Environmental radioactivity in Denmark in 1977

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Publication date:
1978

Document Version
Publisher's PDF, also known as Version of record

Risø Report No. 386

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Risø National Laboratory

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June 1978

Sales distributors: Jul. Gjellerup, Sølvgade 87, DK-1307 Copenhagen K, Denmark
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ENVIRONMENTAL RADIOACTIVITY IN DENMARK IN 1977

A. Aarkrog, L. Bøtter Jensen, H. Dahlgaard, Heinz Hansen,
J. Lippert, S.P. Nielsen and Karen Nilsson

ABSTRACT

Strontium-90 was determined in samples from all over the country of precipitation, ground water, sea water, grass, dried milk, fresh milk, grain, bread, potatoes, vegetables, fruit, total diet, and human bone. Furthermore, ^{90}Sr was determined in local samples of air, rain water, grass, sea plants, fish, and meat. Cesium-137 was determined in soil, sea water, milk, grain products, potatoes, vegetables, fruit, total diet, fish, and meat. It was also measured by wholebody-counting of a control group at Risø Health Physics Department. Estimates of the mean contents of radiostrontium and radiocesium in the human diet in Denmark during 1977 are given. The γ-background was measured regularly by TLD, ionization chamber and on site γ-spectroscopy at locations around Risø, at ten of the State experimental farms along the coasts of the Great Belt and around Gyllingnæs. The marine environments at Barsebäck and Ringhals were monitored for ^{137}Cs and corrosion products (^{58}Co, ^{60}Co, ^{65}Zn, ^{54}Mn). Results of plutonium determinations in soil and sediments from 1977 are presented in this report. Tritium was determined in groundwater and precipitation. Finally the report includes routine surveys of environmental samples from the Risø area.

UDC 614.73(489)

ISBN 87-550-0548-9
ISSN 0418-6443

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ABBREVIATIONS AND UNITS

FP	fission products	Samples:
fCi	femtocurie 10^{-15} Ci	
pCi	picocurie, 10^{-12} Ci, µµCi	H: sea water
nCi	nanocurie, 10^{-9} Ci, mµCi	J: soil
mCi	millicurie, 10^{-3} Ci	L: air
MPC	maximum permissible concentration	B: bed soil
cpm	counts per minute	A: eel
dpm	disintegrations per minute	PG: grass
cph	counts per hour	PH: sea plants
µR	micro-roentgen, 10^{-6} roentgen	D: drain water
S.U.	pCi ^{90}Sr (g Ca)$^{-1}$	S: waste water
O.R.	observed ratio	R: precipitation
M.U.	pCi ^{137}Cs (g K)$^{-1}$	M: milk
V	vertebrae	
m	male	
f	female	
nSr	natural (stable) Sr	
eqv. µgU	equivalents µg uranium: activity as from 1 µg U (∿90 dph)	
eqv. mg KCl	equivalents mg KCl: activity as from 1 mg KCl (∿0.88 dpm)	
S.D.	standard deviation: $\sqrt{\frac{\Sigma(\bar{x}-x_i)^2}{(n-1)}}$	
S.E.	standard error: $\sqrt{\frac{\Sigma(\bar{x}-x_i)^2}{n(n-1)}}$	
U.C.L.	upper control level	
L.C.L.	lower control level	
Δ	one standard deviation due to counting	
S.S.D.	sum of squares of deviation: $\Sigma(\bar{x}-x_i)^2$	
f	degrees of freedom	
s^2	variance	
v^2	ratio between the variance in question and the residual variance	

P	probability fractile of the distribution in question
η	coefficient of variation, relative standard deviation
annova	analysis of variance
A	relative standard deviation 20-33%
B	relative standard deviation >33%, such results are not considered significantly different from zero activity
B.D.L.	below detection limit

In the significance test the following symbols were used:

* : probably significant (P > 95%)

** : significant (P > 99%)

***: highly significant (P > 99.9%)

1. INTRODUCTION

1.1.

The present report is the twenty-first of a series of periodic reports (cf. ref. 1) dealing with measurements of radioactivity in Denmark. The organization of the material in the present report has been altered compared to previous reports. After the introduction and a chapter on organization and facilities there follows a chapter on environmental monitoring around nuclear facilities (Risø, Barsebäck and Ringhals). Chapter four deals with fallout nuclides in the abiotic environment, i.e., air, water and soil. Chapters five and six comprise fallout nuclides in the human diet and human tissues, respectively. Chapter seven is devoted to environmental tritium studies. Plutonium and americium in environmental samples are treated in chapter eight, and external radiation in chapter nine. The names of the authors of each chapter appear at its head.

1.2.

The methods of radiochemical analysis[2-4] and the statistical treatment of the results[5,12] 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 originating from the environmental control of the Risø site. These tables are available in the form of microcards at the Risø library.

1.4.

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

1.5.

In 1977 the personnel of the Environmental Control Section of the Health Physics Department consisted of two chemists, one biologist, ten laboratory technicians, two sample collectors, and two laboratory assistants. The Section for Electronics Development continued to give assistance with the maintenance of counting equipment, with the interpretation of γ-spectra and with data treatment. The program (cf. 2) used in the calculations of ^{90}Sr and the γ-analysis, as well as the program for data treatment, were developed by this Section.

1.6.

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

2. FACILITIES[1,6,7,8]

by J. Lippert

2.1. Detectors

The activity of the samples is measured as follows:

Alpha (^{239}Pu, ^{241}Am): 10 solid-state surface barrier detectors connected to three multichannel analyzers (64 channels per detector).

Beta (^{90}Y mainly): 5 low-level gas-flow Geiger counters, 4 of them provided with automatic sample chambers.

Gamma (natural and fallout isotopes): 5 Ge(Li) detectors in 10 cm lead shields and connected to five 1024-channel analyzers. One further Ge(Li) detector mounted on a tripod and a 4096-channel analyzer are used for field measurements, and a 8" x 4" NaI(Tl) in an underground shielded room is used for whole-body counting.

2.2. Data treatment

Measured spectra are evaluated directly on a desk-top calculator or transferred to a Burroughs B6700 computer.

A program system STATDATA[16] is developed for registration and treatment of environmental measurements including multichannel analyzer spectra. To date, approximately 40 000 sets of results have been registered covering the period from 1957.

3. ENVIRONMENTAL MONITORING AT RISØ, BARSEBÄCK AND RINGHALS IN 1977

by H. Dahlgaard

3.1. Gross β-activity at Risø

3.1.1. Sea water

Fig. 3.1.1.1 shows the sample locations in Roskilde Fjord. Fig. 3.1.1.2 shows the control chart for H I. The yearly mean for H I in 1977 was 60 eqv. mg KCl (2.5 g)$^{-1}$ (in 1976: 58), for H III-VI: 60 eqv. mg KCl (2.5 g)$^{-1}$ (in 1976: 55) and for H VII-X: 60 eqv. mg KCl (2.5 g)$^{-1}$ (in 1976: 55). Fig. 3.1.1.3 shows the mean levels of radioactivity in sea salt since 1957.

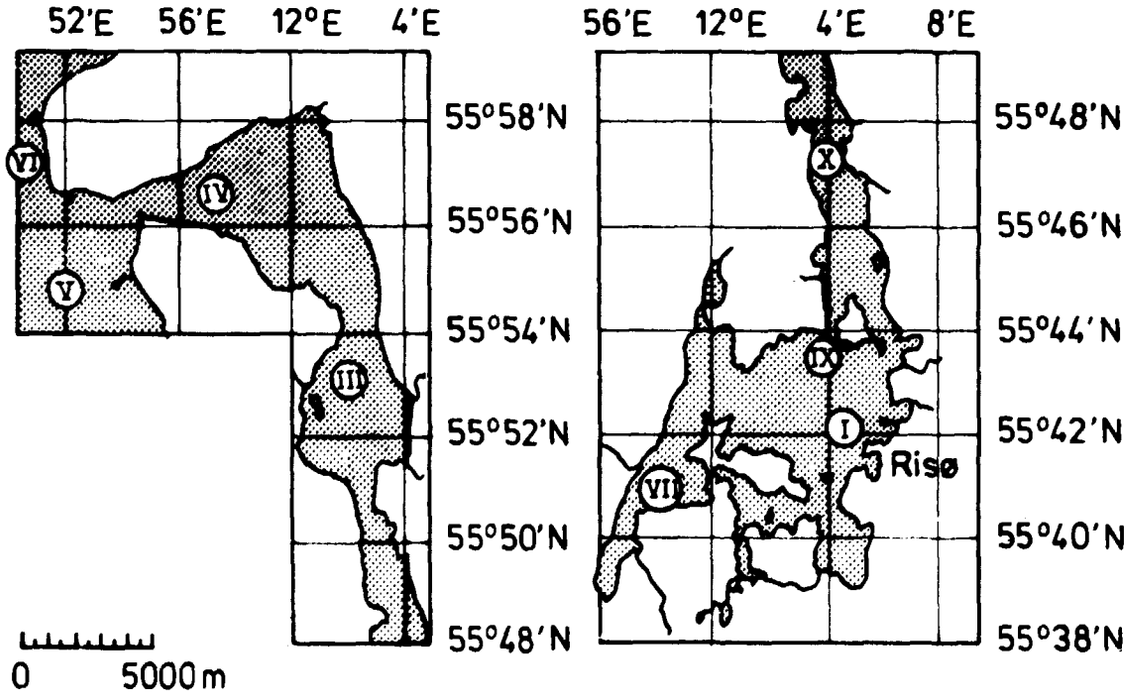

Fig. 3.1.1.1. Roskilde Fjord.

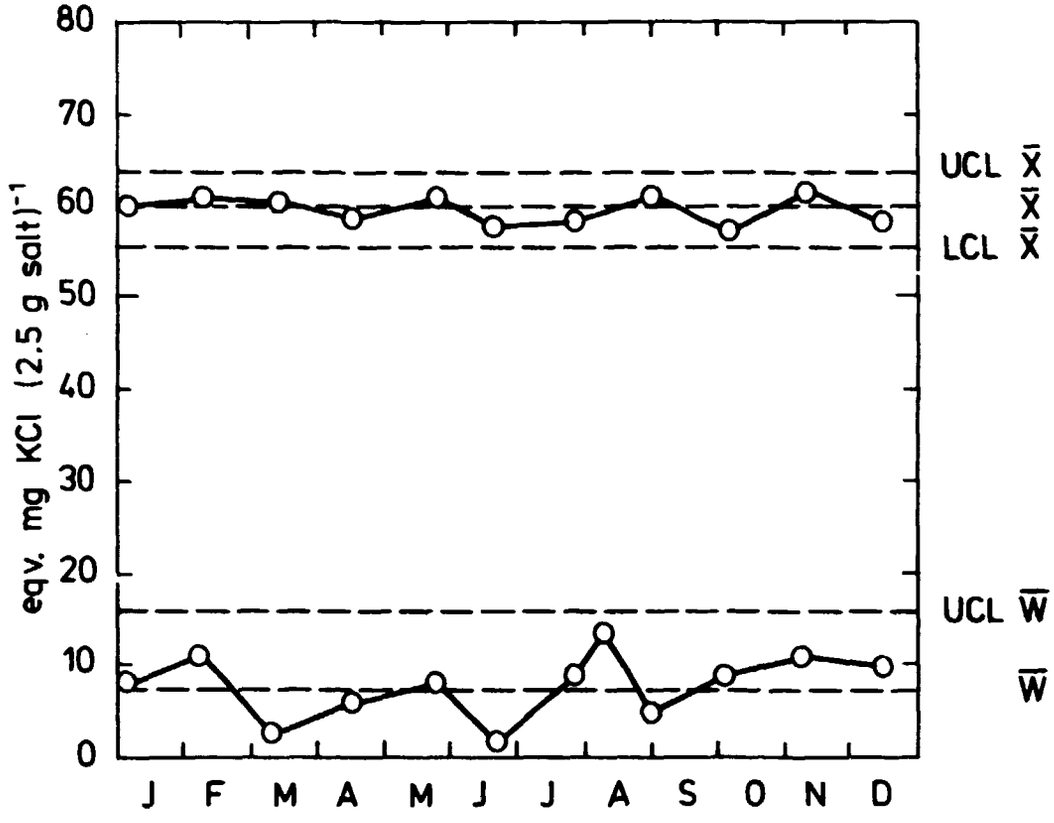

Fig. 3.1.1.2. Control chart for HI, 1977.

3.1.2. Soil

No soil samples from the environment of Risø were measured for total β-activity in 1977.

3.1.3. Air

Fig. 3.1.3.1 shows the diagram for FP activity in air samples in 1977. The mean value for the year was 0.22 eqv. mg KCl m^{-3} as compared with 0.15 eqv. mg KCl m^{-3} in 1976.

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

3.1.4. Sediment samples from the fjord

The mean activity in sediment B I was 162 eqv. mg KCl (3.0 g ash)$^{-1}$ in 1977 as compared with 137 eqv. mg KCl (3.0 g)$^{-1}$ in 1976. Fig. 3.1.4.1 shows the mean levels for B I since 1957 (cf. also 3.4).

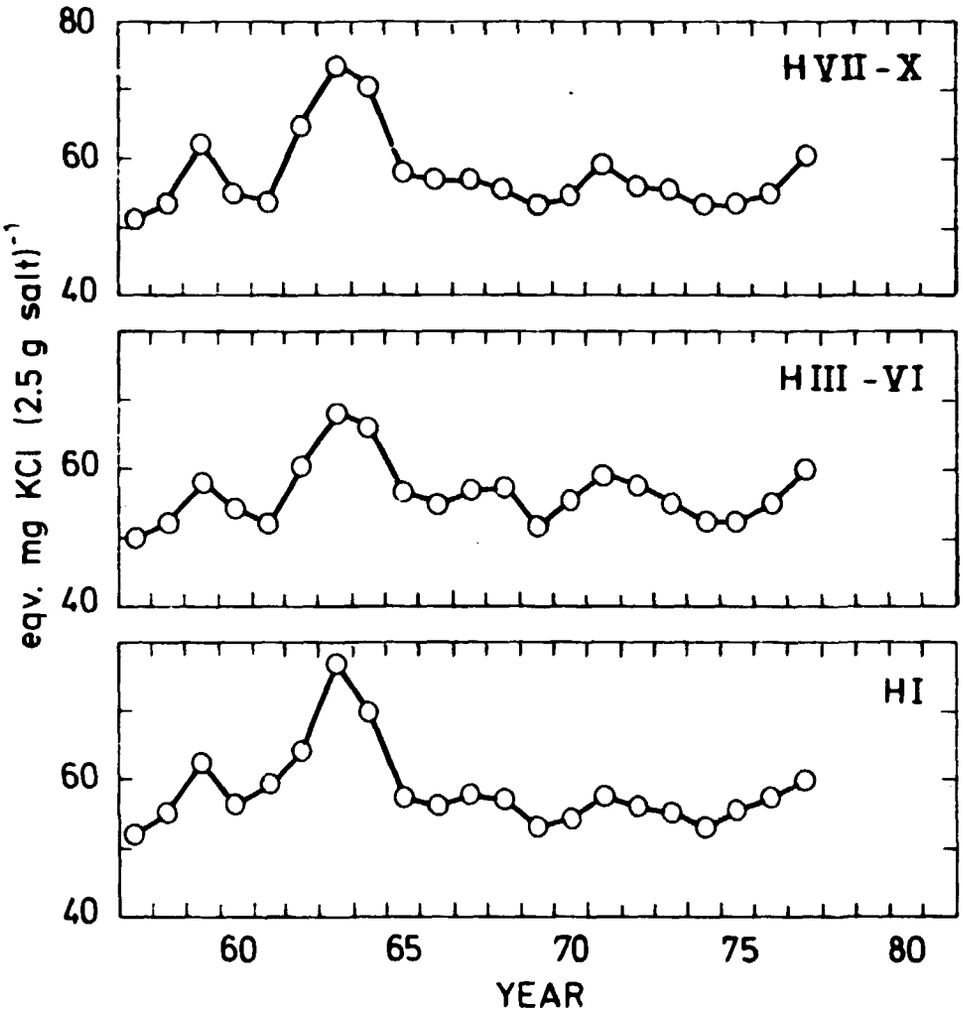

Fig. 3.1.1.3. Mean radioactivity in sea water 1957-1977.

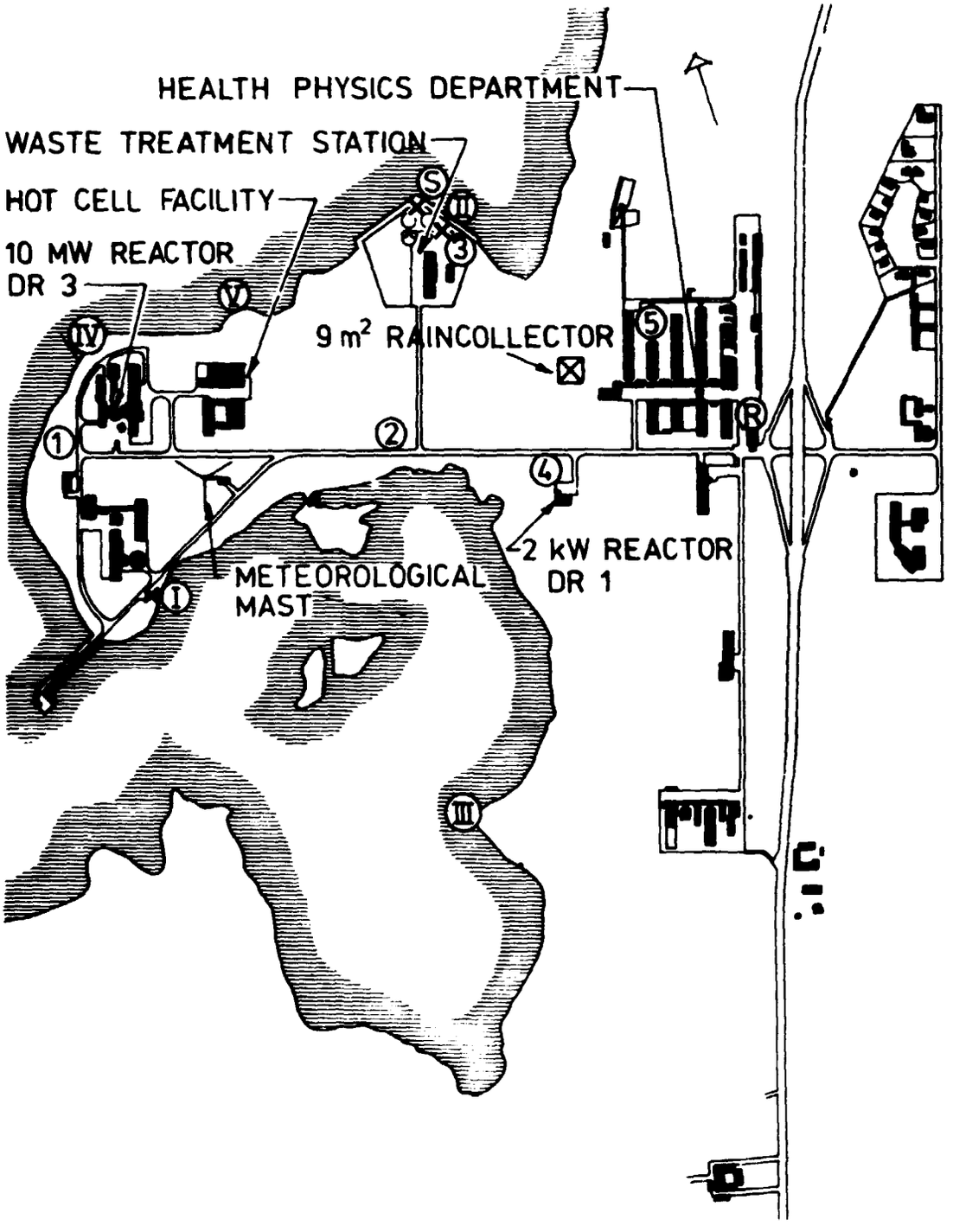

Fig. 3.1.2.1. Sampling locations at Risø National Laboratory. 1-5: locations for rainbottels (0.03 m^2 each), ionexchange collumns (0.06 m^2 each) and grass samples. I-V: sampling locations for drainige water. S: sewage water. R: 1 m^2 daily raincollector. X: 9 m^2 monthly ionexchange raincollector

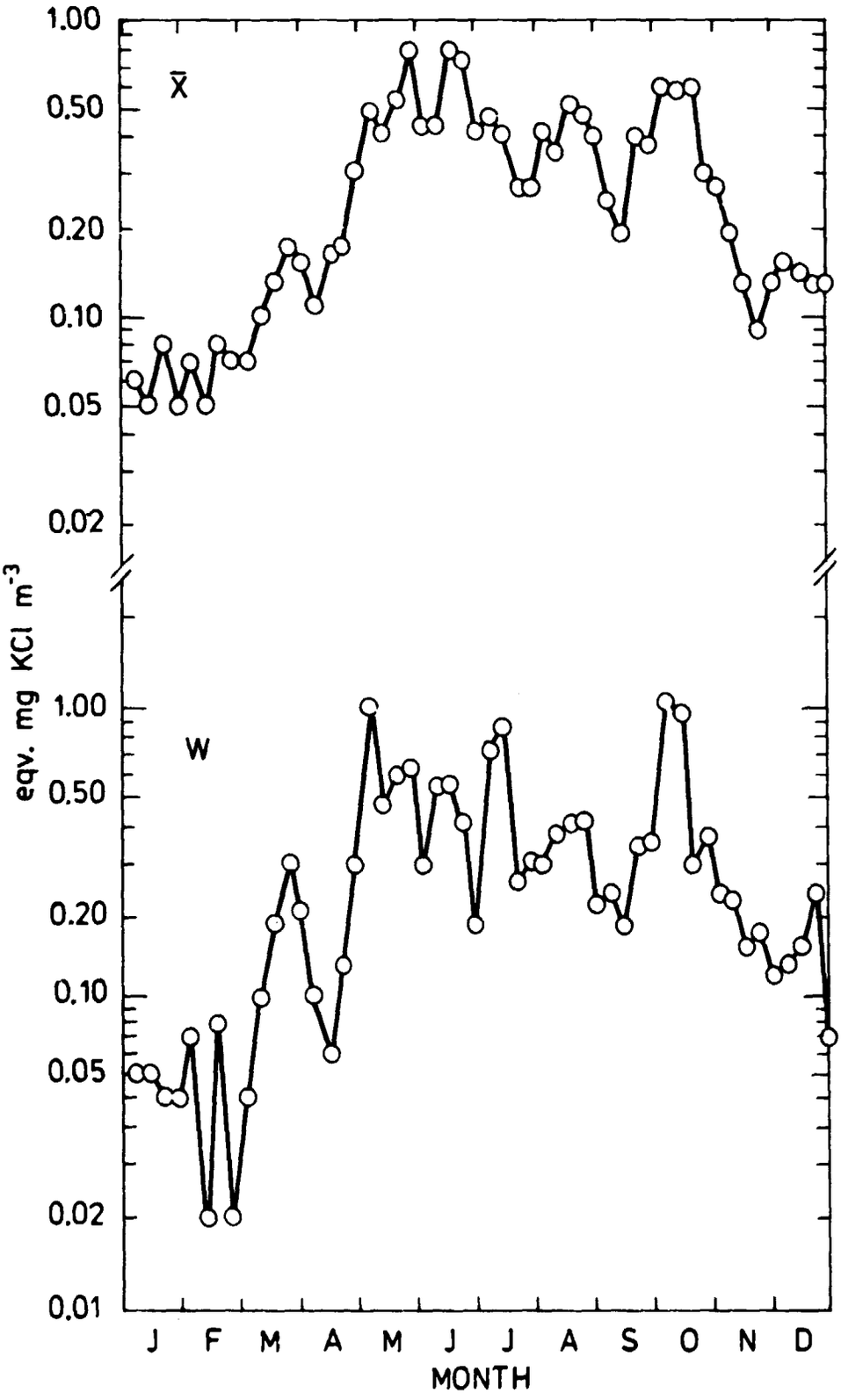

Fig. 3.1.3.1. Control chart for LF, 1977.

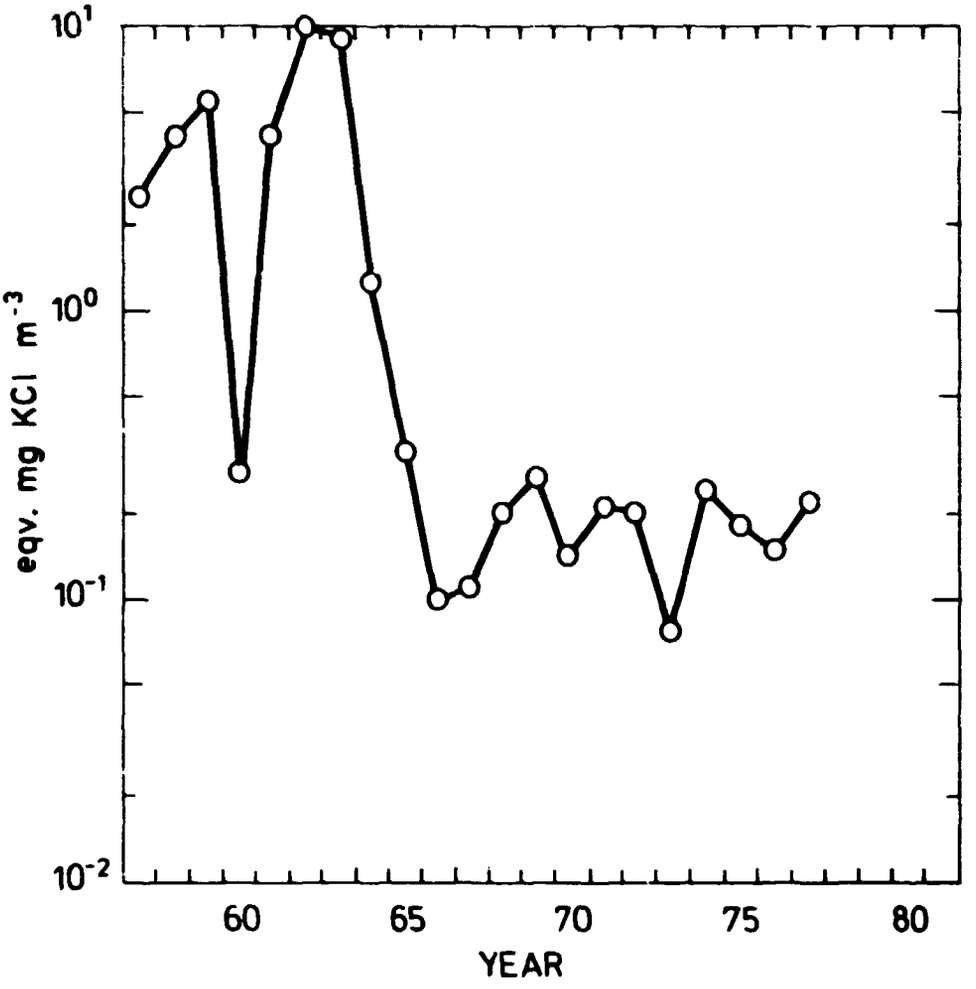

Fig. 3.1.3.2. Mean radioactivity in air, 1957-1977.

3.1.5. Fish

No fish samples from Roskilde Fjord were measured for total β-activity in 1977.

3.1.6. Grass

The mean values were in 1977 for PG I: 23 eqv. mg KCl (0.1 g grass ash)$^{-1}$ (in 1976: 15), for PG II-III: 22 eqv. mg KCl (0.1 g)$^{-1}$ (in 1976: 20) and for PG IV-V: 19 eqv. mg KCl (0.1 g)$^{-1}$ (in 1976: 10). Fig. 3.1.6.1 shows the mean activities in grass ash since 1957.

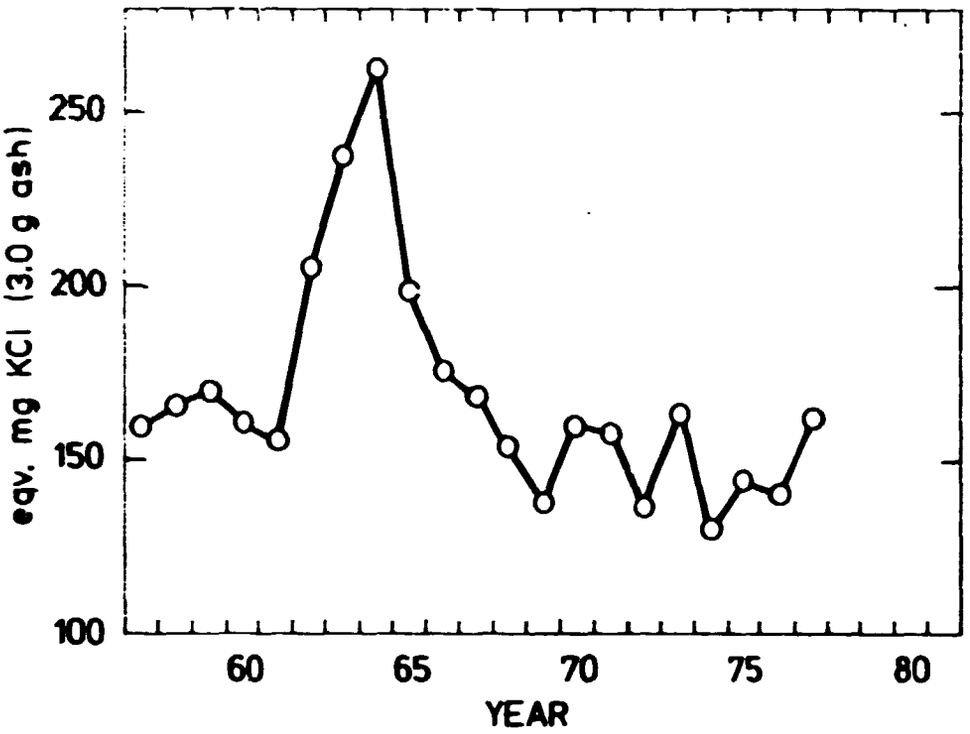

Fig. 3.1.4.1. Mean radioactivity in sediment samples (BI), 1957-1977.

3.1.7. Sea plants

The mean FP level in 1977 in Fucus vesicolosus (PH I) was 6 eqv. mg KCl (0.1 g ash)$^{-1}$ (2 in 1976). In Zostera marina (PH III-IX) we found 4 eqv. mg KCl (0.1 g ash)$^{-1}$ in 1977 (2 in 1976).

3.1.8. Fresh water

Fig. 3.1.8.1 shows the control chart for S (cf. fig. 3.1.2.1). The yearly means for D I, D II, D IV, and S in 1976 were 57 eqv. mg KCl l^{-1} (1976: 17), 19 eqv. mg KCl l^{-1} (1976: 19), 16 eqv. mg KXl l^{-1} (1976: 42), and 52 eqv. mg KCl l^{-1} (1976: 46) respectively. Fig. 3.1.8.2 shows the activity in drainage water (D) and sewage water (S).

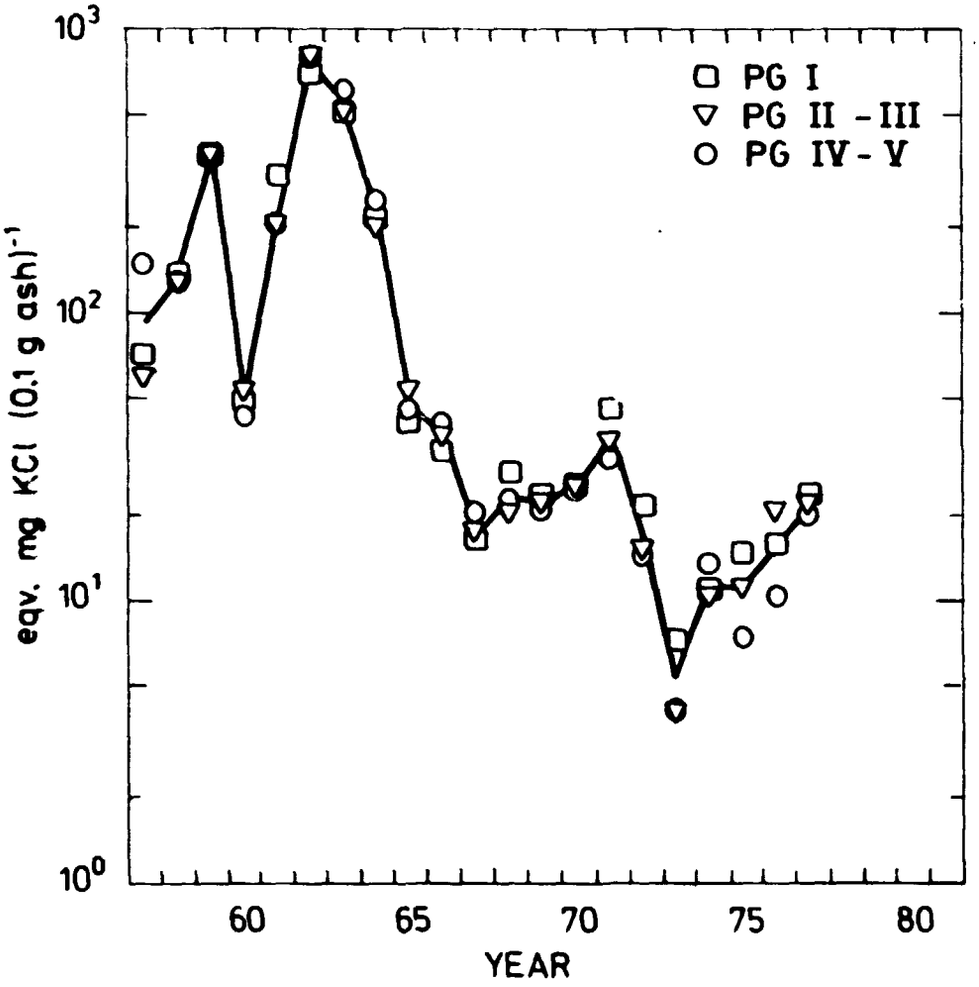

Fig. 3.1.6.1. Mean FP-radioactivity in grass ash, 1957-1977.

3.1.9. Rain water

Figs. 3.1.9.1 shows the total fallout from rain water collected daily at Risø in 1 m^2 rain collector in 1977. The total fallout in 1977 was measured at $0.023 \cdot 10^6$ eqv. mg KCl m^{-2}, and the annual mean concentration in rain water at Risø was 76 eqv. mg KCl/l. In 1976 the corresponding figures were $0.014 \cdot 10^6$ and 42 respectively.

Fig. 3.1.9.2 shows the specific activity in rain water since 1957.

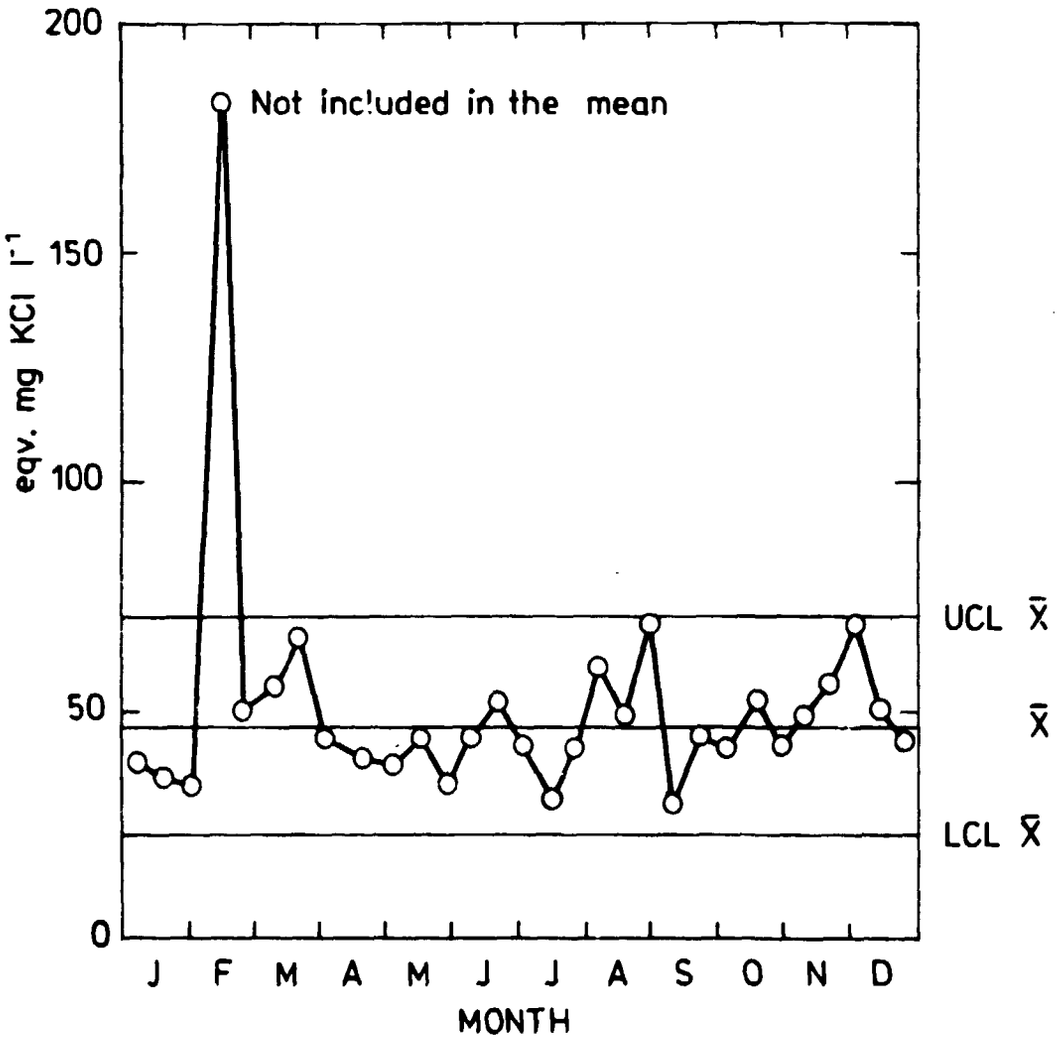

Fig. 3.1.8.1. Control chart for sewage water (S) 1977.

