Technical University of Denmark

Environmental radioactivity in Denmark in 1990 and 1991

Aarkrog, Asker; Bøtter-Jensen, Lars; Chen, Qing Jiang; Dahlgaard, Henning; Hansen, Heinz Johs. Max; Holm, Elis; Lauridsen, Bente; Nielsen, Sven Poul; Strandberg, Morten; Søgaard-Hansen, Jens

Publication date:
1992

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

RISØ

Risø-R-621(EN)

Environmental Radioactivity in Denmark in 1990 and 1991

A. Aarkrog, L. Bøtter-Jensen, Chen Qing Jiang, H. Dahlgaard, Heinz Hansen, Elis Holm+, Bente Lauridsen, S.P. Nielsen, Morten Strandberg and J. Søgaard-Hansen

+University of Lund, Sweden

Risø National Laboratory, Roskilde, Denmark
December 1992

Environmental Radioactivity in Denmark in 1990 and 1991

Risø-R-621(EN)

A. Aarkrog, L. Bøtter-Jensen, Chen Qing Jiang, H. Dahlgaard, Heinz Hansen, Elis Holm[+], Bente Lauridsen, S.P. Nielsen, Morten Strandberg and J. Søgaard-Hansen

[+]University of Lund, Sweden

Risø National Laboratory, Roskilde, Denmark
December 1992

Abstract. Strontium-90, radiocesium, and other radionuclides were determined in samples from all over the country of air, precipitation, stream water, lake water, sea water, soil, sediments, dried milk, fresh milk, meat, fish, cheese, eggs, grain, bread, potatoes, vegetables, fruit, grass, moss, lichen, sea plants, total diet, and humans. Estimates are given of the mean contents of radiostrontium and radiocesium in the human diet in Denmark during 1990 and 1991. Tritium was determined in precipitation, fresh waters, and sea water. The γ-background was measured regularly by TLD's and a NaI detector. Tc-99 determinations were carried out on various marine samples, first of all sea water.

ISBN 87-550-1802-5
ISSN 0106-2840
ISSN 0106-407X

Grafisk Service, Risø, 1992

Contents

Abbreviations and Units

J: joule: the unit of energy; 1 J = 1 Nm (= 0.239 cal)
Gy: gray: the unit of absorbed dose = 1 J kg^{-1} (= 100 rad)
Sv: sievert: the unit of dose equivalent = 1 J kg^{-1} (= 100 rem)
Bq: becquerel: the unit of radioactivity = 1 s^{-1} (= 27 pCi)

cal: calorie = 4.186 J
rad: 0.01 Gy
rem: 0.01 Sv
Ci: curie: 3.7×10^{10} Bq (= 2.22×10^{12} dpm)

E: exa: 10^{18}
P: peta: 10^{15}
T: tera: 10^{12}
G: giga: 10^{9}
M: mega: 10^{6}
k: kilo: 10^{3}
m: milli: 10^{-3}
μ: micro: 10^{-6}
n: nano: 10^{-9}
p: pico: 10^{-12}
f: femto: 10^{-15}
a: atto: 10^{-18}

pro capite: per individual
TNT: trinitrotoluol; 1 Mt TNT: nuclear explosives equivalent to 10^{9} kg TNT.

yr^{-1}: per year (a^{-1})
cpm: counts per minute
dpm: disintegrations per minute
OR: observed ratio
CF: concentration factor
FP: fission products
μR: micro-roentgen, 10^{-6} roentgen
S.U.: pCi ^{90}Sr (g Ca)$^{-1}$
O.R.: observed ratio
M.U.: pCi ^{137}Cs (g K)$^{-1}$
V: vertebrae
m: male
f: female
nSr: natural (stable) Sr
TOR = total observed ratio of Chernobyl and fallout
COR = Chernobyl observed ratio
FOR = Fallout observed ratio

eqv. mg KCl: equivalents mg KCl: activity as from 1 mg KCl
(~0.96 dpm = 0.016 Bq; 1 g K = 30.65 Bq)

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
S.S.D.: sum of squares of deviation: $\Sigma(\bar{x}-x_i)^2$
f: degrees of freedom
s^2: variance
v^2: ratio of the variance in question to the residual variance
P: probability fractile of the distribution in question
η : coefficient of variation, relative standard deviation
anova: analysis of variance
A: relative standard deviation 20-33%
B: relative standard devition >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 thirty-third of a series of periodic reports (Risø Reports 1957-1991) dealing with measurements of radioactivity in Denmark. The organization of the material in the present report corresponds to the report of last year, i.e. this report covers two years: 1990 and 1991. The tables (and figures) representing 1990 are marked with an A and those from 1991 with a B. Tables and Figures are placed after the text in each chapter, and the text has been reduced compared to previously. After the introduction and a chapter on organization and facilities, there follows a chapter on environmental monitoring around Risø. 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, various vegetation and human tissues. Chapter seven is devoted to a general discussion of environmental tritium studies. External radiation is treated in chapter eight. The names of the authors of each chapter appear at its head.

1.2.

The methods of radiochemical analysis (*Osmond* et al. 1959, *Bryant* et al. 1959, *Harley* 1972) and the statistical treatment of the results (*Hald* 1958, *Vestergaard* 1964) are still based on the principles established in previous reports (Risø Reports 1957-1991).

1.3.

The detailed tables of the environmental monitoring programme for Risø National Laboratory appear in semiannual reports: Radioactivity in the Risø district January-June 1990, July-December 1990, January-June 1991 and July-December 1991 which are available from the Ecology Section, Risø.

1.4.

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

1.5.

In 1990 and 1991 the personnel of the Ecology Section of the Department for Environmental Science and Technology consisted of three chemists (incl. one guest scientist), two biologist, one physicist, ten laboratory technicians, one sample collector, and two laboratory assistants.

1.6.

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

1.7.

The Environmental samplings around the Swedish nuclear power plants Barsebäck and Ringhals were discontinued by Risø from 1990.

2. Facilities

By S.P. Nielsen

2.1. Detectors

The samples are measured as follows:

Alpha (^{239}Pu, ^{241}Am and ^{210}Po): 22 semiconductor detectors connected to multichannel analyzers (512 channels per detector).

Beta (^{90}Y and ^{99}Tc): Six "multidetector"-systems each containing 5 sample counters and a common anticoincidence shield are used.

Gamma (natural and fallout isotopes): A total of 11 germanium detectors in 10 cm lead shields are used for gamma spectrometric measurements. Four detectors are connected to a hard-wired multichannel analyzer and 7 to MCA-cards in personal computers. The efficiencies of the detectors are in the range 4-40% relative to a 3" × 3" NaI(Tl) detector. An 8" × 4" NaI(Tl) detector and a detector unit with three 4" × 4" × 16" NaI(Tl) crystals are used in an underground shielded room for gamma-spectrometric whole-body measurements.

2.2. Data Treatment

Measured spectra are transferred to a Unisys A6 computer for evaluation.

A program system STATDATA (*Lippert* 1975) is developed for registration and treatment of environmental measurements including multichannel analyzer spectra. To date, approximately 115 000 sets of results have been registered covering the period from 1957.

3. Environmental Monitoring at Risø

by A. Aarkrog

3.1. Environmental Monitoring at Risø

From the four semiannual reports: Radioactivity in the Risø district January-June 1990, July-December 1990, January-June 1991 and July-December 1991, the results of the environmental monitoring at Risø are presented. The reports are available from the Ecology Section, Risø.

The various anthropogenic radionuclides measured outside the Risø area came from non-Risø sources.

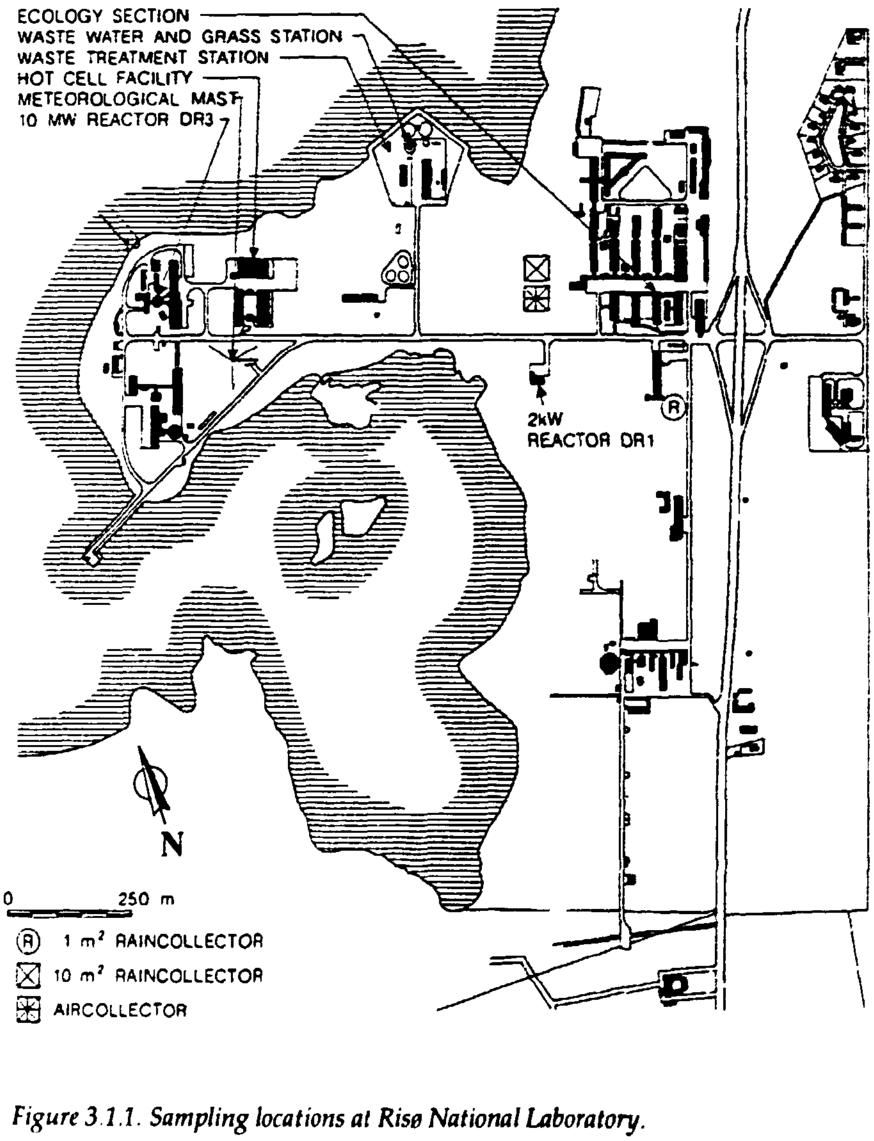


Figure 3.1.1. Sampling locations at Risø National Laboratory.

4. Fallout Nuclides in Abiotic Samples

by A. Aarkrog, H. Dahlgaard and Heinz Hansen

4.1. Air

Air samples are collected at Risø and at Rønne, Bornholm. Weekly samples are measured by Ge-γ-spectroscopy and ^{90}Sr is determined in annual aliquots. The sampling equipment is described in Risø Report No. 421 (Risø Reports 1957-1991).

Figure 4.1.1 shows how the ^{90}Sr concentrations have varied in Risø air since sampling began in 1957.

Table 4.1.2.2 summarizes the ^{137}Cs air concentrations throughout the years. Since Chernobyl the decrease in concentrations has become slower with time. Tables 4.1.2.1 (A & B) suggest a spring peak around April. From Figures 4.1.2.1 and 4.1.2.2 it appears, however, that the peak is not very prominent. It is thus an open question whether there actually is a stratospheric component of the Chernobyl fallout or whether all measured Chernobyl ^{137}Cs in air and precipitation now is due to resuspension.

Figure 4.1.2.4 shows how the resuspension factor for Chernobyl ^{137}Cs in Denmark has decreased with time. A power function seems to give the best fit to the observations (see also Figure 4.1.2.5).

The ^{137}Cs concentrations in air at Risø are about ¾ of those measured at Bornholm. We believe this is due to a higher local and perhaps regional (from Eastern Europe) resuspension at Bornholm. The resuspension factor at Bornholm is twice that at Risø

4.2. Precipitation

Precipitation is collected monthly from the ten »State experimental farms« (Figure 4.2) and from Risø (Figure 3.1.1). The samples are combined before analysis for ^{90}Sr and radiocesium (see Tables 4.2.1.1 and 4.2.2.2).

From 1987 to 1989 the ^{90}Sr deposition in Denmark decayed with a halflife of about 1.4 year. Since then there has been no significant decay. ^{137}Cs also showed a fast decay from 1987 to 1989 (halflife ~ 0.4 year). From 1989 to 1991 the halflife of ^{137}Cs deposition in Denmark increased to nearly 2 years. Local resuspension plays an important role as a source for the ^{137}Cs deposit. We still notice a relationship between the original Chernobyl fallout and the depositions at the various State experimental farms (*Aarkrog* 1988, *Aarkrog* 1989).

The washout ratio (Bq m^{-3} rain/µBq m^{-3} air) calculated from monthly ^{137}Cs values at Risø (Tables 4.1.2.1.A & B and Tables 4.2.2.5.A & B) was 2.3±1.6 (1 S.D.; n = 12) in 1990 and 2.9±1.5 in 1991. This was lower ratios than observed previously, when we found 1987: 6.5, 1988: 3.4 and 1989: 5.0.

4.3. Fresh Water

4.3.1. Ground Water

No collection of ground water took place in 1990 and 1991.

4.3.2. Lakes and Streams

The sampling locations for lake and stream water are shown in Figure 4.3.2.1

Since 1986 Chernobyl ^{137}Cs have been measured along with ^{90}Sr. In the period 1989-1992 the ^{137}Cs concentrations in lake water have shown an effective halflife of 3.8 years and those in streams have decreased with 2.7 years halflife (cf. Figures 4.3.2.2 and 4.3.2.3). The corresponding halflives of ^{90}Sr were 9 and 4.5 years, respectively (Figure 4.3.2.2).

Strontium-90 concentrations in stream (and lake) water are significantly higher then the current ^{90}Sr concentrations in precipitation, whereas the opposite is the case for ^{137}Cs. Hence soil and sediments presently release ^{90}Sr while ^{137}Cs is absorbed.

4.3.3. Drinking Water

No samples in 1990 and 1991.

4.4. Sea Water

Since 1962 samples of surface and bottom sea water have routinely been collected around Zealand summer and winter (Figure 4.4.3). (One summer sampling was missing in 1991).

The ^{90}Sr and the ^{137}Cs concentrations throughout the years are shown in Figures 4.4.1 and 4.4.2, respectively.

Since Chernobyl the Baltic Sea has been the main source to the ^{137}Cs contamination of Danish waters.

The ^{99}Tc measurements (Figures 4.4.5-4.4.9) illustrate that ^{99}Tc enters the Danish inner waters from the North Sea by the Jutland Current.

4.5. Soil

A special soil sampling was carried out at Tornbygård at Bornholm in May 1990 (Table 4.5.1). The purpose was to see if the location used for rain collectors favoured high fallout rates as has been observed for ^{90}Sr in recent years. Five locations were selected out to a distance of 1300 metres west of the rain collectors. The sampling points were located on a downward sloping hill, ending in a forest.

The measurements showed the highest deposit (in the 0-5 cm soil layer) in the forest except for Chernobyl ^{137}Cs, which showed the highest level at the rain collectors.

4.6. Marine Sediments

Samples were collected at Risø in 1990 and 1991 (Table 4.6).

Table 4. Geometric means of Strontium-90 and Cesium-137 levels in Danish environmental abiotic samples collected in 1990 and 1991

Sample type and unit	Strontium-90		Cesium-137	
	1990	1991	1990	1991
Air at Risø, µBq m^{-3}	0.27 B	0.35	0.96	0.91
Air at Bornholm, µBq m^{-3}	0.24 B	0.54 A	1.33	1.32
Countrywide deposition with rain, Bq m^{-2}	0.51*	0.56*	2.6*	1.63*
Countrywide rain samples, Bq m^{-3}	0.67*	0.94*	3.5*	2.8*
Countrywide stream water, Bq m^{-3}	-	6.7	0.70	< 0.74
Countrywide lake water, Bq m^{-3}	-	9.9	4.8	4.1
Countrywide ground water, Bq m^{-3}	-	-	-	-
Countrywide drinking water, Bq m^{-3}	-	-	-	-
Surface sea water around Zealand, Bq m^{-3}	18.0*	14.2*	79*	72*
Bottom sea water around Zealand, Bq m^{-3}	16.1*	11.8*	45*	62*
Baltic Sea water (Bornholm), Bq m^{-3}	19.8†	17.6	103*	103*
North Sea water 50°-60°N, Bq m^{-3}	-	4.4*	-	14*

*Arithmetic means

†Single values.

Table 4.1.1.1. Strontium-90 in air collected at Risø in 1990 and 1991. (Unit: µBq m^{-3})

Year	Big air sampler
1990	0.27 B
1991	0.35 A

Table 4.1.1.2. Strontium-90 in air collected at Bornholm in 1990 and 1991. (Unit: µBq m^{-3})

Year	Big sampler, glass fibre filter, shunt
1990	0.24 B
1991	0.54 B

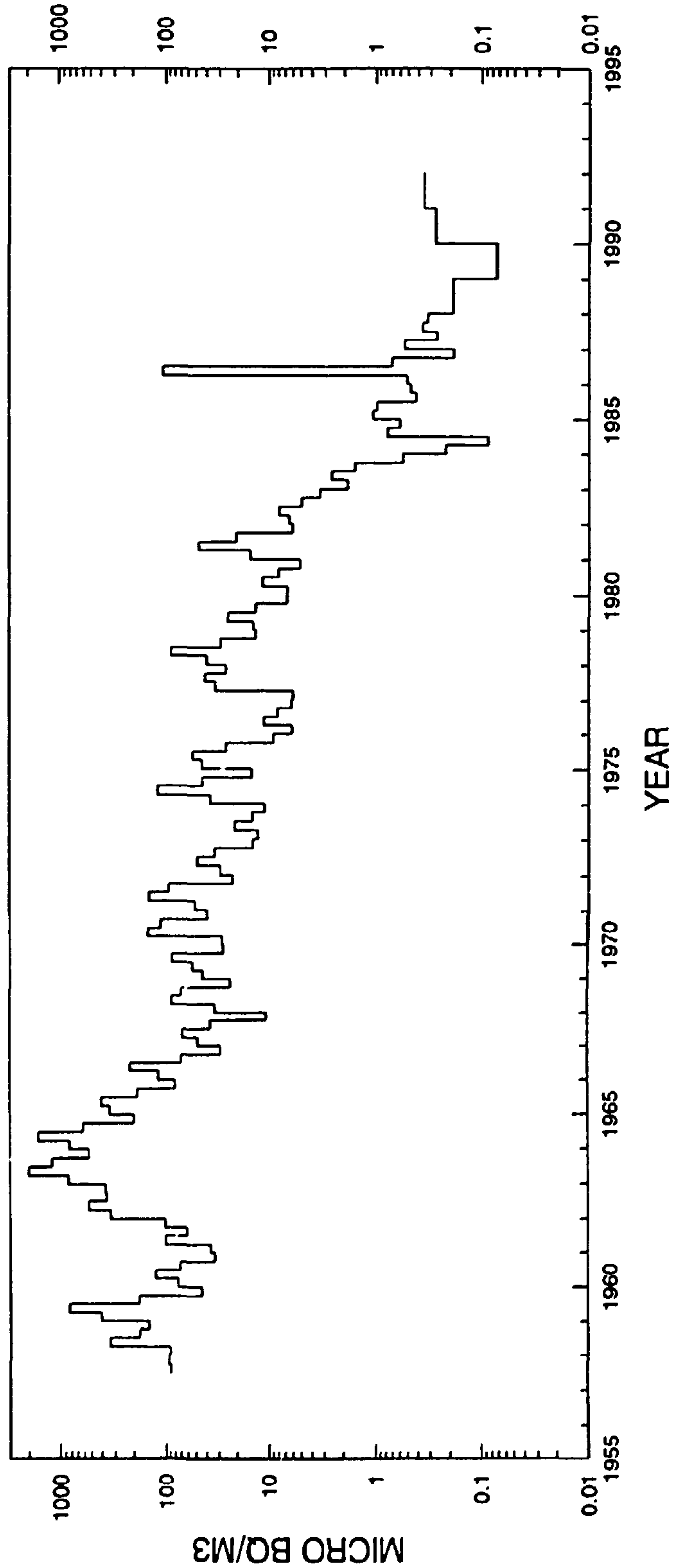


Figure 4.1.1. Strontium-90 in ground level air at Risø, 1957-1991. (μBq m^{-3}).

Table 4.1.2.1.A. Cesium-137 in air collected in glass-fibre filters by the large air sampler at Risø and Bornholm in 1990.
(Unit: µBq m^{-3}) (The error term is 1 S.D.)

Month	Risø	(N)	Bornholm	(N)
January	1.02±0.62	(5)	1.36±0.62	(5)
February	0.83±0.37	(4)	0.88±0.28	(4)
March	1.00±0.52	(4)	1.39±0.55	(4)
April	2.29±1.71	(5)	3.40±2.98	(5)
May	0.75±0.44	(4)	1.58±0.50	(4)
June	0.76±0.27	(4)	1.21±0.52	(4)
July	1.03±0.70	(5)	1.29±0.66	(5)
August	0.86±0.40	(4)	1.12±0.73	(4)
September	0.75±0.39	(4)	1.27±0.78	(4)
October	1.01±0.66	(5)	1.40±0.86	(5)
November	0.99±0.21	(4)	1.05±0.08	(4)
December	0.84±0.47	(5)	1.01±0.46	(5)
1990: Geometric mean	0.96		1.33	
1990: Arithmetic mean	1.01		1.41	

Table 4.1.2.1.B. Cesium-137 in air collected in glass-fibre filters by the large air sampler at Risø and Bornholm in 1991.
(Unit: µBq m^{-3}) (The error term is 1 S.D.)

Month	Risø	(N)	Bornholm	(N)
January	1.02±0.41	(4)	1.17±0.44	(4)
February	2.23±0.96	(5)	2.06±0.59	(4)
March	1.24±0.59	(4)	1.93±0.66	(4)
April	1.55±0.90	(5)	2.68±1.55	(5)
May	0.95±0.34	(4)	1.38±0.67	(4)
June	0.65±0.47	(4)	0.79±0.20	(4)
July	0.66±0.47	(5)	1.12±0.75	(5)
August	0.55±0.15	(5)	1.07±0.35	(4)
September	0.55±0.22	(5)	1.15±0.62	(5)
October	1.17±1.08	(4)	1.71±1.40	(4)
November	0.69±0.45	(4)	1.01±0.64	(4)
December	0.70±0.33	(5)	0.88±0.29	(4)
1991: Geometric mean	0.9[illegible]		1.32	
1991: Arithmetic mean	1.00		1.44	

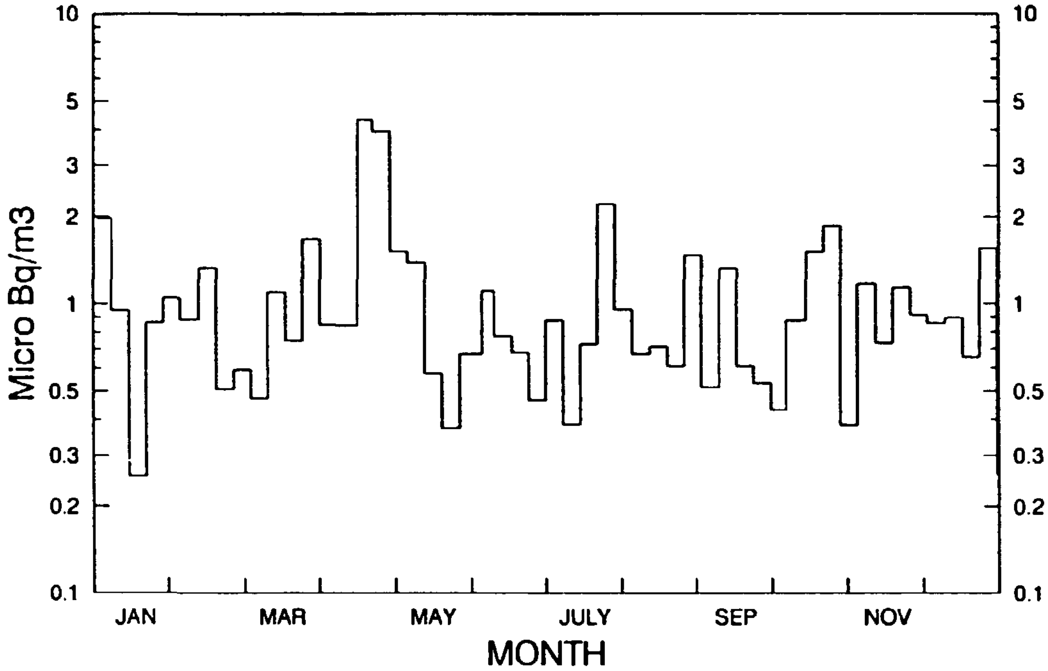


Figure 4.1.2.1.A. Cesium-137 in air collected at Risø, Denmark in 1990. (Unit: $\mu Bq\, m^{-3}$).

Figure 4.1.2.1.B. Cesium-137 in air collected at Risø, Denmark in 1989. (Unit: $\mu Bq\, m^{-3}$).

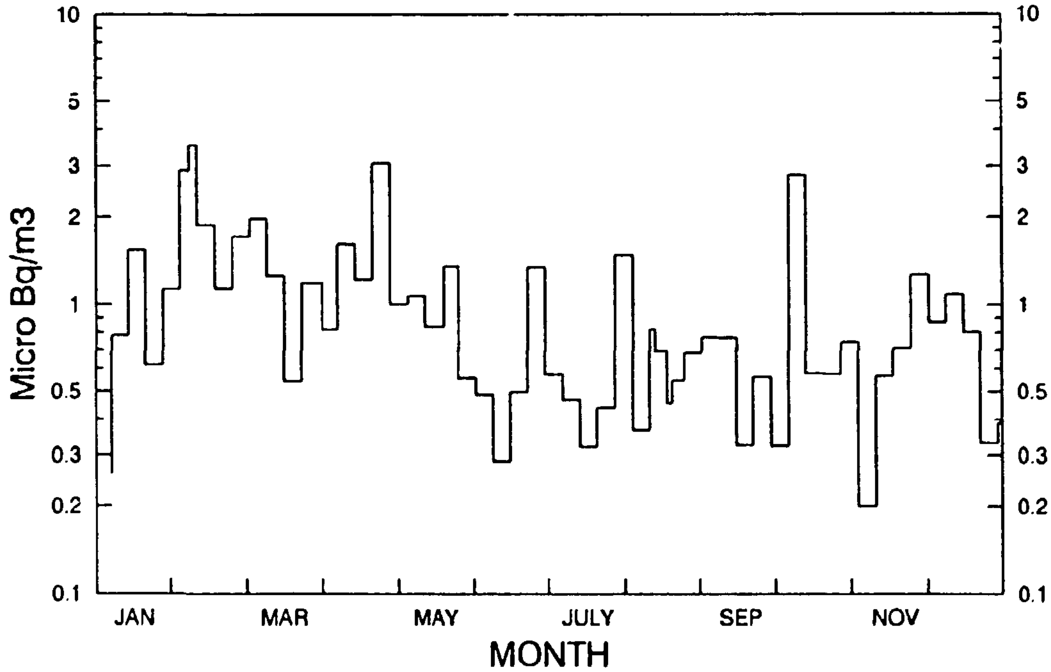


Table 4.1.2.2 Cesium-137 in air collected at Risø 1958-1991. (Unit: μBq m⁻³)

Year	Arithmetic mean	Geometric mean
1958	155	127
1959	490	270
1960	73	60
1961	84	75
1962	850	810
1963	2400	1910
1964	1160	860
1965	390	340
1966	210	162
1967	79	63
1968	88	72
1969	91	77
1970	127	100
1971	98	75
1972	51	43
1973	17.3	14.4
1974	72	52
1975	48	35
1976	15.5	14.8
1977	60	45
1978	116	88
1979	31	23
1980	9.0	7.7
1981	30	18.4
1982	5.7	4.7
1983	2.1	1.81
1984	1.41	1.00
1985	0.68	0.63
1986	1340	35
1987	6.1	4.7
1988	2.6	2.1
1989	1.58	1.41
1990	1.01	0.96
1991	1.00	0.91

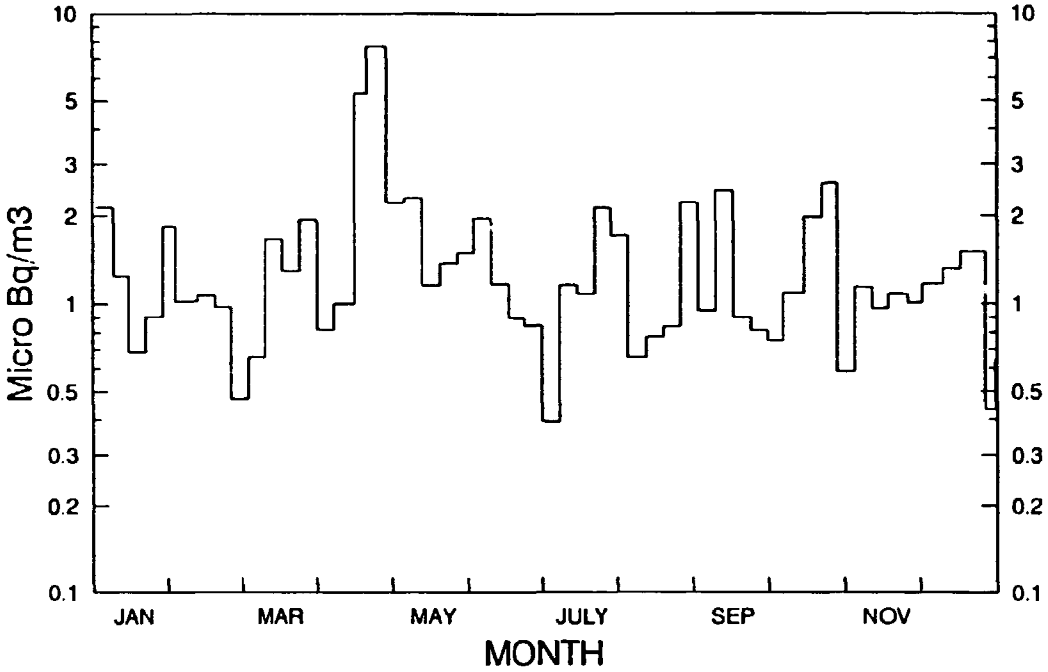
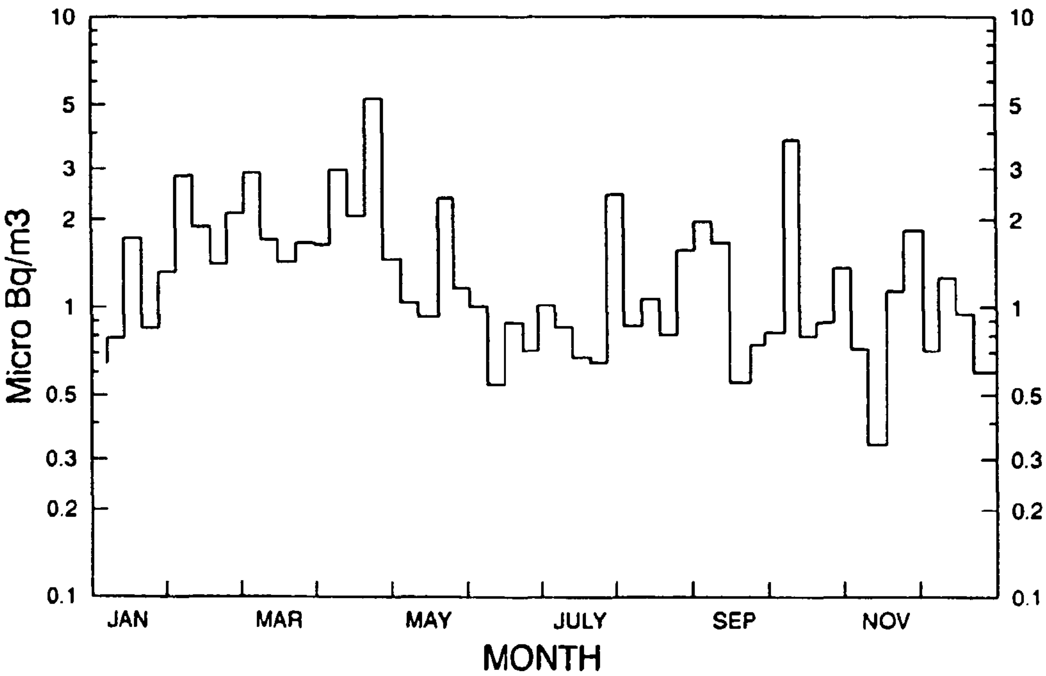


Figure 4.1.2.2.A. Cesium-137 in air collected at Bornholm, Denmark in 1990. (Unit: $\mu Bq\ m^{-3}$).

