# Environmental radioactivity in Denmark in 1971

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# Environmental Radioactivity in Denmark in 1971

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## Abstract

The present report deals with the measurement of fall-out radioactivity in Denmark in 1971. Sr-90 was determined in samples from all over the country of precipitation, soil, ground water, surface 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, and meat. Cs-137 was determined in soil, milk, grain products, potatoes, vegetables, fruit, total diet, and meat, and Cs-137 was measured by whole-body counting in persons from a control group at Risø. Estimates of the mean contents of radiostrontium and radiocaesium in the human diet in Denmark in 1971 are given. The shorter-lived fission products (Ce-144, Ce-141, Ru-103, Ru-106, Zr-95, and Ba-149) were determined by Ge-Y-spectroscopy in air filters. The Y-background was measured regularly at locations around Risø, 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 Risø area.

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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: $\sqrt{\frac{\Sigma(x-x_i)^2}{(n-1)}}$ |
| S. E. | standard error: $\sqrt{\frac{\Sigma(x-x_i)^2}{n(n-1)}}$ |
| U. C. L. | upper control level |
| L. C. L. | lower control level |
| Δ | one standard deviation due to counting |
| S. S. D. | sum of squares of deviation: $\Sigma(x-x_i)^2$ |
| f | degrees of freedom |
| $s^2$ | the variance |
| $v^2$ | the ratio between the variance in question and the residual variance |
| P | probability fractile of the distribution in question |
| η | coefficient of variation |
| anova | analysis of variance |

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 fifteenth of a series of periodical reports (cf. ref. 1) dealing with measurements of radioactivity in Denmark.

The programme is nearly unchanged as compared with 1970. Soil samples were in some cases collected down to a depth of 50 cm. Samples of fresh water were collected twice from Danish streams and lakes. No samples of milk and grass from the state experimental farms were collected in 1971.

## 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 Risø site. These tables are available in the form of microcards at the library of the Danish Atomic Energy Commission at Risø.

## 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 1971 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. The computer programmes (cf. 2) used in the calculations of Sr-90 as well as in the γ-analysis were developed by the Section for Electronics Development.

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[1, 6, 7, 8]

A 9810 A HP-calculator has been added to our equipment. This computer replaces the former B 9100 HP-calculator. The new calculator is among other things well suited for the statistical treatment of our data.

## 3. RISØ ENVIRONMENTAL MONITORING IN 1971

### 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 1. The yearly mean for H I in 1971 was 57 eqv. mg KCl/2.5 g (in 1970: 54), for H III-VI: 59 eqv. mg KCl/2.5 g (in 1970: 56) and for H VII-X: 59 eqv. mg KCl/2.5 g (in 1970: 55). Fig. 3.1.1.3 shows the mean levels of radioactivity in sea salt since 1957.

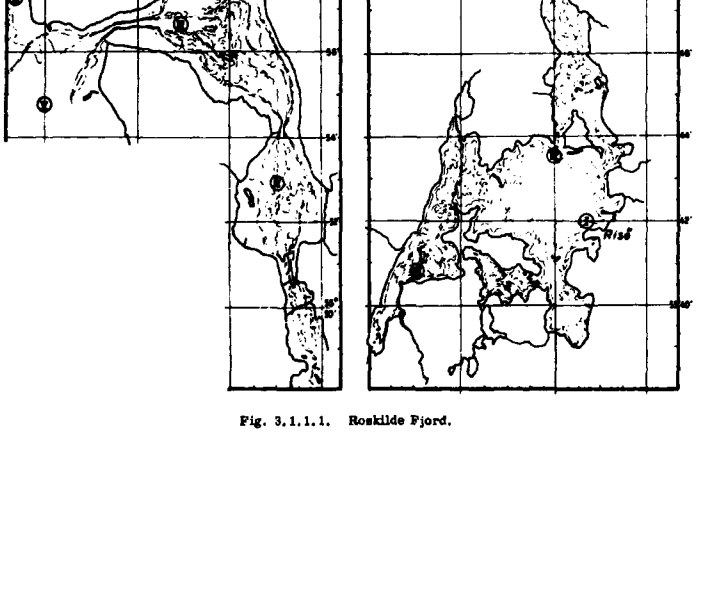



Fig. 3.1.1.1. Roskilde Fjord.

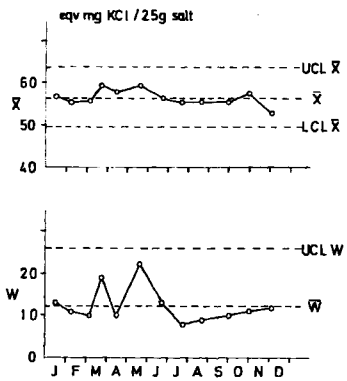



Fig. 3.1.1.2. Control chart for HI, 1971

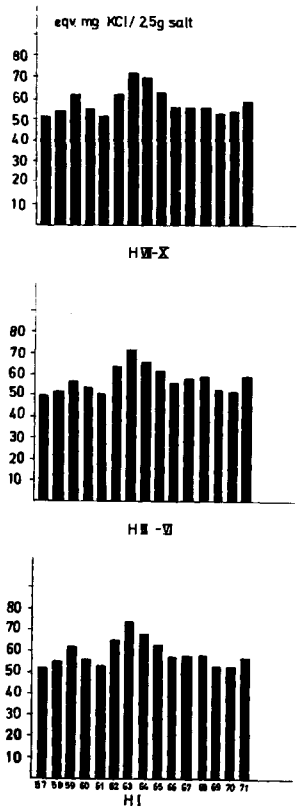



Fig. 3.1.1.3.
Mean radioactivity in sea water, 1957-71



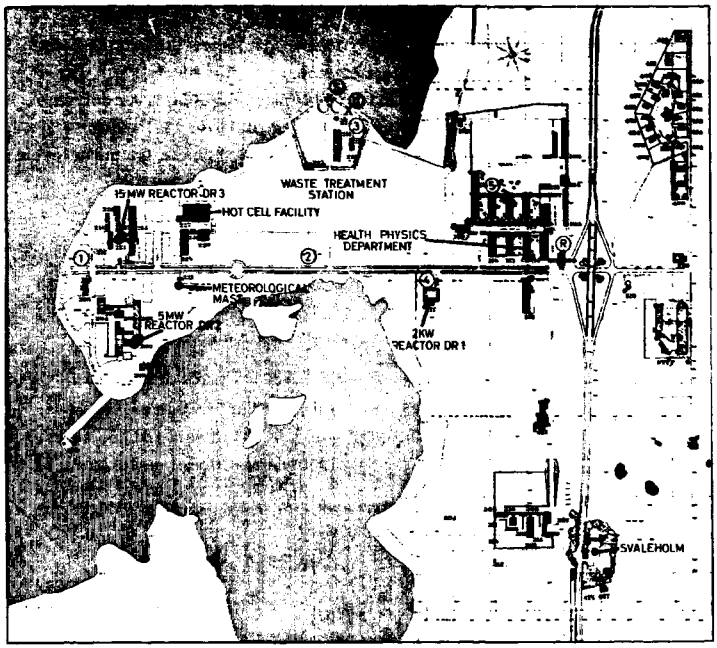



Fig. 3.1.2.1. The Risö Research Establishment.

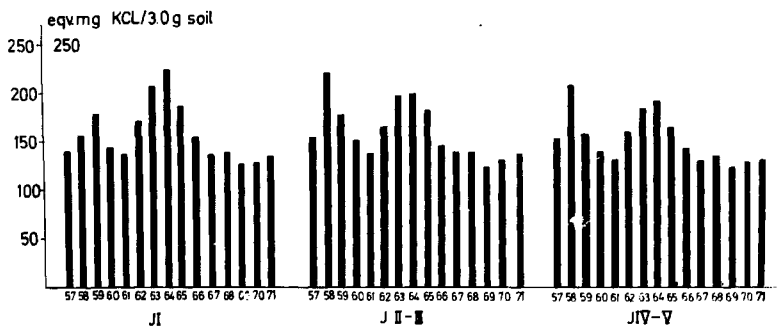



Fig. 3.1.2.3. Mean radioactivity in soil 1957-71

### 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 1 in 1971 was 140 eqv. mg KCl/3.0 g soil (in 1970: 129), for J II-III: 141 eqv. mg KCl/3.0 g (in 1970: 130) and for J IV-V: 139 eqv. mg KCl/3.0 g (in 1970: 129). Fig. 3.1.2.3 shows the mean levels of radioactivity in soil since 1957.

### 3.1.3. Air

Fig. 3.1.3.1 shows the diagram for FP activity in air samples in 1971. The mean value for the year was 0.21 eqv. mg KCl/$m^3$ as compared with 0.14 eqv. mg KCl/$m^3$ in 1970.

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

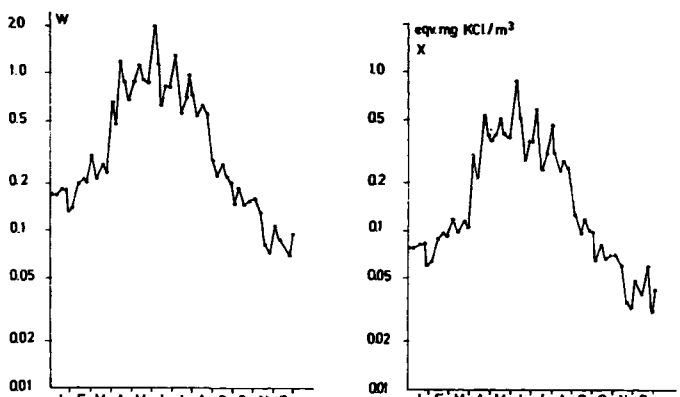



Fig. 3.1.3.1. Control chart for LF, 1971



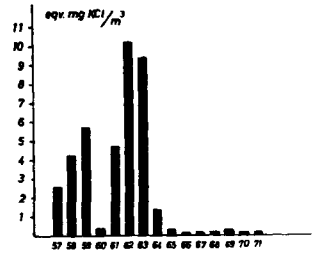



Fig. 3.1.3.2. Mean radioactivity in air, 1957-71

### 3.1.4. Bed Soil from the Fjord

The mean activity in bed soil B I was 151 eqv. mg KCl/3.0 g ash in 1971 as compared with 157 eqv. mg KCl/3.0 g in 1970. Fig. 3.1.4.1 shows the mean levels for B I since 1957.

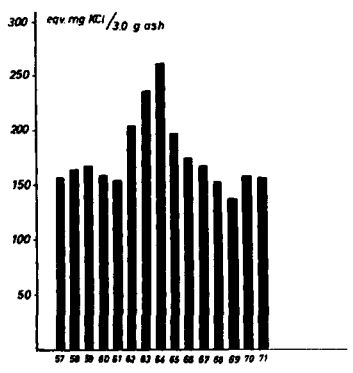



Fig. 3.1.4.1. Mean radioactivity in bed soil, 1957-71

### 3.1.5. Fish

No fish samples from Roskilde Fjord were measured in 1971.

### 3.1.6. Grass

The mean values were in 1971 for PG I: 46 eqv. mg KCl/0.1 g grass ash (in 1970: 25), for PG II-III: 36 eqv. mg KCl/0.1 g (in 1970: 25) and for PG IV-V: 31 eqv. mg KCl/0.1 g (in 1970: 24). Fig. 3.1.6.1 shows the mean activities in grass ash since 1957.

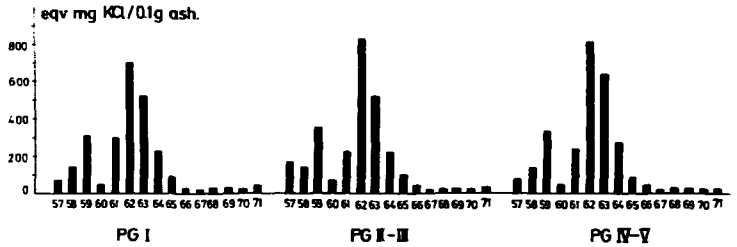



Fig. 3.1.6.1. Mean FP-radioactivity in grass ash, 1957-71

### 3.1.7. Sea Plants

The mean FP level in 1971 in Fucus vesicolosus (PH 1) was 4 eqv. mg KCl/0.1 g ash (7 in 1970). In Zostera marina (PH III-IX) we found 4 eqv. mg KCl/0.1 g ash in 1971 (no samples in 1970).

### 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 1, D II, D IV, and S in 1971 were 46 eqv. mg KCl/l (1970: 42), 16 eqv. mg KCl/l (1970: 28), 40 eqv. mg KCl/l (1970: 49), and 84 eqv. mg KCl/l (1970: 609) respectively. Fig. 3.1.8.2 shows the activity in drainage water (D) and sewage water (S).

The surplus activity in sewage water was, as in 1970, primarily due to minor amounts of S-35 released from the Waste Treatment Station (cf. fig. 3.1.8.1).



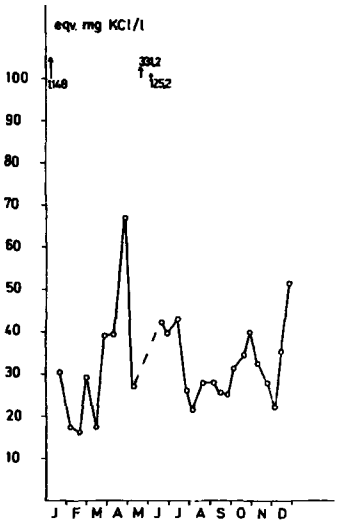



Fig. 3.1.8.1. Control chart for S, 1971

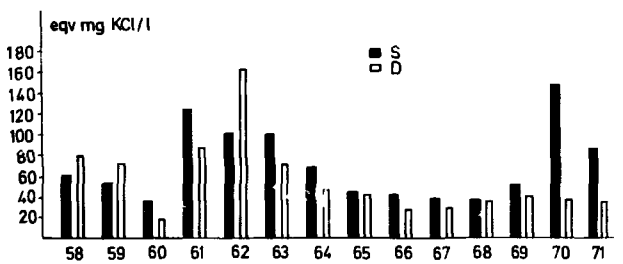



Fig. 3.1.8.2. Mean radioactivity in fresh water, 1958-71

### 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 Risø in 1971. The total fall-out in 1971 was measured at $0.075 \cdot 10^6$ eqv. mg KCl/m$^2$, and the annual mean concentration in rain water at Risø was 162 eqv. mg KCl/l. In 1970 the corresponding figures were $0.042 \cdot 10^6$ and 83 respectively.

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

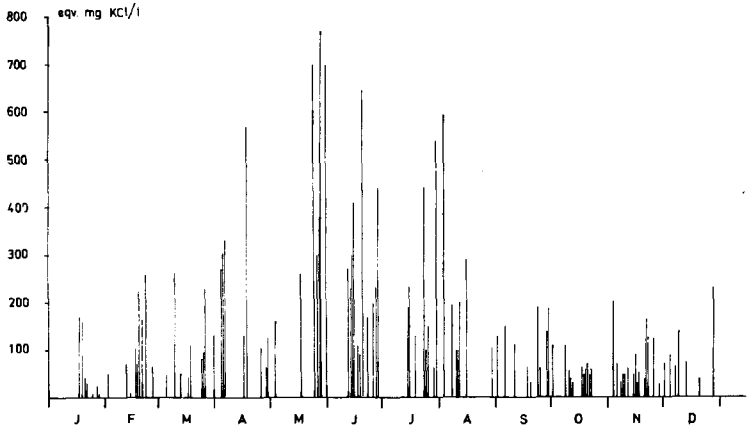



Fig. 3.1.9.1. Concentration of β-activity in 1971

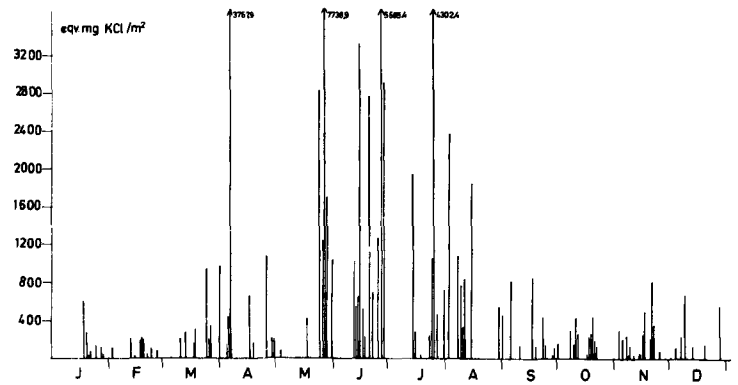
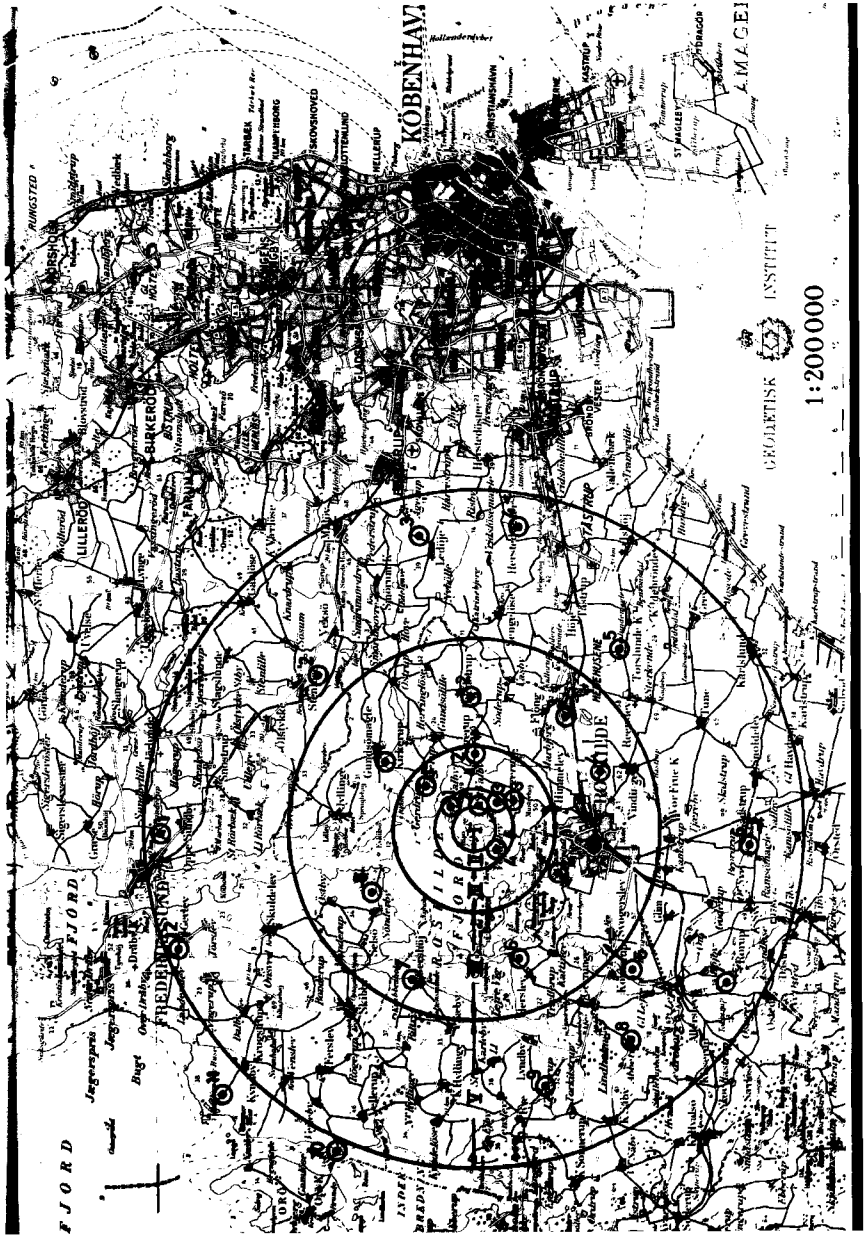



Fig. 3.1.9.2. Total fall-out from precipitation in 1971



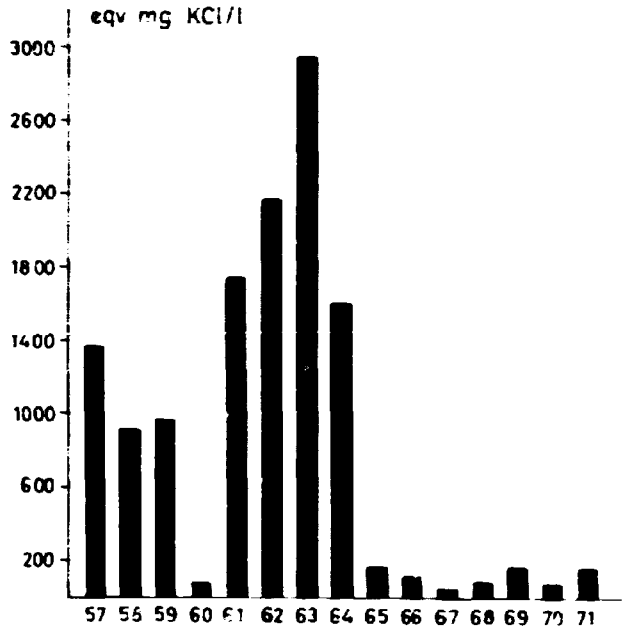



Fig. 3.1.9.3. Specific activity in precipitation in 1971

## 3.2. Radiochemical β-Analysis

### 3.2.1. Air

In 1970[1] we started an experiment in which we alternated between glass-fibre filters and paper filters in our daily air sampler. By March 1971 this experiment had run for one year. The mean ratio in the entire period between daily glass-fibre filters and paper filters was $1.40 \pm 0.15$ (1 SE). This ratio is probably significantly greater than 1 ($P > 97.5\%$), and we may thus conclude that the efficiency of our paper filters is ($70 \pm 8\%$).

The "big air sampler" described in Risø Report No. 23[1] has a shunt through which we determine the air volume. This year we analysed both the shunt filter (I) and aliquouts cut out from the main filter (II) to see whether the activity levels were the same in the two filters. As $I/II = 0.96 \pm 0.06$ (1 SE), we conclude that the two filters showed the same levels. We will report the mean air activity level for 1971 as the mean of the monthly glass-fibre filter collections and the daily paper filter sampling: $1.9 \pm 0.1$ pCi Sr-90/$10^3 m^3$ i.e. 10% lower than the 1970 level. The mean peak activity of the three collections in 1971 was measured in June and July to be 4.0 pCi Sr-90/$10^3 m^3$. Sr-89 from the Chinese tests was detectable in most months of 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 Risø in 1971

pCi Sr-90/$10^3$ $m^3$

| Month | Daily air filters | | Montaly air filters (glass-fibre filters) | | Sr-89/Sr-90 mean ratio |
|---|---|---|---|---|---|
| | Glass fibre | Paper | I | II | |
| Jan. | 1.4 | 0.9 | 0.9 | 0.7 | 3.2±2.3 |
| Feb. | 1.7 | 1.0 | 1.1 | 1.0 | 2.5±0.3 |
| Mar. | 2.6 | 1.2 | 1.4 | 1.6 | 5.4±0.8 |
| Apr. | - | 3.1 | 3.4 | 3.4 | 7.7±1.9 |
| May | - | 3.9 | 2.9 | 3.6 | |
| June | - | 5.7 | 2.9 | 3.5 | |
| July | - | 4.0 | 3.5 | 4.6 | |
| Aug. | - | 2.8 | 1.4 | 2.1 | |
| Sep. | - | 1.2 | 1.0 | 1.0 | |
| Oct. | - | 0.8 | 0.6 | 0.5 | |
| Nov. | - | 0.6 | 0.6 | 0.5 | |
| Dec. | - | 0.6 | 0.4 | 0.5 | |
| 1971 | | 2.2 | 1.7 | 1.9 | |

I: are the normally used shunt filters.
II: are aliquots cut out from the main filters also used for the Cs-137 determination (cf. table 3.3.1)

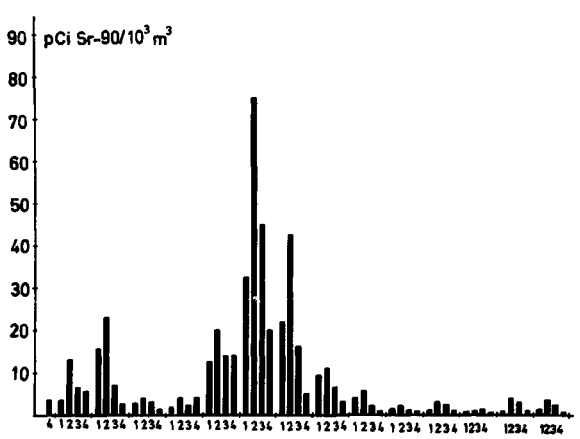



Fig. 3.2.1.1. Sr-90 in air, 1957-71



Table 3.2.2

Sr-90 in grass from Zealand, 1971

| | pCi Sr-90/g ash | pCi Sr-90/g Ca |
|---|---|---|
| Jan.-Mar. | 4.18 | 77 |
| Apr.-June | 3.73 | 59 |
| July-Sep. | 4.16 | 50 |
| Oct.-Dec. | 4.50 | 52 |
| Mean | 4.14 | 60 |

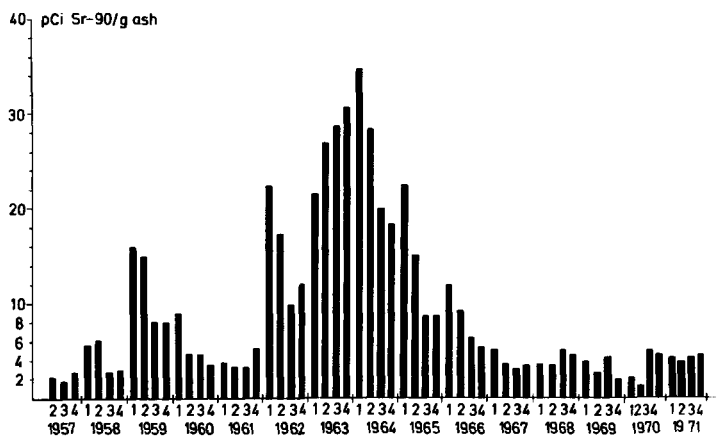



Fig. 3.2.2.1. Sr-90 in grass ash, 1957-71

## 3.2.2. Grass

Table 3.2.2 shows the Sr-90 content in grass ash from Zealand in 1971. The mean Sr-90 activity was 4.1 pCi Sr-90/g ash or 60 S.U. as compared with 3.2 pCi/g ash or 50 S.U. in 1970, i.e. the 1971 level was approx. 20% higher than the 1970 level. Fig. 3.2.2.1 shows the Sr-90 levels in grass since 1957.