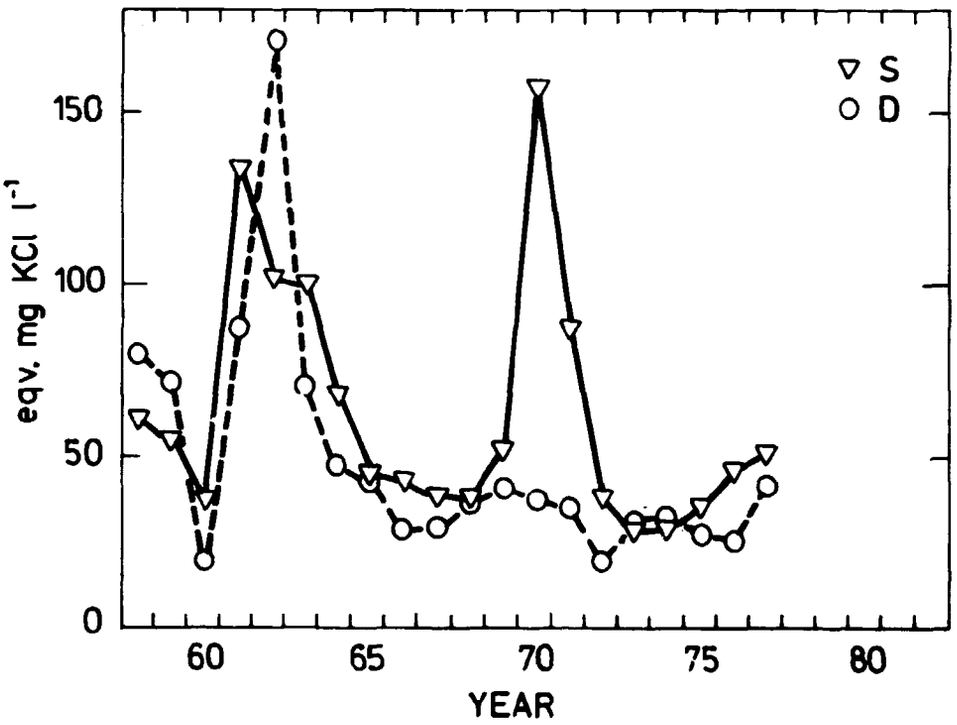

Fig. 3.1.8.2. Annual total-β mean levels in waste water (S) and drain water (D) collected at Risø 1958-1977.

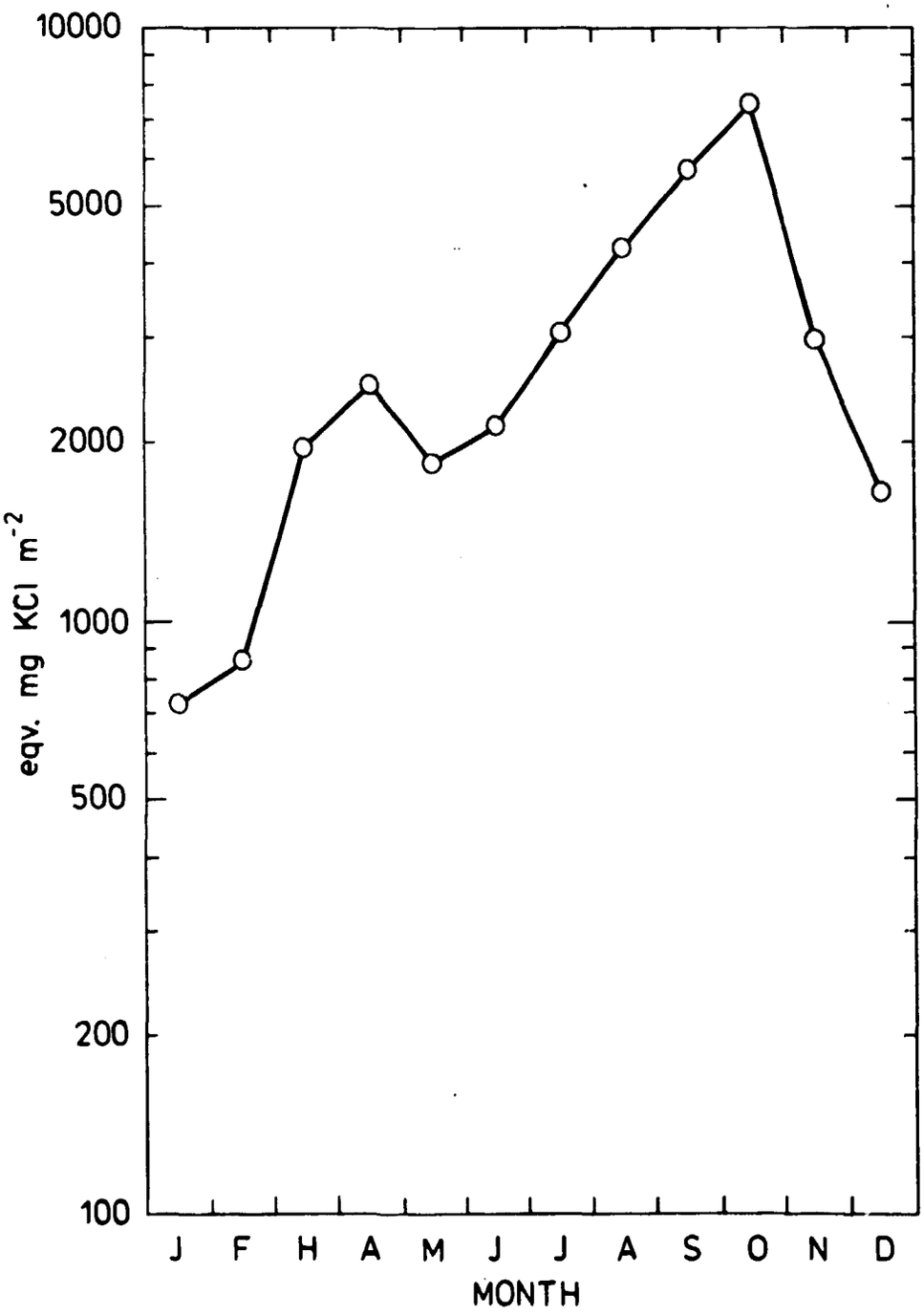

Fig. 3.1.9.1. Total monthly fallout from precipitation in 1977.

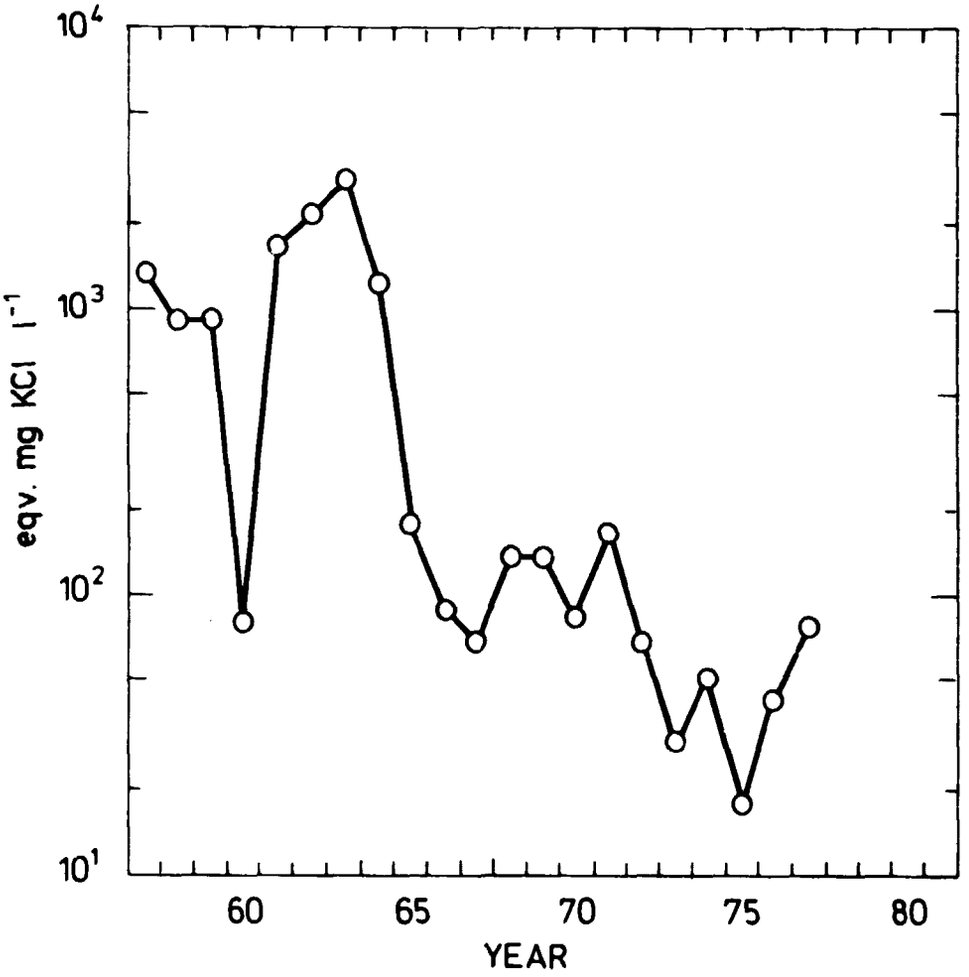

Fig. 3.1.9.2. Specific activity in precipitation, 1957-1977.

3.2. Marine environmental monitoring at Barsebäck and Ringhals

Radiological monitoring of the marine environment around the two nuclear power plants at Barsebäck and Ringhals in Sweden (Risø Report No. 361)[1] was continued and expanded in 1977.

Figures 3.2.1 and 3.2.2 show the sampling locations.

This programme will be continued from 1978 in collaboration with the Department of Radiation Physics of the University of Lund as part of a general study of bioindicator systems for monitoring radioactive pollution of the marine environment.

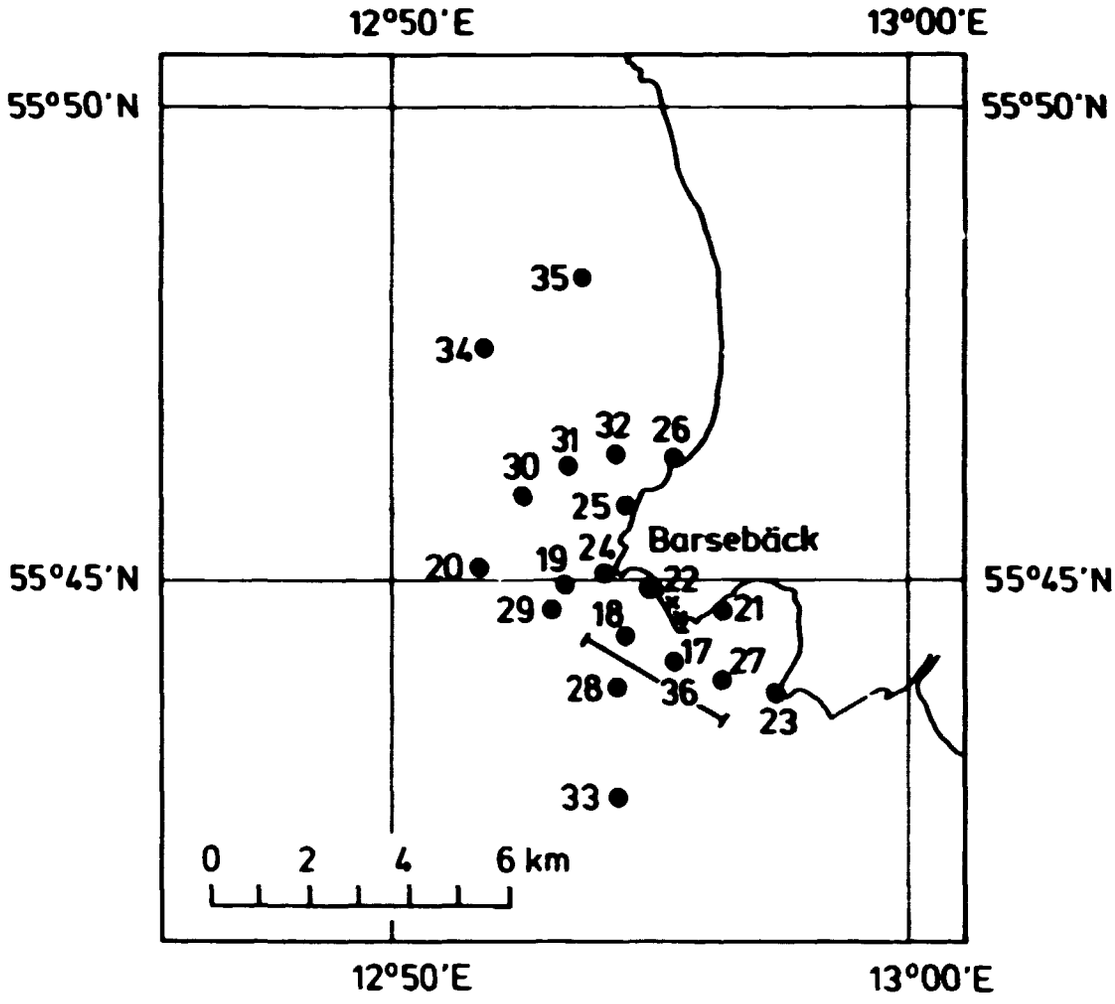

Fig. 3.2.1. Sampling locations at Barsebäck.

3.2.1. γ-emitting radionuclides in brown algae

Benthic brown algae are widely used as biological indicators of radionuclide as well as of stable metal pollution. The reason for the use of, e.g., Fucus as a biological indicator is that this organism concentrates the metals in question and loses them slowly. It has been demonstrated[17,20] that Fucus takes up Zn to a concentration factor of the order of 10^4. Young[20] detected no loss of ^{65}Zn from Fucus serratus over a period of 100 days. Thus, by sampling Fucus instead of water, the limit of detection is lowered and the fluctuating levels of radionuclides are, so to speak, integrated over a certain period of time in the algae.

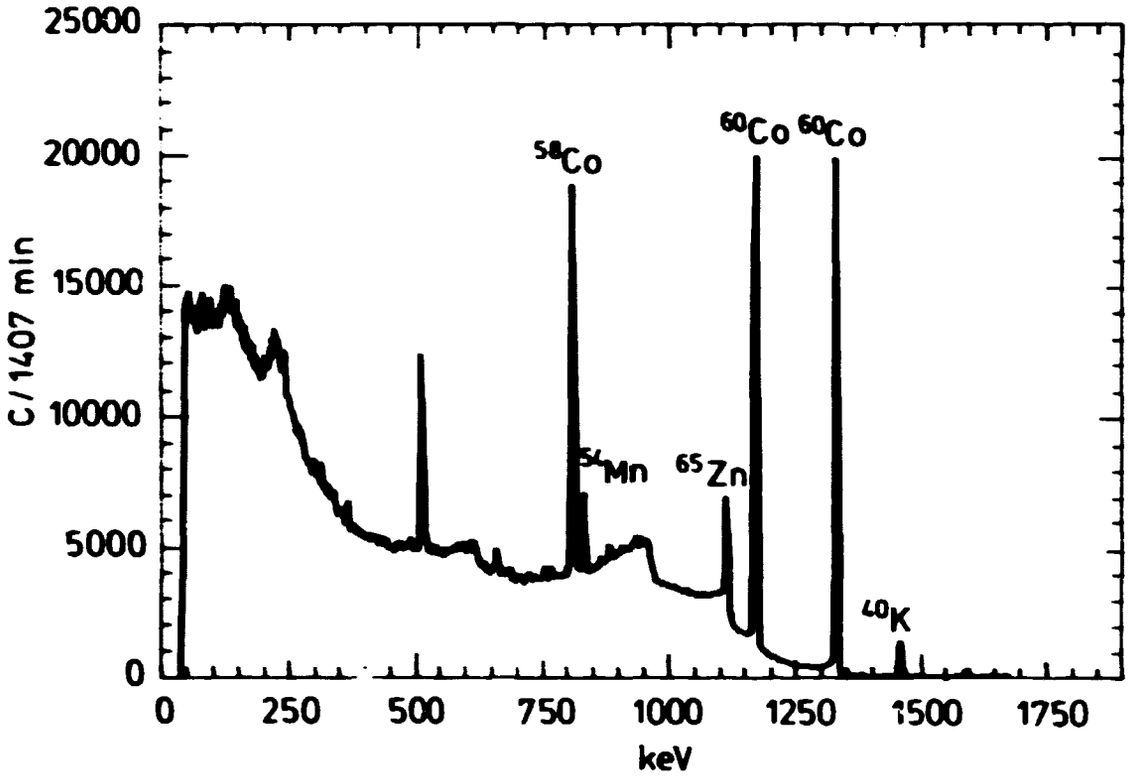

Fig. 3.2.1.1. 1024-channel Ge(Li) γ-spectrum. Fucus vesiculosus collected at Barsebäck, location 24, October 22th 1977.

Tables 3.2.1.1 and 3.2.1.2 show the radionuclide concentration found by γ-spectrometric analysis in brown algae at Barsebäck and Ringhals in 1977. The decrease in concentration with distance from the outlet is pronounced and similar for ^{58}Co, ^{60}Co, ^{54}Mn and ^{65}Zn (Fig. 3.2.1.2). Data on $^{110\,m}Ag$ are few but indicate the same trend. Minor amounts of ^{54}Mn were created in the Chinese test series (cf. 5.3). Fucus serratus sampled at Sjællands Rev (55° 58' N, 11° 22' E) on November 29, 1977 showed a ^{54}Mn content of 12 pCi kg^{-1} (fresh weight), however, this background activity did not influence the ^{54}Mn levels measured around Barsebäck and Ringhals significantly (cf. tables 3.2.1.1 and 3.2.1.2). ^{95}Zr and ^{131}I show no decrease with distance from outlet, which indicates their origin as fallout from the Chinese bomb-tests; ^{137}Cs originates from fallout and from Windscale. The γ-counting of ^{137}Cs is disturbed by high $^{110\,m}Ag$ levels and natural radioisotopes. The marked difference at Barsebäck between the sampling locations north and south of the outlet was expected because of the predominant north-bound surface current.

Table 3.2.1.1. Gamma-emitting radionuclides in Fucus vesiculosus collected at Barsebäck in 1977 (Unit: pCi kg^{-1} fresh weight)

Date of sampling	15 June						22 October						6 December	
Station** No.	22	24	25	26	21*	23*	22	24	25	26	21*	23*	22	24
Distance from outlet in km	0.6	1.4	2.9	4.0	1.5	2.8	0.6	1.4	2.9	4.0	1.5	2.8	0.6	1.4
^{60}Co	3,790	2,540	609	285	182	164	29,600	11,200	4,070	2,320	2,130	1,190	30,500	13,400
^{58}Co	2,490	1,450	394	196	33	32	8,710	3,150	1,130	694	576	340	5,710	2,560
^{54}Mn	465	387	108	60	39	32	1,660	585	248	136	157	61	1,840	757
^{65}Zn	851	557	164	82	54	82	7,480	2,690	989	530	476	299	7,840	3,270
^{110m}Ag	67 A	34 B	123	-	-	-	361	129	91	-	75	-	302	-
^{51}Cr	144 B	92 B	-	-	-	-	-	-	-	-	-	-	-	-
^{137}Cs				57	47	91				82		80		
^{131}I	51 A	33 A	-	-	-	-	-	112	57 A	98	118	87	-	-
^{95}Zr	234	132	115	372	211	173	-	-	107	150	115	126	-	-

*South of the outlet.

**Cf. Fig. 3.2.1.

Table 3.2.1.2. Gamma-emitting radionuclides in Fucus vesiculosus (Fu.ve.), Fucus serratus (Fu.se.) and Ascophyllum nodosum (As.no.) collected at Ringhals in 1977

Date of sampling	7-9 July									10 November					
Station** No.	7	6	5	8	12	10*	9*	11*	13*	7	6	5	8	12	9*
Species	As.no.	Fu.ve.	Fu.se.	Fu.ve.	Fu.ve.	Fu.se.	Fu.se.	Fu.se.	Fu.se.	As.no.	Fu.se.	Fu.se.	Fu.ve.	Fu.ve.	Fu.se.
Distance from outlet in km	0.2	1.9	4.1	4.8	6.3	0.9	1.1	1.9	4.1	0.2	1.9	4.1	4.8	6.3	1.1
^{60}Co	4,320	892	492	400	237	2,440	1,150	1,080	152	4,940	1,460	852	257	246	1,880
^{58}Co	9,480	1,270	1,160	908	592	3,260	2,380	2,390	213	1,890	645	470	147	139	1,020
^{54}Mn	1,670	525	152	151	102	505	319	318	48	272	193	113	61	58	243
^{65}Zn	576	115	88	56	-	503	289	204	45 A	6,260	2,510	1,030	439	264	2,750
^{110m}Ag	-	-	-	-	-	-	-	-	-	422	-	50 A	-	-	94
^{51}Cr	-	-	-	-	-	-	-	-	-	1,040	-	-	-	-	-
^{137}Cs	85	53	44	58	74	43 A	38	44	49	-	103		64	72	
^{134}Cs	132	24 B	28 A	19	-	58	42	36	-	-	-	-	-	-	-
^{131}I	-	-	-	-	-	-	-	-	-	-	-	-	18 A	-	-
^{95}Zr	294	859	488	522	920	244	420	236	726	118	128	101	120	178	111

*Locations south of the outlet; the other locations were situated north of the outlet.

**Cf. Fig. 3.2.2.

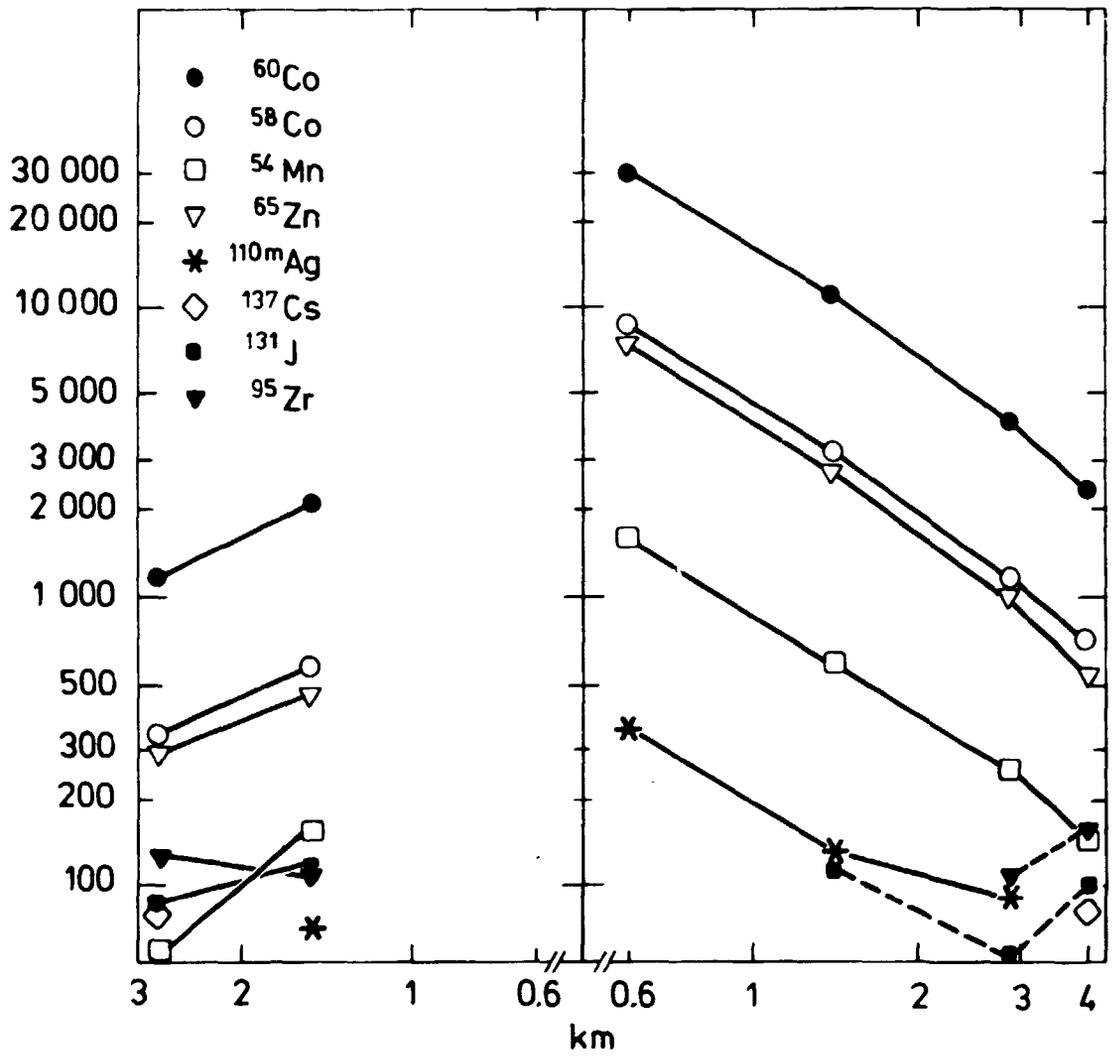

Fig. 3.2.1.2. γ-emitting radionuclides in Fucus vesiculosus collected at Barsebäck in October 1977 (cf. Table 3.2.1.1). Unit: pCi kg^{-1} fresh weight. A linear regression analysis of ln activity concentration normalized to unity against ln distance north from the outlet reveals that for radiocobalt ^{54}Mn and ^{65}Zn the fall in activity concentration with distance north from the outlet can be described by a power function pCi $kg^{-1} = k \cdot x^{-1.33}$ where k is a constant and x is distance in km. The corresponding data from June give an exponent of -1.26.

In 1977 no radioactivity originating from the power plants was detected in water samples.

In order to relate the concentrations of the different isotopes in the brown algae to the actual controlled discharge, calculations are made of the decay-corrected transfer factor and the normal transfer factor.

The decay-corrected transfer factor, DTF

The decay-corrected transfer factor DTF is an aid in the evaluation of bioindicators. The two cobalt isotopes with very different halflives make it possible to estimate the length of time over which the bioindicators integrate the discharge, i.e., to estimate the period of time from which the discharges are represented in the samples. The DTF values also make possible a comparison of the different nuclides irrespective of differences in halflife, i.e. a comparison of relevance to the stable metals too.

The decay-corrected transfer factor for an isotope, e.g. ^{65}Zn, is calculated as:

$$DTF_m(^{65}Zn) = \frac{A_i}{\sum_{j=i-m+1}^{i} D_j e^{-\lambda(i-j)}} (pCi(m\ months)kg^{-1}\ mCi^{-1})$$

where

A_i = activity of the specified isotope (pCi kg^{-1} fresh weight) in algae sampled in month no. i.

i = sampling month number

m = number of months included in calculation

j = number of a specific month

D_j = discharge of the specified isotope (mCi) in month no.j.

λ = radioactive decay constant of the specified isotope ($month^{-1}$).

If the sampling date is not the last day of the month, a correction is made assuming uniform distribution of the discharge over the sampling month. Decay corrected transfer factors for, e.g., ^{65}Zn normalized to DTF_m (^{60}Co) are calculated as:

$$DTF_{m,n}(^{65}Zn) = \frac{DTF_m(^{65}Zn)}{DTF_m(^{60}Co)} .$$

Figure 3.2.1.3 shows $DTF_{m,n}$ values as a function of m.

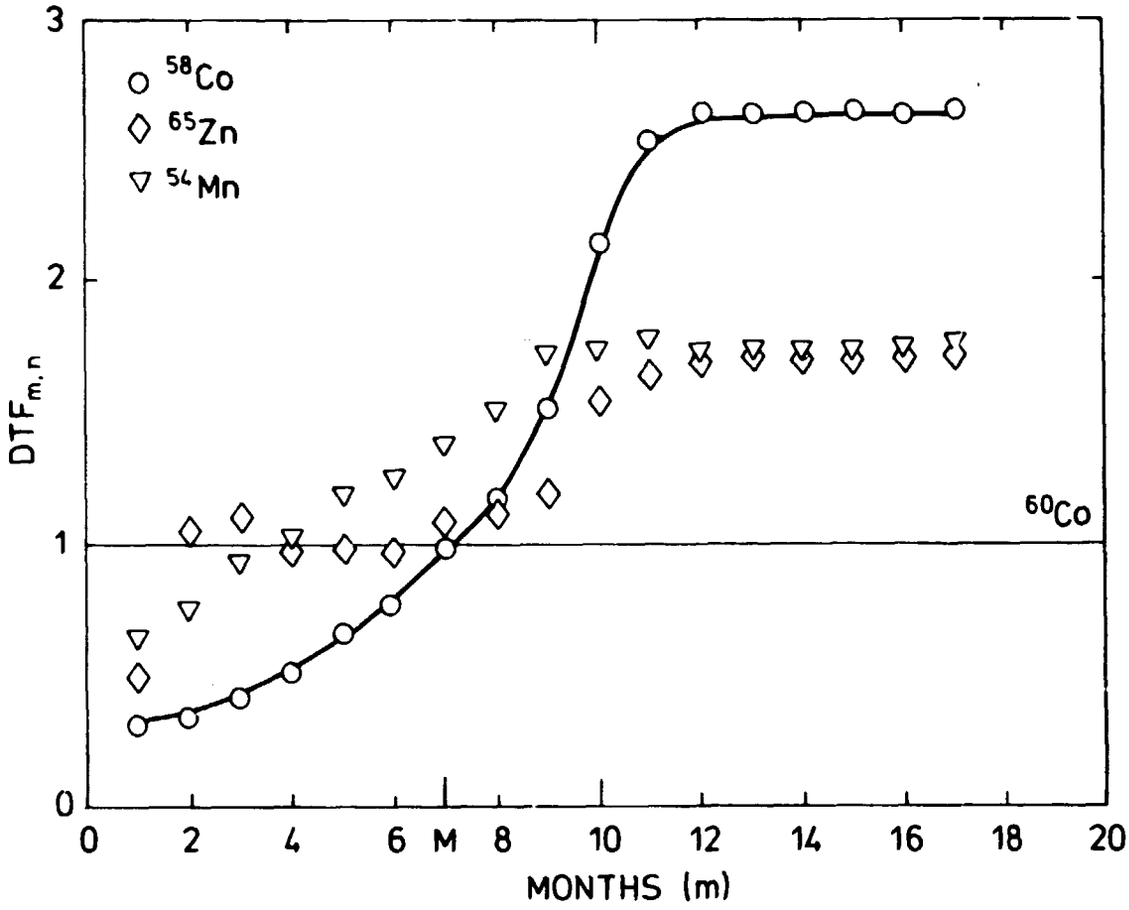

Fig. 3.2.1.3. $DTF_{m,n}$ (cf. text for explanation) as a function of the number of months, m, in calculation. Estimation of M indicated. Fucus vesiculosus, Barsebäck, location 24, June 15th 1977.

Table 3.2.1.3. Fucus vesiculosus collected at Barsebäck in 1977 north of the outlet. Decay-corrected transfer factors DTF_M (see Fig. 3.2.1.3. and the text for explanation). (Unit: pCi (M months) kg^{-1} mCi^{-1})

Date of sampling	15 June				22 October				6 December	
Location No.*	22	24	25	26	22	24	25	26	22	24
Distance from outlet in km	0.6	1.4	2.99	4.0	0.6	1.4	2.9	4.0	0.6	1.4
M months	7.0	7.5	7.0	6.5	10.7	10.7	10.7	10.7	13.2	11.2
DTF_M ^{60}Co	49.60	28.03	7.98	4.33	54.49	20.61	7.51	4.27	42.95	19.84
DTF_M ^{58}Co	50.00	28.06	7.90	4.07	58.24	21.09	7.54	4.64	44.01	19.89
DTF_M ^{54}Mn	52.53	38.77	12.20	7.61	49.32	17.33	7.34	4.04	42.02	18.14
DTF_M ^{65}Zn	52.41	30.77	10.10	5.57	59.37	21.32	7.85	4.21	53.30	22.81
DTF_M ^{110m}Ag	8.16	-	1.50	-	10.89	3.90	2.74	-	6.40	-
DTF_M ^{51}Cr	10.20	-	-	-	-	-	-	-	-	-

*Cf. Fig. 3.2.1.

Table 3.2.1.4. Fucus vesiculosus collected at Barsebäck in 1977 north of the outlet. Decay-corrected transfer factors $DTF_{M,n}$ (cf. Table 3.2.1.3.) normalized to ^{60}Co

Date of sampling	15 June				22 October				6 December	
Location No.*	22	24	25	26	22	24	25	26	22	24
Distance from outlet in km	0.6	1.4	2.9	4.0	0.6	1.4	2.9	4.0	0.6	1.4
M Months	7.0	7.5	7.0	6.5	10.7	10.7	10.7	10.7	13.2	11.2
^{60}Co	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
^{58}Co	1.00	1.00	1.01	0.94	1.07	1.12	1.00	1.09	1.02	1.00
^{54}Mn	1.05	1.38	1.54	1.76	0.91	0.84	0.98	0.95	0.98	0.91
^{65}Zn	1.05	1.10	1.28	1.29	1.09	1.03	1.05	0.99	1.24	1.15
^{110m}Ag	0.16	-	0.18	-	0.20	0.19	0.37	-	0.15	-
^{51}Cr	0.20	-	-	-	-	-	-	-	-	-

*Cf. Fig. 3.2.1.

Considering the two cobalt isotopes ^{60}Co and ^{58}Co, it is seen that as earlier discharges are considered in the calculation, the DTF_m (^{58}Co) value rises from below to above the DTF_m (^{60}Co) value. The reason is that ^{58}Co decays more rapidly than ^{60}Co ($T_{\frac{1}{2}}$ 71.3 d. and 1922 d., respectively) thus making old ^{58}Co discharges without importance in the DTF calculations.

Now, assuming that the two cobalt isotopes discharged are so similar in physicochemical form that Fucus cannot distinguish between them, then the number of months (m=M) for which DTF_m (^{60}Co) = DTF_m (^{58}Co) is the number of months from which radiocobalt discharges are represented in the Fucus sample. Including more than M months in the discharge calculation makes DTF_m (^{60}Co) < DTF_m (^{58}Co) as ^{60}Co discharges unrepresented in the algae are considered in the calculation.

Tables 3.2.1.3 and 3.2.1.4 show the DTF_M and $DTF_{M,n}$ values observed in the different Fucus samples from Barsebäck. In cases where the DTF_m values for ^{60}Co and ^{58}Co cross sharply (see Fig. 3.2.1.3), the cross-points indicate the number of months (M), but in samples from October and December (see Fig. 3.2.1.4), where there is no sharp interception, M is chosen at the point where DTF_m (^{58}Co) rises above the DTF_m (^{60}Co) curve.

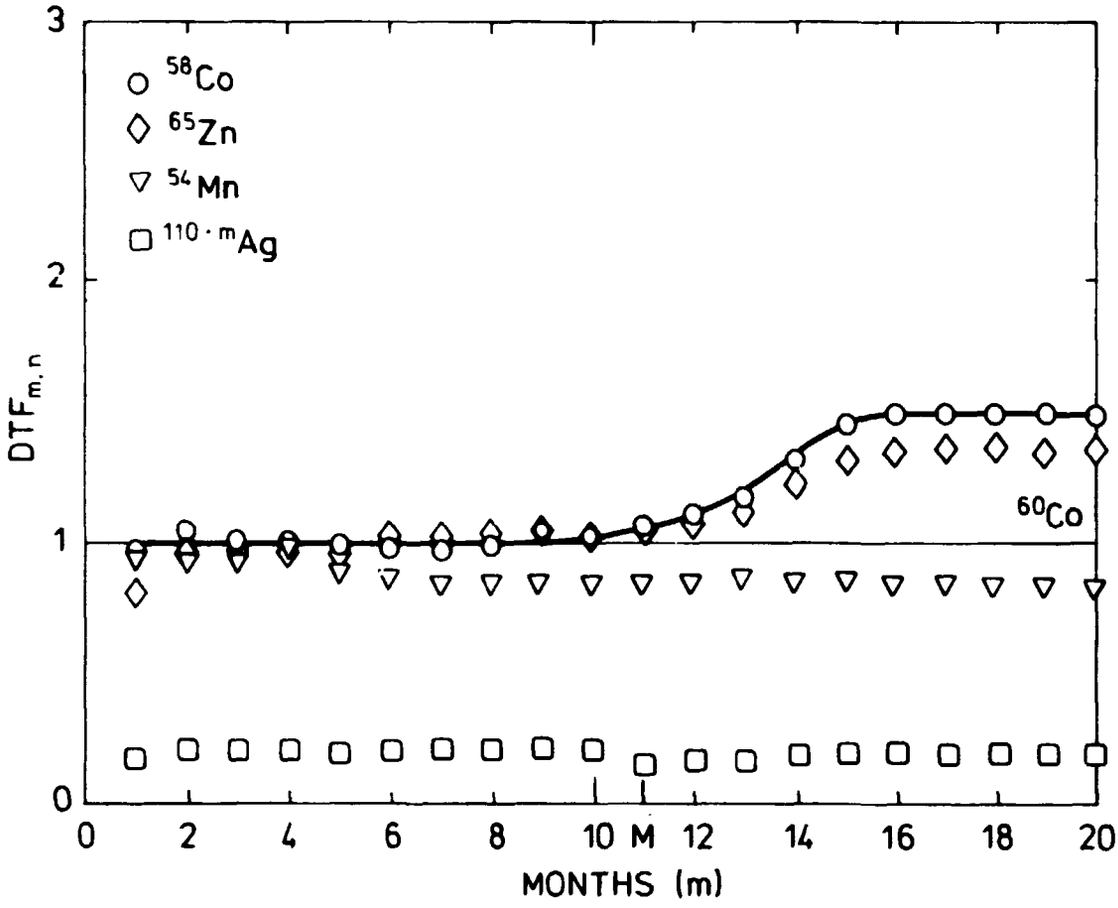

Fig. 3.2.1.4. $DTF_{m,n}$ (cf. text for explanation) as a function of the number of months, m, in calculation. Estimation of M indicated. Fucus vesiculosus, Barsebäck, location 24, October 22th 1977.

Table 3.2.1.5 shows an anova of $DTF_{M,n}$ values from table 3.2.1.4, except for the single ^{51}Cr value.

Table 3.2.1.5. Analysis of variance of $DTF_{M,n}$-values from Table 3.2.1.4. (except $DTF_{M,n}$ (^{51}Cr) and $DTF_{M,n}$ (^{60}Co))

Variation	SSD	f	s^2	v^2	P
Between isotopes	3.465	3	1.155	16.688	>99.5%
Between sampling times	0.151	2	0.076	1.092	-
Between locations	0.097	3	0.032	2.015	-
Isotopes × sampling times	0.415	6	0.069	5.001	>97.5%
Sampling times × locations	0.086	4	0.022	1.555	-
Isotopes × locations	0.125	8	0.016	1.128	-
Iso. × times × loc.	0.125	9	0.014	0.628	-

It is seen that the $^{110\ m}Ag$ values are significantly different from the other isotopes. Excluding $^{110\ m}Ag$ from the anova makes all variations (except interaction: isotope x time) insignificant.

This similarity in $DTF_{M,n}$ for radiocobalt, ^{54}Mn and ^{65}Zn is expected if the uptake and elimination of Co, Mn and Zn are similar.

The normal transfer factor, TF

The transfer factor, TF, calculated as the quotient between algal activity on the day of sampling and average monthly discharge without decay correction:

$$TF = \frac{A_i \cdot m}{\sum_{j=1-m+1}^{i} D_j} \quad (\text{pCi month kg}^{-1}\ \text{mCi}^{-1}),$$

is ideally the steady-state activity (pCi kg^{-1}) in the sample if one mCi is constantly discharged per month. In practice, the monthly discharge is not constant, and samples are not expected to be found in steady-state conditions. However, the value is of great importance in evaluating the capacity of the recipient.

Table 3.2.1.6 shows different TF-values. For Barsebäck, location 22, a mean value of ∿250 pCi month kg^{-1} mCi^{-1} was observed for ^{60}Co, ^{54}Mn and ^{65}Zn. Because of a shorter halflife, TF (^{58}Co) has a lower value.The TF values from Ringhals, location 7, are about 20 times lower for radiocobalt and ^{54}Mn when discharges are averaged over 6 months. The discharge from Ringhals was heavily dominated by an atypical discharge of radiocobalt and ^{54}Mn in April. More data is needed before conclusions can be drawn on possible differences between the TF values at Barsebäck and at Ringhals.