Figure 4.1.2.2.B. Cesium-137 in air collected at Bornholm, Denmark in 1991. (Unit: $\mu Bq\ m^{-3}$).



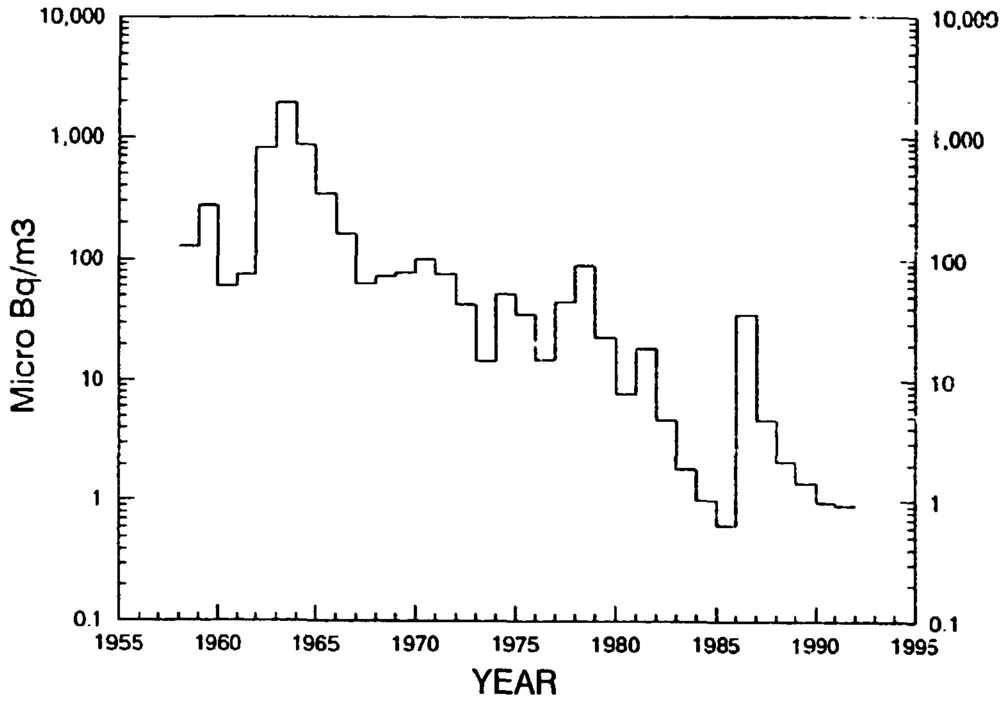
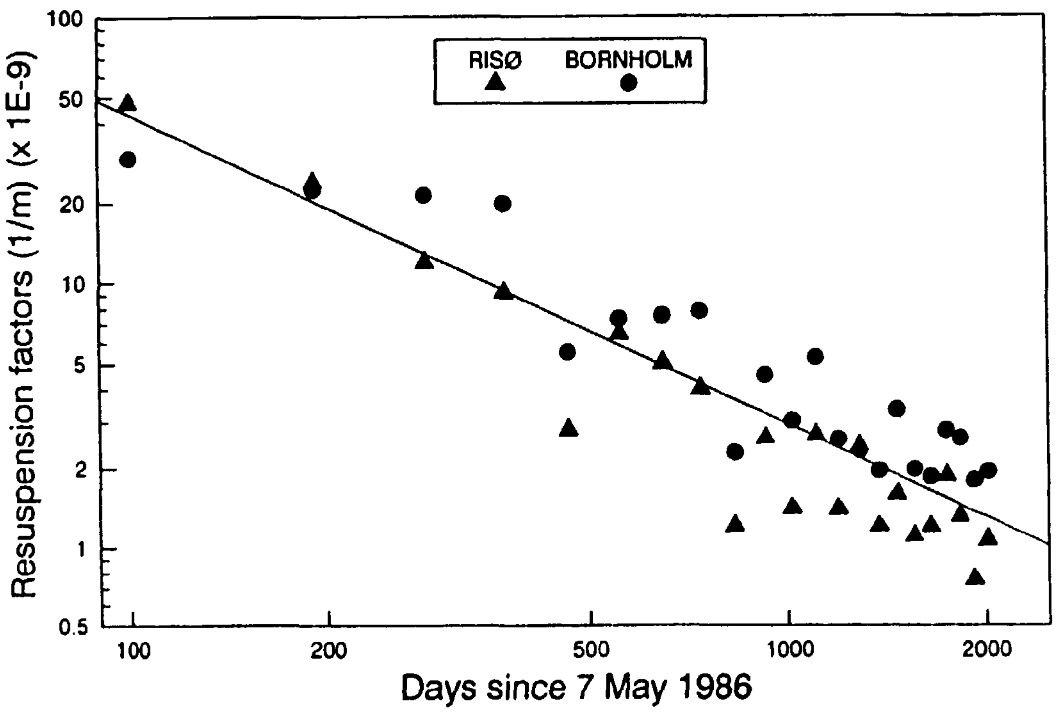


Figure 4.1.2.3. Annual Cesium-137 in air collected at Risø, Denmark. 1958-1991. (Geometric mean). (Unit: $\mu Bq\ m^{-3}$).

Figure 4.1.2.4. Cesium-137 resuspension factors after Chernobyl, July 1986 - December 1991 (quarterly values). $RF = 9.3 \times 10^{-6} D^{-1.17}$. (D = days).



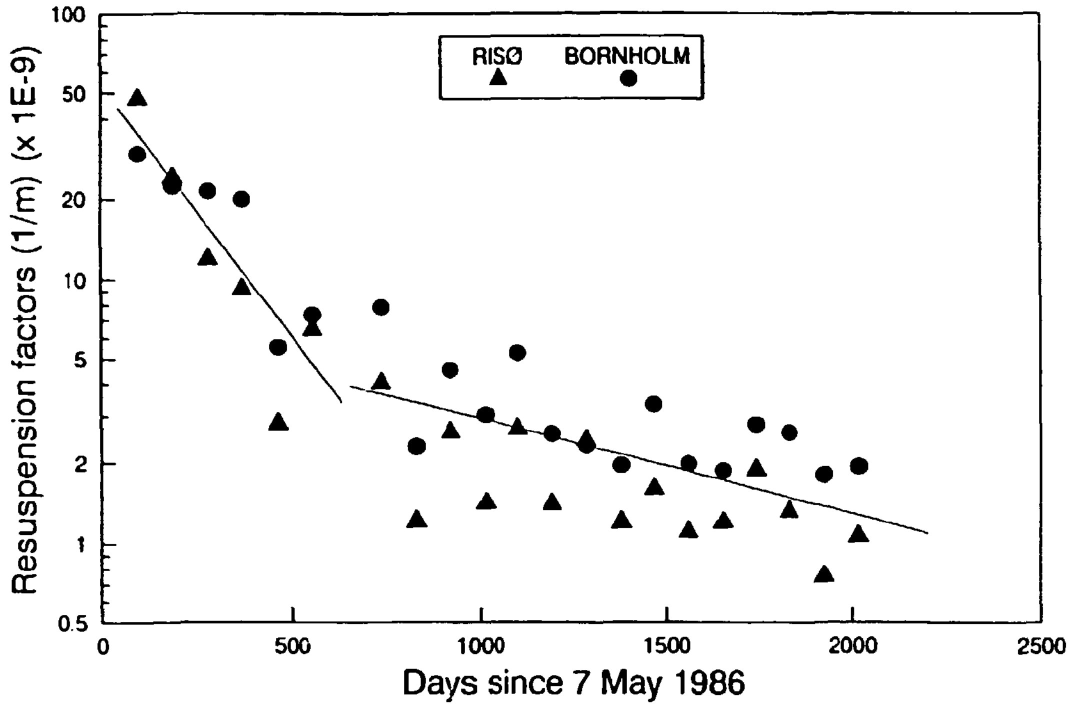
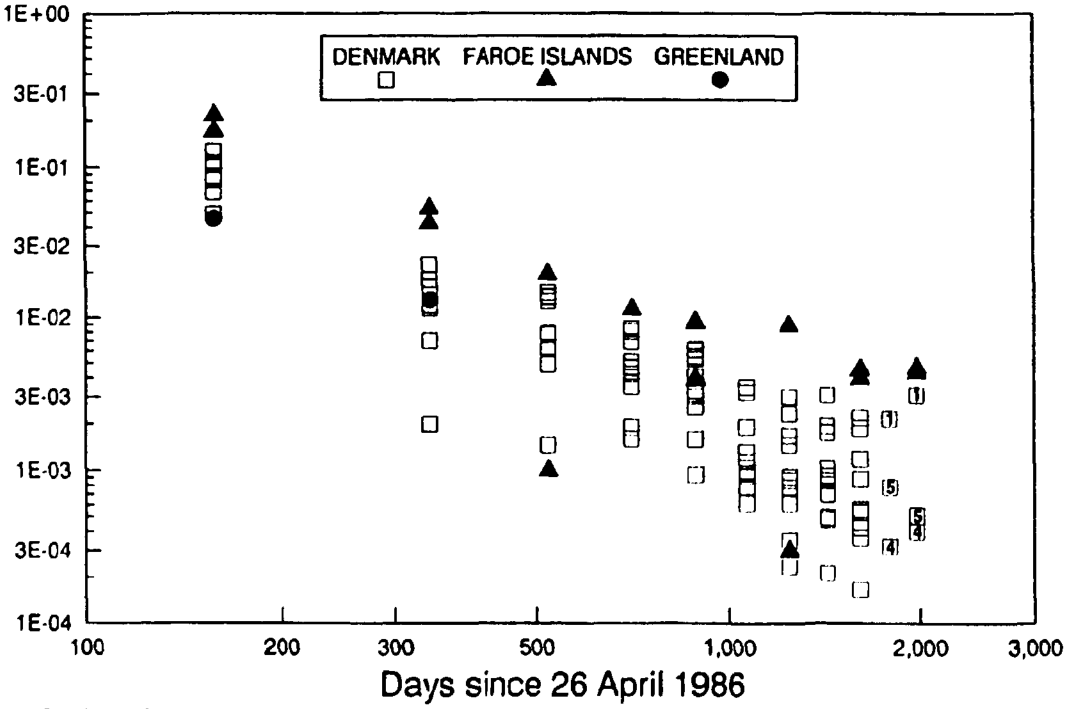


Figure 4.1.2.5. Cesium-137 resuspension factors after Chernobyl.
July 1986 - December 1987: $RF = 5.5 \times 10^{-8} e^{-0.0044\,D}$
Jan 1988 - December 1991: $RF = 6.7 \times 10^{-9} e^{-0.00083\,D}$

Figure 4.1.2.6. Wet deposition of Cs-137 relative to Chernobyl deposit.
(1 is Kannikegård at Bornholm, 5 are he five stations in Jutland and 4 are the four stations from the Islands).



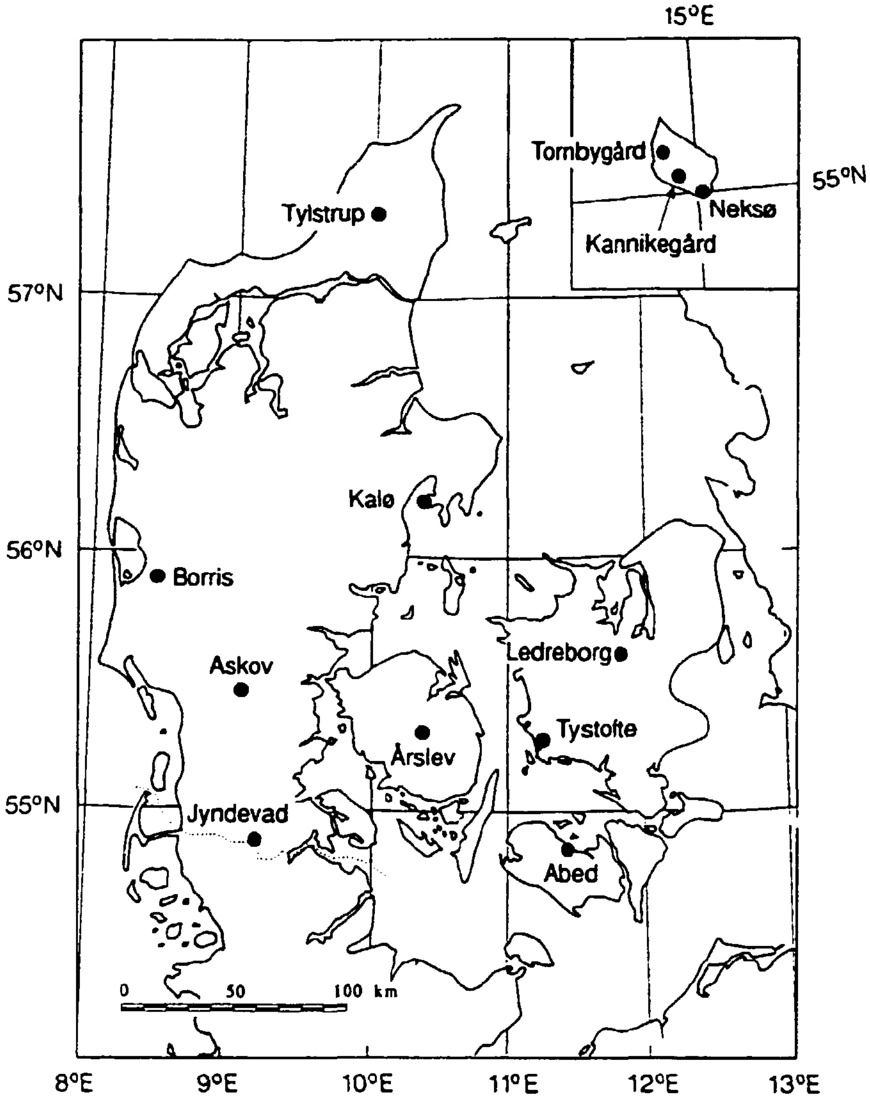


Figure 4.2. State experimental farms in Denmark.

Table 4.2.1.1.A. Strontium-90 fallout in Denmark in 1990. (Unit: Bq m^{-3})

Location	mm	Jan-April	May-June	July-Aug	Sept-Dec	Weighted mean
Tylstrup	880	0.27	1.33	0.47	0.32	0.45
Kalø	664	0.191	1.43	1.76	0.28	0.65
Borris	916	0.22	1.21	0.74	0.21	0.37
Askov	1008	0.43	0.45	1.03	0.29	0.46
St. Jyndevad	984	0.24	1.74	0.99	0.064	0.46
Aarslev	780	0.31	0.57	0.69	0.53	0.49
Tystofte	568	0.37	0.56	1.32 A	0.26	0.48
Ledreborg	552	0.25	0.156 B	0.73	0.42	0.37
Abed	692	0.24	1.64	2.9	2.2	1.83
Kannikegaard } Tornbygaard	456	2.6	8.2	1.45	0.98	1,83
Weighted mean		0.40	1.20	1.24	0.50	0.67
x̄: mm	750	208	97	112	332	
Neksø	564	1.11	1.44	0.39	0.83	0.89
Neksø mm	564	146	47	81	290	

Table 4.2.1.1.B. Strontium-90 fallout in Denmark in 1991. (Unit: Bq m^{-3})

Location	mm	Jan-April	May-June	July-Aug	Sept-Dec	Weighted mean
Tylstrup	541	0.32	1.95	0.97	0.41	0.77
Kalø	438	0.47	0.57	3.26	0.60	0.88
Borris	690	1.04	1.12	0.98	0.43	0.75
Askov	800	0.48	1.28	0.91	0.174	0.52
St. Jyndevad	800	0.74	0.69	0.50	0.132	0.43
Aarslev	512	0.46	0.71	1.93	0.89	0.86
Tystofte	484	0.54	0.32	0.99	0.21	0.40
Ledreborg	592	0.39	0.63	0.21 A	0.22	0.34
Abed	569	0.75	0.29	13.9	3.75	3.57
Kannikegaard	510	1.47	1.11	1.51	1.30	1.30
Weighted mean		0.66	0.86	2.67	0.69	0.94
x̄: mm	594	151	122	85	236	
Neksø	664	0.97	0.68	0.64	0.66	0.75
Neksø mm	664	182	174	60	248	

Table 4.2.1.2.A. Strontium-90 fallout in Denmark in 1990. (Unit: Bq m^{-2})

Location	mm	Jan-April	May-June	July-Aug	Sept-Dec	1990
Tylstrup	880	0.078	0.145	0.063	0.111	0.40
Kalø	664	0.036	0.109	0.21	0.077	0.43
Borris	916	0.063	0.103	0.084	0.091	0.34
Askov	1008	0.125	0.066	0.149	0.124	0.46
St. Jyndevad	984	0.060	0.24	0.125	0.030	0.45
Aarslev	780	0.072	0.071	0.078	0.162	0.38
Tystofte	568	0.056	0.042	0.111 A	0.066	0.28
Ledreborg	552	0.036	0.014 B	0.050	0.105	0.20
Abed	692	0.036	0.170	0.39	0.67	1.27
Kannikegaard	456				0.23	0.84
Tornbygaard		0.27	0.21	0.127		
Geometric mean		0.067	0.091	0.116	0.118	
Arithmetic mean	750	0.083	0.117	0.138	0.167	0.51
Neksø	564	0.162	0.069	0.032	0.24	0.50

Table 4.2.1.2.B. Strontium-90 fallout in Denmark in 1991. (Unit: Bq m^{-2})

Location	mm	Jan-April	May-June	July-Aug	Sept-Dec	1991
Tylstrup	541	0.045	0.23	0.035	0.101	0.42
Kalø	438	0.074	0.049	0.176	0.085	0.38
Borris	690	0.182	0.097	0.093	0.142	0.52
Askov	800	0.101	0.143	0.107	0.063	0.41
St. Jyndevad	800	0.138	0.088	0.072	0.045	0.34
Aarslev	512	0.062	0.077	0.117	0.184	0.44
Tystofte	484	0.063	0.043	0.049	0.039	0.194
Ledreborg	592	0.050	0.073	0.028 A	0.048	0.198
Abed	569	0.114	0.040	1.13	0.75	2.03
Kannikegaard	510	0.160	0.208	0.122	0.173	0.66
Geometric mean		0.088	0.088	0.100	0.105	
Arithmetic mean	594	0.099	0.105	0.193	0.163	0.56
Neksø	664	0.176	0.119	0.039	0.165	0.50

Table 4.2.1.3.A. Analysis of variance of ln Bq $^{90}Sr\ m^{-3}$ precipitation, January-December 1990 (from Table 4.2.1.1.A)

Variation	SSD	f	s^2	v^2	P
Between months	9.645	3	3.215	6.137	> 99.5%
Between locations	13.323	11	1.211	2.312	> 95 %
Remainder	15.192	29	0.524		

Table 4.2.1.4.A. Analysis of variance of ln Bq $^{90}Sr\ m^{-2}$ precipitation, January-December 1990 (from Table 4.2.1.2.A)

Variation	SSD	f	s^2	v^2	P
Between months	1.805	3	0.602	1.266	-
Between locations	8.291	11	0.754	1.586	-
Remainder	13.786	29	0.475		

Table 4.2.1.3.B. Analysis of variance of ln Bq $^{90}Sr\ m^{-3}$ precipitation, January-December 1991 (from Table 4.2.1.1.B)

Variation	SSD	f	s^2	v^2	P
Between months	5.067	3	1.689	2.991	> 95%
Between locations	10.287	10	1.029	1.822	-
Remainder	16.939	30	0.565		

Table 4.2.1.4.B. Analysis of variance of ln Bq $^{90}Sr\ m^{-2}$ precipitation, January-December 1991 (from Table 4.2.1.2.B)

Variation	SSD	f	s^2	v^2	P
Between months	0.273	3	0.091	0.185	-
Between locations	9.734	10	0.973	1.977	-
Remainder	14.769	30	0.492		

Table 4.2.2.1.A. Cesium-137 in precipitation in Denmark in 1990. (Unit: Bq m^{-3})

Location	mm	Jan-April	May-June	July-Aug	Sept-Dec	Weighted mean
Tylstrup	880	1.00	3.0 B	1.08 B	0.60 B	1.10
Kalø	664	2.3 A	2.2 A	1.38 A	1.06 A	1.61
Borris	916	1.68	3.9 A	1.66 B	0.75 A	1.44
Askov	1008	14.8	13.5	10.4	6.6	10.6
St. Jyndevad	984	7.4	8.9	5.7	3.0	5.3
Aarslev	780	1.27	1.25 B	0.60 B	0.89	1.02
Tystofte	568	1.27 B	3.1 B	2.3 A	1.08	1.58
Ledreborg	552	4.4	5.0	4.8	2.4	3.7
Abed	692	1.00 B	4.0 B	0.86 B	0.76 A	1.32
Kannikegaard }	456				2.6	} 5.3
Tornbygaard }		6.5	21.5	6.7	-	
Weighted mean	-	4.47	6.01	3.57	2.13	3.5
$\bar{x}$: mm	750	208	97	112	332	
Neksø	564	14.5	18.6	7.7	5.0	9.0
Neksø mm	564	146	47	81	290	

Table 4.2.2.1.B. Cesium-137 in precipitation in Denmark in 1991. (Unit: Bq m^{-3})

Location	mm	Jan-April	May-June	July-Aug	Sept-Dec	Weighted mean
Jutland	654	3.9	4.5	4.9	1.14	2.93
The Islands	539	1.45	1.55	1.90	1.62	1.61
Kannikegaard	510	3.3 A	5.3	3.3 A	12.7	6.47
Weighted mean	-	2.97	3.45	3.60	1.95	2.75
$\bar{x}$: mm	594	151	122	85	236	
Neksø	664	4.4	2.7	5.8 A	1.96	3.2
Neksø mm	664	182	174	60	248	

Table 4.2.2.2.A. Cesium-137 deposition with precipitation in Denmark in 1990.
(Unit: Bq m^{-2})

Location	mm	Jan-April	May-June	July-Aug	Sept-Dec	1990
Tylstrup	880	0.29	0.32 B	0.144 B	0.21 B	0.97
Kalø	664	0.44 A	0.169 A	0.164 B	0.30 A	1.07
Borris	916	0.48	0.33 A	0.187 B	0.32 A	1.32
Askov	1008	4.34	2.01	1.50	2.8	10.7
St. Jyndevad	984	1.82	1.21	0.72	1.44	5.19
Aarslev	780	0.29	0.157 B	0.068 B	0.28	0.79
Tystofte	568	0.191 B	0.23 B	0.196 A	0.28	0.90
Ledreborg	552	0.64	0.45	0.33	0.60	2.02
Abed	692	0.148 B	0.42 B	0.116 B	0.23 A	0.91
Kannikegaard }	456				0.61	} 2.42
Tornbygaard }		0.67	0.56	0.58		
Geometric mean		0.53	0.42	0.26	0.47	
Arithmetic mean	750	0.93	0.59	0.40	0.71	2.63
Nekso	564	2.1	0.90	0.62	1.46	5.1

Table 4.2.2.2.B. Cesium-137 deposition with precipitation in Denmark in 1991.
(Unit: Bq m^{-2})

Location	mm	Jan-April	May-June	July-Aug	Sept-Dec	1991
Jutland	654	0.67	0.49	0.44	0.32	1.92
The Islands	548	0.192	0.193	0.154	0.33	0.87
Kannikegaard	510	0.36 A	1.00	0.26 A	1.69	3.30
Geometric mean		0.38	0.36	0.27	0.38	
Arithmetic mean	597	0.45	0.42	0.31	0.46	1.63
Nekso	664	0.81	0.47	0.35 A	0.49	2.11

Table 4.2.2.3.A. Analysis of variance of ln Bq ^{137}Cs m^{-3} precipitation, January-December 1990 (from Table 4.2.2.1.A)

Variation	SSD	f	s^2	v^2	P
Between months	6.729	3	2.243	23.842	> 99.95%
Between locations	34.335	11	3.121	33.182	> 99.95%
Remainder	2.728	29	0.094		

Table 4.2.2.4.A. Analysis of variance of ln Bq ^{137}Cs m^{-2} precipitation, January-December 1990 (from Table 4.2.2.2.A)

Variation	SSD	f	s^2	v^2	P
Between months	3.653	3	1.218	13.564	> 99.95%
Between locations	32.050	11	2.914	32.455	> 99.95%
Remainder	2.603	29	0.090		

Table 4.2.2.5.A. Radiocesium in precipitation collected in the 10 m² ion exchanger at Risø in 1990

Month	Bq ^{137}Cs m^{-2}	Bq ^{137}Cs m^{-3}	$\frac{^{134}Cs}{^{137}Cs}$	mm precipitation	Theoretical $^{134}Cs/^{137}Cs$ ratio
Jan	0.120	3.5	0.142 A	34	0.172
Feb	0.061	1.92	0.157	32	0.167
March	0.048	1.31	0.157	37	0.163
April	0.092	3.3	0.154	28	0.159
May	0.086	4.8	0.145	17.9	0.155
June	0.130	2.5	0.111	53	0.151
July	0.094	2.8	0.149	34	0.147
Aug	0.077	2.3	0.149	33	0.143
Sept	0.071	0.72	0.129	98	0.139
Oct	0.049	1.02	0.124	48	0.136
Nov	0.038	0.80	0.102	47	0.132
Dec	0.043	1.33	-	32	0.129
1990	Σ 0.91	$\bar{x}$: 1.84 (weighted mean)		Σ 494	

$\frac{134/137\ Obs}{134/137\ Pred}$ = 0.91±0.10 S.D. 0.03 S.E. (n = 11)

Table 4.2.2.5.B. Radiocesium in precipitation collected in the 10 m² ion exchanger at Risø in 1991

Month	Bq ^{137}Cs m^{-2}	Bq ^{137}Cs m^{-3}	$\frac{^{134}Cs}{^{137}Cs}$	mm precipitation	Theoretical $^{134}Cs/^{137}Cs$ ratio
Jan	0.047	1.24	-	38	0.126
Feb	0.138	4.9	0.102	28	0.122
March	0.057	5.4	-	10.6	0.119
April	0.120	3.1	0.130	38	0.116
May	0.156	4.6	0.118	34	0.113
June	0.22	2.2	-	103	0.110
July	0.119	3.2		38	0.107
Aug	0.056	1.13	-	49	0.105
Sept	0.048	0.75	-	64	0.102
Oct	0.041	1.25	-	33	0.099
Nov	0.086	1.50	-	57	0.097
Dec	0.156	3.4	-	46	0.094
1991	Σ 1.25	$\bar{x}$: 2.3 (weighted mean)		Σ 539	

$\frac{134/137\ Obs}{134/137\ Theor}$ = 1.00±0.15 S.D. 0.09 S.E. (n = 3)

Table 4.2.3.A. Tritium in precipitation collected at Risø in 1990

Month	mm precipitation	1 m² rain collector kBq m^{-3}	1 m² rain collector kBq m^{-2}	10 m² rain collector kBq m^{-3}	10 m² rain collector kBq m^{-2}
Jan	34	2.2±0.2	0.076	1.8±0.2	0.063
Feb	32	2.2±0.0	0.068	2.7±0.0	0.084
March	37	6.8±0.3	0.25	2.7±0.2	0.098
April	28	4.2±0.4	0.118	2.7±0.3	0.077
May	17.9	4.6±0.2	0.082	3.1±0.4	0.056
June	53	3.9±0.2	0.20	11.7±1.4	0.62
July	34	15.4±0.4	0.52	7.9±0.1	0.27
Aug	33	2.9±0.1	0.095	7.2±0.1	0.24
Sept	98	6.3±0.2	0.62	11.6±0.2	1.13
Oct	48	2.6±0.5	0.127	2.2±0.3	0.106
Nov	47	3.8±0.3	0.180	14.9±0.1	0.69
Dec	32	2.2±0.4	0.071	2.1±0.2	0.066
1990	Σ 494	$\bar{x}$: 4.9 (weighted mean)	Σ 2.4	$\bar{x}$: 7.1 (weighted mean)	Σ 3.5

The error term is 1 S.E. of the mean of triple determinations.

