.6

Analysis of variance of ln mCi Sr-90/km^2 from precipitation at Risö in 1969 (from tables 3.2.4.1 - 3.2.4.3)

Variation	SSD	f	s^2	v^2	P
Betw. samplers	1.0164	2	0.5082	1.13	-
Betw. months	37.6861	11	3.4260	7.60	>99.95%
Remainder	9.9112	22	0.4505	-	-
η = 0.75					

monthly samples were subjected to ion exchange in the laboratory on a column similar to those used in the field sampling described above, and analysed for Sr-90.

Precipitation was further collected at eight stations located in the meteorological mast at Risö (cf. 8.1). Thus we have four sampling systems for precipitation covering the Risö area: 1: the 1 m^2 collector (table 3.2.4.3); 2: the eight rain bottles at ground level (table 3.2.4.1); 3: the five ion-exchange collectors (table 3.2.4.2), and 4: the eight rain bottles in the meteorological mast (table 8.1.1). Tables 3.2.4.4 - 3.2.4.6 show the analysis of variance of the three first-mentioned systems (a similar analysis was carried out in the previous years).

3.2.5. Milk from a farm near Risö

Table 3.2.5 shows the radiostrontium and caesium-137 contents in milk collected in 1969 from a farm near Risö. The mean level was 5.1

Table 3.2.5

Sr-90 and Cs-137 in milk from Risö* in 1969

Months	pCi Sr-90/g Ca	pCi Cs-137/g K	pCi Cs-137/l
Jan. - Mar.	2.96	3.86	6.64
Apr. - June	6.97	6.46	10.59
July - Sep.	5.45	8.61	13.78
Oct. - Dec.	5.01	3.10	5.21
1969	5.10	5.51	9.06

*The milk was collected from the milk producing farm nearest to Risö

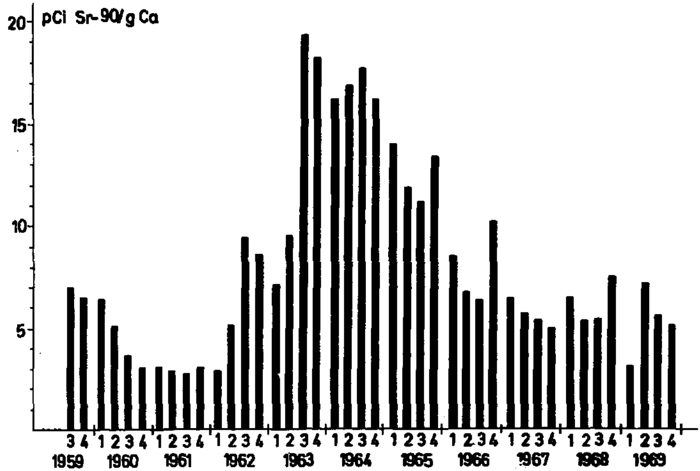


Fig. 3.2.5. Sr-90 in milk from Risö neighbourhood.

S.U. as compared with 5.8 S.U. in 1968. Fig. 3.2.5 shows the Sr-90 levels in "Risö" milk since 1959. The caesium-137 levels were nearly equal to the levels found in 1968 (and 1967).

3.3. γ Spectroscopy of Air Samples

As in 1962-68, half-weekly samples of air were collected by means of the air sampler described in Risö Report No. 23[1]. Parts of the half-weekly filters were bulked into half-monthly samples and measured on a 30 cm^3 Ge(Li) detector[8]. Table 3.3.1 shows the results. The peak value was observed in the first half of August (cf. also Sr-90 in air, table 3.2.1). The mean level in 1969 was nearly equal to the 1968 mean (2.38 pCi Cs-137/ $10^3 m^3$).

Table 3.3.1

Cs-137 in glass-fibre air filters collected twice a week at Risö in 1969
pCi Cs-137/$10^3 m^3$

Month	pCi/$10^3 m^3$
Jan.	1.33±0.05
Feb.	1.51±0.03
Mar.	2.78±0.16
Apr.	2.08±0.06
May	2.22±0.70
June	4.76±0.56
July	3.97±0.59
Aug.	5.56±1.94*
Sep.	1.70±0.05
Oct.	1.26±0.05
Nov.	1.23±0.10
Dec.	0.97±0.22
1969	2.45

The error term is the S. E. of the mean of the activity found in the first and the second half of the month.

* First half of August: 7.60 pCi/$10^3 m^3$

4. RADIOSTRONTIUM IN PRECIPITATION, SOIL AND GROUND WATER IN DENMARK IN 1969

4.1. Precipitation

Samples of rain water were collected in 1969 from the ten State experimental farms (cf. fig. 4.1.1) in accordance with the principles laid down in Risö Report No. 63, p. 51[1].

Table 4.1.1 shows the results of the Sr-90 determinations and tables 4.1.2 and 4.1.3 the analysis of variance of the results. The variation with time was highly significant (P > 99.95%). The maximum specific activity occurred in July-August, when the mean content in precipitation was 3.72 pCi Sr-90/l (cf. also the air measurements in 3.2.1 and 3.3). The minimum

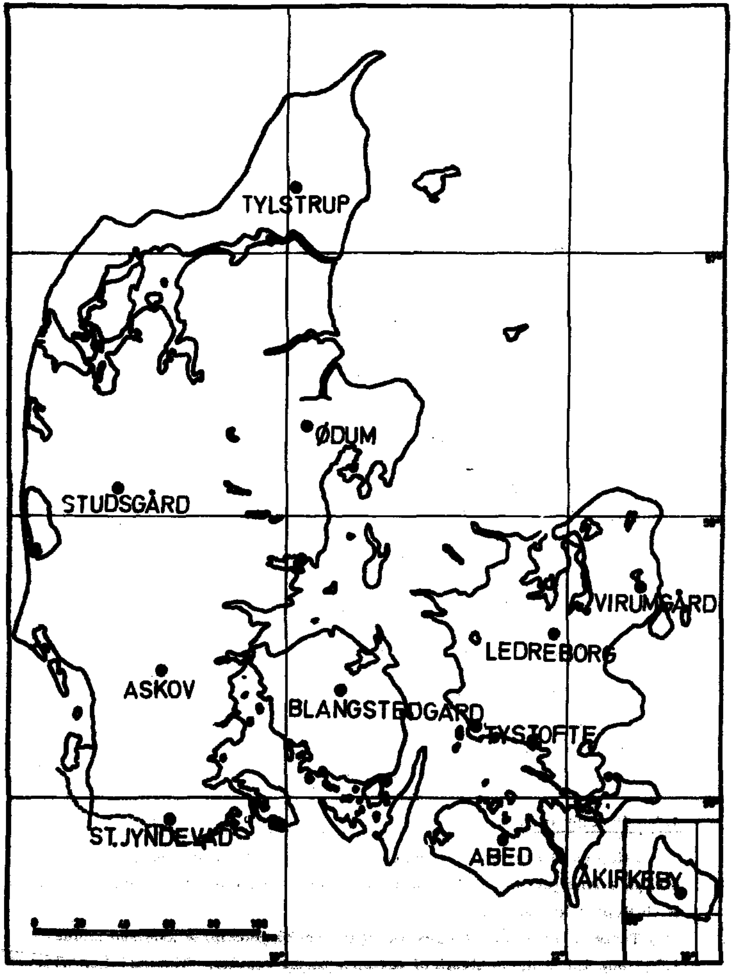


Fig. 4.1.1. State experimental farms in Denmark.

Table 4.1.1

Sr-90 fall-out in Denmark in 1969

Period	Unit	Tylstrup	Studsgård	Ødum	Askov	St. Jyndevad	Blangstedgård	Tystofte	Virumgård	Abed	Åkirkeby	Mean
Jan. - Feb.	pCi/l	1.59	1.46	2.18	1.50	1.39	1.00	1.66	1.22	0.71	2.68	1.54
	mCi/km^2	0.148	0.120	0.093	0.121	0.090	0.067	0.079	0.074	0.044	0.079	0.092
Mar. - Apr.	pCi/l	4.14	2.03	2.52	2.30	3.87	1.35	1.47	1.52	1.42	4.87	2.53
	mCi/km^2	0.232	0.124	0.135	0.087	0.132	0.075	0.070	0.057	0.076	0.217	0.120
May - June	pCi/l	3.83	3.46	2.14	3.20	3.54	2.52	3.46	2.87	2.61	5.32	3.30
	mCi/km^2	0.400	0.423	0.216	0.485	0.499	0.298	0.314	0.325	0.210	0.212	0.338
July - Aug.	pCi/l	6.56	2.86	4.41	4.67	2.63	3.30	4.92	3.09	2.35	2.38	3.72
	mCi/km^2	0.413	0.324	0.329	0.336	0.151	0.104	0.273	0.285	0.190	0.312	0.276
Sep. - Oct.	pCi/l	4.01	3.91	3.04	2.36	1.90	1.26	4.54	2.36	1.93	2.14	2.75
	mCi/km^2	0.260	0.069	0.058	0.109	0.122	0.097	0.062	0.101	0.042	0.118	0.104
Nov. - Dec.	pCi/l	0.93	0.65	0.91	0.80	0.74	0.48	0.65	0.66	0.45	1.31	0.76
	mCi/km^2	0.131	0.146	0.107	0.174	0.129	0.060	0.055	0.064	0.072	0.115	0.105
1969	pCi/l $\bar{x}$	2.97	1.94	2.27	2.16	2.11	1.48	2.50	2.66	1.38	2.71	2.15
	mCi/km^2 Σ	1.584	1.206	0.938	1.312	1.163	0.701	0.853	0.906	0.634	1.053	1.035
mm precipitation Σ		521	621	413	608	551	475	341	443	458	388	482

Table 4.1.2

Analysis of variance of ln pCi Sr-90/l precipitation in 1969
(from table 4.1.1)

Variation	SSD	f	s^2	v^2	P
Betw. locations	3.7018	9	0.4113	5.03	> 99.9%
Betw. months	17.6210	5	3.5242	43.14	> 99.95%
Remainder	3.6746	45	0.0817		
η = 0.29					

Table 4.1.3

Analysis of variance of ln mCi Sr-90/km^2 precipitation in 1969
(from table 4.1.1)

Variation	SSD	f	s^2	v^2	P
Betw. locations	[illegible]	9	0.[illegible]	[illegible].90	>99.95%
Betw. months	15.5732	5	3.1146	[illegible]	>99.95%
Remainder	[illegible]	45	[illegible]		
η = 0.31					

fall-out rate was found in May-June, the mean fall-out rate in that period being 0.34 mCi Sr-90/km^2. Tables 4.1.2 and 4.1.3 show that the variation between locations was highly significant. The specific activity for 1969 was 2.97 pCi Sr-90/l at Tylstrup, while only 1.38 pCi Sr-90/l was measured at Abed. The 1969 mean levels for ten State experimental farms were 1.04 mCi Sr-90/km^2 and 2.15 pCi Sr-90/l. In Appendix A the country mean level (area weighted) is estimated to be 1.4 mCi Sr-90/km^2 ior a mean precipitation amount of 600 mm (area weighted), i.e. equal to the fall-out rate in 1968.

As in 1966-68 precipitation samples were collected with an ion-exchange collector at Abed (cf. also 3.2.4). The specific activity was 1.9 pCi Sr-90/l, i.e. higher than in table 4.1.1, and it is further evident, as also observed in 1966-68, that the total deposition in the ion-exchange collector is approx. 1.4 times as large as that in the rain bottles.

The Sr-89/Sr-90 ratios at the ten stations are shown in table 4.1.4. By the end of the year fresh fall-out began to appear, probably from the Chinese test explosion in September 1969.

Table 4.1.4

Sr-89/Sr-90 in fall-out collected in 1969

Period	Tylstrup	Studsgård	Ødum	Askov	St. Jyndevad	Blangstedgård	Tystofte	Virumgård	Abed	Åkirkeby	Mean
Jan.-Feb.							1.7				
Mar.-Apr.	6.6	0.7	2.9	3.5	13.0	4.5	3.6	4.3	3.6	6.1	4.9 ± 1.0
May-June	8.3	8.1	7.4	7.1	8.3	7.7	7.0	7.6	7.6	4.8	7.4 ± 0.3
July-Aug.	4.7	5.4	2.7	5.2	6.2	4.3	4.2	5.3	6.3	5.1	4.9 ± 0.3
Sep.-Oct.	0.2	0.3	0	1.4	0	1.2	0	0.1	0	0.1	0.3 ± 0.2
Nov.-Dec.	0.3	0.8	0.9	0.8	0.2	1.0	1.4	0.6	0.3	1.3	0.8 ± 0.1

The error term is the S.E. of the mean

Table 4.2.1

	Tylstrup	Studsgård	Ødum xx)	Askov	St. Jyndevad
mCi Sr-90/km^2	53 ± 1	68 ± 1	40 ± 1	50 ± 1	70 ± 3
pCi Sr-90/kg	229 ± 2	301 ± 5	165 ± 1	189 ± 1	220 ± 8

All determinations were triple, except xx) which were double and x) which was single. The error term is the S.E. of the mean

A comparison between the amounts of precipitation found in the rain gauges used by the Danish Meteorological Institute and the amounts collected in our rain bottles at the same locations showed that in 1969 our bottles collected only 85 per cent of the amount measured in the rain gauges. The difference between the two systems was most pronounced during the winter months of January and February, where the percentage was only 68.

We explain this difference by the fact that our bottles will not collect snow very efficiently as contrary to the rain gauges they have no heating system for melting of the snow deposited in the funnels. During warm and dry periods some evaporation will occur from our bottles as was the case in July-August in 1969. Normally these months are rather wet, but in 1969 they were dry, and we found in our bottles only 80% of the precipitation amounts measured in the rain gauges (which are collected daily, while our bottles are collected monthly). As regard the collection of fall-out we can expect this to be considerably better than the 85% measured for the amounts of precipitation, firstly because we get the fall-out in the precipitation even though the water evaporates, and secondly because the amounts of fall-out are smaller during the winter months than during the remaining part of the year, where the collecting efficiency of the bottles is 100%.

4.2. Soil

As in the previous years, soil was collected with a view to estimating the accumulated fall-out of Sr-90. As previously, the samples were collected in September from uncultivated areas (cf. fig. 4.1.1) all over the country.

Table 4.2.1 shows the results from ten State experimental farms. The mean value in September 1969 was 50 mCi Sr-90/km^2. This is somewhat lower than the 1968 value.

Sr-90 in soil collected at the state experimental farms in September 1969

Blangstedgård	Tystofte	Virumgård	Abed xx)	Åkirkeby x	Mean	SD	SE
41 ± 2	34 ± 1	47 ± 1	50 ± 5	44	50	12	4
176 ± 6	110 ± 4	166 ± 5	324 ± 29	164	206	64	21

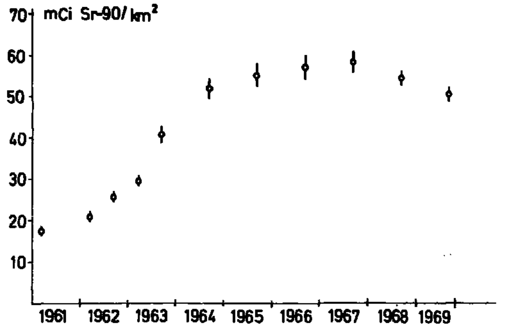


Fig. 4.2. Accumulated Sr-90 fall-out in Danish soil, 1961-69 (1 S.E. indicated).

Table 4.2.2

Sr-90 in soil collected in Zealand in September 1969

	Risö	Roskilde Fælled	Ledre-borg	Eremi-tagen	Mean	S.D.	S.E.
mCi Sr-90/km^2	44±1	50±2	39±2	52±2	46	5	3
pCi Sr-90/kg	235±6	166±6	128±6	210±6	190	45	23

Cf. remarks to table 4.2.1

Table 4.2.2 shows the Sr-90 levels at five soil locations in Zealand, mainly in the neighbourhood of Risö. The levels were also in this case lower than the 1968 values.

4.3. Ground Water

As in previous years, ground water was collected in March from the nine locations selected by L. J. Andersen, M.Sc., Geological Survey of Denmark, in 1961.

Fig. 4.3 shows the sample locations and table 4.3.1 the results of the Sr-90 analyses (cf. also 5.8.4).

The median level of Sr-90 in 1969 was a little higher than in 1967 and 1968, but hardly significantly different from these levels. The highest level is still found at Feldbak. Fig. 4.3.2 shows the median levels in Danish ground water since 1961. It is evident that a maximum occurred in 1964-66, undoubtedly as a result of the 1961-62 test series.

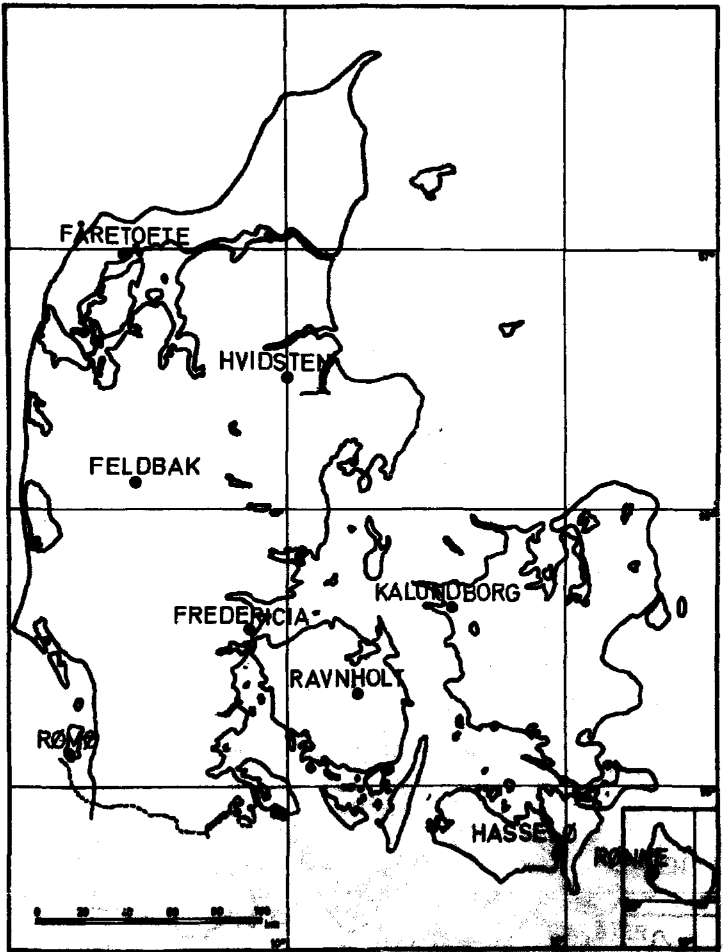


Fig. 4.3.1. Ground-water sampling locations in Denmark.