Table 3.2.1.6. Transfer factor, TF, (pCi month kg^{-1} mCi^{-1}). Fucus vesiculosus collected at location 22, Barsebäck and Ascophyllum nodosum collected at location 7, Ringhals in 1977

Location	Date	Isotope	Algae		Discharge			Transfer factor	
			pCi kg^{-1} fresh weight Mean	rel. SD%	Months	mCi $month^{-1}$ Mean	rel. SD%	pCi month kg^{-1} mCi^{-1} Mean	rel. SD%
Barsebäck location 22	Oct 10 and Dec 6	^{60}Co	30,015	2.1	Aug-Dec (5 months)	133.2	40.1	225	40.2
		^{58}Co	7,209	29.4		48.1	50.2	150	58.2
		^{54}Mn	1,752	7.1		9.1	16.2	193	17.7
		^{65}Zn	7,658	3.3		34.5	60.9	222	61.0
		^{110m}Ag	332	12.6		8.5	76.8	39	77.8
Barsebäck location 22	June 15	^{60}Co	3,787		Jan-June (6 months)	10.63	39.8	356	
		^{58}Co	2,495			14.68	81.8	170	
		^{54}Mn	465			1.62	76.1	288	
		^{65}Zn	851			2.87	66.5	297	
		^{110m}Ag	67			1.02	79.5	65.9	
		^{51}Cr	144			8.52	89.5	16.9	
Ringhals location 7	July 7	^{60}Co	4,323		Feb-July (6 months)	279	134	15.5	
		^{58}Co	9,475			1,271	213	7.5	
		^{54}Mn	1,671			133	189	12.6	
		^{65}Zn	576			10.43	90	55.2	
Ringhals location 7	July 7	^{60}Co	4,323		April	1,002		4.3	
		^{58}Co	9,475			6,773		1.4	
		^{54}Mn	1,671			640		2.6	

3.2.2. γ-emitting radionuclides in Mytilus edulis and other invertebrates

Mytilus is widely used as a biological indicator of radioactive contamination and other pollution for the same reasons as given for Fucus. In contrast to Fucus, Mytilus may enter the human food chain. An extensive sampling of Mytilus was planned, but it was not found in sufficient amounts.

Mytilus edulis, Cyprina islandica, Buccinum undatum and Cancer pagurus were sampled in 1977 (tables 3.2.2.1 and 3.2.2.2). Mytilus from Ringhals locations 7, 5, and 8 was collected from the same sites as the corresponding algal samples. Ratios between the activities in Mytilus and in algae were calculated (table 3.2.2.3). The material is too small to permit extensive conclusions, but there are indications that the brown algae

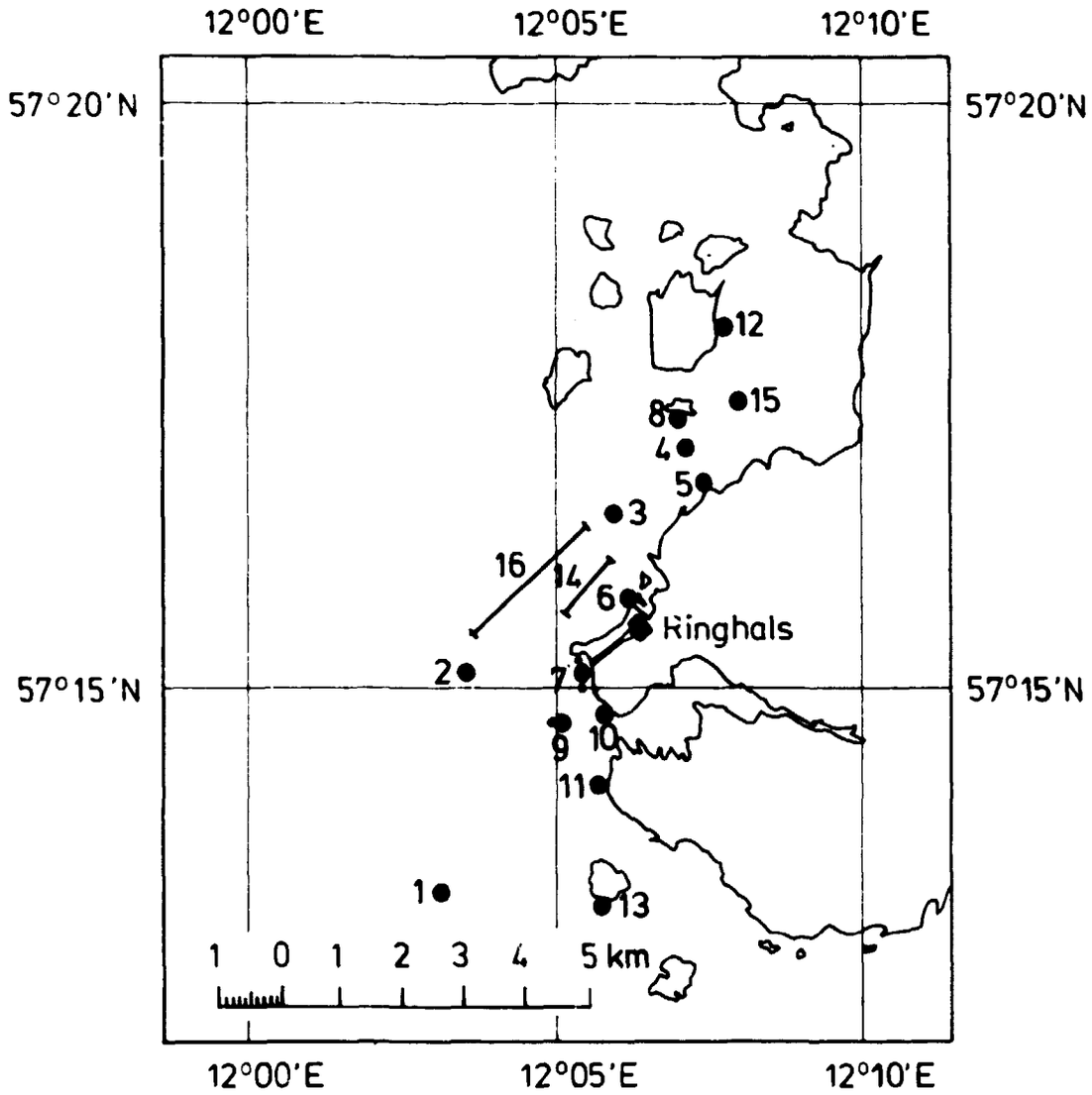

Fig. 3.2.2. Sampling locations at Ringhals.

concentrate about one order of magnitude more radiocobalt and ^{95}Zr and two orders of magnitude more ^{54}Mn on a fresh weight basis than does Mytilus. It seems that the Mytilus : algae activity ratio is somewhat higher for ^{60}Co than for ^{58}Co. This would be the case if Mytilus integrates radiocobalt discharges over a longer period of time than does Fucus, or if physico-chemical differences make the availability of the two isotopes to Fucus and Mytilus differ. There is too little material, however, to draw any conclusions on this point.

Table 3.2.2.1. Gamma-emitting radionuclides in Mytilus edulis collected at location 20 (depth: 11 m) at Barsebäck in 1977. (Unit: pCi kg^{-1} fresh weight)

Date		^{137}Cs	^{54}Mn	^{65}Zn	^{60}Co
June 16	Soft part	23 A	-	-	-
	Shells	-	23	46 A	-
Oct 19	Soft part	16 A	-	-	8.7 A
	Shells	-	-	52 A	15 B

Table 3.2.2.2. Gamma-emitting radionuclides in molluscs and crabs collected at Ringhals in 1977. (Unit: pCi kg^{-1} fresh weight)

Species	Date	Sampling location		^{58}Co	^{54}Mn	^{65}Zn	^{60}Co	^{137}Cs
Mytilus edulis	July 7	7	Soft part	466	31 A	138	412	
			Shells	394	134	-	290	
Mytilus edulis	July 7	5	Soft part	102	-	-	56	
			Shells	-	33	-	37	
Mytilus edulis	July 7	8	Soft part	86	-	-	50	
			Shells	-	22 A	-	14 B	
Cyprina islandica	July 11	16	Soft part	-	-	-	-	
Cyprina islandica	Nov 1	16	Soft part	-	-	-	-	
Buccinum undatum	Nov 1	16	Soft part	-	-	113 A	-	
Cancer pagurus	July 10	14	Whole	-	-	-	-	27

Table 3.2.2.3. Activity-ratios on fresh weight basis, Mytilus edulis soft part (from Table 3.2.2.2.) to Brown algae (from Table 3.2.1.2.). Collected at Ringhals July 1977

Location	^{58}Co	^{60}Co	^{54}Mn	^{65}Zn	^{95}Zr
7	0.049	0.095	0.019	0.24	-
5	0.088	0.114	-	-	0.107
8	0.095	0.125	-	-	0.155

3.2.3. γ-emitting radionuclides in fish

Table 3.2.3.1 shows the concentrations of gamma-emitting radionuclides in fish meat from Barsebäck and Ringhals in 1977. One of the samples showed trace amounts of ^{60}Co.

Table 3.2.3.1. Gamma-emitting radionuclides in fish meat collected at Barsebäck and Ringhals in 1977. (Unit: pCi kg^{-1} fresh weight)

Location		Date	Species	^{137}Cs	^{60}Co
Barsebäck	20	Dec 13	Cod	64	-
Ringhals	14	July 9	Dab	60	-
	14	"	Plaice	41	7 B
	14	"	Lemon sole	42	-
	14	"	Sole	94	-

3.2.4. γ-emitting radionuclides in sea-sediments

Sediments were sampled by the HAPS bottom corer[18] and 3-cm thick sections were analyzed (tables 3.2.4.1 - 3.2.4.4). In most cases only the top-layer was analyzed because counting capacity was limited. If corrosion products were detected in the top-layer, then succeeding slices were analyzed too.

Table 3.2.4.1. Gamma-emitting radionuclides in sediment samples collected at Barsebäck in 1977. Surface layer (0-3 cm)

	Date	June							October			December	
	Location*	32	31	30	29	28	27	35	17	18	19	29	30
	Water depth in m	13	16	24	20	17	12	14	14	16	20	14	14
^{137}Cs	pCi kg^{-1}	374	874	768	603	936	295	385	1100	1050	1170	868	1320
	mCi km^{-2} per 3 cm	9.6	11.8	7.1	7.8	11.3	8.4	9.6	15.8	12.8	7.7	6.8	8.8
^{54}Mn	pCi kg^{-1}								66 A				
	mCi km^{-2} per 3 cm								0.8A				
^{60}Co	pCi kg^{-1}								332			248	
	mCi km^{-2} per 3 cm								4.0			1.6	

*Cf. Fig. 3.2.1.

Table 3.2.4.2. Gamma-emitting radionuclides in sediment samples collected at Ringhals in 1977. Surface layer (0-3 cm)

	Date	July				October			
	Location*	1	2	3	4	1	2	3	4
	Water depth in m	24	26	17	16	25	23	17	15
^{137}Cs	pCi kg^{-1}	234	217	104	83	318	255	200	102
	mCi km^{-2} per 3 cm	6.6	6.1	4.4	3.2	6.1	6.1	5.5	3.4
^{58}Co	pCi kg^{-1}			6720					
	mCi km^{-2} per 3 cm			281					
^{54}Mn	pCi kg^{-1}			64 A					
	mCi km^{-2} per 3 cm			2.7 A					
^{60}Co	pCi kg^{-1}	121	45 A	2150	46	106		180	164
	mCi km^{-2} per 3 cm	2.9	1.3 A	90	2.0	2.1		4.9	5.4

*Cf. Fig. 3.2.2.

Table 3.2.4.3. Cesium-137 and Cobalt-60 in sediment samples collected at Barsebäck in 1977

Position	Date	Depth in cm	pCi ^{137}Cs kg^{-1}	mCi ^{137}Cs km^{-2}	pCi ^{60}Co kg^{-1}
$55^{o}25'N$ $12^{o}39'E$	June 12	0-3	38 A	1.4 A	
- " -	- " -	3-6	62	2.7	
- " -	- " -	6-9	29 A	1.4 A	
		0-9		5.5	
18	Oct 19	0-3*	1050	12.8	330
"	- " -	3-6	530	6.3	
"	- " -	6-9	166 A	2.0 A	
"	- " -	9-12	-	-	
		0-12		21.1	
30	Dec 13	0-3*	1320	8.8	248
"	- " -	3-6	1060	9.2	
		0-6		18.0	

*cf. also Table 3.2.4.1.

Table 3.2.6.4. Cesium-137 and Cobalt-60 in sediment samples collected at Ringhals in 1977

Position	Date	Depth in cm	pCi ^{137}Cs kg^{-1}	mCi ^{137}Cs m^{-2}	pCi ^{60}Co kg^{-1}
1	July 11	0-3*	230	6.9	
"	- " -	3-6	167	6.2	
"	- " -	6-9	56	2.3	
"	- " -	9-11	107	2.4	
		0-11		Σ 17.5	
3	July 11	0-3*	104	4.4	2150
"	- " -	3-6	89	3.3	
"	- " -	6-9	-	-	
		0-9		Σ 7.7	
4	July 11	0-3*	83	3.2	66
"	- " -	3-6	92	4.0	90
"	- " -	6-9	49	3.0	
		0-9		Σ 10.2	
1	Oct 10	0-3*	320	6.3	106
"	- " -	3-6	168	5.0	
"	- " -	6-9	61	2.1	
"	- " -	9-12	56	2.2	
"	- " -	12-16	-	-	
		0-16		Σ 15.6	
2	Oct 27	0-3*	260	6.1	121
"	- " -	3-6	172	5.9	
		0-6		Σ 12.0	
3	Oct 27	0-3*	200	5.5	188
"	- " -	3-6	158	5.7	72
"	- " -	6-9	38	1.5	
"	- " -	9-12	29	1.3	
		0-12		Σ 14.0	
4	Oct 27	0-3*	102	3.4	164
"	- " -	3-6	108	3.6	83
"	- " -	6-9	35 B	1.2	
		0-9		Σ 8.2	

*cf. also Table 3.2.6.2.

4. FALLOUT NUCLIDES IN THE ABIOTIC ENVIRONMENT

by A. Aarkrog and J. Lippert

4.1. Air

4.1.1. Strontium-90

The "big air sampler" described in Risø Report No. 23[1] has a shunt through which the air volume is determined. As in previous years, both the shunt filter (I) and aliquots cut out of the main filter (II) were analyzed to see whether activity levels were identical in the two filters. As I/II = 1.09 $\pm$ 0.05 (1 SE), we still concluded that the two filters showed the same levels. The mean air activity level for 1977 is reported as the mean of the glass-fibre filter collection and the daily paper-filter sampling: 0.71 $\pm$ 0.02 fCi ^{90}Sr m^{-3}, i.e. 3.4 times the 1976 level. The mean peak activity of the three collections in 1977 was measured in June at 1.44 fCi ^{90}Sr m^{-3}.

Figure 4.1.1 shows the quarterly levels of ^{90}Sr in air since 1957.

4.1.2. Cesium-137

As in 1962-1976, samples of air were collected twice a week by means of the air sampler described in Risø Report No. 23[1]. The filters were measured on a 30 cm^3 Ge(Li) detector[8]. Table 4.1.2 shows the monthly means of the ^{137}Cs determinations (cf. also fig. 4.1.2). The peak value was observed in August. The mean level in 1977 was 3.9 times the 1976 mean. The $^{137}Cs/^{90}Sr$ mean ratio in the air filter was 2.2 in 1977.

The increase in the ^{137}Cs and ^{90}Sr levels in air in 1977 resulted from the global fallout originating from the 4 Mt Chinese test explosion on November 17, 1976.

Table 4.1.1. Strontium-90 in air collected at Risø in 1977

Month	Daily air filters	Monthly air filters (glass-fibre filters)	
	Paper	I	II
Jan	0.129	0.094 A	0.087
Feb	0.166	0.142	0.107±0.001
March	0.21	0.27 A	0.189
April	0.29	0.31	0.28 ±0.02
May	0.89	1.05	1.01
June	1.12	1.58	1.63
July	0.90	1.01	0.93
Aug	1.58	1.30	1.37 ±0.03
Sept	0.86	0.88	0.95
Oct	0.74	0.79	0.91 ±0.06
Nov	0.61	0.61	0.59
Dec	0.54	0.83	0.64
1977	0.67	0.74	0.72

I: the normally used shunt filters.

II: aliquots cut out of the main filters also used for ^{137}Cs determination (cf. table 4.1.2)

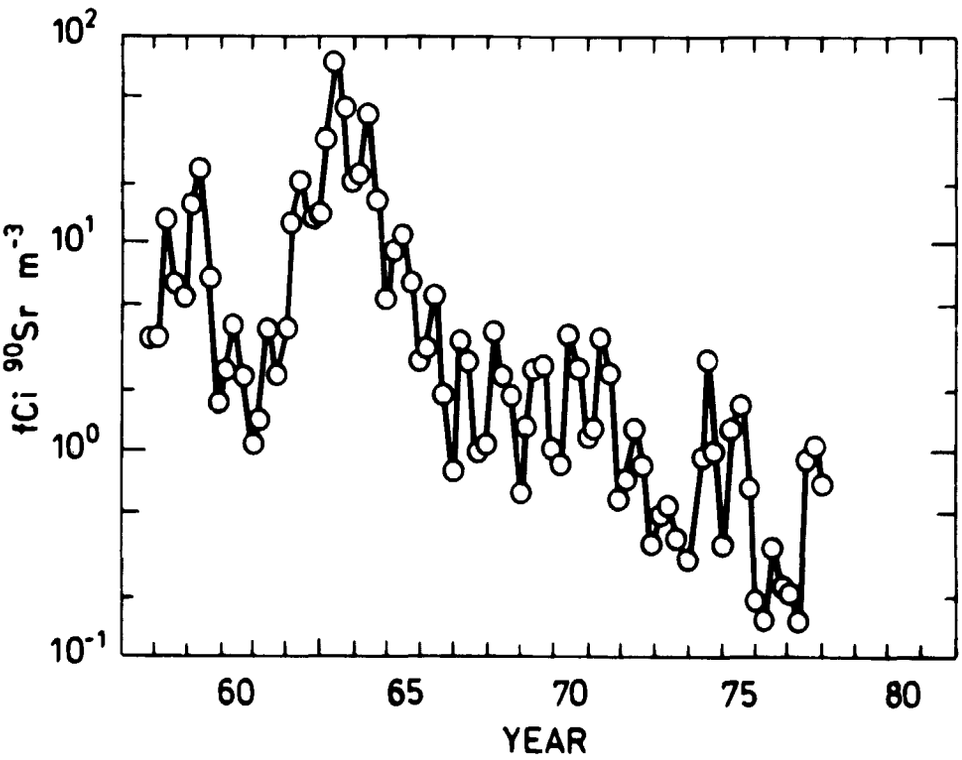

Fig. 4.1.1. Quarterly ^{90}Sr levels in air, 1957-1977.

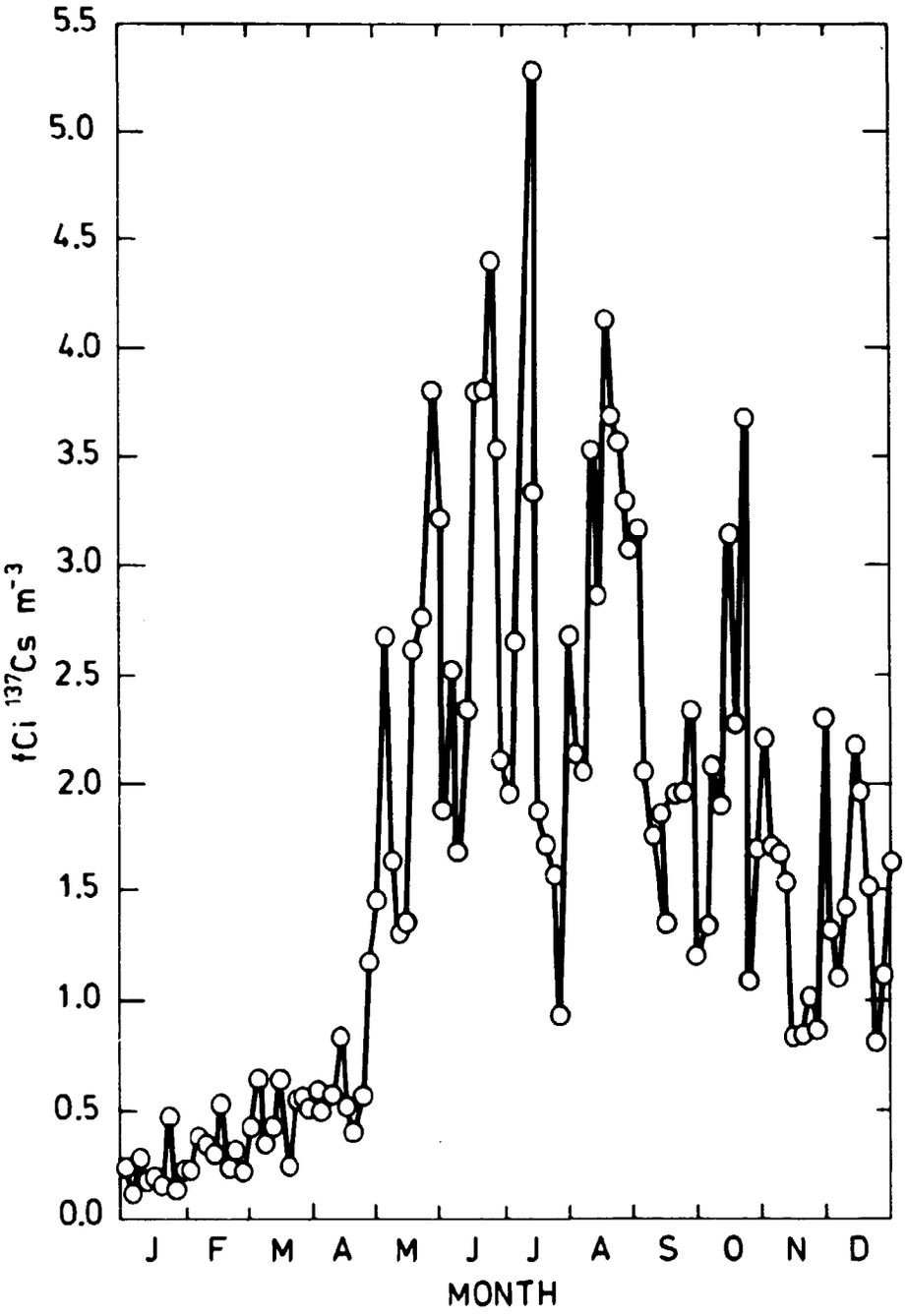

Fig. 4.1.2. Cesium-137 in ground level air at Risø in 1977.

Table 4.1.2. Cesium-137 in glass-fibre air filters collected twice a week at Risø in 1977

Month	pCi ^{137}Cs $10^{-3}m^{-3}$
Jan	0.21±0.04
Feb	0.31±0.04
March	0.48±0.04
April	0.64±0.09
May	2.32±0.30
June	2.91±0.33
July	2.45±0.43
Aug	3.14±0.23
Sept	2.06±0.19
Oct	2.05±0.30
Nov	1.46±0.19
Dec	1.45±0.14
1977	1.62

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

4.1.3. Short-lived γ-emitting nuclides in air and precipitation

On September 17, 1977, China tested a nuclear weapon in the kilotons range in the atmosphere. As shown in fig. 4.1.3, fresh fallout appeared in ground-level air approximately 12 days later, and the peak activities occurred on October 10, i.e., 23 days after the explosion.

Tables 4.1.3.1 and 4.1.3.2 show the concentrations of short-lived γ-emitters in air and rain samples collected at Risø from the end of September to the beginning of November 1977. From these two tables were estimated the washout ratios:

$$W_o = \frac{\text{pCi } l^{-1} \text{ rain}}{\text{fCi } m^{-3} \text{ air}}$$

in table 4.1.3.3. The overall mean of W_o for all nuclides was 0.82. Nuclides such as ^{95}Zr and ^{95}Nb showed lower washout ratios than ^{103}Ru, ^{106}Ru, ^{140}Ba and ^{140}La. The washout ratios also showed a time variation, only the Ce radionuclides deviated from this time variation.

Table 4.1.3.1. Short-lived nuclides in ground-level air samples collected at Risø in 1977 (unit: fCi m^{-3}) (from the Chinese test explosion on 17th September 1977)

Nuclide	Collected 19-22/9	Collected 22-26/9	Collected 26-29/9	Collected 29/9-3/10	Collected 3-6/10	Collected 6-10/10	Collected 10-13/10	Collected 13-17/10	Collected 17-20/10	Collected 20-24/10	Collected 24-27/10	Collected 27-31/10	Collected 31/10-3/11
^{144}Ce	17.3	17.8	21.7	12.6	13.9	22.4	17.3	30.1	23.2	34.8	9.4	14.8	18.7
^{141}Ce	0.6	0.6	2.0	9.1	21.4	49.0	14.7	12.3	19.8	40.2	5.0	7.7	6.3
^{237}U	-	-	-	-	-	-	-	-	-	-	-	-	-
^{239}Np	-	-	-	-	-	-	-	-	-	-	-	-	-
^{140}La	-	-	3.9	20.3	44.5	95.5	23.8	15.4	23.4	44.7	4.8	7.2	5.1
^{131}I	1.1	-	1.6*	8.8*	13.5*	18.9*	4.8*	2.7*	4.1*	6.0*	0.8	1.0	0.8
^{7}Be	111	110	129	69	69	108	84	122	117	225	46	87	100
^{103}Ru	1.9	2.0	3.4	8.6	21.6	59.1	17.5	13.8	22.4	45.2	6.0	9.9	8.8
^{106}Ru	10.6	10.4	13.4	8.4	8.5	13.9	10.0	17.3	13.4	21.0	5.7	9.1	11.3
^{140}Ba	-	-	3.2	19.4	41.6	89.9	22.9	14.1	21.4	43.5	4.7	6.7	4.8
^{132}I	-	-	-	-	-	-	-	-	-	-	-	-	-
^{95}Zr	10.5	9.8	12.7	15.6	20.3	35.0	17.6	22.9	23.9	42.3	7.6	10.9	10.7
^{95}Nb	20.2	20.0	23.9	17.4	18.7	30.0	20.9	32.4	28.7	47.3	10.6	16.2	18.2

*Corrected for a Risø background of ^{131}I estimated at 1 fCi m^{-3}

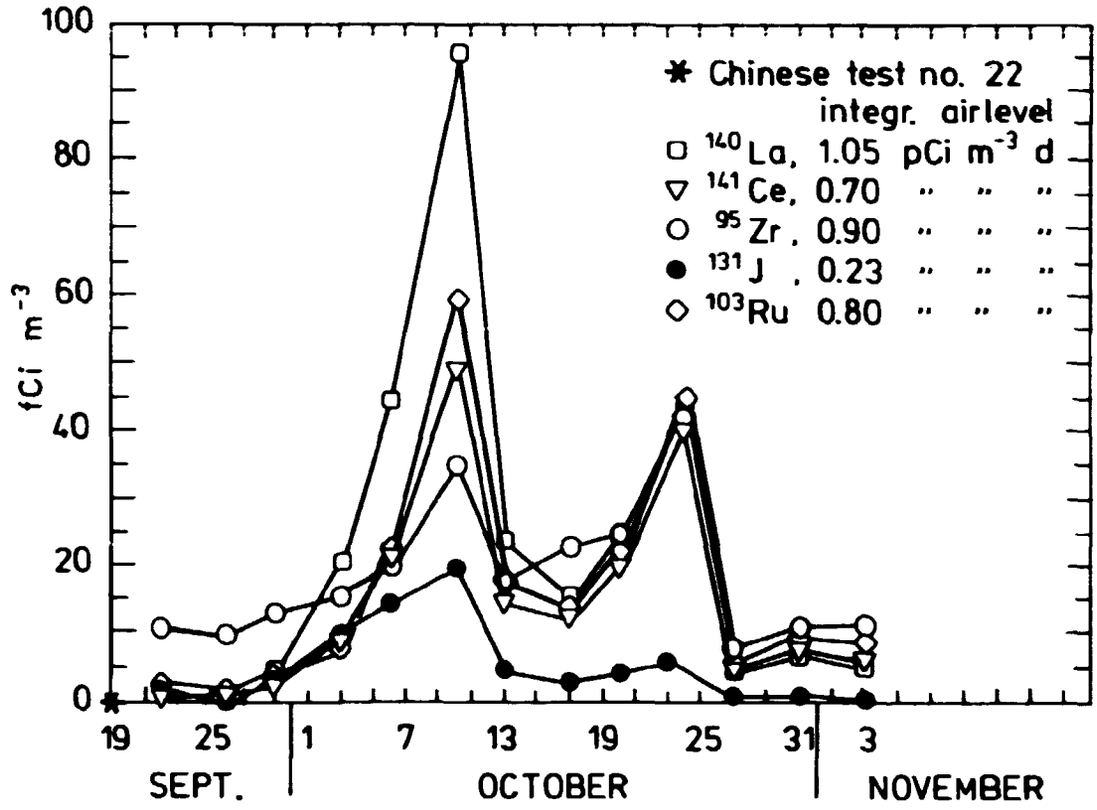

Fig. 4.1.3. Short lived fissions products in airborne debris from the Chineese test explosion 17 September 1977 collected in groundlevel air at Risø, September-October 1977. The time-integrated levels are indicated for the various radionuclides.

Table 4.1.3.2. Short-lived nuclides in rain water collected at Risø in 1977 (pCi l^{-1}) by a 9 m^2 ion exchange collector (from the Chinese test explosion on 17th September 1977)

	Sept 29-Oct 4	Oct 6-Oct 10	Oct 23	Oct 31-Nov 3
^{144}Ce	3.4	17.4	38.8	16.6
^{141}Ce	2.3	16.3	24.9	8.9
^{237}U [a)]	1.1±0.1	3.3±0.3	-	-
^{239}Np [a)]	27.7±2.3	29 ±11	-	-
^{140}La	20.1	133	25.8	11.1
^{131}I	11.1	40	2.3	~0
^{7}Be	25.9	138	93	121
^{103}Ru	7.6	64	14.2	9.8
^{106}Ru	3.6	19.9	12.2	15.6
^{140}Ba	19.8	115	27.2	9.9
^{132}I [a)]	3.1±0.2	6.4±1.2	-	-
^{95}Zr	3.3	18.5	8.1	6.8
^{95}Nb	3.1	18.6	10.4	10.5

[a)] The concentrations of the short-lived nuclides were approximate.

Table 4.1.3.3. Washout factors (W_o) in fresh debris collected in 1977 (cf. tables 4.1.3.1 and 4.1.3.2) $W_o = \frac{\text{pCi } l^{-1} \text{ rain}}{\text{fCi } m^{-3} \text{ air}}$

Precipitation periods	^{7}Be	^{95}Zr	^{95}Nb	^{103}Ru	^{106}Ru	^{131}I	^{140}Ba	^{140}La	^{141}Ce	^{144}Ce	Mean	S.D.
Sept 29-Oct 4	0.38	0.18	0.17	0.50	0.43	1.00	0.65	0.62	0.15	0.26	0.43	0.27
Oct 6-Oct 10	1.28	0.53	0.62	1.08	1.43	2.12	1.28	1.39	0.33	0.78	1.08	0.53
Oct 23	0.41	0.19	0.22	0.31	0.58	0.38	0.63	0.58	0.62	1.11	0.50	0.27
Oct 31-Nov 3	1.21	0.64	0.58	1.11	1.35	-	2.06	2.18	1.41	0.89	1.27	0.56
Mean	0.82	0.39	0.40	0.75	0.96	1.17	1.16	1.19	0.63	0.76		
S.D.	0.49	0.24	0.24	0.41	0.52	0.88	0.67	0.76	0.56	0.36		

The time-integrated air levels of the short-lived fallout nuclides in 1977 were approximately one half of the corresponding values observed in the autumn of 1976, which originated from the Chinese nuclear test on September 26, 1976 (cf. fig. 4.1.3 and Risø Report No. 361)[1].

4.2. Strontium-90 in precipitation

Samples of rain water were collected in 1977 from the State experimental farms (cf. fig. 4.2) in accordance with the principles laid down in Risø Report No. 63, p. 51[1].

Table 4.2.1 shows the results of the ^{90}Sr determinations and tables 4.2.2 and 4.2.3 the analysis of variance of the results.

The maximum concentration in precipitation occurred in July-August, when the mean content in precipitation was 1.10 pCi $^{90}Sr\ l^{-1}$ (cf. also the air measurements in 4.1.1), and the maximum fallout rate also occurred in July-August, 0.107 mCi $^{90}Sr\ km^{-2}$. Tables 4.2.2 and 4.2.3 show that the variation between locations was not significant. The mean levels for ten State experimental farms were 0.38 mCi $^{90}Sr\ km^{-2}$ and 0.63 pCi $^{90}Sr\ l^{-1}$. The fallout rate in 1977 was 3.8 times that observed in 1976.

A comparison between the amounts of precipitation found in the rain gauges used by the Danish Meteorological Institute[9] and the amounts collected in our rain bottles at the same locations in 1977 showed a mean ratio of 1.20 $\pm$ 0.03 (1 SE) between the two sampling systems. The difference between the two systems resulted mainly from evaporation taking place in the Risø rain bottles during the sampling period.

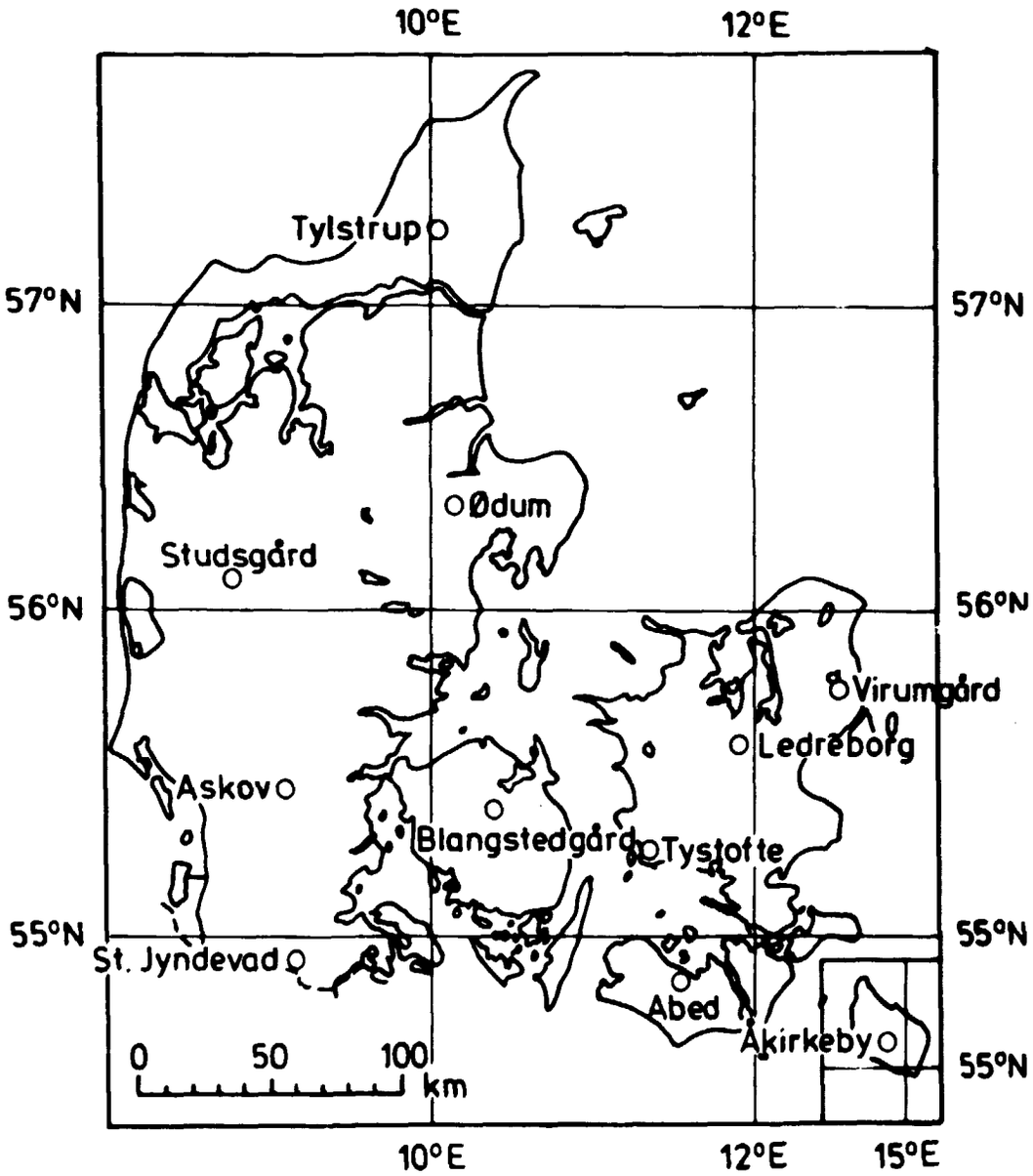

Fig. 4.2. State experimental farms in Denmark.

Table 4.2.1. Strontium-90 fall-out in Denmark in 1977

Period	Unit	Tylstrup	Studs-gård	Ødum	Askov	St. Jyndevad	Blang-stedgård	Tystofte	Virumgård	Abed	Åkirkeby	Ledreborg	Mean*
Jan-Feb	pCi l^{-1}	0.130 A	0.120	0.154 A	0.022	0.041 A	0.094 A	0.116 A	0.047	0.100	0.147	0.029	0.090
	mCi km^{-2}	0.012 A	0.014	0.011	0.003	0.005 A	0.009 A	0.009 A	0.004	0.009	0.010	0.002	0.009
March-April	pCi l^{-1}	0.46	0.51	0.42 A	0.54	0.41	0.39	0.47	0.24	0.38	0.77	1.04	0.47
	mCi km^{-2}	0.047	0.081	0.036 A	0.078	0.033	0.032	0.032	0.024	0.027	0.090	0.037	0.048
May-June	pCi l^{-1}	1.24	0.92	0.88	0.97	0.76	0.94	1.30	0.78	0.78	1.80 A	(1.04)	0.96
	mCi km^{-2}	0.077	0.074	0.041	0.107	0.100	0.065	0.053	0.061	0.061	0.069 A	(0.046)	0.071
July-Aug	pCi l^{-1}	1.53	1.47	1.22	0.91	1.02	0.83	1.50	0.79	0.85	1.26	1.10	1.10
	mCi km^{-2}	0.090	0.106	0.075	0.086	0.066	0.096	0.122	0.083	0.120	0.223	0.094	0.107
Sept-Oct	pCi l^{-1}	0.39	0.30	0.27 A	0.82	0.66	0.41	1.01	0.50	0.61	0.80	(0.55)	0.54
	mCi km^{-2}	0.053	0.046	0.024 A	0.071	0.062	0.023	0.058	0.026	0.038	0.067	(0.036)	0.047
Nov-Dec	pCi l^{-1}	0.68	0.71	0.50	0.63	0.63	0.50	0.73	0.81	0.68	0.65	0.95	0.65
	mCi km^{-2}	0.124	0.168	0.073	0.127	0.136	0.075	0.063	0.074	0.094	0.093	0.071	0.103
1977	pCi l^{-1} $\bar{x}$	0.64	0.60	0.52	0.61	0.57	0.53	0.82	0.53	0.60	0.88	0.76	0.63
	mCi km^{-2} Σ	0.403	0.489	0.260	0.472	0.402	0.300	0.337	0.272	0.349	0.552	0.286	0.384
mm precipitation Σ		633	818	500	773	709	569	411	511	580	627	375	613

*Ledreborg not included in mean. Figures in brackets calculated from VAR $3^{12)}$.