Table 4.2.3.B. Tritium in precipitation collected at Risø in 1991

Month	mm precipitation	1 m² rain collector kBq m^{-3}	1 m² rain collector kBq m^{-2}	10 m² rain collector kBq m^{-3}	10 m² rain collector kBq m^{-2}
Jan	38	2.3±0.3	0.087	2.7±0.2	0.102
Feb	28	4.0±0.2	0.111	2.6±0.1	0.072
March	10.6	2.8±0.1	0.030	3.1±0.3	0.033
April	38	4.2±0.2	0.160	6.0±0.5	0.229
May	34	6.0±0.4	0.205	14.7±0.4	0.503
June	103	5.3±0.3	0.547	6.4±0.6	0.661
July	38	3.6±0.0	0.135	12.4±0.3	0.47
Aug	49	4.1±0.2	0.201	17.3±1.3	0.85
Sept	64	1.9±0.0	0.122	3.9±0.3	0.25
Oct	33	2.2±0.1	0.073	2.7±0.2	0.090
Nov	57	3.2±0.4	0.182	10.2±0.2	0.58
Dec	46	2.2±0.3	0.100	3.9±0.1	0.181
1991	Σ 539	$\bar{x}$: 3.6 (weighted mean)	Σ 1.95	$\bar{x}$: 7.4 (weighted mean)	Σ 4.0

The error term is 1 S.E. of the mean of triple determinations.

Table 4.2.4.A. Tritium in precipitation collected in Denmark in 1990. (Unit: kBq m^{-3})

Date	Tylstrup	Jyndevad	Tornbygaard
January	1.8±0.2	1.9±0.1	2.2±0.2
February	1.3±0.2	1.7±0.1	2.5±0.3
March	1.7±0.1	2.1±0.2	2.7±0.3
April	2.4±0.1	2.1±0.2	4.0±0.1
May	4.5±0.7	3.5±0.4	3.3±0.2*
June	2.9±0.1	3.0±0.0	3.2±0.3
July	2.7±0.5	2.3±0.2	3.1±0.2
August	2.8±0.2	2.0±0.1	2.5±0.2
September	2.4±0.3	1.7±0.1	2.4±0.4Δ
October	1.8±0.2	1.7±0.1	2.5±0.1Δ
November	1.4±0.1	1.9±0.2	2.6±0.1Δ
December	1.6±0.1	1.7±0.2	1.9±0.2Δ**
1990: Geometric mean	2.1	2.1	2.7
1990: Arithmetic mean	2.3	2.1	2.7

ΔCollected at Kannikegård. *Double determinations.
**Quadruple determinations.
The error term is 1 S.E. of the mean of triple determinations.

Table 4.2.4.B. Tritium in precipitation collected in Denmark in 1991. (Unit: kBq m^{-3})

Date	Tylstrup	Jyndevad	Kannikegaard
January	1.4±0.3	1.7±0.3	2.1±0.2
February	1.8±0.2	1.9±0.1	2.8±0.4
March	1.6±0.1	1.9±0.2	2.3±0.4
April	2.5±0.1*	2.6±0.1	3.1±0.3
May	-	2.7±0.2	3.3±0.2
June	2.4±0.2	2.5±0.2	2.5±0.1
July	2.9±0.3	3.6±0.5	3.1±0.2
August	2.2±0.2	2.6±0.3	2.5±0.3
September	1.9±0.3	2.0±0.2	2.1±0.1
October	1.8±0.1	1.7±0.3	3.0±0.2
November	1.3±0.1	1.6±0.2	2.3±0.2
December	1.0±0.1*	1.3±0.2	1.8±0.1
1991: Geometric mean	1.8	2.1	2.8
1991: Arithmetic mean	1.9	2.2	2.6

The error term is 1 S.E. of the mean of triple determinations.
*Quadruple determinations.

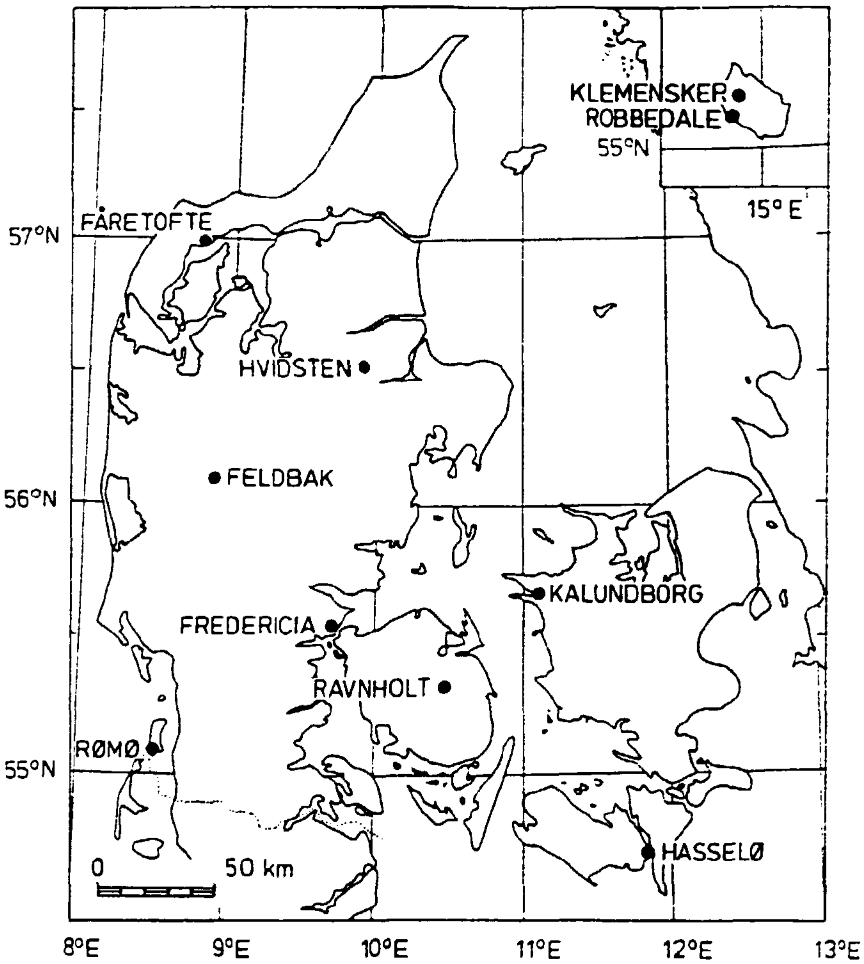


Figure 4.3.1.1. Ground water sampling locations in Denmark.

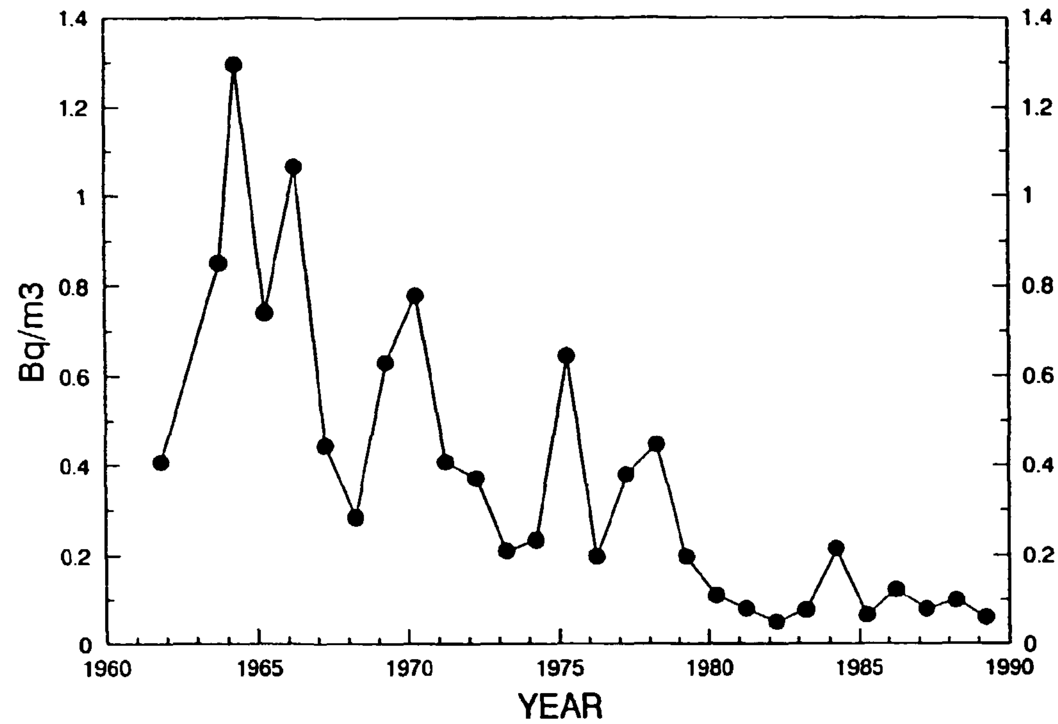
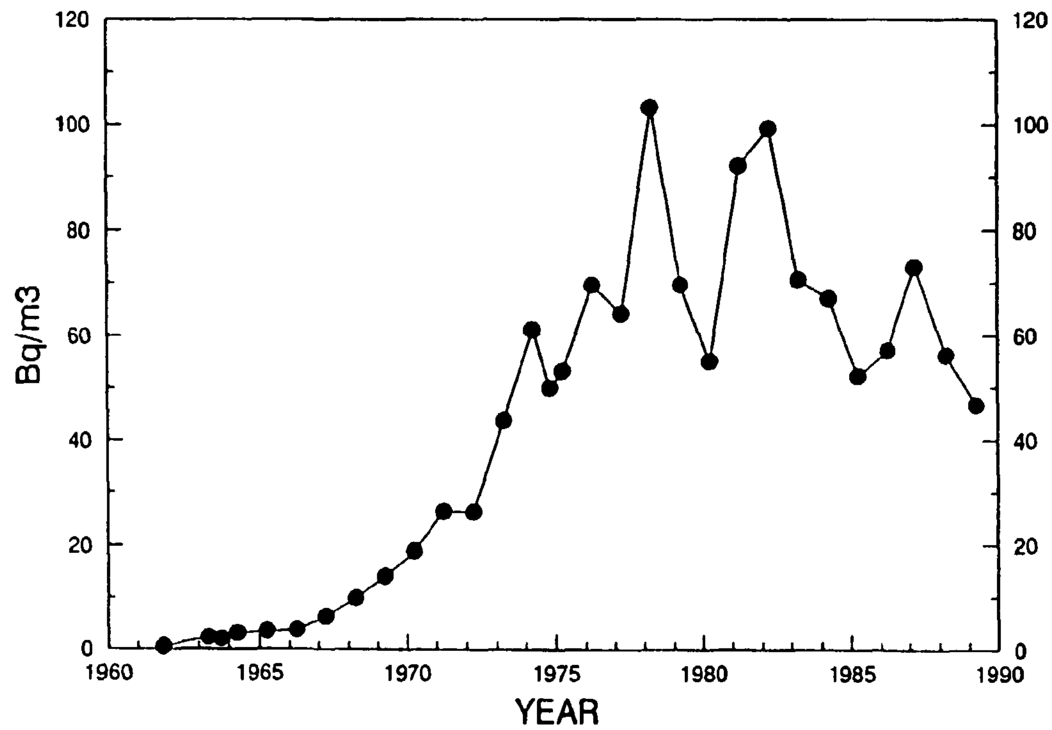


Figure 4.3.1.2. Median ^{90}Sr levels in Danish ground water, 1961-1989. (Unit: Bq m^{-3}).

Figure 4.3.1.3. Strontium-90 in ground water at Feldbak 1961-1989. (Unit: Bq m^{-3}).



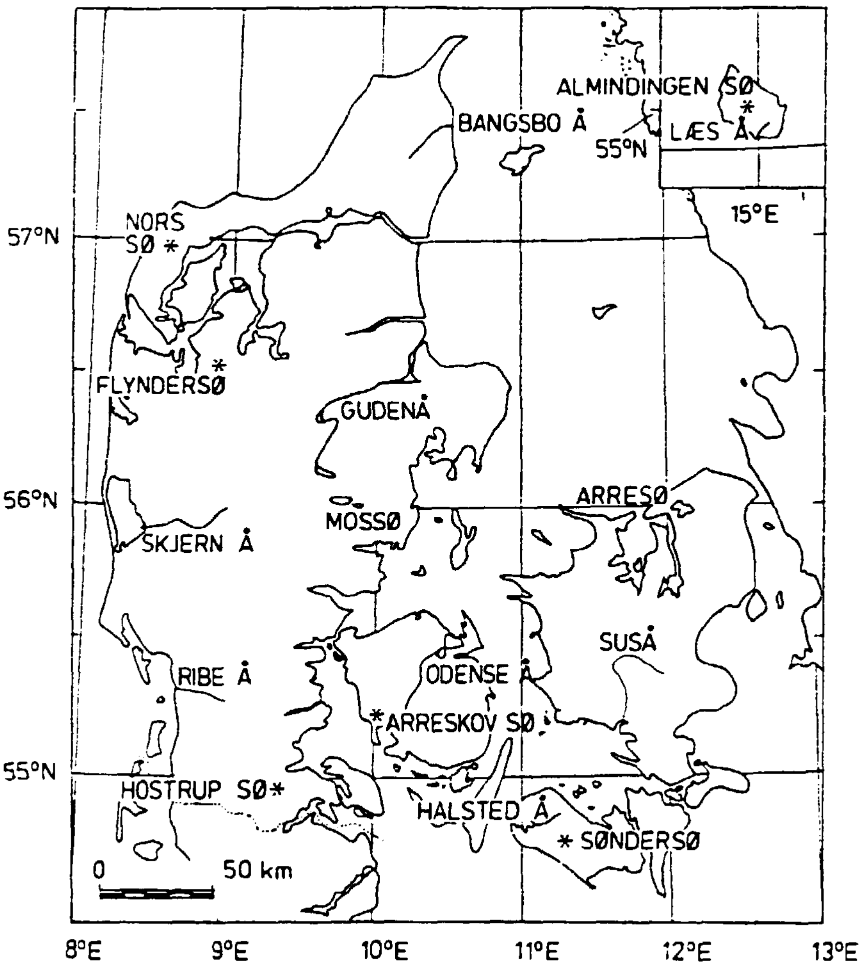


Figure 4.3.2.1 Sample locations for fresh water from Danish streams (å) and lakes (sø).

Table 4.3.2.1.A. Cesium-137 and Tritium in Danish stream water collected in March 1990

Stream	Bq ^{137}Cs m^{-3}	kBq ^{3}H m^{-3}
Bangsbo å	0.41 B	2.5±0.4
Gudenå	1.05 A	2.2±0.2
Skjern å	1.59	1.8±0.1
Ribe å	0.81 A	2.4±0.3
Odense å	0.91	2.1±0.1
Suså	0.96 A	2.2±0.2
Halsted å	0.32 B	2.4±0.4
Læs å (May)	0.37 B	2.6±0.2
1990: Geometric mean	0.70	2.3
S.E. (factor)	1.23	1.04
1990: Arithmetic mean	0.80	2.3
S.E.	19%	9%

The error term is 1 S.E. of the mean of triple determinations.

Table 4.3.2.1.B. Strontium-90, Cesium-137 and Tritium in Danish stream water collected in March 1991

Stream	Bq ^{90}Sr m^{-3}	kg Ca m^{-3}	Bq ^{137}Cs m^{-3}	kBq ^{3}H m^{-3}
Bangsbo å	5.9	0.059	< 0.5	2.2±0.2
Guden å	4.9	0.062	1.28	2.2±0.0
Skjern å	8.6	0.024	0.67 A	2.4±0.1
Ribe å	7.1	0.073	0.64 B	2.5±0.0
Odense å	6.1	0.104	0.61 B	2.3±0.2
Suså	5.1	0.110	< 1.0	2.5±0.2
Halsted å	5.8	0.154	< 0.6	2.4±0.1
Læs å (May)	12.4	0.048	0.86 B	2.7±0.1
1991: Geometric mean	6.7	0.069	< 0.74	2.4
S.E. (factor)	1.11	1.23	1.12	1.03
1991: Arithmetic mean	7.0	0.079	< 0.77	2.4
S.E.	13%	18%	12%	3%

The error term is 1 S.E. of the mean of triple determinations.

Table 4.3.2.2.A. Radiocesium and Tritium in Danish lake water collected in March 1990

Lake	Bq ^{137}Cs m^{-3}	$^{134}Cs/^{137}Cs$	kBq ^{3}H m^{-3}
Norssø	4.0	0.146 A	1.6±0.2
Mossø	1.49 A	-	1.8±0.1
Flyndersø	6.6	0.156 A	2.0±0.2
Hostrupsø	9.5	0.150	2.0±0.1
Arreskovsø	6.2	0.171 A	2.4±0.3
Arresø	9.5	0.137	2.6±0.1
Søndersø	8.8	0.140 A	2.5±0.4
Almindingen sø	1.43 A	-	2.8±0.3
1990: Geometric mean	4.8		2.2
S.E. (factor)	1.32		1.07
1990: Arithmetic mean	5.9		2.2
S.E.	20%		6.8%

The error term is 1 S.E. of the mean of triple determinations.

Table 4.3.2.2.B. Strontium-90, Radiocesium and Tritium in Danish lake water collected in March 1991

Lake	Bq ^{90}Sr m^{-3}	kg Ca m^{-3}	Bq ^{137}Cs m^{-3}	$^{134}Cs/^{137}Cs$	kBq ^{3}H m^{-3}
Norssø	18	0.038	3.8		1.8±0.2
Mossø	6.0	0.066	2.1		1.8±0.1
Flyndersø	3.8	0.027	5.6		1.7±0.2
Hostrupsø	18.3	0.029	6.4		1.8±0.4
Arreskovsø	10.2	0.067	5.2		2.2±0.2
Arresø	7.6	0.066	8.9	0.139	2.3±0.2
Søndersø	9.6	0.076	4.9		2.3±0.2
Almindingen sø (May)	17.0	0.024	1.29		2.3±0.1
1991: Geometric mean	9.9	0.045	4.1		2.0
S.E. (factor)	1.22	1.18	1.25		1.05
1991: Arithmetic mean	11.3	0.049	4.8		2.0
S.E.	18%	16%	18%		4.8%

The error term is 1 S.E. of the mean of triple determinations.

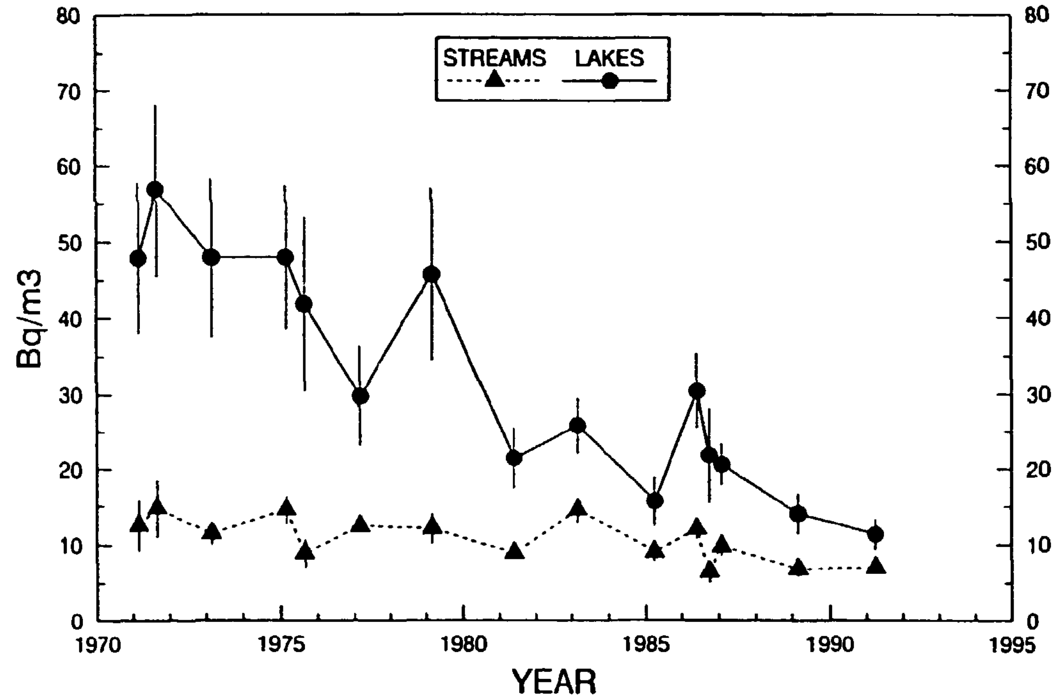


Figure 4.3.2.2. Strontium-90 concentrations (±1 S.E.) in 8 Danish streams and 8 Danish lakes, collected since 1971. (Unit: Bq m^{-3}).

Figure 4.3.2.3. Cesium-137 in 8 Danish streams and 8 Danish lakes, collected since May 1986. (Unit: Bq m^{-3}). (Geometric mean ± 1 S.E.)

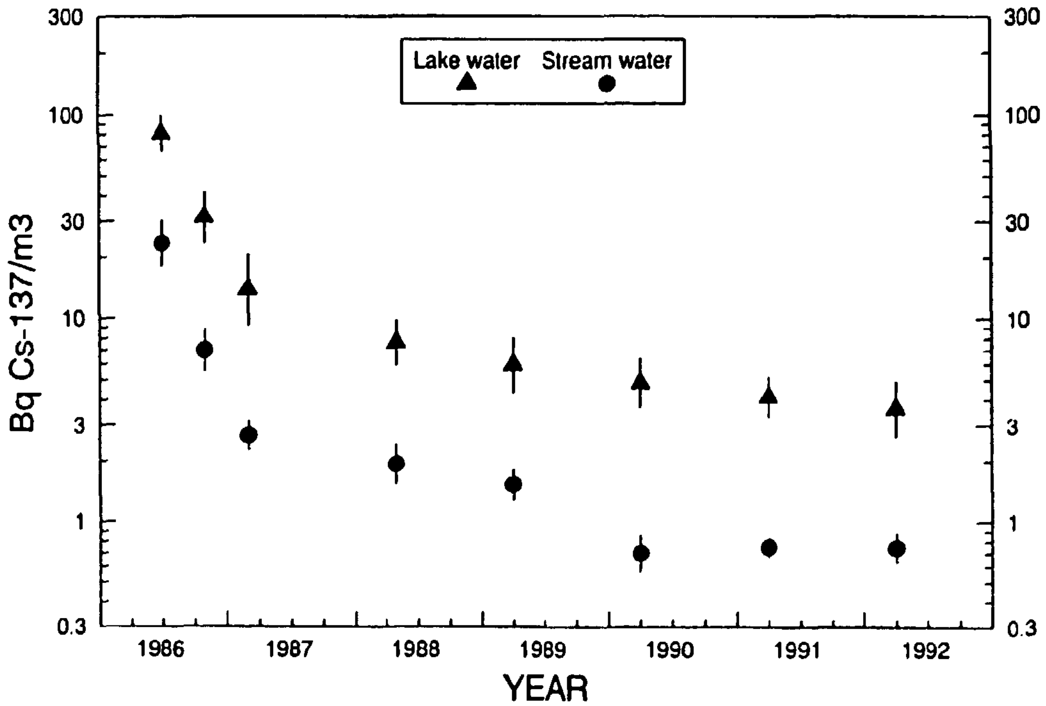


Table 4.4.1.A. Radionuclides in sea water collected around Zealand in May 1990

Location	Date in May	Position N	Position E	Depth in m	^{90}Sr $Bq\,m^{-3}$	^{137}Cs $Bq\,m^{-3}$	$^{134}Cs/^{137}Cs$	^{3}H $kBq\,m^{-3}$	Salinity ‰	Chernobyl $Bq\,^{137}Cs\,m^{-3}$
Kullen	31	56°15'	12°15'	2		69	0.133		15.8	59
"				23		16.1	-		33.9	-
Hesselø	31	56°10'	11°47'	2	19.8	66	0.169	4.6±0.3	16.4	(72)
"				24		17.2	0.109	-	-	12.1
Kattegat SW	31	56°07'	11°10'	2		72	0.138		15.4	64
"				32		25	0.082 A		31.1	13.2
Asnæs rev	29	55°39'	10°46'	2	15.6	72	0.141		16.4	66
" "				33	16.4	25	0.142		30.6	23
Halskov rev	29	55°23'	11°03'	2		71	0.147	3.4±0.2	15.6	67
" "				26		36	0.105	2.9±0.2	28.1	24
Langeland bælt	29	54°52'	10°50'	2		71	0.128		16.3	59
" "				20		51	0.116		24.4	38
Femern bælt	29	54°36'	11°04'	2		77	0.146		13.7	73
" "				22		66	0.144		18.3	61
Gedser odde	29	54°28'	11°59'	2		90	0.145		9.3	84
" "				12		74	0.136		16.9	65
Møen	30	54°57'	12°41'	2	18.5	98	0.158	4.4±0.4	8.4	(100)
"				23	15.8	90	0.128	4.6±0.4	14.6	74
The Sound - South	30	55°25'	12°36'	2		101	0.141		8.8	92
" " "				11		85	0.146		11.0	80
The Sound - North A	31	55°48'	12°45'	2		81	0.142		12.7	75
" " "				18		29	0.104		30.5	19.5
The Sound - North B	31	55°59'	12°42'	2		77	0.149		15.0	74
" " "				27		20	0.04 B		33.5	5.2
Mean				Surface	18.0	79	0.145	4.1	13.7	74
S.D.					2.2	12	0.011	0.6	3.0	13
S.E.					1.2	3	0.003	0.4	0.9	4
Mean				Bottom	16.1	45	0.114	3.8	24.8	38
S.D.					0.4	27	0.032	1.2	8.2	27
S.E.					0.3	8	0.010	0.8	2.5	8

The error term is 1 S.E. of the mean of triple determinations.

Table 4.4.1.B. Radionuclides in sea water collected around Zealand in February 1991

Location	Date in February	Position N	Position E	Depth in m	^{90}Sr Bq m^{-3}	^{137}Cs Bq m^{-3}	^{134}Cs / ^{137}Cs	Salinity ‰	Chernobyl Bq ^{137}Cs m^{-3}
Kullen	12	56°14'	12°20'	2	12.4	72	0.113	18.0	67
"				21	9.2	36	0.086 A	27.1	25 A
Hesselø	11	56°10'	11°47'	2	13.8	77	0.123	14.9	(78)
"				24	9.7	42	0.103	26.1	36
Kattegat SW	11	56°07'	11°10'	2		89	0.117	12.4	85
"				35		71	0.110	16.5	64
Asnæs rev	7	55°39'	10°46'	2		85	0.124	11.3	(86)
" "				23		73	0.110	16.4	66
Halskov rev	7	55°23'	11°03'	2		92	0.109	10.9	83
" "				23		88	0.120	11.5	86
Langeland bælt	25	54°52'	10°50'	0		71	0.116	17.4	67
" "				Bottom		-	-	-	-
Femern bælt	25	54°36'	11°04'	2		80	0.124	12.1	(81)
" "				Bottom		-	-	-	-
Gedser odde	5	54°28'	11°59'	2	18.6	111	0.125	9.8	(113)
" "				18	17.3	100	0.122	9.5	100
Møen	25	54°57'	12°41'	0	18.1	88	0.113	7.8	81
"				Bottom		-	-	-	-
The Sound - South	4	55°25'	12°36'	3		109	0.109	9.8	97
" " "				16		101	0.114	10.2	95
The Sound - North A	12	55°48'	12°44'	2		90	0.115	12.4	84
" " "				20		33	0.082	29.4	22
The Sound - North B	12	55°59'	12°39'	2		80	0.116	15.1	77
" " "				27		41	0.116	26.1	40
Mean				Surface	15.7	87	0.117	12.7	83
S.D.					3.1	13	0.006	3.1	12
S.E.					1.5	4	0.002	0.9	4
Mean				Bottom	12.1	65	0.107	19.2	59
S.D.					4.5	28	0.014	8.0	30
S.E.					2.6	9	0.005	2.7	10

Table 4.4.2.B. Radionuclides in sea water collected around Zealand in November 1991

Location	Date in November	Position N	Position E	Depth in m	^{90}Sr $Bq\,m^{-3}$	^{137}Cs $Bq\,m^{-3}$	^{134}Cs/^{137}Cs	Salinity ‰	Chernobyl $Bq\,^{137}Cs\,m^{-3}$
Kullen	14	56°13'	12°22'	2		45	0.087	24.2	40
"				24		28	0.076	30.0	22
Hesselø	13	56°10'	11°47'	2	12.3	46	0.099	23.8	(47)
"				24	8.9	48	0.079	23.9	39
Kattegat SW	13	56°07'	11°10'	2		52	0.099	22.3	(53)
"				37		51	0.090	22.4	48
Asnæs rev	13	55°39'	10°46'	2		51	0.094	23.7	49
" "				27		49	0.079	24.0	40
Halskov rev	12	55°23'	11°03'	2	10.0	52	0.086	22.6	47
" "				22	9.4	57	0.093	22.6	55
Langeland bælt	12	54°52'	10°50'	2		50	0.096	22.5	50
" "				30		53	0.109	22.6	(60)
Femern bælt	12	54°36'	11°04'	2		60	0.090	20.1	56
" "				30		58	0.104	20.2	(62)
Gedser odde	12	54°28'	11°58'	2		74	0.107	17.2	(82)
" "				19		71	0.125	18.2	(92)
Møen	11	54°57'	12°40'	2	16.0	85	0.107	12.1	(95)
"				24	15.8	87	0.085	12.1	77
The Sound - South	11	55°25'	12°36'	2		87	0.127	12.3	(117)
" " "				15		83	0.114	12.5	(98)
The Sound - North A	17	55°48'	12°44'	2		46	0.082	23.8	39
" " "				20		47	0.098	24.4	(48)
The Sound - North B	15	55°59'	12°39'	2		47	0.089	23.3	43
" " "				13		85	0.086	23.8	76
Mean				Surface	12.8	58	0.097	20.7	60
S.D.					3.0	15	0.012	4.4	25
S.E.					1.7	4	0.004	1.3	7
Mean				Bottom	11.4	60	0.095	21.4	60
S.D.					3.8	18	0.015	5.1	23
S.E.					2.2	5	0.004	1.5	7

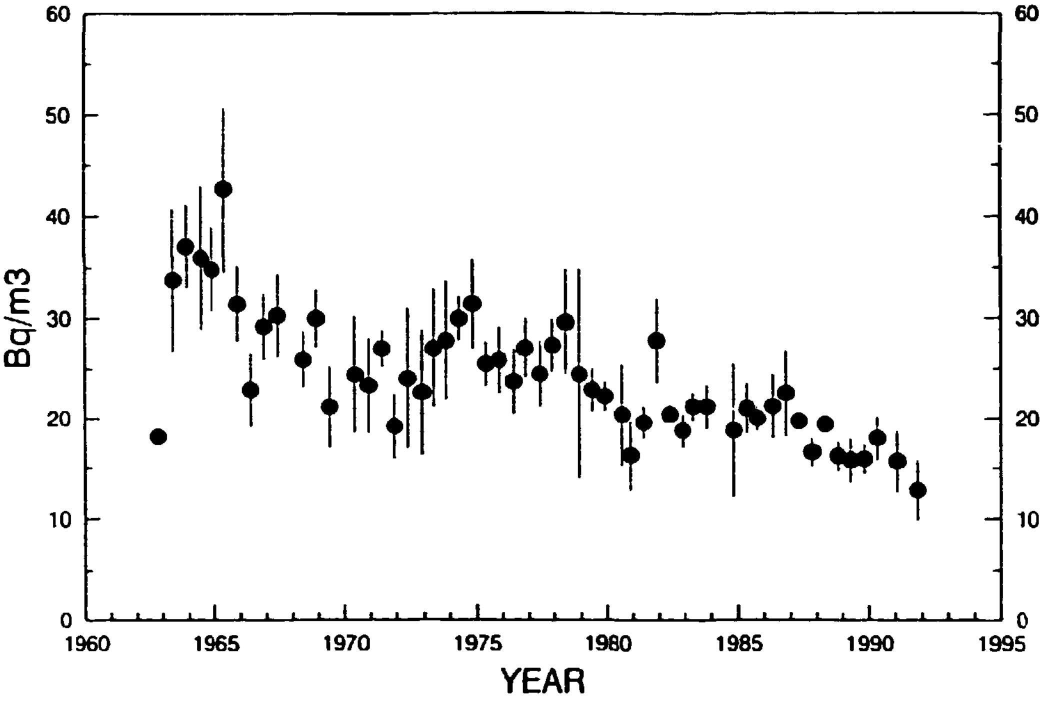
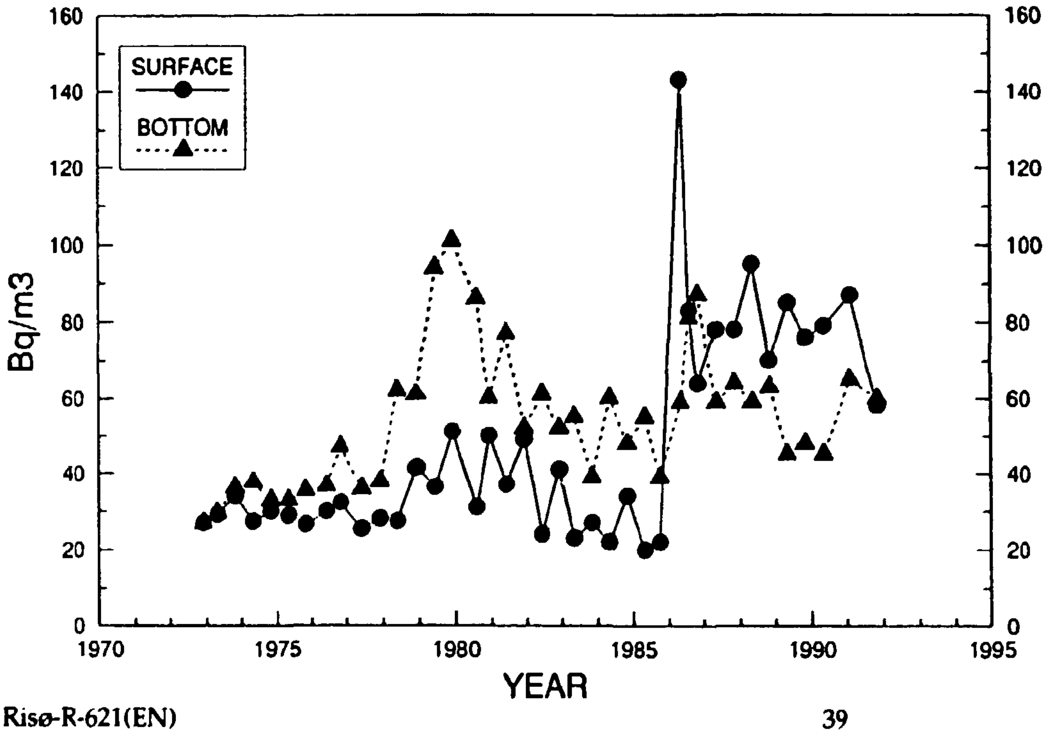


Figure 4.4.1. Strontium-90 in surface sea water from inner Danish waters, 1962-1991. (1 S.D. indicated) (from Tables 4.4.1.A and B and 4.4.2.A and B). (Unit: Bq m^{-3}).