Table 4.3.1

Sr-90 in ground water collected in March 1969

Location	pCi Sr-90/l	pCi Sr-90/g Ca	g Ca/l
Hvidsten	0.0049	0.066	0.075
Feldbak	0.38	17.2	0.022
Rømø Rønne	0.011 0.039	0.32 2.28	0.035 0.017
Hasselø	0.0076	0.049	0.156
Fåretofte	0.0043	0.034	0.125
Kalundborg	0.017	0.171	0.100
Ravnholt	0.022	0.172	0.128
Fredericia	0.042	0.50	0.084
Mean	0.059	-	0.082
Median	0.017	0.17	0.084

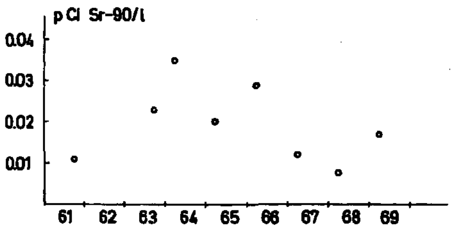


Fig. 4.3.2. Median levels in Danish ground water, 1961-69.

5. RADIOSTRONTIUM AND RADIOCAESIUM IN DANISH FOOD IN 1969

5.1. Sr-90 and Cs-137 in Dried Milk from the Entire Country

As in the previous years, monthly samples of dried milk were collected from seven locations in Denmark (cf. fig. 5.1.1) and analysed for Sr-90 and Cs-137.

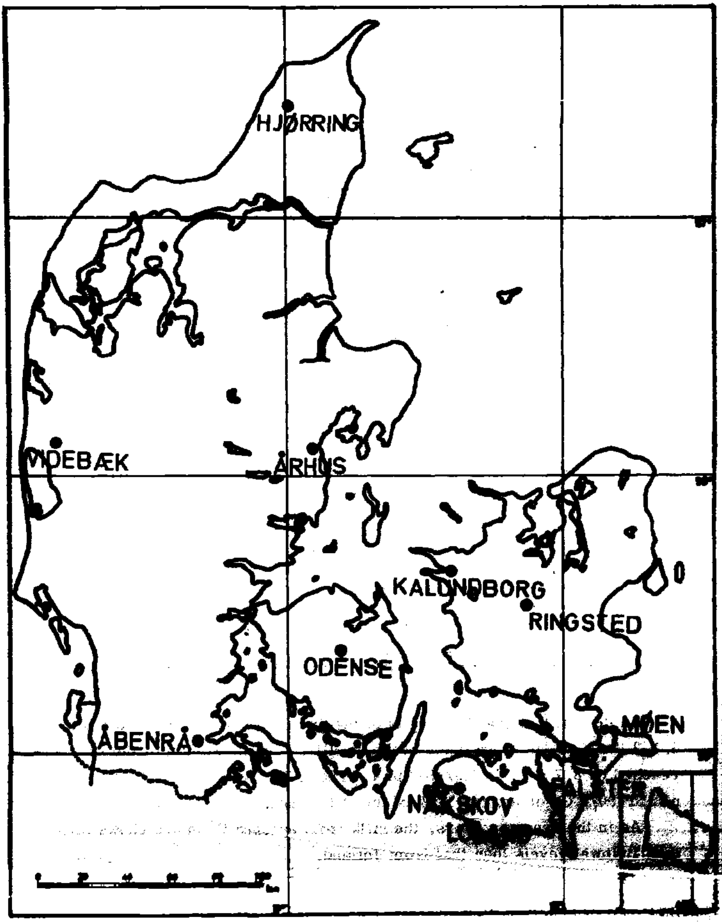


Fig. 5.1.1. Dried-milk factories in Denmark.

Table 5.1.1

pCi Sr-90/g Ca in Danish dried milk in 1969

Month	Hjørring	Århus	Videbæk	Åbenrå	Odense	Ringsted	Lolland-Falster Møn	Mean
Jan.	9.9±1.1	9.8±2.4	9.9±0.6	10.3±1.1	6.6±0.5	5.1±0.1	4.0±0.1	7.9
Feb.	8.6	7.0	11.8	10.0	6.2	5.2	5.0	7.7
Mar.	10.2	9.8	14.1	11.1	6.1	5.1	4.3	8.7
Apr.	9.7	8.9	11.8	9.8	7.2	6.3	4.7	8.3
May	8.4	9.6	11.4	10.8	7.9	5.2	6.0	8.5
June	7.2	8.4	11.2	9.0	7.6	3.4	6.9	7.7
July	6.7	6.7	9.4	8.5	5.6	4.1	4.3	6.5
Aug.	9.7	7.4	6.6	(8.5)	4.6	4.4	4.1	6.8
Sep.	5.8	5.4	9.2	(7.4)	5.4	3.7	3.7	5.8
Oct.	6.9	5.6	8.2	(6.9)	3.7	3.0	4.1	5.5
Nov.	8.6	6.5	10.6	(8.4)	3.7	4.9	4.5	6.7
Dec.	8.1	6.7	9.6	(8.6)	4.4	5.6	4.2	6.7
Mean	8.3	7.7	10.5	(9.1)	5.8	4.7	4.6	7.2

Figures in brackets were calculated by VAR 3[2]. The error term is the S. E. of the mean. As 1 litre of milk contains 1.2 g Ca, the mean Sr-90 content in Danish milk produced in 1969 was 8.6 pCi/l.

Table 5.1.2

Analysis of variance of ln pCi Sr-90/g Ca in dried milk in 1969
(from table 5.1.1)

Variation	SSD	f	s^2	v^2	P
Betw. locations	8.1451	6	1.3575	60.87	>99.95%
Betw. months	1.5711	11	0.1428	6.40	>99.95%
Locations x months	1.3588	61	0.0223	0.78	-
Remainder	0.1990	7	0.0284		
s = 0.17					

Table 5.1.1 shows the results of the Sr-90 determinations and table 5.1.2 the analysis of variance of the results. The maximum of the year was reached by 8.7 S.U. in March-April. The S.U. mean level in 1969 was 7.2 pCi Sr-90/g Ca or approx. 85% of the 1968 mean.

As in the previous years, the milk from eastern Denmark shows significantly lower levels than that from Jutland.

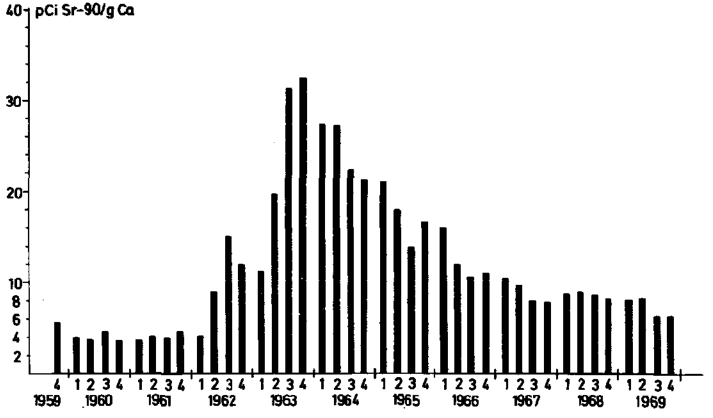


Fig. 5.1.2. Sr-90 in dried milk, 1959-69.

Table 5.1.3

pCi Cs-137/g K in Danish dried milk in 1969

Month	Hjørring	Århus	Videbæk	Åbenrå	Odense	Ringsted	Lolland-Falster Møn	Mean
Jan.	19.8	16.4	27.6	9.6	5.9	4.6	5.3	12.7
Feb.	8.7	9.5	9.5	14.0	5.7	3.3	7.4	8.3
Mar.	8.3	8.3	9.4	10.6	10.3	4.3	4.3	7.9
Apr.	9.3	7.0	10.8	10.0	7.0	5.9	4.1	7.7
May	10.1	7.5	12.0	12.9	11.6	7.0	4.5	9.4
June	16.0	10.7	16.7	13.8	10.2	8.0	5.1	11.5
July	17.9	12.3	19.3	25.0	14.8	6.4	12.6	15.2
Aug.	18.6	17.8	21.4	(15.2)	8.2	4.6	4.7	12.9
Sep.	12.4	13.6	18.2	(13.4)	7.8	5.5	5.0	10.8
Oct.	11.4	6.8	7.9	(7.8)	3.7	2.6	3.9	6.3
Nov.	8.4	5.4	5.6	(7.9)	5.5	3.9	4.5	5.9
Dec.	11.9	6.7	9.7	(8.9)	8.0	4.1	2.6	7.1
Mean	12.7	10.2	14.0	([illegible])	8.1	5.0	5.3	9.7

As 1 litre of milk contains approx. 1.46 g K, the mean Cs-137 content in Danish milk produced in 1969 was estimated at 16 pCi/l.

Table 5.1.4

Analysis of variance of ln M. U. in Danish dried milk in 1969
(from table 5.1.3)

Variation	SSD	f	s^2	v^2	P
Betw. locations	120.1764	6	20.0294	28.29	>99.95%
Betw. months	58.2076	11	5.2916	7.47	>99.95%
Remainder	43.1874	61	0.7080		
η = 1.03					

Table 5.1.3 shows the results of the Cs-137 determinations and table 5.1.4 the analysis of variance of the results. As in the previous years, the maximum level of Cs-137 (15.2 M. U., approx. two thirds of the maximum of 1968) was found in milk from the summer (July). The M. U. mean level in 1969 was 9.7 pCi Cs-137/g K or 85% of the Cs-137 mean content found in 1968.

Figs. 5.1.2 and 5.1.3 show the quarterly S. U. and M. U. values since October-December 1959 (cf. also Appendix C).

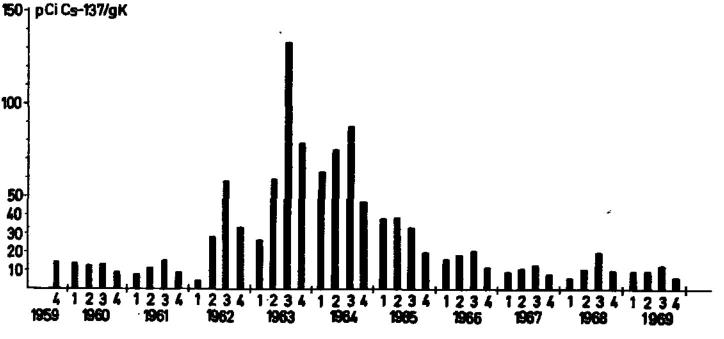


Fig. 5.1.3. Cs-137 in dried milk, 1959-69.

5.2. Sr-90 and Cs-137 in Fresh Milk from the Entire Country

The samples of fresh milk were collected in the eight zones and in Copenhagen as in previous years (cf. figs. 5.2.1 and 5.2.2) in connection with the bread and total-diet collection (cf. 5.7).

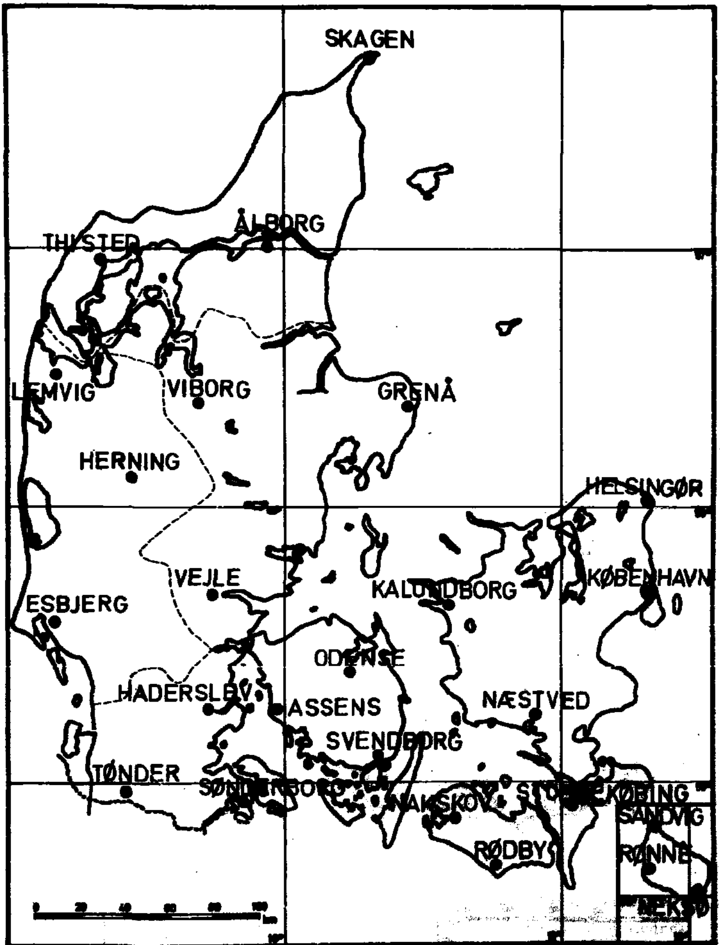


Fig. 5.2.1. Sample locations for fresh milk, bread and total diet (A-towns).

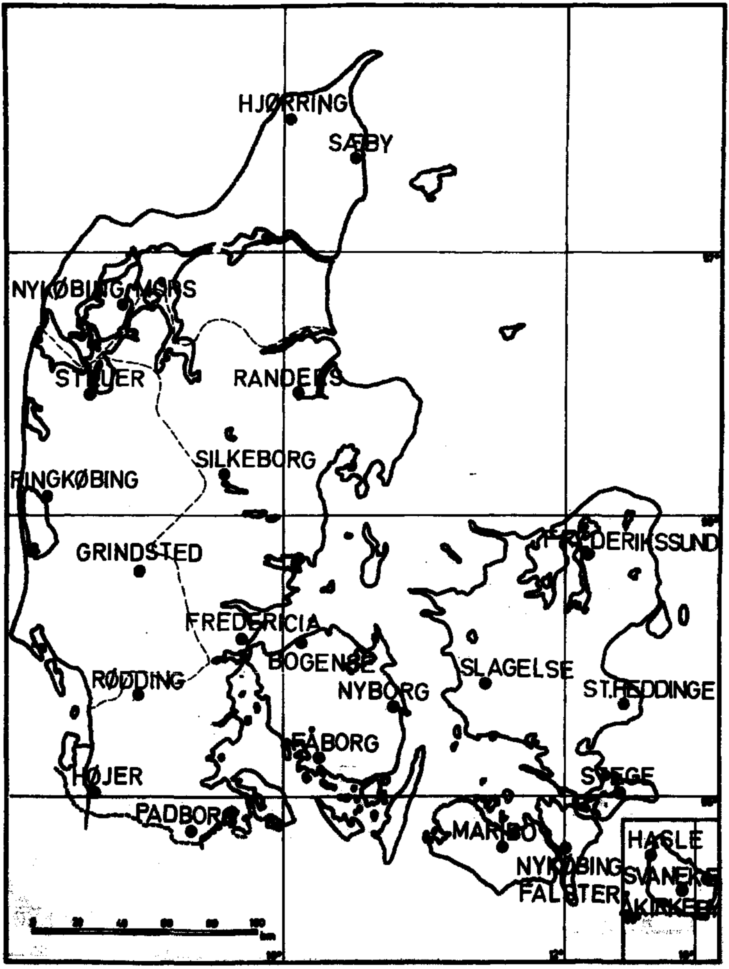


Fig. 5.3.2. Sample locations for fresh milk, bread and total diet (B-towns).

Table 5.2.1

Sr-90 and Cs-137 in fresh milk in 1969

Zone	June			December		
	pCi Sr-90/g Ca	pCi Cs-137/g K	pCi Cs-137/l	pCi Sr-90/g Ca	pCi Cs-137/g K	pCi Cs-137/l
I: N. Jutland	7.6 ± 0.1	12.6	20.6	6.8	5.4	8.7
II: E. Jutland	8.3 ± 0.1	15.2	24.3	6.3	5.1	7.9
III: W. Jutland	8.2	7.5	12.6	7.4	7.1	11.9
IV: S. Jutland	9.1 ± 0.3	8.8	13.7	8.7	5.6	9.2
V: Funen	5.2	9.3	14.8	4.3	5.7	9.1
VI: Zealand	4.6 ± 0.5	9.6	15.4	3.7	4.2	6.9
VII: Lolland-Falster	5.4 ± 0.1	8.4	14.1	3.4	4.0	6.3
VIII: Bornholm	4.9 ± 0.5	5.8	9.3	4.6	4.7	7.5
Mean	6.7	9.7	15.6	5.6	5.2	8.4
Copenhagen	6.1 ± 0.5	11.7	18.2	5.5	4.9	7.6
Population-weighted mean	6.7	11.1	17.7	5.7	5.2	8.4
Production-weighted mean	7.4	11.2	18.0	6.3	6.0	8.9

Table 5.2.1 shows the results of the determinations of radiostrontium and Cs-137 in consumer milk.

The production-weighted means for Sr-90 and Cs-137 in Danish consumer milk in 1969 were 6.9 S.U. (~8.2 pCi Sr-90/l) and 8.6 M.U. or 13.5 pCi Cs-137/l respectively.

As previously it seems reasonable to regard the mean of the levels found in June and December as representative of the annual production-weighted mean, as the mean for these two months calculated from the dried-milk data (cf. tables 5.1.1 and 5.1.2) yielded a reasonable estimate of the annual mean for dried milk.

If the figures in table 5.2.1 are weighted with respect to the population, the country means become 6.0 S.U. and 13 pCi Cs-137/l, i.e. approx. 90% of the production-weighted means.