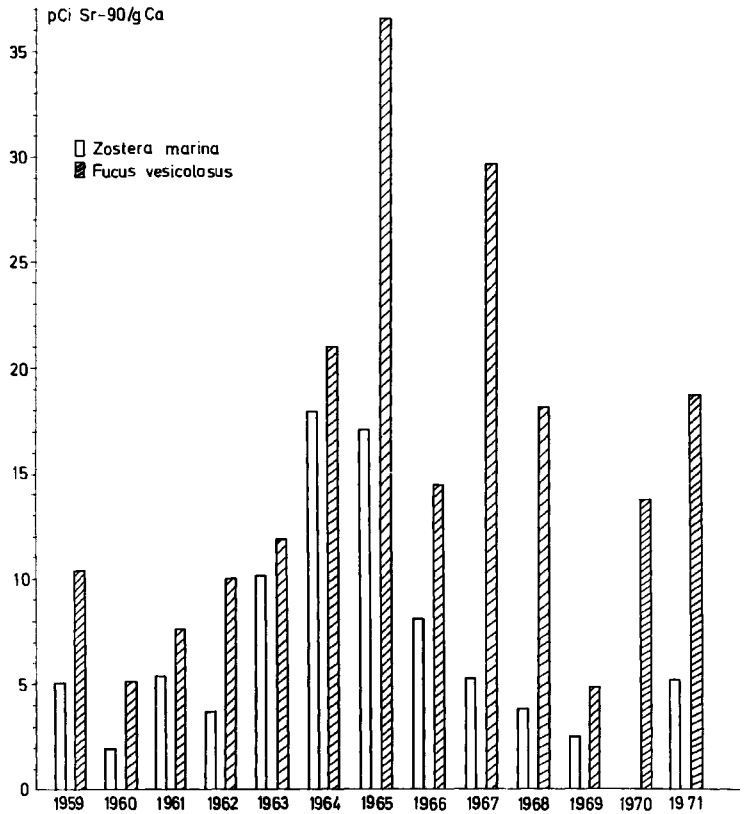



Fig. 3.2.3. Sr-90 in sea plants, 1959-71

### 3.2.3. Sea Plants

Fig. 3.2.3 shows the S.U. levels in sea plants since 1959 and table 3.2.3 the results for 1971. The mean level in Fucus vesicolosus was 18 pCi Sr-90/g Ca, and in Zostera marina we found 6 pCi Sr-90/g Ca.



Table 3.2.3

Sr-90 in sea plants from Roskilde Fjord in 1971

| Sampling period | Location | Species | pCi Sr-90/g Ca | pCi Sr-90/g ash | mg Sr/g Ca |
|---|---|---|---|---|---|
| Jan. - June | pH I | Fucus vesicolosus | 25 | 1.10 | [illegible] |
| Jan. - June | pH III-IX | Zostera marina | 9.8±3.0 | [illegible] | [illegible] |
| July - Dec. | pH I | Focus vesicolosus | 12±0 | 1.15±0.0[illegible] | [illegible] |
| July - Dec. | pH III-IX | Zostera marina[x)] | 7.6±0.1 | 0.36±0.04 | [illegible] |

The error term is the S.E. of double determinations. x) Mean of 4 analyses.

### 3.2.4. Rain Water

Table 3.2.4.1 shows the radiostrontium level in rain water collected at Risø in 1971. The total Sr-90 fall-out in 1971 was 0.96 mCi Sr-90/km$^2$ (509 mm precipitation), and the mean concentration in the rain water was 1.9 pCi Sr-90/l. In 1970 we measured 0.86 mCi Sr-90/km$^2$ (519 mm precipitation and 1.7 pCi Sr-90/l, i.e. the 1971 levels were a little higher than those of 1970.

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

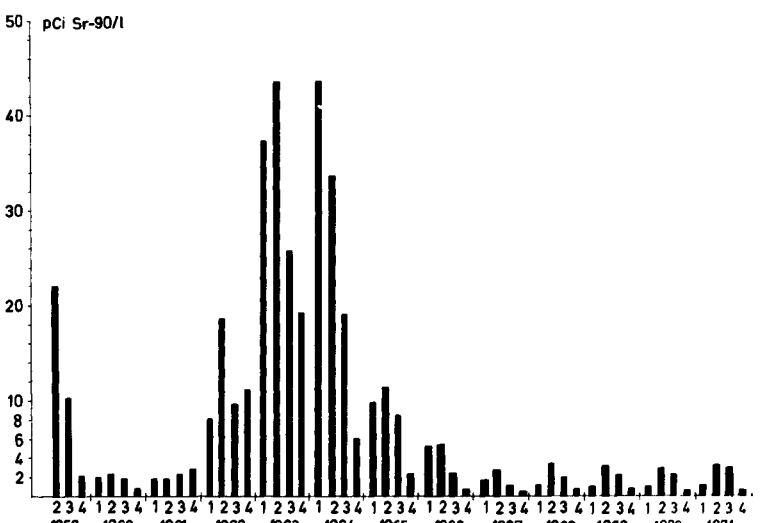



Fig. 3.2.4.1. Sr-90 in precipitation, 1959-71

Table 3.2.4.1

Sr-90 in monthly samples of rain water collected in rain bottles at Risø in 1971 (sampling area 0.236 $m^2$)

| Month | mm | pCi Sr-90/l | mCi Sr-90/$km^2$ |
|---|---|---|---|
| Jan. | 34 | 0.73 | 0.025 |
| Feb. | 20 | 1.41 | 0.028 |
| Mar. | 42 | 1.45 | 0.061 |
| Apr. | 31 | 2.08 | 0.065 |
| May | 33 | 3.99 | 0.132 |
| June | 69 | 3.63 | 0.251 |
| July | 54 | 2.75 | 0.149 |
| Aug. | 43 | 2.61 | 0.112 |
| Sep. | 38 | 1.27 | 0.048 |
| Oct. | 62 | 0.64 | 0.040 |
| Nov. | 56 | 0.62 | 0.035 |
| Dec. | 27 | 0.66 | 0.018 |
| 1971 | 509 | 1.89 | 0.964 |

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



Table 3.2.4.2

Sr-90 in monthly samples of rain water collected in ion-exchange column collectors at Risø in 1971 (sampling area 0.325 $m^2$)

| Month | mm | pCi Sr-90/l | mCi Sr-90/$km^2$ |
|---|---|---|---|
| Jan. | 24 | 0.70 | 0.016 |
| Feb. | 10 | 1.63 | 0.016 |
| Mar. | 39 | 1.18 | 0.046 |
| Apr. | 31 | 1.43 | 0.044 |
| May | 34 | 3.44 | 0.117 |
| June | 31 | 5.02 | 0.156 |
| July | 48 | 2.28 | 0.109 |
| Aug. | 40 | 2.38 | 0.095 |
| Sep. | 37 | 1.03 | 0.038 |
| Oct. | 49 | 0.40 | 0.020 |
| Nov. | 40 | 1.06 | 0.042 |
| Dec. | 18 | 0.80 | 0.014 |
| 1971 | 400 | 1.78 | 0.713 |

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 (Risø 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

Analysis of variance of ln mm precipitation at Risø in 1971 (from tables 3.2.4.1 - 3.2.4.2)

| Variation | SSD | f | $s^2$ | $v^2$ | P |
|---|---|---|---|---|---|
| Betw. samplers | [illegible] | 1 | [illegible] | [illegible] | [illegible] |
| Betw. months | [illegible] | 11 | [illegible] | [illegible] | [illegible] |
| Remainder | [illegible] | 11 | [illegible] | | |

Table 3.2.4.4

Analysis of variance of ln pCi Sr-90/l precipitation collected at Risø in 1971 (from tables 3.2.4.1-3.2.4.2)

| Variation | SSD | f | $s^2$ | $v^2$ | P |
|---|---|---|---|---|---|
| Betw. samplers | 0.0163 | 1 | 0.0163 | 0.37 | |
| Betw. months | 10.4191 | 11 | 0.9472 | 21.33 | >99.95% |
| Remainder | 0.4889 | 11 | 0.0444 | | |

Table 3.2.4.5

Analysis of variance of ln mCi Sr-90/km$^2$ from precipitation at Risø in 1971 (from tables 3.2.4.1 - 3.2.4.2)

| Variation | SSD | f | $s^2$ | $v^2$ | P |
|---|---|---|---|---|---|
| Betw. samplers | 0.5823 | 1 | 0.5823 | 21.97 | >99.9% |
| Betw. months | 15.4886 | 11 | 1.4081 | 53.13 | >99.95% |
| Remainder | 0.2917 | 11 | 0.0265 | | |

Precipitation was further collected at eight stations located in the meteorological mast at Risø (cf. 8.1). Thus we have three sampling systems for precipitation covering the Risø area: 1: the eight rain bottles at ground level (table 3.2.4.1); 2: the five ion exchange collectors (table 3.2.4.2), and 3: the eight rain bottles in the meteorological mast (table 8.1.1). Tables 3.2.4.3 - 3.2.4.5 show the analysis of variance of the two first-mentioned systems.

As in 1970 we found less fall-out in the ion exchange samplers than in the rain bottles; but the specific activity in the two sampling systems was not significantly different.



## 3.2.5. Milk from a farm near Risø

Table 3.2.5 shows the radiostrontium and caesium-137 contents in milk collected in 1971 from a farm near Risø. The mean level was 4.2 S.U. as compared with 3.4 S.U. in 1970. Fig. 3.2.5 shows the Sr-90 levels in "Risø" milk since 1959. The caesium-137 mean level was also higher than in 1970 (7.2 pCi/l against 6.8 pCi/l in 1970).

Table 3.2.5

Sr-90 and Cs-137 in milk from Risø[x] in 1971

| Month | pCi Sr-90/g Ca | pCi Cs-137/g K | pCi Cs-137/l |
|---|---|---|---|
| Jan. - Mar. | 3.9 | 1.41 | 2.00 |
| Apr. - June | 4.6 | 1.56 | 2.49 |
| July - Sep. | 5.0 | 11.05 | 17.52 |
| Oct. - Dec. | 3.3 | 4.09 | 6.54 |
| 1971 | 4.2 | 4.53 | 7.19 |

[x] The milk was collected from the milk-producing farm nearest to Risø




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

Table 3.3.1

Cs-137 in glass-fibre air filters collected twice a week at Risø in 1971
pCi Cs-137/$10^3m^3$

| Month | pCi/$10^3m^3$ |
|---|---|
| Jan.* | 1.11±0.1 |
| Feb.* | 1.51±0.2 |
| Mar.* | 1.99±0.0 |
| Apr.* | 4.16±0.4 |
| May | 5.06±0.5 |
| June | 6.62±1.2 |
| July | 5.18±0.8 |
| Aug. | 2.49±0.2 |
| Sep. | 1.26±0.1 |
| Oct. | 1.07±0.1 |
| Nov. | 0.86±0.1 |
| Dec. | 0.71±0.1 |
| 1971 | 2.67 |

The error term is the S. E. of the mean of the activity found in 8 or 9 filters collected during a month.

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

## 3.3. γ Spectroscopy of Air Samples. Some Nuclear Explosions in 1971

As in 1962-70, half-weekly samples of air were collected by means of the air sampler described in Risø 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 of the Cs-137 determinations. The peak value was observed in June (cf. also Sr-90 in air, table 3.2.1). The mean level in 1971 was 20% lower than the 1970 mean.

Air filters collected in the period April 1 - April 5 showed a significant increase in total β-activity. A γ-spectroscopic analysis of the total air samples from April 1 - 5 revealed the presence of Ba/La-140. The mean level in the sample was 30 pCi Ba-140/$10^3m^3$, (cf. also fig. 3.3.2). No atmospheric explosions had to our knowledge taken place since the Chinese



test explosion on October 14, 1970. Swedish examinations had found short-lived radionuclides (Ba-140 and I-131) in air samples collected at Stockholm and Göteborg in the period March 31 - April 2[18].

From meteorological and seismological investigations carried out by the Swedish National Defense Institute FOA[18] this fresh fall-out had been located to a leaking underground explosion in the USSR which took place north of the city of Perm in the area west of the Ural mountains on March 23, 1971.

On November 18, 1971 a 20 kt nuclear weapon was detonated in the atmosphere over the Sinkiang province in China. This explosion was the twelvth Chinese nuclear test. Figs. 3.3.2 - 3.3.3 show that fresh fall-out (Ba/La-140) Ce-141 and Ru-103 appeared in the air filter collected two weeks later, the period December 2 - 6. Maximum occurred on December 6 - 9. In this filter we found:

1.2 pCi Ce-141/$10^3m^3$, 3.5 pCi Ba-140/$10^3m^3$, 1.5 pCi I-131/$10^3m^3$

2.1 pCi Ru-103/$10^3m^3$, 2.3 pCi U-237/$10^3m^3$ and 4.5 pCi Np-239/$10^3m^3$.

On November 18 the Np-239/U-237 ratio was 128; this indicates that probably the weapon has been a fission weapon. We have earlier for a

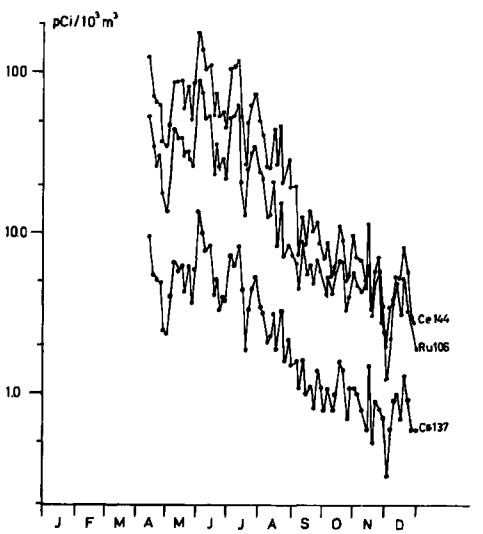



Fig. 3.3.1. Ce-144, Ru-106 and Cs-137 in half-weekly air filters in 1971

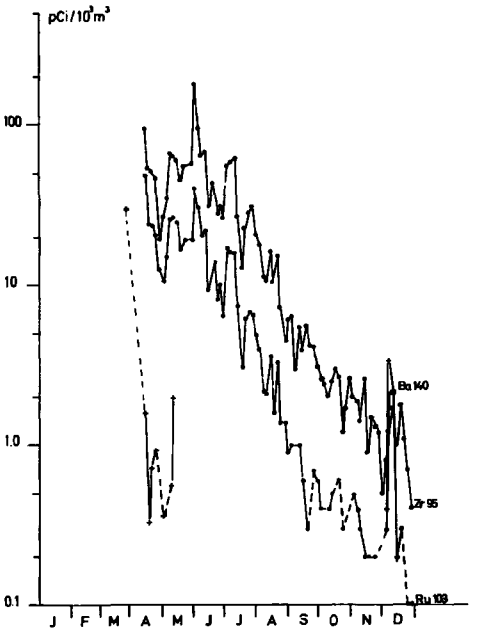



Fig. 3.3.2. Ba-140, Zr-95 and Ru-103 in half-weekly air filters in 1971



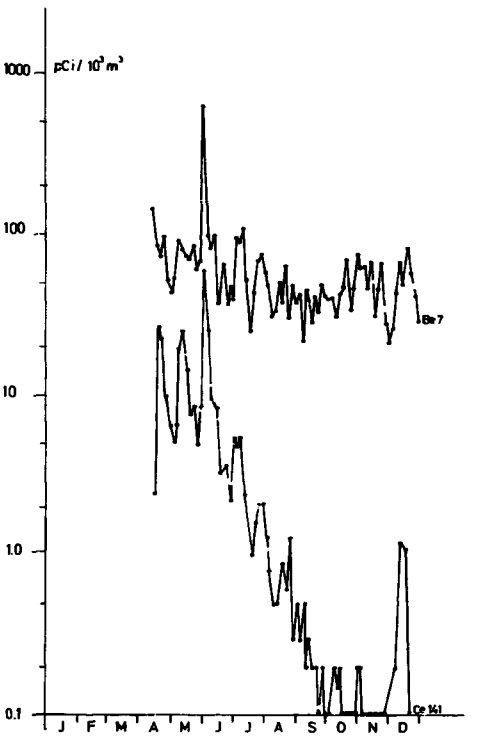



Fig. 3.3.3. Be-7 and Ce-141 in half-weekly air filters in 1971

Chinese thermonuclear weapon (China test No. VIII on December 27, 1968) determined the ratio to 11.

In test No. XII the Np-239 and U-237 concentrations were an order of magnitude higher as compared to the fission product levels than in "normal" fission weapons. The air samples were enriched with volatile nuclides (I-131, Ba-140, Ru-103).

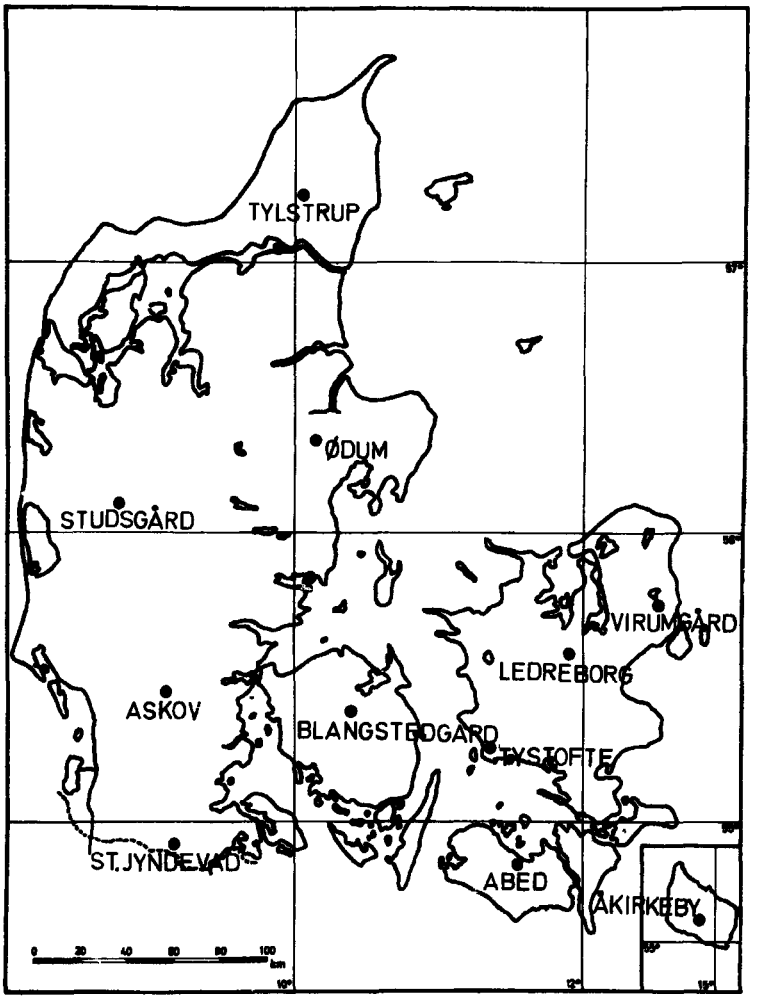



Fig. 4.1.1. State experimental farms in Denmark.

## 4. RADIOSTRONTIUM AND RADIOCAESIUM IN PRECIPITATION, SOIL, GROUND WATER AND STREAM WATER IN DENMARK IN 1971

### 4.1. Sr-90 and Sr-89 in Precipitation

Samples of rain water were collected in 1971 from the ten State experimental farms (cf. fig. 4.1.1) in accordance with the principles laid down in Risø 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 May-June, when the mean content in precipitation was 6.08 pCi Sr-90/l (cf. also the air measurements in 3.2.1). The maximum fall-out rate was also in May-June, the mean fall-out rate in that period being 0.59 mCi Sr-90/km$^2$. Tables 4.1.2 and 4.1.3 show that the variation between locations was significant. The specific activity for 1971 was 3.65 pCi Sr-90/l at Åkirkeby, while only 1.77 pCi Sr-90/l was measured at Blang-

Table 4.1.1

Sr-90 fall-out in Denmark in 1971

| Period | Unit | Tylstrup | Studsgård | Ødum | Askov | St. Jyndevad | Blangstedgård | Tystofte | Virumgård | Abed | Åkirkeby | Mean | Ledreborg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Jan.-Feb. | pCi/l | 2.34 | 1.40 | 2.60 | 2.04 | 1.10 | 0.80 | 1.78 | 1.06 | (1.41) | 2.33 | 1.59 | 1.24 |
| | mCi/km$^2$ | 0.16 | 0.17 | 0.13 | 0.22 | 0.11 | 0.06 | 0.09 | 0.07 | (0.09) | 0.12 | 0.12 | 0.06 |
| Mar.-Apr. | pCi/l | 4.49 | 3.25 | 4.74 | 2.52 | 3.17 | 1.48 | 6.92 | 2.21 | 2.06 | 6.37 | 3.55 | 2.24 |
| | mCi/km$^2$ | 0.27 | 0.16 | 0.20 | 0.20 | 0.26 | 0.10 | 0.40 | 0.17 | 0.13 | 0.28 | 0.22 | 0.14 |
| May-June | pCi/l | 9.66 | 9.13 | 4.77 | 7.29 | 4.87 | 2.56 | 5.16 | 4.28 | 10.45 | 8.44 | 6.08 | 9.19 |
| | mCi/km$^2$ | 0.64 | 1.00 | 0.48 | 0.62 | 0.45 | 0.38 | 0.75 | 0.41 | 0.51 | 0.63 | 0.59 | 0.57 |
| July-Aug. | pCi/l | 2.69 | 4.13 | 2.61 | 3.43 | 4.34 | 3.29 | 3.42 | 3.79 | 2.98 | 5.38 | 3.45 | 3.24 |
| | mCi/km$^2$ | 0.44 | 0.68 | 0.26 | 0.59 | 0.61 | 0.38 | 0.23 | 0.29 | 0.33 | 0.24 | 0.40 | 0.31 |
| Sep.-Oct. | pCi/l | 1.26 | 1.28 | 0.58 | 1.20 | 0.99 | 0.75 | 1.29 | 1.08 | 1.11 | 1.07 | 1.06 | 0.88 |
| | mCi/km$^2$ | 0.14 | 0.11 | 0.06 | 0.13 | 0.12 | 0.08 | 0.09 | 0.10 | 0.06 | 0.09 | 0.10 | 0.08 |
| Nov.-Dec. | pCi/l | 0.77 | 0.67 | 0.67 | 0.75 | 0.77 | 0.57 | 1.21 | 0.75 | 0.74 | 0.89 | 0.78 | 0.61 |
| | mCi/km$^2$ | 0.07 | 0.09 | 0.06 | 0.10 | 0.10 | 0.05 | 0.08 | 0.08 | 0.05 | 0.09 | 0.08 | 0.04 |
| 1971 | pCi/l $\bar{x}$ | 3.09 | 3.29 | 2.47 | 2.73 | 2.47 | 1.77 | 3.59 | 2.18 | 2.86 | 3.65 | 2.78 | 2.66 |
| | mCi/km$^2$ $\Sigma$ | 1.72 | 2.21 | 1.19 | 1.86 | 1.65 | 1.05 | 1.64 | 1.12 | 1.17 | 1.45 | 1.51 | 1.00 |
| mm precipitation $\Sigma$ | | 557 | 672 | 481 | 682 | 668 | 592 | 457 | 513 | 409 | 397 | 543 | 407 |

Table 4.1.2

Analysis of variance of ln pCi Sr-90/l precipitation in 1971
(from table 4.1.1)

| Variation | SSD | f | $s^2$ | $v^2$ | P |
|---|---|---|---|---|---|
| Betw. locations | 3.0363 | 9 | 0.3374 | 3.81 | >99.5% |
| Betw. months | 32.2603 | 5 | 6.4521 | 72.82 | >99.95% |
| Remainder | 3.9891 | 45 | 0.0886 | | |

Table 4.1.3

Analysis of variance of ln mCi Sr-90/$km^2$ precipitation in 1971
(from table 4.1.1)

| Variation | SSD | f | $s^2$ | $v^2$ | P |
|---|---|---|---|---|---|
| Betw. locations | 3.4241 | 9 | 0.3805 | 4.85 | >99.95% |
| Betw. months | 33.1030 | 5 | 6.6206 | 84.45 | >99.95% |
| Remainder | 3.5260 | 45 | 0.0784 | | |

Table 4.1.4

Sr-89/Sr-90 in fall-out collected in 1971

| Period | Tylstrup | Studsgård | Ødum | Askov | St. Jyndevad | Blangstedgård | Tystofte | Virumgård | Abed | Åkirkeby | Ledreborg | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Jan.-Feb. | 3.7 | 3.3 | 3.6 | 2.4 | 2.0 | 2.7 | 2.3 | 1.1 | - | 3.2 | 2.1 | 2.6±0.3 |
| Mar.-Apr. | 4.6 | 6.4 | 4.9 | 5.6 | 5.6 | 6.0 | 6.1 | 5.4 | 5.3 | 5.6 | 5.2 | 5.5±0.2 |
| May-June | 3.8 | 3.3 | 4.0 | 4.2 | 4.0 | 3.6 | 2.8 | 2.8 | 2.9 | 3.4 | 3.5 | 3.5±0.1 |
| July-Aug. | 6.1 | 2.2 | 11.9 | 13.0 | 2.1 | 2.1 | 1.6 | 0.9 | 1.7 | 2.3 | 1.2 | 4.1±1.3 |
| Sep.-Oct. | - | - | - | - | - | - | - | - | - | - | - | - |
| Nov.-Dec. | - | - | - | - | - | - | - | - | - | - | - | - |

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

stedgård. The 1971 mean levels for ten State experimental farms were 1.51 mCi Sr-90/$km^2$ and 2.78 pCi Sr-90/l. In Appendix A the country mean level (area weighted) is estimated to be 1.7 mCi Sr-90/$km^2$ for a mean precipitation amount of 625 mm (area weighted), i.e. 10% less than the fall-out rate in 1970.