Figure 4.4.2. Cesium-137 in surface and bottom water collected in inner Danish waters 1972-1991. (Unit: Bq m^{-3}).



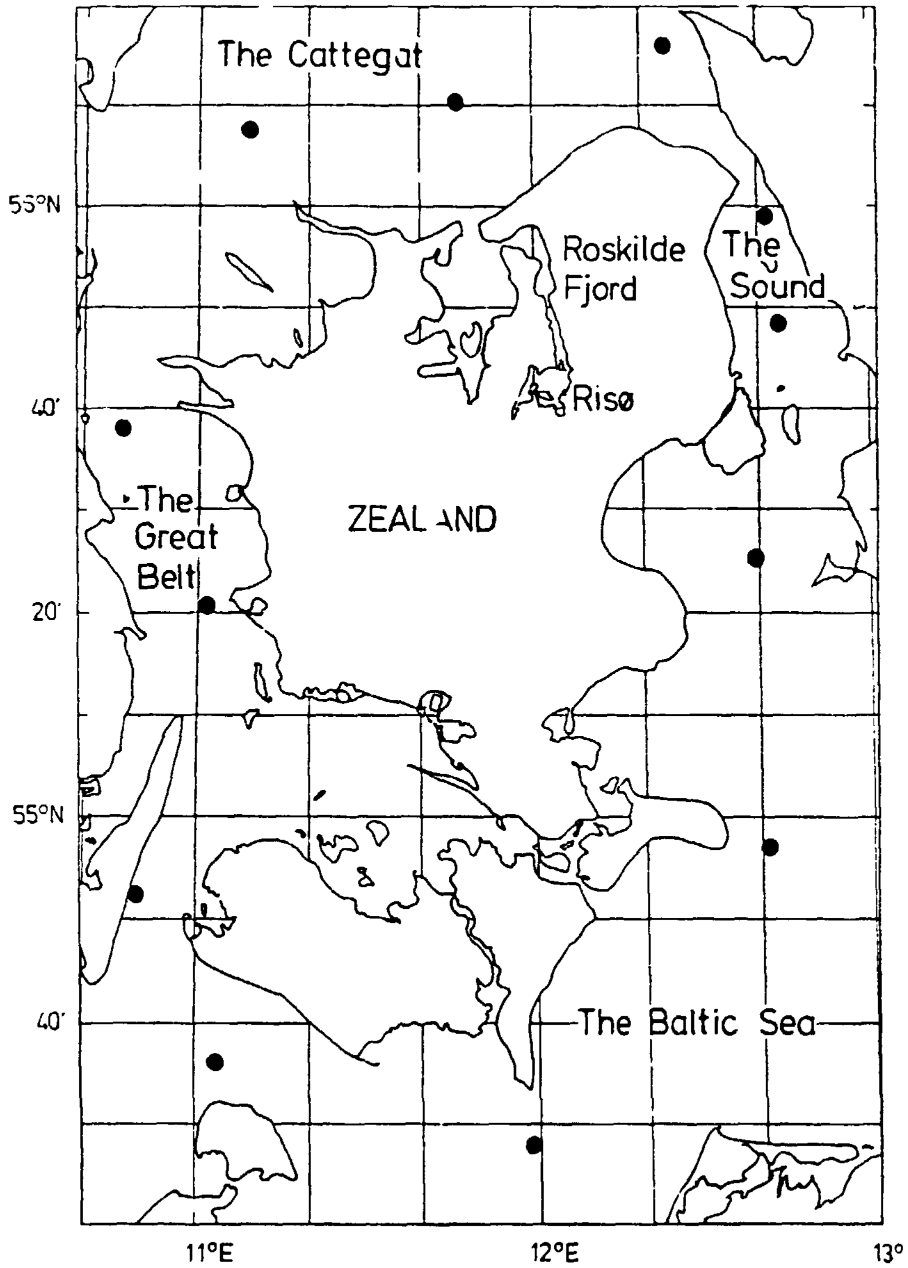


Fig. 4.4.3. Sea water locations around Zealand.

Table 4.4.3. Radionuclides in sea water collected in the Danish Straits, North Sea, and Baltic Sea in 1990 and 1991

Location/ cruise	Year	Date	Position N	Position E	Depth in m	^{90}Sr Bq m^{-3}	^{99}Tc Bq m^{-3}	^{137}Cs Bq m^{-3}	$^{134}Cs/^{137}Cs$	Chernobyl ^{137}Cs Bq m^{-3}	Salinity ‰
Klintholm	1990	Feb 16	54°57'	12°28'	0			87	0.156	81	9.8
"	"	March 23	"	"	0			78	0.143	68	10.4
"	"	April 18	"	"	0			80	0.147	74	9.0
"	"	May 16	"	"	0			92	0.156	(93)	8.7
"	"	June 13	"	"	0			98	0.152	(99)	8.5
"	"	July 19	"	"	0			94	0.137	88	8.7
"	"	Aug 15	"	"	0			93	0.148	(96)	8.4
"	"	Sep 18	"	"	0			101	0.127	92	8.3
"	"	Oct 16	"	"	0			67	0.118	58	18.7
"	"	Nov 13	"	"	0			100	0.128	97	8.3
"	"	Dec 12	"	"	0			89	0.126	87	8.9
% Chernobyl: 95±6; n = 11 (±1 S.D.)											
Halskov	1990	Jan 15	55°21'	11°07'	0			68	0.149	59	16.8
"	"	Feb 15	"	"	0			62	0.135	50	18.6
"	"	March 22	"	"	0			77	0.158	75	14.6
"	"	Apr 17	"	"	0			81	0.141	72	11.5
"	"	May 15	"	"	0			82	0.132	70	10.5
"	"	June 13	"	"	0			82	0.142	77	12.9
"	"	July 19	"	"	0			56	0.125	48	22.0
"	"	Aug 15	"	"	0			78	0.138	75	13.4
"	"	Sep 18	"	"	0			74	0.145	(77)	14.7
"	"	Oct 16	"	"	0			94	0.126	87	9.3
"	"	Nov 12	"	"	0			79	0.102	61	13.6
"	"	Dec 12	"	"	0			64	0.111	55	16.1
% Chernobyl: 90±8; n = 12 (± 1 S.D.)											
Klint	1990	Jan 15	55°58'	11°35'	0		0.36	59	0.123	42	20.3
"	"	Feb 15	"	"	0		0.40	41	0.124	30	25.8
"	"	March 22	"	"	0		0.50	46	0.120	34	23.0
	"	Apr 17	"	"	0		0.40	73	0.152	70	13.9
"	"	May 15	"	"	0		0.26	77	0.157	(78)	13.6
"	"	June 14	"	"	0		0.22	76	0.150	76	13.5
"	"	July 20	"	"	0		0.35	64	0.135	59	18.1
"	"	Aug 15	"	"	0		0.31	69	0.130	59	16.6
"	"	Sep 17	"	"	0		0.35	68	0.112	55	17.2
"	"	Oct 15	"	"	0		0.53	49	0.137	49	22.1
"	"	Nov 12	"	"	0		0.52	56	0.118	50	19.2
	"	Dec 13	"	"	0		0.57	52	0.129	52	21.9
% Chernobyl: 89±11; n = 12 (± 1 S.D.)											

Table 4.4.3. (continued)

Location/ cruise	Year	Date	Position N	Position E	Depth in m	^{90}Sr Bq m^{-3}	^{99}Tc Bq m^{-3}	^{137}Cs Bq m^{-3}	^{134}Cs/^{137}Cs	Chernobyl ^{137}Cs Bq m^{-3}	Salinity ‰
Klint	1991	Jan 16	55°58'	11°35'	0		0.59	42	0.119	40	24.8
"	"	March 14	"	"	0		0.31	81	0.118	80	13.2
"	"	Apr 16	"	"	0		0.56	65	0.106	59	18.0
"	"	May 15	"	"	0		0.48	66	0.113	66	17.2
"	"	June 14	"	"	0		0.32	64	0.108	61	19.7
"	"	July 15	"	"	0		0.26	73	0.096	65	17.0
"	"	Aug 14	"	"	0		0.22	76	0.102	74	15.7
"	"	Sep 16	"	"	0		0.24	70	0.105	72	17.8
"	"	Oct 15	"	"	0		0.24	62	0.096	60	19.8
"	"	Nov 14	"	"	0		0.33	55	0.086	49	21.4
"	"	Dec 16	"	"	0		0.28	60	0.072	46	19.9
% Chernobyl: 94±7; n = 11 (± 1 S.D.)											
Lund fishing port	1990	Jan 16	55°15'	12°18'	0			80	0.159	74	10.2
	"	Feb 16	"	"	0			88	0.160	84	10.5
	"	March 23	"	"	0			73	0.134	60	11.6
"	"	Apr 18	"	"	0			79	0.157	78	9.7
"	"	May 16	"	"	0			82	0.145	77	8.6
"	"	June 13	"	"	0			95	0.159	(100)	8.8
"	"	July 19	"	"	0			98	0.130	87	9.2
"	"	Aug 15	"	"	0			95	0.133	88	8.8
"	"	Sep 18	"	"	0			89	0.133	85	8.2
"	"	Oct 16	"	"	0			89	0.136	89	9.5
"	"	Nov 13	"	"	0			97	0.126	92	8.2
"	"	Dec 12	"	"	0			97	0.128	96	9.0
% Chernobyl: 95±6; n = 12 (± 1 S.D.)											
Svenskehavn (Bornholm)	1990	Jan 2	55°05'	15°09'	0			91	0.167	87	8.1
	"	Feb 4	"	"	0			93	0.163	90	8.2
"	"	March 4	"	"	0			100	0.163	99	8.0
"	"	Apr 1	"	"	0			95	0.162	(96)	7.8
"	"	May 1	"	"	0			98	0.154	96	8.0
"	"	June 1	"	"	0	19.8		102	0.160	(107)	7.8
"	"	July 1	"	"	0			111	0.141	105	7.6
"	"	July 31	"	"	0			115	0.141	112	7.5
"	"	Sep 3	"	"	0			102	0.147	(106)	7.7
"	"	Sep 30	"	"	0			111	0.138	111	7.1
"	"	Nov 3	"	"	0			112	0.120	100	7.1
"	"	Dec 2	"	"	0	16.0		101	0.142	(110)	7.0
% Chernobyl: 99±5; n = 12 (± 1 S.D.)											

Table 4.4.3. (continued)

Location/ cruise	Year	Date	Position N	E	Depth in m	^{90}Sr Bq m^{-3}	^{99}Tc Bq m^{-3}	^{137}Cs Bq m^{-3}	$\frac{^{134}Cs}{^{137}Cs}$	Chernobyl ^{137}Cs Bq m^{-3}	Salinity ‰
Svenskehavn	1991	Jan 1	55°05'	15°09'	0			113	0.126	112	7.2
(Bornholm)	"	Feb 3	"	"	0			100	0.126	(102)	8.1
"	"	March 2	"	"	0			106	0.123	(108)	7.7
"	"	Apr 1	"	"	0			95	0.119	(96)	7.2
"	"	May 1	"	"	0			105	0.115	105	7.4
"	"	June 2	"	"	0	17.4		106	0.114	(108)	7.2
"	"	July 1	"	"	0			105	0.099	95	7.2
"	"	Aug 1	"	"	0			104	0.104	102	7.3
"	"	Sep 1	"	"	0			105	0.101	103	7.2
"	"	Oct 1	"	"	0			106	0.099	104	7.3
"	"	Nov 3	"	"	0			101	0.093	96	7.6
"	"	Nov 30	"	"	0			99	0.095	98	7.4
"	"	Dec 31	"	"	0	17.9		94	0.105	(106)	7.8
% Chernobyl: 100±5; n = 13 (±1 S.D.)											
Gauss no.1	1991	Feb	54°30'	08°00'	0	5.7	1.24	7.6			
Gauss no.2	"	"	55°00'	08°00'	0	5.9	1.08	8.3			
Gauss no.3	"	"	55°30'	07°30'	0	5.8	1.08	8.9			
Gauss no.4	"	"	56°00'	07°45'	0	5.2	0.69	10.1			
Gauss no.5	"	"	56°30'	07°45'	0	4.2	0.73	11.8			
Gauss no.6	"	"	57°00'	08°00'	0	3.3	0.23	13.1			
Gauss no.7A	"	"	57°20'	09°00'	0	3.6	0.44	14.7			
Gauss no.7	"	"	57°20'	09°00'	19		0.51				
Gauss no.8	"	"	57°45'	10°00'	0	3.3	0.39	15.4			
Gauss no.8A	"	"	57°45'	10°00'	84	3.1	0.34	13.5			
Gauss no.9	"	"	57°51'	10°44'	0	10.0	0.44	48	0.157	(62)	
Gauss no.9A	"	"	57°51'	10°44'	106	3.4	0.38	13.6			
Gauss no.10	"	"	56°08'	11°10'	0	11.9	0.32	70	0.121	69	
Gauss no.10A	"	"	56°08'	11°10'	23	7.3	0.63	29	0.076 A	18	
Gauss no.11	"	"	56°40'	12°07'	0	10.3	0.39	59	0.106	51	
Gauss no.11A	"	"	56°40'	12°07'	42	4.3	0.56	18.1	0.092 B	14	
Gauss no.12	"	"	57°22'	11°31'	0	10.3	0.28	52	0.102	43	
Gauss no.12A	"	"	57°22'	11°31'	61	2.2	0.22	9.5			
Gauss no.13	"	"	58°00'	10°58'	0	10.2	0.46	47	0.112	43	
Gauss no.13A	"	"	58°00'	10°58'	149	2.7	0.36	14.1			
Gauss no.17	"	"	57°00'	07°00'	0	3.5	0.41	21			
Gauss no.18	"	"	56°00'	06°00'	0	3.2	0.46	19.3			
Gauss no.19	"	"	56°00'	07°00'	0	4.9	1.12	10.3			
Gauss no.20	"	"	55°00'	07°00'	0	3.4	0.70	16.7			
Gauss no.21	"	"	55°00'	06°00'	0	3.4	0.41	23			
Borkumrif	1990	March 31	53°48'	06°22'	0		2.7				
(Lightshif)	"	May 4	"	"	0		1.59				
"	"	June 1	"	"	0		1.94				
"	"	June 28	"	"	0		2.9				
"	"	Nov 30	"	"	0		2.2				

Table 4.4.3. (continued)

Location/ cruise	Year	Date	Position N	Position E	Depth in m	^{90}Sr Bq m^{-3}	^{99}Tc Bq m^{-3}	^{137}Cs Bq m^{-3}	^{134}Cs/^{137}Cs	Chernobyl ^{137}Cs Bq m^{-3}	Salinity ‰
Borkumrif	1991	Jan	53°48'	06°22'	0		1.80				
(Lightship)	"	Jan 17	"	"	0		1.48				
"	"	Apr 9	"	"	0		2.8				
"	"	May 8	"	"	0		2.6				
"	"	June 8	"	"	0		2.1				
"	"	July 8	"	"	0		2.4				
"	"	Aug 9	"	"	0		1.89				
"	"	Sep 9	"	"	0		1.82				
"	"	Oct 8	"	"	0		1.08				
"	"	Oct 25	"	"	0		1.09				
"	"	Dec 15	"	"	0		1.03				
Elbe 1	1990	Jan 2	54°00'	08°07'	0		1.72				
(Lightship)	"	Jan 31	"	"	0		1.94				
"	"	Apr 3	"	"	0		2.7				
"	"	May 1	"	"	0		2.6				
"	"	May 29	"	"	0		2.5				
"	"	June 30	"	"	0		2.5				
"	1991	Jan	"	"	0		0.76				
"	"	Feb	"	"	0		1.23				
"	"	Feb 26	"	"	0		1.37				
"	"	Apr 1	"	"	0		1.62				
"	"	Apr 29	"	"	0		2.1				
"	"	May 27	"	"	0		1.60				
"	"	July 10	"	"	0		2.2				
"	"	July 30	"	"	0		1.90				
"	"	Sep 11	"	"	0		1.61				
"	"	Oct 11	"	"	0		1.50				
"	"	Nov	"	"	0		1.25				
"	"	Dec 3	"	"	0		1.24				
St. 413/DMU	1990	Jan 9	56°40'	12°07'	5		0.43				23.5
"	"	Jan 9	"	"	32		0.63				33.4
"	"	Feb 12	"	"	5		0.52				27.4
"	"	Feb 12	"	"	40		0.89				31.6
"	"	Mar 22	"	"	5		0.55				26.4
"	"	Mar 22	"	"	40		1.19				32.1
"	"	May 1	"	"	5		0.25				15.5
"	"	Maj 1	"	"	35		1.21				33.6
"	"	June 19	"	"	5		0.23				
"	"	June 19	"	"	30		1.37				
"	"	July 16	"	"	5		0.63				22.0
"	"	July 16	"	"	40		1.32				34.0
"	"	Aug 14	"	"	5						20.3
"	"	Aug 14	"	"	35		1.29				33.5
"	"	Sep 25	"	"	5		0.54				32.5
"	"	Sep 25	"	"	30		0.95				20.6
"	"	Oct 16	"	"	5		0.78				21.9
"	"	Oct 16	"	"	30		0.66				32.6

Table 4.4.3. (continued)

Location/ cruise	Year	Date	Position N	Position E	Depth in m	^{90}Sr Bq m^{-3}	^{99}Tc Bq m^{-3}	^{137}Cs Bq m^{-3}	^{134}Cs/^{137}Cs	Chernobyl ^{137}Cs Bq m^{-3}	Salinity ‰
St. 413/DMU	1990	Nov 6	56°40'	12°07'	5						19.2
"	"	Nov 6	"	"	30		0.27				33.6
"	1991	Jan 8	"	"	5		0.46				25.8
"	"	Jan 8	"	"	45		0.46				33.1
"	"	Feb 11	"	"	5		0.27				17.1
"	"	Feb 11	"	"	35		0.65				33.0
"	"	Mar 18	"	"	5		0.27				16.7
"	"	Mar 18	"	"	35		0.38				31.9
"	"	Apr 30	"	"	5		0.157				13.6
"	"	Apr 30	"	"	35		0.38				34.0
"	"	June 17	"	"	5		0.32				21.7
"	"	June 17	"	"	35		0.46				33.5
"	"	July 16	"	"	5		0.24				18.3
"	"	July 16	"	"	50		0.46				33.5
"	"	Aug 19	"	"	5		0.26				19.5
"	"	Aug 19	"	"	30		0.48				32.8
"	"	Sep 16	"	"	5		0.27				20.6
"	"	Sep 16	"	"	45		0.44				33.0
"	"	Oct 7	"	"	5		0.34				22.0
"	"	Oct 7	"	"	50		0.56				33.2
"	"	Nov 4	"	"	5		0.29				21.4
"	"	Nov 4	"	"	35		0.49				32.9
St. 925/DMU	1990	Jan 10	56°08'	11°10'	5		lost				20.5
"	"	Jan 10	"	"	25		0.63				31.4
"	"	Feb 21	"	"	5		0.34				22.7
"	"	Feb 21	"	"	30		0.57				27.6
"	"	Mar 21	"	"	5		0.47				26.2
"	"	Mar 21	"	"	25		0.51				21.3
"	"	May 2	"	"	5		0.30				13.6
"	"	May 2	"	"	30		1.02				30.4
"	"	June 20	"	"	5		0.30				16.2
"	"	June 20	"	"	25		1.09				32.9
"	"	July 18	"	"	5		0.49				18.6
"	"	July 18	"	"	30		1.31				33.2
"	"	Aug 21	"	"	5		0.23				18.7
"	"	Aug 21	"	"	35		1.11				33.0
"	"	Sep 26	"	"	5		0.76				21.7
"	"	Sep 26	"	"	25		1.07				30.4
"	"	Oct 17	"	"	5		0.75				23.8
"	"	Oct 17	"	"	35		lost				31.6
"	"	Nov 7	"	"	5		lost				19.7
"	"	Nov 7	"	"	30		0.88				32.3
"	1991	Jan 9	"	"	5		0.47				27.4
"	"	Jan 9	"	"	30		0.38				31.3
"	"	Feb 20	"	"	5		0.33				18.9
"	"	Feb 20	"	"	30		0.49				27.8
"	"	Mar 20	"	"	5		0.25				16.6
"	"	Mar 20	"	"	30		0.38				33.3

Table 4.4.3. (continued)

Location/ cruise	Year	Date	Position N	Position E	Depth in m	^{90}Sr Bq m^{-3}	^{99}Tc Bq m^{-3}	^{137}Cs Bq m^{-3}	^{134}Cs/^{137}Cs	Chernobyl ^{137}Cs Bq m^{-3}	Salinity ‰
St. 925/DMU	1991	May 1	56°08'	11°10'	5		0.22				16.6
"	"	May 1	"	"	30		0.41				32.5
"	"	June 19	"	"	5		0.27				19.2
"	"	June 19	"	"	30		0.37				33.4
"	"	July 17	"	"	5		0.26				17.8
"	"	July 17	"	"	30		0.45				32.0
"	"	Aug 21	"	"	5		0.21				18.6
"	"	Aug 21	"	"	30		0.43				32.7
"	"	Oct 9	"	"	5		0.53				21.7
"	"	Oct 9	"	"	44		0.30				31.9
"	"	Sep 18	"	"	5		0.23				18.7
"	"	Sep 18	"	"	41		0.44				32.2
"	"	Nov 11	"	"	5		0.27				19.5
"	"	Nov 11	"	"	30		0.44				30.8
St. 444/DMU	1990	Jan 12	55°00'	13°18'	5		0.29				8.9
"	"	Feb 22	"	"	5		0.087 A				9.6
"	"	Mar 12	"	"	5		0.176				10.3
"	"	June 21	"	"	5		< 0.06				7.8
"	"	July 19	"	"	5		< 0.06				7.8
"	"	Aug 21	"	"	5		< 0.06				8.1
"	"	Sep 28	"	"	5		0.129				8.2
"	"	Oct 19	"	"	5		0.27				8.4
"	"	Nov 8	"	"	5						8.2
"	1991	Jan 10	"	"	5		0.084				9.1
"	"	Feb 20	"	"	5		< 0.05				7.9
"	"	Mar 21	"	"	5		0.067				7.9
"	"	May 2	"	"	5		< 0.05				7.6
"	"	June 20	"	"	5		< 0.05				7.5
"	"	July 18	"	"	5		< 0.05				7.3
"	"	Aug 22	"	"	5		0.056 B				7.5
"	"	Sep 19	"	"	5		0.026 B				7.8
"	"	Oct 10	"	"	5		0.077				7.7
"	"	Nov 7	"	"	5		0.056 A				8.2
Risø	1991	June 6	55°42'	12°05'	0			38.0	0.091	31.4	12.6
Hirtshals	1991	June 28	57°36'	09°58'	0		0.60				32.6
"	"	Nov 26	"	"	0		1.44				32.6
"	"	Dec 20	"	"	0		1.37				32.2

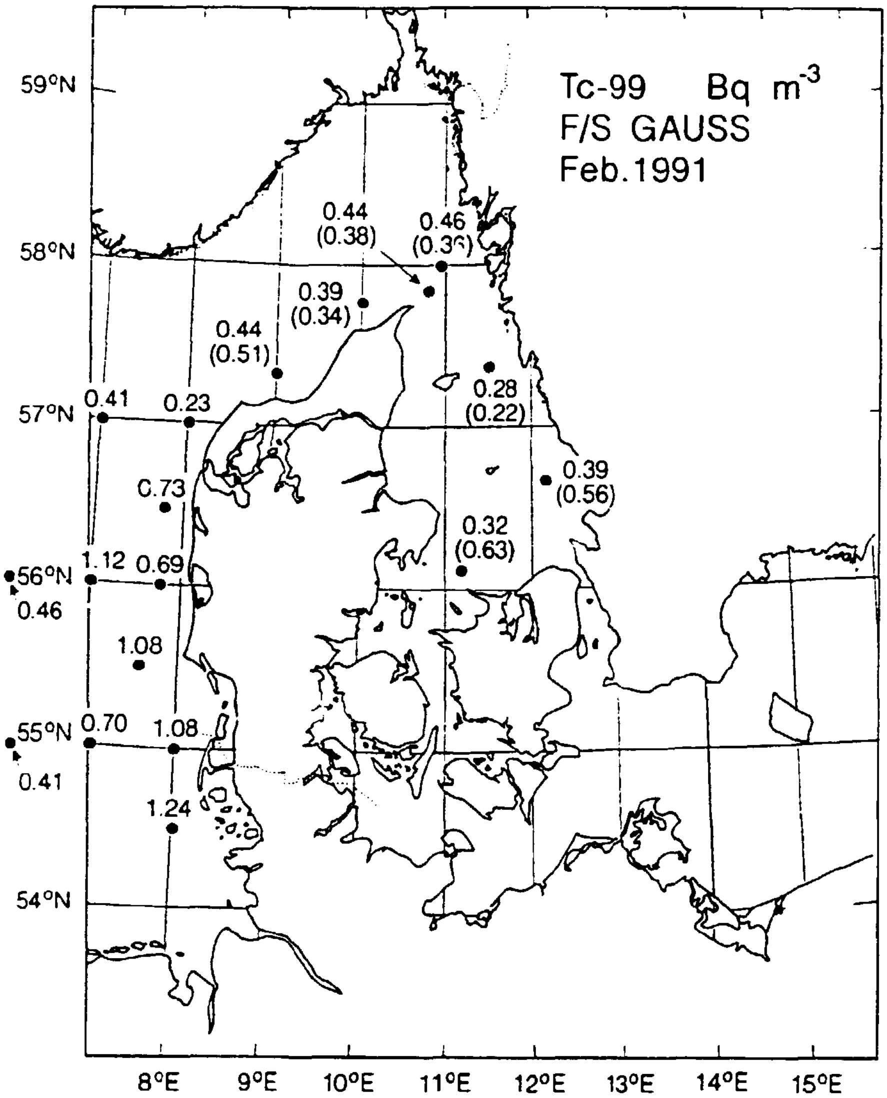


Figure 4.4.5. Technetium-99 in sea water collected in February 1991. Figure in brackets are bottom water. (Unit: Bq m^{-3}).