5.3. Sr-90 and Cs-137 in Grain from the Entire Country

As in the previous years, grain samples were obtained from ten State experimental farms (cf. fig. 4.1.1) Virumgård has been replaced by Ledreborg. Sr-90 was determined as previously (Risö Report No. 63[1]), but Cs-137 was measured on ashed samples by γ-spectrometry on a Ge-detector.

Table 5.3.1

Sr-90 in Danish grain in 1969

	Rye		Barley		Wheat		Oats	
	pCi Sr-90 pr kg	S.U.	pCi Sr-90 per kg	S.U.	pCi Sr-90 per kg	S.U.	pCi Sr-90 per kg	S.U.
Tylstrup	29±4	74±1	32±7	62±4	-	-	43±8	46±8
Studsgård	W:51±12 S:43±2	W:139±28 S: 90±0	50±0	120±5	74±5	200±2	55±3	74±2
Ødum	19±0	61±2	19±2	40±3	W:19±0 S:20±0	W:54±2 S:62±4	37±1	38±1
Askov	W:35±2 S:55±2	W:81±5 S:123±4	29±1	69±2	W:52±0 S:72±2	W:155±2 S:151±1	38±2	46±3
St. Jyndevad	-	-	89±1	212±1	-	-	106±4	153±11
Blangstedgård	-	-	11±2	19±0	-	-	17±3	19±1
Tystofte	-	-	W:14±0 S:13±1	W:30±0 S:32±0	W:18±3 S:21±0	W:40±6 S:42±0	39±13	41±14
Ledreborg	-	-	27±0	57±1	W:23±7 S:21±6	W:62±9 S:63±7	21±1	22±1
Abed	-	-	12±2	28±4	W:10±1 S: 7±1	W:28±2 S:19±1	12±2	14±2
Åkirkeby	20±0	57±5	13±1	35±2	W:28±2 S:38±1	W:76±4 S:87±1	21±0	26±0
Mean	36	89	28	64	31	80	39	48

w: winter variety, s: spring variety. The error term is the S.E. of the mean of double determinations

Table 5.3.2

Analysis of variance of ln S.U. in grain in 1969
(from table 5.3.1)

Variation	SSD	f	s^2	v^2	P
Betw. species	5.5134	3	1.8378	12.72	>99.95%
Betw. locations	27.8390	9	3.0932	21.41	>99.95%
Spec. x locations	2.7463	19	0.1445	5.99	>99.95%
Remainder	1.2068	50	0.0241		

η = 0.16

The main effects were tested against the interaction.

Table 5.3.1 shows the measurements of strontium-90 in grain in 1969. According to Appendix B, approx. 2/3 of all rye in Denmark is grown in Jutland and 1/3 in the eastern part of the country. As regards wheat, 3/4 is produced in eastern Denmark and 1/4 in Jutland. In the calculation of the means in tables 5.3.1 and 5.3.4 Jutland is represented by six rye figures and five wheat figures, while eastern Denmark contributes eight wheat figures and one rye figure. Thus the means for rye and wheat in tables 5.3.1 and 5.3.4 are probably a little higher than the production-weighted means for the country. Table 5.3.2 gives the analysis of variance of the S.U. figures and table 5.3.3 that of the pCi Sr-90/kg grain figures.

Table 5.3.3

Analysis of variance of ln pCi Sr-90/kg grain in 1969 (from table 5.3.1)

Variation	SSD	f	s^2	v^2	P
Betw. species	1.5398	3	0.5132	2.74	>90%
Betw. locations	26.4391	9	2.9376	15.66	>99.95%
Loc. x species	3.5647	19	0.1876	4.61	>99.95%
Remainder	2.0363	50	0.0407		
η = 0.20					

Table 5.3.1 shows that the variation in S.U. between species was significant. Wheat showed the highest S.U. levels and oats the lowest. The pCi Sr-90/kg figures did not show any significant difference between species.

As in previous years, the variation with location was highly significant; the mean pCi Sr-90/kg level for grain from Jutland was approx. 2.4 times that in eastern Denmark.

Table 5.3.4

Cs-137 in Danish grain in 1969

	Rye		Barley		Wheat		Oats	
	pCiCs-137/kg	M.U.	pCiCs-137/kg	M.U.	pCiCs-137/kg	M.U.	pCiCs-137/kg	M.U.
Tylstrup	55	13.1	19	3.7	-	-	53	9.1
Studsgård	w: 61 s: 83	w: 13.7 s: 16.2	39	6.3	46	12.6	36	8.0
Ødum	47	13.2	27	6.0	w: 29 s: 34	w: 7.1 s: 8.9	27	7.8
Askov	w: 51 s: 68	w: 10.4 s: 13.8	40	*7.1	w: 71 s: 64	w: 16.2 s: 16.2	40	8.7
St. Jyndevad	-	-	57	10.2	-	-	40	14.1
Blangstedgård	-	-	22	4.9	-	-	18	8.7
Tystofte	-	-	w: 37 s: 34	w: 8.0 s: 8.8	w: 33 s: 28	w: 7.8 s: 7.7	18	4.3
Ledreborg	-	-	41	8.6	w: 30 s: [illegible]	[illegible]	[illegible]	[illegible]
Abed	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4.8
Åkirkeby	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Mean	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
w: winter variety, s: spring variety								

Table 5.3.5

Analysis of variance of ln pCi Cs-137/g K in grain in 1969
(from table 5.3.4)

Variation	SSD	f	s^2	v^2	P
Betw. species	1.6944	3	0.5648	9.93	>99.5%
Betw. locations	2.5194	9	0.2799	4.92	>97.5%
Spec. x locations	2.0267	19	0.1067	1.87	-
Remainder	0.5124	9	0.0569		
η = 0.24					

Table 5.3.6

Analysis of variance of ln pCi Cs-137/kg grain in 1969
(from table 5.3.4)

Variation	SSD	f	s^2	v^2	P
Betw. species	1.2234	3	0.4078	12.63	>99.5%
Betw. locations	2.5215	9	0.2802	8.67	>99.5%
Spec. x locations	1.8920	19	0.0995	3.08	>95%
Remainder	0.2911	9	0.0323		
η = 0.18					

Table 5.3.4 shows the measurements of Cs-137 in grain in 1969, table 5.3.5 the analysis of variance of the M.U. figures and table 5.3.6 the analysis of variance of the pCi Cs-137/kg grain figures. The variation between locations was significant. The Cs-137 content in grain from Jutland was on the average approx. 1.5 (pCi/kg figures) times as high as the grain level in eastern Denmark. The variation between species was highly significant. Rye contained as previously approx. twice as much Cs-137 as the other grain species.

If the S.U. levels in grain from the harvest of 1969 are compared with the levels from 1968[1], we find the 1969 figures to be smaller by a factor of approx. 1.5.

The Cs-137 content in grain from the 1969 harvest was on the average lower by a factor of 1.7 than that in 1968. The fall-out rate in May-August 1968 was 1.4 times that in May-August 1969. (The period May-August was selected because experiments have shown[10] that the contamination of grain with Cs-137 originates in the period from before the emergence of the ears until harvest). This observation is in reasonable agreement with that of the previous years and fits the hypothesis that the Cs-137 level in grain depends mainly upon the fall-out rate.

In Appendix C is shown a comparison between observed and predicted Sr-90 and Cs-137 levels in 1969. It is evident that the predicted levels for grain were higher than those observed. The observed values were for Sr-90 three fourths of those predicted and for Cs-137 two thirds.

The 1969 summer was relatively dry. The total amount of precipitation in July-August was 96 mm, i.e. two thirds of the normal amount, which is 146 mm. For the prediction of Sr-90 in grain we use the total Sr-90 fall-out in July-August, and for Cs-137 we use the fall-out in the four-month period May-August. In 1969 the harvest was earlier than usual, and 45 mm precipitation fell after the harvest date, which was a considerable fraction of the total fall-out in that summer. If this had been taken into account in our prediction equations, the agreement between observed and predicted levels in grain would have been markedly improved.

The mean ratio between pCi Cs-137/kg rye and pCi Sr-90/kg rye was 1.6, while the Cs-137/Sr-90 ratio for barley, wheat and oats was 1.2. This is in agreement with earlier observations and with the theory that rye depends more on direct contamination than the other cereals, for which the soil uptake of Sr-90 now plays a dominant role.

Table 5.3.7

mg Sr/g Ca in grain collected in 1969

	Rye		Barley		Wheat		Oats
	Winter variety	Spring variety	Winter variety	Spring variety	Winter variety	Spring variety	Spring variety
Tylstrup	0.8			1.2			2.6
Studsgård	3.1	4.0		2.0	7.6		1.4
Ødum	3.0			3.0	4.1	4.2	3.1
Askov	2.9	3.0		2.3	3.9	3.5	2.0
St. Jyndevad				5.8			3.4
Blangstedgård				4.1			3.9
Tystofte			2.0	0.6	1.6	3.0	0.8
Ledreborg				2.8	2.3	3.5	2.0
Abed				6.7	5.0	5.0	2.1
Åkirkeby	1.9			2.4	2.4	2.1	0.4

Table 5.3.8

Analysis of variance of ln mg Sr/g Ca in grain in 1969
(from table 5.3.7)

Variation	SSD	f	s^2	v^2	P
Betw. species	2.9347	3	0.9782	8.01	>99.5%
Betw. locations	7.6886	9	0.8543	7.00	>99.5%
Spec. x locations	4.0204	19	0.2116	1.73	
Remainder	1.0994	9	0.1221		
η = 0.36					

Table 5.3.7 shows the stable-strontium content in grain in relation to the calcium content, and table 5.3.8 is an analysis of variance of the figures. As previously[1], wheat contained significantly more stable strontium per g Ca than the other species, and Studsgård showed higher figures than the eastern locations.

5.4. Sr-90 and Cs-137 in Bread from the Entire Country

In 1969, samples of white bread (75% extraction) and dark rye bread (100% extraction) were collected as previously all over the country in June and December (in both A and B towns, cf. figs. 5.2.1 and 5.2.2). The samples were combined into eight zone samples and a sample from Copenhagen, and Sr-90 and Cs-137 were determined. The Cs-137 determinations were carried out on dried samples of rye bread and on the ash of white bread by γ-spectroscopy.

Tables 5.4.1 and 5.4.2 show the results. In figs. 5.4.1 and 5.4.2 a comparison with grain levels is made for the years 1962-1969. It is assumed that the bread consumed in the first nine months of the i^{th} year has been made of grain from the harvest in the $(i-1)^{th}$ year, while the bread consumed in the last three months has come from the harvest in the i^{th} year. Further it is assumed that 1 kg flour yields approx. 1.35 kg bread[11] and that wheat flour of 75% extraction contains 20% of the Sr-90 and 50% of the Cs-137 found in wheat grain[1].

Figs. 5.4.1 and 5.4.2 show that the Sr-90 and Cs-137 levels in bread were in reasonable agreement with those in grain according to the above-mentioned model.

On comparison of the bread levels in Jutland with those in eastern Denmark it appeared that the Sr-90 and Cs-137 levels in rye bread in Jutland were approx. 1.5 times those in eastern Denmark, whereas Sr-90 and Cs-137 in white bread were nearly equal all over the country. This shows as also observed the other years that it is not necessarily local-grown grain that is used for the bread production (cf. 5.3).

Table 5.4.1

Sr-90 in Danish bread in 1969

Zone		June				December			
		White bread		Rye bread		White bread		Rye bread	
		pCi/kg	S. U.	pCi/kg	S. U.	pCi/kg	S. U.	pCi/kg	S. U.
I:	N. Jutland	8.5±2.5	4.7±1.4	28±2	8.7±0.5	9.6±0.7	4.7±0.4	33	10.4
II:	E. Jutland	10.1±2.7	4.4±1.2	33±2	10.1±0.6	7.6±0.0	3.8±0.0	33	8.2
III:	W. Jutland	7.8±1.6	4.0±0.8	38±1	12.4±0.7	7.2±1.0	4.2±0.7	29	9.6
IV:	S. Jutland	6.7±1.5	3.1±0.7	36±2	11.6±0.8	9.8±1.2	5.8±0.8	33	11.6
V:	Funen	7.2±0.4	3.2±0.1	26±2	7.8±0.6	6.9±1.2	3.2±0.4	19	6.9
VI:	Zealand	5.4±0.4	2.3±0.2	21±1	7.1±0.4	6.8±0.5	3.8±0.3	16	4.7
VII:	Lolland-Falster	9.4±1.1	4.5±0.7	28±3	8.1±1.0	6.5±0.3	3.9±0.2	17	5.3
VIII:	Bornholm	9.3±2.0	4.1±0.9	20±2	6.5±1.2	7.5±0.7	3.1±0.2	15	5.3
Mean		8.0	3.8	29	9.0	7.7	4.1	25	7.8
Copenhagen		7.6±1.5	3.3±0.7	19±1	7.3±0.5	6.0±0.1	2.3±0.1	23	7.7
Population-weighted mean		7.8	3.6	27	8.8	7.2	3.6	25	7.9
Relative analytical error		0.31	0.32	0.09	0.12	0.14	0.16	-	-

Table 5.4.2

Cs-137 in Danish bread in 1969

Zone		June				December			
		White bread		Rye bread		White bread		Rye bread	
		pCi/kg	M. U.	pCi/kg	M. U.	pCi/kg	M. U.	pCi/kg	M. U.
I:	N. Jutland	20.4	13.6	94	31	10.8	6.6	64	18.4
II:	E. Jutland	19.7	14.1	54	17	11.6	7.6	52	8.8
III:	W. Jutland	17.0	12.5	64	23	10.3	8.0	50	8.2
IV:	S. Jutland	14.7	11.3	49	17	9.3	6.7	64	20.5
V:	Funen	17.1	12.7	57	19	10.3	7.8	37	10.0
VI:	Zealand	14.0	12.9	57	19	10.5	7.9	42	11.2
VII:	Lolland-Falster	17.3	13.3	35	14	10.9	8.0	33	10.0
VIII:	Bornholm	18.7	13.8	34	10	10.9	7.9	19	5.9
Mean		17.4	13.0	56	19	10.6	7.6	46	11.6
Copenhagen		11.5	8.8	35	11	11.8	7.9	36	10.4
Population-weighted mean		15.7	11.9	54	18	11.0	7.7	40	11.2

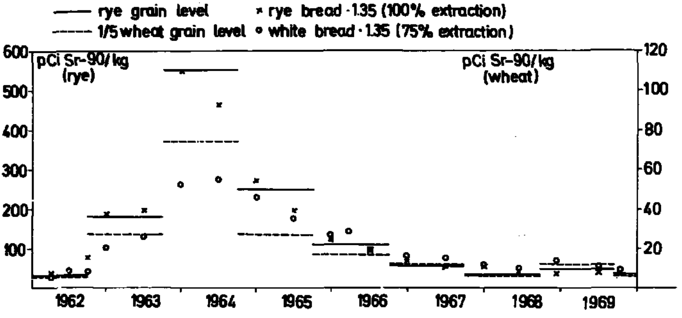


Fig. 5.4.1. Comparison of Sr-90 levels in bread and grain, 1962-69.

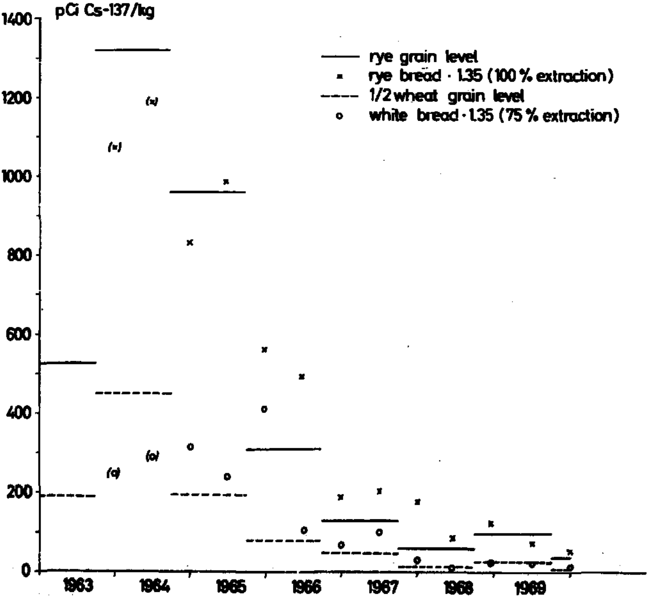


Fig. 5.4.2. Comparison of Cs-137 levels in bread and grain, 1962-69.

5.5. Sr-90 and Cs-137 in Potatoes from the Entire Country

The samples of potatoes were collected in September from nine of the State experimental farms (cf. fig. 4.1.1) and analysed for Sr-90 and Cs-137 (γ-spectroscopy of bulked samples of the ash).

Table 5.5.1 shows the Sr-90 and Cs-137 contents in potatoes. The mean contents for the country were 3.9 pCi Sr-90/kg or 80 S.U. and 7.1 pCi Cs-137/kg or 1.5 M.U. The Sr-90 levels were approx. 1.2 times as high for Jutland as for eastern Denmark, and the Cs-137 levels were 1.8 times as high.

The mean of the Cs-137/Sr-90 ratios (pCi/kg figures) was 1.8 (in 1968: 2.6, in 1967: 2.1, in 1966: 2.6, in 1965: 6, and in 1964: 9).

Table 5.5.1

Sr-90 and Cs-137 in Danish potatoes in 1969

	pCi Sr-90/kg	S.U.	pCi Cs-137/kg	M.U.
Tylstrup	2.8 ± 0.1	94±3		
Studsgård	3.3 ± 0.3	69±20		
Ødum	1.9 ± 0.1	46±1	9.2	1.9
Askov	5.3 ± 0.1	108±6		
St. Jyndevad	6.4 ± 0.5	140±13		
Tystofte	4.6 ± 0.4	47±4		
Ledreborg	3.3 ± 0.2	64±4	5.0	1.0
Abed	3.5 ± 0.1	39±1		
Åkirkeby	3.6 ± 0.1	113±5		
Mean	3.9	80	7.1	1.5

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

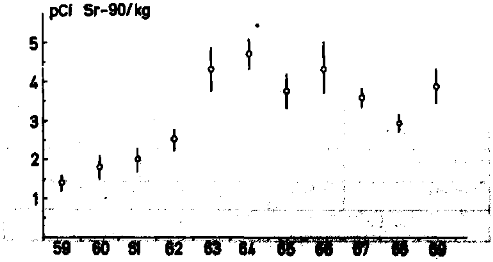


Fig. 5.5. Sr-90 levels in Danish potatoes 1959-69 (1 S.E. indicated).