The Sr-89/Sr-90 ratios at the ten stations are shown in table 4.1.4.



An anova showed significant difference between months, but not between locations. The anova is not shown.

A comparison betwen 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 1971 our bottles collected 90 per cent (1 SE: 2%) of the amount measured in the rain gauges. The implications of this difference were discussed in Risø Report No. 220[1].

## 4.2. Sr-90 and Cs-137 in Soil

As in previous years, soil was collected with a view to estimating the accumulated fall-out. As previously, the samples were collected in September from uncultivated areas all over the country (cf. fig. 4.1.1), and as in 1970 down to a depth of 30 cm, but this year in 3 sections 0-10, 10-20 and 20-30 cm. A few samples were also collected from 30 to 50 cm's depth.

Table 4.2.1 shows the Sr-90 results from the ten State Experimental Farms. The mean value in September 1971 was 54 mCi Sr-90/$km^2$. However, this value should be recalculated to a depth of 20 cm before we compare the results of the years previous to 1970. From 0-20 we found 47 mCi Sr-90/$km^2$.

The 1971 levels were nearly equal to the 1970 figures (0-30 : 55, and 0-20 cm : 46 mCi Sr-90/$km^2$).

From precipitation data[1,17], the accumulated fall-out in Denmark in 1971 was calculated to 54 mCi/$km^2$, i.e. equal to the level found in table 4.2.1. However, two sets of observations disagree with this apparent accordance between data.

Firstly: In the four cases where samples were collected from 30-50 cm we found on the average 10% extra activity at this depth as compared with the column from 0-30 cm.

Secondly: Our Cs-137 determinations showed that the mean Cs-137/Sr-90 ratio from 0-30 cm was $2.15 \pm 0.07$ (table 4.2.6), i.e. significantly greater than 1.6 - 1.7, which is the theoretical ratio in fall-out. Both observations indicate that the accumulated Sr-90 levels in Danish soil might have been underestimated, and samples collected from 0-30 cm depths have thus been insufficient to account for all Sr-90.

On the other hand it is not necessarily true that the "missing Sr-90" has to be found below 30 cm's depth. The high Cs-137/Sr-90 ratios in the samples collected from 30 - 50 cm indicate that some surface soil might

Table 4.2.1

Sr-90 in soil collected at the state experimental farms in September 1971

| mCi Sr-90/km$^2$ | Tylstrup** | Studsgård | Ødum | Askov | St. Jyndevad** | Blangstedgård | Tystofte** | Virumgård | Abed | Åkirkeby | Mean | SD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 10 cm | 37±7 | 47 | 37±5 | 25±0 | 44±2 | 29±1 | 13±0 | 26±2 | 37±4** | 25±1 | 30 | 11 |
| 10 - 20 cm | 14±1 | 14±0 | 15±1** | 7±0 | 15±0 | 22±1 | 28±3 | 13±4 | 15±1** | 15±1 | 14 | 5 |
| 20 - 30 cm | 4.3±0.2 | 3.9±0.0 | 3.0±0.1** | 11±1 | 3.9±0.2 | 5.6±0.4 | 12±1 | 3.1±0.1 | 7.4±0.4** | 4.4±0.2 | 7 | 4 |
| Σ 0 - 30 cm | 54.9±2.8 | 64.8±0.4 | 58.1±2.2 | 43.4±0.7 | 63.8±2.4 | 56.8±3.4 | 53.8±3.6 | 51.6±3.1 | 59.4±2.7 | 44.3±2.2 | 54 | 7 |
| 30 - 50 cm | | 4.9±0.2 | | 7.6±0.3 | | | 3.4±0.3 | | 2.6±0.1 | | 5.5 | 2.1 |

Σ 0-30 was calculated from the single determinations and not as the sum of the means in the table.

| pCi Sr-90/kg | Tylstrup** | Studsgård | Ødum | Askov | St. Jyndevad** | Blangstedgård | Tystofte** | Virumgård | Abed | Åkirkeby | Mean | SD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 10 cm | 319±17 | 773 | 205±37 | 196±0 | 308±5 | 240±7 | 98±2 | 183±12 | 509±47** | 211±3 | 311 | 196 |
| 10 - 20 cm | 93±5 | 74±2 | 98±5** | 146±1 | 76±2 | 151±6 | 157±15 | 124±6 | 140±9** | 93±7 | 115 | 32 |
| 20 - 30 cm | 40±1 | 25±1 | 18±1** | 69±6 | 44±1 | 37±3 | 71±4 | 50±1 | 65±21** | 32±0 | 45 | 18 |
| x̄ 0 - 30 cm | 130 | 177 | 104 | 134 | 127 | 133 | 111 | 113 | 193 | 106 | 133 | 30 |
| 30 - 50 cm | | 12±1 | | 20±1 | | | 12±1 | | 30±7 | | 19 | 9 |

All determinations were double, except ** which were triple.
The error term is the S.E. of the mean.

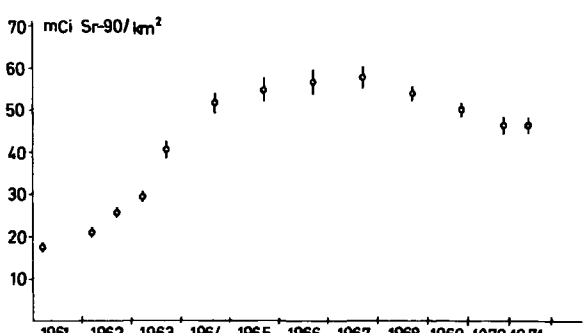



Fig. 4.2. Accumulated Sr-90 fall-out in Danish soil, 1961-71
0-20 cm (1 S.E. indicated)



have contaminated these samples during the sampling, because the Cs-137/Sr-90 is normally decreasing with increasing sampling depth (cf. table 4.2.6). Let us suppose that the deeper samples (i.e. the samples below 10 cm) have been contaminated by surface soil. This would overestimate especially the Cs-137 in these deeper samples, (because the Cs-137/Sr-90 in the surface soil is higher than in the deeper layers). We would therefore find too much Cs-137 in the deeper soil layers, and the Cs-137/Sr-90 ratio in the total soil column (0-30 cm) would be too high.

Table 4.2.2 shows the Sr-90 levels soil locations in Zealand, mainly in the neighbourhood of Risø. The samples from "Skydebanen" were collected both with our own and with the HASL sample device for soil (described in NYO-4700[4]). The agreement between the two samples was satisfactory both as regards Sr-90 and Cs-137 (cf. table 4.2.5).

The use of solid-state detectors (Ge(Li)) has made it possible to determine Cs-137 and potassium directly by γ-spectroscopy of soil samples. Tables 4.2.3 - 4.2.5 show the results for the 1971 samples.

Table 4.2.2

Sr-90 in soil collected from the surroundings of Roskilde in September 1971

| mCi Sr-90/km$^2$ | Bolund | Roskilde Fælled | Skydebanen | Skydebanen * | |
|---|---|---|---|---|---|
| 0 - 10 cm | 26±0 | 25±1 | 37±4 | 0-5 cm | 20±3 |
| 10 - 20 cm | 8.0±0.3 | 27±5 | 12±2 | 5-30 cm | 33±0 |
| 20 - 30 cm | 2.5±0.1 | 8.7±0.2 | 2.9±0.3 | | |
| Σ 0 - 30 cm | 36.8±0 | 60.6±6.1 | 51.9±5.6 | | 52.5±2.3 |

Σ 0-30 was calculated from the single determinations and not as the sum of the means in the table.

| pCi Sr-90/kg | Bolund | Roskilde Fælled | Skydebanen | Skydebanen * | |
|---|---|---|---|---|---|
| 0 - 10 cm | 372±6 | 208±9 | 377±39 | 0-5 cm | 470±63 |
| 10 - 20 cm | 81±3 | 147±27 | 84±11 | 5-30 cm | 93±1 |
| 20 - 30 cm | 31±2 | 60±2 | 19±2 | | |
| x̄ 0 - 30 cm | 146 | 135 | 133 | | 133 |

* HASL-soil sampler

Table 4.2.3

Cs-137 mCi/km² in soil collected at the state experimental farms in September 1971

| | Tylstrup | Studs-gård | Ødum | Askov | St. Jyn-devad | Blang-stedgård | Tystofte | Virum-gård | Abed | Åkirke-by | Mean | SD | SE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-10 cm | 78.5 | 90.3 | 76.8 | 78.8 | 110.8 | 65.6 | 37.7 | 59.6 | 59.8 | 72.0 | 74.0 | 19.3 | 6.1 |
| 10-20 cm | 25.8 | 18.5 | 20.5 | 37.2 | 10.0 | 54.4 | 61.4 | 45.0 | 23.6 | 27.8 | 32.4 | 16.6 | 5.2 |
| 20-30 cm | 8.5 | 8.7 | 4.7 | 13.3 | 7.1 | 9.9 | 12.5 | 14.9 | 9.0 | 8.1 | 9.6 | 3.3 | 1.0 |
| Σ 0-30 cm | 112.8 | 119.5 | 101.0 | 129.3 | 127.9 | 129.9 | 111.6 | 119.5 | 100.4 | 107.9 | 116.0 | 10.5 | 3.3 |
| 30-50 cm | | 11.8 | | 10.9 | | | 5.6 | | 14.2 | | 11.1 | 3.8 | 1.3 |

Cs-137 pCi/kg in soil collected at the state experimental farms in September 1971

| | Tylstrup | Studs-gård | Ødum | Askov | St. Jyn-devad | Blang-stedgård | Tystofte | Virum-gård | Abed | Åkirke-by | Mean | SD | SE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-10 cm | 695 | 1509 | 816 | 604 | 826 | 594 | 291 | 507 | 1059 | 612 | 751 | 337 | 106 |
| 10-20 cm | 171 | 98 | 145 | 226 | 53 | 367 | 339 | 273 | 218 | 169 | 206 | 100 | 32 |
| 20-30 cm | 48 | 77 | 23 | 87 | 40 | 65 | 76 | 92 | 77 | 59 | 64 | 22 | 7 |
| x̄ 0-30 cm | 256 | 330 | 253 | 239 | 255 | 316 | 235 | 291 | 351 | 267 | 281 | 59 | 12 |
| 30-50 cm | | 35 | | 41 | | | 20 | | 50 | | 37 | 13 | 6 |

Table 4.2.4

g K/kg in soil collected at the state experimental farms in September 1971

| | Tylstrup | Studs-gård | Ødum | Askov | St. Jyn-devad | Blang-stedgård | Tystofte | Virum-gård | Abed | Åkirke-by | Mean | SD | SE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-10 cm | 15.1 | 6.7 | 15.6 | 14.0 | 9.2 | 16.8 | 19.5 | 24.4 | 14.3 | 22.2 | 15.8 | 5.4 | 1.7 |
| 10-20 cm | 15.6 | 6.1 | 16.2 | 15.2 | 9.1 | 16.9 | 18.5 | 25.4 | 13.7 | 26.8 | 16.4 | 6.3 | 2.0 |
| 20-30 cm | 14.9 | 8.1 | 15.3 | 14.4 | 9.4 | 17.2 | 18.7 | 25.9 | 15.2 | 25.3 | 16.4 | 5.8 | 1.8 |
| x̄ 0-30 cm | 15.2 | 7.0 | 15.7 | 14.5 | 9.2 | 17.0 | 18.9 | 25.2 | 14.4 | 24.8 | 16.2 | 5.8 | 1.8 |
| 30-50 cm | | 8.1 | | 8.6 | | | 19.7 | | 18.1 | | 13.6 | 6.1 | 3.1 |



Table 4.2.5

**Cs-137 and potassium in soil collected from the surroundings of Roskilde in September 1971**

mCi Cs-137/km²

| | Bolund | Roskilde Fælled | Skydebanen | Skydebanen [x] | |
|---|---|---|---|---|---|
| 0 - 10 cm | 64 | 57 | 73 | 0-5 cm | 54.7 |
| 10 - 20 cm | 13 | 45 | 15 | | |
| 20 - 30 cm | 5 | 10 | 7 | 5-30 cm | 37.5 |
| Σ 0 - 30 cm | 82 | 112 | 95 | Σ | 92.2 |

pCi Cs-137/kg

| | Bolund | Roskilde Fælled | Skydebanen | Skydebanen [x] | |
|---|---|---|---|---|---|
| 0 - 10 cm | 912 | 476 | 743 | 0-5 cm | 1308 |
| 10 - 20 cm | 136 | 248 | 109 | | |
| 20 - 30 cm | 63 | 66 | 45 | 5-30 cm | 106 |
| Weighted mean | 330 | 250 | 245 | Σ | 233 |

gK/kg

| | Bolund | Roskilde Fælled | Skydebanen | Skydebanen [x] | |
|---|---|---|---|---|---|
| 0 - 10 | 16.2 | 22.2 | 19.7 | 0-5 cm | 20.5 |
| 10 - 20 | 21.7 | 22.1 | 18.5 | | |
| 20 - 30 | 21.4 | 23.2 | 20.3 | 5-30 cm | 20.9 |
| Weighted mean | 20.1 | 22.5 | 19.5 | | 20.8 |

[x] HASL - soil sampler

Table 4.2.6

Cs-137/Sr-90 ratios in soil samples collected at the state experimental farms in 1971 (from tables 4.1.2 and 4.2.3)

| cm | Tylstrup | Studs-gård | Ødum | Askov | St. Jyn-devad | Blang-stedgård | Tystofte | Virum-gård | Abed | Åkirke-by | Mean | SD | SE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 10 | 2.18 | 1.9 | 2.95 | 3.07 | 2.70 | 2.52 | 2.90 | 2.29 | 2.05 | 2.88 | 2.55 | 0.41 | 0.13 |
| 10 - 20 | 1.84 | 1.32 | 1.58 | 1.55 | 0.67 | 2.47 | 2.19 | 2.50 | 1.57 | 1.85 | 1.75 | 0.55 | 0.17 |
| 20 - 30 | 1.23 | 3.11 | 1.23 | 1.21 | 0.91 | 1.77 | 1.04 | 1.84 | 1.18 | 1.84 | 1.54 | 0.65 | 0.20 |
| Σ 0 - 30 | 1.98 | 1.87 | 2.50 | 2.14 | 2.01 | 2.39 | 2.11 | 2.31 | 1.82 | 2.40 | 2.15 | 0.24 | 0.07 |
| 30 - 50 | - | 3.03 | - | 2.08 | - | - | 1.65 | - | 1.67 | - | 2.11 | 0.65 | 0.32 |

Table 4.2.7

Cs-137/Sr-90 ratios in soil samples collected at Roskilde in 1971
(from tables 4.2.2 and 4.2.5)

| cm | Bolund | Roskilde Fælled | Skydebanen (Risø) | Skydebanen* (Risø) |
|---|---|---|---|---|
| 0 - 10 | 2.46 | 2.28 | 1.97 | 0-5 cm 2.74 |
| 10 - 20 | 1.63 | 1.67 | 1.25 | |
| 20 - 30 | 2.00 | 1.15 | 2.41 | 5-30 cm 1.14 |
| 0 - 30 | 2.23 | 1.85 | 1.83 | 1.76 |

* HASL-soil sampler

## 4.3. Sr-90 in 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. 4.3.1 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 1971 was half the level found in 1970. The highest level is still found at Feldbak. Fig. 4.3.2 shows the median levels in Danish ground water since 1961.



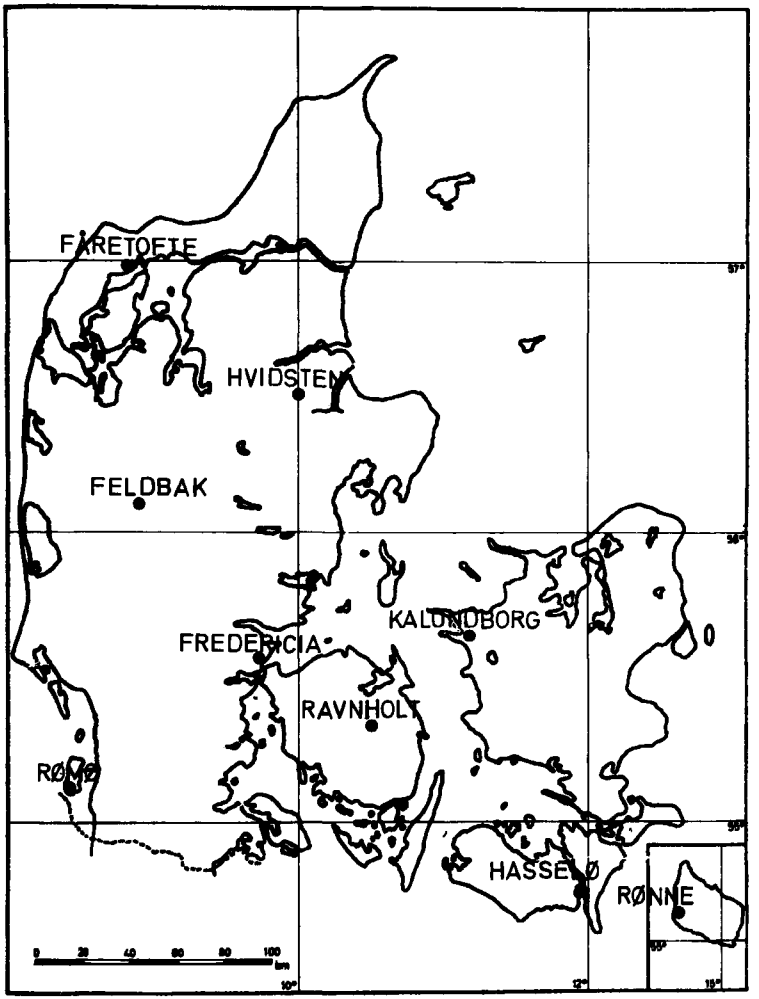



Fig. 4.3.1. Ground-water sampling locations in Denmark.

Table 4.3.1

Sr-90 in ground water collected in March 1971

| Location | pCi Sr-90/l | pCi Sr-90/g Ca | g Ca/l |
|---|---|---|---|
| Hvidsten | B 0.0041 | 0.056 | 0.0724 |
| Feldbak | 0.712 | 28.37 | 0.0251 |
| Rømø | A 0.011 | 0.293 | 0.0372 |
| Rønne | 0.0068 | 0.282 | 0.024 |
| Hasselø | A 0.0067 | 0.050 | 0.134 |
| Færetofte | 0.0083 | 0.064 | 0.129 |
| Kalundborg | B 0.0211 | 0.374 | 0.0596 |
| Ravnholt | B 0.0273 | 0.5196 | 0.0526 |
| Fredericia | B 0.0131 | 0.285 | 0.046 |
| Mean | 0.090 | - | 0.064 |
| Median | 0.011 | 0.285 | 0.0596 |
| A: relative S.D.: 20-33% | | | |
| B: relative S.D.: >33% | | | |

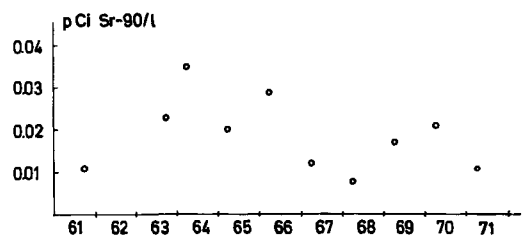



Fig. 4.3.2. Median levels in Danish ground water, 1961-71

## 4.4. Sr-90 in Fresh Water from Danish Streams

In March and September 1971 a number of water samples were collected from Danish streams and lakes. The purpose was to estimate the Sr-90 concentration in the fresh water supplied to the inner Danish waters and to estimate the Sr-90 levels in surface fresh water.

Table 4.4 shows that lake water contained approx. four times more Sr-90 per litre than stream water. It was probably significant (P> 95%)



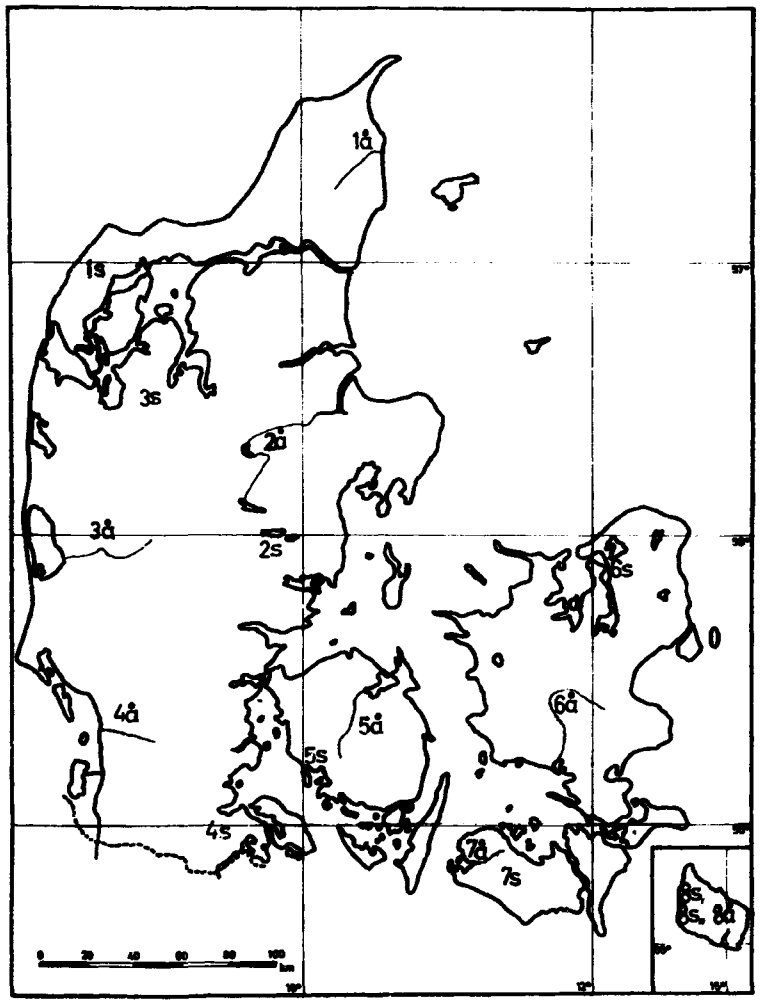



Fig. 4.4. Fresh water locations (å: stream, s: lake; figure is zone number)

Table 4.4

Sr-90 in Danish streams and lakes. March and September 1971

| Location | | March | | | | September | | | |
|---|---|---|---|---|---|---|---|---|---|
| Stream or lake | Country part | pCi Sr-90/l | g Ca/l | mg Sr/g Ca | pH | pCi Sr-90/l | g Ca/l | pH | Symbol on map (fig. 4.4) |
| Bangsbo å (stream) | N-Jutland | 0.33 | 0.074 | 2.1 | 6.0 | 0.30 | 0.043 | 6.4 | 1å |
| Nors sø (lake) | N-Jutland | 2.55 | 0.032 | 1.3 | 5.9 | 2.89 | 0.054 | 6.0 | 1ø |
| Gudenå (stream) | E-Jutland | 0.29 | 0.039 | 3.3 | 6.0 | 0.22 | 0.061 | 6.1 | 2å |
| Mossø (lake) | E-Jutland | 0.51 | 0.061 | 2.5 | 5.9 | 0.48 | 0.058 | 6.0 | 2ø |
| Skjern å (stream) | W-Jutland | 0.14 | 0.022 | 3.0 | 6.2 | 0.20 | 0.055 | 5.5 | 3å |
| Flynder sø (lake) | W-Jutland | 0.20 | 0.026 | 2.5 | 5.9 | 0.41 | 0.072 | 7.6 | 3ø |
| Ribe å (stream) | S-Jutland | 0.12 | 0.038 | 4.7 | 5.9 | 0.09 | 0.088 | 6.3 | 4å |
| Hostrup sø (lake) | S-Jutland | 1.95 | 0.027 | - | 6.3 | 2.59 | 0.062 | 6.8 | 4ø |
| Odense å (stream) | Funen | 0.20 | 0.077 | 3.8 | 6.0 | 0.29 | 0.011 | 6.2 | 5å |
| Arreskov sø (lake) | Funen | 1.01 | 0.064 | 2.5 | 5.8 | 1.21 | 0.050 | 7.0 | 5ø |
| Suså (stream) | Zealand | 0.40 | 0.106 | 3.8 | - | 0.44 | 0.121 | 6.1 | 6å |
| Arresø (lake) | Zealand | 1.21 | 0.053 | 5.1 | 5.7 | 1.51 | 0.069 | 6.4 | 6ø |
| Halsted å (stream) | Lolland-Falster | 0.31 | 0.145 | 5.1 | - | 0.94 | 0.138 | 7.6 | 7å |
| Søndersø (lake) | Lolland-Falster | 1.57 | 0.088 | 3.6 | - | 1.72 | 0.080 | 6.1 | 7ø |
| Læs å (stream) | Bornholm | 0.91 | 0.030 | - | - | 0.70 | 0.086 | 6.4 | 8å |
| Krystal sø (lake) | Bornholm | 2.69 | 0.058 | - | - | - | - | - | $8ø_1$ |
| Alm. Gråmyre sø (lake) | Bornholm | 1.34 | 0.035 | - | - | 1.37 | 0.058 | 6.5 | $8ø_{11}$ |
| Stream mean ± 1 SE | | 0.34±0.09 | 0.067±0.015 | 3.7±0.4 | 6.0±0.0 | 0.40±0.10 | 0.075±0.015 | 6.3±0.2 | |
| Lake mean ± 1 SE | | 1.45±0.28 | 0.049±0.007 | 2.9±0.5 | 5.9±0.1 | 1.54±0.31 | 0.063±0.004 | 6.6±0.2 | |

that lake water from September showed higher levels than lake water from March. There was no significant difference between the stream water from the two samplings.