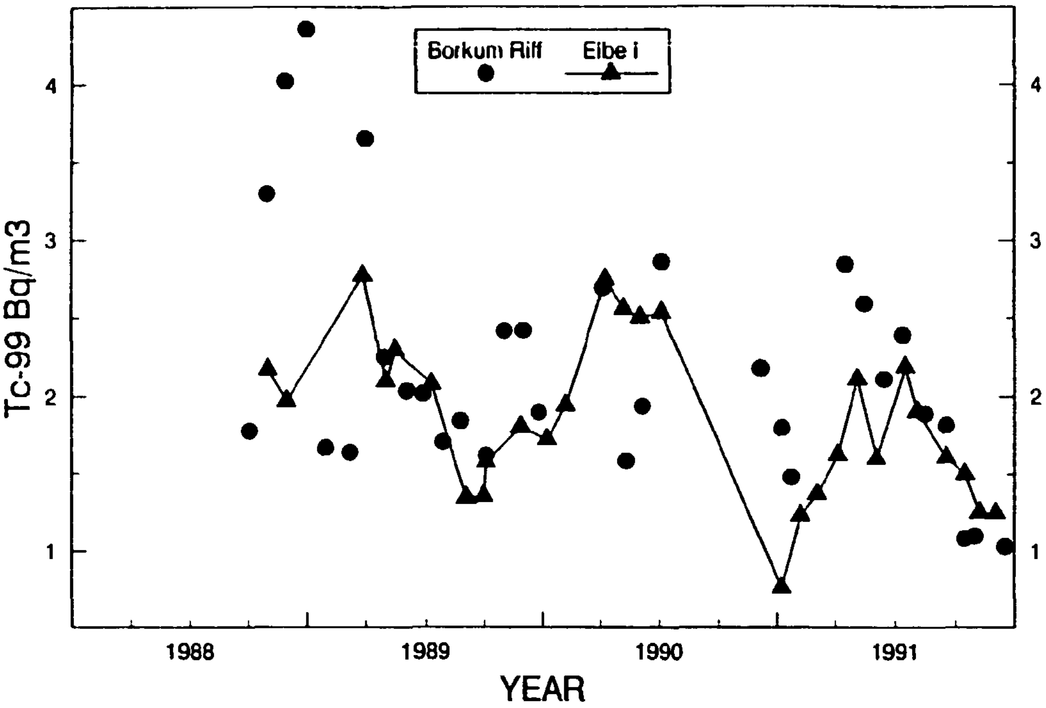
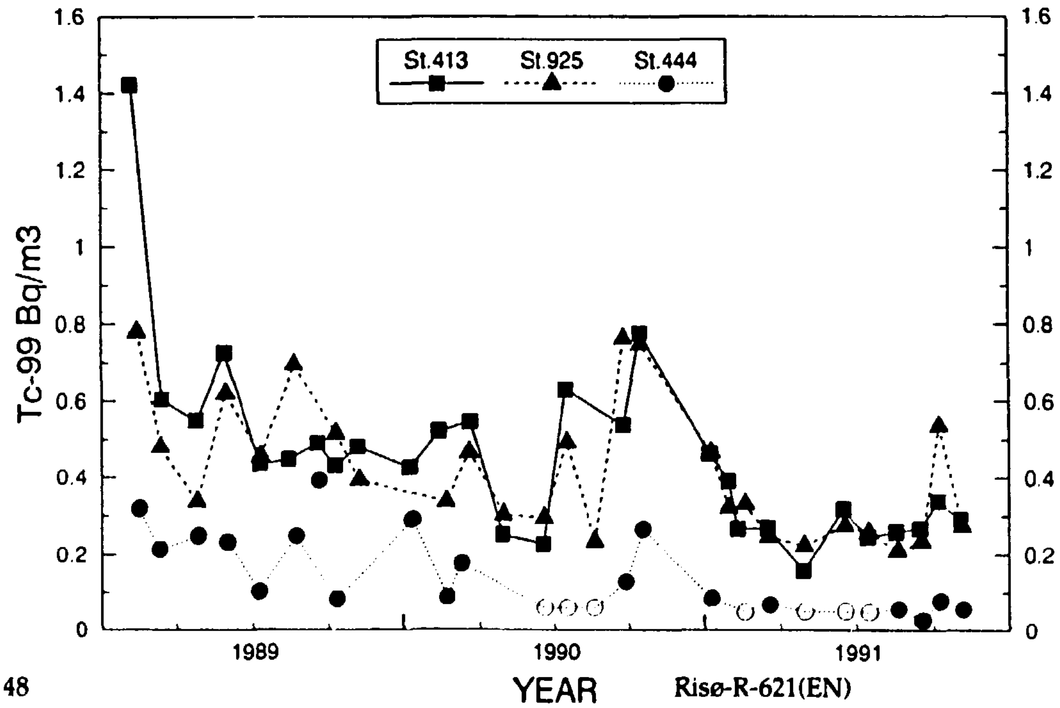


Figure 4.4.6. Technetium-99 in surface sea water from the German Bight 1988-1991. (Unit: Bq m^{-3}). Borkum Riff: 53°48'N, 06°22'E and Elbe I: 54°00'N, 08°07'E.

Figure 4.4.7. Technetium-99 in surface sea water collected in 1989-1991.
(○ = detection limits). (Unit: Bq m^{-3}).
St. 413/DMU: 56°40'N, 12°07'E
St. 925/DMU: 56°08'N, 11°10'E
St. 444/DMU: 55°00'N, 13°18'E



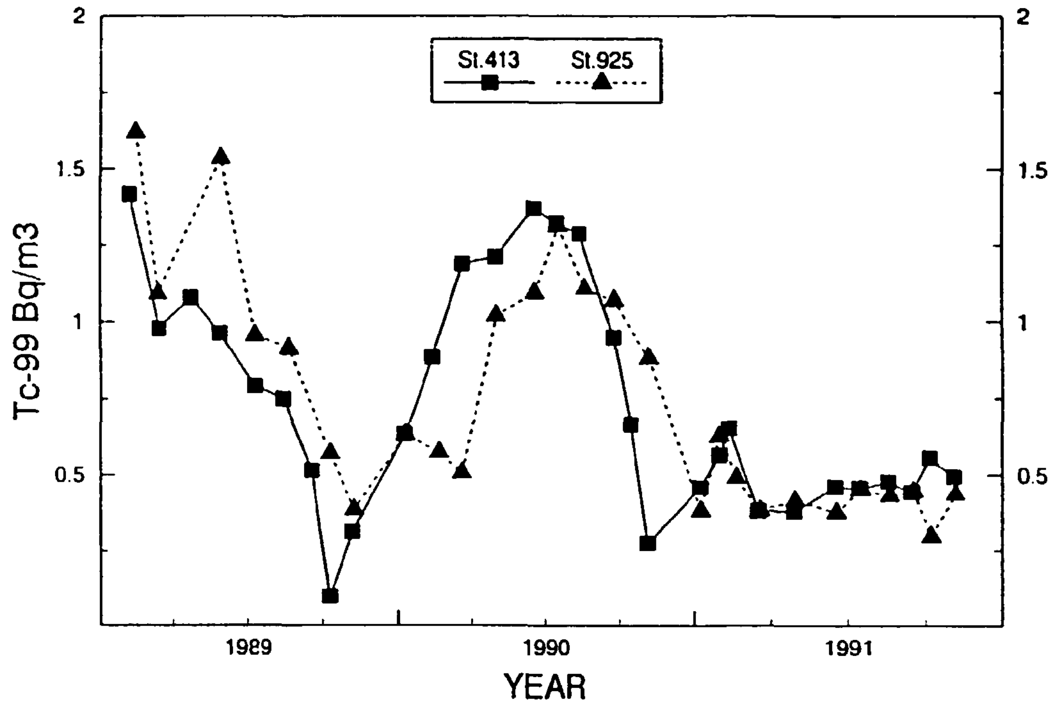


Figure 4.4.8. Technetium-99 in bottom sea water collected in 1989-1991. (Unit: Bq m^{-3}).
St. 413/DMU: 56°40'N, 12°07'E
St. 925/DMU: 56°08'N, 11°10'E

Figure 4.4.9. Technetium-99 in sea water and Fucoids from the shore at Klint: 55°58'N, 11°35'E in 1988-1991.

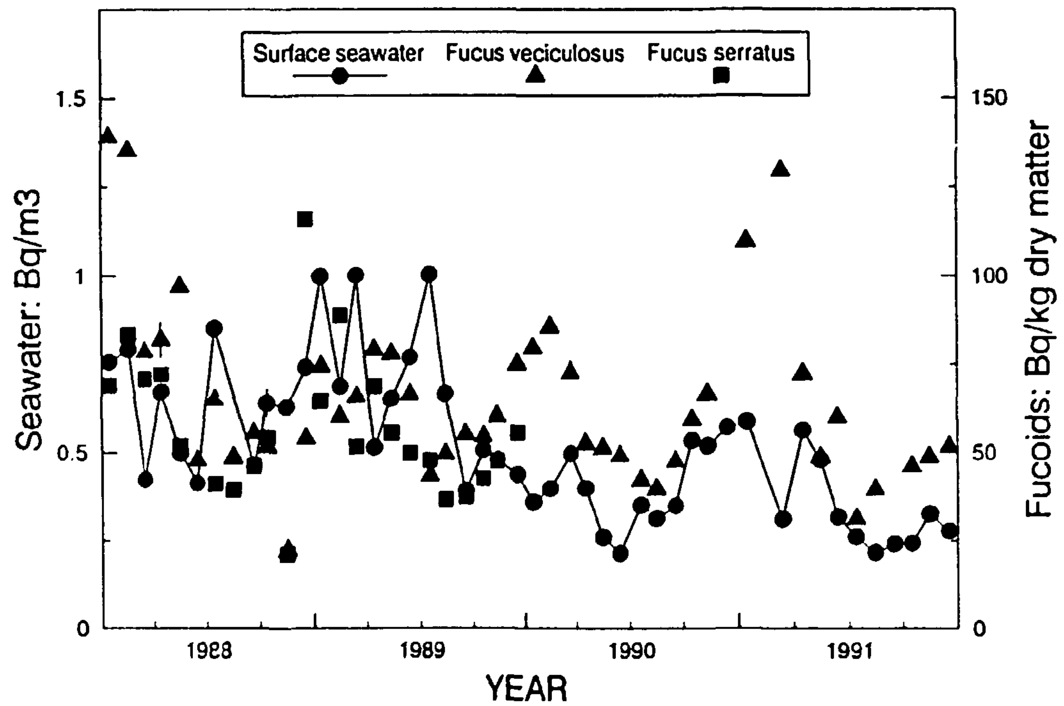


Table 4.5.1. Uncultivated soil (0-5 cm depth) collected at Tornbygård in different distances from the rain collector, May, 17, 1990. (Unit: Bq m^{-2}).

Distance from rain collector in m	^{90}Sr	^{134}Cs	^{137}Cs	Fallout $^{90}Sr/^{137}Cs$	$\frac{^{134}Cs}{^{137}Cs}$	Chernobyl ^{137}Cs	Fallout ^{137}Cs
0	58	62	770	6.3	0.081	402	368
200	142	16.5	770	4.7	0.021	104	666
400	99	36	720	4.9	0.050	233	487
700	35	30	580	11.0	0.052	195	385
1300 (in forest)	147	38	1190	6.4	0.032	246	944
$\bar{x}$	96	36.5	806	6.7	0.047	236	570
S.D. %	52	45	28	38	49	46	42

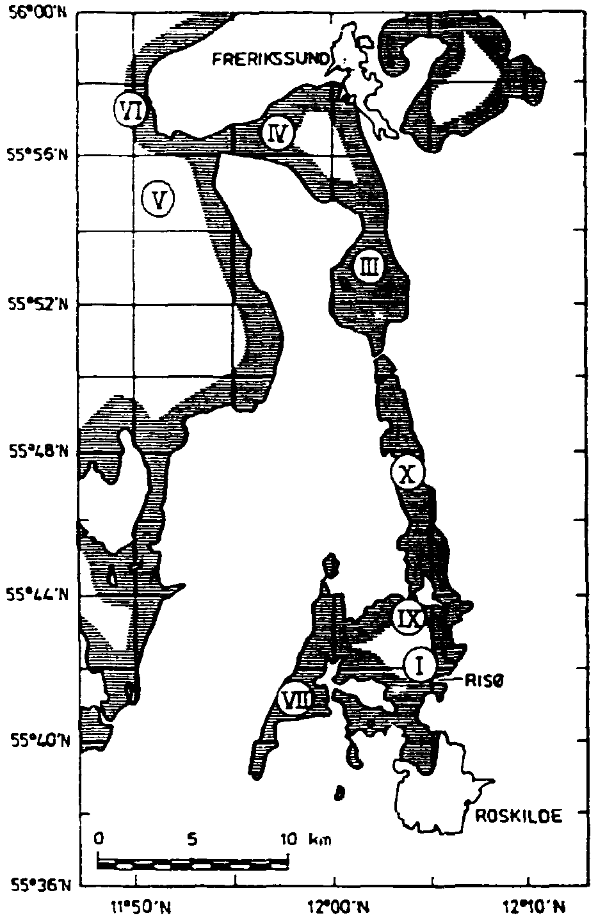


Figure 4.6. Roskilde fjord.

Table 4.6. Radiocesium in marine sediments collected in Roskilde Fjord in 1990 and 1991 at Bolund (55°42'N 12°05'E). (Unit: Bq kg^{-1} dry)

Date	^{134}Cs	^{137}Cs	Chernobyl ^{137}Cs	Chernobyl ^{137}Cs
Aug 28, 1990	0.82 A	22	5.8	27%
July 1, 1991	0.47	10.4	2.7	26%

5. Danish Food and Various Vegetation

by A. Aarkrog

5.1. Cows Milk

Milk samples from seven locations (Figure 5.1.1) were collected monthly and analysed for ^{90}Sr (Tables 5.1.1.A & B) and for ^{137}Cs (Tables 5.1.3.A & B). The samples from Hjørring, Randers and Videbæk were dried milk, the remaining locations were represented by fresh milk samples. Since 1983 the ^{90}Sr concentrations in Danish milk have decayed with a halflife of 10 years; the global fallout ^{137}Cs has shown a halflife of 6 years and that of Chernobyl ^{137}Cs of 1.1 years (1987-1989). During 1989 to 1991 the half-life of Chernobyl ^{137}Cs in Danish milk increased to about 3 years.

5.2. Other Milk Products

No samples in 1990 and 1991.

5.3. Cereal Grain

Grain samples were as previously obtained from the ten Danish experimental farms (cf. Figure 4.2). The samples were combined before analysis as shown in Tables 5.3.1 and 5.3.5. Jutland comprises Tylstrup, Kalø, Borris, Askov and Jyndevad, and the Islands were represented by Årslev, Ledreborg, Tystofte, Abed and Kannikegård (see also Tables 5.3.7.1-5.3.7.2, showing the samples obtained from the various farms).

Figures 5.3.1-5.3.4 show the ^{90}Sr levels since measurements began in 1959 and Figures 5.3.5-5.3.8 show the corresponding ^{137}Cs concentrations for the period 1962-91. The effective halflife of ^{90}Sr in Danish grain has been 10-15 years since 1983.
The effective halflife of global fallout of ^{137}Cs has since 1983 been 12 years (for oats 16 years) and that of Chernobyl ^{137}Cs has since 1987 been about 5 years (shorter for barley and oats, longer for wheat and rye) (cf. Tables 5.3.5A & B).

The predictions of the ^{137}Cs levels in grain from 1990 and 1991 based upon revised models, including root uptake are summarized in Appendix C, cf. also Appendix A. The predicted values for ^{90}Sr and ^{137}Cs in Danish grain from 1990 and 1991 were not systematically different from those observed.

5.4. Bread

The ^{137}Cs rye bread levels in 1990 as well as in 1991 were in general higher than expected from Danish grain measurements (Tables 5.4.3.A & B) while the white bread levels were lower. This may suggest import of rye grain from areas in Europe which were more contaminated by Chernobyl debris than Denmark. Strontium-90 was not determined in bread samples from 1990 and 1991.

5.5. Potatoes

The effective halflife of ^{90}Sr in potatoes in Denmark has since 1983 been about 20 years, somewhat longer in the Islands than in Jutland (cf. Figures 5.5.1-5.5.2). The ^{137}Cs concentrations have shown greater variability partly due to the Chernobyl accident (Figures 5.5.3-5.5.4).

5.6. Vegetables and Fruit

The ^{90}Sr and ^{137}Cs levels in vegetables and fruit were generally a little lower in 1991 than in 1990 (Tables 5.6.3 A & B).

5.7. Meat, Fish, Eggs and Various Vegetable Foodstuffs

5.7.1. Meat

During 1990 and 1991 80% of the ^{137}Cs in Danish beef came from Chernobyl, this activity decayed with an effective halflife of about 2 years which is shorter than that of global fallout. The high variation of the ^{137}Cs concentrations in beef (Table 5.7.1.2.A) suggests import of meat from parts of Europe more contaminated than Denmark by Chernobyl fallout.

5.7.2. Fish

Fish from the inner Danish waters contained 2 times more ^{137}Cs than fish from the North Sea. Fish from the Baltic Sea showed nearly an order of magnitude higher levels than fish from the North Sea.

The contribution from Chernobyl to the total ^{137}Cs concentration in fish was 75% in the inner waters and 62% in the North Sea in 1990 and 1991. Fish from the Baltic Sea showed a percentage of 95%.

The mean content of ^{210}Po in Danish fish was 0.40 Bq kg^{-1}, an anova showed that the levels in herring were higher than those in cod ($P \geq 97\%$). The ^{210}Po concentrations in fish from the Baltic Sea seemed to be higher than those from the Cattegat and the North Sea, but the difference was not significant in the anova ($P \sim 88\%$).

5.7.3. Eggs

The ^{90}Sr concentrations in eggs in 1990 were similar to those in 1989, i.e mean ≤ 0.01 Bq kg^{-1}. The ^{137}Cs levels were an order of magnitude higher.

5.7.4. Various Vegetable Foods

The levels in hazel nuts, oats, banana, orange, coffee and tea in 1990 were similar (within a factor of 2-3) to those observed at the last sampling in 1988; but rize contained significantly less ^{90}Sr and ^{137}Cs in 1990.

5.8. Total Diet (Consumption Data)

The ^{90}Sr intake with total Danish diet has since 1983 decreased with a halflife corresponding to the radiological halflife of ^{90}Sr, i.e. 28.5 years. The daily pro capite intake of Ca with the Danish diet is now 1.12 g Ca corresponding to 409 g per year.

The global fallout ^{137}Cs in the diet decayed with an effective halflife of approx. 5 years whereas Chernobyl ^{137}Cs (~ 70%) decreased with 3 years halflife. The determination of the decay of the global fallout is encumbered with uncertainties due to the contribution of Sellafield radiocesium from fish consumption. As ^{134}Cs was determined reliably only in the June 1990 diet, the estimate of the Chernobyl ^{137}Cs is uncertain too.

5.9. Total Diet (Production Data)

The ^{90}Sr intake with total diet calculated from the concentrations in the various diet constituents may be compared with the measured levels in total diet (consumption data). In 1990 the production data were 0.12 Bq ^{90}Sr day^{-1} cap^{-1} and the consumption figure was 0.13. In 1991 the data were 0.11 and 0 13, respectively. The corresponding figures for ^{137}Cs were in 1990 0.49 and 0.31, respectively, and in 1991 0.40 and 0.24 Bq ^{137}Cs day^{-1} cap^{-1}, respectively. The discrepancy between the two diet estimates observed for ^{137}Cs was due to an overrepresentation of Baltic fish in the diet based upon production data.

5.10. Grass

5.10.1. Grass from Zealand

Strontium-90 in grass collected around Risø has since 1987 decayed with an effective halflife of 5 years and ^{137}Cs with about 1.5 years halflife. These figures are based on monthly samples collected throughout the year.

5.10.2. Grass Collected Countrywide

Since 1987 the ^{137}Cs levels in grass collected during the summer half year at the 10 State experimental farms has decayed with a halflife of about 1.5 years.

5.11. Sea Plants

5.11.1. Sea Plants from Roskilde Fjord

The ^{90}Sr and ^{137}Cs concentrations in Fucus vesiculosus showed an increasing tendency during 1990-1991, perhaps due to inflow of Baltic Sea water in the Fjord.

5.11.2. Sea Plants from Inner Danish Waters

Fucus from the southern locations (Strøby Egede and Nysted) showed two times higher ^{137}Cs levels than those found at the stations in the Cattegat (Klint and Nakkehoved). The ^{137}Cs concentrations in Fucus showed a maximum in May-June. Both observations were in accordance with earlier years (1988-1989) measurements.

The observed mean ratio between Bq kg^{-1} d.w. Fucus and Bq l^{-1} sea water for ^{99}Tc was $(1.71 \pm 0.15) \cdot 10^5$ (±1 S.E.;n = 21) for Fucus vesiculosus sampled monthly at Klint in 1990 and 1991 (cf. also Table 4.4.3). The observed ratio was higher than seen in 1988-1989 ($1.05 \cdot 10^5$). This may be because the water concentrations of ^{99}Tc decreased from 1988-1989 to 1990-1991 (see Figure 4.4.9) and Fucus still »recalls« the higher concentrations.

5.12. Lichen and Moss

In Figure 5.12 six years observations of ^{137}Cs in Danish lichen are shown (1986-1991). It appears that the environmental halflife of global fallout ^{137}Cs was 3.5 years at Oustrup Heather and 5.6 years at Skagen while the Chernobyl ^{137}Cs showed halflives of 3.3 and 2.9 years, respevtively, at the two locations (Figures 5.12.1 and 5.12.2).

Table 5. Geometric means of Strontium-90 and Cesium-137 levels in Danish environmental biological samples collected in 1990 and 1991

Sample type and unit	Strontium-90		Cesium-137	
	1990	1991	1990	1991
Countrywide dried milk, Bq l^{-1} fresh	0.048	0.046	0.101	0.076
Danish cheese, Bq kg^{-1}	-	-	-	-
Countrywide rye, Bq kg^{-1}	0.25	0.23	0.117	0.100
Countrywide barley, Bq kg^{-1}	0.33	0.32	0.046	0.049
Countrywide wheat, Bq kg^{-1}	0.33	0.27	0.057	0.045
Countrywide oats, Bq kg^{-1}	0.37	0.41	0.126	0.159
Countrywide rye bread, Bq kg^{-1}	-	-	0.121	0.21
Countrywide white bread, Bq kg^{-1}	-	-	0.038	0.029
Countrywide potatoes, Bq kg^{-1}	0.032	0.029	< 0.055	0.065
Countrywide cabbage, Bq kg^{-1}	0.152	0.131	0.063	0.058
Countrywide carrot, Bq kg^{-1}	0.30	0.25	0.053	0.033
Countrywide beans, Bq kg^{-1}	0.28	0.25	0.0185	0.0185
Countrywide apples, Bq kg^{-1}	0.0179	0.0125	0.037	0.041
Countrywide Strawberry, Bq kg^{-1}	0.134	0.152	0.031	0.028
Country intake † with diet, Bq day^{-1} cap^{-1}	0.126	0.136	0.33	0.22
Countrywide beef, Bq kg^{-1}	0.0074	0.0069	0.99	0.37
Countrywide pork, Bq kg^{-1}	0.002*	0.0020	0.165*	0.49
Countrywide° plaice, Bq kg^{-1}	0.0132	0.0199	0.95	0.62
Countrywide° herring, Bq kg^{-1}	0.0051	0.0047	2.2	1.50
Countrywide° cod, Bq kg^{-1}	0.0192	0.0093	3.0	5.3
Countrywide grass, Bq kg^{-1} fresh	0.51	0.65	0.126	0.118

†Mean of June and December sampling
*Copenhagen samples only
°Mean of Cattegat and North Sea samples.

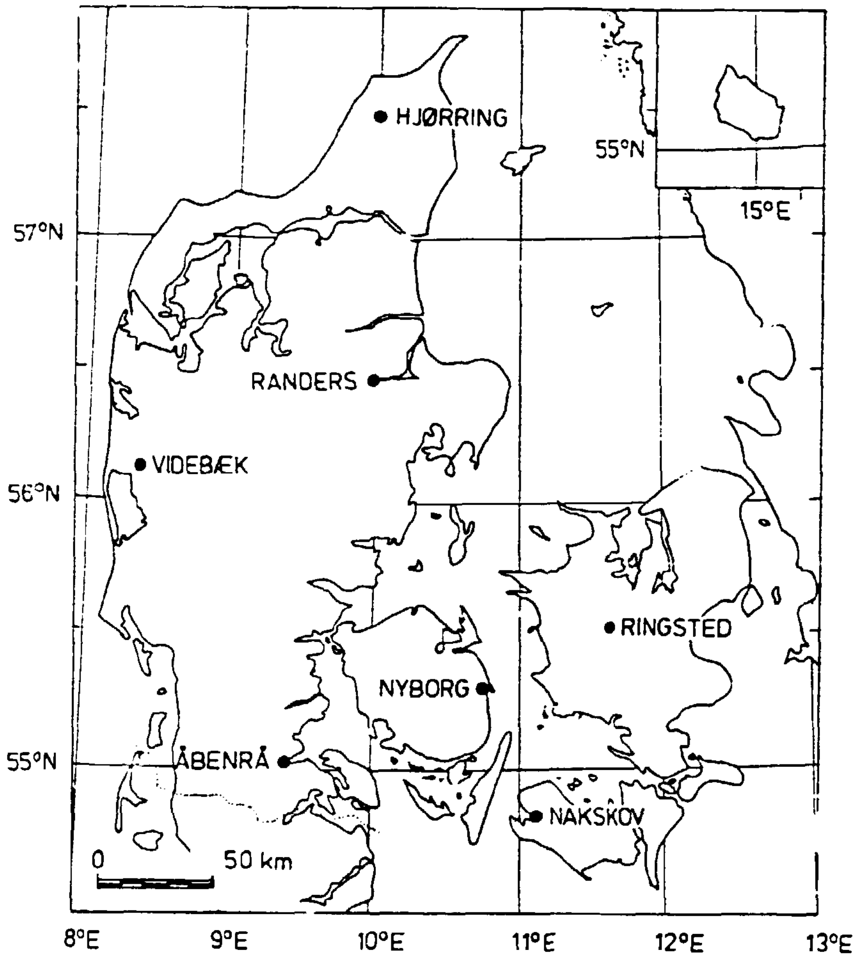


Figure 5.1.1. Dried milk sampling locations in Denmark.

Table 5.1.1.A. Strontium-90 in dried milk in 1990. (Unit: Bq (kg Ca)$^{-1}$)

Period	Jutland	The Islands	Geometric mean	Arithmetic mean
Jan-April	57	36	46	47
May-Oct	44	31	37	37
Nov-Dec	48	35	41	41
1990: Geometric mean*	49	34	41	
1990: Arithmetic mean*	50	34		42

*The data were weighted with the number of months when calculating the mean.

As 1 cubic meter of milk contains 1.2 kg Ca, the mean ^{90}Sr content in Danish milk produced in 1990 was 50 Bq m^{-3} (or 0.050 Bq ^{90}Sr l^{-1}).

Table 5.1.1.B. Strontium-90 in dried milk in 1991. (Unit: Bq (kg Ca)$^{-1}$)

Period	Jutland	The Islands	Geometric mean	Arithmetic mean
Jan-April	47	33	39	40
May-Oct	39	31	35	35
Nov-Dec	44	38	41	41
1991: Geometric mean*	43	34	38	
1991: Arithmetic mean*	43	34		39

*The data were weighted with the number of months when calculating the mean.

As 1 cubic meter of milk contains 1.2 kg Ca, the mean ^{90}Sr content in Danish milk produced in 1991 was 46 Bq m^{-3} (or 0.046 Bq ^{90}Sr l^{-1}).

Table 5.1.3.A. Cesium-137 in Danish dried milk in 1990. (Unit: Bq ^{137}Cs $(kg\ K)^{-1}$)

Month	Hjørring	Randers	Videbæk	Åbenrå	Nyborg	Ringsted	Nakskov	Geometric mean	Arithmetic mean
Jan	50	112	220	94	75	32	22	67	87
Feb	50	56	155	154	58	27	27	60	75
March	86	102	182	101	44	20	40	66	82
April	103	93	195±3	103	57	33	36	75	88
May	62	97	148	93	41	31	29	61	72
June	69	91	174	102	42	46 B	27	66	79
July	79	87	150	71	39	37	24	59	69
Aug	84	85	280	104	38	39	14.4	64	92
Sep	59	116	149	124	41	39	17.2	62	78
Oct	44	110	146	67	46	26	19.2	53	66
Nov	67	82	125	62	43	33	17.0	52	61
Dec	45	64	134	60	35	31	32	50	57
1990: Geometric mean	64	89	167	91	46	32	24	61	
1990: Arithmetic mean	66	91	172	94	47	33	25		76

As 1 cubic meter of milk contains approx. 1.66 kg K, the mean ^{137}Cs content in Danish milk produced in 1990 was estimated at 125 Bq m^{-3} (or 0.125 Bq $^{137}Cs\ l^{-1}$).

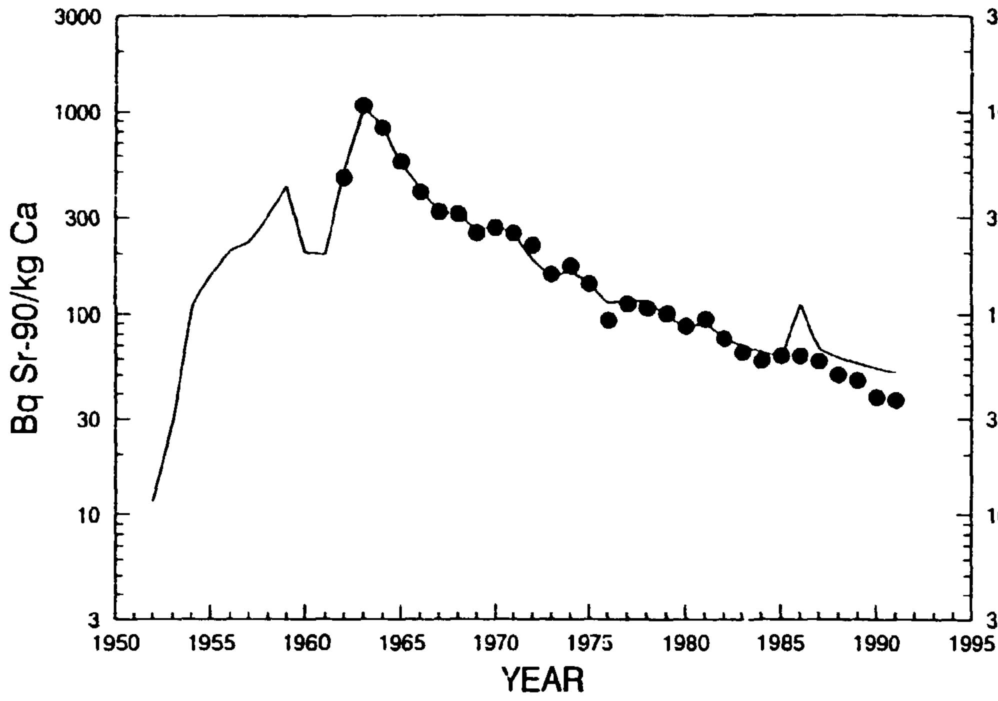


Figure 5.1.2. Predicted (curve) and observed $^{90}Sr/Ca$ levels in dried milk from Denmark (May 1962 - April 1992) (milk year). Prediction model given in Risø-R-540 (Table C.3.1).