Table 4.2.2. Analysis of variance of ln pCi $^{90}Sr\ l^{-1}$ precipitation in 1977 (from table 4.2.1)

Variation	SSD	f	s^2	v^2	P
Between locations	53.371	5	10.674	68.393	>99.95%
Between months	2.481	10	0.248	1.590	-
Remainder	7.491	48	0.156		

Table 4.2.3. Analysis of variance of ln mCi $^{90}Sr\ km^{-2}$ precipitation in 1977 (from table 4.2.1)

Variation	SSD	f	s^2	v^2	P
Between locations	55.296	5	11.059	78.620	>99.95%
Between months	4.236	10	0.424	3.011	>99.5%
Remainder	6.752	48	0.141		

Tables 4.2.4 shows the quarterly ^{90}Sr levels in precipitation samples collected in ion-exchange columns at Risø in 1976. The total deposition was 0.30 mCi $^{90}Sr\ km^{-2}$ and the mean concentration was 0.73 pCi $^{90}Sr\ l^{-1}$. These figures were compatible with those in table 4.2.1 for East Denmark.

Table 4.2.4. Strontium-90 in rain water collected in ion-exchange column collectors at Risø in 1977 (sampling area 0.325 m^2)

Month	mm	pCi $^{90}Sr\ l^{-1}$	mCi $^{90}Sr\ km^{-2}$
Jan-March	102	0.28	0.029
April-June	80	0.73	0.058
July-Sept	94	0.97	0.092
Oct-Dec	132	0.90	0.118
1977	Σ 408	$\bar{x}$ 0.73	Σ 0.297

4.3. Fresh water

4.3.1. Strontium-90 in ground water

As in previous years[1)], ground water was collected in March from the nine locations selected by the Geological Survey of Denmark. Figure 4.3.1.1 shows the sample locations and table 4.3.1 the results of the ^{90}Sr analyses.

The median level of ^{90}Sr in 1977 was compatible with the values found since 1967 (cf. fig. 4.3.1.2).

As appears from fig. 4.3.1.3, the ^{90}Sr levels in ground water from Feldbak have been around 1.5 pCi m^{-3} in later years but seem now (1978) to decrease. ^{137}Cs was not measurable in 45 l samples of Feldbak water from 1977 and 1978; the levels must have been less than 0.2 pCi ^{137}Cs l^{-1}.

Table 4.3.1. Strontium-90 in ground water collected in March 1977

Location	fCi ^{90}Sr l^{-1}	g Ca l^{-1}
Hvidsten	14 B	0.0720
Feldbak	1732	0.0234
Rømø	12 B	0.0409
Rønne New	2 B	0.0068
Rønne Old	17 B	0.0275
Hasselø	6	0.102
Fåretofte	3	0.131
Kalundborg	14	0.0460
Ravnholt	6	0.0667
Fredericia	9	0.0768
Mean	182	0.0593
Median	10	0.0564

A sample of ground water from Maglekilde in Roskilde contained 13 fCi ^{90}Sr l^{-1} and 0.0813 g Ca l^{-1}

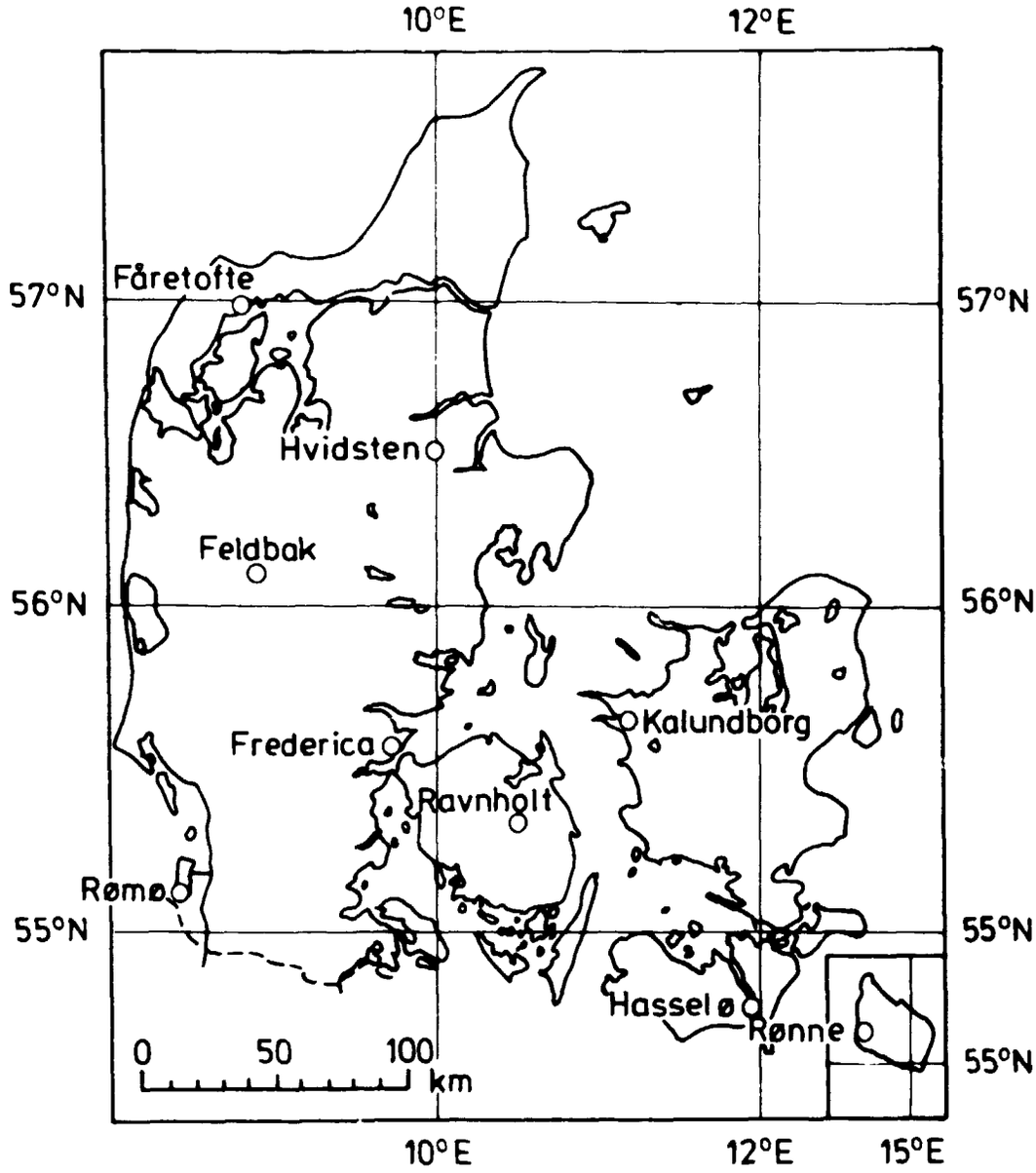

Fig. 4.3.1.1. Ground water sampling locations in Denmark.

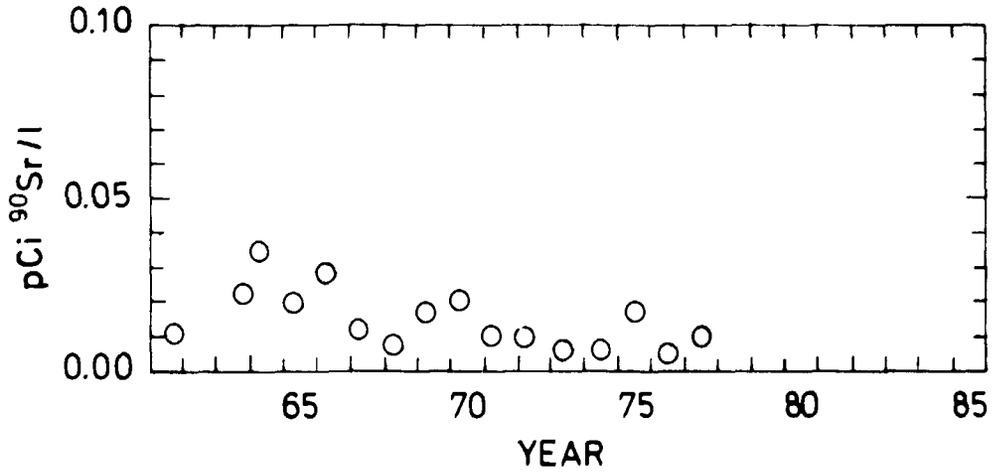

Fig. 4.3.1.2. Median ^{90}Sr levels in Danish ground water, 1961-1977.

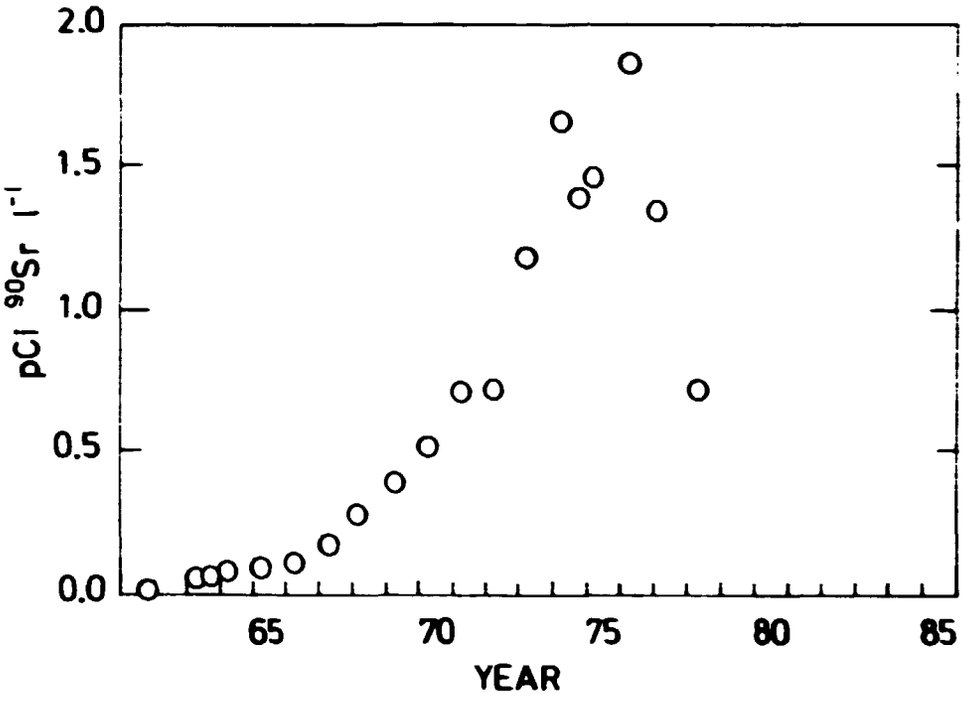

Fig. 4.3.1.3. Strontium-90 in ground water at Feldbæk 1961-1978.

4.3.2. Strontium-90 in fresh water from Danish streams and lakes (fig. 4.3.2)

In March 1977 we repeated the sampling of fresh water from Danish streams and lakes which was first carried out in 1971 (Risø Report No. 265[1]).

The streams contained 0.37 pCi ^{90}Sr l^{-1} in 1971, 0.31 pCi l^{-1} in 1973, 0.33 pCi l^{-1} in 1975 and 0.34 pCi l^{-1} in 1977. The mean levels in the lakes were 1.50, 1.29, 1.34 and 0.80 pCi ^{90}Sr l^{-1} respectively.

The ^{90}Sr levels in Danish streams have been nearly constant since 1971, while the concentrations in lake water have shown a decreasing trend.

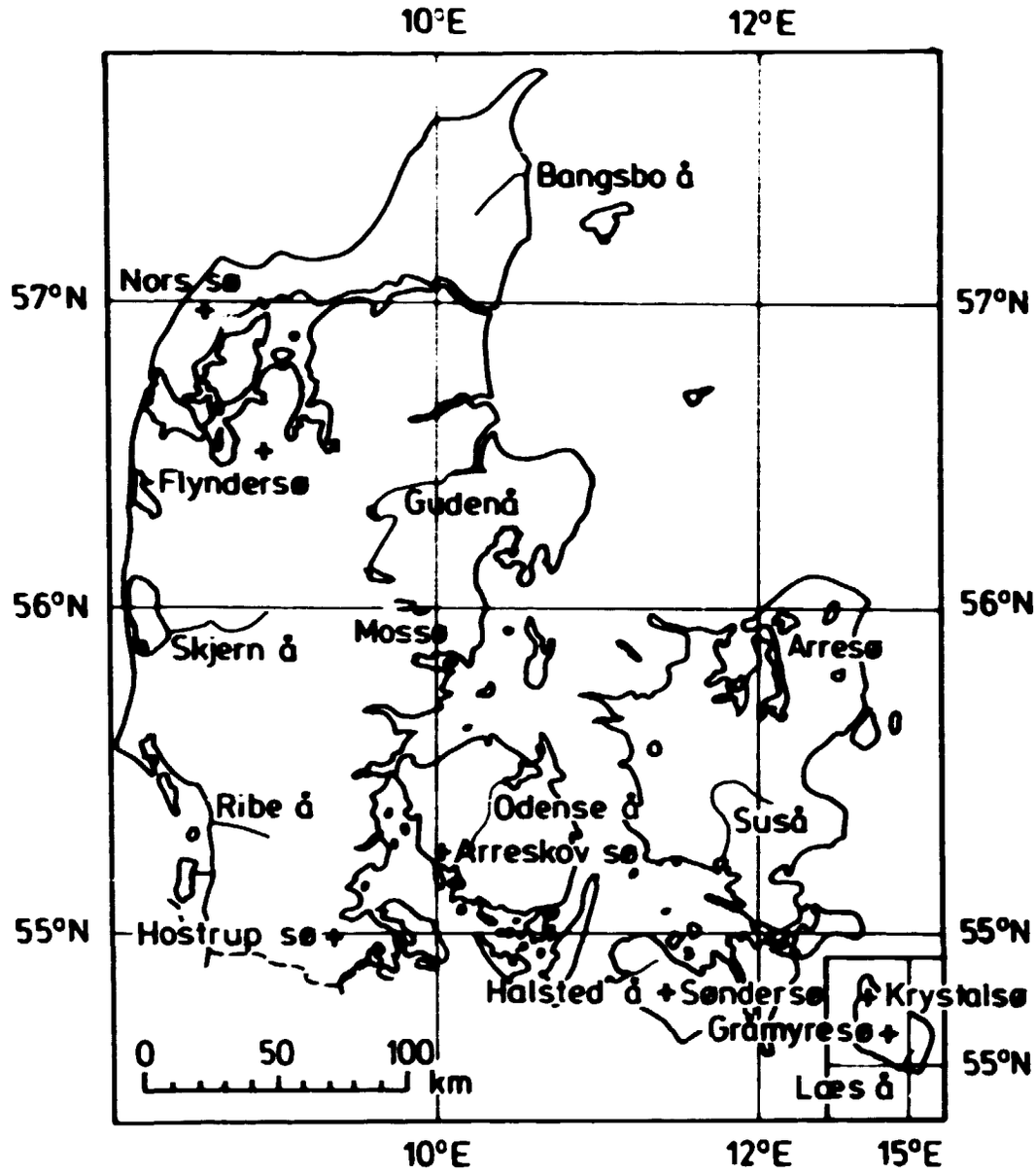

Fig. 4.1.2. Sample locations for fresh water from Danish streams and lakes.

Table 4.3.2. Strontium-90 in Danish streams and lakes in March 1977

Zone		Streams			Lakes		
			pCi ^{90}Sr l^{-1}	g Ca l^{-1}		pCi ^{90}Sr l^{-1}	g Ca l^{-1}
I:	North Jutland	Bangsbo å	0.35	0.056	Norssø	1.55	0.051
II:	East Jutland	Guden å	0.27	0.057	Mossø	0.23	0.057
III:	West Jutland	Skjern å	0.34	0.029	Flyndersø	0.14	0.039
IV:	South Jutland	Ribe å	0.34	0.068	Hostrup sø	1.40	0.021
V:	Funen	Odense å	0.34	0.130	Arreskov sø	0.58	0.081
VI:	Zealand	Suså	0.28	0.114	Arresø	0.67	0.050
VII:	Lolland-Falster	Halsted å	0.28	0.202	Søndersø	1.05	0.093
VIII:	Bornholm	Læså	0.49	0.098	Almindingen sø	0.81	0.033
Mean			0.34	0.094		0.80	0.053

4.4. Strontium-90 and Cesium-137 in sea water in 1977

As in previous years, sea water samples were collected by M/S Fyrholm in the summer and late autumn from inner Danish waters (cf. table 4.4.1 and figs. 4.4.1 and 4.4.2). Furthermore, sea water samples were collected at Barsebäck in the Sound (table 4.4.2), and at Ringhals in the Kattegat (table 4.4.3). The DANA took samples in the North Sea (fig. 4.4.3) and the Kattegat in February (table 4.4.4).

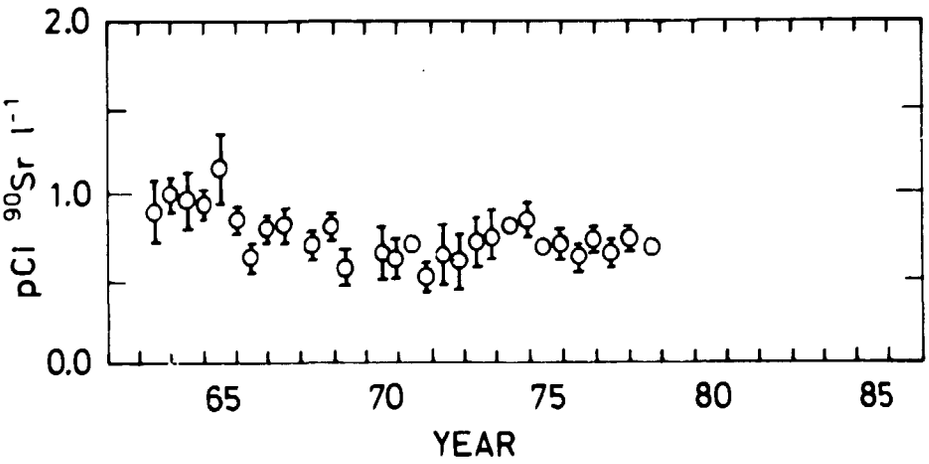

Fig. 4.4.1. Strontium-90 in surface sea-water from inner Danish waters, 1962-1977 (1SD indicated) (from table 4.4.1).

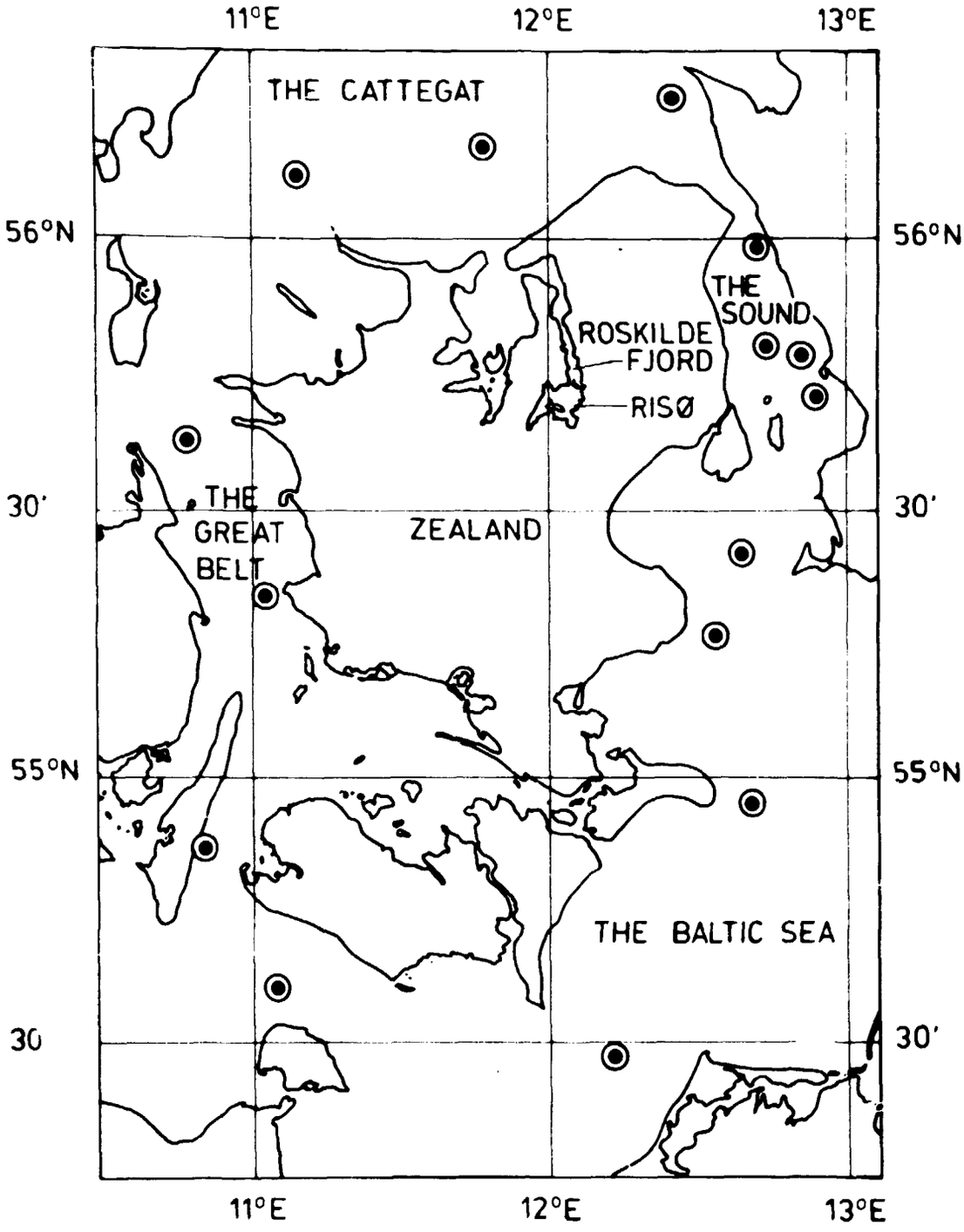

Fig. 4.4.2. Sea-water locations around Zealand.

In Risø Report No. 305[1] it was suggested that the increasing ^{90}Sr and ^{137}Cs levels observed in 1973 in inner Danish waters were the result of contamination from the inflow of water from the North Sea, which was contaminated with ^{137}Cs and ^{90}Sr from nuclear plants in the UK and France.

Table 4.4.1. Strontium-90 and Cesium-137 in sea water collected around Zealand in June and December 1977

	Position		June				December			
	N	E	Depth in m	^{90}Sr pCi l^{-1}	Salinity o/oo	^{137}Cs pCi l^{-1}	Depth in m	^{90}Sr pCi l^{-1}	Salinity o/oo	^{137}Cs pCi l^{-1}
Kullen	56°15'	12°25'	0	0.74	9.4	0.64	0		13.3	0.75
"			21	0.73	33.8	0.82	21		26.2	0.94
Hesselø	56°10'	11°47'	0	0.54	15.2	0.77	0	0.64	25.9	1.16
"			24	0.70	33.3	1.21	24		27.5	1.10
Kattegat SW	56°07'	11°10'	0	0.62	15.1	0.69	0	0.66	24.3	0.94
"			35	0.68	33.0	1.20	30		25.3	1.23
Asnæs rev	55°38'	10°47'	0	0.61	14.9	0.71	0	0.68	20.9	0.86
" "			45	0.62	31.5	1.02	43		25.3	1.20
Halskov rev	55°20'	11°02'	0	0.76	14.3	0.95	0	0.71	19.0	0.93
" "			45	0.71	30.2	1.05	45	0.68	20.5	1.08
Langeland bælt	54°52'	10°50'	0	0.75	12.8	0.82	0	0.81	15.4	0.93
" "			45	0.71	28.4	0.83	45		20.2	0.97
Femern bælt	54°36'	11°05'	0	0.73	8.5	0.65	0	0.71	14.7	0.78
" "			24	0.69	24.3	0.92	23		19.6	0.95
Gedser rev	54°28'	12°13'	0	0.58	8.9	0.84	0	0.77	10.2	0.52
" "			21	0.66	17.0	1.80	25		17.1	0.88
Møen	54°57'	12°41'	0	0.53	7.8	0.61	0	0.82	8.6	0.53
"			20	0.70	7.9	0.75	23		12.6	0.82
The Sound - South	55°25'	12°39'	0	0.79	8.5	0.43 A	0		8.9	0.49
" " "			13	0.46	6.8	0.38 A	12		9.5	0.68
The Sound - North A	55°48'	12°44'	0	0.65	9.0	0.53	0	0.82	8.4	0.58
" " "			26	0.58	32.8	0.58	19		27.8	1.14
The Sound - North B	55°59'	12°42'	0				0	0.79	6.8	0.61
" " "			26	0.66	33.7	1.13	25		30.8	1.26
Mean			Surface	0.66	11.3	0.69		0.74	14.7	0.76
SD				0.09	3.1	0.15		0.07	6.5	0.21
SE				0.03	0.9	0.04		0.02	1.9	0.06
Mean			Bottom	0.66	26.1	0.97		0.68	21.9	1.02
SD				0.08	10.0	0.36			6.5	0.18
SE				0.02	2.9	0.10			1.9	0.05

In accordance with this hypothesis, the ^{90}Sr concentration has increased especially in sea water of high salinity, as shown in the following regression equations:

$$pCi\ ^{90}Sr\ l^{-1} = 0.94 - 0.018\ o/oo \quad (1967\text{-}1971)$$
$$pCi\ ^{90}Sr\ l^{-1} = 0.97 - 0.020\ o/oo \quad (1972)$$
$$pCi\ ^{90}Sr\ l^{-1} = 0.95 - 0.014\ o/oo \quad (1973)$$
$$pCi\ ^{90}Sr\ l^{-1} = 0.93 - 0.010\ o/oo \quad (1974)$$
$$pCi\ ^{90}Sr\ l^{-1} = 0.79 - 0.006\ o/oo \quad (1975)$$
$$pCi\ ^{90}Sr\ l^{-1} = 0.71 - 0.002\ o/oo \quad (1976)$$
$$pCi\ ^{90}Sr\ l^{-1} = 0.71 - 0.0015\ o/oo \quad (1977)$$

The regression analysis showed significant or probably significant regression in all cases except in 1973, 1975, 1976 and 1977.

In analogy with ^{90}Sr, the following regression equations were found for ^{137}Cs in inner Danish waters:

$$pCi\ ^{137}Cs\ l^{-1} = 0.80 - 0.0043\ o/oo \quad (1972)$$
$$pCi\ ^{137}Cs\ l^{-1} = 0.60 + 0.012\ o/oo \quad (1973)$$
$$pCi\ ^{137}Cs\ l^{-1} = 0.54 + 0.018\ o/oo \quad (1974)$$
$$pCi\ ^{137}Cs\ l^{-1} = 0.64 + 0.010\ o/oo \quad (1975)$$
$$pCi\ ^{137}Cs\ l^{-1} = 0.53 + 0.019\ o/oo \quad (1976)$$
$$pCi\ ^{137}Cs\ l^{-1} = 0.41 + 0.027\ o/oo \quad (1977)$$

The regression analysis showed a significant regression in 1974, 1976 and 1977, probably significant in 1973 and 1975, and insignificant in 1972.

According to the above regression lines, the mean levels in Danish surface waters (16 o/oo salinity) were estimated at 0.69 pCi $^{90}Sr\ l^{-1}$ and 0.84 pCi $^{137}Cs\ l^{-1}$ in 1977. The corresponding levels in North Sea water (34 o/oo) were 0.66 and 1.3, respectively, and in Baltic water (9 o/oo) the equations gave 0.70 and 0.65, respectively.

Two samples from the North Sea contained ^{134}Cs (cf. table 4.4.4). The $^{134}Cs/^{137}Cs$ ratios were 0.14 and 0.10. In the Windscale releases in 1974-75 the mean ratio was 0.23. As the halflife of ^{134}Cs is 2.06 y, this may indicate that the contamination of the two sea water samples with radiocesium from Windscale was approximately 2 years old. This estimate is compatible with that of Kupferman et al.[10].

Table 4.4.2. Strontium-90 and Cesium-137 in sea water collected in the Sound (Barsebäck) in 1977 (cf. also 3.2.)

Sampling location (cf. fig. 3.2.1.)	June				December			
	Depth in m	^{90}Sr pCi l^{-1}	^{137}Cs pCi l^{-1}	Salinity o/oo	Depth in m	^{90}Sr pCi l^{-1}	^{137}Cs pCi l^{-1}	Salinity o/oo
33	0	0.73	0.71	8.6	0		0.84	11.3
"	14	0.79	1.17	25.2	15		0.51	9.1
34	0	0.68	0.62	8.4	0	0.79	0.53	9.1
"	15	0.68	1.28	33.2	17		0.82	9.4
35					0		0.46	6.3
"					12		0.54	8.4
18	0	0.70	0.51	8.1				
"	13	0.64	1.45	33.2				
Mean	Surface	0.70	0.61	8.4	Surface	0.79	0.61	9.6
SD		0.03	0.10	0.2			0.20	1.6
SE		0.01	0.06	0.1			0.12	0.9
Mean	Bottom	0.70	1.30	30.5	Bottom		0.62	9.0
SD		0.08	0.14	4.6			0.17	0.5
SE		0.04	0.08	2.7			0.10	0.3

Table 4.4.3. Strontium-90 and Cesium-137 in sea water collected at Ringhals in 1977 (cf. also 3.2.)

Sampling location (cf. fig. 3.2.2.)	July				Oct-Nov		
	Depth in m	^{90}Sr pCi l^{-1}	^{137}Cs pCi l^{-1}	Salinity o/oo	Depth in m	^{137}Cs pCi l^{-1}	Salinity o/oo
0*	0	0.67	1.22	16.5	0	1.01	21.6
"	55	0.67	1.48	33.1	60	1.31	33.6
1	0	0.69	1.16	18.6	0	0.91	20.6
"	23	0.61	1.54	30.6	24	1.63	33.5
2	0	0.39	0.90	18.5	0	0.89	20.5
"	25	0.66	1.34	31.7	22	1.53	33.3
3	0	0.68	0.97	18.6	0	1.04	20.1
"	16	0.71	1.13	25.4	16	1.68	32.2
15	0	0.72	0.78	19.0	0	0.71	19.7
"	10	0.69	1.26	21.2	10	0.76	19.4
Mean	Surface	0.63	1.01	18.2	Surface	0.91	20.5
SD		0.14	0.18	1.0		0.13	0.7
SE		0.06	0.08	0.4		0.06	0.3
Mean	Bottom	0.67	1.35	28.4	Bottom	1.38	30.4
SD		0.04	0.17	5.0		0.38	6.2
SE		0.02	0.07	2.2		0.17	2.8

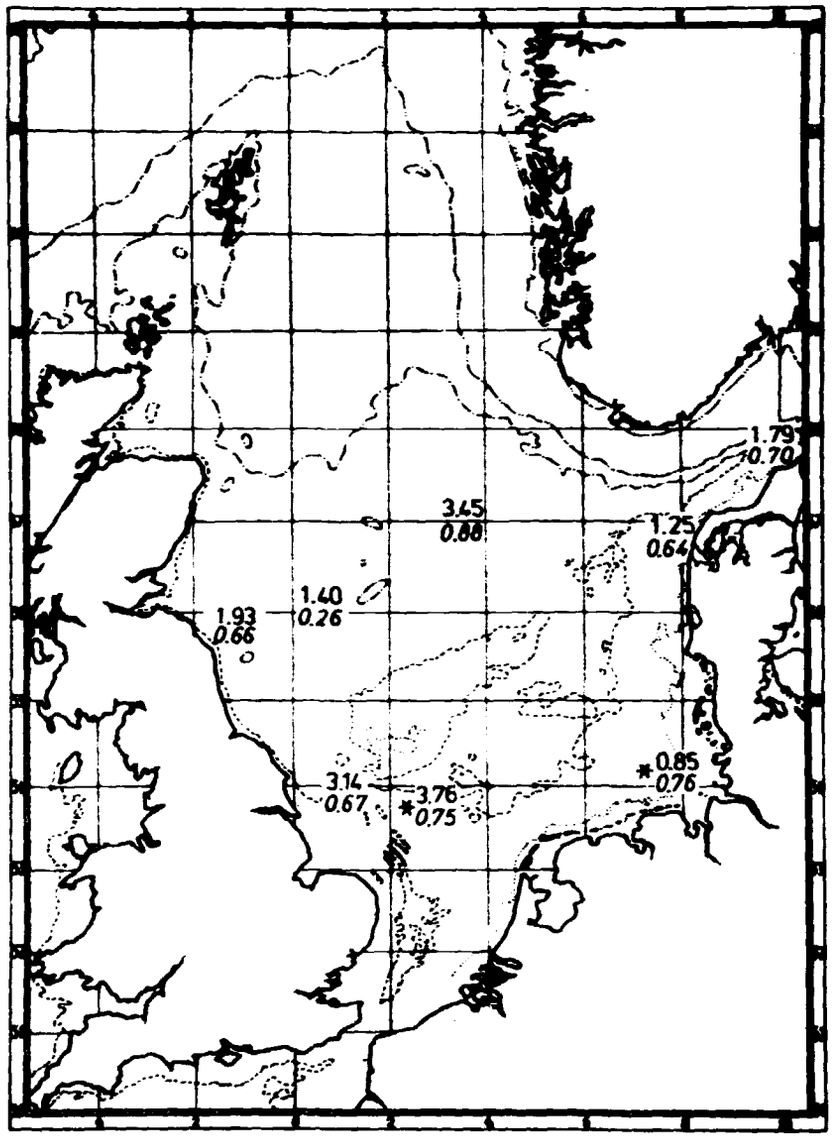

Fig. 4.4.3. Concentrations (pCi l^{-1}) of ^{137}Cs and ^{90}Sr (italics) in surface sea-water collected in February 1977. The asterix indicate locations for sediment samples (cf. table 4.6.2).

Table 4.4.4. Strontium-90 and Cesium-137 in sea water collected by the Dana at the North Sea and the Cattegat in February 1977

Position	^{90}Sr pCi l^{-1}	^{137}Cs pCi l^{-1}	Salinity o/oo
56°42'N 12°00'E	0.56	0.91	20.6
57°28'N 11°27'E	0.53	0.95	23.1
57°40'N 09°45'E	0.70	1.79	32.5
56°43'N 07°58'E	0.64	1.25	33.0
54°09'N 07°51'E	0.76	0.85	33.6
56°56'N 03°30'E	0.88	3.45	34.6
53°40'N 02°56'E*	0.75	3.76	34.3
53°54'N 01°09'E**	0.67	3.14	34.5
56°18'N 00°41'E	0.26	1.40	34.9
55°51'N 01°47'W	0.66	1.93	34.7
Mean	0.64	1.94	31.6
SD	0.17	1.11	5.2
SE	0.05	0.35	1.6

* The sample contained 0.54 pCi ^{134}Cs l^{-1}

**The sample contained 0.30 pCi ^{134}Cs l^{-1}

4.5. Soil samples

During 1977 the sampling error associated with soil sampling was investigated. In normal soil sampling, the samples are collected vertically by means of a 65 mm ϕ auger. As discussed in previous Risø Reports[1)], this method involves a risk of contamination of the deeper low-activity samples by "high" activity surface soil, which is of special relevance to the nuclides with a high vertical activity gradient, such as ^{137}Cs and $^{239,\ 240}Pu$. The Health and Safety Laboratory's trench method of soil sampling (HASL-300)[4)] was applied to this study. Two trenches A and B, each approximately 4 m long, 1.5 m wide and 2 m deep, were dug 1 km south of Risø at Skydebanen. The trenches were approx. 200 m apart. After a careful shaving of one wall in each trench, to avoid contamination from the surface layers, two sets of samples in each trench were cored out

horizontally in the shaved walls at the vertical depths: 5, 10, 15, 20, 25, 30, 40, 50, 65, 80 and 100 cm. The cores were collected with a 65 mm ϕ stainless steel auger to a horizontal depth of 45 cm; two cores were collected at each vertical depth so that the total sample represented a 90 cm long cylinder. The four sets of samples from the two trenches were called A_1, A_2, B_1 and B_2. The samples were analysed for ^{137}Cs (table 4.5.1) and for $^{239, 240}Pu$ (cf. chapter 8).

Table 4.5.1. Cesium-137 in soil samples collected in May 1977 at Skydebanen, Risø

Depth in cm	A_1		A_2		B_1		B_2	
	pCi ^{137}Cs kg^{-1}	mCi ^{137}Cs $km^{-2}cm^{-1}$	pCi ^{137}Cs kg^{-1}	mCi ^{137}Cs $km^{-2}cm^{-1}$	pCi ^{137}Cs kg^{-1}	mCi ^{137}Cs $km^{-2}cm^{-1}$	pCi ^{137}Cs kg^{-1}	mCi ^{137}Cs $km^{-2}cm^{-1}$
2.5	638	4.46	653	5.56	560	4.24	-	-
5	255	2.49	372	4.24	522	5.76	-	-
10	88	0.80	159	1.60	48	0.38	249	2.24
15	53	0.49	10.9	0.122	134	1.16	-	-
20	13.7	0.144	8.4	0.089	30	0.26	17.5	0.19
25	B.D.L.	B.D.L.	4.3	0.042	11.3	0.122	-	-
30	4.3	0.019	3.0	0.035	0.7	0.007	5.6	0.076
40	B.D.L.	B.D.L.	B.D.L.	B.D.L.	0.8	0.009	-	-
50	3.4	0.028	B.D.L.	B.D.L.	8.2	0.073	-	-
65	-	-	-	-	B.D.L.	B.D.L.	-	-
80	-	-	-	-	-	-	-	-
100	-	-	-	-	-	-	-	-

The accumulated ^{137}Cs in mCi km^{-2} in the soil layers was calculated from the mCi $km^{-2}cm^{-1}$ figures by multiplication with 3.75 cm for samples until 5 cm, with 5 cm until 25 cm. For the 30 cm sample 7.5 cm was used and for the remaining samples 10 cm. Hence A_1 became 33.7 mCi ^{137}Cs km^{-2}, A_2: 46.3 and B_1: 48.0. The B.D.L.'s represent the cases when the count rate in the 662 keV ^{137}Cs peak was less than that expected from the contribution of ^{214}Bi to this peak.