As compared with the sampling in 1970 of stream water (Risø Report No. 245[1]) the mean levels in 1971 were a little lower. However, the streams were not identical in the two years. The mean Ca contents were the same in lakes, streams, and ground water (~0.06 g Ca/l).

The lower Sr-90 level in streams is ascribed to a relatively large contribution of water from underground sources where the Sr-90 levels are low (cf. table 4.3.1). Lakes contain more Sr-90 because they receive relatively large quantities of precipitation and surface water from run-off.



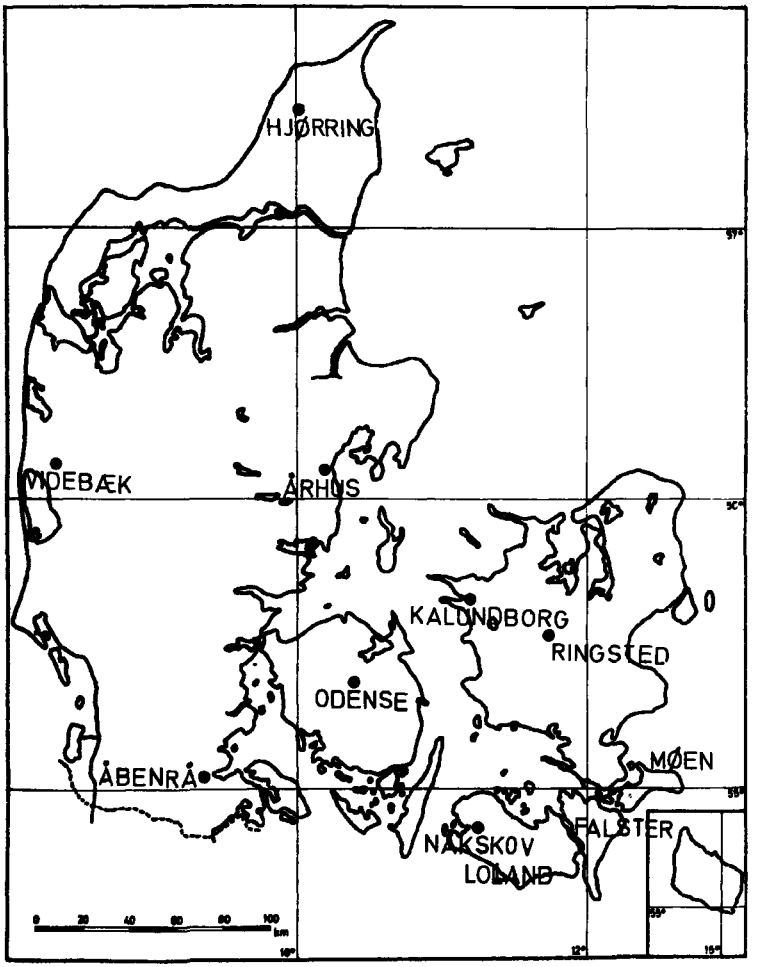



Fig. 5.1.1. Dried-milk factories in Denmark.

# 5. RADIOSTRONTIUM AND RADIOCAESIUM IN DANISH FOOD IN 1971

## 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.

Table 5.1.1 shows the results of the Sr-90 determinations and table

Table 5.1.1

pCi Sr-90/g Ca in Danish dried milk in 1971

| Month | Hjørring | Århus | Videbæk | Åbenrå | Odense | Ringsted | Lolland-Falster Møn | Mean |
|---|---|---|---|---|---|---|---|---|
| Jan. | 7.4 | 9.4 | 9.9 | (8.4) | 6.0 | 3.1 | 4.8 | (7.0) |
| Feb. | 8.7 | 7.3 | 10.4 | (8.3) | 4.4 | 4.9 | 4.1 | (6.9) |
| Mar. | 9.6 | 8.9 | 10.8 | (9.3) | 6.0 | 5.0 | 4.1 | (7.7) |
| Apr. | 8.6 | 7.9 | 12.3 | (9.5) | 6.1 | 5.2 | 4.8 | (7.8) |
| May | 8.2 | 7.5 | 10.4 | (9.6) | 8.5 | 5.5 | 4.3 | (7.7) |
| June | 8.2 | 8.5 | 10.9 | (9.7) | 8.2 | 5.9 | 4.0 | (7.9) |
| July | 7.8 | 6.9 | 8.4 | (8.5) | 5.6 | 4.2 | 6.4 | (6.8) |
| Aug. | 8.7 | 7.8 | 8.7 | (8.7) | 5.9 | 5.3 | 4.0 | (7.0) |
| Sep. | 6.2 | 8.9 | 8.8 | (8.3) | 6.0 | 5.3 | 3.7 | (6.7) |
| Oct. | 9.8 | 6.4 | 7.8 | (8.4) | 6.3 | 4.8 | 4.0 | (6.8) |
| Nov. | 8.4 | 7.8 | 10.7 | (8.9) | 6.9 | 4.4 | 4.1 | (7.3) |
| Dec. | 7.3 | 6.0 | 7.5 | 8.1 | 6.2 | 5.0 | 4.8 | 6.4 |
| Mean | 8.2 | 7.8 | 9.7 | (8.8) | 6.3 | 4.9 | 4.4 | 7.2 |

Figures in brackets were calculated by VARS[1,2]. 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 1971 was 8.6 pCi/l.

Table 5.1.2

Analysis of variance of ln pCi Sr-90/g Ca in dried milk in 1971 (from table 5.1.1)

| Variation | SSD | f | $s^2$ | $v^2$ | P |
|---|---|---|---|---|---|
| Betw. locations | 5.8000 | 6 | 0.9667 | 42.03 | >99.95% |
| Betw. months | 0.2765 | 11 | 0.0251 | 1.09 | >50% |
| Remainder | 1.2653 | 55 | 0.0230 | | |

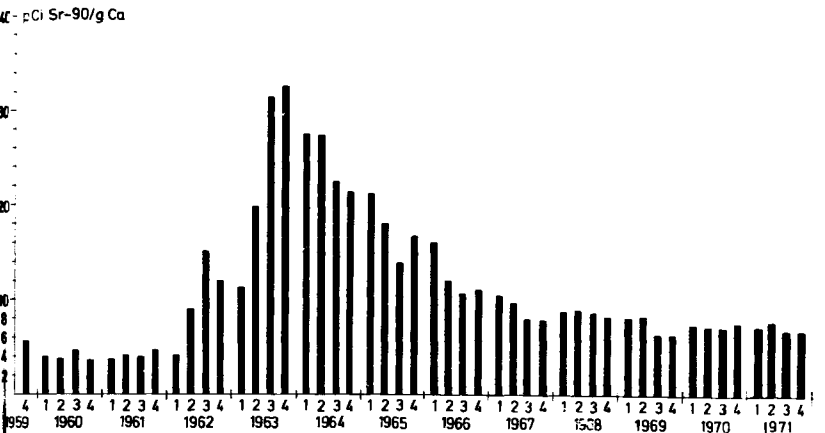



Fig. 5.1.2. Sr-90 in dried milk, 1959-71

Table 5.1.3

pCi Cs-137/g K in Danish dried milk in 1971

| Month | Hjørring | Århus | Videbæk | Åbenrå | Odense | Ringsted | Lolland-Falster Møn | Mean |
|---|---|---|---|---|---|---|---|---|
| Jan. | 6.3 | 5.8 | 9.1 | (6.3) | 3.8 | 3.6 | 2.3 | (5.3) |
| Feb. | 7.8 | 5.5 | 10.4 | (6.7) | 4.0 | 2.4 | 3.7 | (5.8) |
| Mar. | 8.4 | 5.2 | 11.4 | (6.8) | 4.7 | 3.3 | 2.4 | (6.0) |
| Apr. | 9.0 | 5.9 | 10.5 | (6.3) | 5.0 | 3.5 | 1.1 | (5.9) |
| May | 7.6 | 5.9 | 12.2 | (6.5) | 7.2 | 2.7 | 1.3 | (6.2) |
| June | 9.0 | 7.9 | 15.2 | (11.4) | 11.1 | 10.6 | 3.0 | (9.7) |
| July | 12.6 | 10.6 | 16.0 | (12.4) | 7.2 | 6.7 | 6.1 | (10.2) |
| Aug. | 23.0 | 15.4 | 18.8 | (18.5) | 13.4 | 11.0 | 7.2 | (15.3) |
| Sep. | 21.2 | 10.6 | 18.1 | (15.8) | 10.0 | 10.8 | 6.3 | (13.3) |
| Oct. | 12.4 | 7.9 | 10.8 | (10.3) | 8.7 | 4.3 | 5.2 | (8.5) |
| Nov. | 14.2 | 8.5 | 11.7 | (11.4) | 9.8 | 5.5 | 5.1 | (9.5) |
| Dec. | 9.8 | 12.7 | 6.9 | 10.3 | 7.0 | 5.9 | 5.9 | 8.4 |
| Mean | 11.8 | 8.5 | 12.6 | (10.2) | 7.7 | 5.9 | 4.1 | 8.7 |

As 1 litre of milk contains approx. 1.66 g K, the mean Cs-137 content in Danish milk produced in 1971 was estimated at 14.4 pCi/l.

Table 5.1.4

Analysis of variance of ln pCi Cs-137/g K in Danish dried milk 1971
(from table 5.1.3)

| Variation | SSD | f | $s^2$ | $v^2$ | P |
|---|---|---|---|---|---|
| Betw. localities | 12.8655 | 6 | 2.1443 | 27.85 | >99.95% |
| Betw. months | 9.5436 | 11 | 0.8676 | 11.27 | >99.95% |
| Remainder | 4.2345 | 55 | 0.0770 | - | - |

5.1.2 the analysis of variance of the results. As in 1970 the variation between months was not significant for S. U. The S. U. mean level in 1971 was 7.2 pCi Sr-90/g Ca or approx. equal to the 1970 mean.

As previously, the milk from eastern Denmark shows significantly lower levels than that from Jutland.

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 (15.3 M.U., approx. 10% higher than the maximum of 1970) was found in milk from the summer (August). The M. U. mean level in 1971 was 8.7 pCi Cs-137/g K or nearly the same as in 1970.

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).

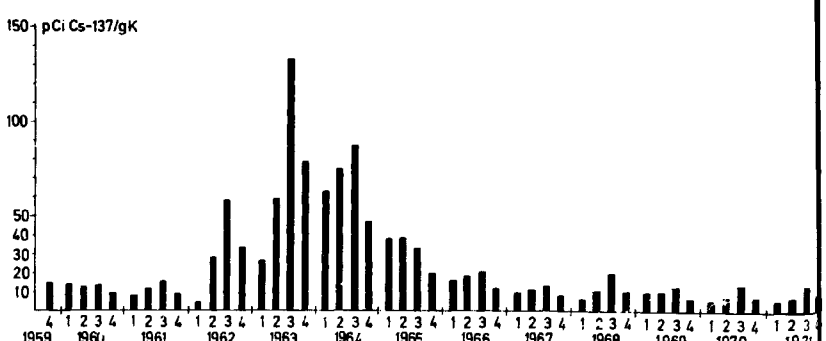



Fig. 5.1.3. Cs-137 in dried milk, 1959-71



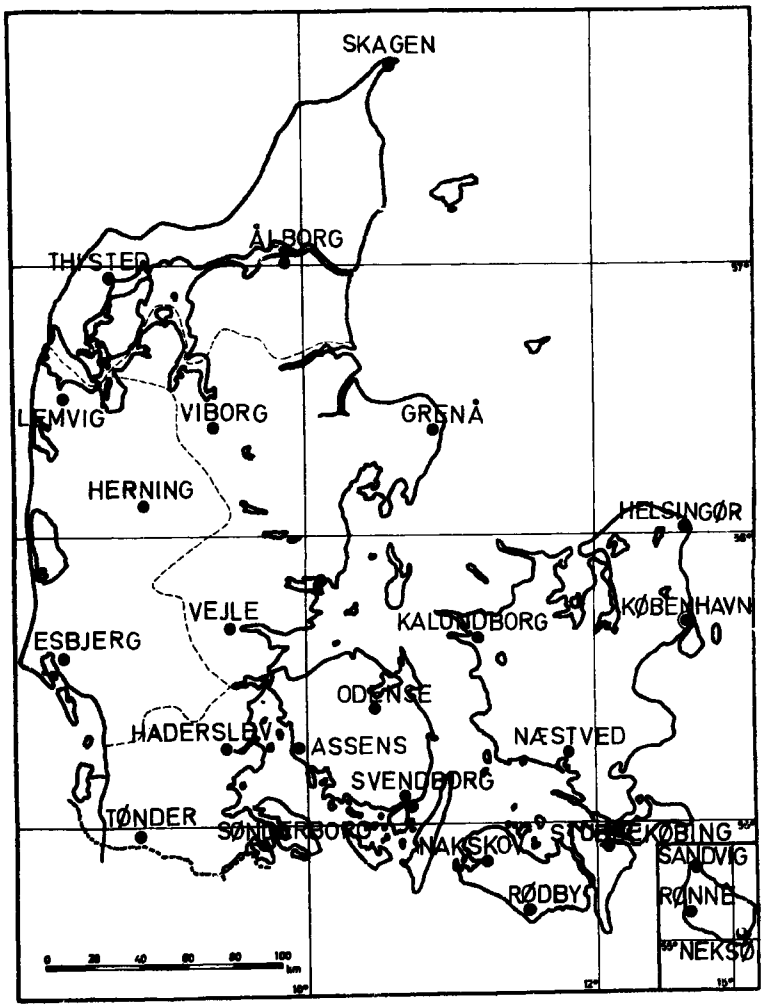



Fig. 5.2.1. Sample locations for fresh milk, bread and total diet (A-towns).

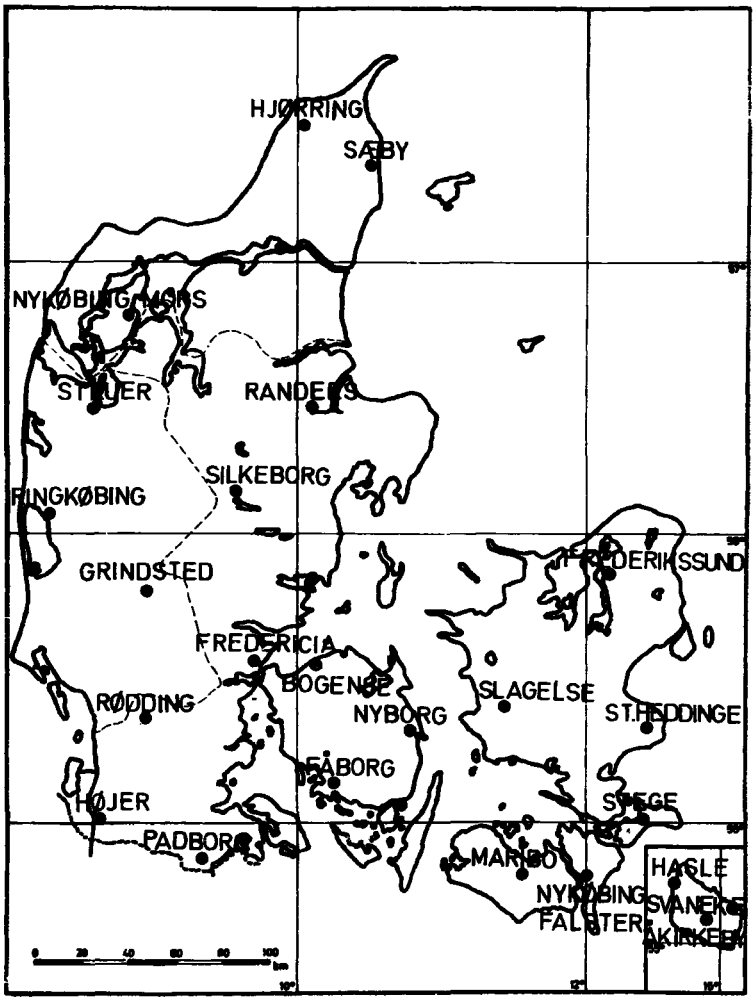



Fig. 5.2.2. Sample locations for fresh milk, bread and total diet (B-towns).



## 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 previously (cf. figs. 5.2.1 and 5.2.2) in connection with the bread and total-diet collection (cf. 5.7).

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 1971 were 7.0 S.U. (~8.5 pCi Sr-90/l) and 7.2 M.U. or 11.4 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.

In the figures in table 5.2.1 are weighted with respect to the population, the country means become 6.8 S.U. and 11.4 pCi Cs-137/l, i.e. almost the same as the production-weighted means.

Table 5.2.1

Sr-90 and Cs-137 in fresh milk in 1971

| Zone | June 1971 | | | December 1971 | | |
|---|---|---|---|---|---|---|
| | 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 | 6.8 | 8.4 | 13.1 | 8.4 | 8.9 | 13.9 |
| II: E-Jutland | 7.0 | 6.3 | 9.9 | 6.9 | 8.2 | 13.1 |
| III: W-Jutland | 7.4 | 10.3 | 16.5 | 9.0 | 6.9 | 11.4 |
| IV: S-Jutland | 6.2 | 5.3 | 8.3 | 9.3 | 7.9 | 12.0 |
| V: Funen | 4.7 | 3.1 | 4.9 | 5.8 | 5.8 | 9.1 |
| VI: Zealand | 5.9 | 6.4 | 10.3 | 5.2 | 4.6 | 7.5 |
| VII: Lolland-Falster | 4.9 | 2.6 | 4.3 | 5.5 | 4.0 | 6.3 |
| VIII: Bornholm | 6.4 | 7.1 | 11.3 | 5.8 | 3.9 | 6.0 |
| Mean | 6.2 | 6.2 | 9.8 | 7.0 | 6.3 | 9.9 |
| Copenhagen | 6.7 | 9.8 | 14.9 | 6.7 | 6.8 | 10.8 |
| Population-weighted mean | 6.5 | 7.6 | 11.9 | 7.0 | 6.8 | 10.9 |
| Production-weighted mean | 6.6 | 7.0 | 11.1 | 7.5 | 7.3 | 11.6 |

## 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 was replaced by Ledreborg in 1969. Sr-90 was detern ined as previously (Risø Report No. 63[1]), and Cs-137 was measured or ashed samples by Y-spectrometry on a Ge-detector.

Table 5.3.1

Sr-90 in Danish grain in 1971

| | Rye | | Barley | | Wheat | | Oats | |
|---|---|---|---|---|---|---|---|---|
| | pCi Sr-90/kg | S. U. | pCi Sr-90/kg | S. U. | pCi Sr-90/kg | S. U. | pCi Sr-90/kg | S. U. |
| Tylstrup | 71±8 | 190±24 | 69±5 | 140±10 | 72±3 | 192±18 | 106±10 | 124±12 |
| Studsgård | w:103±10 | w:228±18 | 87±12 | 167±18 | s:63±3<br>w:65±10 | s:164±15<br>w:209±21 | 100±7 | 121±1 |
| Ødum | 33±3 | 87±8 | 35±1 | 67±1 | s:34±5 | s: 80±3 | 37±0 | 43±3 |
| Askov | s: 77±1<br>w:117±2 | s:143±2<br>w:168±5 | 64±11 | 116±26 | s:78±1<br>w:81±4 | s:185±2<br>w:205±7 | 134±6 | 132±7 |
| St. Jyndevad | 69±4 | 174±11 | 91±6 | 159±14 | - - | - - | 123±0 | 140±2 |
| Blangstedgård | 43±2 | 96±6 | 35±3 | 60±7 | w:29±2 | w: 93±6 | 49±3 | 46±3 |
| Tystofte | 36±1 | 93±2 | s:43±4<br>w:40±1 | s:79±10<br>w:85±3 | s:42±3<br>w:49±2 | s: 89±7<br>w:128±11 | 103±2 | 102±2 |
| Ledreborg | 42±1 | 97±5 | 46±1 | 91±3 | s:30±7<br>w:39±1 | s:62±19<br>w:90±4 | 50±1 | 53±1 |
| Abed | - | - | 36±3 | 57±4 | 42±7 | 95±17 | 38±2 | 38±3 |
| Åkirkeby | 33±0 | 81±3 | 22±3 | 44±3 | s:22±4<br>w:22±5 | s:50±13<br>w:90±23 | 23±4 | 34±5 |
| Mean | 62 | 136 | 52 | 99 | 48 | 124 | 76 | 85 |

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 1971
(from table 5.3.1)

| Variation | SSD | f | $s^2$ | $v^2$ | P |
|---|---|---|---|---|---|
| Betw. species | 3.2411 | 3 | 1.0804 | 16.03 | >99.95% |
| Betw. locations | 16.7392 | 9 | 1.8599 | 27.58 | >99.95% |
| Spec. x loc. | 1.6861 | 25 | 0.0674 | 2.01 | >97.5% |
| Remainder | 1.8116 | 54 | 0.0335 | | |



Table 5.3.1 shows the measurements of strontium-90 in grain in 1971. 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 six wheat figures, while eastern Denmark contributes eight wheat figures and four rye figures. Thus the means in tables 5.3.1 - 5.3.4 for rye are a little lower and those for wheat are probably 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 1971
(from table 5.3.1)

| Variation | SSD | f | $s^2$ | $v^2$ | P |
|---|---|---|---|---|---|
| Betw. species | 1.7802 | 3 | 0.5941 | [illegible] | >99.5% |
| Betw. locations | 17.7496 | 9 | 1.9722 | 22.13 | >99.95% |
| Loc. x species | 2.2276 | 25 | 0.0891 | 3.69 | >99.95% |
| Remainder | 1.3038 | 54 | 0.0241 | | |

Table 5.3.4

Cs-137 in Danish grain in 1971

| | 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 | 71 | 17 | 52 | 15 | 70 | 19 | 47 | 15 |
| Studsgård | w:159 | w:32 | 57 | 16 | w:93<br>s:99 | w:16<br>s:24 | 138 | 32 |
| Ødum | 146 | 33 | 73 | 24 | w:40<br>s:43 | w: 9<br>s: 9 | 78 | 16 |
| Askov | w:202<br>s:184 | w:39<br>s:34 | 95 | 15 | w:89<br>s:81 | w:20<br>s:16 | 119 | 24 |
| St. Jyndevad | 98 | 24 | 78 | 18 | - | - | 102 | 28 |
| Blangstedgård | 85 | 19 | 39 | 9 | w:49 | w:12 | 59 | 12 |
| Tystofte | 84 | 21 | w:103<br>s: 54 | w:20<br>s:11 | w:72<br>s:69 | w:18<br>s:14 | 101 | 20 |
| Ledreborg | 107 | 23 | 58 | 13 | w:94<br>s:73 | w:14<br>s:15 | 89 | 18 |
| Abed | - | - | 63 | 11 | 54 | 12 | 61 | 14 |
| Åkirkeby | 112 | 25 | 42 | 11 | w:35<br>s:57 | w: 9<br>s:15 | 26 | 10 |
| Mean | 125 | 27 | 65 | 15 | 66 | 15 | 82 | 21 |

w: winter variety, s: spring variety

Table 5.3.5

Analysis of variance of ln pCi Cs-137/g K grain in 1971
(from table 5.3.4)

| Variation | SSD | f | $s^2$ | $v^2$ | P |
|---|---|---|---|---|---|
| Betw. species | 2.3130 | 3 | 0.7710 | 9.17 | >99.95% |
| Betw. location | 2.3128 | 9 | 0.2569 | 3.05 | >97.5% |
| Species x loc. | 2.1028 | 25 | 0.0841 | 1.45 | |
| Remainder | 0.4627 | 8 | 0.0578 | | |
| Main effects were tested against interaction. | | | | | |

Table 5.3.6

Analysis of variance of ln pCi Cs-137/kg grain in 1971
(from table 5.3.4)

| Variation | SSD | f | $s^2$ | $v^2$ | P |
|---|---|---|---|---|---|
| Betw. species | 2.4635 | 3 | 0.8212 | 10.36 | >99.95% |
| Betw. locations | 2.4056 | 9 | 0.2673 | 3.37 | >99% |
| Species x loc. | 1.9837 | 25 | 0.0793 | 1.82 | |
| Remainder | 0.3495 | 8 | 0.0437 | | |
| Main effects were tested against interaction. | | | | | |

Table 5.3.2 shows that the variation in S.U. between species was significant. Rye showed the highest S.U. levels and oats the lowest. The pCi Sr-90/kg figures also show a significant difference between species. (Oats > wheat).