Figure 5.1.3. Predicted (curve) and observed $^{137}Cs/K$ levels in dried milk from Denmark (May 1962 - April 1992) (milk year) (cf. Figure 5.1.2).

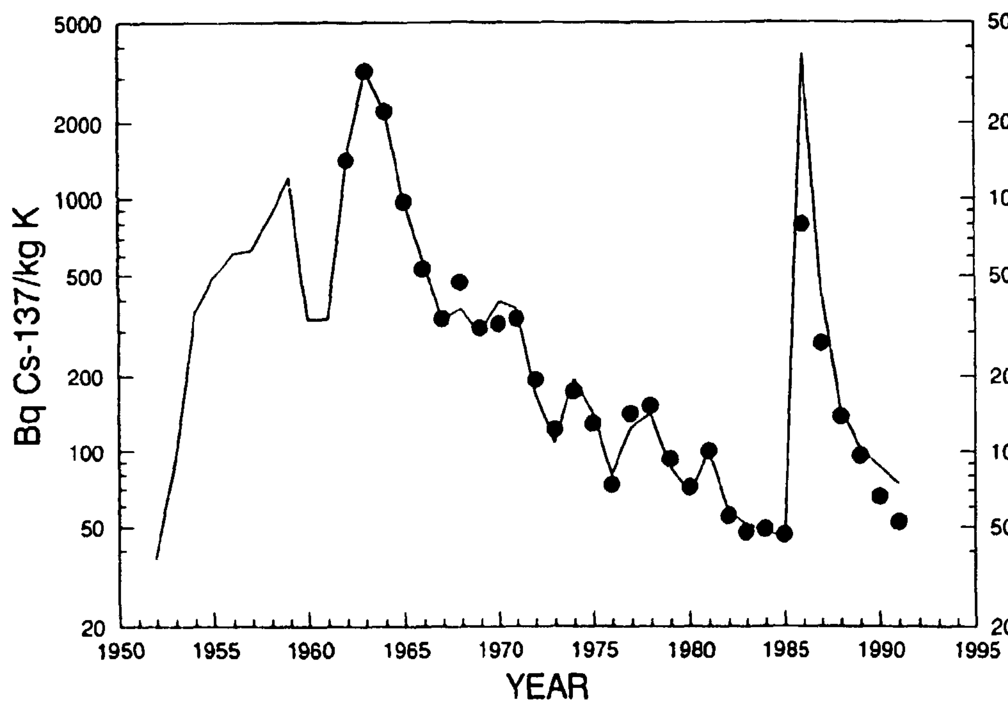


Table 5.1.3.B. Cesium-137 in Danish dried milk in 1991. (Unit: Bq ^{137}Cs $(kg\ K)^{-1}$)

Month	Hjørring	Randers	Videbæk	Åbenrå	Nyborg	Ringsted	Nakskov	Geometric mean	Arithmetic mean
Jan	67	74	91	63	26	40	26	50	55
Feb	42	57	161	63	24	26	21	44	56
March	46	60	106	59	29	23	25	43	50
April	42	68	129	62	37	30	14.3	45	55
May	55	79	84	66	39	17.0	20	44	51
June	53	65	101	70	28	28	21	45	52
July	66	59	120	121	29	27	15.3	49	62
Aug	79	61	160	83	54	26	16.9	55	68
Sep	77	63	126	40	45	18.8	20	46	56
Oct	59	59	113	76	49	21	16.9	47	56
Nov	40	56	98	72	40	29	13.4	42	50
Dec	53	64	93	94	32	15.8	7.6 B	38	51
1991: Geometric mean	55	63	113	70	35	24	17.4	46	
1991: Arithmetic mean	56	64	115	73	36	25	18.2		55

As 1 cubic meter of milk contains approx. 1.66 kg K, the mean ^{137}Cs content in Danish milk produced in 1991 was estimated at 92 Bq m^{-3} (or 0.092 Bq ^{137}Cs l^{-1}).

Table 5.1.4.A. Analysis of variance of ln Bq ^{137}Cs $(kg\ K)^{-1}$ in Danish dried milk in 1990 (from Table 5.1.3.A) (milk year May 1990 - April 1991)

Variation	SSD	f	s^2	v^2	P
Between months	1.758	11	0.160	3.634	> 99.95%
Between locations	29.988	6	4.998	113.670	> 99.95%
Remainder	2.902	66	0.044		

Table 5.1.4.B. Analysis of variance of ln Bq ^{137}Cs $(kg\ K)^{-1}$ in Danish dried milk in 1991 (from Table 5.1.3.B) (milk year May 1991 - April 1992)

Variation	SSD	f	s^2	v^2	P
Between months	1.256	11	0.114	1.888	-
Between locations	33.290	6	5.548	91.709	> 99.95%
Remainder	3.872	64	0.060		

Table 5.1.5.A. Radiocesium: $^{134}Cs/^{137}Cs$ in Danish dried milk in 1990

Month	Hjørring	Randers	Videbæk	Åbenrå	Nyborg	Ringsted	Nakskov	Mean ± 1 S.D.	Theoretical $^{134}Cs/^{137}Cs$
Jan		0.138	0.158	0.136	0.080			0.128±0.034	0.172
Feb		0.111	0.154	0.085	0.120			0.118±0.028	0.167
March	0.061	0.106	0.142	0.107	0.129			0.109±0.031	0.163
April	0.138	0.099	0.128	0.127	0.121			0.123±0.015	0.159
May		0.121	0.116	0.115				0.117±0.003	0.155
June	0.100	0.112	0.111	0.106	0.091	0.076		0.099±0.014	0.151
July		0.084	0.095	0.108				0.096±0.012	0.147
Aug	0.090	0.141	0.122	0.117		0.121		0.118±0.021	0.143
Sept		0.090	0.090	0.116	0.087			0.096±0.014	0.139
Oct		0.092	0.115	0.141	0.081			0.107±0.027	0.136
Nov		0.114	0.077		0.061			0.084±0.027	0.132
Dec									0.129

$\frac{\text{Observed } ^{134}Cs/^{137}Cs}{\text{Theoretical } ^{134}Cs/^{137}Cs}$ = 0.72±0.06 (1 S.D.; n = 11)

Table 5.1.5.B. Radiocesium: $^{134}Cs/^{137}Cs$ in Danish dried milk in 1991

Month	Randers	Videbæk	Åbenrå	Mean ± 1 S.D.	Theoretical $^{134}Cs/^{137}Cs$
Jan	0.110 A	0.141		0.126±0.022	0.126
Feb		0.090	0.095 A	0.092±0.004	0.122
March					0.119
April		0.103		0.103	0.116
May					0.113
June		0.117 A		0.117	0.110
July		0.086 A	0.083 A	0.084±0.002	0.107
Aug		0.078		0.078	0.105
Sept		0.073		0-073	0.102
Oct					0.099
Nov		0.067 A		0.067	0.097
Dec	0.122 A		0.091 A	0.106±0.022	0.094

$\frac{\text{Observed } ^{134}Cs/^{137}Cs}{\text{Theoretical } ^{134}Cs/^{137}Cs}$ = 0.86±0.16 (1 S.D.; n = 9)

Table 5.3.1.A. Strontium-90 in Danish grain in 1990. (Unit: Bq kg^{-1})

Location	Rye Winter	Barley		Wheat		Oats Spring	Triticale
		Spring	Winter	Winter	Spring		
Jutland	0.38	0.46	0.67	0.41	0.82	0.63	0.58*
The Islands	0.168	0.20	0.188	0.146	0.25	0.22	0.24**
1990: Geometric mean	0.25	0.30	0.36	0.25	0.45	0.37	0.38
1990: Arithmetic mean	0.28	0.33	0.43	0.28	0.54	0.42	0.41

*Collected at Borris.
**Collected at Kannikegård and Tystofte.

Table 5.3.1.B. Strontium-90 in Danish grain in 1991. (Unit: Bq kg^{-1})

Location	Rye Winter	Barley		Wheat		Oats Spring	Triticale
		Spring	Winter	Winter	Spring		
Jutland	0.32	0.39	0.33	0.25	0.45	0.55	0.174*
The Islands	0.169	0.31	0.27	0.150	0.33	0.30	0.24**
1991: Geometric mean	0.23	0.35	0.30	0.19	0.39	0.41	0.20
1991: Arithmetic mean	0.24	0.35	0.30	0.20	0.39	0.42	0.21

*Collected at Tylstrup.
**Collected at Kannikegård.

Table 5.3.2.A. Strontium-90 in Danish grain in 1990. (Unit: Bq (kg Ca)$^{-1}$)

Location	Rye Winter	Barley Spring	Barley Winter	Wheat Winter	Wheat Spring	Oats Spring	Triticale*
Jutland	1190	1170	1580	1410	2100	820	1560
The Islands	470	500	410	500	780	260	570
1990: Geometric mean	750	770	800	840	1260	460	940
1990: Arithmetic mean	830	830	990	960	1420	540	1060

*Cf. Table 5.3.1.A.

Table 5.3.2.B. Strontium-90 in Danish grain in 1991. (Unit: Bq (kg Ca)$^{-1}$)

Location	Rye Winter	Barley Spring	Barley Winter	Wheat Winter	Wheat Spring	Oats Spring	Triticale*
Jutland	960	1230	790	920	1420	770	750
The Islands	490	780	640	460	860	410	800
1991: Geometric mean	690	980	710	650	1110	560	770
1991: Arithmetic mean	720	1000	720	690	1140	590	780

*Cf. Table 5.3.1.B.

Table 5.3.3.A. Analysis of variance of ln Bq ^{90}Sr kg^{-1} in grain in 1990 (from Table 5.3.1.A)

Variation	SSD	f	s^2	v^2	P
Between species	0.156	3	0.052	5.435	-
Between locations	3.220	1	3.220	46.667	> 99.95%
Remainder + (spec. × loc.)	0.483	7	0.069		

Table 5.3.4.A. Analysis of variance of ln Bq ^{90}Sr $(kg\ Ca)^{-1}$ in grain in 1990 (from Table 5.3.2.A)

Variation	SSD	f	s^2	v^2	P
Between species	0.868	3	0.289	49.664	> 99.5%
Between locations	3.303	1	3.303	566.872	> 99.5%
Spec. × loc.	0.017	3	0.006	0.099	-
Remainder	0.236	4	0.059		

Table 5.3.3.B. Analysis of variance of ln Bq ^{90}Sr kg^{-1} in grain in 1991 (from Table 5 3.1.B)

Variation	SSD	f	s^2	v^2	P
Between species	0.383	3	0.128	4.556	-
Between locations	0.504	1	0.504	17.996	> 97.5%
Spec. × loc.	0.084	3	0.028	0.213	-
Remainder	0.526	4	0.132		

Table 5.3.4.B. Analysis of variance of ln Bq ^{90}Sr $(kg\ Ca)^{-1}$ in grain in 1991 (from Table 5.3.2.B)

Variation	SSD	f	s^2	v^2	P
Between species	0.288	3	0.096	4.808	-
Between locations	0.844	1	0.844	42.200	> 99%
Spec. × loc.	0.060	3	0.020	0.200	
Remainder	0.400	4	0.100		

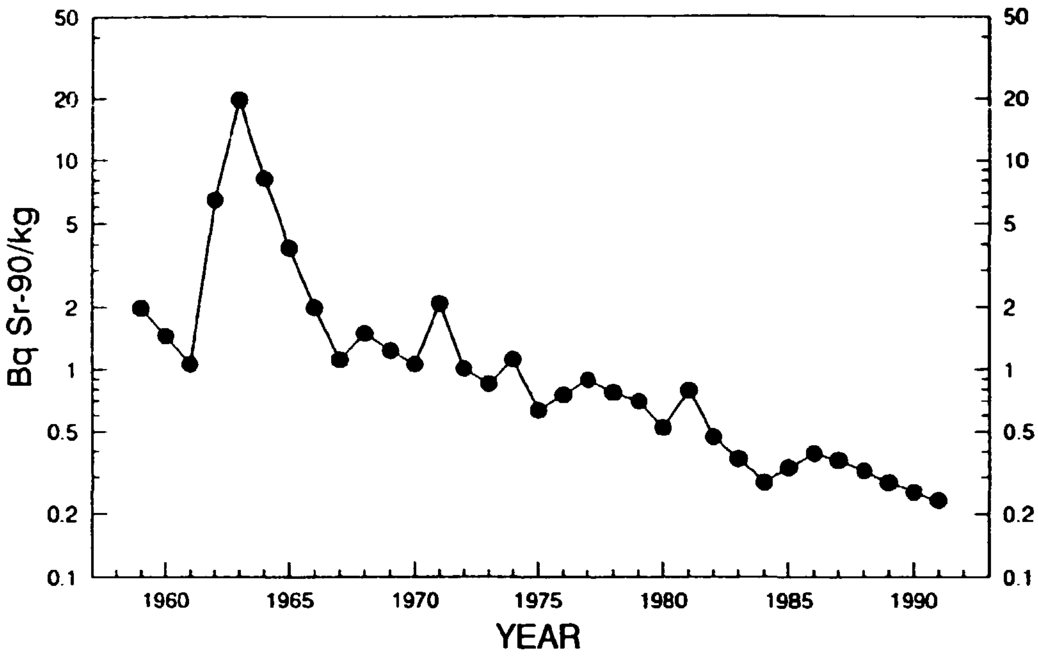
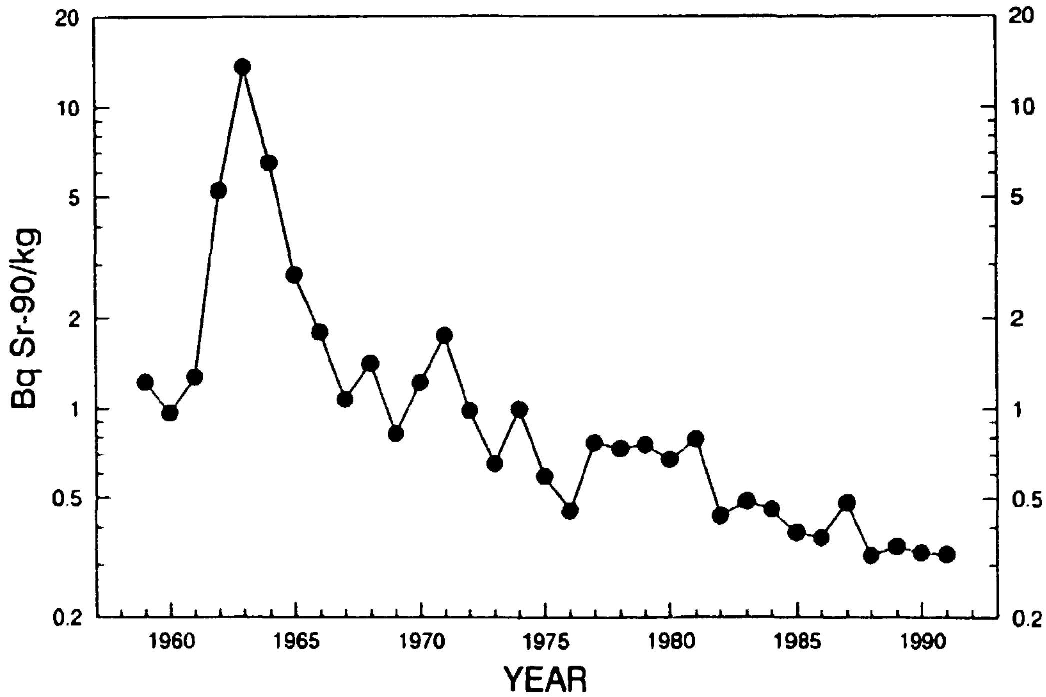


Figure 5.3.1. Strontium-90 in rye collected in Denmark in 1959-1991. (Geometric mean). (Unit: Bq kg^{-1}).

Figure 5.3.2. Strontium-90 in barley collected in Denmark in 1959-1991. (Geometric mean). (Unit: Bq kg^{-1}).



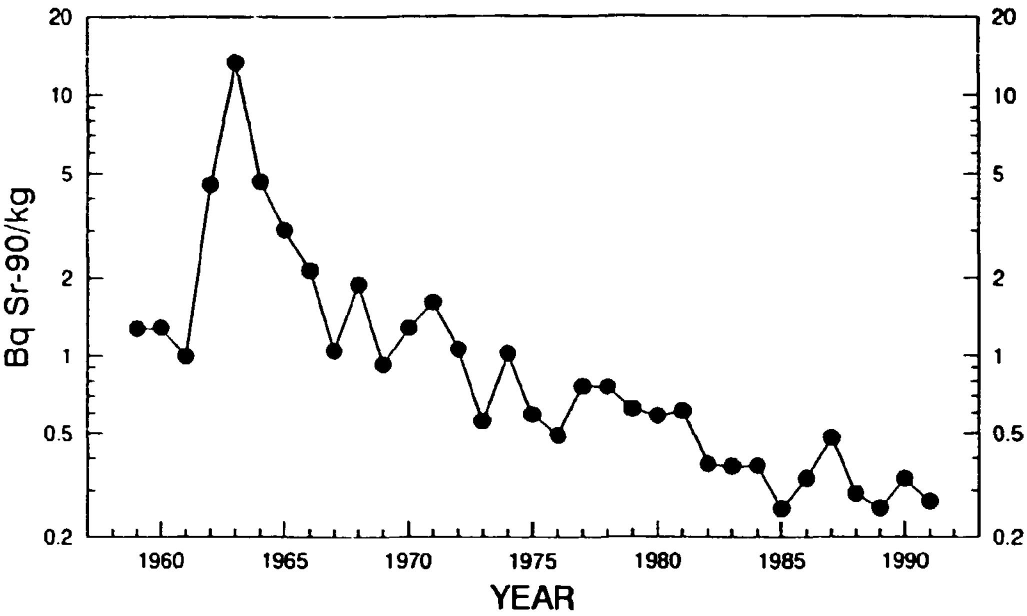


Figure 5.3.3. Strontium-90 in wheat collected in Denmark in 1959-1991. (Geometric mean). (Unit: Bq kg^{-1}).

Figure 5.3.4. Strontium-90 in oats collected in Denmark in 1959-1991. (Geometric mean). (Unit: Bq kg^{-1}).

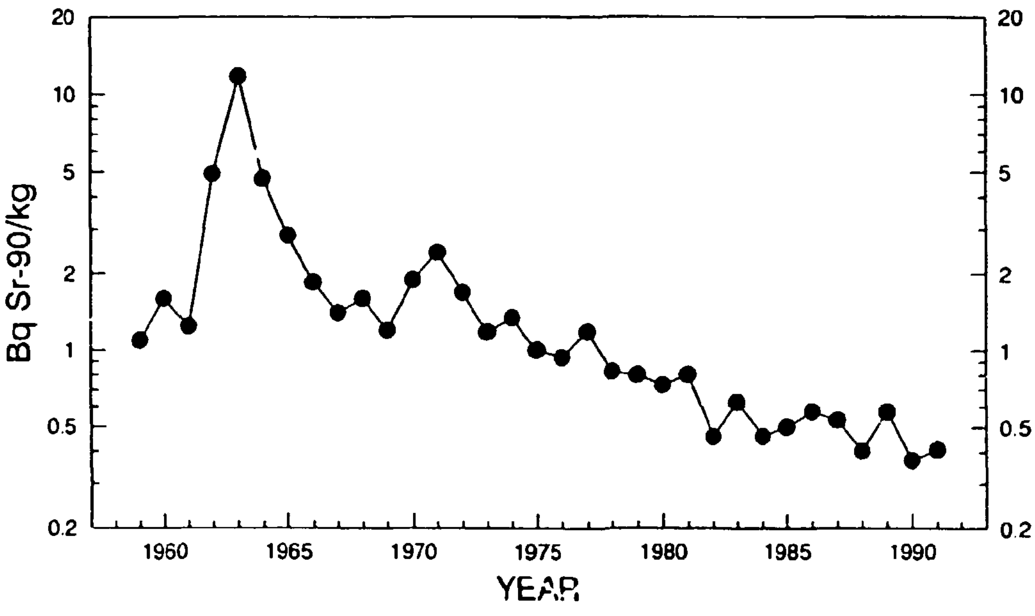


Table 5.3.5.A. Radiocesium in Danish grain in 1990. (Unit: Bq kg^{-1})

Location	Rye Winter	Barley Spring	Barley Winter	Wheat Winter	Wheat Spring	Oats Spring	Triticale
Jutland							
(- Askov)	0.194	0.102	0.073	0.139	0.23	0.26	0.197
Askov	1.020	0.26		0.33		0.124	
	(0.137)	(0.22)		(0.130)		(0.26)	
Årslev	0.32	0.055		0.016 B		0.091	
	(0.080 A)						
Zealand +							
Lolland-Falster	0.021 B	0.020 B	0.017 B	0.016 B	0.037 B	0.035 B	0.043 A
Kannikegård	0.020 B	0.021 B	0.023 A	0.017 A			0.021 A
1990: Geometric mean	0.117	0.055	0.032	0.052	0.092	0.126	
1990: Arithmetic mean	0.24	0.080	0.041	0.097	0.134	0.166	

In brackets the $^{134}Cs/^{137}Cs$ are shown.

Table 5.3.5.B. Cesium-137 in Danish grain in 1991. (Unit: Bq kg^{-1})

Location	Rye Winter	Barley Spring	Barley Winter	Wheat Winter	Wheat Spring	Oats Spring	Triticale
Jutland							
(- Askov)	0.148	0.077	0.060	0.068	0.112	0.35	0.195
Askov	0.191	0.24		0.077		0.34	
Årslev		0.51	0.122	0.048 A	0.033 A	0.153	
Zealand +							
Lolland-Falster	0.065	0.016 B	0.023 B	0.024 B	<0.025	0.035 B	
Kannikegård	0.026 A	0.028 A	0.012 B	0.013 B	0.024 A	0.068	0.037 B
1991: Geometric mean	0.100	0.059	0.039	0.041	<0.049	0.159	
1991: Arithmetic mean	0.117	0.113	0.049	0.048	<0.063	0.23	

Table 5.3.6.A. Cesium-137 in Danish grain in 1990. (Unit: Bq (kg K)$^{-1}$)

Location	Rye Winter	Barley Spring	Barley Winter	Wheat Winter	Wheat Spring	Oats Spring	Triticale
Jutland							
(- Askov)	42	21	16.8	31	72	71	38
Askov	230	62		95		36	
Årslev	69	10.1		4.5 B		28	
Zealand +							
Lolland-Falster	4.6 B	4.2 B	4.1 B	4.0 B	10.3 B	8.1 A	8.1 A
Kannikegård	4.1 B	5.0 B	7.4 A	5.2 A			4.5 A
1990: Geometric mean	25	11.6	8.1	12.9	27	34	
1990: Arithmetic mean	53	17.4	9.8	24	41	46	

Table 5.3.6.B. Cesium-137 in Danish grain in 1991. (Unit: Bq (kg K)$^{-1}$)

Location	Rye Winter	Barley Spring	Barley Winter	Wheat Winter	Wheat Spring	Oats Spring	Triticale
Jutland							
(- Askov)	35	17.0	13.7	17.0	28	81	43
Askov	44	52		20.0		80	
Årslev		115	29	12.2 A	8.7 A	40	
Zealand +							
Lolland-Falster	15.0	3.5 B	4.9 B	6.3 B	<6.2	7.9 B	
Kannikegård	6.2 A	6.2 A	2.7 B	3.0 B	5.9 A	15.3	7.8 B
1991: Geometric mean	23	13	8.8	10.4	<12.3	37	
1991: Arithmetic mean	28	25	11.2	12.2	<15.9	53	

Table 5.3.7.1.A. Grain samples obtained from Jutland - Askov in 1990.

Location	Rye Winter	Barley Spring	Barley Winter	Wheat Winter	Wheat Spring	Oats Spring	Triticale
Tylstrup	x	x	x	x		x	
Kalø	x	x		x		x	
Borris	x	x	x	x	x	x	x
St. Jyndevad	x	x		x		x	

Table 5.3.7.2.A. Grain samples obtained from the Islands - Kannikegård in 1990.

Location	Rye Winter	Barley Spring	Barley Winter	Wheat Winter	Wheat Spring	Oats Spring	Triticale
Tystofte	x	x		x	x	x	x
Ledreborg	x	x	x	x		x	
Abed		x	x	x			

Table 5.3.7.1.B. Grain samples obtained from Jutland - Askov in 1991.

Location	Rye Winter	Barley Spring	Barley Winter	Wheat Winter	Wheat Spring	Oats Spring	Triticale
Tylstrup	x	x	x	x	x	x	x
Kalø	x	x	x	x	x	x	
Borris	x	x	x	x	x	x	
St. Jyndevad	x	x	x	x		x	

Table 5.3.7.2.B. Grain samples obtained from the Islands - Kannikegård in 1991.

Location	Rye Winter	Barley Spring	Barley Winter	Wheat Winter	Wheat Spring	Oats Spring	Triticale
Tystofte	x	x	x	x	x	x	
Ledreborg	x	x	x	x	x	x	
Abed		x	x	x			

Table 5.3.7.A. Analysis of variance of ln Bq $^{137}Cs\ kg^{-1}$ in grain in 1990 (from Table 5.3.5.A)

Variation	SSD	f	s^2	v^2	P
Between species	2.306	3	0.769	1.385	-
Between locations	24.825	4	6.206	11.182	> 99.9%
Spec. × loc.	6.105	11	0.555	4.917	> 95%
Remainder	0.564	5	0.113		

Table 5.3.8.A. Analysis of variance of ln Bq $^{137}Cs\ (kg\ K)^{-1}$ in grain in 1990 (from Table 5.3.6.A)

Variation	SSD	f	s^2	v^2	P
Between species	1.843	3	0.614	1.085	-
Between locations	24.761	4	6.190	10.938	> 99.9%
Spec. × loc.	6.225	11	0.566	3.178	-
Remainder	0.891	5	0.178		

Table 5.3.7.B. Analysis of variance of ln Bq $^{137}Cs\ kg^{-1}$ in grain in 1991 (from Table 5.3.5.B)

Variation	SSD	f	s^2	v^2	P
Between species	4.876	3	1.625	4.154	> 95%
Between locations	16.876	4	4.219	10.782	> 99.9%
Spec. × loc.	4.304	11	0.391	[illegible]40	-
Remainder	1.902	7	0.272		

Table 5.3.8.B. Analysis of variance of ln Bq $^{137}Cs\ (kg\ K)^{-1}$ in grain in 1991 (from Table 5.3.6.B)

Variation	SSD	f	s^2	v^2	P
Between species	4.473	3	1.491	3.855	> 95%
Between locations	17.531	4	4.383	11.333	> 99.9%
Spec. × loc.	4.254	11	0.387	1.501	-
Remainder	1.803	7	0.258		

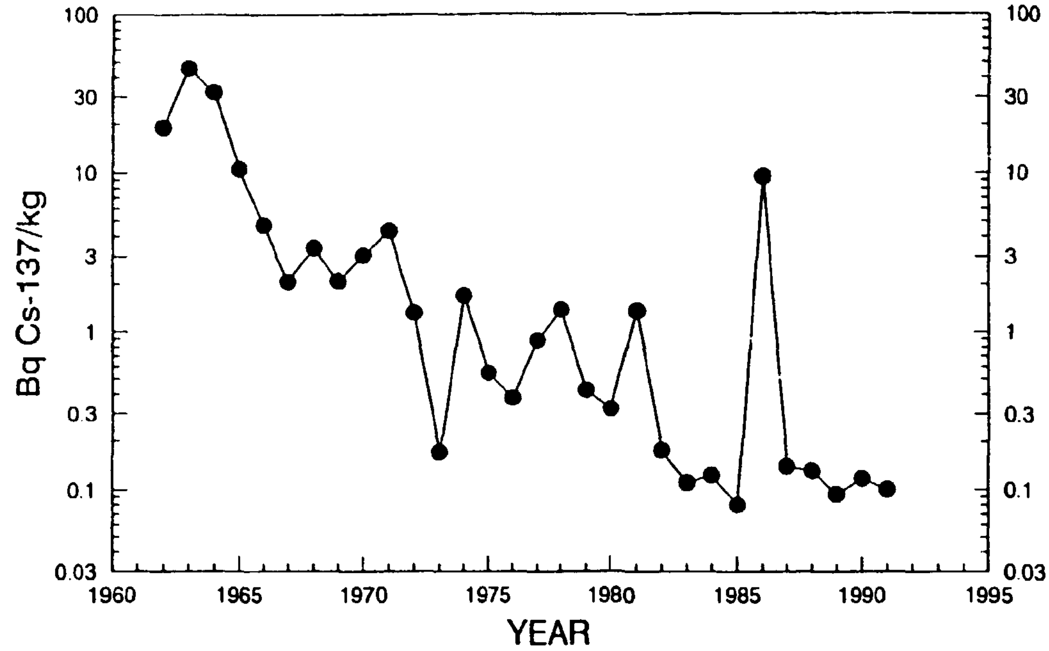
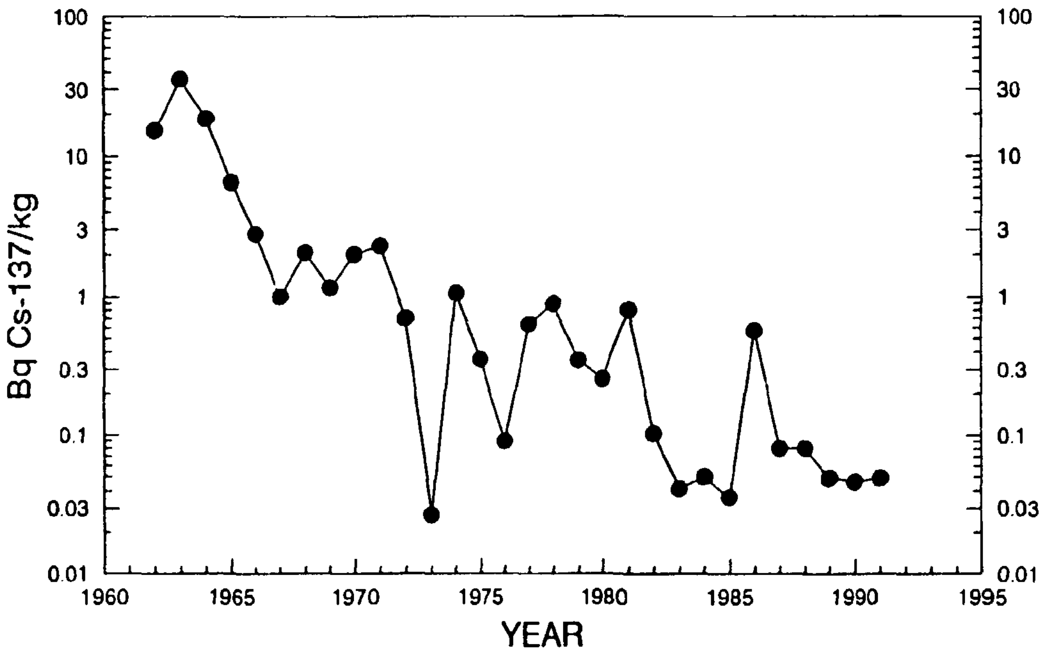


Figure 5.3.5. Cesium-137 in rye collected in Denmark in 1962-1991. (Geometric mean). (Unit: Bg kg^{-1}).