5.6. Sr-90 and Cs-137 in Vegetables and Fruits from the Entire Country

In 1969 as in previous years, vegetables and fruits were collected in September and December from eight greater provincial towns, one in each of the eight zones, and from Copenhagen.

Carrots and onions were collected in September, cabbages and apples in December, and a few samples of peas and gooseberries were collected in June.

The γ-measurements were performed on bulked ash samples representing the entire country (cf. table 5.6.4). Tables 5.6.1 - 5.6.3 show the results and the analysis of variance of the Sr-90 determinations.

The variations between species were highly significant. The highest Sr-90 levels (pCi/kg) were found in onion, the lowest in apple.

Table 5.6.1

Sr-90 in vegetables and fruits in 1969

Zone		Cabbage		Carrot		Onion		Apple	
		pCi/kg	S.U.	pCi/kg	S.U.	pCi/kg	S.U.	pCi/kg	S.U.
I:	N-Jutland	11±2	21±4	29±0	111±22	40±3	108±9	0.57	12
II:	E-Jutland	10±4	18±7	19±3	69±21	42±1	109±9	0.86	11
III:	W-Jutland	11±4	18±4	14±1	41±3	10±2	20±2	2.24	29
IV:	S-Jutland	7±1	11±1	11±2	38±6	15±1	42±3	1.68	30
V:	Funen	13±2	22±2	14±4	55±14	16±1	48±3	0.82	15
VI:	Zealand	9±4	15±7	28±2	90±6	16±2	36±5	0.69	18
VII:	Lolland-Falster	8±3	11±4	10±2	32±10	16±2	35±5	1.38	19
VIII:	Bornholm	7±1	13±4	12±0	36±1	20±3	55±7	1.12	46
Mean		10	16	17	59	22	57	1.17	23
Copenhagen		16	15	12±4	40±10	20±1	55±1	1.54	38
Population-weighted mean		12	17	18	61	23	61	1.22	24
Relative analytical error		40%	40%	18%	31%	13%	15%	-	-

Table 5.6.2

Analysis of variance of ln pCi Sr-90/kg in vegetables and fruits in 1969
(from table 5.6.1)

Variation	SSD	f	s^2	v^2	P
Betw. species	49.7376	3	16.5792	59.35	>99.95%
Betw. locations	2.2874	7	0.3267	1.17	-
Spec. x locations	5.8653	21	0.2793	2.96	>99%
Remainder	2.2618	24	0.0942		
η = 0.31					

Table 5.6.3

Analysis of variance of ln S.U. in vegetables and fruits in 1969
(from table 5.6.1)

Variation	SSD	f	s^2	v^2	P
Betw. species	17.4156	3	5.8052	17.26	>99.95%
Betw. locations	3.4061	7	0.4865	1.45	-
Spec. x locations	7.0632	21	0.3363	3.48	>99.5
Remainder	2.3199	24	0.0967		
η = 0.32					

Table 5.6.4

Cs-137 in vegetables and fruits in 1969

	Cabbage	Carrot	Onion	Apple	Pea	Goose-berry
pCi/kg	5.3 ± 1.0	4.5	9.2	12	7.4	6.7
pCi/g K	2.1 ± 0.4	2.1	4.7	10	2.2	3.2

Table 5.6.5

Calculated Sr-90 and Cs-137 mean levels in vegetables in 1969

Daily intake in g	Species	pCi Sr-90 per kg	S.U.	pCi Cs-137 per kg	M.U.
50	Leafy vegetables (cabbage)	12	17	5.3	2.1
30	Root vegetables (carrot, onion)	20	61	6.8	3.4
40	Pea (and bean)	9	33	7.4	2.2
120	Vegetable total	13	33	6.4	2.5

Pea and bean were calculated as the mean of 3 pea samples collected in zones VI and VIII and in Copenhagen.

Table 5.6.5 shows a calculation of the mean contents of Sr-90 and Cs-137 in Danish vegetables collected in 1969. The levels were the population-weighted means calculated in tables 5.6.1 - 5.6.4.

The 1969 levels in Danish fruit were calculated from apple and from gooseberry (10.8 pCi Sr-90/kg, 34 S.U., 6.7 pCi Cs-137, 3.2 M.U.). Apples got a weight factor of 85 and gooseberries one of 15, and the mean levels in fruit were thus 2.6 pCi Sr-90/kg and 11.2 Cs-137/kg.

The 1969 Sr-90 and Cs-137 levels in vegetables and fruits were not different from the 1968 levels, (cf. also Appendix C).

5.7. Sr-90 and Cs-137 in Total Diet from the Entire Country

In 1969 total-food samples representing an average Danish diet according to Hoff-Jørgensen (cf. Appendix B in Risö Report No. 63[1]) were collected according to the principles followed in 1961-1968. As previously, two groups of towns (A and B, cf. figs. 5.2.1 and 5.2.2) supplied the samples.

Tables 5.7.1 and 5.7.2 show the results. The population-weighted mean levels were 9.9 S.U. and 21 pCi Cs-137/day in June and 7.2 S.U.

Table 5.7.1

Sr-90 and Cs-137 in total Danish diet collected in June 1969

Zone	pCi Sr-90/g Ca	pCi Sr-90/day	g Ca/day	pCi Cs-137/g K	pCi Cs-137/day
I: N-Jutland	10.7 ± 2.1	18.1 ± 3.4	1.71 ± 0.02	8.4 ± 0.1	29 ± 1
II: E-Jutland	11.5 ± 0.5	21.8 ± 1.5	1.89 ± 0.06	8.6 ± 0.2	33 ± 1
III: W-Jutland	11.6 ± 0.5	20.1 ± 1.7	1.73 ± 0.07	9.8 ± 0.3	32 ± 2
IV: S-Jutland	10.2 ± 1.0	17.5 ± 1.6	1.71 ± 0.01	10.1 ± 1.0	35 ± 2
V: Funen	9.5 ± 0.1	20.8 ± 2.8	2.17 ± 0.26	9.3 ± 0.3	36 ± 1
VI: Zealand	8.8 ± 0.1	17.0 ± 0.1	1.95 ± 0.03	6.5 ± 0.5	19 ± 1
VII: Lolland-Falster	7.1 ± 0.1	12.8 ± 0.8	1.80 ± 0.10	8.7 ± 0.4	27 ± 3
VIII: Bornholm	8.4 ± 0.4	14.9 ± 0.9	1.78 ± 0.04	4.6 ± 0.2	16 ± 1
Mean	9.7	17.9	1.84	8.3	28
Copenhagen	8.8 ± 0.1	16.4 ± 0.2	1.87 ± 0.01	7.6	25
Population-weighted mean	9.9	18.3	1.87	7.3	21
Relative error due to sampling and analysis	13%	15%	8%	6%	8%

Table 5.7.2

Sr-90 and Cs-137 in Danish total diet collected in December 1969

Zone	pCi Sr-90/g Ca	pCi Sr-90/day	g Ca/day	pCi Cs-137/g K	pCi Cs-137/day
I: N-Jutland	9.6 ± 0.8	16.0 ± 0.6	1.68 ± 0.08	6.5 ± 1.5	26 ± 6
II: E-Jutland	8.5 ± 0.4	14.7 ± 0.9	1.73 ± 0.02	7.4 ± 0.1	29 ± 1
III: W-Jutland	9.4 ± 0.4	15.2 ± 0.2	1.64 ± 0.07	7.3 ± 0.8	28 ± 3
IV: S-Jutland	9.2 ± 1.5	14.3 ± 1.3	1.56 ± 0.09	6.9 ± 0.5	27 ± 2
V: Funen	6.2 ± 1.0	10.4 ± 1.4	1.70 ± 0.06	5.8 ± 0.6	22 ± 2
VI: Zealand	5.7 ± 0.6	9.2 ± 0.8	1.62 ± 0.01	6.0 ± 0.4	22 ± 2
VII: Lolland-Falster	5.6 ± 0.7	9.2 ± 1.4	1.69 ± 0.00	5.4 ± 1.0	20 ± 3
VIII: Bornholm	5.6 ± 0.7	9.7 ± 1.2	1.73 ± 0.00	5.6 ± 0.9	22 ± 4
Mean	7.5	12.3	1.67	6.3	25
Copenhagen	5.4 ± 0.8	11.4 ± 1.8	2.10 ± 0.01	7.4	29
Population-weighted mean	7.2	12.6	1.79	6.9	26.5
Relative error due to sampling and analysis	16%	12%	5%	19%	18%

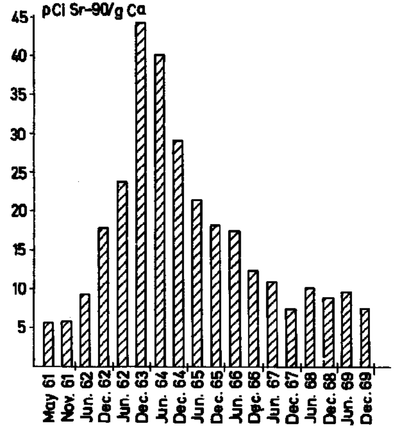


Fig. 5.7.1. pCi Sr-90/g Ca in Danish total diet, 1961-69.

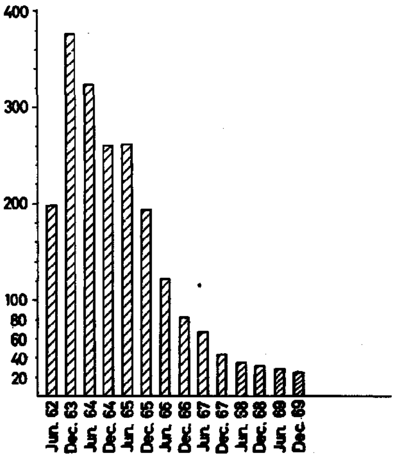


Fig. 5.7.2. pCi Cs-137/day from Danish total diet, 1962-69.

and 27 pCi Cs-137/day in December. As in the previous years, the variation between locations was significant. The S. U. levels in the total diet were approx. 40% higher in Jutland than in eastern Denmark.

Fig. 5.7.1 shows the zone mean levels (not population weighted) of S. U. in total diet since May 1961. Fig. 5.7.2 shows the daily Cs-137 intake since June 1963.

The 1969 Sr-90 levels in June and December in total diet were approx. 90% of the 1968 levels, while the Cs-137 levels were approx. 70% of the 1968 ones.

From the total-diet sampling it is possible to estimate the mean levels of Sr-90 and Cs-137 in the Danish diet in 1969. For the period January-April 1969 the Sr-90 level in the total diet is assumed to have been equal to that measured in December 1968, Risö Report No. 201 [1]. For the period May-September we assume the level to have corresponded to that measured in June 1969. The December 1969 figure is taken to represent the last three months of the year. The population-weighted mean of Sr-90 in total-diet samples was 9.1 pCi Sr-90/g Ca in December 1968. Hence the mean content in the total diet in 1969 was 9.0 pCi Sr-90/g Ca or 15.8 pCi Sr-90/day.

In a similar way the Cs-137 content in the Danish diet in 1969 was estimated to be 28 pCi Cs-137/day or 7.9 pCi Cs-137/g K (cf. also Appendix C).

5.8. Sr-90 and Cs-137 in Miscellaneous Foodstuffs

5.8.1. Sr-90 and Cs-137 in Meat

Pork and beef samples were collected in Copenhagen (cf. figs. 5.2.1 and 5.2.2) in three big shops in March, June, September, and December. Table 5.8.1 shows the results. The levels were nearly the same as in 1967 and 1968. Figs. 5.8.1.1 and 5.8.1.2 show a comparison between milk and meat levels. The ratio pCi Sr-90/kg meat/pCi Sr-90/l milk was 0.21 (S.E. 0.02), and the corresponding ratio for Cs-137 was 5.2 (S.E. 0.4) for the period 1962-69. (In these calculations meat consisted of 2/3 pork and 1/3 beef) (cf. also Appendix C).

Table 5.8.1

Sr-90 and Cs-137 in pork, beef and veal from Copenhagen in 1969

Species	Unit	Mar.	June	Sep.	Dec.	Mean
Pork	pCi Sr-90/kg	1.1	7.0	2.2	1.1	2.8
	pCi Sr-90/g Ca	12	7	14	8	10
	pCi Cs-137/kg	75	68	90	72	76
	pCi Cs-137/g K	20	21	23	22	22
Beef	pCi Sr-90/kg	1.2	1.4	1.5	0.7	1.2
	pCi Sr-90/g Ca	18	11	6	9	11
	pCi Cs-137/kg	60	59	147	34	75
	pCi Cs-137/g K	14	15	35	10	19
Veal	pCi Sr-90/kg	1.3	1.4	1.5	1.8	1.5
	pCi Sr-90/g Ca	17	14	20	13	16
	pCi Cs-137/kg	33	67	68	47	54
	pCi Cs-137/g K	8	15	18	15	14

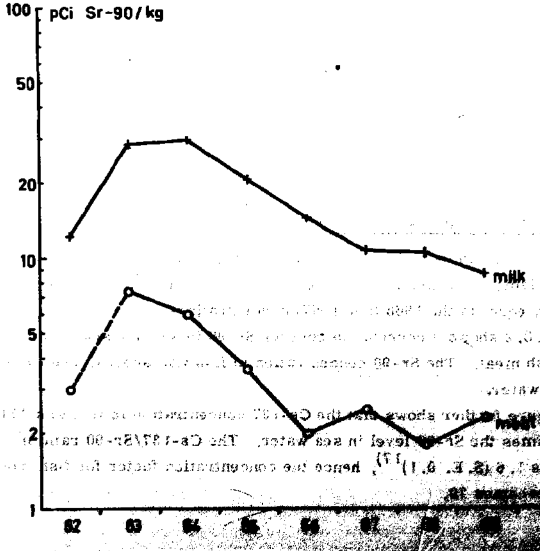


Fig. 5.8.1.1. [illegible]

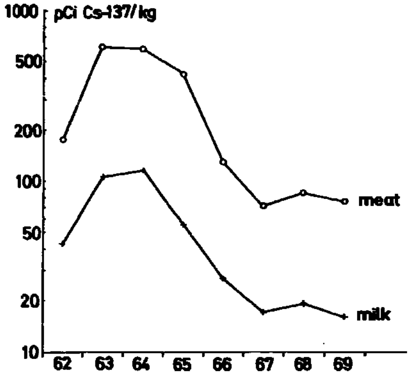


Fig. 5.8.1.2. Cs-137 in Danish milk and meat (2/3 pork and 1/3 beef) 1962-69.

5.8.2. Sr-90 and Cs-137 in Fish

Fish samples were collected at three coastal locations, Rødvig, Hundested and Helsingør, in Zealand. Table 5.8.2 shows the results. The levels were nearly equal to the 1968 (and 1967) concentrations.

Fig. 5.8.2 shows a correlation between Sr-90 in surface sea water and Sr-90 in fish meat. The Sr-90 concentration in fish was approx. two times that in sea water.

The figure further shows that the Cs-137 concentration in fish was 111 (S.E. 17) times the Sr-90 level in sea water. The Cs-137/Sr-90 ratio in sea water is 1.6 (S.E. 0.1)[17], hence the concentration factor for fish from sea water becomes 70.

Table 5.8.2

Sr-90 and Cs-137 in fish collected in 1969 in inner Danish waters

Species		Month	pCi Sr-90 per kg	pCi Sr-90 per g Ca	pCi Cs-137 per kg	pCi Cs-137 per g K
Garfish	meat	June	1.28	1.49	125	31
	bone		-	0.53	-	-
Plaice	meat	Dec.	0.71	1.41	25	6
	bone		-	0.66	-	-
Mackerel	meat	Dec.	0.03	0.05	12	4
	bone		-	0.34	-	-
Cod	meat	Dec.	1.56	1.68	126	32
	bone		-	1.81	-	-
Herring	meat	Dec.	0.95	0.72	28	8
	bone		-	0.13	-	-
Salmon	meat	Dec.	2.59	3.57	161	48
	bone		-	1.33	-	-
Trout	meat	Dec.	1.22	1.00	44	13
	bone		-	0.61	-	-
Eel	meat	Dec.	1.59	1.17	83	42
	bone		-	1.42	-	-
Mean	meat		1.24	1.39	74	23
	bone		-	0.85	-	-

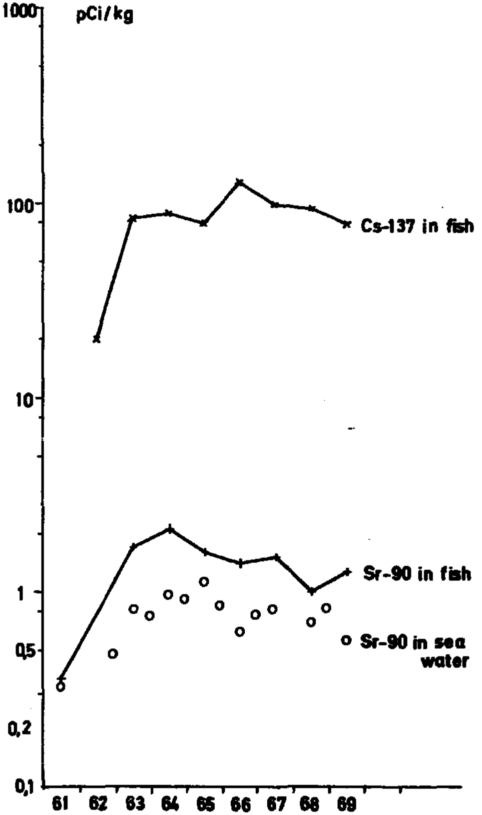


Fig. 5.8.2. Sr-90 and Cs-137 in Danish fish compared with Sr-90 in sea water 1961-69.