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 times that in eastern Denmark.

Table 5.3.4 shows the measurements of Cs-137 in grain in 1971, 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. 1.4 (pCi/kg figures) times as high as the grain level in eastern Denmark. The variation between species was highly significant. Rye contained as previously more Cs-137 than did the other grain species.



If the S.U. levels in grain from the harvest of 1971 are compared with the levels from 1970[1], we find the 1971 figures to be greater by a factor of approx. 1.5.

The Cs-137 content in grain from the 1971 harvest was on the average greater by a factor of 1.3 than that in 1970. The fall-out rate in May-August 1971 was 1.1 times that in May-August 1970. (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. It is, however, a little surprising that the Sr-90 levels were significantly higher in 1971 than in 1970 as the fall-out rate in July-August, which determines the Sr-90 levels in grain, was lower in 1971 than in 1970.

In Appendix C is shown a comparison between observed and predicted Sr-90 and Cs-137 levels in 1971. Contrary to the past years the predicted levels for grain were not significantly higher than those observed.

The mean ratio between pCi Cs-137/kg rye and pCi Sr-90/kg rye was 2.0, 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 1971

| | Rye | | Barley | | Wheat | | Oats |
|---|---|---|---|---|---|---|---|
| | W | S | W | S | W | S | S |
| Tylstrup | 4.6 | | | 5.65 | 4.7 | | 4.5 |
| Studsgård | 3.2 | | | 4.6 | 3.7 | 3.6 | 3.1 |
| Ødum | 2.4 | | | 5.5 | 4.75 | 4.4 | 2.4 |
| Askov | 2.5 | 3.1 | | 3.0 | 2.5 | 4.2 | 2.75 |
| St. Jyndevad | 2.2 | | | 2.6 | | | 2.4 |
| Blangstedgård | 2.6 | | | 2.25 | 2.75 | | 2.45 |
| Tystofte | 1.9 | | 3.0 | 6.35 | 3.5 | | 1.7 |
| Lødreborg | 2.3 | | | 3.45 | 3.45 | 3.8 | 2.4 |
| Abed | | | | 3.2 | 2.9 | 3.8 | 2.4 |
| Åkirkeby | 1.3 | | | 1.5 | 3.9 | 3.3 | 1.8 |

Table 5.3.8

Analysis of variance of ln mg Sr/g Ca in grain in 1971
(from table 5.3.7)

| Variation | SSD | f | $s^2$ | $v^2$ | P |
|---|---|---|---|---|---|
| Betw. species | 1.4252 | 3 | 0.4751 | 7.84 | >99.5% |
| Betw. locations | 2.2135 | 9 | 0.2459 | 4.06 | >99.5% |
| Spec. x locations | 1.5139 | 25 | 0.0606 | 0.97 | |
| Remainder | 0.5646 | 9 | 0.0627 | | |

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 more stable strontium per g Ca than the other species, and the stations in Jutland showed generally higher figures than the eastern locations.

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

In 1970, samples of white bread (75% extraction) and dark rye bread (100% extraction) were collected all over the contry in June, but not as previously in 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 determination 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. 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], hence we can compare the 1971 bread levels with the 1970 grain levels (cf. table 5.4.3).

Table 5.4.3 shows 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. 1.4 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 June, 1971

| Zone | | White bread | | Rye bread | |
|---|---|---|---|---|---|
| | | pCi/kg | S.U. | pCi/kg | S.U. |
| I: | N. Jutland | 7.8±0.5 | 3.9±0.2 | 26±0 | 9.2±0.3 |
| II: | E. Jutland | 6.2±1.1 | 3.1±0.6 | 32±0 | 10.6±0.1 |
| III: | W. Jutland | 7.1±2.2 | 4.0±1.3 | 28±0 | 8.8±0.2 |
| IV: | S. Jutland | 6.4±0.7 | 3.2±0.3 | 25±0 | 8.3±0.1 |
| V: | Fynen | 8.2±2.8 | 4.0±1.5 | 24±0 | 7.9±0.1 |
| VI: | Zealand | 6.4±0.1 | 2.9±0.1 | 21±3 | 6.6±0.8 |
| VII: | Lolland-Falster | 6.5±0.4 | 3.3±0.3 | 20±3 | 6.8±1.1 |
| VIII: | Bornholm | 8.9±0.5 | 4.7±0.3 | 19±3 | 6.3±1.0 |
| Mean | | 7.2 | 3.6 | 24 | 8.1 |
| Copenhagen | | 5.1±0.9 | 2.7±0.5 | 23±1 | 7.3±0.5 |
| Population-weighted mean | | 6.4 | 3.3 | 25 | 8.2 |
| Relative error due to sampling and analyses | | 27% | 29% | 10% | 11% |

Table 5.4.2

Cs-137 in Danish bread in June 1971

| Zone | | White bread | | Rye bread | |
|---|---|---|---|---|---|
| | | pCi/kg | M.U. | pCi/kg | M.U. |
| I: | N. Jutland | 15.9 | 10.1 | 66 | 19 |
| II: | E. Jutland | 13.6 | 9.3 | 69 | 20 |
| III: | W. Jutland | 17.1 | 11.8 | 80 | 24 |
| IV: | S. Jutland | 16.9 | 12.1 | 44 | 18 |
| V: | Fynen | 13.2 | 9.6 | 41 | 14 |
| VI: | Zealand | 20.0 | 13.3 | 35 | 12 |
| VII: | Lolland-Falster | 18.6 | 12.7 | 40 | 15 |
| VIII: | Bornholm | 23.3 | 15.0 | 64 | 17 |
| Mean | | 17.3 | 11.7 | 55 | 17 |
| Copenhagen | | 20.8 | 13.9 | 51 | 18 |
| Population-weighted mean | | 17.6 | 11.9 | 55 | 18 |

Table 5.4.3

A comparison of Sr-90 and Cs-137 levels in bread and grain in 1971

| Nuclide | Species | Bread activity in June 1971 calculated as grain activity in pCi/kg (cf. text) | Activity in grain from harvest 1970[1] pCi/kg | "Bread"/grain ratio |
|---|---|---|---|---|
| Sr-90 | Wheat | 43 | 40 | 1.08 |
| | Rye | 34 | 31 | 1.10 |
| Cs-137 | Wheat | 47 | 57 | 0.82 |
| | Rye | 74 | 85 | 0.87 |

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

The samples of potatoes were collected in September from ten 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 3.5 pCi Sr-90/kg or 72 S.U. and 10.8 pCi Cs-137/kg or 2.0 M.U.

The mean of the Cs-137/Sr-90 ratios (pCi/kg figures) was 3.1 (in 1970: 3.8, in 1969: 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 1971

| | pCi Sr-90/kg | S.U. | pCi Cs-137/kg | M.U. |
|---|---|---|---|---|
| Tylstrup | 2.9±0.3* | 68±14* | | |
| Studsgård | 4.5±0.5 | 80±10 | | |
| Østum | 1.8±0.2* | 40±5* | 11.8 | 2.2 |
| Askov | 5.9±1.3 | 127±36 | | |
| St. Jyndevad | 5.0±2.0 | 108±52 | | |
| Blangstedgård | 3.5±0.7 | 55±11 | | |
| Tystofte | 2.5±0.4* | 56±6* | | |
| Ledreborg | 2.7±0.1 | 40±3 | 9.8 | 1.8 |
| Abed | 3.1±0.5 | 50±9 | | |
| Åkirkeby | 3.0±0.7 | 100±46 | | |
| Mean | 3.5 | 72 | 10.8 | 2.0 |

The error terms are the S.E. of the mean of double determinations except x, which are based on triple analysis.



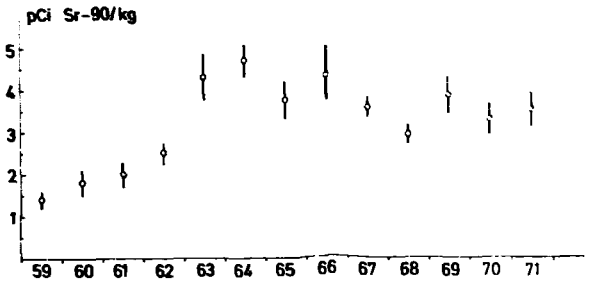



Fig. 5.5. Sr-90 levels in Danish potatoes 1959-71 (1 S.E. indicated)

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

In 1971 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, strawberries and gooseberries were collected in June-July.

Table 5.6.1

*Sr-90 in vegetables and fruits in 1971*

| Zone | | Cabbage | | Carrot | | Onion | | Apple | | Pea | | Strawberry | | Gooseberry | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | pCi/kg | S.U. | pCi/kg | S.U. | pCi/kg | S.U. | pCi/kg | S.U. | pCi/kg | S.U. | pCi/kg | S.U. | pCi/kg | S.U. |
| I: | N-Jutland | 14±2 | 32±4 | 20 | 51 | 20 | 53 | 1.5 | 38 | (10) | (45) | (22) | (95) | (15) | (47) |
| II: | E-Jutland | 10±1 | 20±4 | 37 | 116 | 23 | 59 | 2.1±0.1 | 75±22 | 13 | 62 | 13 | 40 | (14) | (43) |
| III: | W-Jutland | 13±1 | 25±3 | 28 | 72 | 17 | 54 | 1.9 | 72 | (11) | (48) | (24) | (103) | 29 | 84 |
| IV: | S-Jutland | 13±2 | 26±6 | 9 | 34 | 32 | 90 | 3.5 | 46 | (10) | (36) | (22) | (77) | 12 | 21 |
| V: | Funen | 8±2 | 16±3 | 13 | 39 | 13±0 | 47±3 | 4.4 | 45 | 5 | 19 | 22 | 72 | (11) | (31) |
| VI: | Zealand | 10±2 | 19±2 | 9 | 25 | 18 | 55 | 1.7 | 45 | (7) | (25) | (15) | (54) | 7 | 23 |
| VII | Lolland-Falster | 6±1 | 12±2 | 18 | 57 | 14 | 40 | 1.4 | 30 | 6 | 22 | 15 | 76 | (8) | (24) |
| VIII: | Bornholm | 15±2 | 27±2 | 22 | 48 | 22 | 54 | 2.8 | 39 | (11) | (37) | 28 | 137 | 8 | 31 |
| Mean | | 11 | 22 | 20 | 55 | 20 | 57 | 2.4 | 49 | 9 | 37 | 20 | 82 | 15 | 38 |
| Copenhagen | | 7±1 | 15±2 | 8±2 | 44±12 | 15±3 | 45±10 | 1.5±0.4 | 43±2 | (6) | (31) | 11 | 43 | 17 | 55 |
| Population-weighted mean | | 10 | 20 | 18 | 57 | 18 | 53 | 2.0 | 51 | 8 | 38 | 16 | 63 | 15 | 46 |

Values in brackets were calculated from VAR 3

The error term is ± 1 SE of the mean of double determinations, in the case of cabbage four double

Table 5.6.2

Analysis of variance of ln pCi Sr-90/kg in vegetables and fruits in 1971 (from table 5.6.1)

| Variation | SSD | f | $s^2$ | $v^2$ | P |
|---|---|---|---|---|---|
| Betw. species | 34.6248 | 6 | 5.7708 | 31.9535 | >99.95% |
| Betw.locations | 4.5832 | 8 | 0.5729 | 3.1722 | >97.5% |
| Loc. x species | 6.1396 | 34 | 0.1806 | 2.26 | >97.5% |
| Remainder | 2.3982 | 30 | 0.0799 | | |

Table 5.6.3

Analysis of variance of ln S.U. in vegetables and fruits in 1971 (from table 5.6.1)

| Variation | SSD | f | $s^2$ | $v^2$ | P |
|---|---|---|---|---|---|
| Betw. species | 14.3591 | 6 | 2.3932 | 11.0082 | >99.95% |
| Betw. locations | 4.5472 | 8 | 0.5684 | 2.6145 | >97.5% |
| Loc. x species | 7.3902 | 34 | 0.2174 | 2.20 | >97.5% |
| Remainder | 2.9648 | 30 | 0.0988 | | |

Table 5.6.4

Cs-137 in vegetables and fruits in 1971

| | Cabbage | Carrot | Onion | Apple | Pea | Strawberry | Gooseberry |
|---|---|---|---|---|---|---|---|
| pCi/kg | 2.9±0.1 | 2.9 | 0 | 7.7 | 0 | 4.2 | 2.4 |
| pCi/g K | 1.2±0.0 | 1.1 | 0 | 5.4 | 0 | 2.4 | 0.9 |
| The error term is the S.E. of the mean | | | | | | | |

Table 5.6.5

Calculated Sr-90 and Cs-137 mean levels in vegetables in 1971

| Daily intake in g | Species | pCi Sr-90 per kg | S.U. | pCi Cs-137 per kg | M.U. |
|---|---|---|---|---|---|
| 50 | Leafy vegetables (cabbage) | 10 | 20 | 2.9 | 1.2 |
| 30 | Root vegetables (carrot, onion) | 18 | 55 | 1.5 | 0.6 |
| 40 | Pea (and bean) | 8 | 38 | 0 | 0 |
| 120 | Vegetable total | 11 | 35 | 1.6 | 0.6 |



The Y-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 (pCi Sr-90 figures). The highest Sr-90 levels (pCi/kg) were found in strawberry, onion and carrot, the lowest in apple.

Table 5.6.5 shows a calculation of the mean contents of Sr-90 and Cs-137 in Danish vegetables collected in 1971. The levels were the population-weighted means calculated in tables 5.6.1 - 5.6.4.

The 1971 levels in Danish fruit were calculated from apple and from strawberry. Apples got a weight factor of 85 and strawberries one of 15, and the mean levels in Danish fruit were thus 5.0 pCi Sr-90/kg and 7 Cs-137/kg.

The 1971 Sr-90 levels in vegetables and fruits were a little higher and the Cs-137 levels somewhat lower than the 1970 levels.

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

In 1971 total-food samples representing an average Danish diet according to E. Hoff-Jørgensen (cf. Appendix B in Risø Report No. 63[1]) where collected according to the principles followed in 1961-1970. As previously, two groups of towns (A and B, cf. figs. 5.2.1 and 5.2.2) supplied the samples.

Table 5.7.1 and 5.7.2 show the results. As in the previous years, the variation between locations was significant. The S.U. levels in the total diet were approx. 30% 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 1971 Sr-90 levels in total diet were 10% lower than the 1970 levels, while the Cs-137 levels were approx. 10% greater than the 1970 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 1971. For the period January-April 1971 the Sr-90 level in the total diet is assumed to have been equal to that measured in December 1970, Risø Report No. 245[1]. For the period May-September we assume the level to have corresponded to that measured in June 1971. The December 1971 figure is taken to represent the last three months of the year. The population-weighted mean of Sr-90 in total-diet samples was 7.5 pCi Sr-90/g Ca in December 1970. Hence the mean content in the total diet in 1971 was 7.5 pCi Sr-90/g Ca or 13.2 pCi Sr-90/day.

In a similar way the Cs-137 content in the Danish diet in 1971 was estimated to be 33 pCi Cs-137/day or 9.1 pCi Cs-137/g K (cf. also Appendix C).

Table 5.7.1

Sr-90 and Cs-137 in total Danish diet collected in June 1971

| 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 | 9.4±1.0 | 16.0±2.4 | 1.70±0.08 | 6.9±0.2 | 28±2 |
| II: E. Jutland | 7.8±1.2 | 13.9±2.2 | 1.78±0.01 | 6.2±0.3 | 27±1 |
| III: W. Jutland | 8.9±0.5 | 15.7±1.5 | 1.76±0.08 | 11.5±2.7 | 48±21 |
| IV: S. Jutland | 8.0±0.2 | 14.7±0.2 | 1.83±0.01 | 9.6±0.0 | 39±3 |
| V: Funen | 5.4±1.5 | 9.5±1.9 | 1.82±0.17 | 6.3±0.2 | 21±1 |
| VI: Zealand | 8.4±0.8 | 15.7±2.3 | 1.87±0.09 | 6.3±0.4 | 26±3 |
| VII: Lolland-Falster | 6.2±0.2 | 10.4±0.6 | 1.68±0.03 | 6.7±0.3 | 22±0 |
| VIII: Bornholm | 8.5±0.3 | 15.0±0.1 | 1.77±0.07 | 9.8±0.1 | 35±0 |
| Mean | 7.8 | 13.9 | 1.78 | 7.9 | 31 |
| Copenhagen | 6.8±1.1 | 13.2±2.3 | 1.93±0.05 | 11.2 | 42 |
| Population-weighted mean | 7.7 | 14.0 | 1.83 | 8.6 | 34 |
| Relative error due to sampling and analysis | 15% | 17% | 7% | 18% | 35% |

Table 5.7.2

Sr-90 and Cs-137 in Danish total diet collected in December 1971

| 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 | 7.5±0.0 | 13.2±1.4 | 1.77±0.18 | 13.2±1.8 | 42±8 |
| II: E. Jutland | 7.2±0.0 | 12.2±0.4 | 1.69±0.06 | 11.1±0.4 | 39±1 |
| III: W. Jutland | 7.5±0.1 | 13.5±0.3 | 1.81±0.04 | 12.4±1.6 | 45±8 |
| IV: S. Jutland | 9.0±0.0 | 14.5±0.5 | 1.61±0.05 | 11.8±1.1 | 44±8 |
| V: Funen | 5.6±0.1 | 9.8±0.1 | 1.77±0.02 | 7.7±0.8 | 28±1 |
| VI: Zealand | 6.9±0.1 | 12.7±0.9 | 1.83±0.10 | 10.5±1.7 | 36±6 |
| VII: Lolland-Falster | 4.2±0.4 | 7.5±0.8 | 1.81±0.03 | 9.0±1.8 | 32±5 |
| VIII: Bornholm | 5.6±0.3 | 10.4±0.8 | 1.86±0.04 | 8.7±0.1 | 33±1 |
| Mean | 6.7 | 11.7 | 1.77 | 10.6 | 37 |
| Copenhagen | 7.0±0.2 | 12.0±0.6 | 1.71±0.05 | 7.9 | 27 |
| Population-weighted mean | 7.0 | 12.2 | 1.75 | 10.1 | 35 |
| Relative error due to sampling and analysis | 4% | 9% | 7% | 18% | 21% |



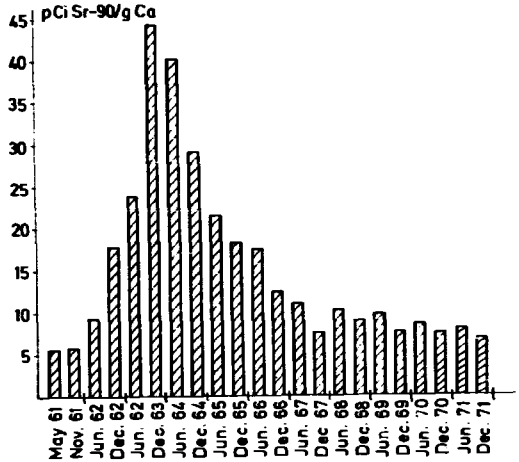



Fig. 5.7.1. pCi Sr-90/g Ca in Danish total diet 1963-71

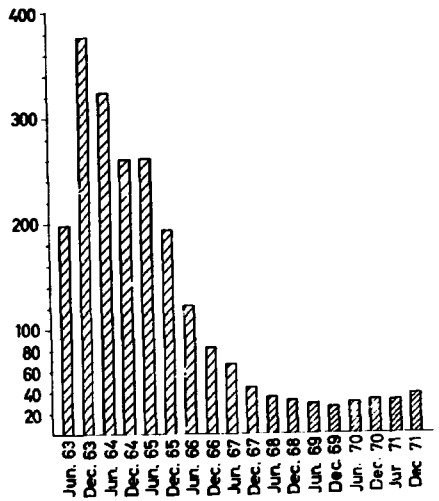



Fig. 5.7.2. pCi Cs-137/day from Danish total diet, 1963-71

## 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. 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 0.20 (S.E. 0.02), and the corresponding ratio for Cs-137 was 5.1 (S.E. 0.4) for the period 1962-1971. (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 and beef from Copenhagen in 1971

| Species | Unit | March | June | Sep. | Dec. | Mean |
|---|---|---|---|---|---|---|
| Pork | pCi Sr-90/kg | 1.3 | 0.8 | 1.1 | 1.2 | 1.1 |
| | pCi Sr-90/g Ca | 17 | 11 | 7 | 11 | 12 |
| | pCi Cs-137/kg | 74 | 71 | 118 | 103 | 92 |
| | pCi Cs-137/g K | 20 | 19 | 36 | 31 | 27 |
| Beef | pCi Sr-90/kg | 1.8 | 1.0 | 2.4 | 1.2 | 1.6 |
| | pCi Sr-90/g Ca | 15 | 15 | 16 | 15 | 15 |
| | pCi Cs-137/kg | 66 | 28 | 64 | 82 | 60 |
| | pCi Cs-137/g K | 17 | 7 | 19 | 25 | 17 |

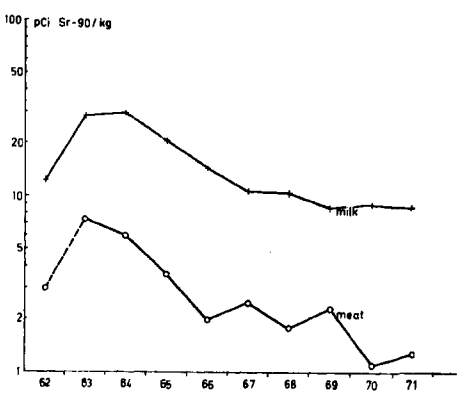



Fig. 5.8.1.1. Sr-90 in Danish milk and meat (2/3 pork and 1/3 beef), 1962-71



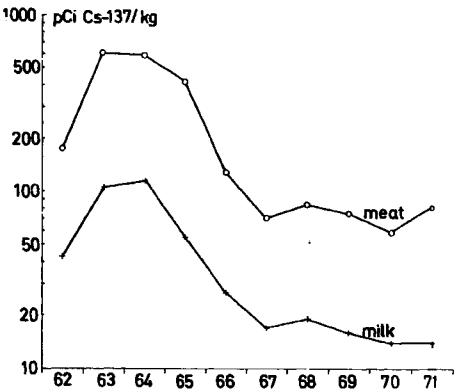



Fig. 5.8.1.2. Cs-137 in Danish milk and meat (2/3 pork and 1/3 beef), 1962-71

### 5.8.2. Sr-90 and Cs-137 in Fish

Fish samples were collected around Zealand in June-December. Tables 5.8.2.1 and 5.8.2.2 show the results. The mean levels were 1.4 pCi Sr-

Table 5.8.2.1

Sr-90 and Cs-137 in cod collected in 1971 in Danish waters

| Cod | | Month | pCi Sr-90/kg | pCi Sr-90/g Ca | pCi Cs-137/kg | pCi Cs-137/g K |
|---|---|---|---|---|---|---|
| 55°32'5N 12°39'E | meat | June | 1.13 | 0.79 | 67 | 18 |
| | bone | | - | 0.46 | - | - |
| Barsebäck C | meat | Oct. | 1.13 | 0.81 | 71 | 17 |
| | bone | | - | 0.55 | - | - |
| Barsebäck B | meat | Oct. | 0.98 | 0.78 | 124 | 28 |
| | bone | | - | 0.47 | - | - |
| 55°52'7N z) 12°39'5E 15 m | meat | Dec. | - | - | 138 | 42 |
| | bone | | - | 8.8 | - | - |
| 55°52'7N y) 12°39'5E 15 m | meat | Dec. | - | - | 192 | 38 |
| | bone | | - | 1.2 | - | - |
| 55°52'7N z) 12°39'5E 15 m | meat | Dec. | - | - | 53 | 17 |
| | bone | | - | 0.7 | - | - |
| Mean ± 1 SE | meat | | 1.08±0.05 | 0.79±0.01 | 108±22 | 27±5 |
| Mean ± 1 SE | bone | | - | 2.03±1.36 | | |

x, y, z collected in 1970

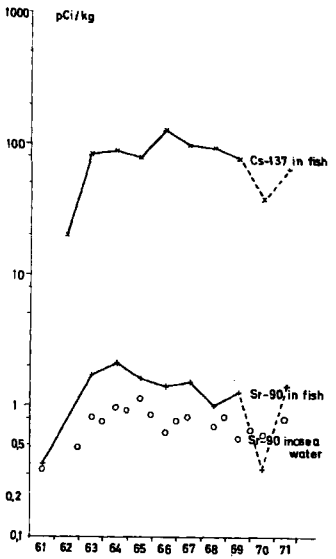



Fig. 5.8.2. Sr-90 and Cs-137 in Danish fish compared with Sr-90 in sea water, 1961-71

90/kg meat (1 SE:0.3) and 61 pCi Cs-137/kg meat (1 SE:9). The levels were higher than in 1970 but in agreement with the 1969, 1968 and 1967 concentrations. Hence we will consider the 1970 results atypical because the fish in 1970 were from the North sea and not from inner Danish waters as usual. In table 5.8.2.1 is shown 3 cod samples from 1970, the mean level of these samples was 133 pCi Cs-137 (± 41).