Significant amounts of ^{137}Cs were generally not observed below 30 cm. If the natural logarithms of the mCi ^{137}Cs km^{-2} cm^{-1} figures were plotted against the depth, the following regression was found:

$$\text{mCi } ^{137}\text{Cs km}^{-2}\text{ cm}^{-1} = 8.1\ e^{-0.194\ \text{depth in cm.}} \quad \text{(Eq. 4.5).}$$

Table 4.5.2. Anova table with regression of ^{137}Cs in soil from Skydebanen, Risø (Eq. 4.5)

Sources of variation	df	SSD	s^2	v^2	P
Among depth	6	78.12	13.02	22.96	>99.95%
Linear regression	1	77.79	77.79	1226.03	>99.95%
Deviations from regression	5	0.32	0.063	0.11	-
Within groups	16	9.07	0.57	-	-
Total	28	165.30			

As shown in table 4.5.2, the deviations from linear regression are zero and the regression is highly significant.

If the infinite depth integral of Eq. 4.5 was calculated, the accumulated ^{137}Cs at Skydebanen became 42 mCi ^{137}Cs km^{-2}; this agreed with the mean of the estimates shown in table 4.5.1 (42.7 mCi ^{137}Cs km^{-2}). A soil sample collected by the old method of taking vertical cores at Skydebanen near to trench A yielded 51 mCi ^{137}Cs km^{-2} in the upper 50 cm soil (0 - 10 cm: 42.8 mCi km^{-2}, 10 - 20: 7.15, 20 - 30: 0.55, 30 - 40: 0.51, 40 - 50: 0). Compared with the previous samplings at Skydebanen[1], the 1977 samples were lower by a factor of approx. 1.5. The reason may be that the previous samples were collected from a lower-lying part of the area.

The 1977 samples showed that vertical as well as horizontal variations in the levels of ^{137}Cs in soil occur even within a relatively limited area of a few thousand m^2.

4.6. Sediments

North of the outlet from the Waste Treatment Station at Risø (fig. 3.1.2.1), marine sediment samples were collected with a HAPS sampler. Cores down to a depth of approx. 15 cm were analysed by Ge (γ) spectrometry. Table 4.6.1 shows the results, which are equal to those in previous years.

Table 4.6.1. Cesium-137 in sediment samples collected in Roskilde Fjord in 1977 (HAPS) (145 cm^2)

Date	Depth in cm	pCi ^{137}Cs kg^{-1}	mCi ^{137}Cs km^{-2}
March 3	0-15	174	22
May 10	0-15	152±19	26±2
June 2	0-14	142±39	21±4
July 13	0-14	176±12	27±2
August 12	0-14	149±8	23±1
September 23	0-13	120	19
Mean		152	23
S.D.		21	3
S.E.		9	1

In table 4.6.2 the vertical distribution of ^{137}Cs in two sediment cores collected in the North Sea in 1977 is shown. The sample collected northwest of the outlet of the Elbe showed a deposition of 52 mCi ^{137}Cs km^{-2} in the sediment layer 0-18 cm, probably a result of a high sedimentation rate in this area. The other sediment sample contained 16 mCi ^{137}Cs km^{-2} i.e. comparable to the levels in sediments collected in inner Danish waters[1].

Table 4.6.2. Cesium-137 in sediment samples collected by the Dana in the North Sea in February 1977. (Unit: mCi km^{-2} per 3 cm)

Depth in cm	Sandy $53^{\circ}40'N$ $02^{\circ}56'E$ 40 m	Clay $54^{\circ}14'N$ $07^{\circ}46'E$ 32 m
0-3	5.4±0.8	4.4
3-6	6.4±0.2	8.6
6-9	4.6±0.9	10.9
9-12		8.6
12-15		11.6
15-18		7.9

5. DANISH FOOD AND VARIOUS VEGETATION

by A. Aarkrog

5.1. Strontium-90 and Cesium-137 in dried milk from the entire country

As in previous years, monthly samples of dried milk were collected from seven locations in Denmark (cf. fig. 5.1.1) but some of the analyses for ^{137}Cs were performed on pooled quarterly samples.

Table 5.1.1 shows the results of the ^{90}Sr determinations and table 5.1.2 the analysis of variance of the results. As in recent years, the time variation was significant for S.U.; the levels in the last quarter of the year were the highest. The S.U. mean level in 1977 was 2.9 pCi ^{90}Sr (g Ca)$^{-1}$, i.e. 0.85 times the 1976 mean.

Table 5.1.1. Strontium-90 (pCi (g Ca)$^{-1}$) in Danish dried milk in 1977

Month	Hjørring	Århus	Videbæk	Åbenrå	Odense	Ringsted	Lolland Falster Møn	Mean
Jan	2.9	2.7	4.2	3.2	1.62	1.77	1.68 A	2.6
Feb	2.9	2.4	2.9	2.8	1.91	2.1	1.45 A	2.4
March	3.1	2.6	3.2	3.5	1.65	1.68 A	1.50 A	2.5
April	2.8	2.9	3.8	3.3	2.05	1.52 A	1.36	2.5
May	2.3	2.5±0.2	3.3	3.0	1.76±0.02	1.67 A	1.66±0.14	2.3
June	3.3±0.7	3.1±0.5	3.8±1.0	3.9±0.4	2.5 ±0.4	2.0 ±0.4	1.68±0.21	2.9
July	2.9±0.5	3.0±0.4	3.4±0.2	3.9±0.5	2.1 ±0.2	1.65±0.2	1.60±0.27	2.6
Aug	3.2±0.4	3.0±0.4	3.6±0.3	3.8±0.2	2.3 ±0.2	2.1 ±0.4	2.1 ±0.2	2.9
Sept	3.1±0.5	3.8±0.2	4.8±0.3	4.5±0.2	2.8 ±0.4	2.8 ±0.3	2.1 ±0.4	3.4
Oct	3.4±0.2	3.5±0.4	4.8±0.2	4.1±0.5	2.6 ±0.5	2.7 ±0.4	2.0 ±0.3	3.3
Nov	3.7±0.3	3.3±0.2	3.9±0.2	4.2±0.2	2.7 ±0.3	2.8 ±0.0	1.97±0.08	3.2
Dec	3.7	3.6	4.8	5.1	3.2	3.0	2.4	3.7
Mean	3.1	3.0	3.9	3.8	2.3	2.2	1.8	2.9

As 1 litre of milk contains 1.2 g Ca, the mean ^{90}Sr content in Danish milk produced in 1977 was 3.5 pCi l^{-1}.

Table 5.1.2. Analysis of variance of ln pCi ^{90}Sr (g Ca)$^{-1}$ in dried milk in 1977 (from table 5.1.1)

Variation	SSD	f	s^2	v^2	P
Between locations	2.605	11	0.237	18.831	>99.95%
Between months	9.642	6	1.607	127.797	>99.95%
Loc. × months	0.830	66	0.013	0.413	-
Remainder	1.401	46	0.030		

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

Table 5.1.3 shows the results of the ^{137}Cs determinations and table 5.1.4 the analysis of variance of the results. The M.U. mean level in 1977 was 3.1 pCi ^{137}Cs (g K)$^{-1}$, or 1.2 times the 1976 level.

Table 5.1.3. Cesium-137 (pCi (g K)$^{-1}$) in Danish dried milk in 1977

Month	Hjørring	Århus	Videbæk	Åbenrå	Odense	Ringsted	Lolland Falster Møn	Mean
Jan Feb Mar	3.0	1.55	0.92 B	2.2	1.02 A	0.75 A	0.97 A	1.49
Apr	2.3	1.40	1.70	2.8	0.56 B	1.45	1.16 A	1.62
May	2.1	2.2	3.0	1.85	1.58 A	1.91	4.2	2.4
June	4.0	4.9	6.4	5.8	1.75	3.6	0.74 A	3.9
July	3.9	4.6	8.0	7.1	2.7	2.6	1.98	4.4
Aug	4.6	5.9	5.8	7.4	3.4	3.5	2.0	4.7
Sept	5.0	4.8	8.2	6.5	3.7	2.9	1.8	4.7
Oct	5.1	4.6	6.3	6.8	2.3 A	1.72	2.7	4.2
Nov	3.8	3.5	5.1	4.8	2.7	2.6	2.3	3.5
Dec	3.8	3.1	5.5	5.0	3.7	2.4	2.4	3.7
Mean*	3.6	3.3	4.4	4.6	2.1	2.1	1.86	3.1

As 1 litre of milk contains approx. 1.66 g K, the mean ^{137}Cs content in Danish milk in 1977 was estimated at 5.1 pCi l^{-1}.

*Weighted mean.

Table 5.1.4. Analysis of variance of ln ^{137}Cs pCi kg^{-1} in Danish dried milk 1977 (from table 5.1.3)

Variation	SSD	f	s^2	v^2	P
Between locations	18.470	11	1.725	13.990	>99.95%
Between months	10.330	6	1.722	13.967	>99.95%
Remainder	8.136	66	0.123		

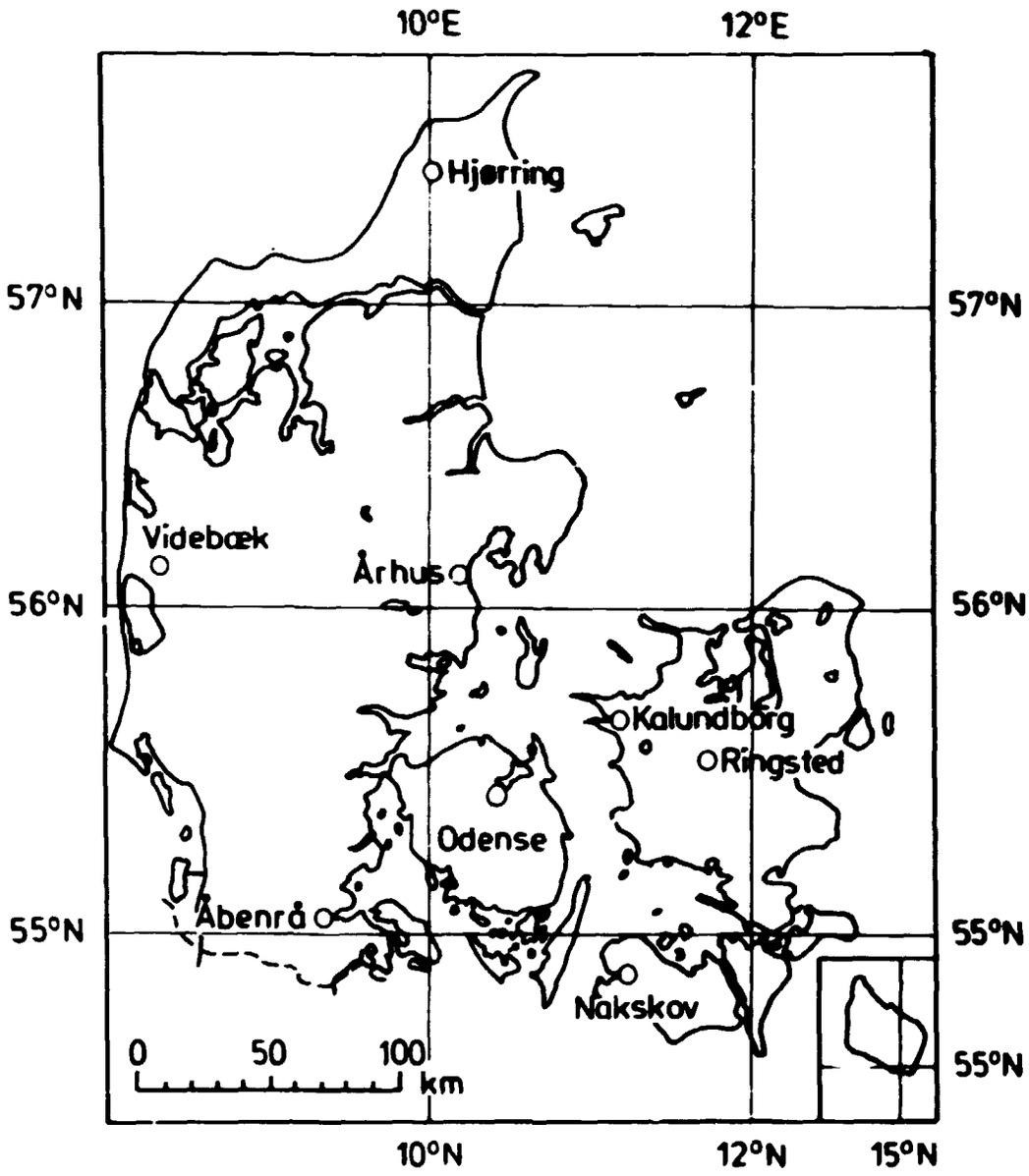

Fig. 5.1.1. Dried milk factories in Denmark.

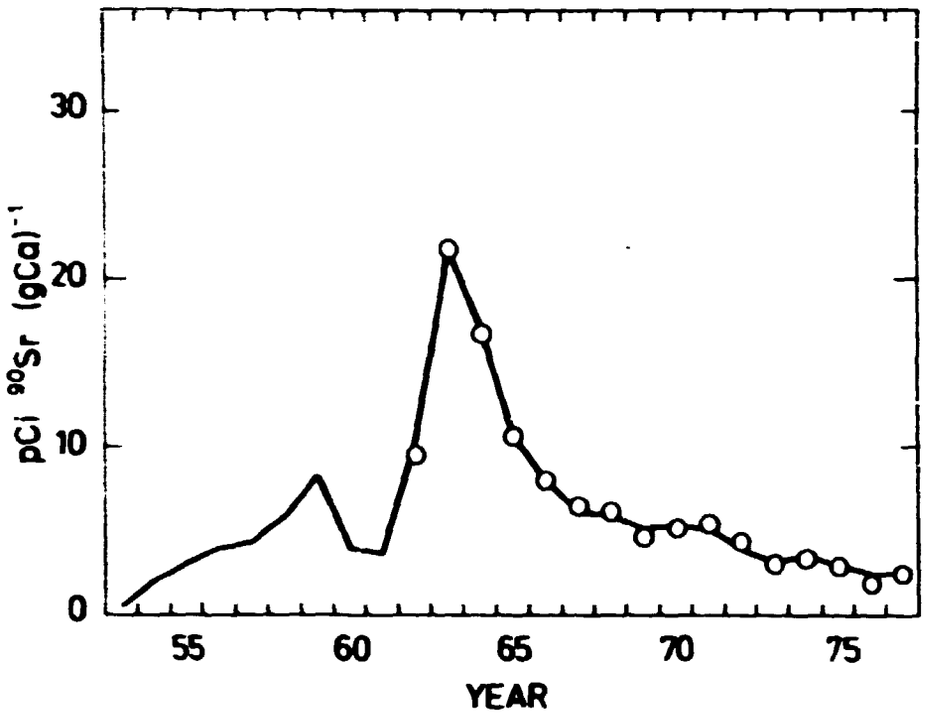

Fig. 5.1.2. Predicted and observed S.U. levels in dried milk from The Islands (May 1962-April 1978).

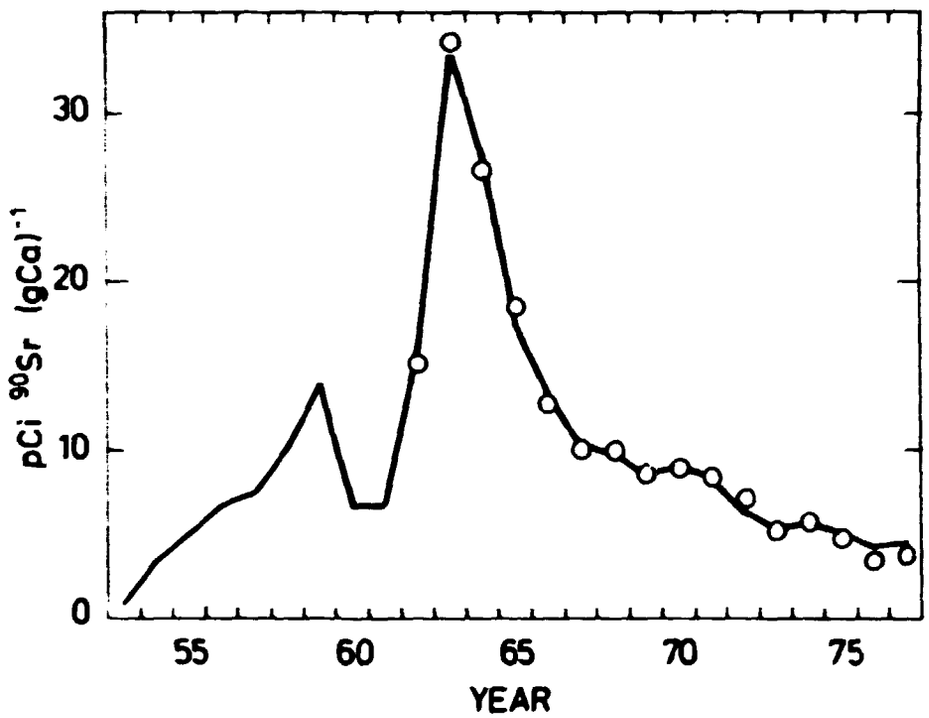

Fig. 5.1.3. Predicted and observed S.U. levels in dried milk from Jutland (May 1962-April 1978).

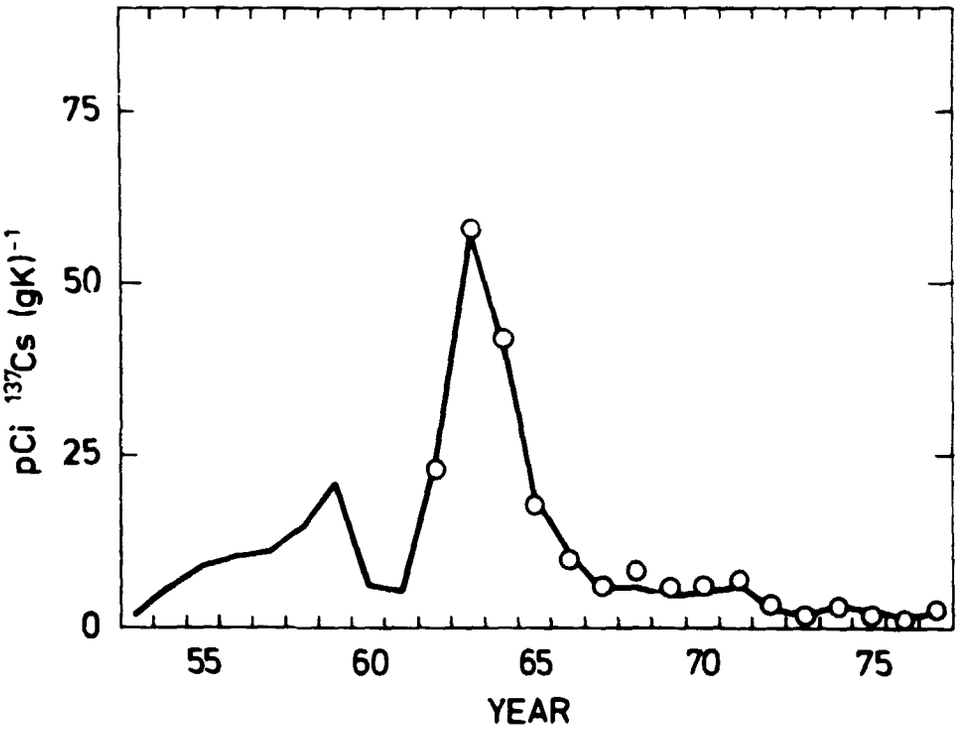

Fig. 5.1.4. Predicted and observed M.U. levels in dried milk from The Islands (May 1962-April 1978).

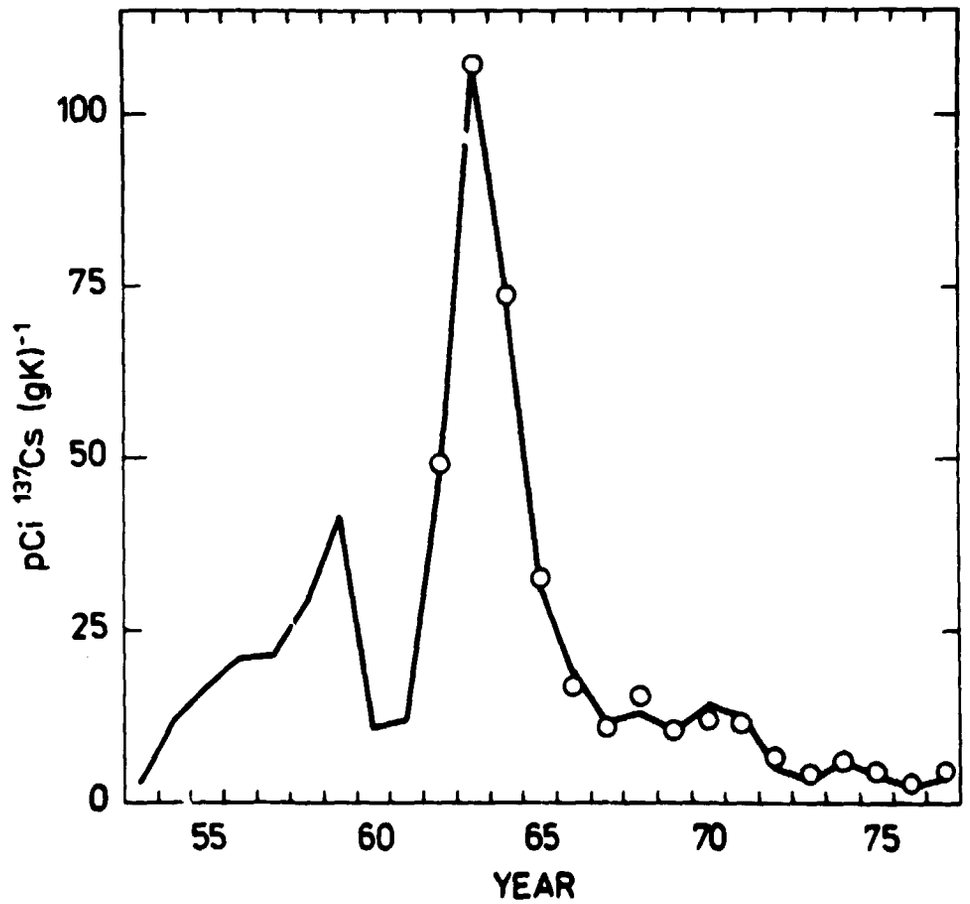

Fig. 5.1.5. Predicted and observed M.U. levels in dried milk from Jutland (May 1962-April 1978).

Figures 5.1.2 - 5.1.5 show the S.U. and M.U. levels in dried milk compared with the predicted values (cf. Appendix C). The observed S.U. levels in 1977 were 0.90 times the predicted, while the observed M.U. levels were 1.27 times the predicted ones.

5.2. Fresh milk

5.2.1. Strontium-90 and Cesium-137 in fresh milk from the entire country

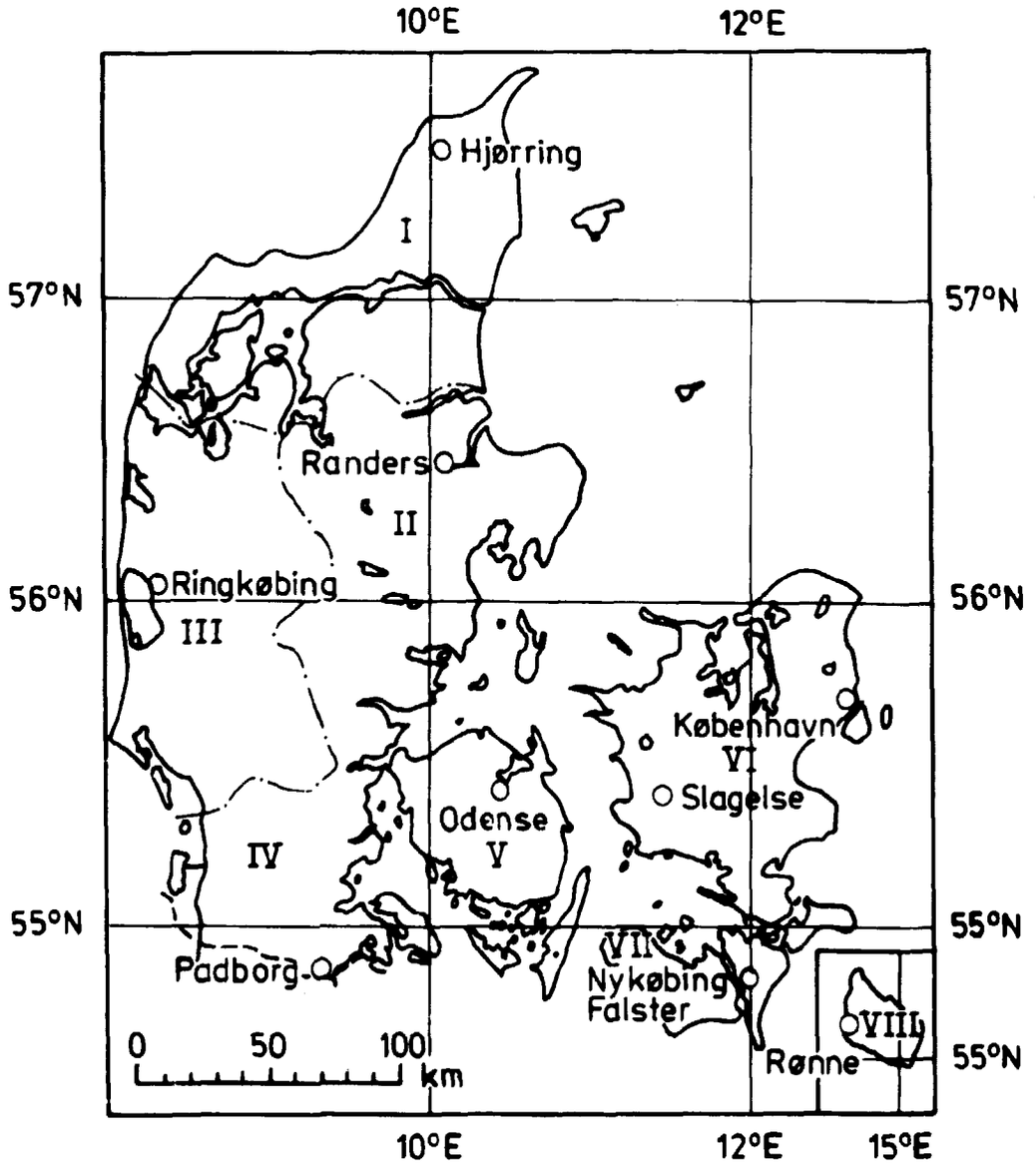

Fig. 5.2.1. Sample locations for fresh milk, bread and total diet.

Table 5.2.1. Strontium-90 and Cesium-137 in fresh milk in 1977

Zone	June 1977			December 1977		
	pCi ^{90}Sr (g Ca)$^{-1}$	pCi ^{137}Cs (g K)$^{-1}$	pCi ^{137}Cs l^{-1}	pCi ^{90}Sr (g Ca)$^{-1}$	pCi ^{137}Cs (g K)$^{-1}$	pCi ^{137}Cs l^{-1}
I: North Jutland	2.7	2.2	3.7	(2.8)	(3.4)	(5.8)
II: East Jutland	2.6±0.1	1.6	2.5	3.4	2.9	4.6
III: West Jutland	3.1±0.4	3.8	6.0	3.6	5.0	8.2
IV: South Jutland	2.6	1.6	2.6	2.8	3.0	4.8
V: Funen	2.2	1.9	3.2	2.4	3.5	5.5
VI: Zealand	2.6	1.5	2.1	2.5±0.1	1.7	2.6
VII: Lolland-Falster	1.9	1.5	2.3	2.1±0.1	3.0	4.6
VIII: Bornholm	2.9	1.4	2.3	3.2±0.0	2.2	3.6
Mean	2.6	1.9	3.1	2.8	3.1	5.0
Copenhagen	3.6	3.0	5.0	2.6±0.1	3.3	5.2
Population-weighted mean	2.9	2.3	3.8	2.9	3.2	5.1
Production-weighted mean	2.7	2.2	3.5	3.1	3.4	5.5

The samples of fresh milk were collected in the eight zones and in Copenhagen (cf. fig. 5.2.1) in connection with the total-diet collection (cf. 5.7).

Table 5.2.1 shows the results of the determinations of ^{90}Sr and ^{137}Cs in consumer milk.

The production-weighted means for ^{90}Sr and ^{137}Cs in Danish consumer milk in 1977 collected in June and December were 2.9 S.U. ($\sim$ 3.5 pCi ^{90}Sr l^{-1}) and 2.8 M.U., or 4.5 pCi ^{137}Cs l^{-1}, respectively.

As observed previously (except in 1973), fresh milk showed lower levels of caesium than the corresponding dried milk. The ^{90}Sr levels in fresh milk were also lower than those in the corresponding dried milk.

5.2.2. Iodine-131 in fresh milk

In the first three weeks of October 1977 milk contained measurable ^{131}I concentrations as a result of the Chinese test explosion on September 17, 1977 (cf. 4.1.3).

In milk samples collected near Risø the integrated level was 65 pCi ^{131}I d l^{-1} (table 5.2.2). This level arose from an integrated air level of 0.194 pCi ^{131}I d m^{-3}. Hence the transfer factor from air to milk became 335 pCi ^{131}I l^{-1} pr. pCi ^{131}I m^{-3}. In 1976 (Risø Report No. 361)[1] the corresponding figure was 357.

Table 5.2.2. Iodine-131 in milk from Risø* in 1977

Date	pCi ^{131}I l^{-1}	
Oct 3-7	10	A
Oct 10	4.9	
Oct 14	2.5	A
Oct 17	2.2	A
Oct 21	1.1	A

*The milk was obtained from the milk-producing farm nearest to Risø.

5.3. Strontium-90 and Cesium-137 in grain from the entire country

As in previous years, grain samples were obtained from the State experimental farms (cf. fig. 4.2). Strontium-90 was determined as previously (Risø Report No. 63[1]), and ^{137}Cs was measured on ashed samples by γ-spectrometry on a Ge detector. In a few samples ^{54}Mn was detectable.

Table 5.3.1 shows the measurements of ^{90}Sr in grain in 1977. 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, 4/5 is produced in eastern Denmark and 1/5 in Jutland. In the calculation of the means in tables 5.3.1 and 5.3.4, Jutland is represented by five rye samples and five wheat samples, while eastern Denmark contributes eight wheat and three rye samples. Thus the means in table 5.3.1 for wheat are a little higher than the production-weighted means for the country. Table 5.3.2 gives the analysis of variance of the S.U. figures and table 5.3.3 that of the pCi ^{90}Sr kg^{-1} grain figures.

Table 5.3.1. Strontium-90 in Danish grain in 1977

	Rye		Barley		Wheat		Oats	
	pCi ^{90}Sr kg^{-1}	S.U.	pCi ^{90}Sr kg^{-1}	S.U.	pCi ^{90}Sr kg^{-1}	S.U.	pCi ^{90}Sr kg^{-1}	S.U.
Tylstrup	20	58	28	56	s:19	s: 53	40	49
Studsgård	40	124	44	97	45	215		
Ødum	20	57	s:21 w:14	s:35 w:26	w:12	w: 32	17	11
Askov	28±1	85±3	29±3	71±7	32±2	105±5	47±0	51±1
St. Jyndevad	39	95	39	78	87	206	67	87
Blangstedgård			18±3	27±1				
Tystofte	14	39	s:19 w: 9	s:34 w:18	s:17 w:15	s: 43 w: 42	34	33
Ledreborg	16±0	44±1	s:19 w:13	s:37 w:24	s:17 w:17	s: 41 w: 28	18±2	26±6
Abed			16±0	30±2	s:14±1 w:13	s: 35±1 w: 38	20±1	23±1
Åkirkeby	28	92	34	75	s:23 w:15	s: 67 w: 59	35	39
Mean	26	74	23	47	25	74	35	40

Table 5.3.2. Analysis of variance of ln S.U. in grain in 1977 (from table 5.3.1)

Variation	SSD	f	s^2	v^2	P
Between species	2.367	3	0.789	8.852	>99.95%
Between locations	12.274	9	1.364	15.298	>99.9%
Spec. x loc.	1.961	22	0.089	3.301	>99%
Remainder	0.459	17	0.027		

Table 5.3.3. Analysis of variance of ln pCi ^{90}Sr kg^{-1} grain in 1977 (from table 5.3.1)

Variation	SSD	f	s^2	v^2	P
Between species	1.238	3	0.413	6.252	>99.5%
Between locations	8.544	9	0.949	14.375	>99.95%
Spec. x loc.	1.453	22	0.066	1.980	-
Remainder	0.567	17	0.033		

Tables 5.3.2 and 5.3.3 show that the variations in S.U. between species and locations were significant. Rye and wheat showed the highest S.U. levels and oats the lowest, while the pCi ^{90}Sr kg^{-1} figures were higher in oats than in the other species.

As in previous years, the variation with location was highly significant; the mean pCi ^{90}Sr kg^{-1} level for grain from Jutland was 1.8 times that in eastern Denmark. The observed pCi ^{90}Sr kg^{-1} levels in grain from 1977 were 1.15 times those predicted (cf. Appendix C).

Table 5.3.4 shows the measurements of ^{137}Cs in grain in 1977. The ^{137}Cs levels in grain from 1977 were 3.3 times the levels in 1976.

For rye, barley and wheat the observed pCi ^{137}Cs kg^{-1} levels in grain from 1977 were 1.10 times those predicted (cf. Appendix C). In the case of oats, the observed values were 1.8 times the predicted ones.

Table 5.3.4. Cesium-137 in Danish grain in 1977

	Rye		Barley		Wheat		Oats	
	pCi ^{137}Cs kg^{-1}	M.U.	pCi ^{137}Cs kg^{-1}	M.U.	pCi ^{137}Cs kg^{-1}	M.U.	pCi ^{137}Cs kg^{-1}	M.U.
Tylstrup	14	3.4	18	3.8	s:13	s:3.2	22	5.2
Studsgård	33	9.7	15	3.3	23	6.3		
Ødum	19	4.8	s:17 w:12	s:3.6 w:3.2	14	3.9	28	8.3
Askov	33	8.7	20	4.9	20	6.2	30	9.2
St. Jyndevad	32	5.1	7	1.7	12	3.3	32	8.5
Blangstedgård			15	3.9				
Tystofte	18	3.7	s:16 w:20	s:3.4 w:3.9	s:22 w:16	s:7.6 w:4.7	18	9.5
Ledreborg	20	9.0	s:17 w:19	s:4.5 w:3.7	s:22 w:22	s:5.3 w:5.0	23	8.6
Abed			21	5.2	s:19 w:15	s:4.5 w:3.7	15	6.2
Åkirkeby	32	9.4	37	6.9	s:22±2 w:14	s:4.4±0.4 w:3.9	38	12.8
Mean	25	6.7	18	4.0	18	4.8	26	8.5

Table 5.3.5. Analysis of variance of ln pCi ^{137}Cs (g K)$^{-1}$ in grain in 1977 (from Table 5.3.4)

Variation	SSD	f	s^2	v^2	P
Between species	3.049	3	1.016	11.860	>99.95%
Between locations	1.942	9	0.216	2.517	>95%
Spec. x loc.	1.885	22	0.086	2.476	-
Remainder	0.277	8	0.035		

Table 5.3.6. Analysis of variance of ln pCi ^{137}Cs kg^{-1} in grain in 1977 (from Table 5.3.4)

Variation	SSD	f	s^2	v^2	P
Between species	1.132	3	0.377	3.826	>97.5%
Between locations	1.240	9	0.138	1.397	-
Spec. x loc.	2.169	22	0.099	2.624	-
Remainder	0.301	8	0.038		

Table 5.3.7. Manganese-54 in Danish grain in 1977. (Unit: pCi kg^{-1})

	Rye	Barley	Wheat	Oats
Tylstrup			3.2	1.6
Studsgård				
Ødum	1.5		4.6	
Askov	1.5	1.6		4.6
St. Jyndevad			1.5	
Blangstedgård				
Tystofte		s:1.3 w:1.5		
Ledreborg		6.6	7.7	
Abed		6.1		6.1
Åkirkeby	1.6			
Mean	1.5	3.8	4.3	4.1

Table 5.3.7 shows the ^{54}Mn levels in Danish grain. The ^{54}Mn was ascribed to the Chinese 4 Mt test on November 17, 1976 (cf. 4.1.2). The ^{54}Mn fallout in May-August 1977 was estimated at 0.06 mCi km^{-2} (the mean air level was 0.35 fCi ^{65}Mn m^{-3}, the scavenging ratio was 1 pCi l^{-1} precipitation pr. fCi m^{-3} air and the precipitation was 171 mm in May-August). From the prediction models for ^{54}Mn in grain based on observations in 1963-65[21], it appears that the observed mean level in 1977 grain (3.4 pCi ^{54}Mn kg^{-1}) was compatible with the predicted one (3.1 pCi ^{54}Mn kg^{-1}).

5.4. Strontium-90 and Cesium-137 in bread from the entire country

In 1977, samples of white bread (75% extraction) and dark rye bread (100% extraction) were collected all over the country in June, and ^{90}Sr and ^{137}Cs were determined on pooled samples. The ^{137}Cs determinations were carried out on the ash by Ge γ-spectroscopy.

Table 5.4.1 shows 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 ^{90}Sr and 50% of the ^{137}Cs found in wheat grain[1], while rye flour is 100% extraction. Hence we can compare the 1977 bread levels with the 1976 grain levels (cf. table 5.4.2).

Table 5.4.1. Strontium-90 and Cesium-137 in Danish bread collected in June 1977

	Rye bread				White bread			
	pCi ^{90}Sr kg^{-1}	S.U.	pCi ^{137}Cs kg^{-1}	M.U.	pCi ^{90}Sr kg^{-1}	S.U.	pCi ^{137}Cs kg^{-1}	M.U.
Jutland	13.1	5.3	9.2	2.2	3.9	2.4	1.9	1.6
Islands	11.7	3.9	9.2	2.3	3.5	1.6	1.8	1.2
Mean	12.4	4.6	9.2	2.2	3.7	2.0	1.8	1.4
Copenhagen	9.5	4.8	8.0	2.4	3.0	0.8	3.7	2.1
Population-weighted mean	11.7	4.8	8.9	2.3	3.5	1.7	2.4	1.6

Table 5.4.2. A comparison between ^{90}Sr and ^{137}Cs levels in bread and grain in 1977

Nuclide	Species	Bread activity in June 1977 calculated as grain in pCi kg^{-1} (cf. text)	Activity in grain from harvest 1976[1] pCi kg^{-1}	"Bread"/grain ratio
^{90}Sr	Wheat	23.6	17	1.4
	Rye	15.8	22	0.7
^{137}Cs	Wheat	6.5	4.8	1.4
	Rye	12.0	12	1.0

5.5. Strontium-90 and Cesium-137 in potatoes from the entire country

The samples of potatoes were collected in September from ten of the State experimental farms (cf. fig. 4.2) and analysed for ^{90}Sr and ^{137}Cs (γ-spectroscopy of bulked samples of the ash).