5.8.3. Sr-90 in Drinking Water

Along with the total-diet samples, 10 l of drinking water was collected in June in each of the 48 towns (cf. figs. 5.2.1 and 5.2.2). The 10 l samples were bulked into eight zone samples, each comprising 60 l of water. Furthermore, 3 · 20 l of water were collected from three different parts of Copenhagen and combined to a 60 l sample. The samples were analysed, by the method used for ground water, for Sr-90, stable strontium and calcium.

Table 5.8.4 shows the results.

Table 5.8.3

Sr-90 in Danish drinking water in 1969

Zone	June	
	pCi Sr-90/l	g Ca/l
I: N-Jutland	0.017	0.076
II: E-Jutland	0.019	0.075
III: W-Jutland	0.002	0.066
IV: S-Jutland	0.001	0.085
V: Funen	0.004	0.126
VI: Zealand	0.005	0.106
VII: Lolland-Falster	0.003	0.097
VIII: Bornholm	0.042	0.077
Mean	0.012	0.089
Copenhagen	0.015	0.138
Population-weighted mean	0.0112	0.102
Median	0.005	0.085

Table 5.8.4

Sr-90 and Cs-137 in coffee, tea and egg in 1969

Sample	Month	pCi Sr-90/kg	S. U.	pCi Cs-137/kg	M. U.
Coffee	Dec.	28.5 ± 0.3	20 ± 1	56	3
Tea	Dec.	25	100	391	10
Egg	Sep.	2.2	4.4	14	0.4
Egg	Dec.	1.5	2.7	10	0.3

The Sr-90 and Cs-137 levels in coffee and tea were the levels found in the coffee and tea made of 1 kg beans and 1 kg leaves respectively. (The S.U. and M.U. figures indicate the levels in the coffee and tea as drunk.

The variation between locations was in all cases highly significant (cf. Risö Report No. 154, p. 72[1]). The highest Sr-90 levels were found in drinking water from Bornholm, East Jutland and Copenhagen. As compared with 1967 and 1968 the 1968-Sr-90 levels were mostly lower.

The calcium (and stable strontium) levels were in close agreement with the observations made earlier.

5.9. Estimate of the Mean Contents of Sr-90 and Cs-137 in the Human Diet in Denmark in 1969

5.9.1. The Annual Quantities

The annual quantities are calculated by multiplication of the daily quantities (as stated by E. Hoff-Jørgensen, cf. Risö Report No. 63, table B[1]) by 365.

5.9.2. Milk and Cream

The Sr-90 and Cs-137 contents per kg milk were calculated from the annual mean values for dried milk (cf. tables 5.1.1 and 5.1.3). 1 kg ~1 1 milk, containing approx. 1.2 g Ca and 1.66 g K. Hence the mean contents in milk were 8.6 pCi Sr-90/kg and 16 pCi Cs-137/kg.

5.9.3. Cheese

1 kg of cheese contains approx. 8.5 g Ca and 1.2 g K. The Sr-90 and Cs-137 contents in cheese were calculated from these figures and from the S.U. and M.U. levels in dried milk (cf. tables 5.1.1 and 5.1.3). 1 kg of cheese appeared to contain 61.1 pCi Sr-90 and 12 pCi Cs-137.

5.9.4. Grain Products

Tables 5.9.1 and 5.9.2 show the estimates of Sr-90 and Cs-137 respectively in grain products consumed in 1969. From these tables the activity levels in grain products were estimated at 23.2 pCi Sr-90/kg and 48 pCi Cs-137/kg.

Table 5.9.1

Estimate of the Sr-90 content in grain products consumed per capita in 1969

Type	Fraction from harvest 1968			Fraction from harvest 1969			Total
	kg flour	pCi/kg	pCi	kg flour	pCi/kg	pCi	pCi
Rye flour (100% extraction)	21.9	46.0	1007	7.3	36.0	263	1270
Wheat flour (75% extraction)	32.9	11.8	388	10.9	6.1	66	454
Grits	5.5	20.0	110	1.8	15.6	28	138
Total	60.3	25.0	1505	20.0	17.9	357	1862

Table 5.9.2

Estimate of the Cs-137 content in grain products consumed per capita in 1969

Type	Fraction from harvest 1968			Fraction from harvest 1969			Total
	kg flour	pCi/kg	pCi	kg flour	pCi/kg	pCi	pCi
Rye flour (100% extraction)	21.9	96	2102	7.3	59	431	2533
Wheat flour (75% extraction)	32.9	26	855	10.9	19	207	1062
Grits	5.5	46	253	1.8	23	41	294
Total	60.3	53	3210	20.0	34	679	3889

5.9.5. Potatoes

The figures in table 5.5.1 were used, i.e. 3.9 pCi Sr-90/kg and 7.1 pCi Cs-137/kg.

5.9.6. Vegetables

Table 5.6.5 shows the calculation of Sr-90 and Cs-137 in Danish vegetables consumed in 1969. The mean contents were 13 pCi Sr-90/kg and 6.4 pCi Cs-137/kg.

5.9.7. Fruit

The levels in imported fruit in 1969 are assumed to be equal to the mean levels found in oranges and bananas collected in Copenhagen in December 1968, i.e. 5.6 pCi Sr-90/kg and 15 pCi Cs-137/kg. The mean levels in Danish fruit in 1969 were 2.6 pCi Sr-90/kg and 11.2 pCi Cs-137/kg (cf. 5.6). The daily mean consumption of fruit consisted of 100 g of Danish and 40 g of foreign origin. Hence the mean contents in fruit were 3.5 pCi Sr-90/kg and 12.3 pCi Cs-137/kg.

5.9.8. Meat

From table 5.8.1 the annual mean values of Sr-90 and Cs-137 in meat were calculated: 2.3 pCi Sr-90/kg and 76 pCi Cs-137/kg. (Danish meat consists of 2/3 pork and 1/3 beef).

5.9.9. Fish

The Sr-90 and Cs-137 contents in fish are shown in table [illegible]. The means of these figures are used as [illegible], i.e. 1.2 pCi Sr-90/kg and 74 pCi Cs-137/kg.

5.9.10. Eggs

The activity contents in eggs were estimated from the measurements in table 5.8.4. The levels were 1.8 pCi Sr-90/kg and 12 pCi Cs-137/kg.

5.9.11. Coffee and Tea

The levels, indicated in table 5.8.4, were used. 1/3 of the total consumption consists of tea and 2/3 of coffee. The mean contents were consequently 27 pCi Sr-90/kg and 168 pCi Cs-137/kg.

5.9.12. Drinking Water

The Sr-90 level found in drinking water collected in June (cf. table 5.8.3) was used as the country mean for drinking water, i.e. 0.01 pCi Sr-90/l. The Cs-137 content in drinking water is assumed to be negligible.

5.9.13. Discussion

Tables 5.9.3 and 5.9.4 show the estimates of Sr-90 and Cs-137 in the Danish diet in 1969. The figures should be compared with the levels cal-

Table 5.9.3

Estimate of the mean content of Sr-90 in the human diet in Denmark in 1969

Type of food	Annual quantity in kg	pCi Sr-90 per kg	Total pCi Sr-90	Percentage of total pCi Sr-90 in food
Milk and cream	164.0	8.6	1410	27.2
Cheese	9.1	61.1	556	10.7
Grain products	80.3	23.2	1862	36.0
Potatoes	73.0	3.9	285	5.5
Vegetables	43.8	13.0	569	11.0
Fruit	51.1	3.5	179	3.5
Meat	54.7	2.3	126	2.4
Eggs	10.9	1.8	20	0.4
Fish	10.9	1.4	15	0.3
Coffee and tea	5.5	27	149	2.9
Drinking water	548.0	0.01	5	0.1
Total			5176	

The mean calcium intake was estimated at [illegible] g (approx. [illegible] g Ca [illegible]). Hence the Sr-90/Ca ratio in the total diet was [illegible] S.U. in 1969.

Table 5.8.4

Estimate of the mean content of Cs-137 in the human diet in Denmark in 1969

Type of food	Annual quantity in kg	pCi Cs-137 per kg	Total pCi Cs-137	Percentage of total pCi Cs-137 in food
Milk and cream	164.0	16	2624	18.7
Cheese	9.1	12	109	0.7
Grain products	80.3	48	3854	27.5
Potatoes	73.0	7.1	518	3.7
Vegetables	43.8	6.4	280	2.0
Fruit	51.1	12.3	629	4.5
Meat	54.7	76	4157	29.6
Eggs	10.9	12	131	0.9
Fish	10.9	74	807	5.8
Coffee and tea	5.5	168	924	6.6
Drinking water	548	0	0	0
Total			14033	
As the approximate intake of potassium was 1365 g, the pCi Cs-137/g K ratio was approx. 10.3. The daily mean intake in 1969 was 38 pCi Cs-137 per capita.				

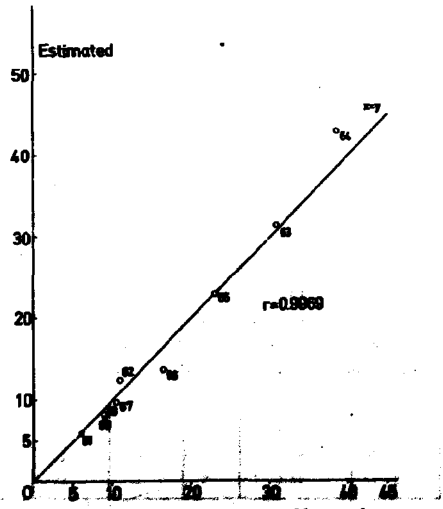


Fig. 5.8.1. A comparison between estimated (cf. 5.8) and measured (cf. 5.7) Sr-90 levels in total Danish diet 1961-69.

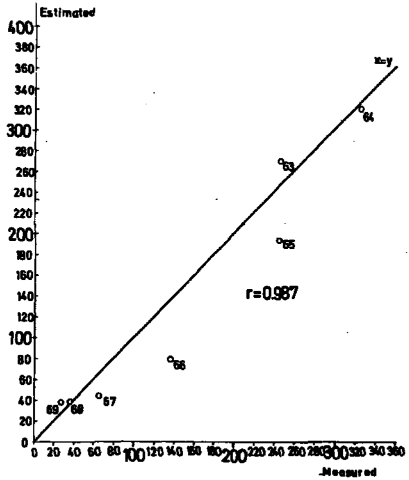


Fig. 5.9.2. A comparison between estimated (cf. 5.9) and measured (cf. 5.7) Cs-137 levels in total Danish diet 1963-69.

culated from the total-diet samples (cf. 5.7). The Sr-90 estimates obtained by the two methods were 8.3 S.U. and 9.0 S.U. respectively, and the Cs-137 estimates were 38 pCi Cs-137/day and 28 pCi Cs-137/day. Figs. 5.9.1 and 5.9.2 show a comparison between the measured and calculated levels in total Danish diet since 1961. The agreement between the two methods was satisfactory.

The relative contribution of Sr-90 from milk products decreased from approx. 46% in 1968 to 38% in 1969, whereas that from grain products increased from 30 to 36%. The contribution from potatoes, other vegetables and fruit was 20%, i.e. the same as in 1968. The relative contribution of Cs-137 in the total diet changed as follows from 1968 to 1969: Milk products showed a decrease from 23 to 19%, grain products an increase from 21 to 28%, and meat a decrease from 32 to 30%.

6. STRONTIUM-90 AND CAESIUM-137 IN MAN IN 1969

6.1. Sr-90 in Human Bone

The collection of human vertebrae from the institutes of forensic medicine in Copenhagen and Århus was continued in 1969. As in the total-food survey (cf. 5.7), the country was divided into eight zones. The samples were divided into five age groups: new-born (⟨1 month), infants (1 month - 4 years), children and teen-agers (5 - 19 years), adults (≤29 years) and adults (⟩29 years).

Tables 6.1.1 - 6.1.5 show the results for the five groups.

The levels were lower in 1969 than in 1968 for all age groups. The highest levels in vertebrae were found in the infant and children groups, the

Table 6.1.1

Sr-90 in bone from new-born children (⟨1 month old) in 1969

Zone	Age in days	Month of death	Sex	pCi Sr-90/g Ca	Sample no.
I	2	4	F	1.74	MK 29
I	27	4	F	2.35	MK 47
I	4	10	F	1.11	MK 122
I	1	9	M	0.64	MK 92
II	19	2	M	1.18	MK 14
II	4	2	F	2.27	MK 19
II	15	3	F	0.55	MK 39
II	22	3	F	0.53	MK 48
II	7	8	F	1.21	MK 65
II	5	7	F	1.00	MK 72
II	5	7	F	1.03	MK 74
II	4	7	M	1.12	MK 75
II	1	9	M	1.07	MK 95
II	11	9	M	1.19	MK 101
II	2	10	M	1.18	MK 98
II	6	11	M	1.35	MK 125
II	6	9	M	1.11	MK 99
III	5	4	-	0.74	MK 41
IV	21	2	F	0.66	MK 82

Table 6.1.2

Sr-90 in bone from infants (≤4 years old) in 1969

Zone	Age in years and months	Month of death	Sex	pCi Sr-90/g Ca	Sample no.
I	1 m	4	M	0.99	MK 36
I	2 m	4	M	1.94	MK 37
I	1 m	3	F	2.52	MK 44
I	3 1/2 m	6	M	0.91	MK 54
I	6 1/2 m	7	M	5.60	MK 69
I	1 1/2 m	10	F	2.19	MK 118
I	2 m	10	M	1.13	MK 119
II	1 m	1	F	0.36	MK 7
II	4 m	2	M	0.99	MK 8
II	1 1/2 m	2	M	0.75	MK 9
II	9 m	1	F	2.24	MK 10
II	5 m	2	F	2.90	MK 11
II	7 m	2	M	2.24	MK 12
II	1 m	2	M	0.94	MK 13
II	3 y 10 m	2	F	2.07	MK 15
II	9 m	3	M	0.80	MK 16
II	1 y 2 m	1	F	1.24	MK 18
II	4 m	3	F	1.48	MK 42
II	1 m	3	F	3.44	MK 43
II	5 m	6	M	1.96	MK 52
II	1 m	6	F	1.60	MK 51
II	3 m	7	F	1.61	MK 55
II	11 m	7	M	2.02	MK 60
II	4 m	7	M	1.21	MK 65
II	3 m	8	M	1.27	MK 66
II	5 m	8	F	1.42	MK 70
II	1 1/2 m	8	M	1.28	MK 71
II	2 m	11	F	1.27	MK 144
II	2 m	11	F	1.58	MK 142
II	4 m	9	M	1.10	MK 96
II	4 1/2 m	10	M	1.74	MK 107
II	1 y	10	M	3.82	MK 106
II	4 y	10	F	2.01	MK 121
III	3 m	3	F	3.02	MK 40
III	8 m	7	M	1.21	MK 58
III	4 y 1 m	7	F	1.63	MK 67
III	4 y 8 m	8	M	1.73	MK 68
III	3 m	7	F	1.55	MK 74
VI	1 y	12	F	2.04	MK 133
VI	3 m	12	F	1.97	MK 140
VI	4 m	11	M	1.29	MK 132

Table 6.1.3

Sr-90 in bone from children and teen-agers (≤19 years) in 1969

Zone	Age in years	Month of death	Sex	pCi Sr-90/g Ca	Sample no.
I	13	10	M	1.70	MK 115
I	5	11	M	2.95	MK 143
I	11	3	F	1.48	MK 45
II	7	4	F	2.26	MK 30
II	5	9	F	3.89	MK 148
II	16	9	M	3.92	MK 89
II	15	6	M	1.80	MK 64
II	19	11	M	2.36	MK 5
II	13	3	F	1.36	MK 20
II	6	1	F	2.27	MK 21
II	5	9	F	1.85	MK 100
II	6	8	F	5.18	MK 61
II	9	9	M	1.47	MK 97
III	8	9	M	1.86	MK 88
III	12	9	F	0.98	MK 90
III	18	10	M	1.55	MK 105
III	10	10	-	2.09	MK 120
III	6	5	M	2.56	MK 62
III	16	9	F	0.90	MK 94
IV	17	10	M	1.78	MK 116
IV	12	4	F	2.02	MK 28
VI	19	11	M	1.92	MK 128
VI	15	11	M	2.67	MK 126
VI	17	12	F	1.55	MK 136
VI	15	9	M	1.40	MK 87
VI	17	9	M	1.24	MK 86
VI	11	5	M	1.14	MK 25
VI	17	10	M	1.58	MK 113
VI	17	12	M	1.48	MK 135
VI	19	4	F	2.38	MK 31
VI	19	5	M	1.35	MK 27
VI	11	10	M	0.97	MK 114
VI	16	12	F	1.77	MK 137
VI	16	12	F	3.06	MK 141
VI	8	5	-	1.04	MK 24
VI	12	5	F	1.04	MK 26
VI	7	7	F	2.25	MK 57
VI	15	8	F	1.02	MK 80
VI	17	9	F	3.40	MK 82

Table 6.1.4

Sr-90 in vertebrae from adults (≤29 years) in 1969

Zone	Age in years	Month of death	Sex	pCi Sr-90/g Ca Ca	Sample no.
II	20	11	M	1.59	MK 117
IV	25	7	M	1.55	MK 76
IV	20	9	M	1.73	MK 91
VI	22	11	M	1.46	MK 129
VI	29	10	F	0.90	MK 127
VI	25	11	F	2.05	MK 125
VI	29	11	F	1.54	MK 124
VI	28	7	M	0.93	MK 49
VI	28	1	M	1.80	MK 4
VI	24	9	M	1.54	MK 65
VI	24	10	M	1.22	MK 111
VI	23	12	F	1.00	MK 138
VI	22	2	M	1.64	MK 32
VI	29	7	M	1.21	MK 50
VI	28	9	F	1.78	MK 79
VI	27	9	F	1.31	MK 83

Table 6.1.5

Sr-90 in vertebrae from adults (>29 years) in 1969

Zone	Age in years	Month of death	Sex	pCi Sr-90/g Ca	Sample No.
II	34	3	M	1.49	MK 34
VI	33	1	M	1.01	MK 1
VI	55	9	M	0.60	MK 78
VI	46	9	M	0.48	MK 81
VI	34	9	F	1.01	MK 84
VI	69	1	M	1.05	MK 3
VI	38	10	F	1.39	MK 110
VI	46	10	F	1.40	MK 112
VI	49	4	M	1.09	MK 33
VI	34	12	M	2.00	MK 139
VI	40	12	M	1.37	MK 134
VI	54	1	M	0.99	MK 2
VI	35	4	F	1.62	MK 35
VI	35	7	M	1.69	MK 53
VI	32	8	F	1.24	MK 56
VI	49	9	M	1.56	MK 77
VI	36	5	F	1.27	MK 23

lowest among new-born (cf. fig. 6.1). Adults between 20 and 29 years showed higher levels than adults of more than 29 years. The adult levels were lower than expected (cf. Appendix C) probably because most of the samples came from the eastern part of the country with the lower diet levels (cf. 5.7).