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 approx. a hundred times the Sr-90 level in sea water. The Cs-137/Sr-90 ratio in sea water is 1.6 (S.E. 0.1)[16], hence the concentration factor for fish from sea water becomes 65.



Table 5.8.2.2

Sr-90 and Cs-137 in fish collected in 1971 in Danish waters

| Species | | Month | pCi Sr-90/kg | pCi Sr-90/g Ca | pCi Cs-137/kg | pCi Cs-137/g K |
|---|---|---|---|---|---|---|
| x Dab 55°52'7N 12°39'5E | total | Dec. | 14.2 | 9.2 | 37 | 9 |
| Dab 56°06'N 11°47'5E | total | June | 3.02 | 0.32 | 37 | 16 |
| Plaice Hundested | meat<br>bone | June | 0.62<br>- | 1.09<br>0.49 | 21<br>- | 10<br>- |
| x Plaice 55°52'7N 12°39'5E | meat<br>bone | Dec. | -<br>- | -<br>7.2 | 33<br>- | 10<br>- |
| x Sprat 55°52'7N 12°39'5E | meat<br>bone | Dec. | -<br>- | -<br>- | 54<br>- | 18<br>- |
| x xx Sprat 55°52'7N 12°39'5E | meat<br>bone | Dec. | -<br>- | -<br>- | 63<br>- | 18<br>- |
| x Whiting 55°52'7N 12°39'5E | total | Dec. | - | - | 36 | 12 |
| Garfish Møn | total | June | 1.73 | 2.20 | 132 | 75 |
| x Flounder 55°52'7N 12°39'5E | total | Dec. | 32.0 | 3.7 | 65 | 20 |
| x Herring 55°52'7N 12°39'5E | total | Dec. | - | - | 62 | 21 |
| Mean ± 1 SE | bone | | 1.8±0.7 | 3.8±3.4 | | |
| Mean ± 1 SE | total | | 10.31±5.94 | 1.2±0.5 | 53±10 | 21±6 |

x collected in 1970
xx stomach content of cod

### 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. The samples were analysed, by the method used for ground water, for Sr-90, stable strontium and calcium.

Table 5.8.3 shows the results.

Table 5.8.3

Sr-90 in Danish drinking water in June 1971

| Zone | | pCi Sr-90/l | g Ca/l | mg Sr/g Ca |
|---|---|---|---|---|
| I: | N-Jutland | 0.042 | 0.085 | 3.7 |
| II: | E-Jutland | 0.045 | 0.075 | 4.7 |
| III: | W-Jutland | 0.022 | 0.056 | 1.6 |
| IV: | S-Jutland | 0.024 | 0.095 | 1.4 |
| V: | Funen | A 0.038 | 0.111 | 3.7 |
| VI: | Zealand | 0.023 | 0.085 | 10.4 |
| VII: | Lolland-Falster | 0.027 | 0.090 | 16.6 |
| VIII: | Bornholm | 0.091 | 0.079 | 4.3 |
| Mean | | 0.039 | 0.085 | 5.8 |
| Median | | 0.033 | 0.085 | 4.0 |

A: counting error: 20-33%

## 5.9. Estimate of the Mean Contents of Sr-90 and Cs-137 in the Human Diet in Denmark in 1971

### 5.9.1. The Annual Quantities

The annual quantities are calculated by multiplication of the daily quantities (as stated by E. Hoff-Jørgensen, cf. Risø 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 l 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 14 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 pCi Sr-90 and 10 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 1971. From these tables the activity levels in grain products were estimated at 20.9 pCi Sr-90/kg and 55 pCi Cs-137/kg.

Table 5.9.1

Estimate of the Sr-90 content in grain products consumed per capita in 1971

| Type | Fraction from harvest 1970 | | | Fraction from harvest 1971 | | | Total |
|---|---|---|---|---|---|---|---|
| | kg flour | pCi/kg | pCi | kg flour | pCi/kg | pCi | pCi |
| Rye flour (100% extraction) | 21.9 | 31.0 | 679 | 7.3 | 62 | 453 | 1132 |
| Wheat flour (75% extraction) | 32.9 | 8.0 | 263 | 10.9 | 9.6 | 105 | 368 |
| Grits | 5.5 | 22.0 | 121 | 1.8 | 30.4 | 55 | 176 |
| Total | 60.3 | 17.6 | 1063 | 20.0 | 30.6 | 613 | 1676 |

Table 5.9.2

Estimate of the Cs-137 content in grain products consumed per capita in 1971

| Type | Fraction from harvest 1970 | | | Fraction from harvest 1971 | | | Total |
|---|---|---|---|---|---|---|---|
| | kg flour | pCi/kg | pCi | kg flour | pCi/kg | pCi | pCi |
| Rye flour (100% extraction) | 21.9 | 85 | 1862 | 7.3 | 125 | 912 | 2774 |
| Wheat flour (75% extraction) | 32.9 | 29 | 954 | 10.9 | 33 | 360 | 1314 |
| Grits | 5.5 | 42 | 231 | 1.8 | 62 | 112 | 343 |
| Total | 60.3 | 51 | 3047 | 20.0 | 69 | 1384 | 4431 |

### 5.9.5. Potatoes

The figures in table 5.5.1 were used, i.e. 3.5 pCi Sr-90/kg and 10.8 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 1971. The mean contents were 11 pCi Sr-90/kg and 1.6 pCi Cs-137/kg.

### 5.9.7. Fruit

The levels in imported fruit in 1971 are assumed to be equal to the mean levels found in lemons, oranges and bananas collected in Copenhagen in 1970, i.e. 4.0 pCi Sr-90/kg and 3 pCi Cs-137/kg (cf. 5.8.4). The mean levels in Danish fruit in 1971 were 5.0 pCi Sr-90/kg and 7 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 4.7 pCi Sr-90/kg and 5.9 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: 1.3 pCi Sr-90/kg and 81 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 given in 5.8.2., i.e. 1.4 pCi Sr-90/kg and 61 pCi Cs-137/kg.

### 5.9.10. Eggs

The activity contents in eggs were estimated from the measurements of a sample collected in September in Copenhagen. The levels were 2 pCi Sr-90/kg and 4 pCi Cs-137/kg.

### 5.9.11. Coffee and Tea

The levels, measured in 1969, were used, i.e. 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. 0.03 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 1971. The figures should be compared with the levels calculated from the total-diet samples (cf. 5.7). The Sr-90 estimates obtained by the two methods were 7.9 S.U. and 7.5 S.U. respectively, and the Cs-137 estimates were 38 pCi Cs-137/day and 33 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. 44% in 1970 to 40% in 1971, whereas that from grain products increased from 31 to 34%. The contribution from potatoes, other vegetables and fruit was 20%, i.e. nearly the same as in 1970. The relative contribution of Cs-137 in the total diet changed as follows from 1970 to 1971: Milk products decreased from 20 to 17%, grain products increased from 26 to 32%, and meat from 28 to 32%.

Table 5.9.3

Estimate of the mean content of Sr-90 in the human diet in Denmark in 1971

| 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 | 28.8 |
| Cheese | 9.1 | 61 | 555 | 11.4 |
| Grain products | 80.3 | 20.9 | 1676 | 34.3 |
| Potatoes | 73.0 | 3.5 | 256 | 5.2 |
| Vegetables | 43.8 | 11 | 482 | 9.8 |
| Fruit | 51.1 | 4.7 | 240 | 4.9 |
| Meat | 54.7 | 1.3 | 71 | 1.5 |
| Eggs | 10.9 | 2 | 22 | 0.5 |
| Fish | 10.9 | 1.4 | 15 | 0.3 |
| Coffee and tea | 5.5 | 27 | 148 | 3.0 |
| Drinking water | 548 | 0.03 | 16 | 0.3 |
| Total | | | 4891 | |
| The mean calcium intake was estimated at 820 g (approx. 200-250 g Creta praeparata). Hence the Sr-90/Ca ratio in the total diet was 7.9 S.U. in 1971 | | | | |

Table 5.9.4

Estimate of the mean content of Cs-137 in the human diet in Denmark in 1971

| 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 | 14 | 2296 | 16.4 |
| Cheese | 9.2 | 10 | 91 | 0.6 |
| Grain products | 80.3 | 55 | 4431 | 31.5 |
| Potatoes | 73.0 | 10.8 | 788 | 5.6 |
| Vegetables | 43.8 | 1.6 | 70 | 0.5 |
| Fruit | 51.1 | 5.9 | 301 | 2.1 |
| Meat | 54.7 | 81 | 4431 | 31.6 |
| Eggs | 10.9 | 4 | 44 | 0.3 |
| Fish | 10.9 | 61 | 665 | 4.7 |
| Coffee and tea | 5.5 | 168 | 924 | 6.6 |
| Drinking water | 548 | 0 | 0 | 0 |
| Total | | | 14041 | |

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 1971 was 38 pCi Cs-137 per capita.

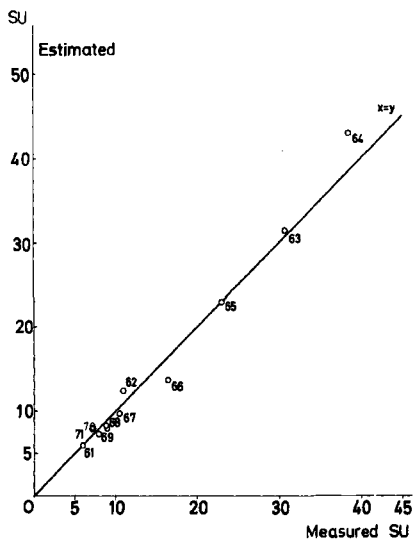



Fig. 5.9.1. A comparison between estimated (cf. 5.9) and measured (cf. 5.7) Sr-90 levels in total Danish diet, 1963-71



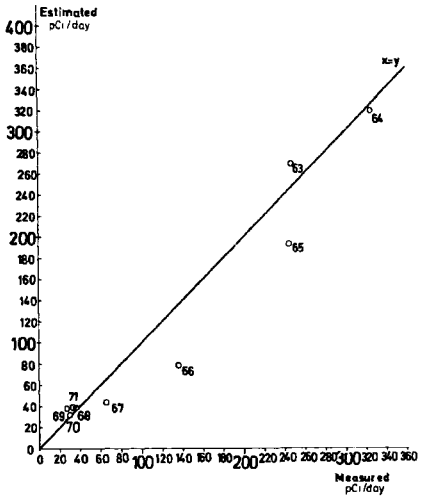



Fig. 5.9.2. A comparison between estimated (cf. 5.9) and measured (cf. 5.7) Cs-137 levels in total Danish diet, 1963-71

## 6. STRONTIUM-90 AND CAESIUM-137 IN MAN IN 1971

### 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 1971. 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 ( $\langle$ 1 month), infants (1 month - 4 years), children and teen-agers (5 - 19 years), adults ( $\leq$ 29 years) and adults ( $\rangle$ 29 years).

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

The levels were higher in 1971 than in 1970 for all age groups. The highest levels in vertebrae were found in the infant and children groups, the lowest among new-born (cf. fig. 6.1). Adults between 20 and 29 years showed as previously higher levels than adults of more than 29 years.

As in the previous years[1], the mean OR: S. U. (new borns' bone)/S. U. (mothers' diet during pregnancy) was calculated from tables 6.1.1, 5.7.1 and 5.7.2 and Risø Report No. 245, tables 5.7.1 and 5.7.2[1]. Tables 6.1.7 shows the result compared with the OR values from previous years.

Table 6.1.1

Sr-90 in bone from new-born children ( <1 month old) in 1971

| Zone | Age in days | Month of death | Sex | pCi Sr-90/g Ca | Sample no. |
|---|---|---|---|---|---|
| II | 15 | 5 | F | 1.20 | MK 87 |
| II | 10 | 3 | F | 1.11 | MK 51 |
| II | 5 | 3 | M | 1.42 | MK 55 |
| II | 5 | 3 | F | 0.82 | MK 57 |
| II | 10 | 4 | M | 1.08 | MK 64 |

Table 6.1.2

Sr-90 in bone from infants ( <4 years old) in 1971

| Zone | Age in years and months | Month of death | Sex | pCi Sr-90/g Ca | Sample no. |
|---|---|---|---|---|---|
| I | 6 m | 10 | M | 2.89 | MK 154 |
| I | 4.5 m | 3 | F | 1.91 | MK 49 |
| I | 4 y | 3 | F | 1.59 | MK 59 |
| II | 3 y | 5 | M | 3.33 | MK 97 |
| II | 1 y | 10 | F | 4.46 | MK 146 |
| II | 4 y | 10 | M | 2.34 | MK 149 |
| II | 4 y | 10 | M | 2.09 | MK 150 |
| II | 5 m | 9 | F | 3.28 | MK 151 |
| II | 2 y | 10 | M | 2.86 | MK 152 |
| II | 4 y | 11 | M | 2.42 | MK 161 |
| II | 1.5 m | 6 | M | 1.80 | MK 92 |
| II | 4.5 m | 3 | M | 1.54 | MK 47 |
| II | 3.5 m | 3 | F | 1.29 | MK 60 |
| III | 4 y | 4 | M | 1.71 | MK 69 |
| III | 11.5 m | 4 | F | 1.47 | MK 70 |
| III | 1 m | 4 | F | 1.22 | MK 85 |
| IV | 4 m | 6 | M | 2.16 | MK 91 |
| VI | 4 y | 9 | F | 1.87 | MK 128 |
| VI | 3 m | 1 | F | 2.58 | MK 39 |
| VI | 1 m | 11 | M | 4.10 | MK 196 |
| VI | 2 y | 6 | F | 3.70 | MK 105 |
| VI | 2 m | 9 | M | 2.70 | MK 140 |
| VI | 10 m | 11 | F | 4.78 | MK 190 |
| VI | 4 m | 12 | M | 6.15 | MK 198 |



Table 6.1.3

Sr-90 in bone from children and teen-agers (<19 years) in 1971

| Zone | Age in years | Month of death | Sex | pCi Sr-90/g Ca | Sample no. |
|---|---|---|---|---|---|
| I | 6 | 3 | M | 2.37 | MK 46 |
| I | 6 | 4 | M | 1.65 | MK 48 |
| I | 19 | 3 | M | 1.23 | MK 50 |
| I | 9 | 10 | M | 2.58 | MK 153 |
| I | 18 | 11 | F | 1.01 | MK 170 |
| I | 12 | 5 | M | 1.94 | MK 95 |
| II | 17 | 4 | M | 1.89 | MK 58 |
| II | 16 | 11 | F | 1.65 | MK 179 |
| II | 17 | 4 | M | 1.50 | MK 71 |
| II | 6 | 4 | F | 2.33 | MK 84 |
| II | 16 | 11 | F | 1.90 | MK 183 |
| II | 5 | 3 | M | 1.15 | MK 10 |
| II | 7 | 2 | M | 3.15 | MK 42 |
| II | 11 | 6 | F | 2.25 | MK 90 |
| III | 11 | 5 | M | 3.81 | MK 89 |
| III | 7 | 5 | M | 3.08 | MK 88 |
| III | 18 | 5 | M | 3.11 | MK 96 |
| IV | 19 | 1 | M | 2.56 | MK 23 |
| IV | 15 | 5 | M | 2.75 | MK 94 |
| VI | 16 | 4 | M | 3.19 | MK 72 |
| VI | 15 | 4 | M | 3.22 | MK 73 |
| VI | 17 | 4 | F | 1.30 | MK 75 |
| VI | 17 | 4 | F | 3.05 | MK 76 |
| VI | 17 | 4 | M | 1.90 | MK 81 |
| VI | 17 | 4 | M | 2.73 | MK 82 |
| VI | 19 | 10 | M | 1.22 | MK 118 |
| VI | 17 | 9 | F | 1.17 | MK 123 |
| VI | 16 | 9 | M | 1.53 | MK 124 |
| VI | 17 | 9 | F | 1.43 | MK 125 |
| VI | 17 | 9 | M | 1.69 | MK 126 |
| VI | 15 | 8 | F | 5.63 | MK 136 |
| VI | 11 | 9 | F | 1.36 | MK 138 |
| VI | 17 | 11 | F | 1.23 | MK 186 |
| VI | 17 | 4 | | 1.02 | MK 77 |
| VI | 15 | 1 | M | 1.21 | MK 31 |
| VI | 19 | 1 | M | 1.19 | MK 32 |
| VI | 15 | 5 | M | 3.45 | MK 98 |
| VI | 13 | 5 | M | 2.82 | MK 99 |
| VI | 9 | 5 | F | 3.66 | MK 100 |
| VI | 18 | 5 | M | 2.26 | MK 101 |

Table 6.1.4

Sr-90 in vertebrae from adults (≤29 years) in 1971

| Zone | Age in years | Month of death | Sex | pCi Sr-90/g Ca | Sample no. |
|---|---|---|---|---|---|
| I | 20 | 11 | F | 2.33 | MK 180 |
| II | 23 | 2 | M | 2.97 | MK 36 |
| II | 29 | 10 | F | 1.53 | MK 155 |
| IV | 25 | 1 | M | 2.42 | MK 8 |
| VI | 26 | 9 | F | 1.66 | MK 127 |
| VI | 22 | 9 | F | 1.82 | MK 134 |
| VI | 20 | 8 | M | 1.65 | MK 142 |
| VI | 20 | 10 | F | 1.53 | MK 166 |
| VI | 29 | 11 | M | 1.41 | MK 173 |
| VI | 27 | 1 | F | 2.03 | MK 33 |
| VI | 25 | 2 | F | 1.20 | MK 27 |
| VI | 25 | 2 | M | 1.21 | MK 26 |

Table 6.1.5

Sr-90 in vertebrae from adults (≥ 29 years old) in 1971

| Zone | Age in years | Month of death | Sex | pCi Sr-90/g Ca | Sample no. |
|---|---|---|---|---|---|
| I | 75 | 2 | | 3.48 | MK 44 |
| I | 80 | 2 | M | 1.71 | MK 35 |
| I | 55 | 1 | M | 1.05 | MK 6 |
| I | 49 | 1 | M | 1.33 | MK 7 |
| I | 63 | 1 | F | 1.39 | MK 9 |
| II | 48 | 2 | M | 1.87 | MK 37 |
| II | 38 | 2 | F | 2.38 | MK 38 |
| II | 46 | 2 | M | 1.11 | MK 41 |
| II | 50 | 2 | F | 2.02 | MK 45 |
| II | 62 | | M | 1.53 | MK 157 |
| II | 51 | 11 | M | 1.94 | MK 181 |
| II | 55 | 11 | M | 1.50 | MK 182 |
| II | 62 | 2 | M | 1.25 | MK 24 |
| II | 39 | 2 | F | 1.80 | MK 30 |
| II | 38 | 1 | M | 1.65 | MK 21 |
| II | 44 | 1 | M | 1.37 | MK 22 |
| II | 84 | 2 | F | 1.72 | MK 34 |
| III | 53 | 2 | F | 1.43 | MK 43 |
| III | 39 | 11 | M | 1.44 | MK 184 |
| III | 63 | 1 | F | 1.71 | MK 20 |
| IV | 35 | 1 | M | 1.90 | MK 19 |
| VI | 45 | 2 | M | 1.15 | MK 29 |
| VI | 54 | 1 | M | 1.13 | MK 18 |
| VI | 43 | 2 | | 1.35 | MK 25 |



Table 6.1.6

Sr-90 (pCi/g Ca) in human vertebrae collected in Denmark in 1971

| Age group | Number of samples | Min. | Max. | Median | Mean |
|---|---|---|---|---|---|
| New-born (< 1 month) | 5 | 0.82 | 1.42 | 1.11 | 1.14 |
| Infants (≤ 4 years) | 24 | 1.22 | 6.15 | 2.48 | 2.98 |
| Children (≤ 19 years) | 40 | 1.01 | 5.63 | 1.90 | 2.30 |
| Adults (≤ 29 years) | 12 | 1.20 | 2.97 | 1.66 | 1.81 |
| Adults (> 30 years) | 24 | 1.05 | 3.48 | 1.52 | 1.63 |

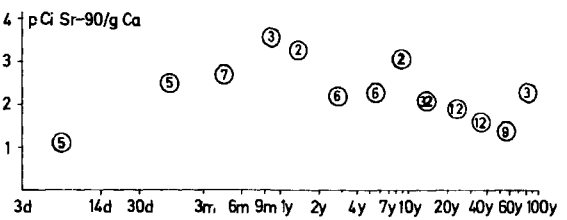



Fig. 6.1. Sr-90 in human vertebrae in 1971 (the figures in the circles indicate the number of samples)

Table 6.1.7

Observed ratios:
OR S.U. new borns' bone/S.U. mothers' diet during pregnancy 1963-1971

| Year | 1963 | 1964 | 1965 | 1966 | 1967 | 1968 | 1969 | 1970 | 1971 | Mean |
|---|---|---|---|---|---|---|---|---|---|---|
| OR | 0.11 | 0.09 | 0.08 | 0.09 | 0.13 | 0.13 | 0.11 | 0.10 | 0.13 | 0.108 |
| SD | 0.04 | 0.02 | 0.03 | 0.03 | 0.06 | 0.05 | 0.05 | 0.03 | 0.03 | 0.019 |
| SE | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.006 |

Table 6.1.8

Sr-90 in vertebrae collected in 1970

| Zone | Age | Month of death | Sex | pCi Sr-90/g Ca | Sample no. |
|---|---|---|---|---|---|
| I | 1 day | 8 | M | 2.39 | MK 61 |
| VI | 13 year | 12 | F | 1.12 | MK 11 |
| VI | 14 - | 11 | M | 1.70 | MK 15 |
| VI | 17 - | 12 | F | 1.48 | MK 13 |
| IV | 34 - | 12 | F | 1.34 | MK 3 |
| II | 38 - | 12 | F | 1.12 | MK 4 |
| I | 44 - | 12 | F | 1.48 | MK 5 |
| IV | 47 - | 12 | M | 2.01 | MK 1 |
| VI | 47 - | 12 | M | 0.75 | MK 14 |
| I | 60 - | 12 | F | 2.91 | MK 2 |