Table 5.5.1 shows the ^{90}Sr and ^{137}Cs contents in potatoes. The mean contents for the country were 1.6 pCi ^{90}Sr kg^{-1}, or 35 S.U., and 4.6 pCi ^{137}Cs kg^{-1}, or 1.0 M.U. The ^{90}Sr levels were similar to those in 1976, while the ^{137}Cs concentrations were approx. twice as high in 1977.

Table 5.5.1. Strontium-90 and Cesium-137 in Danish potatoes in 1977

	pCi ^{90}Sr kg^{-1}	S.U.	pCi ^{137}Cs kg^{-1}	M.U.
Tylstrup	1.44±0.10	45±5		
Studsgård	1.15±0.03	59±0		
Ødum	2.26±0.16	45±3	5.8	1.3
Askov	2.08±0.16	35±2		
St. Jyndevad	1.70±0.11	33±1		
Blangstedgård	1.33±0.05	24±3		
Tystofte	1.16±0.12	26±3		
Ledreborg	0.72±0.14	16±4	3.4	0.7
Abed	2.34±0.08	18±1		
Åkirkeby	1.97±0.73	46±17		
Mean	1.62	35	4.6	1.0

5.6. Strontium-90 and Cesium-137 in vegetables and fruit from the entire country

In 1977, as in previous years, vegetables and fruit were collected in the autumn from eight larger provincial towns, one in each of the eight zones.

Table 5.6.1. Strontium-90 in vegetables and fruits collected in September 1977

Zone	Cabbage		Carrot		Peas		Apples	
	pCi ^{90}Sr kg^{-1}	S.U.	pCi ^{90}Sr kg^{-1}	S.U.	pCi ^{90}Sr kg^{-1}	S.U.	pCi ^{90}Sr kg^{-1}	S.U.
I: North Jutland	13.8	36	7.9	25			1.52	41
II: East Jutland	9.5	34	16.5	52	5.7	16	0.66	17
III: West Jutland	7.8	18	19.6	59			1.09	28
IV: South Jutland	8.0	18	14.1	39			0.55	12
V: Funen	9.8	22	5.7	30			0.79	16
VI: Zealand	8.7	17	7.4	24	1.4	8	0.89	19
VII: Lolland-Falster	4.6	9	7.9	21			0.51	11
VIII: Bornholm	6.4	17	5.8	17			0.81	14
Mean	8.6	21	10.6	33	3.55	12	0.85	20
Copenhagen	5.8	11	4.0	15	-	-	0.45	10
Population-weighted mean	8.3	20	9.9	32	-	-	0.78	19

Table 5.6.2. Cesium-137 in Danish vegetables and fruits in 1977

	Cabbage		Carrot		Peas		Apples	
	pCi ^{137}Cs kg^{-1}	M.U.	pCi ^{137}Cs kg^{-1}	M.U.	pCi ^{137}Cs kg^{-1}	M.U.	pCi ^{137}Cs kg^{-1}	M.U.
Jutland	2.3	0.9	3.1	1.2	B.D.L.	B.D.L.	3.5	2.2
The Islands	2.1	1.0	2.1	1.1	3.2	0.2	4.3	3.6
Mean	2.2	1.0	2.6	1.2	1.6	0.1	3.9	2.9

The γ-measurements were performed on bulked ash samples representing the entire country (cf. table 5.6.2).

The highest ^{90}Sr levels (pCi kg^{-1}) were found in carrots, the lowest in apple.

Table 5.6.3 shows a calculation of the mean contents of ^{90}Sr and ^{137}Cs in Danish vegetables collected in 1977. The levels are the population-weighted means.

The 1977 levels in Danish fruit were calculated from apples and the mean levels in Danish fruit were thus 0.8 pCi ^{90}Sr kg^{-1} and 3.9 pCi ^{137}Cs kg^{-1}. The observed pCi ^{90}Sr kg^{-1} levels in vegetables and fruits in 1977 were 0.94 times those predicted (cf. Appendix C). In the case of ^{137}Cs, the observed values were 1.8 times the predicted ones.

Table 5.6.3. Calculated ^{90}Sr and ^{137}Cs mean levels in vegetables in 1977

Daily intake in g	Species	pCi ^{90}Sr kg^{-1}	S.U.	pCi ^{137}Cs kg^{-1}	M.U.
50	Leaf vegetables (cabbage)	8.3	20	2.2	1.0
30	Root vegetables (carrot)	9.9	32	2.6	1.2
40	Pea	3.6	12	1.6	0.1
120	Vegetables total	7.1	20.3	2.1	0.75

5.7. Strontium-90 and Cesium-137 in total diet from the entire country

In 1977 total-food samples representing an average Danish diet according to E. Hoff-Jørgensen (cf. Appendix B in Risø Report No. 63[1]) were collected from eight towns each representing one of the eight zones (cf. fig. 5.2.1) and from Copenhagen. The sampling took place as previously in June and December.

Table 5.7.1. Strontium-90 and Cesium-137 in Danish total diet collected in June 1977

Zone		pCi ^{90}Sr (g Ca)$^{-1}$	pCi ^{90}Sr day^{-1}	g Ca day^{-1}	pCi ^{137}Cs (g K)$^{-1}$	pCi ^{137}Cs day^{-1}
I:	North Jutland	4.3±0.3	7.3±0.5	1.68±0.03	2.00	8.3
II:	East Jutland	4.4±0.6	6.6±0.8	1.49±0.01	3.39	13.1
III:	West Jutland	5.0±0.7	7.4±0.9	1.48±0.01	2.89	11.9
IV:	South Jutland	4.0±0.6	6.1±0.8	1.52±0.02	1.72	6.6
V:	Funen	3.6±0.0	5.4±0.1	1.51±0.02	1.58	6.6
VI:	Zealand	3.6±0.4	6.0±0.7	1.67±0.01	1.56	6.0
VII:	Lolland-Falster	3.0±0.0	5.8±0.0	1.91±0.01	1.87	6.5
VIII:	Bornholm	4.0±0.4	6.4±0.6	1.59±0.01	1.27	4.9
Mean		4.0	6.4	1.61	2.03	8.0
Copenhagen		3.3±0.2	6.2±0.4	1.89±0.00	2.14	8.1
Population-weighted mean		3.9	6.4	1.67	2.27	8.9

Table 5.7.2. Strontium-90 and Cesium-137 in Danish tot.l diet collected in December 1977

Zone		pCi ^{90}Sr (g Ca)$^{-1}$	pCi ^{90}Sr day^{-1}	g Ca day^{-1}	pCi ^{137}Cs (g K)$^{-1}$	pCi ^{137}Cs day^{-1}
I:	North Jutland	4.5±0.1	7.3±0.5	1.64±0.06	5.01	17.9
II:	East Jutland	4.0±0.2	6.1±0.4	1.52±0.03	4.66	16.2
III:	West Jutland	4.7±0.3	7.0±0.5	1.50±0.01	3.94	15.1
IV:	South Jutland	3.9±0.5	5.9±0.6	1.51±0.03	3.44	11.6
V:	Funen	3.6±0.0	6.0±0.5	1.64±0.11	3.27	12.3
VI:	Zealand	3.5±0.4	6.0±0.7	1.68±0.01	3.27	12.7
VII:	Lolland-Falster	3.3±0.3	5.8±0.1	1.79±0.14	2.50	9.7
VIII:	Bornholm	3.9±0.3	6.3±0.6	1.61±0.02	3.80	14.3
Mean		3.9	6.3	1.61	3.74	13.7
Copenhagen		3.3±0.2	5.8±0.1	1.76±0.14	2.25	8.5
Population-weighted mean		3.8	6.2	1.64	3.49	12.9

Tables 5.7.1 and 5.7.2 show the results. The diet levels from Jutland were higher than those from the Islands.

Figure 5.7.1 show the zone mean S.U. levels (not population-weighted) in total diet compared with the predicted values (cf. Appendix C).

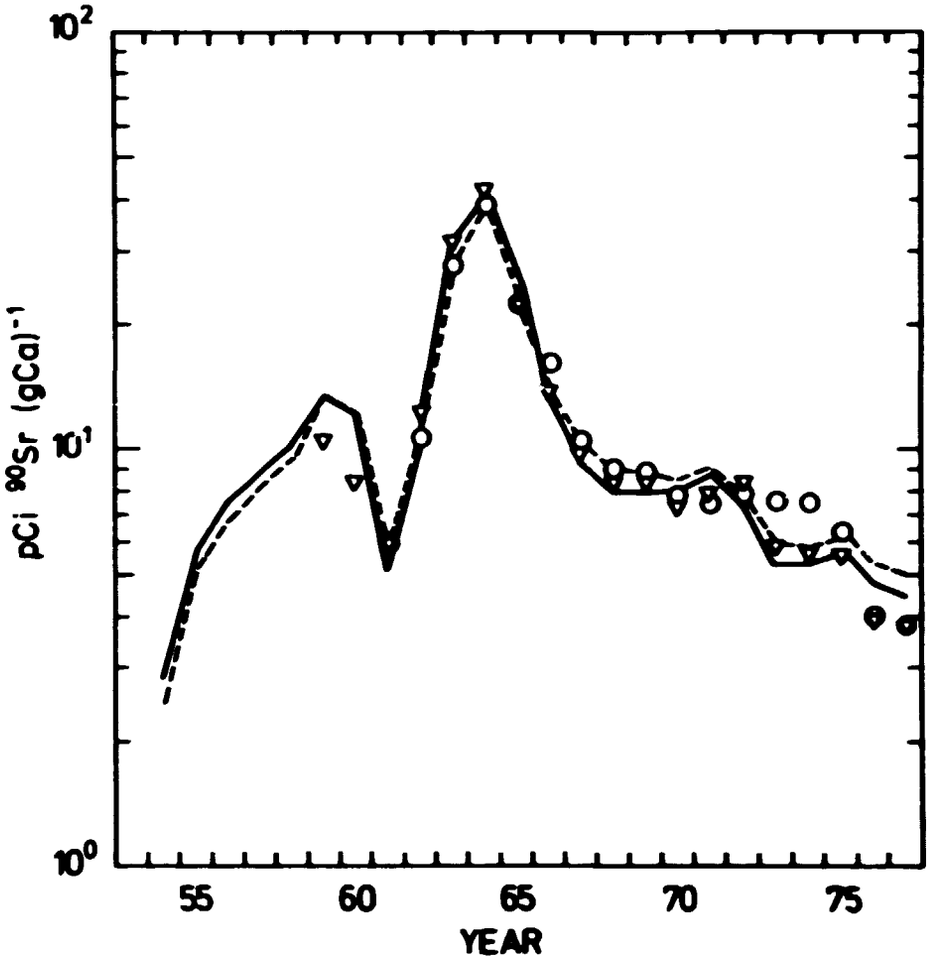

Fig. 5.7.1. Predicted and observed ^{90}Sr levels in the Danish total diet. The dotted curve represents the predicted values for "Diet C" (cf. Tables 5.7.1 and 5.7.2) and the circles are the corresponding observed values. The unbroken curve represents the predicted values for "Diet P" (cf. Table 5.9.3), and the triangles the corresponding observed values.

The 1977 levels in the total diet were approx. 15% higher than the 1976 levels.

From the total-diet sampling it is possible to estimate the mean levels of ^{90}Sr and ^{137}Cs in the Danish diet in 1977. For the period January-March 1977, the ^{90}Sr level in the total diet is assumed to have been equal to that measured in December 1976, Risø Report No. 361[1]. For the period April-September we assume the level to have corresponded to that measured in June 1977. The December 1977 figures are taken to represent the last three months of the year. The population-weighted mean of ^{90}Sr in total-diet samples was 3.4 pCi ^{90}Sr (g Ca)$^{-1}$ in December 1976. Hence the mean content in the total diet in 1977 was 3.8 pCi ^{90}Sr (g Ca)$^{-1}$, or 6.1 pCi ^{90}Sr (day)$^{-1}$.

Similarly, the ^{137}Cs content in the Danish diet in 1977 was estimated to be 10.4 pCi ^{137}Cs (day)$^{-1}$ or 2.7 pCi ^{137}Cs (g K)$^{-1}$.

5.8. Strontium-90 and Cesium-137 in miscellaneous foodstuffs

5.8.1. Strontium-90 and Cesium-137 in meat

Pork and beef samples were collected in Copenhagen in three large shops in June and November. Table 5.8.1 shows the results. As compared with 1976, the mean levels were nearly unchanged in 1977.

Table 5.8.1. Strontium-90 and Cesium-137 in Danish meat collected in Copenhagen in 1977

Month	Pork				Beef			
	pCi ^{90}Sr kg^{-1}	S.U.	pCi ^{137}Cs kg^{-1}	M.U.	pCi ^{90}Sr kg^{-1}	S.U.	pCi ^{137}Cs kg^{-1}	M.U.
June	0.47	4.6	9.5	2.9	0.76	5.3	9.2	3.2
November	0.28	2.7	37	9	0.33	2.2	51	13
Mean	0.38	3.6	23	6	0.54	3.8	30	8

5.8.2. Strontium-90 and Cesium-137 in fish

Fish samples were collected in the North Sea together with the sea-water samples (table 4.4.4). Table 5.8.2.1 shows the results. Furthermore, samples of fish from shops in Roskilde were analyzed (table 5.8.2.2). The mean levels of the two samplings were 1.0 pCi $^{90}Sr\ kg^{-1}$ and 84 pCi $^{137}Cs\ kg^{-1}$.

Table 5.8.2.1. Strontium-90 and Cesium-137 in fish caught by the Dana in the North Sea in 1977

Species	Position Lattitude	Longitude	Date	pCi $^{90}Sr\ kg^{-1}$	S.U.	pCi $^{137}Cs\ kg^{-1}$	M.U.	S.U. in bone
Herring*	54°22'N	07°49'E	Feb 8	1.40	0.21	87	20	-
Herring*	53°58'N	03°55'E	Feb 12	0.63	0.12	142	39	-
Sprat*	54°22'N	07°49'E	Feb 8	1.46	0.26	34	15	-
Cod	56°00'N	01°26'W	Feb 19	1.77	0.40	141	33	0.23
Cod	56°12'N	02°06'E	Feb 23	1.04	0.63	161	38	0.68
Flounder	56°33'N	06°49'E	Feb 6	1.66	1.81	84	28	0.37
Flounder	53°57'N	03°49'E	Feb 12	0.70	0.68	33	10	0.45
Mean				1.24	0.59	97	26	0.43

*including bone.

Table 5.8.2.2. Strontium-90 and Cesium-137 in fish purchased in Roskilde in December 1977

	pCi $^{90}Sr\ kg^{-1}$	S.U.	pCi $^{137}Cs\ kg^{-1}$	M.U.	S.U. in bone
Herring	0.42	0.74	73	20	0.24
Cod	1.00	1.25	92	26	0.65
Flounder	0.91	2.14	47	12	0.37
Mean	0.78	1.38	71	19	0.42

5.8.3. Strontium-90 and Cesium-137 in various foods

Eggs were collected in Copenhagen in August 1977; they contained 0.91 pCi $^{90}Sr\ kg^{-1}$ (1.7 S.U.) and 0.33 pCi $^{137}Cs\ kg^{-1}$ (0.54 M.U.).

5.9. Estimate of the mean contents of ^{90}Sr and ^{137}Cs in the human diet in Denmark in 1977

5.9.1. The annual quantities

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

5.9.2. Milk and cream

The ^{90}Sr and ^{137}Cs 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 3.5 pCi ^{90}Sr kg^{-1} and 5.1 pCi ^{137}Cs kg^{-1}.

5.9.3. Cheese

One kg of cheese contains approx. 8.5 g Ca and 1.2 g K. The ^{90}Sr and ^{137}Cs 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). One kg of cheese appeared to contain 24.6 pCi ^{90}Sr and 3.7 pCi ^{137}Cs.

5.9.4. Grain products

Tables 5.8.1 and 5.9.2 show the estimates of ^{90}Sr and ^{137}Cs, respectively, in grain products consumed in 1977. From these tables, the activity levels in grain products were estimated at 11.3 pCi ^{90}Sr kg^{-1} and 8.2 pCi ^{137}Cs kg^{-1}.

5.9.5. Potatoes

The figures in table 5.5.1 were used, i.e. 1.6 pCi ^{90}Sr kg^{-1} and 4.6 pCi ^{137}Cs kg^{-1}.

Table 5.9.1. Estimate of the ^{90}Sr content in grain products consumed per capita in 1977

Type	Fraction from harvest 1976			Fraction from harvest 1977			Total
	kg flour	pCi kg^{-1}	pCi	kg flour	pCi kg^{-1}	pCi	pCi
Rye flour (100% extraction)	21.9	22	482	7.3	26	190	672
Wheat flour (75% extraction)	32.9	3.4	112	10.9	5.0	54	166
Grits	5.5	9.2	51	1.8	11.6	21	72
Total	60.3	10.7	645	20.0	13.2	265	910

Table 5.9.2. Estimate of the ^{137}Cs content in grain products consumed per capita in 1977

Type	Fraction from harvest 1976			Fraction from harvest 1977			Total
	kg flour	pCi kg^{-1}	pCi	kg flour	pCi kg^{-1}	pCi	pCi
Rye flour (100% extraction)	21.9	11.8	258	7.3	25	182	440
Wheat flour (75% extraction)	32.9	2.4	79	10.9	9.0	98	177
Grits	5.5	4.2	23	1.8	11.7	21	44
Total	60.3	6.0	360	20.0	15.0	301	661

5.9.6. Vegetables

Table 5.6.3 shows the calculation of ^{90}Sr and ^{137}Cs in Danish vegetables consumed in 1977. The mean contents were 7.1 pCi ^{90}Sr kg^{-1} and 2.1 pCi ^{137}Cs kg^{-1}.

5.9.7. Fruit

The levels in imported fruit in 1977 are assumed to be equal to the mean levels found in oranges and bananas collected in Copenhagen in 1976, i.e. 5.6 pCi $^{90}Sr\ kg^{-1}$ and 2.1 pCi $^{137}Cs\ kg^{-1}$. The mean levels in Danish fruit (apples) in 1977 were 0.8 pCi $^{90}Sr\ kg^{-1}$ and 3.9 pCi $^{137}Cs\ kg^{-1}$ (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 2.2 pCi $^{90}Sr\ kg^{-1}$ and 3.4 pCi $^{137}Cs\ kg^{-1}$.

5.9.8. Meat

The annual mean values of ^{90}Sr and ^{137}Cs in meat were calculated from table 5.8.1: 0.4 pCi $^{90}Sr\ kg^{-1}$ and 25.3 pCi $^{137}Cs\ kg^{-1}$. (In a Danish diet meat comprises 2/3 pork and 1/3 beef).

5.9.9. Fish

The ^{90}Sr and ^{137}Cs contents in fish are estimated from 5.8.2 at 1.0 pCi $^{90}Sr\ kg^{-1}$ and 84 pCi $^{137}Cs\ kg^{-1}$.

5.9.10. Eggs

The contents of activity in eggs were estimated from 5.8.3. The levels were 0.9 pCi $^{90}Sr\ kg^{-1}$ and 0.8 pCi $^{137}Cs\ kg^{-1}$.

5.9.11. Coffee and tea

One third of the total consumption consists of tea and two thirds of coffee. The mean contents from 1976 (Risø Report No. 361[1]) were used: 7.3 pCi $^{90}Sr\ kg^{-1}$ and 35.7 pCi $^{137}Cs\ kg^{-1}$.

5.9.12. Drinking water

The ^{90}Sr level (population-weighted mean) found in drinking water collected in June 1973 was used as the mean level for drinking water, i.e. 0.02 pCi $^{90}Sr\ l^{-1}$. The ^{137}Cs content in drinking water is assumed to be negligible, because it cannot be detected even in surface fresh water.

Table 5.9.3. Estimate of the mean content of ^{90}Sr in the human diet in Denmark in 1977

Type of food	Annual quantity in kg	pCi ^{90}Sr per kg	Total pCi ^{90}Sr	Percentage of total pCi ^{90}Sr in food
Milk and cream	164.0	3.5	574	24.5
Cheese	9.1	24.6	224	9.6
Grain products	80.3	11.3	910	38.8
Potatoes	73.0	1.6	117	5.0
Vegetables	43.8	7.1	311	13.3
Fruit	51.1	2.2	112	4.8
Meat	54.7	0.4	22	0.9
Eggs	10.9	0.9	10	0.4
Fish	10.9	1.0	11	0.5
Coffee and tea	5.5	7.3	40	1.7
Drinking water	548	0.02	11	0.5
Total			2342	

The mean calcium intake was estimated at 620 g (approx. 200-250 g Creta praeparata). Hence the $^{90}Sr/Ca$ ratio in the total diet was 3.8 S.U. in 1977.

Table 5.9.4. Estimate of the mean content of ^{137}Cs in the human diet in Denmark in 1977

Type of food	Annual quantity in kg	pCi ^{137}Cs per kg	Total pCi ^{137}Cs	Percentage of total pCi ^{137}Cs in food
Milk and cream	164.0	5.1	836	18.0
Cheese	9.1	3.7	34	0.7
Grain products	80.3	8.2	661	14.3
Potatoes	73.0	4.6	336	7.2
Vegetables	43.8	2.1	92	2.0
Fruit	51.1	3.4	174	3.8
Meat	54.7	25.3	1384	29.8
Eggs	10.9	0.8	9	0.2
Fish	10.9	84	916	19.8
Coffee and tea	5.5	35.7	196	4.2
Drinking water	548	0	0	0
Total			4638	

As the approximate intake of potassium was 1365 g, the pCi ^{137}Cs $(g\ K)^{-1}$ ratio was approx. 3.4. The daily mean intake in 1977 was 12.7 pCi ^{137}Cs per capita.

5.9.13. Discussion

Tables 5.9.3 and 5.9.4 show the estimates of ^{90}Sr and ^{137}Cs in the Danish diet in 1977. The figures should be compared with the levels calculated from the total-diet samples (cf. 5.7). The ^{90}Sr estimates obtained by the two methods (cf. also fig. 5.7.1) were 3.8 S.U. and 3.8 S.U., respectively, and the ^{137}Cs estimates were 12.7 pCi ^{137}Cs day^{-1} and 10.4 pCi ^{137}Cs day^{-1}.

The relative contributions of ^{90}Sr from milk products (∿34%) and from grain (39%) were similar to those in 1976. The contribution from potatoes, other vegetables, and fruit was ∿23%, i.e. also nearly unchanged from 1976. The relative contribution of ^{137}Cs in the total diet changed from 1976 to 1977 as follows: milk products were a little higher (18 to 19%), grain products decreased from 18 to 14%, and meat was also lower (34 to 30%). Fish contributed nearly 20% to the total ^{137}Cs intake in 1977, and has thus become just as important a source of ^{137}Cs as milk products.

5.10. Strontium-90 and Cesium-137 in grass and milk samples collected at the state experimental farms in July 1977

Table 5.10 shows that the observed mean ratio between pCi ^{90}Sr $(g\ Ca)^{-1}$ in milk and grass was 0.09 in July 1977. This is in agreement with the observations of earlier years[1]. If an average cow consumes 9 feed units ∿50 kg grass and produces 11 kg milk d^{-1} (4.25% fat) ∿ fodder class 5, then she secretes 1.5 ± 0.5% (1 SD) of the ingested ^{90}Sr in her milk (∿0.14% per liter) and 4.5 ± 2.2% of the ingested ^{137}Cs (∿0.4% per liter). Table 5.10 furthermore shows that 1 m^2 Danish grass field corresponds to 1.06 ± 0.19 (1 SD) kg^{-1} grass, 1.60 ± 0.39 g Ca and 7.0 ± 2.2 g K.

Table 5.10. Strontium-90 and Cesium-137 in grass and milk collected in July 1977 at the state experimental farms

	Strontium-90 in grass			Cesium-137 in grass			Milk			Observed ratio milk/grass	
	pCi kg^{-1}	pCi m^{-2}	pCi (g Ca)$^{-1}$	pCi kg^{-1}	pCi m^{-2}	pCi (g K)$^{-1}$	pCi ^{90}Sr (g Ca)$^{-1}$	pCi ^{137}Cs (g K)$^{-1}$	pCi ^{137}Cs l^{-1}	S.U.	M.U.
Tylstrup	44.3	48.C	31.3	11.6	12.6	1.20	3.5	2.4	3.8	0.11	2.0
Studsgård	61.0	69.4	54.5	23.5	26.7	3.10	2.6	2.9	4.5	0.05	0.9
Ødum	37.7	28.5	19.2	9.1	6.9	1.70	2.2	1.6	2.4	0.12	0.9
Askov	57.6	77.3	44.7	11.4	15.2	1.59	3.9	1.9	3.2	0.09	1.2
St. Jyndevad	59.1	76.7	40.2	33.3	43.2	5.51	4.9	4.6	8.1	0.12	0.8
Blangstedgård	21.0	21.8	16.4	10.9	11.2	2.02	1.3	2.1	3.2	0.08	1.0
Tystofte	35.3	29.5	19.9	28.8	24.0	3.67	1.6	1.2	2.0	0.08	0.3
Ledreborg	37.0	35.3	20.6	31.8	30.4	6.39	1.1	1.8	3.0	0.05	0.3
Abed	31.6	35.3	13.6	30.1	33.6	5.55	1.3	1.9	2.8	0.10	0.3
Mean	42.7	46.9	28.9	21.2	22.6	3.41	2.5	2.3	3.7	0.088	0.88
S.D.	13.8	22.0	14.5	10.3	12.0	1.97	1.3	1.0	1.8	0.026	0.54

5.11. Grass collected around Risø

Table 5.11.2 shows the ^{90}Sr content in grass ash from Zealand in 1977. The mean ^{90}Sr activity was 1.8 pCi ^{90}Sr (g ash)$^{-1}$, or 31 S.U., as compared with 1.6 pCi (g ash)$^{-1}$, or 25 S.U., in 1976, i.e. the 1977 level was 1.2 times the 1976 level. Figure 5.11 shows the ^{90}Sr concentration in grass since 1957.

Table 5.1 1. Strontium-90 in grass from Zealand, 1977

	pCi ^{90}Sr (g ash)$^{-1}$	pCi ^{90}Sr (g Ca)$^{-1}$
Jan-March	1.06	24.8
April-June	1.10	25.5
July-Sept	2.27	35.5
Oct-Dec	2.60	37.3
Mean	1.76	30.8

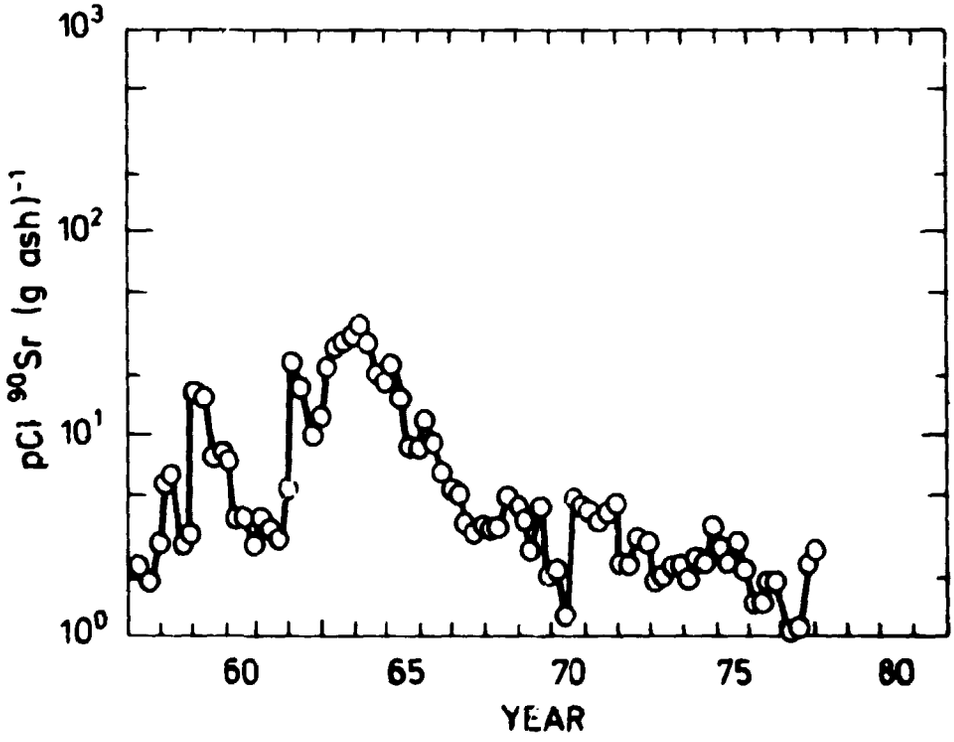

Fig. 5.11. Quarterly ^{90}Sr levels in grass, 1957-1977.

5.12. Sea plants collected in Roskilde Fjord

Figure 5.12 shows the S.U. levels in sea plants since 1959 and table 5.12 the results for 1977. The level in Fucus vesiculosus was 8.9 pCi ^{90}Sr (g Ca)$^{-1}$, and in Zostera marina 2.2 pCi ^{90}Sr (g Ca)$^{-1}$. Both levels were lower than those observed in 1976.

Table 5.1 2. Strontium-90 in sea plants from Roskilde Fjord in 1977

Month	Location	Species	pCi ^{90}Sr (g Ca)$^{-1}$	pCi ^{90}Sr (g ash)$^{-1}$
July	I	Fucus vesiculosus	8.9	0.61
June	III	Zostera marina	2.31	0.123
June	IX	Zostera marina	2.08	0.164

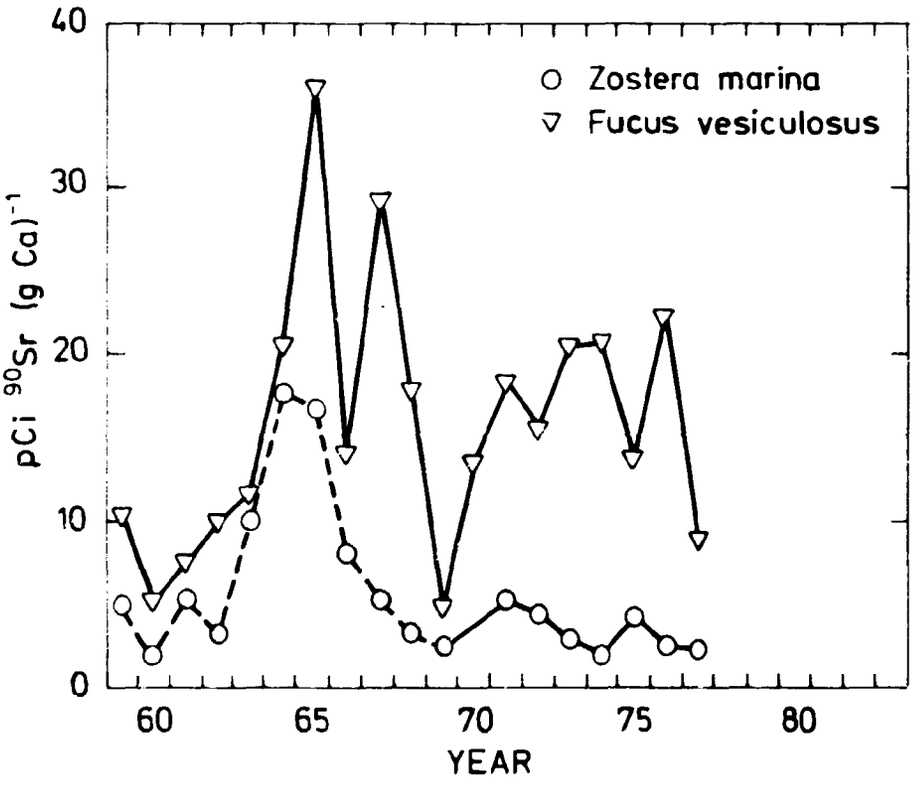

Fig. 5.12. Strontium-90 in sea plants from Roskilde Fjord, 1959-1977.

6. STRONTIUM-90 AND CESIUM-137 IN MAN IN 1977

by A. Aarkrog and J. Lippert

6.1. Strontium-90 in human bone

The collection of human vertebrae from the institutes of forensic medicine in Copenhagen and Århus was continued in 1977. As in the total-feed survey (cf. 5.7), the country was divided into eight zones. The samples were divided into five age groups: new-born (< 1 month), infants (1 month-4 years), children and teenagers (5 - 19 years), adults (≤ 29 years), and adults (> 29 years).

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

The levels were on the average a little lower than those in 1976. The highest mean level in vertebrae was found in infants, but the levels in the different age groups were not much different.

Table 6.1.1. Strontium-90 in bone from new-born children (< 1 month old) in 1977

Zone	Age in days	Month of death	Sex	pCi ^{90}Sr (g Ca)$^{-1}$
II	0	4	M	0.88 A
VI	6	6	M	0.55 A

Table 6.1.2. Strontium-90 in bone from infants (≤ 4 years old) in 1977

Zone	Age in years and months	Month of death	Sex	pCi ^{90}Sr (g Ca)$^{-1}$
I	3m	5	M	1.28
I	4m	2	M	1.17 A
IV	7m	5	M	1.42
VI	4m	4	M	1.77 A
VI	1y 1m	11	M	0.74 B
VI	3y 0m	4	F	0.78 A

Table 6.1.3. Strontium-90 in bone from children and teenagers (≤ 19 years) in 1977

Zone	Age in years	Month of death	Sex	pCi ^{90}Sr (g Ca)$^{-1}$
I	14	2	M	0.89
I	16	7	M	0.65
II	6	5	M	0.81
II	10	8	M	0.70
II	16	8	M	0.85
VI	5	3	F	0.92 A
VI	16	8	F	0.79 A
VI	17	5	F	0.54 B
VI	17	10	F	0.67 B
VI	17	11	F	1.07 A
VI	18	4	F	0.76
VI	18	4	F	1.06 A
VI	9	4	M	0.88 A
VI	17	9	M	0.75
VI	17	9	M	0.77 B
VI	17	11	M	1.11
VI	18	8	M	0.69 A
VI	18	11	M	0.66 A
VI	18	11	M	2.36
VI	19	8	M	0.85
VI	19	10	M	0.51 A

Table 6.1.4. Strontium-90 in vertebrae from adults (≥ 29 years) in 1977

Zone	Age in years	Month of death	Sex	pCi ^{90}Sr (g Ca)$^{-1}$
III	29	6	M	1.47
V	20	7	M	0.80
VI	20	10	F	0.63 A
VI	20	10	F	0.61 A
VI	22	11	F	0.91 A
VI	24	11	F	0.84
VI	27	2	F	0.84
VI	20	3	M	0.40 B
VI	20	4	M	0.57 A
VI	21	1	M	0.58 A
VI	21	3	M	0.34 B
VI	21	4	M	0.79 A
VI	22	6	M	0.65 A
VI	22	9	M	1.24
VI	24	10	M	0.58
VI	25	11	M	0.85
VI	26	8	M	1.49

Table 6.1.5. Strontium-90 in vertebrae from adults (> 29 years old) in 1977

Zone	Age in years	Month of death	Sex	pCi ^{90}Sr (g Ca)$^{-1}$
I	30	8	F	0.98
I	50	4	F	0.65
I	74	2	F	1.24
I	30	5	M	0.91
I	40	8	M	0.94
I	42	8	M	1.29
I	51	3	M	0.94
I	63	5	M	0.84
I	69	5	M	1.04
I	74	7	M	0.76
II	30	4	F	0.58
II	32	7	F	1.58
II	40	2	F	0.87
II	47	1	F	0.47 B
II	52	5	F	0.79
II	53	3	F	0.79 A
II	66	4	F	0.55 A
II	71	5	F	1.10
II	77	7	F	0.76
II	33	4	M	0.75
II	41	2	M	0.86
II	42	2	M	0.78 A
II	45	5	M	2.23
II	48	2	M	0.70
II	56	4	M	1.36
II	59	6	M	1.06
II	63	4	M	0.76
II	71	7	M	0.97
II	82	3	M	0.90
III	42	1	F	1.18
III	59	8	F	1.22
III	68	8	F	1.13
III	71	1	F	0.64 A
III	43	7	M	1.75
III	48	3	M	1.03 A
III	51	8	M	0.87
III	62	7	M	1.20
IV	62	4	M	0.98
IV	70	3	M	1.34
IV	75	7	M	1.42
V	46	7	M	0.66

Table 6.1.6. Strontium-90 (pCi (g Ca)$^{-1}$) in human vertebrae collected in Denmark 1977

Age group	Number of samples	Min.	Max.	Median	Mean
New-born (< 1 month)	2	0.55	0.86	0.70	0.70
Infants (≤ 4 years)	6	0.74	1.77	1.23	1.19
Children (≤ 19 years)	21	0.51	2.36	0.79	0.87
Adults (≥ 29 years)	17	0.34	1.49	0.79	0.80
Adults (≥ 30 years)	41	0.47	2.23	0.94	1.00

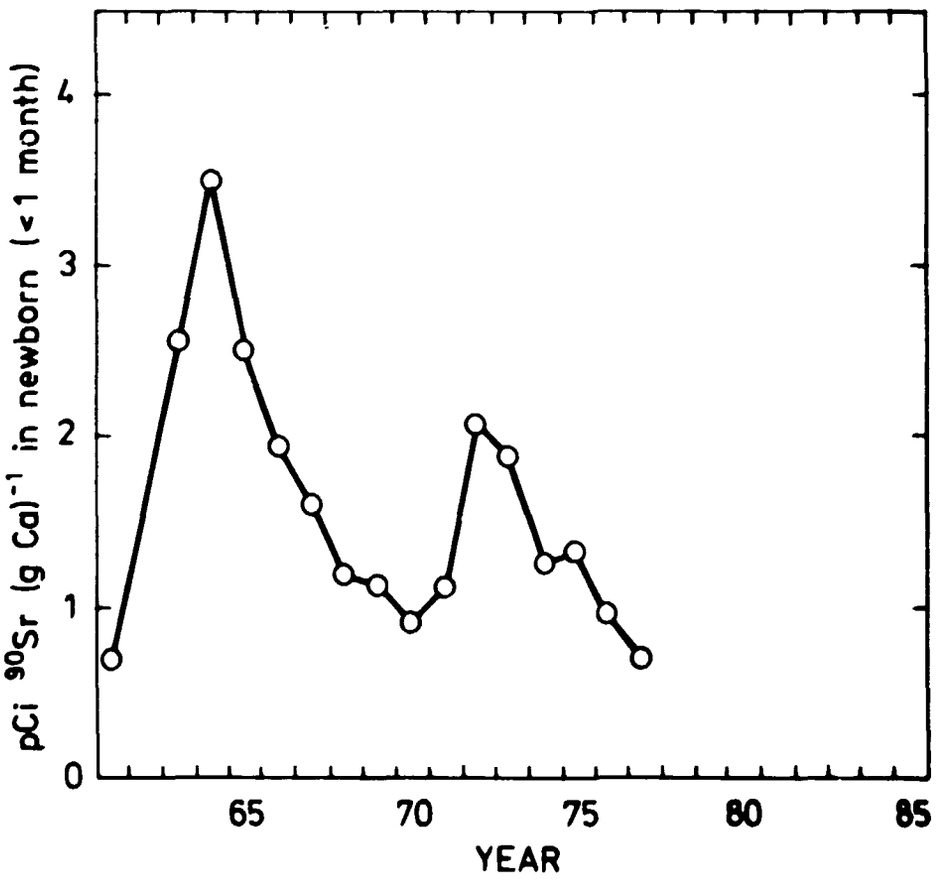

Fig. 6.1.1. Strontium-90 in bone from newborn 1961-1977.