As in the previous years[1], the mean OR: S.U. (new born's bone)/S.U. (mother's diet) was calculated from tables 6.1.1, 5.7.1 and 5.7.2 and Risö Report No. 201, tables 5.7.1 and 5.7.2[1]. Table 6.1.7 shows the result compared with the OR values from previous years.

Table 6.1.6

Sr-90 (pCi/g Ca) in human vertebrae collected in Denmark in 1969

Age group	Number of samples	Min.	Max.	Median	Mean
New-born (< 1 month)	13	0.53	2.35	1.12	1.16
Infants (≤4 years)	41	0.36	5.60	1.60	1.78
Children (≤19 years)	39	0.90	5.18	1.78	1.94
Adults (≤29 years)	16	0.90	2.05	1.54	1.56
Adults (≥30 years)	17	0.48	2.00	1.27	1.25

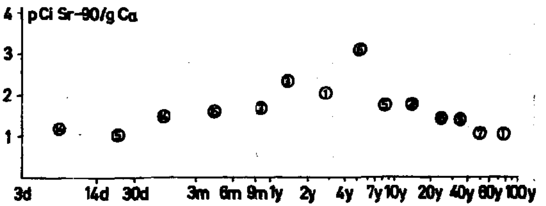


Fig. 6.1. Sr-90 in human vertebrae in 1969 (the figures in the circles indicate the number of samples).

Table 6.1.7

Observed ratios:

OR S.U. new borns' bone/S.U. mothers' diet during pregnancy 1963-69

Year	1963	1964	1965	1966	1967	1968	1969	Mean
OR	0.11	0.09	0.08	0.09	0.13	0.13	0.11	0.106
SD	0.04	0.02	0.05	0.05	0.06	0.05	0.05	0.020
SE	[illegible]	[illegible]	0.01	0.01	0.02	0.01	0.01	0.008

6.2. Cs-137 in the Human Body

In July 1963, whole-body measurements were initiated at Risö in the low-level counting room in the Health Physics Department (cf. 2.3 in Risö Report No. 85[1]). A control group from the Health Physics Department was selected and has since then been measured three times a year.

Table 6.2 shows the results. The control group is indicated by small letters in the table.

The annual mean value of the control group was 40.3 pCi Cs-137/g K. As earlier, we shall consider this figure representative of the mean of the Danish population in 1969. The total-body content of Cs-137 in 1969 for a standard man containing 140 g of potassium equals $140 \cdot 40.3 \cdot 10^{-3}$ nCi = 5.6 nCi Cs-137, i.e. approx. 85% of the 1968 level.

Fig. 6.2 shows the mean M.U. values (with one S.D.) for men and women measured in 1963-1969.

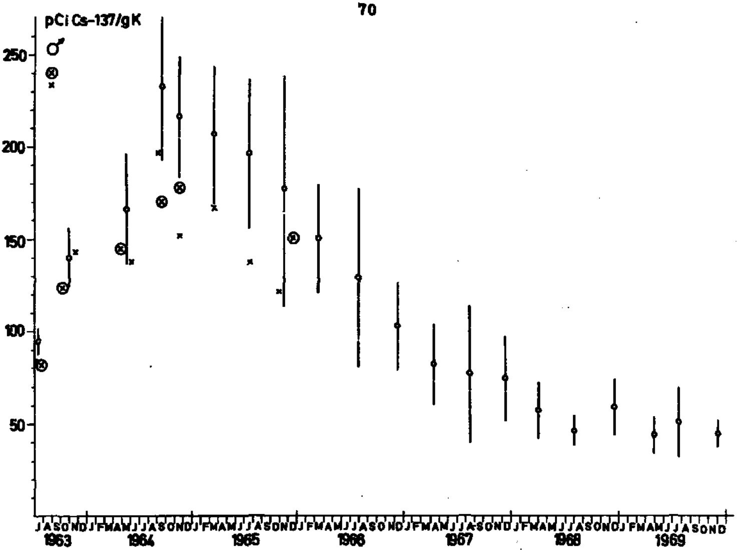
Table 6.2

Whole-body measurements of caesium-137 and potassium in 1969

No.	Sex	Counting date	Age	Height in cm	Weight in kg	Daily milk concumption	-M.U. in body	Body burden in nCi Cs-137	g K/kg body weight
a 22	f	18/4	32	164	59	1/4 1	47.3	3.78	1.36
b 28	f	30/4	38	176	62	1/4 1	38.9	5.03	2.13
c 20	m	21/4	44	174	86	0 1	36.5	3.21	1.03
d 23	f	17/4	41	171	64	1/2 1	44.2	6.50	2.3
e 21	m	19/4	31	174	73	1/4 1	38.1	6.46	2.3
g 27	f	28/4	22	164	48	1/2 1	33.9	4.71	3.29
i 18	m	22/4	40	170	66	0 1	34.2	2.58	1.16
k 26	f	28/4	37	161	55	1/4 1	47.2	5.86	2.22
l 15	m	23/4	37	172	66	3/4 1	44.0	5.70	2.06
m 13	m	25/4	37	193	79	1/4 1	41.2	5.15	1.33
n 12	m	25/4	38	170	71	0 1	31.5	5.90	2.27
o 17	m	24/4	44	170	64	1/2 1	44.8	6.87	2.4
p 6	f	6/5	37	178	65	0 1	33.1	4.18	1.92
q 16	m	23/4	39	192	83	1/2 1	48.4	4.94	1.23
u 25	f	25/4	30	162	49	1/4 1	39.2	4.53	2.3
v 11	m	24/4	27	174	74	1/2 1	49.0	4.29	1.42
x 14	m	30/4	30	178	79	1/4 1	35.8	4.61	1.75
y 8	f	5/5	34	160	54	1/4 1	32.2	3.72	2.1
z 9	f	5/5	30	160	58	3/4 1	35.7	3.80	1.85
å 7	m	6/5	46	183	73	1/4 1	69.2	11.25	2.23
a 45	f	4/7	32	164	60	1/4 1	47.6	3.20	1.12
b 44	f	4/7	38	176	62	1/4 1	47.1	4.45	1.5
c 36	m	10/7	44	174	85	0 1	41.1	5.95	1.46
d 29	f	17/7	41	171	63.5	1/2 1	27.3	4.98	2.8
e 34	m	16/7	31	174	71	1/4 1	38.1	4.68	1.7

No.	Sex	Counting date	Age	Height in cm	Weight in kg	Daily milk concump-tion	M. U. in body	Body burden in nCi Cs-137	g K/kg body weight
g 43	f	4/7	22	164	48	1/4 l	36,6	4,53	?,6
i 30	m	16/7	40	170	66	0 l	97,2	10,27	1,6
k 33	f	22/7	37	161	56	1/4 l	32,2	4,77	2,6
l 39	m	9/7	37	172	66	3/4 l	32,0	5,91	2,8
m 50	m	1/8	37	193	72,5	1/4 l	62,0	9,49	2,1
n 40	m	8/7	38	170	71	0 l	37,2	5,41	2,01
o 37	m	10/7	44	170	63	1/2 l	55,5	7,46	2,15
p 47	f	8/7	37	178	65	1/4 l	29,2	2,73	1,44
q 35	m	19/7	39	192	85	1/2 l	53,6	7,26	1,6
t 31	f	18/7	39	168	56	1/2 l	23,3	2,99	2,3
u 38	f	9/7	30	162	50	1/4 l	24,1	2,66	2,2
v 41	m	7/7	27	174	74,5	1/2 l	47,8	5,18	1,46
x 32	f	17/7	45	161	65	0 l	38,5	3,33	1,37
z 42	m	7/7	30	178	79	1/4 l	34,1	4,78	1,74
æ 49	f	31/7	34	160	53	1/4 l	28,7	3,20	2,13
ø 51	f	4/8	30	160	58	1/2 l	38,5	3,98	1,78
å 46	m	3/7	46	183	71	1/4 l	43,1	7,42	2,4
a 52	f	12/12	32	164	60	1/4 l	14,8	1,54	1,16
b 71	f	25/11	38	176	62	1/4 l	33,1	5,24	2,55
c 66	m	28/11	44	174	89	0 l	36,7	5,72	1,75
d 64	f	1/12	41	171	65	1/2 l	46,1	7,60	2,62
e 53	m	11/12	31	174	70	1/4 l	49,6	9,14	2,63
g 57	f	4/12	22	164	47,5	1/4 l	33,9	5,28	3,29
i 61	m	2/12	40	170	64	0 l	53,2	8,60	2,53
k 55	f	8/12	37	161	55	1/4 l	34,0	5,53	2,96
l 70	m	26/11	37	172	66	3/4 l	47,1	7,53	2,42
m 68	m	27/11	37	193	78	1/4 l	53,9	10,25	2,44
n 69	m	26/11	38	170	75	0 l	40,6	6,95	2,28
p 65	f	28/11	37	178	64	0 l	37,8	5,44	2,25
q 59	m	3/12	39	192	85	1/2 l	48,0	7,68	1,88
t 54	f	9/12	39	168	57	1/2 l	32,9	4,65	2,48
u 63	f	25/11	30	162	52	1/4 l	35,7	5,85	3,14
v 60	m	3/12	27.	174	73	1/2 l	43,4	7,85	2,47
y 62	f	2/12	21	165	52,5	1/4 l	32,9	8,60	3,09
z 67	m	27/11	30	178	80	1/4 l	34,6	5,62	2,03
ø 58	f	4/12	34	160	54	1/4 l	45,2	6,95	2,85
å 56	m	3/12	46	183	74	1/4 l	37,8	8,98	3,21

The maximum was reached in August 1964. The figure also shows that the mean level in the male group was approx. 1.3 - 1.5 times as high as that in the female group. The levels were nearly constant throughout 1969 (cf. also Appendix C).



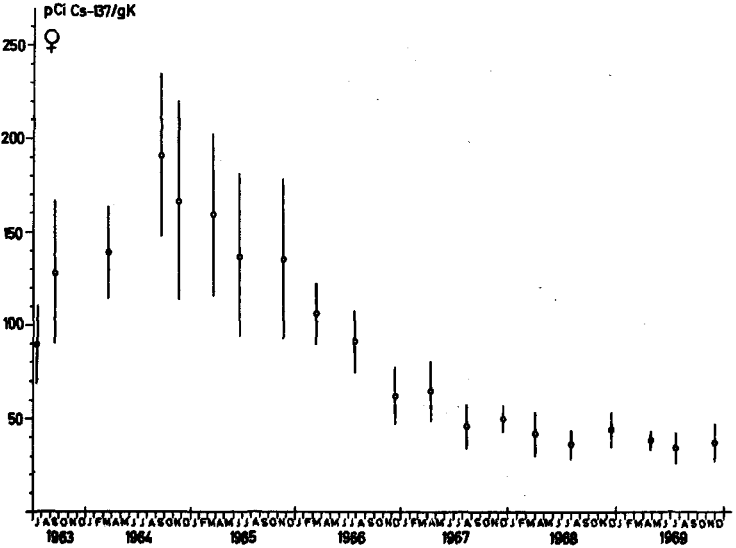


Fig. 6.2. Cs-137 mean levels in humans, 1963-69 (1 S.D. indicated).

7. STRONTIUM-90 IN SEA WATER IN 1969

The collection of sea-water samples initiated in 1961-62 was continued in 1969. The samples, all of them surface samples, were collected only in June around Zealand at the locations used in November-December 1962 (cf. Risö Report No. 63[1]).

The one-litre samples from the Sound were bulked into three-monthly samples. The 40 locations in the Sound were those used in 1961 (cf. Risö Report No. 41, fig. 7.1.1.2[1]).

Tables 7.1 and 7.2 show the results.

Fig. 7.1 shows the mean content of Sr-90 in sea water collected since November-December 1962 at the locations in table 7.1 (cf. also fig. 5.8.2).

Table 7.1

Sr-90 in sea water collected around Zealand in June 1969

Latitude N	Longitude E	Water	pCi Sr-90/l	pCi Sr-90/g Ca	Salinity in o/oo
56°11' 56°06'	11°45' 11°08'	The Cattegat (Hesselø, Sjællands Odde)	0.47	1.76	20.0
55°46'	11°28'	The Cattegat (Samsø)	0.47	1.68	20.8
55°27' 55°17'	10°42' 10°49'	The Great Belt (Kerteminde Bay, Nyborg Fjord)	0.51	1.97	19.5
55°01' 54°57'	10°31' 10°42'	The Great Belt (Svendborg Sound, Rudköbing löb)	0.66	3.12	15.8
55°10' 54°53'	11°37' 11°28'	The Great Belt (Karrebaksminde, Askö)	0.66	3.33	14.8
54°12' 54°36'	10°40' 11°09'	The Femern Belt (Kjelds Nor, Fehmern Belt)	0.66	2.81	17.6
54°33' 54°46'	11°56' 11°52'	The Baltic Sea (Gedser rev, Nykøbing Falster)	0.70	4.31	12.2
54°53'	12°09'	Grønsund	0.42	3.50	8.9
54°58' 55°08'	12°36' 12°17'	Fakse Bay (Möns Klint, Fakse Bay)	0.62	5.21	9.2
		Mean	0.57	3.07	15.4
		SD	0.11	1.17	4.5
		SE	0.04	0.39	1.5

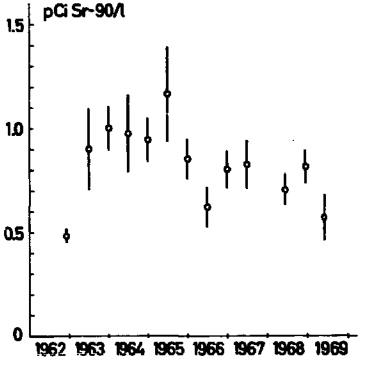


Fig. 7.1. Sr-90 in sea water from inner Danish waters, 1962-69 (1 S.D. indicated).

<u>Table 7.2</u>

Sr-90 in the Sound in 1969, mean of 40 stations (cf. Risö Report No. 41[1])

Sampling period	pCi Sr-90/l	pCi Sr-90/g Ca	Salinity in o/oo
July-September	0.76 ± 0.04	4.80 ± 0.20	11.8
October-December	0.41	2.42	12.7
The error term is the S.E. or a double determination.			

8. SPECIAL SURVEYS

8.1. Meteorological Mast Experiment

As in the previous years, samples of precipitation were collected from the meteorological mast at Risö at eight different heights (cf. fig. 3.1.2.2).

Table 8.1.1 shows the Sr-90 levels in the eight bottles throughout the year and tables 8.1.2 and 8.1.3 the analysis of variance of the natural logarithm of the pCi Sr-90/l and the mCi Sr-90/km^2 figures respectively. As previously, the variations between months were highly significant (P > 99.95%).

The variation between locations was probably significant, undoubtedly owing to the great analytical error.

The mean amount of precipitation in the eight bottles on the mast was 321 mm in 1969, i.e. 75% of the level measured in rain bottles at ground level at Risö (cf. table 3.2.4.1). The total deposition was 0.87 mCi Sr-90/km^2, i.e. equal to the level measured at the ground stations at Risö (cf. 3.2.4).

8.2. Levels of Sr-90 and Cs-137 in Grass and Milk from the Entire Country

In September grass and milk samples were as previously collected from the State experimental farms (cf. fig. 4.1.1). (As no milk was obtainable from Virumgård, this farm was omitted from the sampling.)

Table 8.2.1 shows the Sr-90 and Cs-137 contents in grass and milk from the sample collection. The mean Sr-90 level in grass was in September 63 S.U. (in 1968 the September level was 77 S.U.), and the mean level at Risö (cf. table 3.2.2) in July-September 1969 was 55 S.U.

The mean milk levels were 5.6 S.U. and 9.6 M.U. In dried milk we found in September 5.8 S.U. and 10.8 M.U.

The OR between mean S.U. in milk and grass was 0.10 in 1969 i.e. nearly the same as in 1965-68.

8.3. Sr-90 and Cs-137 in Human Milk

Donor A was identical to donor A in 1965 (cf. Risö Report No. 130, p. 92[1]) and donor D was identical to donor D in 1964 (cf. Risö Report No. 107, p. 88[1]).