Figure 5.3.6. Cesium-137 in barley collected in Denmark in 1962-1991. (Geometric mean). (Unit: Bg kg^{-1}).



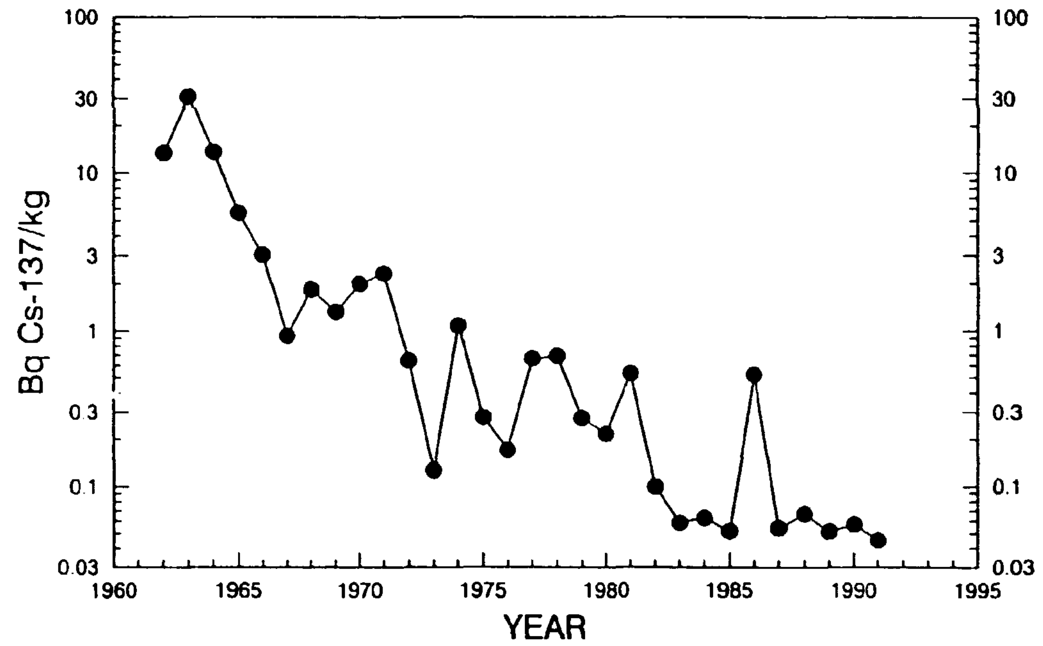
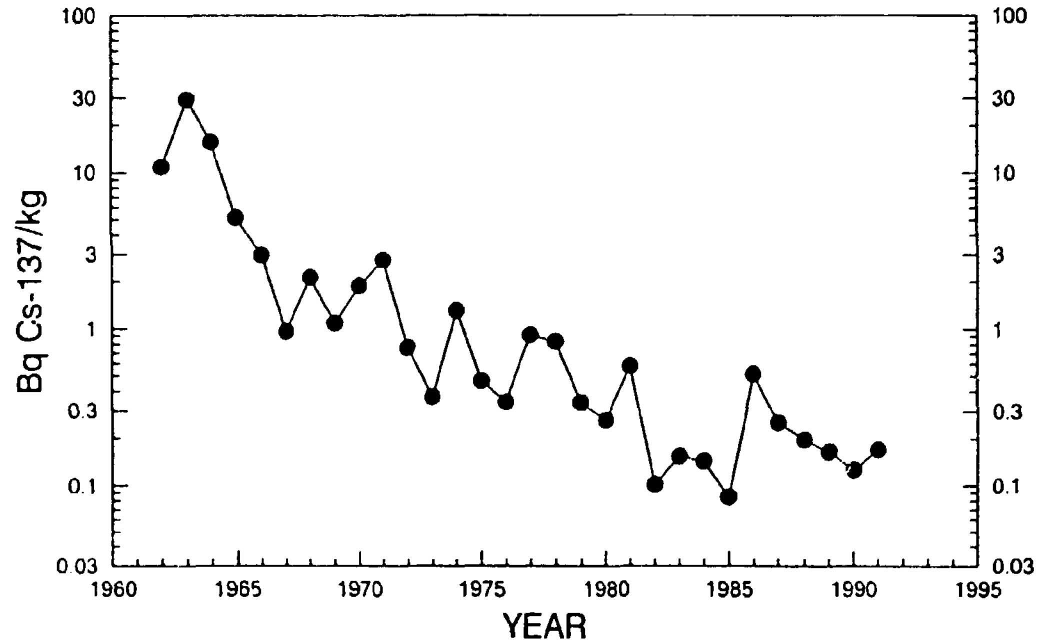


Figure 5.3.7. Cesium-137 in wheat collected in Denmark in 1962-1991. (Geometric mean). (Unit: Bg kg^{-1}).

Figure 5.3.8. Cesium-137 in oats collected in Denmark in 1962-1991. (Geometric mean). (Unit: Bg kg^{-1}).



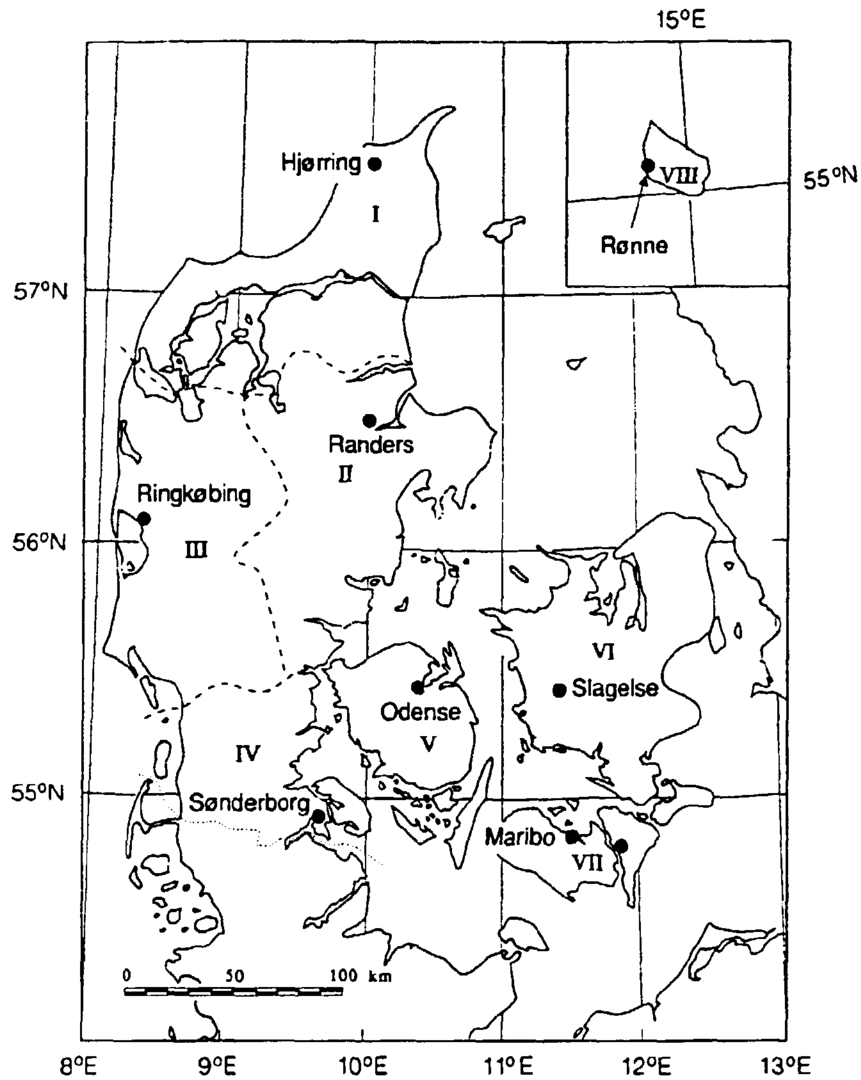


Figure 5.4. Sample locations for bread and total diet.

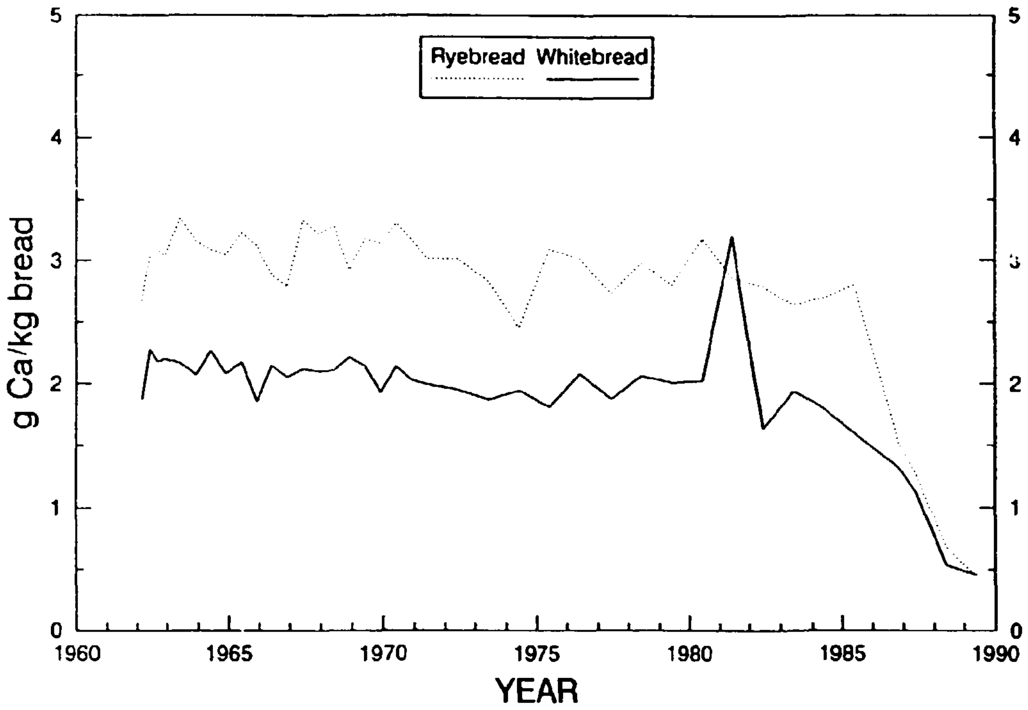


Figure 5.4.3. Calcium in Danish bread 1962-1989. (Unit: g Ca kg^{-1} bread).

Table 5.4.2.A. Radiocesium in Danish bread collected in June 1990

Location		Rye bread			White bread		
		Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs $(kg\,K)^{-1}$	$\frac{^{134}Cs}{^{137}Cs}$	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs $(kg\,K)^{-1}$	$\frac{^{134}Cs}{^{137}Cs}$
I	North Jutland	0.21	85	0.140 A	0.065	49	0.137 A
II	East Jutland	0.183	82	0.118 A	0.048	36	0.148 A
III	West Jutland	0.187	72	0.092 A	0.046	34	0.077 B
IV	South Jutland	0.58	189	0.127	0.059	51	0.038 B
V	Funen	0.110	43	0.21 A	0.027 A	21 A	-
VI	Zealand	0.054 A	22 A	-	0.026 A	22 A	-
VII	Lolland-Falster	0.051	22	-	0.023	19.7	-
VIII	Bornholm	0.037 B	9.1 B	-	0.033	25	-
1990: Geometric mean		0.121	45	0.132	0.038	30	0.088
1990: Arithmetic mean		0.176	66	0.137	0.041	32	0.100
Copenhagen		0.061 A	22 A	-	0.027 B	26	-
Population-weighted mean		0.141	55	-	0.038	31	-

Table 5.4.2.B. Radiocesium in Danish bread collected in June 1991

Location		Rye bread			White bread	
		Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs $(kg\,K)^{-1}$	$\frac{^{134}Cs}{^{137}Cs}$	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs $(kg\,K)^{-1}$
I	North Jutland	0.46	168	-	0.086	60
II	East Jutland	0.23	95	-	0.024 A	21 A
III	West Jutland	0.36	130	0.083 A	0.020 A	17.0 A
IV	South Jutland	0.73	300	0.040	0.052	45
V	Funen	0.091	36	-	0.042	35
VI	Zealand	0.25	91	-	0.0166 A	13.5 A
VII	Lolland-Falster	0.056	19.7	-	0.0152 A	12.8 A
VIII	Bornholm	0.120	33	-	0.022 B	17.4
1991: Geometric mean		0.21	78	-	0.029	24
1991 Arithmetic mean		0.29	109	-	0.035	28
Copenhagen		0.72	260	0.070	0.024 A	17.5
Population-weighted mean		0.41	153	-	0.031	24

Table 5.4.3.A. A comparison between ^{137}Cs levels in bread (June) and grain, 1990

Species	ᐞBread activity in June 1990 calculated as grain in Bq kg^{-1}	ᐞActivity in grain from harvest 1989 Bq kg^{-1}	"Bread"/grain ratio
Wheat	0.103	0.113	0.91
Rye	0.190	0.151	1.26

ᐞ (Risø Reports 1957-1991).

Table 5.4.3.B. A comparison between ^{137}Cs levels in bread (June) and grain, 1991

Species	ᐞBread activity in June 1991 calculated as grain in Bq kg^{-1}	ᐞActivity in grain from harvest 1990 Bq kg^{-1}	"Bread"/grain ratio
Wheat	0.084	0.116	0.72
Rye	0.55	0.24	2.3

ᐞ (Risø Reports 1957-1991).

Table 5.5.1.A. Strontium-90 in Danish potatoes in 1990

Location	Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr (kg Ca)$^{-1}$
Jutland	0.027	910
The Islands	0.038	780
1990: Geometric mean	0.032	840
1990: Arithmetic mean	0.033	850

Table 5.5.1.B. Strontium-90 in Danish potatoes in 1991

Location	Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr (kg Ca)$^{-1}$
Jutland	0.031±0.003	870±122
The Islands	0.027±0.001	600± 24
1991: Geometric mean	0.029	720
1991: Arithmetic mean	0.029	740

The error term is 1 S.E. of the mean of double determinations.

Table 5.5.2.A. Radiocesium in Danish potatoes in 1990

Location	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs (kg K)$^{-1}$	$\frac{^{134}Cs}{^{137}Cs}$
Jutland (-Askov)	0.054	13.8	
Askov	0.35	87	0.119
Årslev	0.25	61	0.120 A
Zealand + Lolland-Falster	< 0.025	< 5.2	
Bornholm	0.021 A	5.9	
1990: Geometric mean	< 0.055	< 13.2	
1990: Arithmetic mean	< 0.091	< 22	

Table 5.5.2.B. Radiocesium in Danish potatoes in 1991

Location	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs (kg K)$^{-1}$
Jutland (-Askov)	0.108	26
Askov	0.134	32
Årslev	0.086	19.1
Zealand + Lolland-Falster	0.035	8.4
Kannikegård	0.020 B	4.9 B
1991: Geometric mean	0.065	15.5
1991: Arithmetic mean	0.078	18.5

Table 5.6.1.A. Strontium-90 in vegetables and fruit collected in 1990

	Cabbage		Carrots		Beans		Apples		Strawberry	
Location	Bq kg^{-1}	Bq (kg Ca)$^{-1}$	Bq kg^{-1}	Bq (kg Ca)$^{-1}$	Bq kg^{-1}	Bq (kg Ca)$^{-1}$	Bq kg^{-1}	Bq (kg Ca)$^{-1}$	Bq kg^{-1}	Bq (kg Ca)$^{-1}$
Jutland	0.21	500	0.43	1490	0.39	700	0.034	670	0.157	1030
The Islands	0.111	250	0.22	670	0.20	410	0.0095	230	0.115	530
1990: Geometric mean	0.152	360	0.30	1000	0.28	540	0.0179	390	0.134	740
1990: Arithmetic mean	0.159	380	0.32	1080	0.30	560	0.022	450	0.136	780

Table 5.6.1.B. Strontium-90 in vegetables and fruit collected in 1991

	Cabbage		Carrots		Beans		Apples		Strawberry	
Location	Bq kg^{-1}	Bq (kg Ca)$^{-1}$	Bq kg^{-1}	Bq (kg Ca)$^{-1}$	Bq kg^{-1}	Bq (kg Ca)$^{-1}$	Bq kg^{-1}	Bq (kg Ca)$^{-1}$	Bq kg^{-1}	Bq (kg Ca)$^{-1}$
Jutland	0.22 ±0.00	420±	0.29±0.01	1080±17	0.33	700	0.0156±0.0005	370±13	0.167	940
The Islands	0.077±0.002	143±10	0.21±0.00	590± 9	0.187	360	0.0100±0.0002	250± 3	0.139	680
1991: Geometric mean	0.131	250	0.25	800	0.25	500	0.0125	307	0.152	800
1991: Arithmetic mean	0.149	280	0.25	830	0.26	530	0.0128	310	0.153	810

The error term is 1 S.E. of the mean of double determinations.

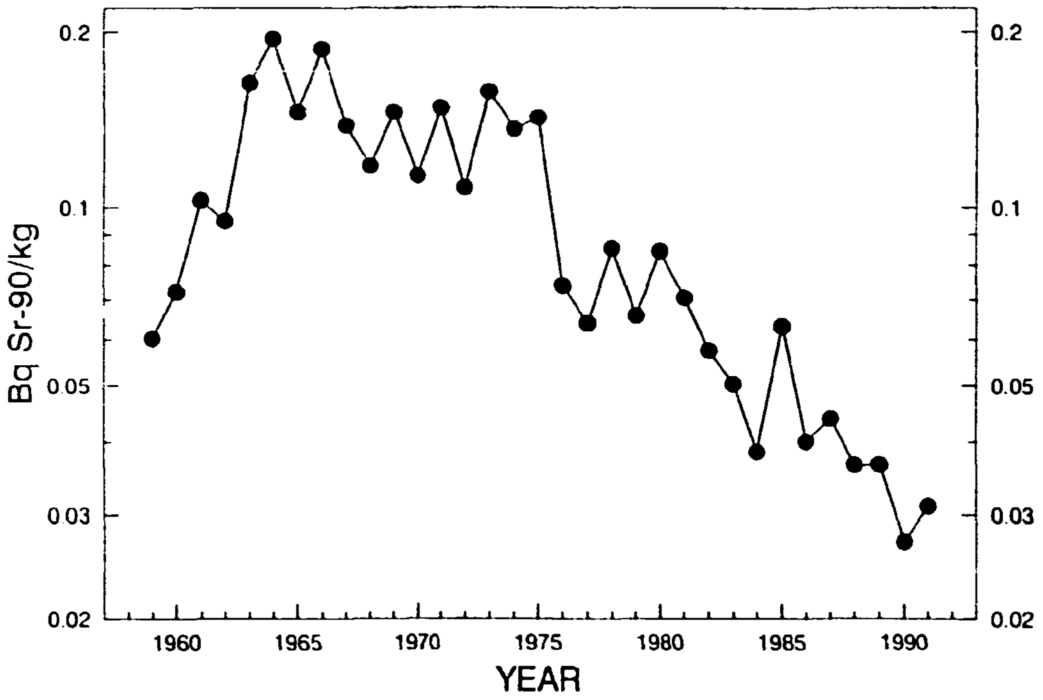
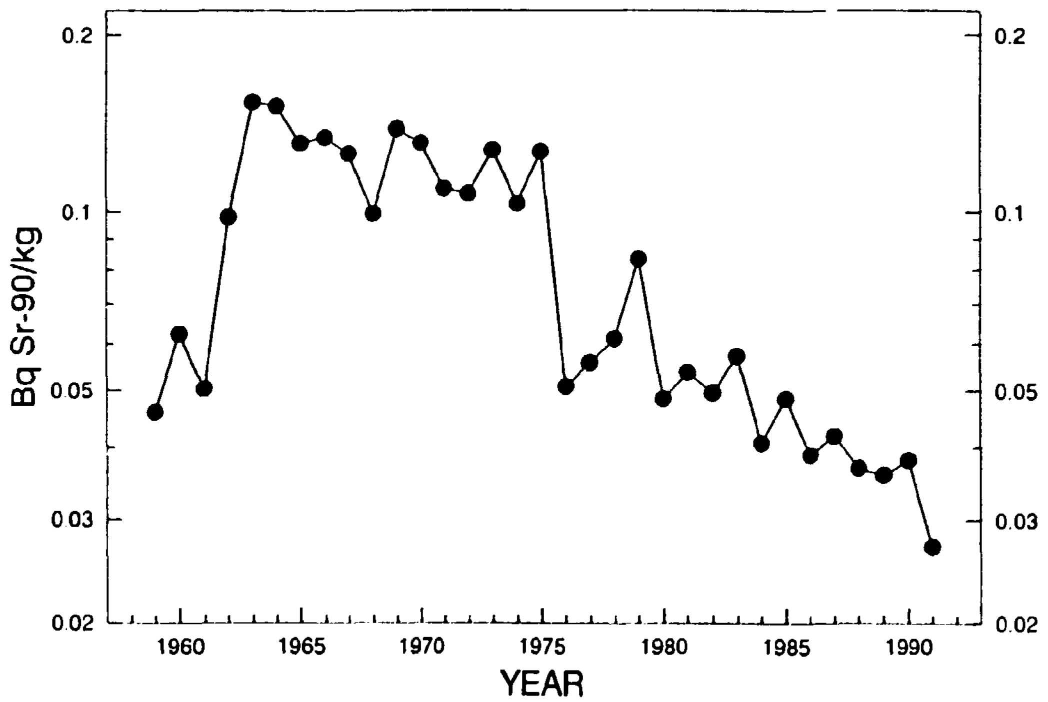


Figure 5.5.1. Strontium-90 in potatoes collected in Jutland in 1959-1991. (Unit: Bq kg^{-1}).

Figure 5.5.2. Strontium-90 in potatoes collected in the Islands in 1959-1991. (Unit: Bq kg^{-1}).



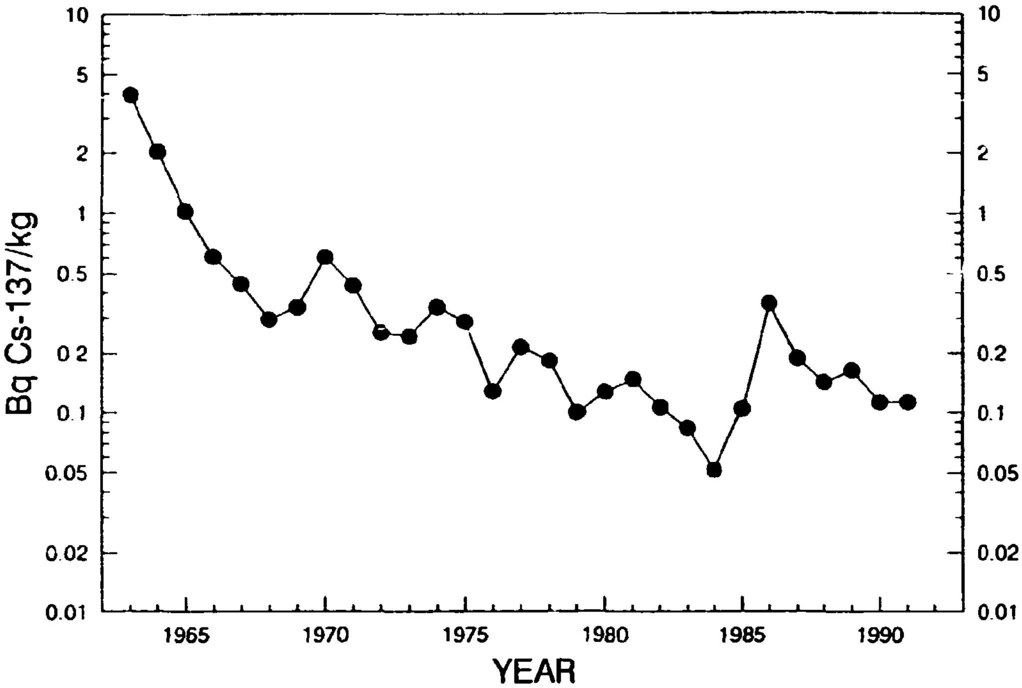


Figure 5.5.3. Cesium-137 in potatoes collected in Jutland in 1963-1991. (Unit: Bq kg^{-1}).

Figure 5.5.4. Cesium-137 in potatoes collected in the Islands in 1963-1991. (Unit: Bq kg^{-1}).

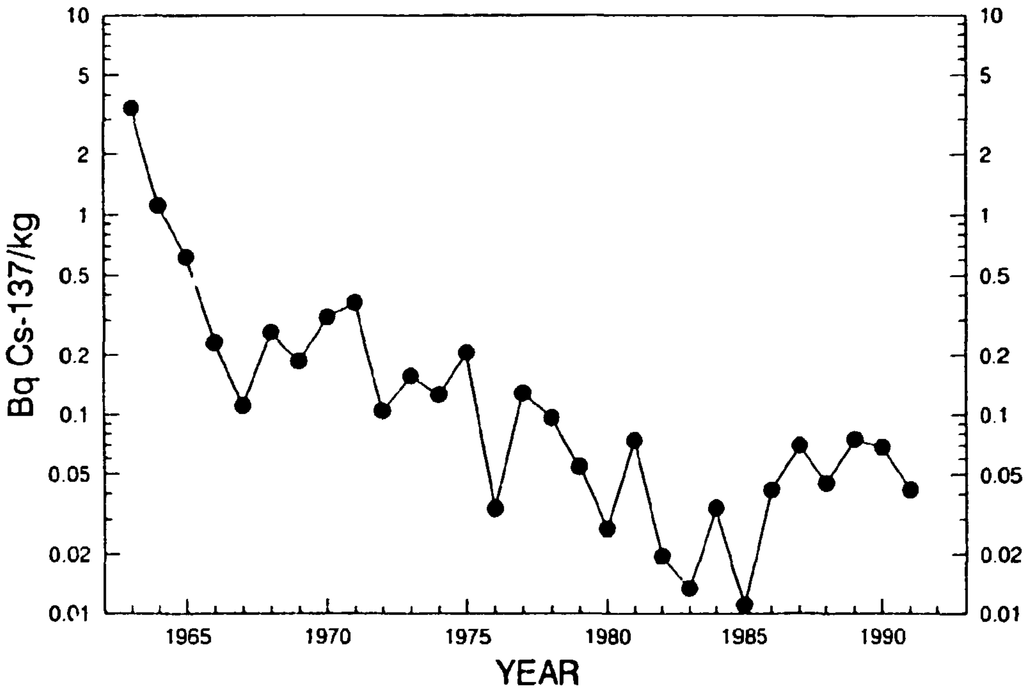


Table 5.6.2.A Radiocesium in vegetables and fruit collected in 1990

	Cabbage		Carrots		Beans*		Apples		Strawberry*	
Location	Bq kg^{-1}	Bq (kg K)$^{-1}$	Bq kg^{-1}	Bq (kg K)$^{-1}$	Bq kg^{-1}	Bq (kg K)$^{-1}$	Bq kg^{-1}	Bq (kg K)$^{-1}$	Bq kg^{-1}	Bq (kg K)$^{-1}$
Jutland	0.159 (0.083)	79	0.157 (0.078 A)	91	0.030	10.5	0.047 (0.164 A)	47	0.068 (0.124 A)	51
The Islands	0.025	10.9	0.018 A	8.2	0.011 A	5.1 A	0.030	26	0.0139	9.2
1990: Geometric mean	0.063	29	0.053	27	0.0185	7.3	0.037	35	0.031	22
1990: Arithmetic mean	0.092	45	0.087	49	0.021	7.8	0.038	36	0.041	30

*See also Table 5.6.2.C.
In brackets the $^{134}Cs/^{137}Cs$ are shown.

Table 5.6.2.B. Cesium-137 in vegetables and fruit collected in 1991

	Cabbage		Carrots		Beans		Apples		Strawberry	
Location	Bq kg^{-1}	Bq (kg K)$^{-1}$	Bq kg^{-1}	Bq (kg K)$^{-1}$	Bq kg^{-1}	Bq (kg K)$^{-1}$	Bq kg^{-1}	Bq (kg K)$^{-1}$	Bq kg^{-1}	Bq (kg K)$^{-1}$
Jutland	0.063	32	0.044	20	0.031	12.7	0.060	57	0.053	33
The Islands	0.053	25	0.024 A	7.4 A	0.011 A	6.0 A	0.028	25	0.0144	9.3
1991: Geometric mean	0.058	28	0.033	12.2	0.0165	8.7	0.041	38	0.028	17.5
1991: Arithmetic mean	0.058	29	0.034	13.7	0.021	9.4	0.044	41	0.034	21

Table 5.6.2.C. Radiocesium in beans and strawberry collected in 1990. (Measured before the ash was bulked in two locations)

		Beans		Strawberry	
Location		Bq kg^{-1}	Bq (kg K)$^{-1}$	Bq kg^{-1}	Bq (kg K)$^{-1}$
I	North Jutland	0.016 B	4.8 B	0.034	21
II	East Jutland	0.027	8.0	0.032	22
III	West Jutland	0.066	30	0.055	41
IV	South Jutland	0.021 B	6.7 B	0.27(0.144)	114
V	Funen	< 0.026	< 8.0	0.012 A	5.7
VI	Zealand	< 0.015	< 7.9	0.0167	11.3
VII	Lolland-Falster	0.016 A	10.0 A	0.0088 B	3.3 B
VIII	Bornholm	0.011 B	4.4 B	0.024	15.1
1990:	Geometric mean	< 0.021	< 8.2	0.030	17.0
1990:	Arithmetic mean	< 0.025	< 9.9	0.057	29

In brackets the $^{134}Cs/^{137}Cs$ is shown.