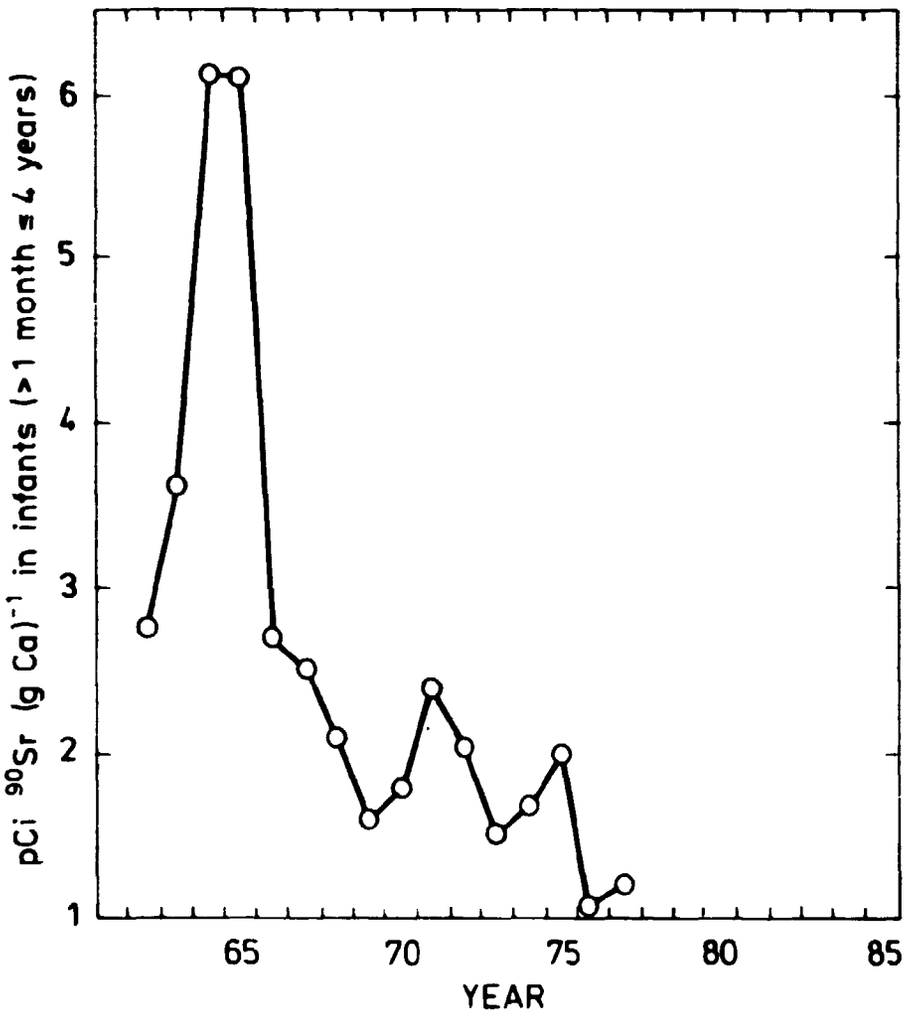

Fig. 6.1.2. Strontium-90 in bone from infants 1962-1977.

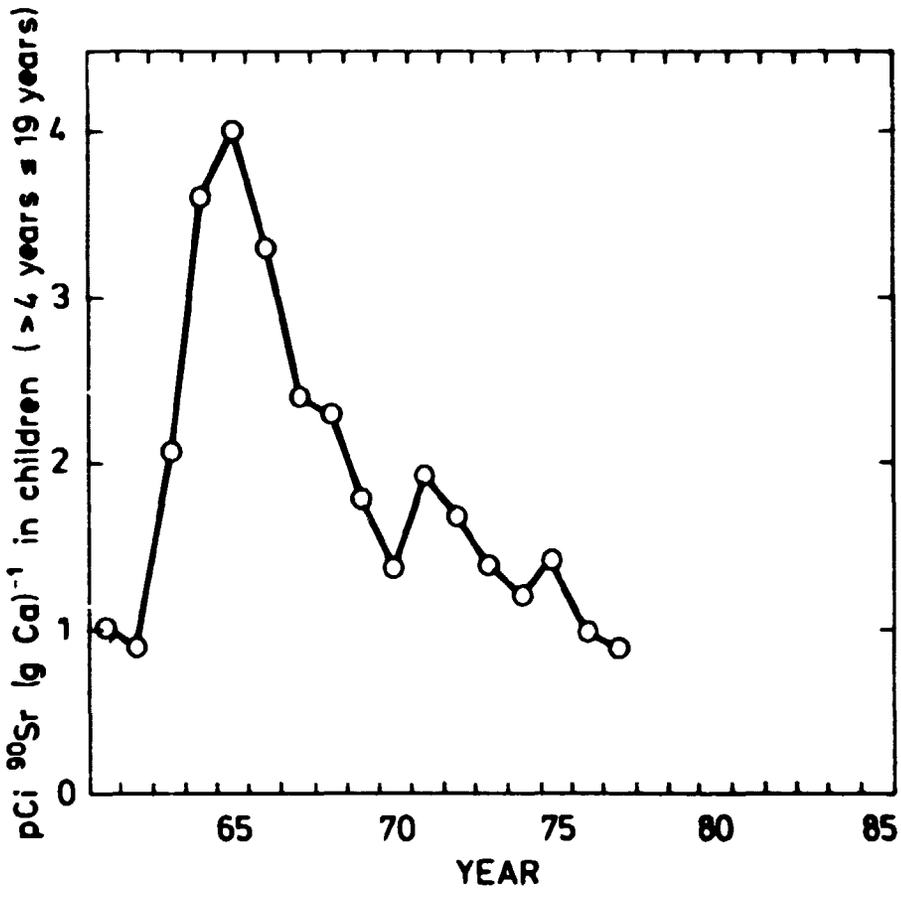

Fig. 6.1.3. Strontium-90 in bone from children 1961-1977.

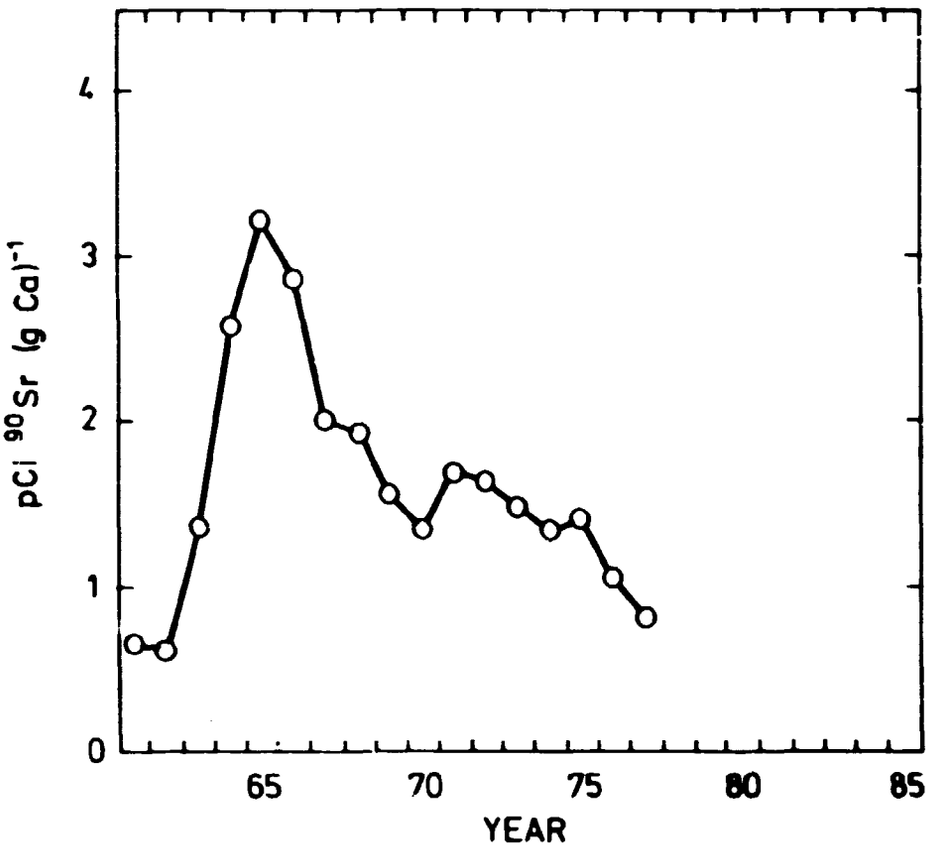

Fig. 6.1.4. Strontium-90 in vertebrae from adults ≤ 29 y, 1961-1977.

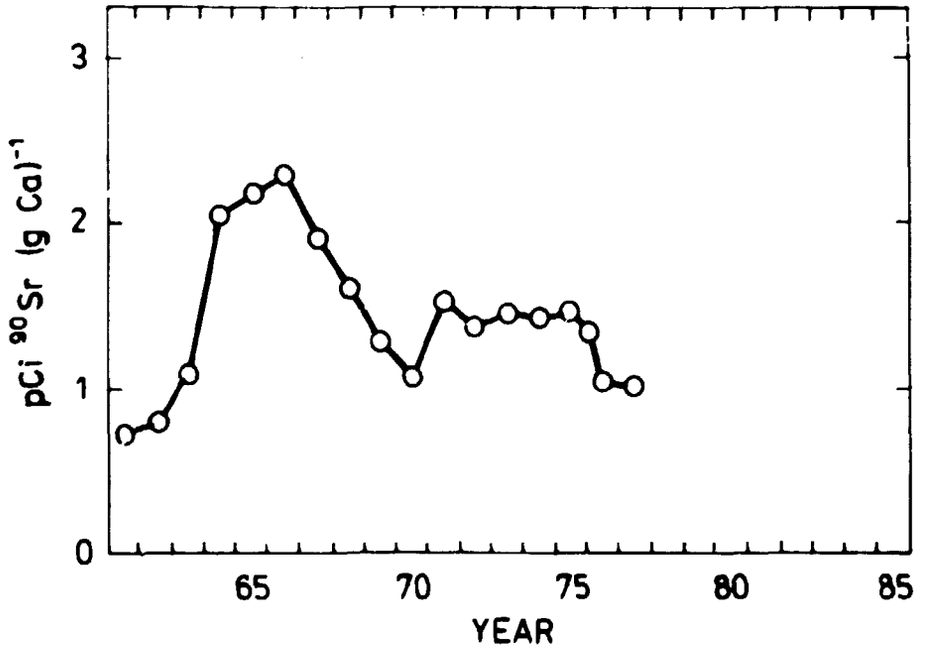

Fig. 6.1.5. Strontium-90 in vertebrae from adults > 29 y, 1961-1977.

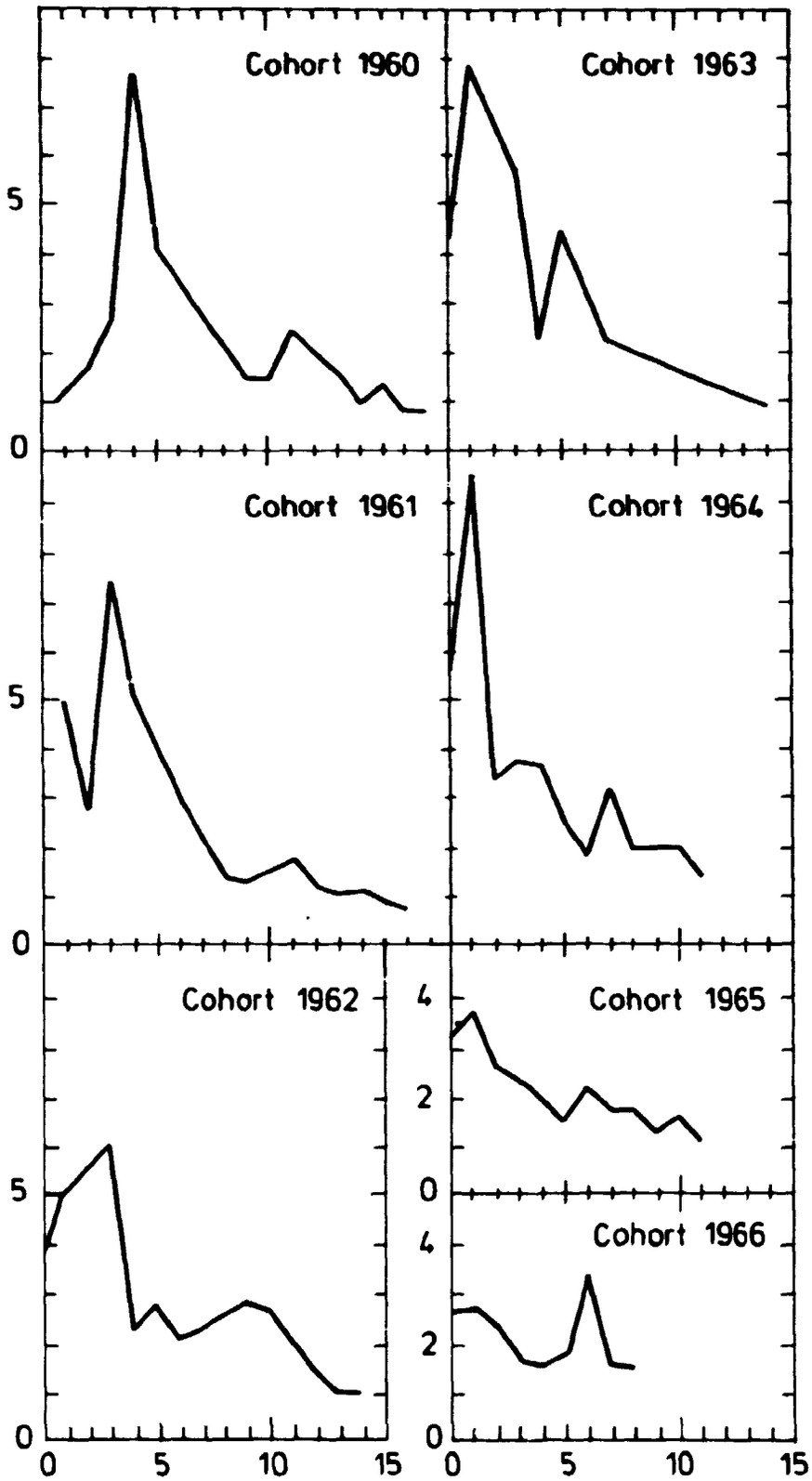

Fig. 6.1.6. Strontium-90 in human bone from Danish cohorts 1960-1966. (Abscissa: age in years. Ordinate: bone level in pCi ^{90}Sr (g Ca)$^{-1}$).

6.2. Cesium-137 in the human body

Whole-body measurements were initiated at Risø in July 1963 (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 as far as possible three times a year. Table 6.2 shows the results.

The annual mean value of the control group was 8.4 pCi ^{137}Cs $(g\ K)^{-1}$. As earlier, we shall consider this figure representative of the mean of the Danish population in 1977. The total-body content of ^{137}Cs in 1977 for a standard man containing 140 g of potassium equals $140 \cdot 8.4 \cdot 10^{-3}$ nCi = 1.2 nCi ^{137}Cs, i.e. approx. 90% of the 1976 level.

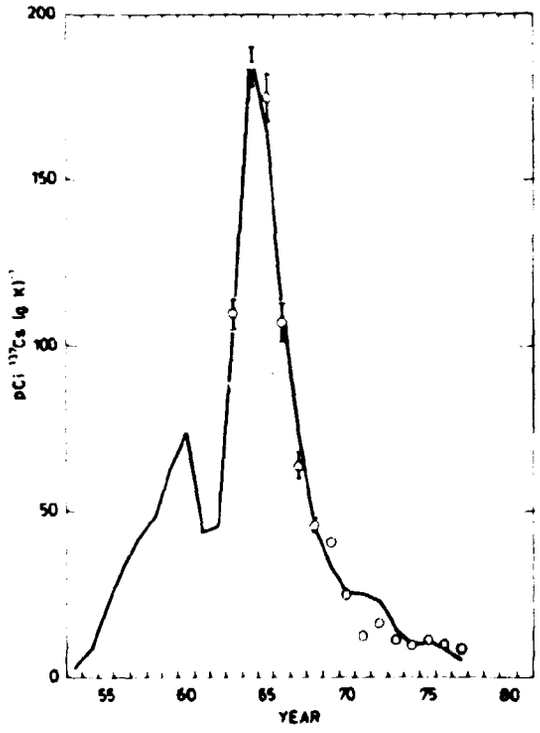

Fig. 6.2. A comparison between observed (± 1 SE) and calculated (curve, cf. Appendix C) pCi ^{137}Cs $(g\ K)^{-1}$ levels in whole-body from the Islands.

Figure 6.2 shows the mean M.U. values (with one S.E.) for men and women measured in 1963-1977.

The maximum was reached in August 1964. The mean level in the male group was approx. 1.3 times as high as that in the female group.

Table 6.2. Whole-body measurements of cesium-137 and potassium in 1977

Sex	Counting date	Age	Height in cm	Weight in kg	K.U. in body	pCi ^{137}Cs kg^{-1}	g K kg^{-1} body weight
M	May	25	170	67	B.D.L.	B.D.L.	1.8
M	- " -	46	192	88	2.0	3.7	1.6
M	- " -	31	168	61	1.3	2.5	1.9
M	- " -	35	182	75	2.0	3.7	1.9
M	- " -	65	167	70	B.D.L.	B.D.L.	1.7
F	- " -	39	173	57	10.8	14.1	1.3
F	August	27	160	57	1.9	2.8	1.5
M	- " -	38	178	79	5.6	9.3	1.7
M	- " -	34	174	71	8.8	15.5	1.8
M	- " -	44	172	69	14.4	25.4	1.8
M	- " -	54	183	72	9.4	22.1	2.4
F	- " -	38	160	54	17.7	24.9	1.4
F	- " -	48	157	62	2.4	3.6	1.5
M	- " -	45	184	62	11.7	26.8	2.2
M	- " -	35	181	74	13.9	25.4	1.8
F	- " -	27	172	69	6.7	9.4	1.4
M	- " -	65	167	70	24.6	49.5	2.0
F	- " -	38	162	49	28.4	45.4	1.6
M	- " -	45	175	87	2.2	1.2	1.8
F	- " -	51	154	101	10.4	12.4	1.2
F	- " -	34	158	44	5.6	9.7	1.7
M	- " -	29	180	73	18.2	34.5	1.9
F	- " -	22	169	49	4.1	5.8	1.4
F	December	49	171	65	12.8	15.4	1.2
M	- " -	45	183	77	6.5	9.3	1.4
M	- " -	39	174	81	3.8	6.7	1.7
M	- " -	35	174	71	7.6	11.8	1.6
M	- " -	45	172	69	8.3	11.4	1.4
M	- " -	47	192	89	0.8	1.6	1.9
M	- " -	45	170	75	3.4	4.6	1.4
F	- " -	35	167	58	3.5	3.9	1.1
M	- " -	31	168	63	5.1	8.5	1.7
F	- " -	48	157	66	5.0	6.1	1.2
M	- " -	45	184	65	2.7	4.9	1.8
F	- " -	28	173	70	10.2	12.4	1.2
F	- " -	38	162	51	4.2	5.3	1.3
M	- " -	29	169	69	12.6	20.4	1.6
F	- " -	51	154	101	8.5	9.0	1.1
M	- " -	30	190	94	6.9	10.5	1.5
F	- " -	34	158	44	8.7	11.3	1.3
M	- " -	29	180	72	16.3	26.3	1.6
M	- " -	46	182	77	18.2	33.7	1.9
M	- " -	21	170	60	2.1	4.4	2.1
M	- " -	21	172	62	4.6	6.1	1.3
M	- " -	27	177	63	26.2	30.5	1.2

7. TRITIUM IN THE ENVIRONMENT

by Heinz Hansen

7.1. Introduction

Tritium is produced naturally in the atmosphere by the interaction of cosmic-ray protons and neutrons with nitrogen, oxygen or argon. Surface waters contain about 0.01 nCi/l from this source[25]. Tritium is also produced and injected into the stratosphere as the result of thermonuclear explosions. At present, this latter source has enhanced the natural inventory by about a factor of ten[25]. Finally, tritium is produced as a by-product of the peaceful uses of atomic energy: it is released both during reactor operation and during fuel reprocessing.

Before Denmark builds any nuclear power stations of her own, it is of interest to know the general tritium levels in the environment that could be affected by this new energy source. Also, an assay of the current tritium levels can be used to control any tritium release from the Swedish nuclear power stations at Barsebäck and Ringhals, and from the reprocessing plants at Windscale and La Hague.

7.2. Assay of tritium in low-level amounts

The present assays of tritium levels in water are based on a relative enrichment of ^3H_2O by electrolysis and subsequent liquid scintillation counting. The method was developed by P. Theodorsson from the University of Iceland, as previously described[26].

Our apparatus for sample electrolysis is shown in figs. 7.2.1 and 7.2.2. The cells are of a construction similar to that

Fig. 7.2.1. Combined setup for electrolysis of 6 samples. Each cell has its own power supply. Glass bulbs are placed on top of the cells at the beginning of the process to catch any escaping liquid due to bubble formation. A termistor-sensored ventillation control stops electrolysis if ventillation fails.

Fig. 7.2.2. An electrolysis cell with the anode partly drawn out. Notice holes in the anode to help circulation of liquid.

used at the IAEA tritium laboratory in Vienna[27], except that we use an initial sample volume of 100 ml. We use nickel anodes and iron cathodes with an initial NaOH concentration of 0.7%. Each of the 6 parallel cells has its own power supply. The cells are run at 0°C with an initial current of about 9 amps at 3 volt. After about 48 h of electrolysis the samples are reduced to 3 ml, with a ^3H_2O recovery of 75-80%. They are counted with Instagel as emulsifier in a Packard 2425 Tri-carb liquid scintillation spectrometer, after vacuum distillation directly into the counting vial. During the distillation, the cell is heated to 150°C and the vial is cooled with liquid nitrogen.

7.3. Results

Table 7.3.1. Tritium in precipitation collected at Risø in 1977

Month	mm	nCi ^3H l^{-1}	mCi ^3H km^{-2}
Jan	38.5	0.19±0.035*	7.3
Feb	35.3	0.15±0.029*	5.3
March	44.5	0.20±0.026*	8.9
April	41.7	0.26±0.030*	10.8
May	18.2	0.27±0.019*	4.9
June	23.0	0.71±0.093*	16.3
July	57.7	0.44±0.005	25.4
Aug	29.1	0.35±0.040	10.2
Sept	47.9	0.21±0.010	10.1
Oct	29.9	0.33±0.020	9.9
Nov	50.4	0.54±0.035	27.2
Dec	37.7	0.31±0.010	11.7
1977	Σ 454	$\bar{x}$ 0.33	Σ 148

*Triple determination.
The error term was ±1 SE.

Table 7.3.2. Tritium in ground water collected in March 1977

Location	nCi ^3H l^{-1}
Hvidsten	0.06±0.005
Feldbæk	0.48±0.005
Rømø	0.08±0.010
Rønne New	0.09±0.020
Rønne Old	0.20±0.000
Hasselø	0.26±0.025
Fåretofte	0.18±0.055
Kalundborg	0.27±0.010
Ravnholt	0.32±0.005
Fredericia	0.22±0.035
Mean	0.22
Median	0.21

A sample of ground water from Maglekilde in Roskilde contained 0.20±0.000 nCi l^{-1}.
The error term was ±1 SE.

8. TRANSURANICS IN ENVIRONMENTAL SAMPLES

by Karen Nilsson

8.1. Introduction

The release of radioactive elements into the biosphere has made it desirable to assess their influence on the environment. Some of the longest-lived and more abundant of the radio-nuclides are the trans-uranic elements, among which are plu-tonium and americium. The plutonium stems from atmospheric nuclear testings and from the expanding nuclear power industri. The following isotopes are released to the environment,

	Half-life	α-Energy
^{238}Plutonium	86 years	5.49 MeV
^{239}Plutonium	24.400 years	5.15 MeV
^{240}Plutonium	6.580 years	5.15 MeV
^{241}Plutonium	14 years	-

The plutonium isotopes are alpha-emitters except ^{241}Plutonium, which is a beta-emitter, producing the alpha-emitting,

^{241}Americium	458 years	5.48 MeV

When it is considered, that ^{241}Plutonium is released in amounts that exceed $^{(239+240)}$Plutonium by a factor of at least 15 and that the half-life of ^{241}Plutonium is 14 years against a half-life of 456 years for ^{241}Americium, it is appearent that the amounts of ^{241}Americium present in the surroundings will in-crease steadily in the years to come.

Alpha-emitters are known to be highly radio-toxic, and in view of their long half-life it is of great importance to study the behaviour and destiny of these nuclides. The current evidence

show that the movement of plutonium is extremely slow once it reaches the biosphere, whereas there are indications that americium is much more mobile and thus more of a potential hazard in the biological environment. Most of the released plutonium is to be found in the sea, and the programme initiated at Risø for studying the behaviour of $^{(239,240)}$Plutonium and ^{241}Americium concentrates on samples from the marine environment. However, a more limited study of the content and distribution of the elements in samples from the terrestic environment, is also being performed.

8.2. Radiochemical analysis

The radiochemical determination of plutonium and americium employs a method developed by N.A. Talvite[19,30]. During the preparative phase a sample is dried, radioactive spikes ^{236}Plutonium ($T_{\frac{1}{2}}$ = 2.85 years, E_{α} = 5.76 MeV) and ^{243}Americium ($T_{\frac{1}{2}}$ = 7580 years, E_{α} = 5.28 MeV) are added and the sample is ashed. In the case of soil and sediment which constitute the larger number of samples, this is done by treatment with alternately hydrofluoride and nitric acid. In the end, the sample is made 9 M with respect to hydrochloric acid. Under these circumstances, iron and such trace elements as plutonium, uranium and polonium will form negatively charged complexes. When placed on a strong anion exchanger, all but the mentioned chloride complexes will pass through the column. Iron, polonium and uranium are removed by employing 7.2 M nitric acid, and plutonium is finally eluted from the column using 1.2 M hydrochloric acid. After evaporation, plutonium now freed from contaminants, is electroplated as a virtually weightless sample on stainless steel discs from a sulphuric acid media at pH = 3 and finally the alpha-spectrum is measured. The peaks are generally well-resolved except for ^{239}Plutonium and ^{240}Plutonium; they are counted as one. The recovery as measured with the yield-determining spikes is mostly between 60 and 80%. If a sample for some reason does not present a satisfactory alpha spectrum, then the disc is immersed in 9 M hydrochloric acid for 30 min, and the resulting solution submitted to a repeat of the ionchromatography and electroplating procedure. The

recovery will then be between 20 and 40%, but the resolution is always satisfactory the second time.

Americium, which is to be found in the eluate from the anion-exchanger along with other cations, can be recovered from the eluate by chromatography on a cation exchanger followed by anion-chromatography in mixtures of methanol and nitric acid. The method will have to be revised because of very low recovery especially in the case of samples of soil or sediment, the matrix of which contain large amounts of inorganic matter.

8.3. Results

Table 8.1 shows the $^{239,240}Pu$ determinations in the soil sampling experiment mentioned in 4.5. As for ^{137}Cs (cf. eq. 4.5) the plutonium activity followed an exponential expression:

$$mCi\ ^{239,240}Pu\ km^{-2}\ cm^{-1} = 0.145\ e^{-0.157\ cm} \qquad \text{Eq. 8.3}$$

and if the infinite depth integral was calculated for this expression the accumulated $^{239,240}Pu$ in the soil column at Skydebanen, Risø was estimated at 0.92 mCi km^{-2}; this was 2.1% of the ^{137}Cs level in soil, i.e. the same ratio as observed for the entire country in 1975 (cf. table 4.2.14 in Risø Report No. 361[1]).

The sediment layers (0-3 cm) at Ringhals (table 8.2) and at Barsebäck (table 8.3) contained 0.46 $\pm$ 0.11 (1 SD) and 0.44 $\pm$ 0.23 mCi $^{239,240}Pu\ km^{-2}$ respectively, while the concentrations at the two locations were 16 $\pm$ 4 and 54 $\pm$ 28 pCi $^{239,240}Pu\ kg^{-1}$ respectively. The mean ratios of $^{238}Pu/^{239,240}Pu$ in sediments were 0.018 $\pm$ 0.015 (1 SD) at Ringhals and 0.026 $\pm$ 0.020 at Barsebäck. There was no indication of any releases of plutonium from the two power plants (cf. table 8.5.3 in Risø Report No. 361[1]).

The $^{239,240}Pu$ concentration in Fucus from Ringhals (table 8.4) was probably significantly higher (P > 97%) than in Fucus from Barsebäck (table 8.5), which again contained significantly (P > 99.9%) more $^{239,240}Pu$ than Laminaria from Barsebäck. The $^{238}Pu/$

Table 8.1. Plutonium in soil samples collected in May 1977 at Skydebanen, Risø

Depth cm	A_1		A_2		B_1		B_2	
	pCi $^{239,240}Pu$ kg^{-1}	mCi $^{239,240}Pu$ km^{-2} cm^{-1}	pCi $^{239,240}Pu$ kg^{-1}	mCi $^{239,240}Pu$ km^{-2} cm^{-1}	pCi $^{239,240}Pu$ kg^{-1}	mCi $^{239.240}Pu$ km^{-2} cm^{-1}	pCi $^{239,240}Pu$ kg^{-1}	mCi $^{239,240}Pu$ km^{-2} cm^{-1}
2.5	11.07	0.077	10.68	0.091	8.67	0.066	-	-
5	5.35	0.052	8.09	0.092	11.39	0.126	-	-
10	2.27	0.021	2.76	0.028	3.28	0.026	5.23	0.047
15	1.49	0.0138	B.D.L.	B.D.L.	2.76	0.024	-	-
20	B.D.L.	B.D.L.	B.D.L.	B.D.L.	0.63	0.0055	0.42	0.0046
25	B.D.L.	B.D.L.	B.D.L.	B.D.L.	B.D.L.	B.D.L.	-	-
30	B.D.L.	B.D.L.	B.D.L.	B.D.L.	B.D.L.	B.D.L.	B.D.L.	B.D.L.
40	B.D.L.	B.D.L.	B.D.L.	B.D.L.	B.D.L.	B.D.L.	-	-
50	B.D.L.	B.D.L.	B.D.L.	B.D.L.	B.D.L.	B.D.L.	-	-
65	-	-	-	-	B.D.L.	B.D.L.	-	-
80	-	-	-	-	-	-	-	-
100	-	-	-	-	-	-	-	-

Table 8.2. Plutonium in sediment samples collected at Ringhals in 1976 and 1977

Date	Position (cf. Fig. 3.2.2)	Depth in cm	pCi ^{239,240}Pu kg^{-1}	mCi ^{239,240}Pu km^{-2}	pCi ^{238}Pu kg^{-1}	mCi ^{238}Pu km^{-2}
July 1, 1976	1	0-3	20.3	0.36	0.80	0.014
- " -	2	0-3	19.6	0.47	B.D.L.	B.D.L.
- " -	3	0-3	14.5	0.43	0.51	0.015
- " -	4	0-3	7.8	0.34	B.D.L.	B.D.L.
July 11, 1977	1	0-3	21.4	0.60	0.69	0.0194
- " -	"	6-9	4.3	0.177	0.06 B	0.0025 B
- " -	2	0-3	16.4	0.46	B.D.L.	B.D.L.
- " -	3	0-3	14.9	0.63	0.53 A	0.022 A
- " -	"	3-6	9.0 B	0.34 B	0.32 A	0.0119 A
- " -	"	6-9	1.82	0.086	0.09 B	0.0042 B
- " -	4	0-3	13.5	0.52	B.D.L.	B.D.L.
Oct. 27, 1977	1	0-3	17.6	0.35	B.D.L.	B.D.L.
- " -	"	3-6	15.7	0.47	B.D.L.	B.D.L.
- " -	"	6-9	4.2	0.116	B.D.L.	B.D.L.

Table 8.3. Plutonium in sediment samples collected at Barsebäck in 1976 and 1977

Date	Position (cf. Fig. 3.2.1)	Depth in cm	pCi ^{239,240}Pu kg^{-1}	mCi ^{239,240}Pu km^{-2}	pCi ^{238}Pu kg^{-1}	mCi ^{238}Pu km^{-2}
June 17, 1976	28	0-3	74.4	0.43	1.75 B	0.0101 B
- " -	27	0-3	2.6	0.103	B.D.L.	B.D.L.
- " -	29	0-3	68.4	0.49	B.D.L.	B.D.L.
Dec. 8, 1976	28	0-3	62.5	0.40	2.46 A	0.016 A
- " -	27	0-3	52.2	0.177	1.46 B	0.0050 B
- " -	29	0-3	64.2	0.41	1.16 B	0.0074 B
June 16, 1977	32	0-3	10.8	0.28	B.D.L.	B.D.L.
Oct. 19, 1977	19	0-3	91.7	0.61	2.34 A	0.016 A
- " -	17	0-3	41.9	0.60	2.38 A	0.034 A
- " -	18	0-3	73.8	0.90	3.70	0.045
- " -	18	3-6	40.7	0.48	1.69 A	0.020 A

^{239,240}Pu ratio in seaweed from Ringhals was probably significantly higher (P > 95%) than in seaweed from Barsebäck. The probable differences between the plutonium levels at Barsebäck

and Ringhals may be a result of the different salinities at the two locations (cf. 4.4). Inflow of seawater from the North Sea contaminated with plutonium isotopes from reprocessing plants (Windscale and Cap de la Hague) may however also have contributed to the observed differences.

Table 8.4. Plutonium in Fucus vesiculosus collected at Ringhals July 7, 1977

Position	^{239,240}Pu pCi kg^{-1}	^{238}Pu pCi kg^{-1}
6	18.1	1.47
7	12.3	-
9	17.1	1.06
10	17.0	4.2
12	10.9±0.4	0.73±0.06
13	15.9	2.3

Table 8.5. Plutonium in seaweed collected at Barsebäck in June, 1977

Type	Position	Date	^{239,240}Pu pCi kg^{-1}	^{238}Pu pCi kg^{-1}
Fucus vesiculosus	21	June 15	10.9±0.2	0.46±0.17
- " -	22	June 14	8.7	0.27
- " -	23	June 14	12.0	0.90
- " -	24	June 14	11.3	1.09
Laminaria saccharina	55°48'N 12°44'E	June 16	7.7	0.23
- " -	- " -	June 16	5.8±0.1	0.18±0.07

9. COUNTRY-WIDE MEASUREMENTS OF BACKGROUND RADIATION IN 1977

by L. Bøtter Jensen and S.P. Nielsen

9.1. Measuring programme

The results of routine measurements of the γ-background in 1977 made using the large NaI(Tl) detector[1] were discarded due to a malfunction of the apparatus. However, other measurements of background radiation were made using thermoluminescence dosimeters (TLD's), a mobile Ge(Li) spectrometer system, and a high-pressure ionization chamber.

The TLD measurements[23] comprise two periods each representing about 6 months of integration time, while the measurements made with the Ge(Li) spectrometer and the ionization chamber[24] represent short-term observations. Measurements were made at the same locations as in previous years.

9.2. State experimental farms

The State experimental farms are situated as shown in fig. 4.2. The results of the TLD measurements are shown in table 9.2.1. Results of the Ge(Li) spectrometer measurements are shown in tables 9.2.2 - 9.2.4. Tables 9.2.2 and 9.2.3 show concentrations in the soil of naturally occurring radionuclides and fallout radionuclides, respectively, and table 9.2.4 shows the exposure rates from the individual contributors and the total exposure rates measured with the ionization chamber. It is noted that the variation of the exposure rates between the locations results mainly from the varying concentrations in the soil of the naturally occurring radionuclides.

Table 9.2.1. TLD-measurements of the background radiation (μR h^{-1}) at the state experimental farms in 1977

	Winter 1976-1977	Summer 1977	Mean
Tylstrup	7.2	7.3	7.2
Studsgård	6.6	6.7	6.7
Ødum	8.1	8.6	8.4
Askov	7.7	7.9	7.8
St. Jyndevad	6.3	6.0	6.2
Blangstedgård	7.8	8.2	8.0
Tystofte	8.0	8.2	8.1
Virumgård	8.1	8.4	8.3
Abed	7.7	8.1	7.9
Mean	7.5	7.7	7.6

9.3. Risø environment

The results of the TLD measurements from the five zones around Risø are shown in table 9.3.1. The locations for zone I are shown in fig. 3.1.2.1 and for the remaining zones in fig. 9.3.1.

In the Risø environment a few Ge(Li) spectroscopic measurements were made in zone I. At location 4, which is 80 m north of the reactor DR 1, an increase in background of 15 μR/h was detected during reactor operation at full power (2 kW), and the recorded γ-spectrum showed the increase to result from direct and scattered annihilation radiation from the reactor. Furthermore, emission of ^{41}A from the stack of the reactor DR 3 (15 MW) was detected at distances of up to 1 km.

9.4. Gyllingnæs environment

The Gyllingnæs environment (a potential nuclear power plant site) is routinely monitored with TLD's, and the results from three zones around the site are given in table 9.4.1. The locations are shown in fig. 9.4.1.

Table 9.2.2. Naturally occurring radionuclides in the soil at the state experimental farms estimated from field spectroscopic measurements made in June 1977 (pCi g^{-1})

Nuclide	Tylstrup	Studsgård	Ødum	Askov	St. Jyndevad	Blangstedgård	Tystofte	Ledreborg	Abed	Tornbygård*	Mean	S.D.	S.E.
^{40}K	10.4	5.8	12.0	9.1	7.3	11.7	14.1	13.2	9.5	13.4	10.7	2.7	0.9
^{226}Ra	0.38	0.26	0.47	0.34	0.18	0.47	0.54	0.59	0.41	0.98	0.46	0.22	0.07
^{232}Th	0.33	0.20	0.47	0.40	0.18	0.46	0.59	0.54	0.46	0.69	0.43	0.16	0.05

*Bornholm.