Table 8.1.1

Sr-90 in the meteorological mast 1969

	0 m		7 m		23 m		39 m	
	pCi/l	mCi/km^2	pCi/l	mCi/km^2	pCi/l	mCi/km^2	pCi/l	mCi/km^2
Jan.	1,15	0,041	1,13	0,048	1,65	0,057	1,50	0,048
Feb.	3,04	0,017	1,54	0,005	4,17	0,012	10,66	0,016
Mar.	21,50	0,073	23,30	0,065	22,10	0,062	10,61	0,030
Apr.	1,72	0,071	2,29	0,086	1,98	0,061	3,21	0,098
May	3,22	0,173	4,22	0,254	4,25	0,226	5,51	0,286
June	3.47	0,159	3.26	0,144	3.54	0,153	3.93	0,163
July	5.19	0,058	6,19	0,059	7.37	0,062	5.73	0,048
Aug.	1,86	0,101	2,37	0,123	2,38	0,120	2,57	0,125
Sep.	1,83	0,038	2,16	0,038	1,28	0,022	1,48	0,024
Oct.	0,56	0,026	0,66	0,032	0,86	0,040	0,54	0,023
Nov.	0,46	0,023	0,90	0,043	0,60	0,028	0,48	0,022
Dec.	1,74	0,006	2,48	0,009	1,400	0,009	4,24	0,020
1969	$\bar{x}$ 2,11	Σ 0,786	$\bar{x}$ 2,46	Σ 0,908	$\bar{x}$ 2,47	Σ 0,846	$\bar{x}$ 2,77	Σ 0,903
	372 mm		369 mm		342 mm		326 mm	

Table 8.1.2

Analysis of variance of ln pCi Sr-90/l in precipitation in 1969
(from table 8.1.1)

Variation	SSD	f	s^2	v^2	P
Between locations	2.3528	7	0.3361	2.86	>97.5%
Between months	86.6239	11	7.8749	67.02	>99.95%
Remainder	8.8120	75	0.1175		
η = 0.35					

Table 8.1.3

Analysis of variance of ln mCi Sr-90/km^2 in precipitation in 1969
(from table 8.1.1)

Variation	SSD	f	s^2	v^2	P
Between locations	1.7157	7	0.2451	2.85	>97.5%
Between months	84.8339	11	7.7121	89.78	>99.95%
Remainder	6.4415	75	0.0859		
η = 0.30					

56 m		72 m		96 m		123 m		Mean	
pCi/l	mCi/km^2	pCi/l	mCi/km^2	pCi/l	mCi/km^2	pCi/l	mCi/km^2	pCi/l	mCi/km^2
1.44	0.043	1.47	0.048	(1.79)	(0.052)	(1.34)	(0.032)	1.51	(0.048)
9.91	0.008	8.65	0.012	7.79	0.014	19.78	0.010	8.19	0.012
20.80	0.064	14.40	0.045	20.60	0.052	25.60	0.048	19.86	0.055
1.97	0.054	2.70	0.085	2.41	0.062	3.15	0.059	2.42	0.072
5.02	0.256	5.91	0.357	5.95	0.290	4.85	0.190	4.86	0.251
3.57	0.147	4.15	0.180	3.59	0.147	3.80	0.138	3.66	0.154
5.64	0.043	6.46	0.045	8.01	0.056	12.10	0.059	7.09	0.054
2.44	0.110	3.50	0.178	4.85	0.202	2.85	0.108	2.85	0.134
1.48	0.026	1.61	0.026	1.42	0.019	0.92	0.009	1.52	0.025
0.71	0.035	0.58	0.029	0.82	0.034	0.52	0.017	0.66	0.030
0.56	0.026	0.58	0.026	0.63	0.025	0.65	0.017	0.61	0.026
3.14	0.014	2.25	0.008	5.65	0.022	9.92	0.008	3.85	0.012
$\bar{x}$ 2.54	Σ 0.826	$\bar{x}$ 2.97	Σ 1.017	$\bar{x}$ 3.67	Σ (0.975)	$\bar{x}$ 3.06	Σ (0.679)	$\bar{x}$ 2.72	Σ (0.873)
325 mm		342 mm		266 mm		222 mm		321 mm	

Table 8.2.1

Sr-90 and Cs-137 in grass and milk in Sept. 1969 collected on the State experimental farms

	Milk pCi Sr-90/g Ca	Milk pCi Cs-137/g K	Milk pCi Cs-137/l	Grass pCi Sr-90/g Ca	Grass pCi Cs-137/g K	Grass pCi Cs-137/kg	S.U. milk / S.U. grass	Milk M.U./S.U.
Tylstrup	6.0	10.6	18.6	48	9.4	109	0.13	1.8 1.1
Studsgård	6.3	6.3	10.6	104	6.4	95	0.06	1.0 1.0
Ødum	5.0	7.5	12.6	41	3.2	30	0.12	1.5 2.3
Askov	5.2	6.9	11.0	87	3.8	27	0.06	1.3 1.8
St. Jyndevad	8.7	8.2	13.7	123	5.0	41	0.07	0.9 1.6
Blangstedgård	5.3	11.3	18.6	44	4.2	33	0.12	2.1 2.7
Tystofte	5.8	17.0	27.8	27	0.5	5	0.21	2.9 (34.0)
Virumgård								
Abed	4.2	11.6	19.5	54	12.3	96	0.08	2.8 0.9
Åkirkeby	4.0	7.2	11.9	43	5.4	41	0.09	[illegible] 1.4
Mean	5.6	9.6	16.0	63	5.6	53	0.10	[illegible] (1.6)
S.D.	1.4	3.4	5.6	33	3.5	37	[illegible]	0.7 (0.6)
v	0.25	0.35	0.35	0.52	0.63	0.70	0.46	0.40 (0.40)

The Cs-137 determinations were performed by γ-spectroscopy of the dried milk, and Sr-90 was determined in the ash by the usual method[3]. Table 8.3.1 shows the results.

Table 8.3.1

Sr-90 and Cs-137 in human milk collected in Jan.-Oct. 1969

Donor	Location	Period of collection	pCi Cs-137/l	pCi Cs-137/g K	g K/l	pCi Sr-90/l	pCi Sr-90/g Ca	g Ca/l	Cs-137/Sr-90 (pCi/l)
D	Holbæk	Jan.	4.8	7.9	0.61	0.45	1.15±0.13	0.39	11
A	Copenhagen	Jan.	8.1±1.2	11.7±1.8	0.69	0.86	1.87±0.22	0.46	9.4
A	"	Feb.	7.3±0.1	12.3±0.2	0.59	0.69	1.84±0.20	0.38	10.6
A	"	Mar.	7.0±0.7	11.8±1.2	0.59	0.97	2.36±0.18	0.41	7.2
A	"	Apr.	8.8±3.4	12.7±3.5	0.69	1.12	2.48±0.24	0.44	7.9
A	"	May	4.9±0.1	6.8±0.2	0.72	0.82	1.72±0.08	0.48	6.0
A	"	June	12.9	17.5	0.74	0.67	1.50±0.01	0.45	19.2
A	"	July	8.0±1.5	13.2±2.4	0.61	0.45	1.30±0.03	0.35	17.8
A	"	Aug.	7.6±1.0	12.8±1.6	0.59	0.46	1.30	0.36	16.5
A	"	Sept.	10.6	15.4	0.69	0.53	1.29	0.41	20.0
A	"	Oct.	8.4±2.3	11.5±3.1	0.73				

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

The Sr-90 mean levels in the donor milk in 1969 were 0.70 pCi Sr-90/l (S.D.: 0.24 pCi/l) and 1.74 pCi Sr-90/g Ca (S.D.: 0.45), and the mean levels of Cs-137 were 8.4 pCi Cs-137/l (S.D.: 2.1) and 12.6 pCi Cs-137/g K (S.D.: 2.8). If the mean level of the food collected in zone VI and Copenhagen in December 1968 and in June 1969 is considered to be representative of the donors' diet (cf. the observations in 1964 and 1965[1]), we can estimate the diet level at 8.4 pCi Sr-90/g Ca or 15.2 pCi Sr-90/day and 7.9 pCi Cs-137/g K or 28 pCi Cs-137/day. The percentage of the daily Cs-137 intake with food that is excreted per litre of milk has been calculated at 30%, the ratio $\frac{\text{M.U. in human milk}}{\text{M.U. in diet}}$ was 1.6, and the OR $\frac{\text{S.U. in human milk}}{\text{S.U. in diet}}$ was 0.21 (cf. table 8.3.2).

Table 8.3.2

A comparison between Cs-137 and Sr-90 levels in human milk and diet collected in 1961-69

Period	Percentage of the daily Cs-137 intake excreted per litre of milk	(pCi Cs-137/g K) human milk / (pCi Cs-137/g K) diet	OR: S.U. human milk / S.U. diet
Nov. 61 - Mar. 62	-	-	0.16
Mar. 62	32 *	1.9*	0.18*
July-Sept. 62	-	-	0.14
Sept. 62	28 *	1.1 *	0.08*
Dec. 63-May 64	14	0.9	0.15
May-Nov. 64	21	1.7	0.10
Oct. 64	21 *	2.3*	0.09*
Feb.-Mar. 65	20	1.3	0.24
Jun.-Sept. 65	22	1.6	0.13
Oct. 65	51 *	1.7*	0.13*
Oct.-Dec. 65	23	1.7	0.11
Apr.-May 66	17	1.2	0.15
May-Sep. 66	27	1.8	0.10
Oct.-Nov. 66	41	2.5	0.14
Apr.-May 67	8	0.5	0.13
June 67	15	0.7	0.09
Oct.-Dec. 68	18	1.1	0.24
Jan.-Apr. 69	21	1.3	0.24
May-Oct. 69	40	2.2	0.16
Mean	25	1.5	0.14
S.D.	11	0.5	0.05
S.E.	3	0.1	0.01

The diet levels were the means of zone VI and Copenhagen in tables 5.7.1 and 5.7.2[1] except for * where the milk donor's diet was collected for one week and analysed. In some of the periods milk was obtained from more than one donor.

8.4. Country-wide Measurement of the γ-Background in 1969

8.4.1. State Experimental Farms

As in the previous years[1], the γ-background was measured in March, June, September, and December at ten State experimental farms. Table 8.4.1.1 shows the results, and table 8.4.1.2 gives the analysis of variance.

Table 8.4.1.1

γ-background at the State experimental farms in 1969 (μR/h)

	Mar.	June	Sep.	Dec.	Mean
Tylstrup	4.8	5.1	6.2	5.4	5.4
Studsgård	4.9	5.2	4.7	4.3	4.8
Ødum	7.2	6.8	7.0	6.1	6.8
Askov	6.5	4.4	6.2	6.1	5.8
St. Jyndevad	4.5	4.4	3.8	4.4	4.3
Blangstedgård	6.8	6.8	7.6	6.4	7.2
Tystofte	8.0	8.0	7.6	7.7	7.8
Virumgård	7.5	6.8	7.3	7.0	7.0
Abed	4.1	4.6	7.9	6.5	5.8
Åkirkeby	(8.2)	9.1	8.2	7.6	(8.3)
Mean	6.3	6.1	6.7	6.2	6.3

Table 8.4.1.2

Analysis of variance of the γ-background at the State experimental farms in 1969 (from table 8.4.1.1)

Variation	SSD	f	s^2	v^2	P
Between locations	56.6841	9	6.2982	10.54	>99.95%
Between months	1.6422	3	0.5474	0.92	-
Remainder	15.5333	26	0.5974		
η = 0.12					

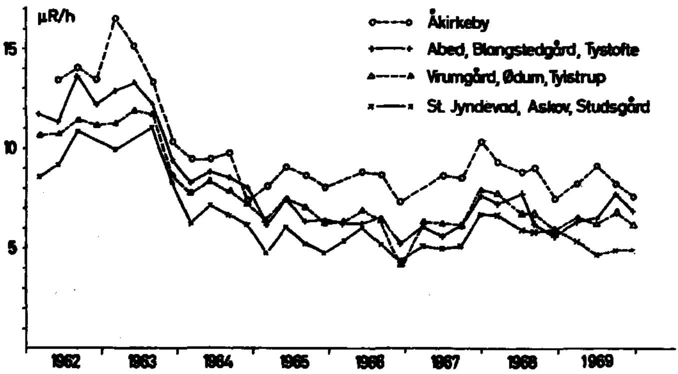


Fig. 8.4. The γ-background at the State experimental farms, 1962-69.

The variation between locations was highly significant (P > 99.95%). As in the previous years, it was evidently not the fall-out that determined the variation between locations.

Fig. 8.4 shows the γ-background in four groups of sampling stations since 1962. The fact that stations with a low fall-out rate and a high clay content in the soil (Abed, Blangstedgård and Tystofte) show higher γ-levels than stations with a high fall-out rate and a low clay content (but a high sand content) (Studsgård, St. Jyndevad and Askov) was discussed in Risö Report No. 154[1].

8.4.2. The Risö Environment

γ-background measurements were performed in the five zones round Risö in February, May, August, and November. The measurements were carried out at the locations where grass and soil are collected (cf. figs. 3.1.2.1 and 3.1.2.2 (the coloured map)).

Table 8.4.2.1 shows the results and tables 8.4.2.2 - 8.4.2.6 the analysis of variance.

Table 8.4.2.1

γ-background (μR/h) in the five zones around Risö in 1969

Risö zone (cf. coloured map)	Location	Feb.	May	Aug.	Nov.	Mean
I	1	9.3	6.4	9.2	8.2	8.3
-	2	7.5	6.4	8.3	7.8	7.5
-	3	15.2	19.3	12.7	18.9	16.5
-	4	9.0	8.6	10.0	9.1	9.2
-	5	(8.9)	8.3	9.2	9.4	9.0
Mean		10.0	9.8	9.9	10.7	10.2
II	1	6.0	6.1	8.0	6.7	6.7
-	2	7.8	6.4	9.2	6.4	7.5
-	3	6.6	5.8	7.1	6.4	6.5
-	4	7.2	7.6	8.3	7.6	7.7
Mean		6.9	6.5	8.2	6.8	7.1
III	1	6.9	6.7	8.9	6.7	7.3
-	2	6.0	6.4	7.4	6.4	6.6
-	3	6.3	6.4	8.9	6.4	7.0
-	4	6.6	6.1	7.4	6.4	6.6
Mean		6.5	6.4	8.2	6.5	6.9

Table 8.4.2.1

γ-background (μR/h) in the five zones around Risö in 1969

Risö zone (cf. coloured map)	Location	Feb.	May	Aug.	Nov.	Mean
IV	1	6.0	6.1	7.7	6.1	6.5
-	2	6.3	6.4	8.3	7.0	7.0
-	3	6.6	6.4	7.4	7.0	6.9
-	4	6.0	5.4	7.7	6.1	6.3
-	5	6.6	6.1	7.7	6.4	6.7
-	6	6.3	5.8	6.5	6.4	6.3
-	7	7.2	6.1	7.4	6.1	6.7
-	8	7.8	6.4	7.7	6.1	7.0
Mean		6.6	6.1	7.6	6.4	6.7
V	1	6.6	6.4	6.8	6.1	6.5
-	2	6.3	6.4	7.4	6.7	6.7
-	3	7.2	6.4	5.9	6.4	6.5
-	4	6.6	6.1	7.4	5.8	6.5
-	5	7.5	7.3	8.9	7.0	7.7
-	6	6.6	6.4	7.7	6.7	6.9
-	7	6.9	6.4	8.3	7.0	7.2
-	8	8.4	6.7	8.0	7.3	7.6
-	9	7.5	6.4	8.3	7.0	7.3
-	10	6.6	6.1	7.1	6.7	6.6
-	11	7.5	6.7	7.7	7.0	7.2
-	12	7.8	6.4	8.0	6.7	7.2
Mean		7.1	6.5	7.6	6.7	7.0

Table 8.4.2.2

Analysis of variance of the results from table 8.4.2.1, zone I Risö

Variation	SSD	f	s^2	v^2	P
Betw. locations	212.9720	4	53.2430	16.03	>99.95%
Betw. months	2.3313	3	0.7771	0.23	-
Remainder	36.5387	11	3.3217		
η = 0.18					

Table 8.4.2.3

Analysis of variance of the results from table 8.4.2.1, zone II Risö

Variation	SSD	f	s^2	v^2	P
Betw. locations	3.7262	3	1.2421	3.42	-
Betw. months	7.0357	3	2.3452	6.45	>97.5%
Remainder	3.2713	9	0.3635		
η = 0.09					

Table 8.4.2.4

Analysis of variance of the results from table 8.4.2.1, zone III Risö

Variation	SSD	f	s^2	v^2	P
Betw. locations	1.7286	3	0.5762	3.11	-
Betw. months	9.0691	3	3.0230	16.30	>99.9%
Remainder	1.6689	9	0.1854		
η = 0.06					

Table 8.4.2.5

Analysis of variance of the results from table 8.4.2.1, zone IV Risö

Variation	SSD	f	s^2	v^2	P
Betw. locations	2.3466	7	0.3352	1.72	-
Betw. months	10.6458	3	3.5486	18.17	>99.95%
Remainder	4.1022	21	0.1953		
η = 0.07					

Table 8.4.2.6

Analysis of variance of the results from table 8.4.2.1, zone V Risö

Variation	SSD	f	s^2	v^2	P
Betw. locations	8.5051	11	0.7732	4.31	>99.9%
Betw. months	9.3285	3	3.1094	17.35	>99.95%
Remainder	5.9122	33	0.1792		
η = 0.06					

In all locations in zone I and in location 2 in zone II the Y-background was increased because of the various radiation sources at the research establishment. The weighted annual mean for zones III-V was 6.9 μR/h, i.e. a little higher than found for the State experimental farms in table 8.4.1.1. In zone 1 the surplus activity from the research establishment was 10.2 - 6.9 = 3.3 μR/h (in 1967: 4.0 and in 1968: 3.9). A man working in the open in the Risö area 40 hours a week for 45 weeks a year would thus get a surplus dose of 6 mR/year from the research establishment.

The background activity was highest in August (cf. 3.2.1 and 3.3).

Table 8.4.3.1

Y-background (μR/h) around a location in Zealand in 1969

Zone and sector	Jan.	Apr.	July	Oct.	Mean
A 2	-	7.4	-	7.3	7.4
A 3	6.6	-	6.5	-	6.6
A 4	-	9.4	-	8.2	8.8
A 5	5.4	-	7.1	-	6.3
A 6	-	7.8	-	7.8	7.8
A 7	7.2	-	7.4	-	7.3
A 8	-	7.4	-	7.0	7.2
A 9	7.2	-	7.7	-	7.5
Mean	6.6	8.0	7.2	7.6	7.4
B 1	-	7.2	-	7.0	7.1
B 2	7.5	-	7.4	-	7.5
B 3	-	8.1	-	7.6	7.9
B 4	6.9	-	7.1	-	7.0
B 5	-	9.0	-	7.0	8.0
B 6	7.5	-	7.1	-	7.3
B 7	-	7.4	-	7.0	7.2
B 8	8.7	-	8.0	-	8.4
B 9	7.5	7.4	-	7.8	7.6
B 10	-	-	7.1	-	7.1
Mean	7.6	7.8	7.3	7.3	7.5

Table 8.4.3.1

γ-background (μR/h) around a location in Zealand in 1969

Zone and sector	Jan.	Apr.	July	Oct.	Mean
C 1	6.0	-	5.9	-	6.0
C 2	-	7.4	-	6.7	7.1
C 3	6.0	-	6.5	-	6.3
C 4	-	7.4	-	7.8	7.6
C 5	7.5	-	6.5	-	7.0
C 6	-	8.1	-	6.7	7.4
C 7	7.8	-	7.7	-	7.8
C 8	-	7.2	-	7.6	7.4
C 9	6.9	-	7.1	-	7.0
C 10	-	7.4	-	7.8	7.6
C 11	8.7	-	7.1	-	7.9
C 12	-	7.2	-	6.1	6.7
Mean	7.2	7.5	6.8	7.1	7.2
D 1	-	8.7	-	5.8	7.3
D 2	6.9	-	7.1	-	7.0
D 3	-	8.7	-	7.8	8.3
D 4	6.9	-	6.8	-	6.9
D 5	-	7.8	-	7.8	7.8
D 6	7.5	-	7.1	-	7.3
D 7	-	7.2	-	7.0	7.1
D 8	7.2	-	7.7	-	7.5
D 9	-	6.8	-	7.3	7.1
D 10	8.7	-	8.3	-	8.5
D 11	-	7.2	-	7.0	7.1
D 12	5.4	-	5.4	-	5.4
Mean	7.1	7.7	7.1	7.1	7.3

8.4.3. A Location in Zealand

As it is important to have knowledge of the preoperational radiation-levels of a nuclear power plant, it was in 1967 decided to initiate such measurements at a location in Zealand (and one in Jutland) which might be used for nuclear power plants in the future.