Table 6.2

Whole-body measurements of caesium-137 and potassium in 1971

| No. | Sex | Counting date | Age | Height in cm | Weight in kg | pCi Cs-137/g K | pCi Cs-137/kg | g K/kg body weight |
|---|---|---|---|---|---|---|---|---|
| 1 | F | April | 21 | 160 | 57 | 12.9 | 26.4 | 2.0 |
| 2 | F | - | 23 | 170 | 56 | 14.4 | 28.9 | 2.0 |
| 3 | F | - | 39 | 178 | 66 | 8.6 | 14.3 | 1.7 |
| 4 | F | - | 47 | 161 | 60 | 6.4 | 11.5 | 1.8 |
| 5 | F | - | 27 | 171 | 99 | 6.6 | 8.0 | 1.2 |
| 6 | F | - | 34 | 164 | 66 | 3.9 | 5.2 | 1.3 |
| 7 | F | - | 43 | 171 | 64 | 15.9 | 27.7 | 1.7 |
| 8 | M | - | 39 | 193 | 80 | 15.2 | 28.2 | 1.9 |
| 9 | M | - | 43 | 170 | 66 | 13.8 | 24.9 | 1.8 |
| 10 | F | - | 24 | 164 | 45 | 15.9 | 28.6 | 1.8 |
| 13 | F | - | 39 | 161 | 55 | 11.8 | 21.9 | 1.9 |
| 15 | F | - | 35 | 165 | 54 | 5.6 | 9.4 | 1.7 |
| 16 | M | - | 44 | 184 | 79 | 12.2 | 22.2 | 1.8 |
| 17 | F | - | 31 | 159 | 58 | 10.8 | 18.8 | 1.7 |
| 18 | M | - | 32 | 178 | 78 | 6.4 | 14.3 | 2.2 |
| 19 | M | - | 29 | 174 | 75 | 14.3 | 29.3 | 2.1 |
| 20 | M | - | 39 | 172 | 64 | 11.6 | 23.8 | 2.1 |
| 21 | F | - | 50 | 176 | 64 | 9.6 | 16.3 | 1.7 |
| 22 | M | - | 48 | 183 | 75 | 16.5 | 37.4 | 2.3 |
| 23 | M | - | 41 | 192 | 89 | 20.2 | 43.1 | 2.1 |
| 24 | M | - | 40 | 170 | 78 | 10.8 | 22.0 | 2.0 |
| 25 | F | - | 29 | 167 | 58 | 11.0 | 18.8 | 1.7 |
| 26 | F | - | 32 | 160 | 55 | 14.7 | 27.0 | 1.8 |
| 1 | F | July | 21 | 160 | 57 | 9.8 | 17.9 | 1.8 |
| 2 | F | - | 23 | 170 | 56 | 27.6 | 54.2 | 2.0 |
| 4 | F | - | 47 | 161 | 60 | 5.2 | 10.9 | 2.1 |
| 5 | F | - | 27 | 171 | 99 | 4.3 | 5.7 | 1.3 |



| No. | Sex | Counting date | Age | Height in cm | Weight in kg | pCi Cs-137/g K | pCi Cs-137/kg | g K/kg body weight |
|---|---|---|---|---|---|---|---|---|
| 6 | F | - | 34 | 164 | 66 | 5.7 | 8.3 | 1.5 |
| 7 | F | - | 43 | 171 | 64 | 12.1 | 19.7 | 1.6 |
| 8 | M | - | 39 | 193 | 80 | 25.? | 28.9 | 1.1 |
| 10 | F | - | 24 | 164 | 45 | 11.1 | 24.1 | 2.2 |
| 11 | F | - | 32 | 180 | 74 | 11.5 | 20.0 | 1.7 |
| 12 | M | - | 33 | 174 | 72 | 11.1 | 24.0 | 2.2 |
| 13 | F | - | 39 | 161 | 55 | 11.8 | 20.9 | 1.8 |
| 15 | F | - | 35 | 165 | 54 | 6.3 | 10.2 | 1.6 |
| 18 | M | - | 32 | 178 | 78 | 10.1 | 20.0 | 2.0 |
| 19 | M | - | 29 | 174 | 75 | 11.8 | 24.7 | 2.1 |
| 20 | M | - | 39 | 172 | 64 | 15.4 | 32.4 | 2.1 |
| 23 | M | - | 41 | 192 | 89 | 21.6 | 42.6 | 2.0 |
| 24 | M | - | 40 | 170 | 78 | 8.8 | 16.6 | 1.9 |
| 26 | F | - | 32 | 160 | 55 | 11.7 | 20.0 | 1.7 |
| 90 | M | - | 50 | 185 | 101 | 24.6 | 38.3 | 1.6 |
| 91 | M | - | 46 | 174 | 87 | 7.5 | 12.0 | 1.6 |
| 92 | M | - | 32 | 180 | 80 | 11.8 | 26.9 | 2.3 |
| 93 | F | - | 31 | 159 | 58 | 8.3 | 14.9 | 1.8 |
| 2 | F | Dec. | 23 | 170 | 61 | 12.5 | 23.0 | 1.8 |
| 3 | F | - | 39 | 178 | 66 | 3.2 | 5.2 | 1.6 |
| 4 | F | - | 47 | 161 | 60 | 12.7 | 20.9 | 1.6 |
| 5 | F | - | 27 | 171 | 99 | 8.3 | 11.3 | 1.4 |
| 6 | F | - | 34 | 164 | 59 | 4.0 | 6.5 | 1.6 |
| 7 | F | - | 43 | 171 | 64 | 20.2 | 29.9 | 1.5 |
| 8 | M | - | 39 | 193 | 80 | 21.2 | 38.8 | 1.8 |
| 9 | M | - | 43 | 170 | 66 | 8.3 | 14.3 | 1.7 |
| 10 | F | - | 24 | 164 | 46 | 15.3 | 29.6 | 1.9 |
| 11 | F | - | 32 | 180 | 71 | 12.1 | 21.7 | 1.8 |
| 12 | M | - | 33 | 174 | 72 | 17.3 | 34.1 | 2.0 |
| 13 | F | - | 39 | 161 | 56 | 12.1 | 20.6 | 1.7 |
| 18 | M | - | 32 | 178 | 76 | 8.6 | 16.6 | 1.9 |
| 19 | M | - | 29 | 174 | 73 | 15.3 | 31.2 | 2.0 |
| 20 | M | - | 39 | 172 | 66 | 17.8 | 35.1 | 2.0 |
| 21 | F | - | 50 | 176 | 65 | 8.6 | 13.0 | 1.5 |
| 22 | M | - | 48 | 183 | 76 | 15.8 | 37.8 | 2.4 |
| 24 | M | - | 40 | 170 | 71 | 11.8 | 23.7 | 2.0 |
| 25 | F | - | 29 | 167 | 57 | 4.8 | 7.6 | 1.6 |
| 26 | F | - | 32 | 160 | 56 | 11.4 | 23.5 | 2.1 |
| 30 | M | - | 25 | 168 | 58 | 19.1 | 39.2 | 2.1 |
| 31 | M | - | 29 | 182 | 78 | 24.0 | 41.5 | 1.7 |
| 32 | F | - | 42 | 157 | 64 | 10.3 | 16.5 | 1.6 |
| 33 | M | - | 40 | 184 | 63 | 23.2 | 48.5 | 2.1 |
| 36 | F | - | 25 | 158 | 45 | 5.5 | 10.5 | 1.9 |
| 91 | M | - | 46 | 174 | 86 | 19.3 | 37.0 | 1.9 |
| 92 | M | - | 32 | 180 | 80 | 19.1 | 43.0 | 2.3 |

## 6.2. Cs-137 in the Human Body

In July 1963, whole-body measurements were initiated at Risø in the low-level counting room in the Health Physics Department (cf. 2.3 in Risø 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 annual mean value of the control group was 13 pCi Cs-137/g K. As earlier, we shall consider this figure representative of the mean of the Danish population in 1971. The total-body content of Cs-137 in 1970 for a standard man containing 140 g of potassium equals $140 \cdot 13 \cdot 10^{-3}$ nCi = 1.8 nCi Cs-137, i.e. approx. 60% of the 1970 level.

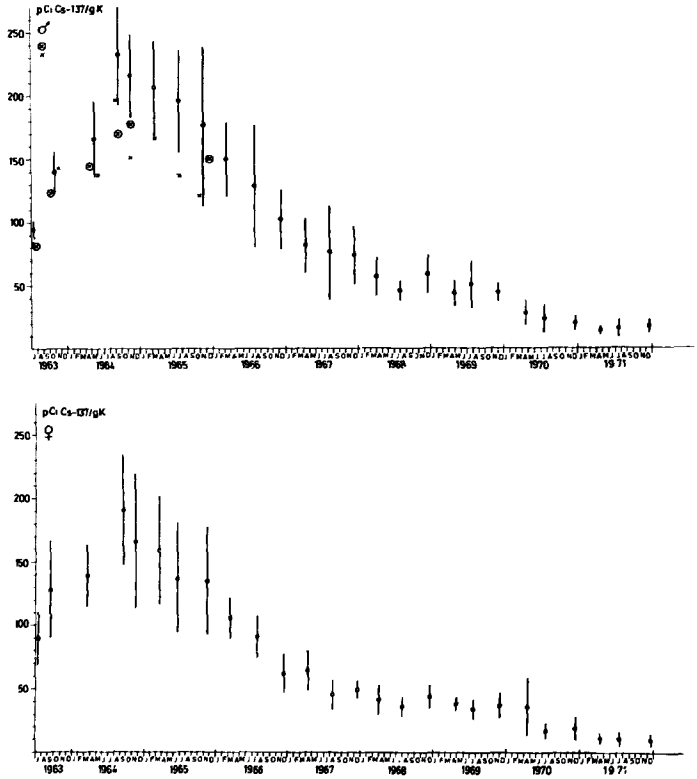



Fig. 6.2. Cs-137 mean levels in humans, 1963-71 (1 S.D. indicated)



The decrease from 1970 to 1971 is of the same order as from 1969 to 1970. As discussed in the 1970 report (Risø Report No. 245[1]) we suspect the figures from 1969 (and 1968) to be too high. We have, however, not finished the recalibration of our whole-body counter, and the results since 1968 are thus still subject to a possible revision.

Fig. 6.2 shows the mean M.U. values (with one S.D.) for men and women measured in 1963-1971.

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 (cf. also Appendix C).

## 7. STRONTIUM-90 IN SEA WATER IN 1971

The collection of sea-water samples initiated in 1961-62 was continued in 1971. The samples were collected by "Fyrholm" in June and December around Zealand at the same locations as in 1970.

Fig. 7.1 shows the mean content of Sr-90 in sea water collected since November-December 1962 in inner Danish waters (cf. also fig. 5.8.2). The levels have been rather constant in recent years.

Table 7.1.2 shows the Sr-90 levels in sea-water samples collected in Øresund at Barsebäck, where a Swedish nuclear power plant is under construction.

Table 7.1.1

Sr-90 in sea water collected around Zealand in June and December 1971

| | Position | | June | | | December | | |
|---|---|---|---|---|---|---|---|---|
| | N | E | depth in m | pCi/l | Salinity o/oo | depth in m | pCi/l | Salinity o/oo |
| Kullen | 56°15' | 12°25' | | | | 0 | 0.57 | 24.7 |
| " | | | | | | bottom | 0.53 | 28.1 |
| Hesselø | 56°10' | 11°47' | 0 | 0.74 | 18.5 | 0 | 0.50 | 17.4 |
| " | | | 27 | 0.29 | 33.2 | bottom | 0.51 | 29.3 |
| Kattegat SW | 56°07' | 11°10' | | | | 0 | 0.62 | 20.8 |
| " | | | | | | bottom | 0.75 | 26.5 |
| Anholt rev | 56°38' | 11°47' | 1 | 0.75 | 24.0 | 0 | 0.69 | 21.9 |
| " " | | | 40 | 0.27 | 31.9 | bottom | 0.44 | 28.1 |
| Halskov rev | 55°20' | 11°02' | | | | 0 | 0.43 | 18.8 |
| " " | | | | | | bottom | 0.78 | 21.2 |
| Langeland bælt | 54°52' | 10°50' | 1 | 0.80 | 13.8 | 0 | 0.49 | 19.8 |
| " " | | | 45 | 0.42 | 28.8 | bottom | 0.76 | 19.8 |
| Dragør | 55°35' | 12°44' | 0 | 0.69 | 18.5 | | | |
| " | | | 0 | 0.76 | 8.2 | | | |
| Gedser rev | 54°28' | 12°13' | 1 | 0.73 | 13.2 | | | |
| " " | | | 20 | 0.72 | 14.4 | | | |
| Stevns | 55°16' | 12°34' | 0 | 0.79 | 7.9 | | | |
| " | | | 22 | 0.60 | 17.4 | | | |
| The Sound - South | 55°25' | 12°39' | | | | 0 | 0.43 | 9.2 |
| " " " | | | | | | bottom | 0.48 | 10.8 |
| The Sound - North A | 55°48' | 12°44' | | | | 0 | 0.57 | 20.0 |
| " " " | | | | | | bottom | 0.26 | 21.2 |
| The Sound - North B | 55°59' | 12°42' | 0 | 0.73 | 12.6 | 0 | 0.48 | 15.5 |
| " " " | | | 27 | 0.25 | 32.6 | bottom | 0.40 | 24.6 |
| Møns klint | 54°57' | 12°41' | | | | 0 | 0.42 | 9.1 |
| " " | | | | | | bottom | 0.68 | 14.4 |
| Mean | | | surface | 0.73 | 13.4 | surface | 0.52 | 17.7 |
| SD | | | | 0.05 | 4.0 | | 0.09 | 5.1 |
| SE | | | | 0.02 | 1.4 | | 0.03 | 1.6 |
| Mean | | | bottom | 0.42 | 26.4 | bottom | 0.52 | 21.8 |
| SD | | | | 0.20 | 8.3 | | 0.17 | 5.9 |
| SE | | | | 0.08 | 3.4 | | 0.05 | 1.9 |



Table 7.1.2

Sr-90 in sea water collected at Barcebäck in June 1971

| Position | | depth in m | pCi/l | Salinity o/oo |
|---|---|---|---|---|
| N | E | | | |
| 55°43' | 12°54' | 0 | 0.80 | 7.9 |
| 55°43' | 12°54' | 15 | 0.80 | 9.8 |
| 55°43' | 12°54' | 14 | 0.37 | 30.6 |
| 55°43' | 12°54' | 0 | 0.81 | 8.2 |
| 55°48' | 12°52' | 15.5 | 0.84 | 10.6 |
| 55°48' | 12°52' | 16 | 0.32 | 31.6 |
| 55°48' | 12°52' | 0 | 0.81 | 9.0 |
| Mean | | surface | 0.81 | 8.4 |
| SD | | | 0.01 | 0.6 |
| SE | | | 0.00 | 0.3 |
| Mean | | bottom | 0.58 | 20.7 |
| SD | | | 0.28 | 12.1 |
| SE | | | 0.14 | 6.0 |

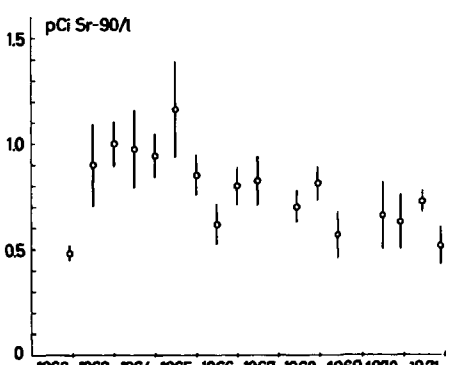



Fig. 7.1. Sr-90 in sea water from inner Danish waters, 1962-71 (1 S.D. indicated)

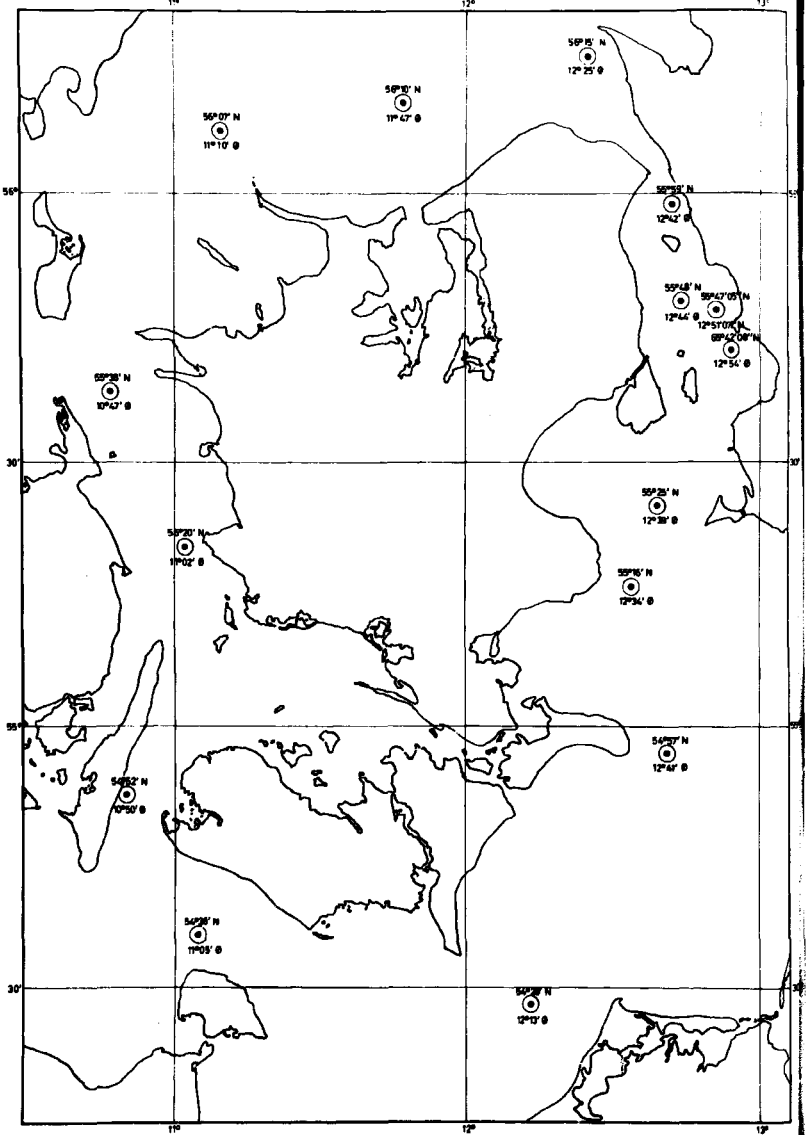


Fig. 7.2. Sea water locations around Zealand

## 8. SPECIAL SURVEYS

### 8.1. Meteorological Mast Experiment

As in the previous years, samples of precipitation were collected from the meteorological mast at Risø at eight different heights. The Sr-90 analyses were, however, carried out on quarterly and not as previously on monthly samples (cf. fig. 3.1.2.2).

Table 8.1.1 shows the Sr-90 levels in the eight bottles throughout the year. An analysis of variance of the natural logarithm of the pCi Sr-90/l and the mCi Sr-90/km$^2$ figures showed as previously that the variations between months were highly significant (P $>$ 99.95%). The variations between the different locations were significant (P $>$ 99.5%) in the case of pCi/l, but not for mCi/km$^2$. The monthly mean evaporation of the year was measured at 7 and 123 m. We found 12.6 $\pm$ 2.5% and 9.0 $\pm$ 1.4% respectively, i.e. the evaporation was not higher at the top of the mast than at bottom (cf. also Risø Reports Nos. 107, 130, and 154[1]).

The mean amount of precipitation in the eight bottles on the mast was 475 mm in 1971, i.e. as in 1970 approx. 90% of the level measured in rain bottles at ground level at Risø (cf. table 3.2.4.1). The total deposition was 1.07 mCi Sr-90/km$^2$, i.e. 10% higher than the level measured at the ground stations at Risø (cf. 3.2.4).

Table 8.1.1

Sr-90 in the meteorological mast 1971

| | 9 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. | | | | | | | | |
| Feb. | 1.01 | 0.109 | 1.10 | 0.133 | 1.46 | 0.194 | 1.58 | 0.236 |
| Mar. | | | | | | | | |
| Apr. | | | | | | | | |
| May | 3.20 | 0.432 | 3.91 | 0.516 | 4.61 | 0.622 | 3.83 | 0.536 |
| June | | | | | | | | |
| July | | | | | | | | |
| Aug. | 2.38 | 0.271 | 2.32 | 0.281 | 2.58 | 0.307 | 2.84 | 0.307 |
| Sep. | | | | | | | | |
| Oct. | | | | | | | | |
| Nov. | 0.58 | 0.084 | 0.58 | 0.08 | 0.70 | 0.094 | 0.70 | 0.077 |
| Dec. | | | | | | | | |
| 1971 | $\bar{x}$ 1.79 | Σ 0.896 | $\bar{x}$ 2.03 | Σ 0.998 | $\bar{x}$ 2.34 | Σ 1.217 | $\bar{x}$ 2.28 | Σ 1.156 |
| | 501 mm | | 491 mm | | 521 mm | | 507 mm | |

| 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$^2$ |
| 1.35 | 0.168 | 1.86 | 0.242 | 1.91 | 0.210 | 1.97 | 0.132 | 1.53 | 0.178 |
| 4.11 | 0.510 | 3.81 | 0.511 | 4.62 | 0.531 | 3.54 | 0.432 | 3.95 | 0.511 |
| 2.69 | 0.312 | 3.07 | 0.325 | 2.95 | 0.298 | 3.50 | 0.281 | 2.77 | 0.298 |
| 0.74 | 0.085 | 0.69 | 0.083 | 0.67 | 0.072 | 0.96 | 0.100 | 0.70 | 0.083 |
| $\bar{x}$ 2.25 | Σ 1.075 | $\bar{x}$ 2.37 | Σ 1.161 | $\bar{x}$ 2.57 | Σ 1.111 | $\bar{x}$ 2.50 | Σ 0.945 | $\bar{x}$ 2.25 | Σ 1.070 |
| 478 mm | | 490 mm | | 433 mm | | 378 mm | | 475 mm | |



## 8.2. Fission Product Ratios in Air Samples Collected in the Meteorological Mast in 1972

Air samplers of the injector type have been installed in the meteorological mast at the same altitudes as the rain bottles. Each sampler was equipped with an 8 cm glass-fibre filter which was changed every Monday. The thirteen filters from three months were combined to a quarterly sample from each height. The total amount of air in a sample was approx. 7500 m$^3$. The samples were counted on a Ge(Li) detector for 24 hours. Sr-90 (and Sr-89) were also determined.

Tables 8.2.1 - 8.2.7 show isotope ratios determined at the different heights. Analysis of variance were carried out on the ratios. We found no indication of any variation in the ratios with altitude.