Table 9.2.3. Fallout radionuclides in the soil at the state experimental farms estimated from field spectroscopic measurements made in June 1977

Nuclide	Unit	Tylstrup	Studsgård	Ødum	Askov	Jyndevad	Blangstedgård	Tystofte	Ledreborg	Abed	Tornbygård***	Mean	S.D.	S.E.
^{137}Cs	pCi g^{-1}*	0.26	0.25	0.33	0.26	0.22	0.39	0.17	0.14	0.21	0.22	0.25	0.07	0.02
^{95}Zr	mCi km^{-2}**	2.1	3.0	2.0	2.5	2.5	2.2	2.0	1.0	1.2	1.7	2.0	0.6	0.2
^{95}Nb	mCi km^{-2}**	2.3	5.4	3.4	4.4	4.9	3.4	2.4	2.4	2.2	2.7	3.4	1.2	0.4

* Assuming a homogeneous distribution 0-20 cm (cf. also tables 4.2.4 and 4.2.9 in Risø Report No. 345[1])

** Assuming a surface deposition.

***Bornholm.

Table 9.2.4. Exposure rates at the state experimental farms estimated from field spectroscopic measurements made in June 1977 ($\mu R\ h^{-1}$)

	^{40}K	^{238}U series	^{232}Th series	Fallout	Terrestrial exposure rate	Total exposure rate	Cosmic exposure rate
Tylstrup	1.9	0.7	0.9	0.2	3.7	7.8	4.1
Studsgård	0.9	0.5	0.6	0.5	2.5	6.8	4.3
Ødum	2.2	0.9	1.3	0.2	4.6	8.8	4.2
Askov	1.7	0.7	1.1	0.2	3.7	7.8	4.1
St. Jyndevad	1.3	0.3	0.5	0.1	2.2	6.6	4.4
Blangstedgård	2.2	0.9	1.3	0.2	4.6	8.7	4.1
Tystofte	2.6	1.1	1.6	0.1	5.4	9.4	4.0
Ledreborg	2.4	1.1	1.5	0.1	5.1	9.2	4.1
Abed	1.8	0.8	1.3	0.2	4.1	8.1	4.0
Tornbygård*	2.5	1.9	2.0	0.2	6.6	10.4	3.8
Mean	2.0	0.9	1.2	0.20	4.3	8.4	4.1
S.D.	0.5	0.4	0.5	0.12	1.3	1.2	0.2
S.E.	0.2	0.1	0.1	0.04	0.4	0.4	0.1

*Bornholm.

9.5. Great Belt and Langeland Belt areas

Locations on both shores of the Great Belt and the Langeland Belt (an international shipping route) are likewise routinely monitored with TLD's; the results and locations are shown in table 9.5.1 and fig. 9.5.1, respectively.

9.6. Discussion of results

It is noted that the results from the TLD measurements and the ionization chamber measurements at the State experimental farms are in good agreement, as seen from tables 9.2.1 and 9.2.4.

Measurements of the γ-background made in previous years by means of the large NaT(Tl) detector (fig. 9.6.1) seem somewhat higher

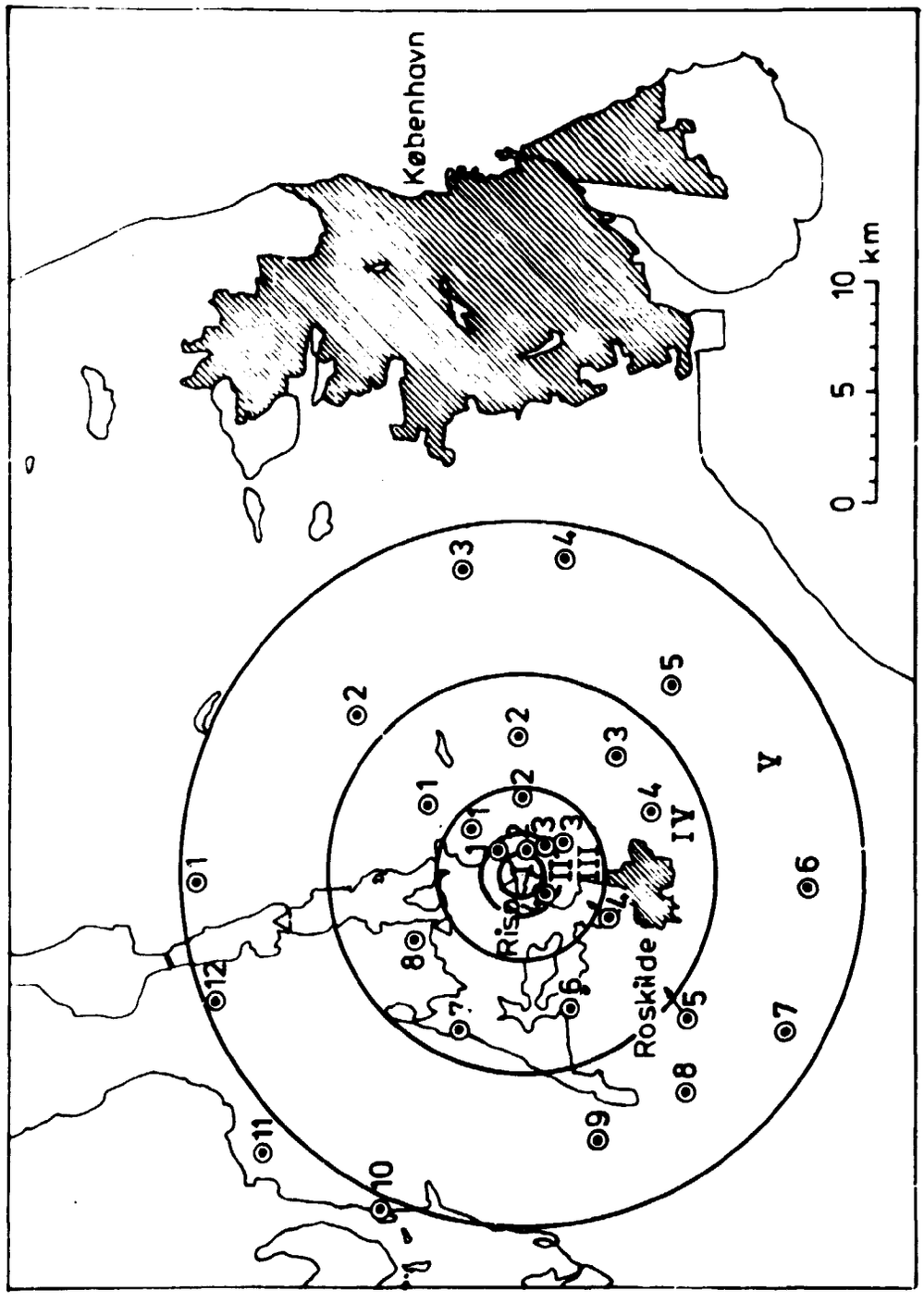

Fig. 9.3.1. The environment of Risø. Locations for background radiation.

Table 9.3.1. TLD-measurements of the background radiation (uR h^{-1}) in five zones (I-V) around Risø in 1977

Risø zone	Location	Winter 1976-1977	Summer 1977	Mean
I	1	8.4	8.5	8.5
"	2	8.9	8.7	8.8
"	3	18.1	19.2	18.6
"	4	10.4	9.8	10.1
"	5	20.8	19.3	20.0
Mean		13.3	13.1	13.2
II	1	8.3	8.5	8.4
"	2	8.7	8.9	8.8
"	3	8.1	8.1	8.1
"	4	8.7	9.0	8.9
Mean		8.5	8.6	8.6
III	1	8.9	9.2	9.1
"	2	8.2	8.5	8.3
"	3	8.7	9.1	8.9
Mean		8.6	8.9	8.8
IV	1	8.2	7.8	8.0
"	2	8.5	8.8	8.7
"	3	-	8.5	8.5
"	4	9.1	9.4	9.2
"	5	6.7	6.9	6.8
"	6	8.5	8.9	8.7
"	7	9.1	9.1	9.1
Mean		8.4	8.5	8.4
V	1	8.3	7.9	8.1
"	2	9.2	9.8	9.5
"	3	6.7	7.9	7.3
"	4	8.1	8.1	8.1
"	5	9.0	9.2	9.1
"	6	9.0	9.0	9.0
"	7	8.6	8.3	8.4
"	8	7.4	8.1	7.7
"	9	9.0	8.8	8.9
"	10	8.0	7.6	7.8
Mean		8.3	8.5	8.4

Table 9.4.1. TLD-measurements of the background radiation (μR h^{-1}) in four zones (I-IV) around the Gyllingnæs site in 1977

Gyllingnæs zone	Location	Winter 1976-1977	Summer 1977	Mean
I	1	7.8	7.3	7.6
"	2	7.4	7.5	7.5
"	3	8.1	8.6	8.4
"	4	7.0	7.2	7.1
Mean		7.6	7.7	7.6
II	1	8.8	8.7	8.7
"	2	8.5	8.3	8.4
Mean		8.6	8.5	8.6
III	1	7.7	-	7.7
"	2	7.7	8.1	7.9
"	3	8.4	8.5	8.4
"	4	6.4	6.8	6.6
"	5	8.3	8.4	8.4
Mean		7.7	7.9	7.8
IV	1	8.2	8.3	8.3
"	2	8.6	8.8	8.7
"	3	8.0	8.3	8.2
Mean		8.3	8.5	8.4

Table 9.5.1. TLD-measurements of the background radiation (μR h^{-1}) along the coasts of the Great Belt and Langeland Belt in 1977

Location	Winter 1976-1977	Summer 1977	Mean
Røsnæs	7.4	7.7	7.5
Reersø	8.3	8.9	8.6
Svendstrup	8.0	8.0	8.0
Frederiksdal	9.0	9.4	9.2
Vesternæs	9.1	8.8	8.9
Kelds Nor	9.8	9.9	9.8
Tranekær	8.6	8.7	8.6
Hov	7.8	7.4	7.6
Fyns Hoved	8.3	8.0	8.2
Knuds Hoved	8.5	8.3	8.4
Mean	8.5	8.5	8.5

when compared to the terrestrial exposure rates from table 9.2.4. The scintillation measurements probably overestimate the γ-background because of the high response of the NaT(Tl) detector to low-energy gamma rays. This is substantiated from measurements made near the waste treatment station at Risø (zone I, location 3) where the TLD measurements (∿20 μR/h) yield significantly lower values than the scintillation measurements (∿60 μR/h).

A systematic comparison between the previously mentioned measuring systems is presently being made.

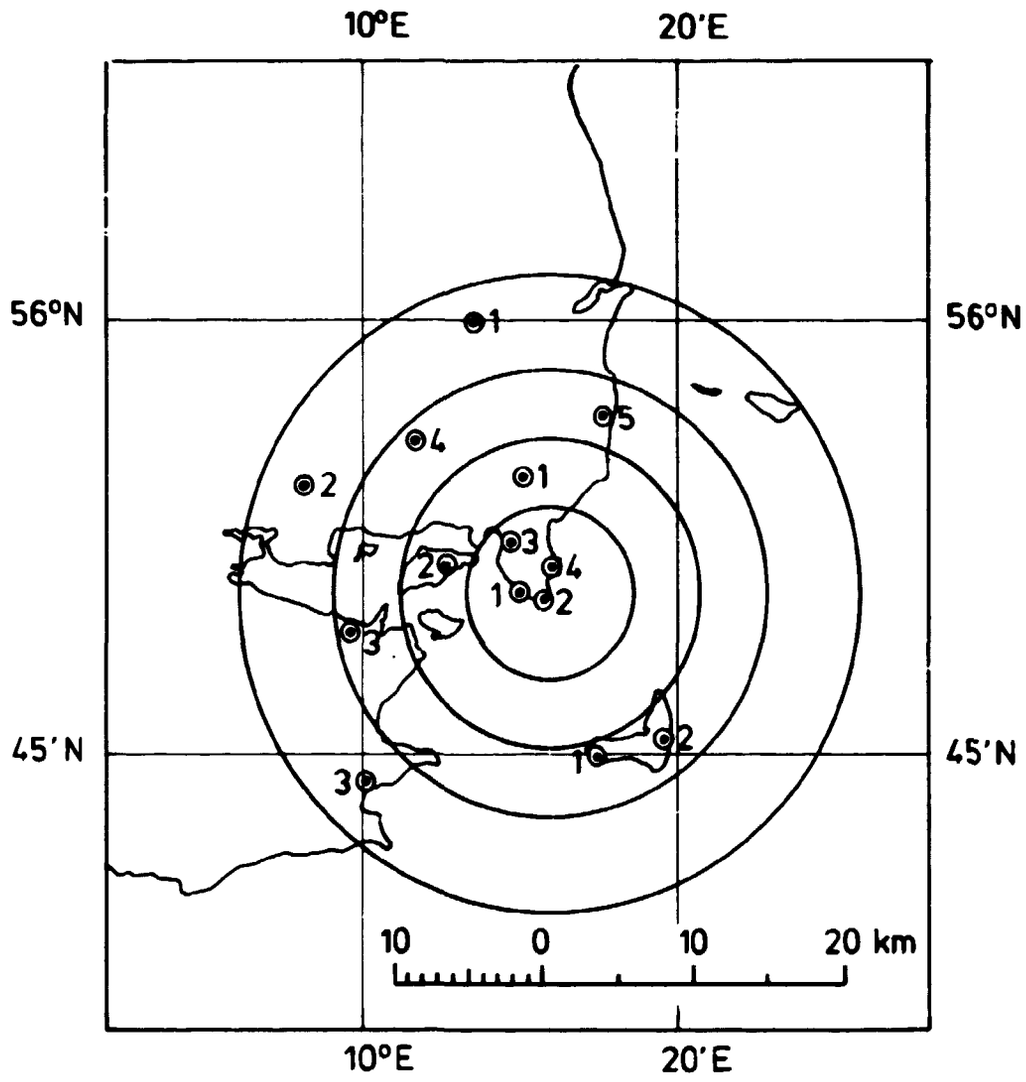

Fig. 9.4.1. The environment of Gyllingnæs. Locations for background radiation.

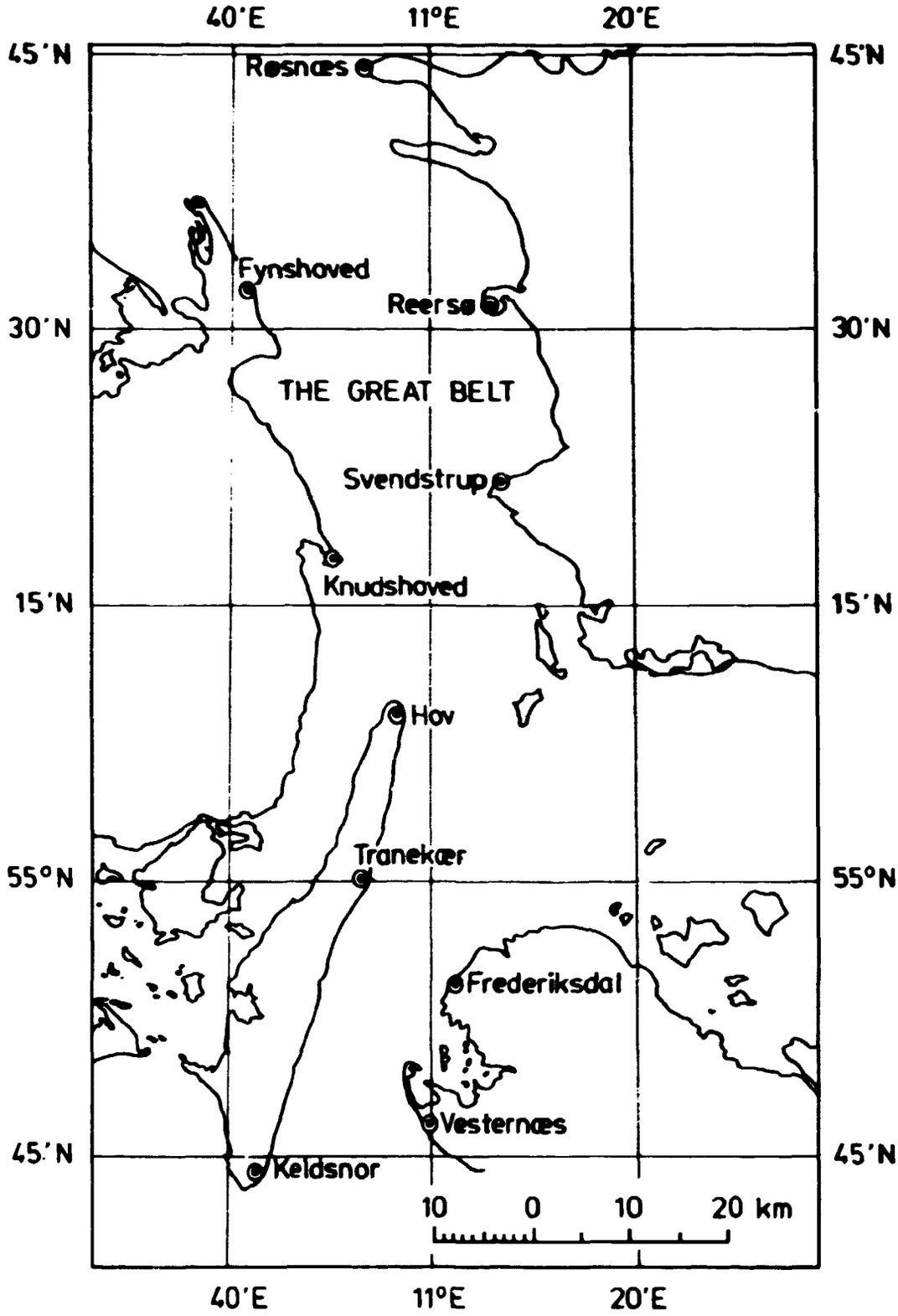

Fig. 9.5.1. The coasts of the Great Belt. Locations for background radiation.

10. CONCLUSION

10.1. Environmental monitoring at Risø, Barsebäck and Ringhals

No radioactive contamination of the environment originating from the operation of the research establishment was ascertained outside Risø in 1977. As in previous years, the variations in contamination level were independent of the distance of the sampling locations from Risø.

Benthic brown algae and mussels collected at the Swedish nuclear plants at Barsebäck and Ringhals were used as biological indicators of radioactive pollution. Transfer factors to Fucus were calculated. Apparantly Fucus did not distinguish between radiocobalt, ^{65}Zn and ^{54}Mn whereas lower transfer factors were calculated for $^{110\,m}Ag$ and ^{51}Cr. The discharged cobalt isotopes were integrated over 7-13 months in Fucus vesiculosus.

10.2. Nuclear-weapon debris in the abiotic environment

The mean content of ^{90}Sr in air collected in 1977 was 0.7 fCi $^{90}Sr\ m^{-3}$, i.e. approx. 3 times the 1976 level. The average fallout at the State experimental farms in 1977 was 0.4 mCi $^{90}Sr\ km^{-2}$ or nearly four times the 1976 figure, and the mean concentration of ^{90}Sr in rain water was 0.63 pCi $^{90}Sr\ l^{-1}$.

By the end of 1977 the accumulated fallout was approx. 50 mCi $^{90}Sr\ km^{-2}$. The corresponding ^{137}Cs was estimated at 80 mCi km^{-2}.

In agreement with the greater precipitation in that part of the country, fallout levels in Jutland were 15-25% higher than levels found in eastern Denmark.

The median level of ^{90}Sr in Danish ground water was 10 fCi $^{90}Sr\ l^{-1}$.

Danish streams contained 0.3 pCi $^{90}Sr\ l^{-1}$ and Danish lakes showed a mean concentration of 0.8 pCi $^{90}Sr\ l^{-1}$ in 1977.

Inner Danish surface waters (salinity 16 o/oo) contained 0.7 pCi $^{90}Sr\ l^{-1}$ and 0.8 pCi $^{137}Cs\ l^{-1}$, i.e. unchanged as compared with 1976.

10.3. Fallout nuclides in the human diet

The mean level of ^{90}Sr in Danish milk was 2.9 S.U., and the mean content of ^{137}Cs was approx. 5.1 pCi $^{137}Cs\ l^{-1}$.

The 1977 ^{90}Sr and ^{137}Cs levels were lower than the levels found in milk produced in 1976.

The ^{90}Sr mean content in grain from the 1977 harvest was 27 pCi $^{90}Sr\ kg^{-1}$. The ^{137}Cs mean content in grain was 22 pCi $^{137}Cs\ kg^{-1}$. The ^{90}Sr level in grain from the 1977 harvest was 35% higher than the level found in the 1976 harvest, and ^{137}Cs was 3 times the 1976 level.

The mean contents of ^{90}Sr and ^{137}Cs in Danish vegetables collected in 1977 were 7 pCi $^{90}Sr\ kg^{-1}$ (20 S.U.) and 2 pCi $^{137}Cs\ kg^{-1}$, respectively, and in fruits 0.8 pCi $^{90}Sr\ kg^{-1}$ and 3.9 pCi $^{137}Cs\ kg^{-1}$; potatoes contained 1.6 pCi $^{90}Sr\ kg^{-1}$ and 4.6 pCi $^{137}Cs\ kg^{-1}$.

The mean levels of ^{90}Sr and ^{137}Cs in total-diet samples collected in 1977 were 3.8 S.U., or 6 pCi $^{90}Sr\ day^{-1}$ and 10 pCi $^{137}Cs\ day^{-1}$, respectively. From analyses of the individual diet components, the ^{90}Sr level in the Danish average diet was estimated to be 3.8 S.U. and the ^{137}Cs intake to be 13 pCi $^{137}Cs\ day^{-1}$. The levels of ^{90}Sr and ^{137}Cs in the Danish total diet consumed in 1977 were close to the levels observed in 1976.

Grain products contributed 39% and milk products 34% to the total ^{90}Sr intake; 30% of the ^{137}Cs in the diet originated from meat, 14% from grain products, and 19% from milk products.

Both ^{90}Sr and ^{137}Cs diet levels were on the average higher in Jutland than in eastern Denmark.

The Chinese test explosion on 17 September 1977 resulted in a temporary contamination of cows' milk with ^{131}I. The estimated dose to an infant thyroid in Denmark from this contamination was less than 1 mrad.

10.4. Strontium-90 and Cesium-137 in humans

The ^{90}Sr mean content in human bone (vertebrae) collected in 1977 was about 1 S.U. in all age groups. The 1977 bone levels were a little lower than the 1976 levels.

The mean content of ^{137}Cs in the human body in 1977 was estimated from whole-body countings to be 1.2 nCi (8 pCi ^{137}Cs/g K), i.e. a little lower than the 1976 level.

10.5. Tritium in environmental samples

Tritium levels varied between 0.2 and 0.7 nCi/l in rain water and between 0.1 and 0.3 nCi/l in ground water. The variation with time in rain water corresponded to the equivalent variation in ^{90}Sr levels.

10.6. Plutonium in environmental samples

Plutonium was determined in soil, sediments and seaweed. The main source of plutonium in these samples was nuclear weapons fallout, however minor contributions of Pu from reprocessing plants to the levels observed in seaweed samples were possible.

10.7. Background radiation

The average background radiation measured with TLD's was 8.3 μR/h. The contribution of the secondary cosmic radiation was estimated to be 4.1 μR/h and that of the γ-background from terrestrial sources to be 4.2 μR/h. The γ-background in Denmark consists on the average of 45% from ^{40}K, 20% from the uranium series, 30% from the thorium series, and 5% from fallout.

At Risø three locations showed elevated γ-background levels. At one location, the increase above the background was caused by radioactive waste at the waste treatment station, at the other the increase resulted from operation of the reactor DR 1, and at the third the deposition nearby of uranium tailings caused the increase.

ACKNOWLEDGEMENTS

The authors wish to thank Miss Anna Holm Pedersen, Miss Lone Dyrgaard Jensen, Mrs. Karen Mandrup Jensen, Miss Karen Wie Nielsen, Mrs. Jytte Lene Clausen, Mrs. Ulla Wilhelmsen, Mrs. Anna Madsen, Mrs. Laila Leth, Mrs. Pearl Baade Pedersen, Mrs. Alice Kjølhede, Mrs. Else Sørensen and Mr. Michael Brandt Svendsen for their conscientious performance of the analyses. We are grateful to Mr. Peder Kristiansen and Mr. Gunnar Bitsch for collection of the samples and performance of the γ-background measurements.

We are specially indebted to the staffs of the eleven State experimental farms at Tylstrup, Ødum, Studsgård, Askov, St. Jyndevad, Blangstedgård, Tystofte, Ledreborg, Virumgård, Abed, and Åkirkeby, who have continued to supply us with a number of the most important samples dealt with in this report.

APPENDIX A. Calculated Fallout in the Eight Zones in 1977

Zone	mm precipitation in 1977	mCi ^{90}Sr km^{-2} in 1977	Accumulated mCi ^{90}Sr km^{-2} by the end of 1977
I: N. Jutland II: E. Jutland III: W. Jutland IV: S. Jutland	777 (790)	0.40	56
V: Funen VI: Zealand VII: Lolland-Falster	591 (578)	0.32	45
VIII: Bornholm	706 (763)	0.51	-
Area-weighted mean	721 (727)	0.38	53

The amounts of precipitation were obtained from ref. 9. The ^{90}Sr deposition was estimated from 4.2 and appendix D.

The precipitations in brackets were the mean of values measured by the Meteorological Institute at the state experimental farms: Jutland: Tylstrup, Ødum, Studsgård, Askov, St. Jyndevad; The Islands: Blangstedgård, Tystofte, Virumgård, Abed; Bornholm: Åkirkeby.

APPENDIX B. Statistical information

Zone		Area in km^2 15) 1971	Population in thousands 28) 1976	Annual milk production in mega-kg 14) 1971	Annual wheat production in mega-kg 13) 1972	Annual rye production in mega-kg 13) 1972	Annual potato production in mega-kg 13) 1972	Vegetable area in km^2 13) 1972
I:	N. Jutland	6,171	471	911				
II:	E. Jutland	7,561	881	1,258	145	155	609	14
III:	W. Jutland	12,104	687	926				
IV:	S. Jutland	3,929	245	572				
V:	Funen	3,486	446	393				
VI:	Zealand	7,435	2,165*	395				
VII:	Lolland-Falster	1,795	123	68	448	71	100	73
VIII:	Bornholm	588	47	39				
Total		43,069	5,065	4,562	593	226	709	87

*1,270,000 people were living in Greater Copenhagen and 895,000 in the remaining part of Zealand.

APPENDIX C

Appendix C.1. Comparison between observed and predicted ^{90}Sr levels in environmental samples collected in 1977

Sample	Location	Unit	Observed	Predicted	Obs./pred.	Model in reference (21)
Dried milk*	Jutland	pCi ^{90}Sr (g Ca)$^{-1}$	3.8	4.5	0.84	C.3.2.1 No.1
" "	Islands	- " -	2.4	2.5	0.96	- " - No.3
Fresh milk	Jutland	- " -	3.0	3.7	0.81	- " - No.5
" "	Islands	- " -	2.5	3.6	0.69	- " - No.7
Rye	Jutland	pCi ^{90}Sr kg^{-1}	29	21	1.38	C.2.2.1 No.1
"	Islands	- " -	18.5	14.5	1.28	- " - No.3
Barley	Jutland	- " -	29	26	1.12	- " - No.4
"	Islands	- " -	17	15	1.13	- " - No.6
Wheat	Jutland	- " -	38	27	1.41	- " - No.8
"	Islands	- " -	16	17	0.94	- " - No.10
Oats	Jutland	- " -	44	47	0.94	- " - No.12
"	Islands	- " -	26	26	1.00	- " - No.13
Rye bread	Denmark	- " -	12.4	10.6	1.17	C.2.3.1 No.1
White bread	"	- " -	3.7	3.5	1.06	- " - No.2
Potatoes	Jutland	- " -	1.8	3.2	0.56	C.2.5.1 No.8
"	Islands	- " -	1.5	2.7	0.56	- " - No.10
Cabbage	Jutland	- " -	9.8	10.1	0.97	- " - No.1
"	Islands	- " -	7.4	8.4	0.88	- " - No.3
Carrot	Jutland	- " -	14.5	17.1	0.85	- " - No.5
"	Islands	- " -	6.7	7.7	0.87	- " - No.6
Peas	Denmark	- " -	3.5	3.6	0.97	C.2.5.5 No.3
Apples	"	- " -	0.85	0.8	1.06	C.2.5.1 No.13
Pork	"	- " -	0.38	0.94	0.40	C.3.4.1 No.3
Beef	"	- " -	0.54	1.25	0.43	- " - No.1
Eggs	"	- " -	0.91	0.8	1.14	C.3.6.1 No.6
Total diet C	"	pCi ^{90}Sr (g Ca)$^{-1}$	3.8	5.0	0.76	C.4.2.1 No.1
" " P	"	- " -	3.8	4.7	0.81	- " - No.7
Human bone > 29 yr	"	- " -	1.0	1.2	0.83	C.4.3.1 No.13
Summer grass	"	- " -	28.9	11.6	2.49	C.2.4.1 No.3
Whole year grass	Islands	- " -	31	23	1.35	- " - No.1
Fucus vesiculosus	"	- " -	8.9	14	0.64	C.2.7.1 No.3
Zostera marina	"	- " -	2.2	2.4	0.92	- " - No.1
Stream water	Denmark	pCi ^{90}Sr l^{-1}	0.34	0.29	1.17	C.1.4.1 No.3
Lake water	"	- " -	0.80	0.57	1.40	- " - No.5
Ground water	"	- " -	0.010	0.010	1.00	- " - No.1

*May 1977 - April 1977 ("milk year" (21)).

Appendix C.2. Comparison between observed and predicted ^{137}Cs levels in environmental samples collected in 1977

Sample	Location	Unit	Observed	Predicted	Obs./pred.	Model in reference (21)
Dried milk*	Jutland	pCi ^{137}Cs (g K)$^{-1}$	4.7	3.6	1.31	C.3.2.2 No.1
" "	Islands	- " -	2.6	2.1	1.24	- " - No.3
Fresh milk	Jutland	- " -	2.9	2.0	1.45	- " - No.5
" "	Islands	- " -	2.1	1.5	1.40	- " - No.7
Rye	Jutland	pCi ^{137}Cs kg^{-1}	26	23	1.13	C.2.2.4 No.2
"	Islands	- " -	23	24	0.96	- " - No.3
Barley	Jutland	- " -	15	17	0.88	- " - No.4
"	Islands	- " -	21	16	1.31	- " - No.5
Wheat	Jutland	- " -	16	17	0.94	- " - No.6
"	Islands	- " -	19	14	1.36	- " - No.7
Oats	Jutland	- " -	28	14	2.00	- " - No.8
"	Islands	- " -	24	15	1.60	- " - No.9
Rye bread	Denmark	- " -	9.2	6.6	1.39	C.2.3.1 No.4
White bread	"	- " -	1.8	3.2	0.56	- " - No.5
Potatoes	Jutland	- " -	5.8	5.7	1.02	C.2.5.3 No.5
"	Islands	- " -	3.4	1.9	1.79	- " - No.7
Cabbage	Denmark	- " -	2.3	1.9	1.21	- " - No.1
Carrot	"	- " -	3.1	1.4	2.21	- " - No.3
Apples	"	- " -	3.9	2.1	1.86	- " - No.11
Pork	"	- " -	23	14	1.64	C.3.4.2 No.3
Beef	"	- " -	30	19	1.58	- " - No.1
Eggs	"	- " -	0.83	1.1	0.75	C.3.6.2 No.6
Total diet C	"	pCi ^{137}Cs (g K)$^{-1}$	2.6	1.8	1.44	C.4.2.2 No.1
" " p	"	- " -	3.4	2.5	1.36	- " - No.6
Human body	"	- " -	8.4	5.2	1.62	C.4.5.1 No.1
Summer grass	"	- " -	3.4	5.7	0.60	C.2.4.2 No.1

* (cf. note to appendix C.1)

The mean ratio between observed and predicted values was 0.99 $\pm$ 0.37 (1 SD) for ^{90}Sr and 1.33 $\pm$ 0.41 for ^{137}Cs. In general, the prediction models overestimated the ^{90}Sr levels in 1977, while the ^{137}Cs concentrations were underestimated. An explanation of the higher ^{137}Cs levels observed in 1977, compared

with those expected from the prediction models, could be a higher $^{137}Cs/^{90}Sr$ ratio than hitherto observed in fallout from 1976 and 1977. As the ^{137}Cs deposition is calculated from the ^{90}Sr fallout by multiplication by 1.6, and as the $^{137}Cs/^{90}Sr$ ratio in 1976 and 1977 was approx. 2.1, the models may have underestimated the levels in samples from 1977 by a factor of approx. $\frac{2.1}{1.6} = 1.3$. This is because the fallout rate rather than the accumulated deposit has generally determined the ^{137}Cs concentrations in environmental samples.

APPENDIX D

d_i:

Annual fallout rate in mCi ^{90}Sr km^{-2} y^{-1}.

$A_{i(5)}$:

Accumulated fallout by the end of the year (i) assuming an effective half-life of ^{90}Sr of 5 y. Unit: mCi ^{90}Sr km^{-2}.

$A_{i(15)}$ and $A_{i(27.7)}$:

Accumulated fallout by the end of the year (i) assuming effective half-lives of ^{90}Sr of 15 y and 27.7 y, respectively. Unit: mCi ^{90}Sr km^{-2}.

$d_{i(May-Aug.)}$ and $d_{i(July-Aug.)}$:

The fallout rates in the periods: May-Aug. and July-Aug., respectively. Unit: mCi ^{90}Sr km^{-2} $period^{-1}$.

The fallout rate (d_i) was based on precipitation data collected for all Denmark in the period 1962-1977 (cf. table 4.2.1[1]). Before 1962 the levels in the tables were estimated from the HASL data for New York (HASL Appendix 291, 1975)[29] considering that the mean ratio between ^{90}Sr fallout in Denmark and New York was 0.7 in the period 1962-1974.

The $d_{i(May-Aug.)}$ and $d_{i(July-Aug.)}$ values were also obtained from table 4.2.1[1] for the period 1962-1977. For the years 1959-1961 the values were calculated from data obtained from ^{90}Sr analysis of air (1959) and precipitation samples (1962 and 1961) collected at Risø. Before 1959, the values were estimated from the corresponding d_i values assuming that the ratios $d_{i(May-Aug.)}/d_i$ and $d_{i(July-Aug.)}/d_i$ were constant in time and equal to the means found for the period 1962-1974, which were 0.54 (1 S.D.: 0.09) and 0.24 (1 S.D.: 0.06), respectively.

APPENDIX D. Fallout rates and accumulated fallout (mCi ^{90}Sr km^{-2}) in Denmark 1950-1977

	Denmark				Jutland				Islands			
	di	$Ai_{(5)}$	$Ai_{(15)}$	$Ai_{(27.7)}$	di	$Ai_{(5)}$	$Ai_{(15)}$	$Ai_{(27.7)}$	di	$Ai_{(5)}$	$Ai_{(15)}$	$Ai_{(27.7)}$
1950	0.021	0.018	0.020	0.020	0.022	0.019	0.021	0.021	0.020	0.017	0.019	0.020
1951	0.101	0.104	0.116	0.118	0.114	0.116	0.129	0.132	0.088	0.092	0.102	0.105
1952	0.198	0.263	0.299	0.309	0.224	0.296	0.337	0.347	0.172	0.230	0.262	0.270
1953	0.500	0.664	0.763	0.789	0.566	0.751	0.862	0.891	0.434	0.578	0.665	0.687
1954	1.901	2.233	2.544	2.623	2.152	2.526	2.878	2.967	1.650	1.939	2.210	2.279
1955	2.501	4.121	4.817	4.997	2.831	4.664	5.451	5.655	2.171	3.578	4.183	4.340
1956	3.101	6.287	7.560	7.898	3.510	7.116	8.557	8.939	2.692	5.458	6.564	6.858
1957	3.101	8.173	10.180	10.728	3.510	9.251	11.522	12.142	2.692	7.095	8.838	9.313
1958	4.302	10.860	13.828	14.658	4.869	12.292	15.651	16.591	3.734	9.427	12.004	12.725
1959	6.102	14.766	19.030	20.247	6.908	16.715	21.540	22.918	5.297	12.817	16.519	17.576
1960	1.140	13.847	19.259	20.859	1.291	15.675	21.800	23.610	0.990	12.020	16.718	18.107
1961	1.481	13.344	19.803	21.787	1.676	15.105	22.416	24.661	1.285	11.583	17.190	18.913
1962	7.428	18.083	26.001	28.493	7.976	20.093	29.019	31.830	6.880	16.073	22.983	25.155
1963	16.695	30.276	40.768	44.071	18.453	33.556	45.329	49.041	14.937	26.996	36.208	39.101
1964	10.412	35.421	48.869	53.136	11.685	39.384	54.439	59.225	9.139	31.457	43.299	47.048
1965	3.954	34.277	50.437	55.679	4.204	37.946	55.994	61.861	3.704	30.609	44.880	49.497
1966	2.145	31.707	50.207	56.395	2.166	34.919	55.534	62.445	2.124	28.495	44.881	50.345
1967	1.047	28.514	48.940	56.023	1.176	31.423	54.149	62.048	0.918	25.606	43.731	49.997
1968	1.403	26.044	48.069	56.006	1.568	28.720	53.201	62.045	1.237	23.368	42.938	49.968
1969	1.035	23.574	46.887	55.632	1.241	26.083	51.983	61.721	0.829	21.065	41.791	49.542
1970	1.647	21.956	46.342	55.863	1.993	24.442	51.539	62.140	1.301	19.471	41.146	49.586
1971	1.506	20.425	45.688	55.951	1.726	22.780	50.860	62.288	1.286	18.070	40.515	49.615
1972	0.435	18.160	44.040	54.993	0.457	20.229	49.000	61.194	0.413	16.090	39.080	48.792
1973	0.192	15.976	42.235	53.821	0.215	17.798	46.993	59.891	0.168	14.153	37.476	47.750
1974	0.710	14.526	41.006	53.183	0.779	16.172	45.615	59.171	0.643	12.881	36.398	47.197
1975	0.414	13.006	39.550	52.272	0.452	14.472	43.987	58.150	0.376	11.541	35.113	46.397
1976	0.103	11.413	37.862	51.082	0.116	12.699	42.117	56.826	0.090	10.1.6	33.614	45.339
1977	0.384	10.320	36.536	50.204	0.405	11.460	40.620	55.827	0.362	9.177	32.458	44.581

Denmark		Jutland		Islands	
$di_{(May-Aug.)}$	$di_{(July-Aug.)}$	$di_{(May-Aug.)}$	$di_{(July-Aug.)}$	$di_{(May-Aug.)}$	$di_{(July-Aug.)}$
0.01	0.01	0.01	0.01	0.01	0.01
0.05	0.02	0.06	0.03	0.05	0.02
0.11	0.05	0.12	0.05	0.09	0.04
0.27	0.12	0.31	0.14	0.23	0.10
1.03	0.46	1.16	0.52	0.89	0.40
1.35	0.60	1.53	0.68	1.17	0.52
1.67	0.74	1.90	0.84	1.45	0.65
1.67	0.74	1.90	0.84	1.45	0.65
2.32	1.03	2.63	1.17	2.02	0.90
2.50	0.68	2.76	0.75	2.24	0.61
0.47	0.31	0.52	0.34	0.42	0.28
0.66	0.47	0.73	0.52	0.59	0.42
4.223	1.857	4.56o	2.052	3.880	1.662
9.965	5.629	10.753	5.932	9.177	5.327
6.235	2.568	7.170	2.910	5.299	2.226
2.029	0.850	2.094	0.852	1.964	0.848
1.049	0.418	0.984	0.496	1.114	0.340
0.367	0.141	0.380	0.134	0.354	0.148
0.848	0.426	0.910	0.460	0.786	0.392
0.614	0.276	0.723	0.319	0.505	0.233
0.908	0.547	1.076	0.632	0.740	0.462
0.992	0.405	1.154	0.516	0.830	0.294
0.253	0.084	0.262	0.084	0.244	0.084
0.075	0.033	0.093	0.039	0.057	0.027
0.421	0.190	0.463	0.219	0.378	0.162
0.159	0.075	0.179	0.091	0.157	0.060
0.032	0.010	0.032	0.011	0.032	0.009
0.178	0.107	0.164	0.085	0.190	0.129

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