The area around the location was divided into four zones: A, B, C, and D, with radii of 5, 10, 15, and 20 km respectively. The zones were each divided into 12 30° sectors, sector 1 being from straight north and 30° clockwise, sector 2 from 30 to 60° and so on. A measuring location was thus determined by a zone letter and a sector number. Locations in the sea were omitted.

Table 8.4.3 shows the results. The annual mean for all locations was 7.4 μR/h. An analysis of variance (table 8.4.3.2) showed no significant difference between zones, but probably between sectors ($P > 97.5\%$). Sectors 1 and 12 showed lower levels than the other sectors. April showed higher levels than the other months.

Table 8.4.3.2

Analysis of variance of the results in table 8.4.3.1

Effect	Source	SSD	f	s^2	v^{2*}	P
Main	Months	5.6829	2	2.8415	6.20	>99.5%
	Zones	1.1680	3	0.3893	0.85	-
	Sectors	11.4634	11	1.0421	2.28	>97.5%
2-factor inter-action	Mon. x Zon.	1.3162	6	0.2194	0.50	
	Zon. xSec.	8.4351	27	0.3124	0.71	
	Sec. x Mon.	4.3083	20	0.2154	0.49	
3-factor interaction	Mon. x Zon. x Sec.	6.1456	14	0.4390		
η = 0.09						

* Main effects tested against the total interaction

2-factor interaction tested against 3-factor interaction

8.4.4. A Location in Jutland

Table 8.4.4 shows a similar investigation as in 8.4.3 for a location in Jutland. The annual mean for all locations was 7.2 μR/h, i.e. nearly the same as in 1967 and 1968. An analysis of variance showed higher levels in April than in the other months. Sector 9 showed levels probably lower than the other sectors.

Table 8.6.4.1

γ-background (μR/h) around a location in Jutland in 1969

Zone and sector	April	July	Oct.	Mean
A 1	-	7.1	-	7.1
A 2	8.7	-	7.8	8.3
A 3	-	7.8	-	7.8
A 4	5.5	-	6.1	5.8
A 5	-	7.5	-	7.5
A 6	5.8	-	6.4	6.1
A 7	-	7.1	-	7.1
A 8	6.8	-	6.4	6.6
A 9	-	6.9	-	6.8
A 10	7.8	-	6.7	7.3
A 11	-	7.8	-	7.8
A 12	8.7	-	7.3	8.0
Mean	7.2	7.4	6.8	7.2
B 1	8.4	-	7.3	7.9
B 2	-	7.5	-	7.5
B 3	7.4	-	7.6	7.5
B 4	-	6.5	-	6.5
B 5	8.4	-	7.3	7.9
B 6	-	7.8	-	7.8
B 7	7.8	-	7.3	7.6
B 8	-	7.1	-	7.1
B 9	6.8	-	7.0	6.9
B 10	-	6.8	-	6.8
B 11	7.8	-	7.3	7.6
B 12	-	7.5	-	7.5
Mean	7.8	7.2	7.3	7.4

Table 8.4.4.1

γ-background (μR/h) around a location in Jutland in 1969

Zone and sector	April	July	Oct.	Mean
C 1	-	6.8	-	6.8
C 2	8.4	-	7.3	7.9
C 3	-	5.8	-	5.8
C 4	8.4	-	7.8	8.1
C 5	-	6.5	-	6.5
C 6	7.4	-	6.4	6.9
C 7	-	7.8	-	7.8
C 8	7.8	-	6.7	7.3
C 9	-	5.8	-	5.8
C 10	6.8	-	7.0	6.9
C 11	-	6.2	-	6.2
C 12	8.1	-	7.3	7.7
Mean	7.8	6.5	7.1	7.0
D 1	8.1	-	7.0	7.6
D 2	-	6.8	-	6.8
D 3	7.4	-	7.3	7.4
D 4	-	7.1	-	7.1
D 5	6.5	-	6.7	6.6
D 6	-	6.8	-	6.8
D 7	7.8	-	7.3	7.6
D 8	-	6.2	-	6.2
D 9	7.4	-	6.4	6.9
D 10	-	6.5	-	6.5
D 11	7.4	-	7.0	7.2
D 12	-	6.5	-	6.5
Mean	7.4	6.7	7.0	7.0

Table 8.4.4.2

Analysis of variance of the results in table 8.4.4.1

Effect	Source	SSD	f	s^2	v^2	P
Main	Months	5.4514	1	5.4514	14.75	>99.95%
	Zones	1.6121	3	0.5374	1.45	-
	Sectors	8.0460	11	0.7315	1.98	95%
2-factor interaction	Mon. x Zon	0.3493	3	0.1164	0.49	-
	Zon. x Sec.	13.6284	33	0.4130	1.75	-
	Sec. x Mon.	1.6404	10	0.1640	0.69	-
3-factor interaction	Mon. x Zon. x Sec.	2.3657	10	0.2366		

η = 0.07
(cf. remarks to table 8.4.3.2)

8.4.5. The Coasts of the Great Belt

The Great Belt is a main shipping route for international traffic through the inner Danish waters. Occasionally this waterway will be passed by nuclear ships. An environmental γ-survey of the coastline along the Great Belt has therefore been initiated. Table 8.4.5.1 shows the results and table 8.4.5.2 the analysis of variance. The levels were a little lower than those found in other parts of the country. The annual mean was 6.0 μR/h.

It is remarkable that the lowest γ-background levels are found near the sea. This was also the fact in the case of sectors 1 and 12 in 8.4.3 and of sector 9 in 8.4.4.

Table 8.4.5.1

The γ-background (μR/h) along the coasts of the Great Belt in 1969

Location	Feb.	May	Aug.	Nov.	Mean
Agersø	6.0	4.5	5.9	6.4	5.7
Omø	5.7	4.5	5.9	6.1	5.5
Røsnæs	5.7	4.5	6.7	5.5	5.6
Reersø	6.9	5.8	6.5	6.7	6.5
Halskov	7.5	6.1	5.9	6.2	6.6
Sprogø	5.4	5.8	6.2	6.4	6.0
Knudshoved	5.7	4.5	6.2	6.1	5.6
Risinge	6.3	5.1	6.7	6.7	6.2
Fyns Hoved	6.6	5.4	7.6	7.3	[illegible]
Tårup Strand	6.6	5.4	6.5	7.0	6.4
Hov, Langeland	5.1	4.5	5.9	[illegible]	5.3
Mean	6.1	5.1	6.4	[illegible]	[illegible]

Table 8.4.5.2

Analysis of variance of the results in table 8.4.5.1

Variation	SSD	f	s^2	v^2	P
Betw. locations	8.9147	7	1.2735	6.28	>99.95%
Betw. months	11.7800	3	3.9267	19.37	>99.95%
Remainder	6.0805	30	0.2027		
η = 0.08					

9. CONCLUSION

9.1. Risö Environmental Monitoring

No radioactive contamination of the environment originating from the operation of the research establishment was ascertained outside Risö in 1969. As in the previous years, the variations in contamination levels were quite independent of the distance of the sampling locations from Risö.

9.2. Nuclear-Weapon Debris in Air, Precipitation, Soil, and Ground Water

The mean content of Sr-90 in air collected in 1969 was 0.0014 pCi Sr-90/m^3, i.e. equal to the 1968 level. The average fall-out for the State experimental farms in 1969 was 1.0 mCi Sr-90/km^2 or 40% lower than the 1968 figure, and the mean concentration of Sr-90 in rain water was 2.2 pCi Sr-90/l, i.e. nearly equal to the 1968 level.

The accumulated fall-out by the end of 1969 was approx. 50 mCi Sr-90/km^2.

The median level of Sr-90 in Danish ground water was 0.017 pCi Sr-90/l.

The fall-out levels in Jutland, in conformity with the greater amounts of precipitation in that part of the country, were 15-25% higher than the levels found in eastern Denmark.

9.3. Sr-90 and Cs-137 in the Human Diet

The mean level of Sr-90 in Danish milk was 7.2 S.U., and the mean content of Cs-137 was approx. 16 pCi Cs-137/l.

The 1969 Sr-90 and Cs-137 levels were 85% of the levels found in milk produced in 1968.

The Sr-90 mean content in grain from the 1969 harvest was 44 pCi Sr-90/kg. The Cs-137 mean content in grain was 40 pCi Cs-137/kg. The Sr-90 level in grain from the 1969 harvest was approx. 10% lower than the level found in the 1968 harvest, and Cs-137 was approx. two thirds of the 1968 level.

The mean contents of Sr-90 and Cs-137 in Danish vegetables collected in 1969 were 13 pCi Sr-90/kg (33 S. U.) and 6.4 pCi Cs-137/kg respectively, and in fruits 2.6 pCi Sr-90/kg and 11 pCi Cs-137/kg; potatoes contained 3.9 pCi Sr-90/kg and 7 pCi Cs-137/kg.

The mean levels of Sr-90 and Cs-137 in total-diet samples collected in 1969 were 9.0 S. U. or 15.8 pCi Sr-90/day and 28 pCi Cs-137/day respectively. From analyses of the individual diet components the Sr-90 level in the Danish average diet was estimated to be 8.3 S. U. and the Cs-137 intake to be 38 pCi Cs-137/day. The Sr-90 and Cs-137 levels in the Danish total diet consumed in 1969 were nearly equal to the 1968 levels.

Grain products contributed 36% and milk products 38% to the total Sr-90 intake, and 30% of the Cs-137 in the diet came from meat, 28% from grain products and 19% from milk products.

The Sr-90 as well as the Cs-137 diet levels were on the average significantly higher in Jutland than in eastern Denmark.

9.4. Sr-90 and Cs-137 in Humans

The Sr-90 mean content in human bone (vertebrae) collected in 1969 was 1.2 S. U. in new-born children, 1.8 S. U. in infants, 1.9 S. U. in children and teen-agers, 1.4 S. U. in adults (20 - 29 years old) and 1.3 S. U. in adults of more than 29 years. The 1969 bone levels for all age groups were lower than the 1968 levels.

The mean content of Cs-137 in the human body in 1969 was estimated from whole-body countings to be 5.6 nCi (40 pCi Cs-137/g K), i. e. approx. 85% of the 1968 level.

9.5. Sr-90 in Sea Water

The mean content of Sr-90 in the inner Danish waters was approx. 0.8 pCi Sr-90/l in 1969, i. e. nearly the same as the 1968 and 1967 levels.

9.6. The γ-Background

The γ-background measured at the State experimental farms in 1969 was 6.3 μR/h.

9.7. Summary

The Chinese thermo-nuclear test explosions in 1967-68 have stopped the rapid decrease of the environmental Sr-90 and Cs-137 levels observed in the first years after the test moratorium.

The concentrations of long-lived fall-out nucleides in ground-level air and precipitation collected in 1969 were nearly equal to the levels found in 1968.

In milk produced in 1969 the Sr-90 and Cs-137 levels were a little lower than the 1968 levels. In grain from 1969 the levels were somewhat lower than the 1968 concentrations, but nearly equal to the 1967 concentrations.

The Sr-90 and Cs-137 levels in the total diet consumed in 1968 were nearly equal to the 1968 concentrations.

The Sr-90 concentrations in human bone were lower in 1969 than in 1968.

APPENDIX A

Calculated Fall-out in the Eight Zones in 1969

Zone		mm precipitation in 1969	mCi Sr-90/km^2 in 1969	Accumulated mCi Sr-90/km^2 by the end of 1969
I:	N. Jutland	612	1.8	53
II:	E. Jutland	600	1.4	40
III:	W. Jutland	713	1.5	59
IV:	S. Jutland	620	1.3	60
V:	Funen	555	0.8	41
VI:	Zealand	469	1.2	40
VII:	Lolland-Falster	516	0.7	50
VIII:	Bornholm	494	1.3	44
Area-weighted mean		600	1.4	49

The amounts of precipitation were obtained from ref. 8. The fall-out rate in 1969 was calculated from table 4.1.1 (Askov was included in both zone III and zone IV) and from the amounts of precipitation in the zones. The accumulated fall-out in the zones was calculated from tables 4.2.1 and 4.1.1 on the assumption that the Sr-90 soil levels on the farms were representative of the zones in which the farms were located.

APPENDIX B

Statistical Information

Zone	Area in km² 14)	Population in thousands 14) 1965	Annual milk production in mega-kg 15) 1967	Annual wheat production in mega-kg 14) 1966	Annual rye production in mega-kg 14) 1966	Annual potato production in mega-kg 14) 1966	Vegetable** area in km² 16) 1961	Fruit area in km² 16) 1961
I: N. Jutland	7,544	515	1,117	94	60	853	24	16
II: E. Jutland	7,338	764	1,380					
III: W. Jutland	10,764	579	976					
IV: S. Jutland	3,964	230	515					
V: Funen	3,482	425	494				25	38
VI: Zealand	7,542	2,055 *	604	306	56	119	39	45
VII: Lolland-Falster	1,798	139	96					
VIII: Bornholm	588	49	62					
Total	43,020	4,766	5,244	400	136	972	88	101

* 1,378,000 people were living in Greater Copenhagen and 677,000 in the remaining part of Zealand.

** Only horticultural holdings were included.

APPENDIX C

The agreement between observed and predicted levels is acceptable for most samples. Grain is an exception; the explanation has been given in 5.3. The predicted Sr-90 levels in milk, total diet and human bone are all higher than the observed levels, perhaps owing to a more rapid decrease in the availability of old Sr-90 from soil than in more recently deposited Sr-90. Allowance for this decreasing soil uptake could possibly be made by the introduction of an exponential correction term to the soil factors in the equations; however, more data are needed for the calculation of such a correction.

<u>Appendix C</u>

A comparison between observed and predicted levels in the human food chain in Denmark in 1969

Nuclide and sample	Observed	Predicted	Equation used for the prediction
S. U. in milk	7.2	8.8	S. U. = 0.92 d(i) + 0.61 d(i-1) + 0.13 A by(i-1)
M. U. in milk	9.7	9.1	M. U. = 3.65 d(i) + 1.59 d(i-1) + 0.057 A by(i-1)
S. U. in rye	89	102	S. U. = 192 d(j-a) + 0.91 A by(i-1)
S. U. in barley	64	94	S. U. = 134 d(j-a) + 1.05 A by(i-1)
S. U. in wheat	80	114	S. U. = 157 d(j-a) + 1.30 A by(i-1)
S. U. in oats	48	57	S. U. = 87 d(j-a) + 0.72 A by(i-1)
pCi Cs-137/kg rye	59	77	pCi Cs-137/kg = 126 d(m-a)
pCi Cs-137/kg barley	33	60	pCi Cs-137/kg = 97 d(m-a)
pCi Cs-137/kg wheat	38	53	pCi Cs-137/kg = 86 d(m-a)
pCi Cs-137/kg oats	31	49	pCi Cs-137/kg = 80.5 d(m-a)
pCi Sr-90/kg potatoes	3.9	3.4	pCi Sr-90/kg = 0.17 d(j) + 0.059 A by(i-1)
pCi Cs-137/kg potatoes	7	8	pCi Cs-137/kg = 5.45 d(i)
pCi Sr-90/kg cabbage	10	13	pCi Sr-90/kg = 0.44 d(i) + 0.24 A by(i-1)
pCi Sr-90/kg carrots	17	15	pCi Sr-90/kg = 0.58 d(i) + 0.27 A by(i-1)
pCi Cs-137/kg beef	75	75	pCi Cs-137/kg = 34.9 d(i) + 2.8 d(i-1) + 0.64 A by(i-1)
pCi Cs-137/kg pork	76	76	pCi Cs-137/kg = 34.8 d(i) + 22.4 d(i-1) + 0.15 A by(i-1)
S. U. in diet	9.0	9.5	S. U. = 0.82 d(i) + 1.41 d(i-1) + 0.124 A by(i-1)
pCi Cs-137/day in diet	28	30	pCi Cs-137/day = 7.8 d(i) + 11.6 d(i-1) + 5.5 d(i-1)
S. U. in newborn bone	1.2	1.4	S. U. = $0.168\, d\frac{i+(i-1)}{2} + 0.031\, d(i-2) + 0.021\, A\, by(i-1)$
S. U. in adult vertebrae	1.3	1.6	S. U. = $0.0245\, d\frac{i+(i-1)}{2} + 0.059\, d(i-2) + 0.032\, A\, by(i-1)$
M. U. in adult body	40	40	M. U. = $6.8\, d\frac{i+(i-1)}{2} + 5.8\, d(i-2) + 0.48\, A\, by(i-1)$

The prediction models were calculated from data collected 1962-69[18].
<u>d</u> is the fall-out rate in mCi Sr-90/km^2. <u>A</u> is the accumulated fall-out in mCi Sr-90/km^2
<u>(i)</u> is the current year, <u>(i-1)</u> the year before etc. <u>(j-a)</u> is July-August and <u>(m-a)</u> is May-August.

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