Table 8.2.1

Ce141/Ce144 in air filters collected quarterly at 8 different heights in the meteorological mast at Risø in 1971

| | Jan.-Mar. | Apr.-June | July-Sep. | Oct.-Dec. |
|---|---|---|---|---|
| 0 m | 0.35 | 0.11 | - | 0.21 |
| 7 m | 0.12 | 0.09 | - | - |
| 23 m | 0.39 | 0.11 | - | 0.36 |
| 39 m | 0.32 | 0.10 | - | 0.23 |
| 56 m | 0.34 | 0.14 | - | - |
| 72 m | 0.34 | 0.10 | - | - |
| 96 m | 0.36 | 0.11 | - | - |
| 123 m | 0.32 | 0.10 | - | 0.62 |
| $\bar{x}$ | 0.32 | 0.11 | - | 0.33 |
| η | 0.26 | 0.14 | - | 0.65 |

Table 8.2.2

Zr95/Ce144 in air filters collected quarterly at 8 different heights in the meteorological mast at Risø in 1971

| | Jan.-Mar. | Apr.-June | July-Sep. | Oct.-Dec. |
|---|---|---|---|---|
| 0 m | 0.72 | 0.75 | 0.42 | 0.31 |
| 7 m | 0.72 | 0.77 | 0.40 | 0.45 |
| 23 m | 0.66 | 0.75 | 0.41 | 0.19 |
| 39 m | 0.69 | 0.75 | 0.43 | 0.42 |
| 56 m | 0.69 | 0.81 | 0.42 | 0.36 |
| 72 m | 0.65 | 0.80 | 0.38 | 0.20 |
| 96 m | 0.73 | 0.77 | 0.30 | - |
| 123 m | 0.49 | 0.72 | 0.45 | 0.36 |
| $\bar{x}$ | 0.67 | 0.77 | 0.40 | 0.33 |
| $\eta$ | 0.12 | 0.04 | 0.11 | 0.31 |

Table 8.2.3

Zr95/Cs137 in air filters collected quarterly at 8 different heights in the meteorological mast at Risø in 1971

| | Jan.-Mar. | Apr.-June | July-Sep. | Oct.-Dec. |
|---|---|---|---|---|
| 0 m | 7.34 | 8.80 | 5.42 | 2.02 |
| 7 m | 12.75 | 11.46 | 4.51 | 12.77 |
| 23 m | 10.73 | 10.68 | 4.35 | 1.30 |
| 39 m | 8.42 | 10.37 | 5.28 | 4.44 |
| 56 m | 9.04 | 9.82 | 4.63 | 3.63 |
| 72 m | 6.44 | 10.10 | 5.10 | 1.83 |
| 96 m | 9.61 | 9.46 | 3.59 | - |
| 123 m | 4.65 | 9.31 | 5.32 | 3.09 |
| $\bar{x}$ | 8.62 | 10.00 | 4.78 | 4.15 |
| $\eta$ | 0.29 | 0.08 | 0.13 | 0.95 |



Table 8.2.4

Ru106/Zr95 in air filters collected quarterly at 8 different heights in the meteorological mast at Risø in 1971

| | Jan.-Mar. | Apr.-June | July-Sep. | Oct.-Dec. |
|---|---|---|---|---|
| 0 m | 0.76 | 0.62 | 1.52 | 5.28 |
| 7 m | 0.56 | 0.65 | 1.42 | 2.30 |
| 23 m | 0.76 | 0.55 | 1.39 | 6.00 |
| 39 m | 0.61 | 0.64 | 1.25 | 2.23 |
| 56 m | 0.64 | 0.59 | 1.20 | 2.43 |
| 72 m | 0.73 | 0.56 | 1.26 | 1.42 |
| 96 m | 0.80 | 0.67 | 2.18 | - |
| 123 m | 0.27 | 0.58 | 1.48 | 3.65 |
| $\bar{x}$ | 0.64 | 0.61 | 1.46 | 3.91 |
| $\eta$ | 0.27 | 0.07 | 0.21 | 0.52 |

Table 8.2.5

Ru103/Ru106 in air filters collected quarterly at 8 different heights in the meteorological mast at Risø in 1971

| | Jan.-Mar. | Apr.-June | July-Sep. | Oct.-Dec. |
|---|---|---|---|---|
| 0 m | 0.79 | 0.65 | - | 0.26 |
| 7 m | 1.14 | 0.65 | 0.23 | - |
| 23 m | 0.69 | 0.62 | 0.16 | 0.50 |
| 39 m | 0.85 | 0.62 | - | 0.26 |
| 56 m | 0.90 | 0.64 | 0.26 | 0.24 |
| 72 m | 0.80 | 0.60 | - | - |
| 96 m | 0.64 | 0.59 | 0.12 | 0.38 |
| 123 m | 1.62 | 0.66 | 0.09 | 0.24 |
| $\bar{x}$ | 0.93 | 0.63 | 0.17 | 0.31 |
| $\eta$ | 0.34 | 0.04 | 0.42 | 0.34 |

Table 8.2.6

Cs137/Sr90 in air filters collected quarterly at 8 different heights in the meteorological mast at Risø in 1971

| | Jan.-Mar. | Apr.-June | July-Sep. | Oct.-Dec. |
|---|---|---|---|---|
| 0 m | 2.02 | 1.92 | 1.26 | 2.02 |
| 7 m | 1.24 | 1.49 | 1.41 | 0.43 |
| 23 m | 1.51 | 1.68 | 1.65 | 1.61 |
| 39 m | 1.94 | 1.64 | 1.56 | 1.41 |
| 56 m | 1.49 | 1.50 | 2.02 | 1.13 |
| 72 m | 2.09 | 1.62 | 1.62 | 1.04 |
| 96 m | 1.50 | 1.67 | 1.46 | - |
| 123 m | 2.54 | 1.57 | 1.38 | 1.05 |
| $\bar{x}$ | 1.79 | 1.64 | 1.55 | 1.24 |
| $\eta$ | 0.24 | 0.08 | 0.15 | 0.41 |

Table 8.2.7

Sr89/Sr90 in air filters collected quarterly at 8 different heights in the meteorological mast at Risø in 1971

| | Jan.-Mar. | Apr.-June | July-Sep. | Oct.-Dec. |
|---|---|---|---|---|
| 0 m | 8.0 | 3.68 | - | - |
| 7 m | 10.1 | 3.94 | - | - |
| 23 m | 11.6 | 3.79 | - | - |
| 39 m | 10.1 | 0.89 | - | - |
| 56 m | 5.0 | - | - | - |
| 72 m | 2.0 | 4.37 | - | - |
| 96 m | 4.0 | 2.87 | - | - |
| 123 m | 2.8 | 4.19 | - | - |
| $\bar{x}$ | 6.7 | 3.39 | - | - |
| $\eta$ | 0.55 | 0.35 | - | - |



## 8.3. Human Milk

No human milk samples were collected in 1971.

## 8.4. Country-wide Measurement of the γ-Background in 1971

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

As the accumulated fall-out levels have been rather constant since 1966, we have no reason to expect a significant decrease in the γ-background levels since that year. In the period 1966-69 the mean background for the ten state experimental farms was $6.33 \pm 0.17$ μR/h, but in 1970 we found 5.4 and in 1971 4.5 μR/h. We ascribe these low mean levels to a decreasing sensitivity of our scintillation crystal for γ-energies, for which we cannot compensate when we calibrate it with a Ra-226 source. We have therefore corrected our 1970 (Risø Report No. 245[1]) and 1971 results by multiplication by factors of 1.17 and 1.40 respectively.

Table 8.4.1.1

γ-background at the state experimental farms in 1971 (μR/h)
(Correction factor 1.40 has been applied to all data)

| | Mar. | June | Sep. | Dec. | Mean |
|---|---|---|---|---|---|
| Tylstrup | 4.9 | 5.3 | 5.7 | 5.2 | 5.3 |
| Studsgård | 5.0 | 4.3 | 4.3 | 4.2 | 4.4 |
| Ødum | 6.3 | 7.7 | 6.3 | 7.0 | 6.8 |
| Askov | 6.2 | 6.2 | 5.9 | 5.7 | 6.0 |
| St. Jyndevad | 4.3 | 4.2 | 4.3 | 4.2 | 4.2 |
| Blangstedgård | 6.7 | 7.4 | 6.2 | 6.6 | 6.7 |
| Tystofte | 7.1 | 7.0 | 7.1 | 8.3 | 7.4 |
| Virumgård | 6.4 | 7.4 | 7.0 | 7.4 | 7.0 |
| Abed | 7.0 | 6.7 | 5.6 | 5.7 | 6.2 |
| Åkirkeby | (9.0) | 8.7 | 9.5 | 8.8 | 9.0 |
| Mean | 6.3 | 6.5 | 6.2 | 6.3 | 6.3 |

Table 8.4.1.2

Analysis of variance of the γ-background at the state experimental farms in 1971 (from table 8.4.1.1)

| Variation | SSD | f | $s^2$ | $v^2$ | F |
|---|---|---|---|---|---|
| Between locations | 1.3837 | 9 | 0.2113 | 31.42 | >99.99% |
| Between months | 0.0127 | 3 | 0.0038 | 0.65 | - |
| Remainder | 0.1579 | 27 | 0.0058 | | |

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 Risø Report No. 154[1].

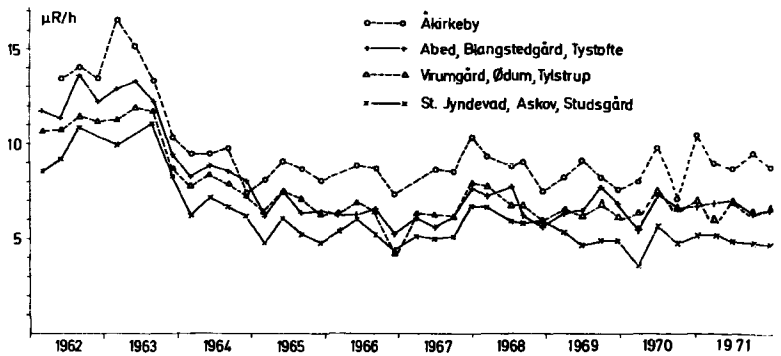



Fig. 8.4. The γ-background at the State experimental farms, 1962-71

## 8.4.2. The Risø Environment

γ-background measurements were performed in the five zones round Risø in July. 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. shows the results.



Table 8.4.2

γ-background (µR/h) in the five zones around Risø in 1971 (Correction factor 1.40 has been applied to all data)

| Risø zone (cf. coloured map) | Location | July |
|---|---|---|
| I | 1 | 7.4 |
| - | 2 | 8.3 |
| - | 3 | 7.0 |
| - | 4 | 10.9 |
| - | 5 | 10.5 |
| Mean | | 8.8 |
| II | 1 | 6.6 |
| - | 2 | 9.7 |
| - | 3 | 7.0 |
| - | 4 | 7.8 |
| Mean | | 7.6 |
| III | 1 | 7.3 |
| - | 2 | 7.8 |
| - | 3 | 7.4 |
| - | 4 | 7.4 |
| Mean | | 7.5 |
| IV | 1 | 7.0 |
| - | 2 | 7.8 |
| - | 3 | 7.4 |
| - | 4 | 7.4 |
| - | 5 | 6.6 |
| - | 6 | 6.6 |
| - | 7 | 7.4 |
| - | 8 | 7.8 |
| Mean | | 7.2 |
| V | 1 | 6.2 |
| - | 2 | 7.4 |
| - | 3 | 5.3 |
| - | 4 | 6.6 |
| - | 5 | 7.8 |
| - | 6 | 7.4 |
| - | 7 | 7.4 |
| - | 8 | 7.8 |
| - | 9 | 7.8 |
| - | 10 | 6.6 |
| - | 11 | 7.4 |
| - | 12 | 7.0 |
| Mean | | 7.1 |

Table 8.4.3

γ-background (µR/h) around a location in Greenland in 1971 (Correction factor 1.40 has been applied to all data)

| Zone and sector | July |
|---|---|
| A 2 | 7.4 |
| A 3 | 6.4 |
| A 4 | 8.8 |
| A 5 | 7.4 |
| A 6 | 7.0 |
| A 7 | 7.0 |
| A 8 | 7.4 |
| A 9 | 7.4 |
| Mean | 6.6 |
| B 1 | 7.0 |
| B 2 | 7.4 |
| B 3 | 7.0 |
| B 4 | 8.2 |
| B 5 | 7.4 |
| B 6 | 7.4 |
| B 7 | 7.4 |
| B 8 | 7.8 |
| B 9 | 7.4 |
| B 10 | 6.6 |
| Mean | 7.0 |
| C 1 | 5.7 |
| C 2 | 5.3 |
| C 3 | 6.2 |
| C 4 | 7.0 |
| C 5 | 7.8 |
| C 6 | 7.4 |
| C 7 | 7.4 |
| C 8 | 7.0 |
| C 9 | 6.6 |
| C 10 | 7.8 |
| C 11 | 7.0 |
| C 12 | 5.7 |
| Mean | 6.9 |
| D 1 | 9.2 |
| D 2 | 7.8 |
| D 3 | 5.7 |
| D 4 | 7.0 |
| D 5 | 7.4 |
| D 6 | 7.8 |
| D 7 | 6.6 |
| D 8 | 8.2 |
| D 9 | 6.6 |
| D 10 | 7.4 |
| D 11 | 6.6 |
| D 12 | 4.8 |
| Mean | 7.0 |

In all locations in zone I and in location 2 in zone II the γ-background was increased because of the various radiation sources at the research establishment. The weighted annual mean for zones III-V was 7.2 μR/h, i.e. equal to the (corrected) 1970 level. In zone I the surplus activity from the research establishment was 8.8 - 7.2 = 1.6 μR/h (in 1967: 4.0, in 1968: 3.9, and in 1969: 3.3). A man working in the open in the Risø area 40 hours a week for 45 weeks a year would thus get a surplus dose of 3 mR/year.

### 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 $30^{o}$ sectors, sector 1 being from straight north and $30^{o}$ clockwise, sector 2 from 30 to $60^{o}$ 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 6.8 μR/h, i.e. nearly equal to the level found in zone III-V around Risø, and to the levels in previous years.

### 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 6.0 μR/h, i.e. lower than levels of Zealand (cf. 8.4.2 and 8.4.3), and lower than in 1967-70.

### 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. shows the results. The levels were a little lower than those found in most of the other parts of the country. The annual mean was 6.1 μR/h.

It is remarkable that the lowest γ-background levels are found near the sea.



Table 8.4.4

γ-background (μR/h) around a location in Jutland in 1971
(Correction factor 1.40 has been applied to all data)

| Zone and sector | July |
|---|---|
| A 1 | 6.6 |
| A 2 | 7.0 |
| A 3 | 7.0 |
| A 4 | 4.8 |
| A 5 | 6.6 |
| A 6 | 4.3 |
| A 7 | 6.2 |
| A 8 | 4.8 |
| A 9 | 4.3 |
| A 10 | 6.6 |
| A 11 | 6.6 |
| A 12 | 6.2 |
| Mean | 5.9 |
| B 1 | 6.6 |
| B 2 | 6.6 |
| B 3 | 5.3 |
| B 4 | 6.6 |
| B 5 | 7.0 |
| B 6 | 5.7 |
| B 7 | 5.7 |
| B 8 | 5.3 |
| B 9 | 5.3 |
| B 10 | 5.7 |
| B 11 | 5.7 |
| B 12 | 6.2 |
| Mean | 6.0 |
| C 1 | 7.0 |
| C 2 | 7.4 |
| C 3 | 4.3 |
| C 4 | 7.4 |
| C 5 | 7.0 |
| C 6 | 5.7 |
| C 7 | 6.2 |
| C 8 | 5.3 |
| C 9 | 6.2 |
| C 10 | 5.3 |
| C 11 | 5.7 |
| C 12 | 6.2 |
| Mean | 6.1 |
| D 1 | 6.6 |
| D 2 | 6.6 |
| D 3 | 5.7 |
| D 4 | 7.0 |
| D 5 | 5.3 |
| D 6 | 6.6 |
| D 7 | 6.2 |
| D 8 | 5.3 |
| D 9 | 5.3 |
| D 10 | 5.7 |
| D 11 | 5.7 |
| D 12 | 6.2 |
| Mean | 6.0 |

Table 8.4.5

The γ-background (μR/h) along the coasts of the Great Belt in 1971
(Correction factor 1.40 has been applied to all data)

| Location | July |
|---|---|
| Agerse | 5.3 |
| Orne | 5.3 |
| Resnæs | 5.3 |
| Reerse | 6.2 |
| Halskov | 8.3 |
| Sproge | 6.2 |
| Knudshoved | 5.3 |
| Risinge | 5.7 |
| Fyns Hoved | 6.6 |
| Tårup Strand | 6.2 |
| Hov, Langeland | 6.2 |
| Mean | 6.1 |

## 9. CONCLUSION

### 9.1. Risø Environmental Monitoring

No radioactive contamination of the environment originating from the operation of the research establishment was ascertained outside Risø in 1971. As in the previous years, the variations in contamination levels were quite independent of the distance of the sampling locations from Risø.

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

The mean content of Sr-90 in air collected in 1971 was 0.0019 pCi Sr-90/$m^3$, i.e. 10% lower than the 1970 level. The average fall-out for the State experimental farms in 1971 was 1.5 mCi Sr-90/$km^2$ or a little lower than the 1970 figure, and the mean concentration of Sr-90 in rain water was 2.8 pCi Sr-90/l, i.e. 15% higher than the 1970 level.

The accumulated fall-out down to a depth of 30 cm by the end of 1971 was approx. 54 mCi Sr-90/$km^2$. From 0-20 cm the level was 47 mCi Sr-90/$km^2$.

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.

The median level of Sr-90 in Danish ground water was 0.09 pCi Sr-90/l.

The mean level of Sr-90 in fresh water from Danish streams was 0.37 pCi/l and in lakes we found 1.50 pCi Sr-90/l.

### 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. 14 pCi Cs-137/l.

The 1971 Sr-90 and Cs-137 levels were nearly equal to the levels found in milk produced in 1969 and 1970.

The Sr-90 mean content in grain from the 1971 harvest was 60 pCi Sr-90/kg. The Cs-137 mean content in grain was 84 pCi Cs-137/kg. The Sr-90 level in grain from the 1971 harvest was nearly 50% higher than the level found in the 1970 harvest, and Cs-137 was 30% higher than the 1970 level.



The mean contents of Sr-90 and Cs-137 in Danish vegetables collected in 1971 were 11 pCi Sr-90/kg (35 S.U.) and 1.6 pCi Cs-137/kg respectively, and in fruits 5 pCi Sr-90/kg and 7 pCi Cs-137/kg; potatoes contained 3.5 pCi Sr-90/kg and 11 pCi Cs-137/kg.

The mean levels of Sr-90 and Cs-137 in total-diet samples collected in 1971 were 7.5 S.U. or 13.2 pCi Sr-90/day and 33 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 7.9 S.U. and the Cs-137 intake to be 38 pCi Cs-137/day. The Sr-90 levels in the Danish total diet consumed in 1971 were nearly equal to the 1970 levels, while the Cs-137 levels were a little higher.

Grain products contributed 34% and milk products 40% to the total Sr-90 intake, and 32% of the Cs-137 in the diet came from meat, 32% from grain products, and 17% 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 1971 was 1.1 S.U. in new-born children, 2.7 S.U. in infants, 2.2 S.U. in children and teen-agers, 1.8 S.U. in adults (20-29 years old) and 1.6 S.U. in adults of more than 29 years. The 1971 bone levels were generally higher than the 1970 levels.

The mean content of Cs-137 in the human body in 1971 was estimated from whole-body countings to be 1.8 nCi (13 pCi Cs-137/g K), i.e. approx. 60% of the 1970 level.

### 9.5. Sr-90 in Sea Water

The mean content of Sr-90 in the inner Danish waters was approx. 0.6 pCi Sr-90/l in 1971, i.e. unchanged from the levels in previous years.

### 9.6. The γ-Background

The γ-background measured at the State experimental farms in 1971 was 6.3 μR/h.

### 9.7. Summary

The concentrations of long-lived fall-out nucleides in ground-level air and precipitation collected in 1971 were nearly equal to the levels found in 1970.

In milk produced in 1971 the Sr-90 and Cs-137 levels were the same as the 1970 levels. In grain from 1971 the levels were 30-50% higher than the 1970 concentrations.

The Sr-90 and Cs-137 levels in the total diet consumed in 1970 were nearly equal to the 1968, 1969, and 1970 concentrations.

The Sr-90 concentrations in human bone were a little higher in 1971 than in 1970.

APPENDIX A

Calculated Fall-out in the Eight Zones in 1971

| Zone | mm precipitation in 1971 | mCi Sr-90/km$^2$ in 1971 | Accumulated mCi Sr-90/km$^2$ by the end of 1971 (0-30 cm) |
|---|---|---|---|
| I: N. Jutland | | | |
| II: E. Jutland | | | |
| III: W. Jutland | 658 | 1.8 | 57 |
| IV: S. Jutland | | | |
| V: Funen | | | |
| VI: Zealand | 557 | 1.4 | 54 |
| VII: Lolland-Falster | | | |
| VIII: Bornholm | 444 | 1.6 | 45 |
| Area-weighted mean | 625 | 1.7 | 56 |

The amounts of precipitation were obtained from ref. 9, and from 4.1, and 4.2.



APPENDIX B

Statistical information

| Zone | | Area in km$^2$ 13) | Population in thousands 13) 1965 | Annual milk production in mega-kg 14) 1967 | Annual wheat production in mega-kg 13) 1966 | Annual rye production in mega-kg 13) 1966 | Annual potato production in mega-kg 13) 1966 | Vegetable** area in km$^2$ 15) 1961 | Fruit area in km$^2$ 15) 1961 |
|---|---|---|---|---|---|---|---|---|---|
| I: | N. Jutland | 7,544 | 515 | 1,117 | | | | | |
| II: | E. Jutland | 7,338 | 784 | 1,380 | 84 | 80 | 853 | 24 | 18 |
| III: | W. Jutland | 10,764 | 579 | 976 | | | | | |
| IV: | S. Jutland | 3,964 | 230 | 515 | | | | 25 | 38 |
| V: | Funen | 3,482 | 425 | 494 | | | | | |
| VI: | Zealand | 7,542 | 2,055* | 604 | 306 | 56 | 119 | 39 | 45 |
| VII: | Lolland-Falster | 1,788 | 128 | 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 prediction models used hitherto[17] have been corrected by the introduction of an exponential term in the soil factor. Hence A is now the calculated, available, accumulated fall-out (in mCi Sr-90/km$^2$) in the soil. The effective half life of Sr-90 in the soil is 4 years corresponding to a decay constant $\lambda$ of 0.17 years$^{-1}$. The models for Cs-137 have been changed, the soil term has been deleted, and in some cases replaced by a second lag term (the fall-out rate of the year (i-2)).

Table C1 shows that the mean ratio between observed and predicted Sr-90 levels in 1971 was $1.16 \pm 0.05$ (1 SE), and from table C2 it appears that the corresponding ratio for Cs-137 was $0.99 \pm 0.05$. Thus we may conclude that the prediction models for Cs-137 have yielded acceptable estimates for 1971, while the Sr-90 models, contrary to the two previous years, have this year overestimated the levels. The discrepancy has been especially evident for the Sr-90 levels in grain.

Table C 1

A comparison between observed and predicted Sr-90 levels in the human food chain in Denmark in 1971

| Sample and location | Observed | Predicted | Equation used for the prediction |
|---|---|---|---|
| Milk from Jutland | 8.6 | 8.6 | S. U. = $1.04d_{(i)} + 0.47d_{(i-1)} + 0.26A_{by(i-1)}$ |
| Milk from the Islands | 5.2 | 4.8 | S. U. = $0.78d_{(i)} + 0.47d_{(i-1)} + 0.18A_{by(i-1)}$ |
| Rye from Jutland | 167 | 155 | S. U. = $204d_{(j-a)} + 2.06A_{by(i-1)}$ |
| Rye from the Islands | 92 | 69 | S. U. = $156d_{(j-a)} + 1.20A_{by(i-1)}$ |
| Barley from Jutland | 134 | 135 | S. U. = $161d_{(j-a)} + 2.14A_{by(i-1)}$ |
| Barley from the Islands | 67 | 52 | S. U. = $94d_{(j-a)} + 1.24A_{by(i-1)}$ |
| Wheat from Jutland | 163 | 152 | S. U. = $154d_{(j-a)} + 3.14A_{by(i-1)}$ |
| Wheat from the Islands | 88 | 85 | S. U. = $136d_{(j-a)} + 2.24A_{by(i-1)}$ |
| Oats from Jutland | 115 | 76 | S. U. = $70d_{(j-a)} + 1.60A_{by(i-1)}$ |
| Oats from the Islands | 55 | 36 | S. U. = $56d_{(j-a)} + 0.96A_{by(i-1)}$ |
| Potatoes from Jutland | 4.0 | 2.7 | pCi Sr-90/kg = $0.13d_{(i)} + 0.11A_{by(i-1)}$ |
| Potatoes from the Islands | 3.0 | 2.8 | pCi Sr-90/kg = $0.18d_{(i)} + 0.062A_{by(i-1)}$ |
| Total diet from Jutland | 8.4 | 9.7 | S. U. = $0.89d_{(i)} + 1.26d_{(i-1)} + 0.25A_{by(i-1)}$ |
| Total diet from the Islands | 6.5 | 6.5 | S. U. = $0.84d_{(i)} + 1.27d_{(i-1)} + 0.21A_{by(i-1)}$ |
| Newborns' bone | 1.1 | 1.1 | S. U. = $0.164d_{\frac{i+(i-1)}{2}} + 0.017d_{(i-2)} + 0.037A_{by(i-1)}$ |
| Adults' vertebrae | 1.6 | 1.3 | S. U. = $0.021d_{\frac{i+(i-1)}{2}} + 0.039d_{(i-2)} + 0.056A_{by(i-1)}$ |

The prediction models were calculated from data collected in 1962-70 (for grain 1962-71)

d is the fall-out rate in mCi Sr-90/km$^2$ (table 4.1.1). A is the estimated, available accumulated fall-out in mCi Sr-90/km$^2$ calculated for an effective half-life of Sr-90 in the soil of 4 years.

(i) is the current year, (i-1) the year before etc. (j-a) is July-August.



Table C 2

A comparison between observed and predicted Cs-137 levels in the human food chain in Denmark in 1971

| Sample and location | Observed | Predicted | Equation used for the prediction |
|---|---|---|---|
| Milk from Jutland | [illegible] | [illegible] | pCi Cs-137/g K = [illegible] |
| Milk from the Islands | [illegible] | [illegible] | pCi Cs-137/g K = [illegible] |
| Rye from Jutland | 188 | 202 | pCi Cs-137/kg = [illegible] |
| Rye from the Islands | 95 | 92 | pCi Cs-137/kg = [illegible] |
| Barley from Jutland | 77 | 106 | pCi Cs-137/kg = [illegible] |
| Barley from the Islands | 52 | 69 | pCi Cs-137/kg = [illegible] |
| Wheat from Jutland | 78 | 105 | pCi Cs-137/kg = [illegible] |
| Wheat from the Islands | 58 | 59 | pCi Cs-137/kg = [illegible] |
| Oats from Jutland | 97 | 76 | pCi Cs-137/kg = [illegible] |
| Oats from the Islands | [illegible] | [illegible] | pCi Cs-137/kg = [illegible] |
| Potatoes from Jutland | 12 | 9 | pCi Cs-137/kg = [illegible] |
| Potatoes from the Islands | 10 | 7 | pCi Cs-137/kg = [illegible] |
| Beef | 60 | 64 | pCi Cs-137/kg = [illegible] |
| Pork | 92 | 99 | pCi Cs-137/kg = [illegible] |
| Total diet from Jutland | 38 | 44 | pCi Cs-137/day = [illegible] |
| Total diet from the Islands | 27 | 23 | pCi Cs-137/day = [illegible] |
| Whole body from the Islands | 13 | 17 | pCi Cs-137/g K = [illegible] |

The prediction models were for milk calculated from data collected (1962-70), for grain (1962-71), for potatoes (1963-71), for meat, total diet and whole body (1963-70).

(m-a) is May-August and the fall-out rates are measured in mCi Sr-90/km$^2$

(cf. also remarks to table C 1)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