Table 5.6.3.A. Calculated ^{90}Sr and ^{137}Cs mean levels in vegetables in 1990

Daily intake in g		Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr (kg Ca)$^{-1}$	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs (kg K)$^{-1}$
50	leaf vegetables (cabbage)	0.159	380	0.092	45
30	root vegetables (carrot)	0.32	1080	0.087	49
40	beans	0.30	560	0.021	7.8
120 g		0.25	620	0.067	34

Table 5.6.3.B. Calculated ^{90}Sr and ^{137}Cs mean levels in vegetables in 1991

Daily intake in g		Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr (kg Ca)$^{-1}$	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs (kg K)$^{-1}$
50	leaf vegetables (cabbage)	0.149	280	0.058	29
30	root vegetables (carrot)	0.25	830	0.034	13.7
40	beans	0.26	530	0.021	9.4
120 g		0.21	500	0.040	18.6

Table 5.7.1.1. Strontium-90 in beef and pork collected in Denmark in June 1990 and June 1991

Year	Location	Species	Bq kg^{-1}	Bq (kg Ca)$^{-1}$
1990	Denmark	Beef	0.0074 A	100 A
1991	"	"	0.0069	81
1990	Copenhagen	Pork	0.002 B	24 B
1991	Denmark	"	0.0020 A	27 A

Table 5.7.1.2.A. Radiocesium in beef and pork collected countrywide in Denmark in June 1990

Zone		Beef: Bq ^{137}Cs kg^{-1}	Beef: Bq ^{137}Cs (kg K)$^{-1}$	Beef: ^{134}Cs/^{137}Cs	Pork: Bq ^{137}Cs kg^{-1}	Pork: Bq ^{137}Cs (kg K)$^{-1}$
I.	North Jutland	0.51	161	0.093		
II.	East Jutland	0.32	111	0.079 A		
III.	West Jutland	5.7	1920	0.115		
IV.	South Jutland	0.75	220	0.119		
V.	Funen	0.40	117	0.082 A		
VI.	Zealand	0.30	100	0.122 A		
VII.	Lolland-Falster	19.7	6000	0.154		
VIII.	Bornholm	0.58	182	0.152		
Geometric mean		0.99	320	0.111		
Arithmetic mean		3.5	1110	0.115		
Copenhagen		0.096	34	-	0.165	50
Population-weighted mean		1.51	490			

Table 5.7.1.2.B. Radiocesium in beef and pork collected countrywide in Denmark in June 1991

Zone		Beef: Bq ^{137}Cs kg^{-1}	Beef: Bq ^{137}Cs (kg K)$^{-1}$	Beef: ^{134}Cs/^{137}Cs	Pork: Bq ^{137}Cs kg^{-1}	Pork: Bq ^{137}Cs (kg K)$^{-1}$	Pork: ^{134}Cs/^{137}Cs
I.	North Jutland	0.25	85	-			
II.	East Jutland	0.96	350	0.087			
III.	West Jutland	0.61	160	0.084 A			
IV.	South Jutland	0.50	185	0.087 A			
V.	Funen	0.51	168	0.086 A			
VI.	Zealand	0.182	60	-			
VII.	Lolland-Falster	0.156	52	-			
VIII.	Bornholm	0.32	114	0.112			
Geometric mean		0.37	123	0.090			
Arithmetic mean		0.44	147	0.091	0.49	156	0.033 A
Copenhagen		0.80	220	0.058 A			
Population-weighted mean		0.59	185				

Table 5.7.2.1.A. Strontium-90 in fish (flesh) collected in Danish waters in 1990 (samples were obtained from Hundested (Cattegat), Ringkøbing (North Sea), and Bornholm (Baltic Sea)) (Cf. Table 5.7.2.2.A)

Species	Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr $(kg\,Ca)^{-1}$
Cod	0.0192	22
Plaice	0.0132	21
Herring	0.0051	8.0
1990: Geometric mean	0.0109	15.4
1990: Arithmetic mean	0.0125	17.0

Table 5.7.2.1.B. Strontium-90 in fish (flesh) collected in Danish waters in 1991 (samples were obtained from Hundested (Cattegat), Ringkøbing (North Sea), and Bornholm (Baltic Sea)) (Cf. Table 5.7.2.2.B)

Species	Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr $(kg\,Ca)^{-1}$
Cod	0.0093	19
Plaice	0.0199	27
Herring	0.0047	8.3
1991: Geometric mean	0.0095	16.1
1991: Arithmetic mean	0.0113	18.0

Table 5.7.2.2.A. Radiocesium and Polonium-210 in fish (flesh) from Danish waters in 1990

Location	Month	Species	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs $(kg\ K)^{-1}$	$\frac{^{134}Cs}{^{137}Cs}$	Bq ^{210}Po kg^{-1}	(n)
Hundested	Feb	Cod	6.0	2000	0.148	-	
(Cattegat)	Feb	Plaice	2.3	780	0.132	-	
- " -	Feb	Herring	1.62	390	0.097	-	
- " -	Oct	Cod	11.9	3400	0.128	0.095±0.020	(3)
- " -	Oct	Plaice	0.68	290	0.067 A	0.27 ±0.016	(3)
- " -	Oct	Herring	1.28	390	0.104	0.62 ±0.098	(3)
1990: Geometric mean			2.5	790		0.25	
1990: Arithmetic mean			4.1	1220		0.33	
Ringkøbing	March	Cod	1.16	400	0.053 A	-	
(North Sea)	March	Plaice	1.28	480	0.038 A	-	
- " -	March	Herring	1.56	610	0.131	-	
- " -	Sept	Cod	0.99	290	-	0.085±0.012	(3)
- " -	Sept	Plaice	0.41	154	-	0.38 ±0.034	(3)
- " -	Sept	Herring	7.6	2700	0.134	0.37 ±0.049	(2)
1990: Geometric mean			1.39	490		0.23	
1990: Arithmetic mean			2.2	770		0.28	
Bornholm	Jan	Cod	14.0	3800	0.162		
(Baltic Sea)	Jan	Plaice	11.3	3800	0.165		
- " -	Jan	Herring	10.6	2600	0.161		
- " -	Sept	Cod	16.7	5000	0.135		
- " -	Sept	Plaice	7.5	2500	0.127		
- " -	Sept	Herring	7.1	2100	0.131		
1990: Geometric mean			10.7	3200			
1990: Arithmetic mean			11.2	3300			
Roskilde Fjord	May	Garpike	2.4	650	0.062		
Ringkøbing	November	Plaice	-	-	-	0.053	(1)
1990: Total Geometric mean			3.3	1040		0.19	
1990: Total Arithmetic mean			5.6	1710		0.27	

The error term is 1 S.E. of the mean.

Table 5.7.2.2.B. Radiocesium and Polonium in fish (flesh) from Danish waters in 1991

Location	Month	Species	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs (kg K)$^{-1}$	^{134}Cs / ^{137}Cs	Bq ^{210}Po kg^{-1}	(n)
Hundested	March	Cod	20	5500	0.119	-	
(Cattegat)	March	Plaice	0.56	250	-	0.54	(1)
-"-	March	Herring	1.48	560	0.096	0.24	(1)
1991: Geometric mean			2.6	910		0.36	
1991: Arithmetic mean			7.4	2100		0.39	
Ringkøbing	March	Cod	1.41	420	-	0.175±0.007	(2)
(North Sea)	March	Plaice	0.68	290	-	0.25 ±0.066	(2)
-"-	March	Herring	1.51	510	0.091	0.27 ±0.002	(2)
1991: Geometric mean			1.13	400		0.23	
1991: Arithmetic mean			1.20	410		0.23	
Bornholm	March	Cod	19.6	5300	0.117	0.22 ±0.011	(4)
(Baltic Sea)	March	Plaice	13.0	4300	0.113	0.43 ±0.141	(3)
-"-	June	Herring	11.3	3700	0.110	1.64 ±0.086	(2)
1991: Geometric mean			14.2	4400		0.54	
1991: Arithmetic mean			14.6	4400		0.76	
Hundested	April	Garpike	1.11	470	0.047 A	-	
Bornholm	March	Herring	-	-	-	0.23	(1)
1991: Total Geometric mean			3.1	1070		0.34	
1991: Total Arithmetic mean			7.1	2100		0.44	

The error term is 1 S.E. of the mean.

Table 5.7.2.4. Polonium-210 in shrimps and Mytilus edulis flesh collected in Ringkøbing and Hundested in 1990

Species	Location	Date	Bq ^{210}Po kg^{-1}	(n)
Shrimps	Hundested	6 September	4.3±0.99	(2)
Mytilus edulis	- " -	6 September	17.6±0.45	(2)
Shrimps	Ringkøbing	22 October	3.1±0.47	(3)

The error term is 1 S.E. of the mean.

Table 5.7.3. Strontium-90 and radiocesium in eggs collected in Denmark in 1991

Year	Month	Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr (kg Ca)$^{-1}$	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs (kg K)$^{-1}$
1991	June	0.0109	21	0.030	23

Table 5.7.4. Strontium-90 and radiocesium in various imported vegetable food purchased in Copenhagen in November 1990

Sample	Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr (kg Ca)$^{-1}$	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs (kg K)$^{-1}$	^{134}Cs / ^{137}Cs
Rize	0.0153	18.5	0.009 B	7.8 B	-
Oats	0.38	550	1.46	[illegible]	0.075
Hazel nuts	3.6	2200	0.60	96	0.106
Bananas	0.002 B	41 B	0.041 B	13 B	-
Orange	0.048	137	0.017 A	14 A	-
Coffee	0.23	380	0.30 A	18 A	-
Tea	0.[illegible]2	1980	0.73	58	0.037 B

Table 5.8.1.A. Strontium-90 in Danish total diet collected in June 1990

Location	Bq (kg Ca)$^{-1}$	Bq day^{-1} cap^{-1}	g Ca day^{-1} cap^{-1}
Jutland	121	0.133	1.10
The Islands	117	0.124	1.06
Geometric mean	119	0.128	1.08
Arithmetic mean	119	0.128	1.08
Copenhagen	83	0.096	1.16
Population-weighted mean	110	0.121	1.11

Table 5.8.1.B. Strontium-90 in Danish total diet collected in June 1991

Location	Bq (kg Ca)$^{-1}$	Bq day^{-1} cap^{-1}	g Ca day^{-1} cap^{-1}
Jutland	123	0.128	1.05
The Islands	116	0.127	1.10
Geometric mean	120	0.128	1.07
Arithmetic mean	120	0.128	1.08
Copenhagen	102	0.118	1.16
Population-weighted mean	116	0.126	1.10

Table 5.8.2.A. Strontium-90 in Danish total diet collected in December 1990

Location	Bq (kg Ca)$^{-1}$	Bq day^{-1} cap^{-1}	g Ca day^{-1} cap^{-1}
Jutland	140	0.145	1.04
The Islands	95	0.108	1.14
Geometric mean	115	0.125	1.09
Arithmetic mean	118	0.126	1.09
Copenhagen	99	0.133	1.35
Population-weighted mean	117	0.132	1.16

Table 5.8.2.B. Strontium-90 in Danish total diet collected in December 1991

Location	Bq (kg Ca)$^{-1}$	Bq day^{-1} cap^{-1}	g Ca day^{-1} cap^{-1}
Jutland	149	0.159	1.07
The Islands	116	0.133	1.15
Geometric mean	131	0.145	1.11
Arithmetic mean	133	0.146	1.11
Copenhagen	110	0.124	1.13
Population-weighted mean	130	0.143	1.11

Table 5.8.3.A. Radiocesium in Danish total diet collected in June 1990

Location	Bq ^{137}Cs (kg K)$^{-1}$	Bq ^{137}Cs day^{-1} cap^{-1}	g K day^{-1} cap^{-1}	$\frac{^{134}Cs}{^{137}Cs}$
Jutland	105	0.37	3.5	0.102
The Islands	128	0.44	3.5	0.113
Geometric mean	116	0.40	3.5	0.107
Arithmetic mean	117	0.41	3.5	0.108
Copenhagen	49	0.161	3.3	-
Population-weighted mean	97	0.33	3.5	-

Table 5.8.3.B. Cesium-137 in Danish total diet collected in June 1991

Location	Bq ^{137}Cs (kg K)$^{-1}$	Bq ^{137}Cs day^{-1} cap^{-1}	g K day^{-1} cap^{-1}
Jutland	67	0.23	3.4
The Islands	45	0.161	3.5
Geometric mean	55	0.192	3.4
Arithmetic mean	56	0.196	3.5
Copenhagen	87	0.32	3.7
Population-weighted mean	66	0.24	3.5

Table 5.8.4.A. Radiocesium in Danish total diet collected in December 1990

Location	Bq ^{137}Cs (kg K)$^{-1}$	Bq ^{137}Cs day^{-1} cap^{-1}	g K day^{-1} cap^{-1}
Jutland	85	0.29	3.4
The Islands	75	0.26	3.6
Geometric mean	80	0.27	3.5
Arithmetic mean	80	0.28	3.5
Copenhagen	51	0.184	3.6
Population-weighted mean	73	0.25	3.5

Table 5.8.4.B. Cesium-137 in Danish total diet collected in December 1991

Location	Bq ^{137}Cs (kg K)$^{-1}$	Bq ^{137}Cs day^{-1} cap^{-1}	g K day^{-1} cap^{-1}
Jutland	68	0.25	3.7
The Islands	73	0.27	3.8
Geometric mean	70	0.26	3.7
Arithmetic mean	71	0.26	3.8
Copenhagen	37	0.137	3.7
Population-weighted mean	61	0.23	3.7

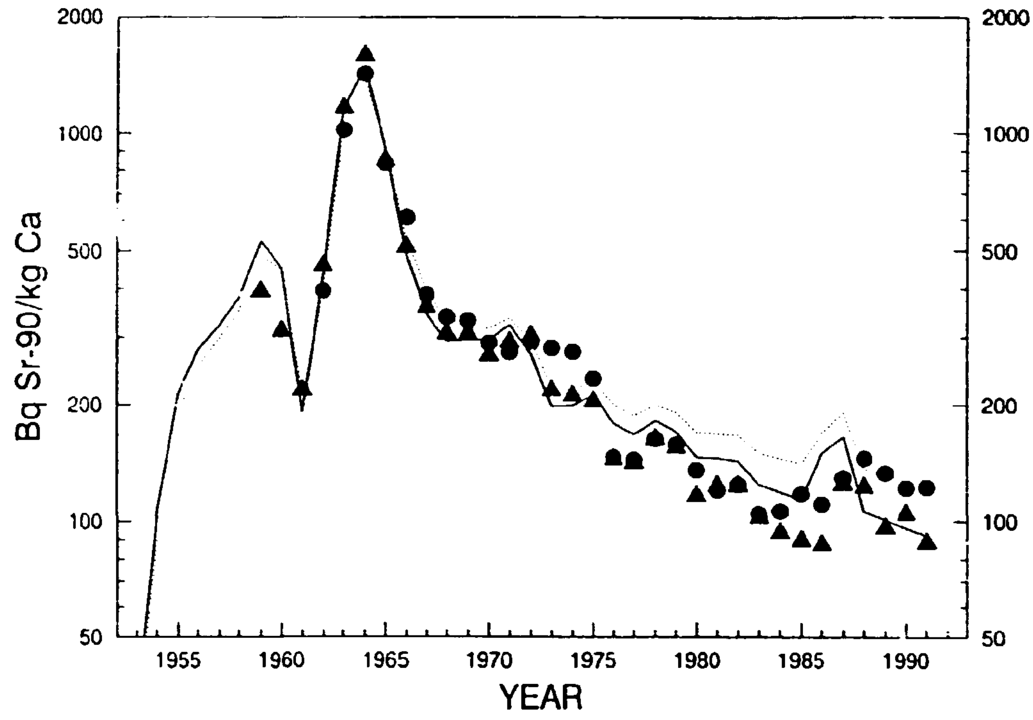


Figure 5.8.1. Predicted and observed ^{90}Sr levels in the Danish total diet. The dotted curve represents the predicted values for »Diet C« (cf. Tables 5.8.1 and 5.8.2) and the circles are the corresponding observed values. The unbroken curve represents the predicted values for »Diet P« (cf. Table 5.9.3), and the triangles the corresponding observed values.

Fig. 5.8.2. Calcium in Danish average diet 1962-1991. (Unit: g Ca day^{-1}).

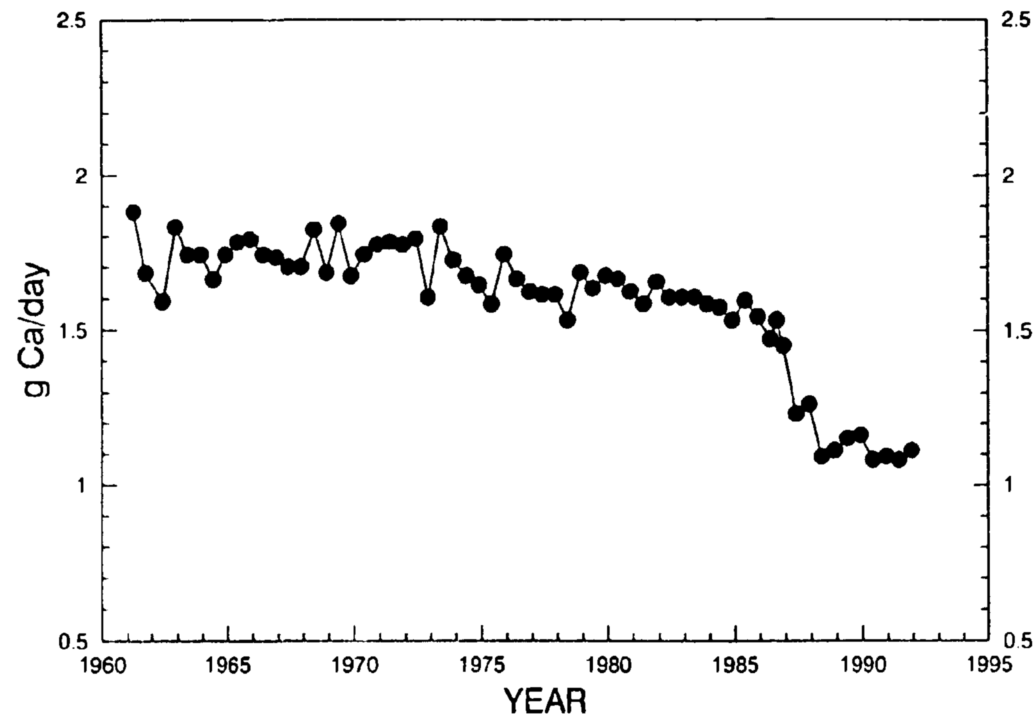


Table 5.9.1.A Estimate of the ^{90}Sr content in grain products consumed pro capite in 1990

Type	Fraction from harvest 1989			Fraction from harvest 1990			Total
	kg flour	Bq kg^{-1}	Bq	kg flour	Bq kg^{-1}	Bq	Bq
Rye flour 100% extraction	21.9	0.30	6.57	7.3	0.28	2.04	8.61
Wheat flour 75% extraction	32.9	0.072	2.37	10.9	0.082	0.89	3.26
Grits	5.5	0.23	1.27	1.8	0.168	0.30	1.57
Total	60.3	0.169	10.20	20.0	0.162	3.24	13.44

The Sr-90 content in wheat flour (75% extraction) was calculated from the levels in wheat grain by division by 5 (Risø Report No. 23). The Sr-90 content in grits was calculated as approx. 40% of the level found in oats.

Table 5.9.1.B. Estimate of the ^{90}Sr content in grain products consumed pro capite in 1991. (Cf. notes to Table 5.9.1.A).

Type	Fraction from harvest 1990			Fraction from harvest 1991			Total
	kg flour	Bq kg^{-1}	Bq	kg flour	Bq kg^{-1}	Bq	Bq
Rye flour 100% extraction	21.9	0.28	6.13	7.3	0.24	1.75	7.88
Wheat flour 75% extraction	32.9	0.082	2.70	10.9	0.059	0.64	3.34
Grits	5.5	0.168	0.92	1.8	0.168	0.30	1.22
Total	60.3	0.162	9.75	20.0	0.135	2.70	12.44

Table 5.9.2.A. Estimate of the ^{137}Cs content in grain products consumed pro capite in 1990

Type	Fraction from harvest 1989			Fraction from harvest 1990			Total
	kg flour	Bq kg^{-1}	Bq	kg flour	Bq kg^{-1}	Bq	Bq
Rye flour 100% extraction	21.9	0.151	3.31	7.3	0.24	1.75	5.06
Wheat flour 75% extraction	32.9	0.056	1.84	10.9	0.058	0.63	2.47
Grits	5.5	0.20	1.10	1.8	0.125	0.23	1.33
Total	60.3	0.104	6.25	20.0	0.130	2.61	8.86

The Cs-137 level in wheat flour (75% extraction) was found to be approx. 50% of the level in wheat grain. The Cs-137 content in grits was calculated as 75% of the level found in oats.

Table 5.9.2.B. Estimate of the ^{137}Cs content in grain products consumed pro capite in 1991. (Cf. notes to Table 5.9.2.A).

Type	Fraction from harvest 1990			Fraction from harvest 1991			Total
	kg flour	Bq kg^{-1}	Bq	kg flour	Bq kg^{-1}	Bq	Bq
Rye flour 100% extraction	21.9	0.24	5.26	7.3	0.117	0.85	6.11
Wheat flour 75% extraction	32.9	0.058	1.91	10.9	0.028	0.31	2.21
Grits	5.5	0.125	0.69	1.8	0.173	0.31	1.00
Total	60.3	0.130	7.85	20.0	0.074	1.47	9.32

Table 5.9.3.A. Estimate of the mean content of ^{90}Sr in the human diet in 1990

Type of food	Annual quantity in kg	Bq ^{90}Sr per kg	Total Bq ^{90}Sr	Percentage of total Bq ^{90}Sr in food	References
Milk and cream	164.0	0.049	8.04	18.9	(Table 5.1.1.A)
*Cheese	9.1	0.35	3.19	7.5	
Grain products	80.3	0.167	13.44	31.6	(Table 5.9.1.A)
Potatoes	73.0	0.033	2.41	5.6	(Table 5.5.1.A)
Vegetables	43.8	0.26	11.39	26.8	(Table 5.6.3.A)
Fruit	51.1	0.039	1.99	4.7	1)
Meat	54.7	0.0038	0.21	0.5	2)
**Eggs	10.9	0.0109	0.12	0.3	(Table 5.7.3)
Fish	10.9	0.0125	0.14	0.3	(Table 5.7.2.1.A)
Coffee and tea	5.5	0.26	1.43	3.4	3)
***Drinking water	548	0.33×10^{-3}	0.18	0.4	(Table 4.3.3.1.A)
Total			42.54		

The mean Ca intake was estimated at 0.41 kg y^{-1} (approx. 0.1 kg creta praeparata). Hence the $^{90}Sr/Ca$ ratio in total diet was 104 Bq ^{90}Sr (kg Ca)$^{-1}$ in 1990.

*Calculated from milk. **No collections in 1990, 1991 data used. ***No collections in 1990, 1989 data used.

Table 5.9.4.A. Estimate of the mean content of ^{137}Cs in the human diet in 1990

Type of food	Annual quantity in kg	Bq ^{137}Cs per kg	Total Bq ^{137}Cs	Percentage of total Bq ^{137}Cs in food	References
Milk and cream	164.0	0.125	20.50	11.5	(Table 5.1.3.A)
*Cheese	9.1	0.088	0.80	0.5	
Grain products	80.3	0.110	8.86	5.0	(Table 5.9.2.A)
Potatoes	73.0	0.09	6.64	3.7	(Table 5.5.1.A)
Vegetables	43.8	0.067	2.93	1.7	(Table 5.6.3.A)
Fruit	51.1	0.036	1.84	1.0	1)
Meat	54.7	1.28	70.02	39.4	2)
**Eggs	10.9	0.030	0.33	0.2	(Table 5.7.3)
Fish	10.9	5.8	63.22	35.6	(Table 5.7.2.2.A)
Coffee and tea	5.5	0.44	2.42	1.4	3)
***Drinking water	548	0.105×10^{-3}	0.06	0.0	(Table 4.3.3.1.A)
Total			177.62		

As the approximate intake of potassium was 1.365 kg y^{-1} the $^{137}Cs/K$ ratios were 130 Bq ^{137}Cs (kg K)$^{-1}$ in 1990.

*Calculated from milk. **No collections in 1990, 1991 data used. ***No collections in 1990, 1989 data used.

Notes to Tables 5.9.3 and 5.9.4.

1) Calculated from apples in Tables 5.6.1.B and 5.6.2.B and from banana and orange in Table 5.7.4 with the relative weighting factors 0.714, 0.143, 0.143, respectively.

2) Calculated from the mean of the June and December sampling for ^{137}Cs in beef (Tables 5.7.1.2.B and 5.7.1.3.B) and from Table 5.7.1.4.B (^{137}Cs in pork). Table 5.7.1.1 gives ^{90}Sr data for beef and pork. In the calculation beef is weighted by 0.33 and pork by 0.67.

3) One third of the total consumption consists of tea and two-thirds of coffee. The data from Table 5.7.4. are used for the calculation.

Arithmetic means are used all through.

Table 5.9.3.B. Estimate of the mean content of ^{90}Sr in the human diet in 1991 (cf. notes to A tables)

Type of food	Annual quantity in kg	Bq ^{90}Sr per kg	Total Bq ^{90}Sr	Percentage of total Bq ^{90}Sr in food
Milk and cream	164.0	0.046	7.54	19.5
*Cheese	9.1	0.33	3.00	7.8
Grain products	80.3	0.155	12.44	32.2
Potatoes	73.0	0.029	2.12	5.5
Vegetables	43.8	0.22	9.64	25.0
Fruit	51.1	0.036	1.84	4.7
Meat	54.7	0.0036	0.20	0.5
Eggs	10.9	0.0109	0.12	0.3
Fish	10.9	0.0113	0.12	0.3
Coffee and tea	5.5	0.26	1.43	3.7
**Drinking water	548	0.33×10^{-3}	0.18	0.5
Total			38.63	

The mean Ca intake was estimated at 0.44 kg y^{-1} (approx. 0.1 kg creta praeparata). Hence the $^{90}Sr/Ca$ ratio in total diet was 88 Bq ^{90}Sr (kg Ca)$^{-1}$ in 1991.

*Calculated from milk. **No collections ir, 1991, 1989 data used.

Table 5.9.4.B. Estimate of the mean content of ^{137}Cs in the human diet in 1991 (cf. notes to A tables)

Type of food	Annual quantity in kg	Bq ^{137}Cs per kg	Total Bq ^{137}Cs	Percentage of total Bq ^{137}Cs in food
Milk and cream	164.0	0.092	15.09	10.3
*Cheese	9.1	0.064	0.58	0.4
Grain products	80.3	0.116	9.32	6.4
Potatoes	73.0	0.078	5.69	3.9
Vegetables	43.8	0.038	1.66	1.1
Fruit	51.1	0.038	1.94	1.3
Meat	54.7	0.47	25.71	17.5
Eggs	10.9	0.030	0.33	0.2
Fish	10.9	7.7	83.93	57.2
Coffee and tea	5.5	0.44	2.42	1.7
**Drinking water	548	0.105×10^{-3}	0.06	0.0
Total			146.73	

As the approximate intake of potassium was 1.3[illegible] kg y^{-1} the $^{137}Cs/K$ ratios were 107 Bq ^{137}Cs (kg K)$^{-1}$ in 1991.

*Calculated from milk. **No collections in 1991, 1989 data used.

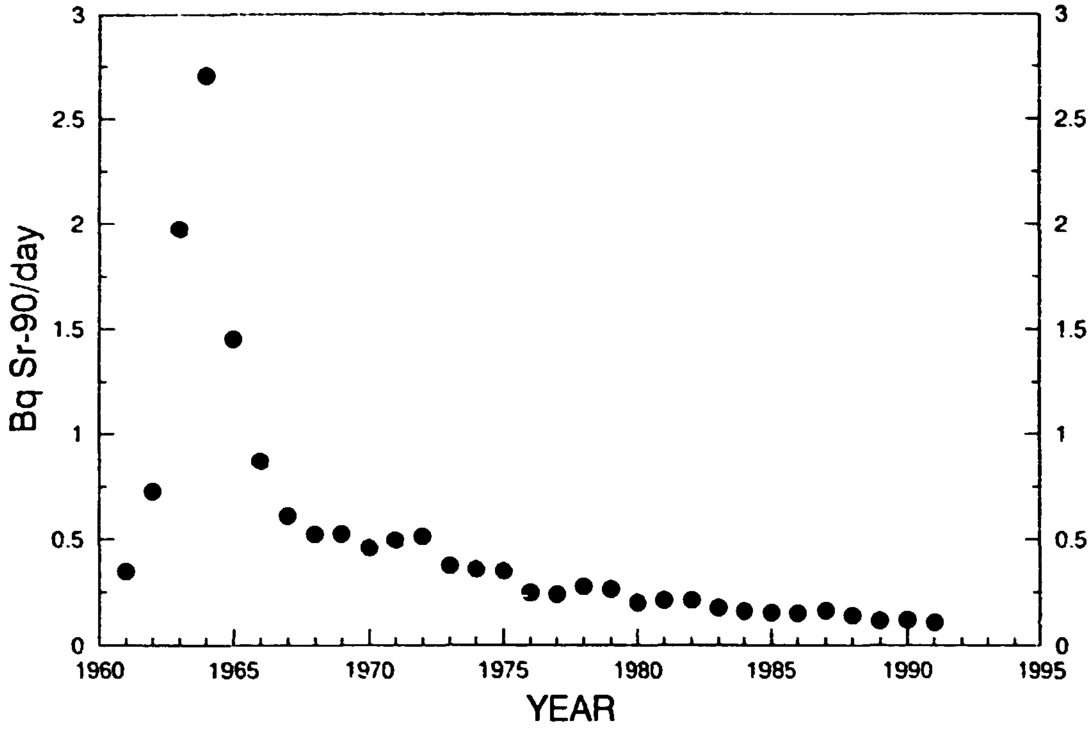


Figure 5.9.3. Strontium-90 in Danish diet, 1961-1991. (Unit: Bq day^{-1}). (Production data).

Figure 5.9.4. Cesium-137 in Danish diet, 1962-1991. (Unit: Bq day^{-1}). (Production data).

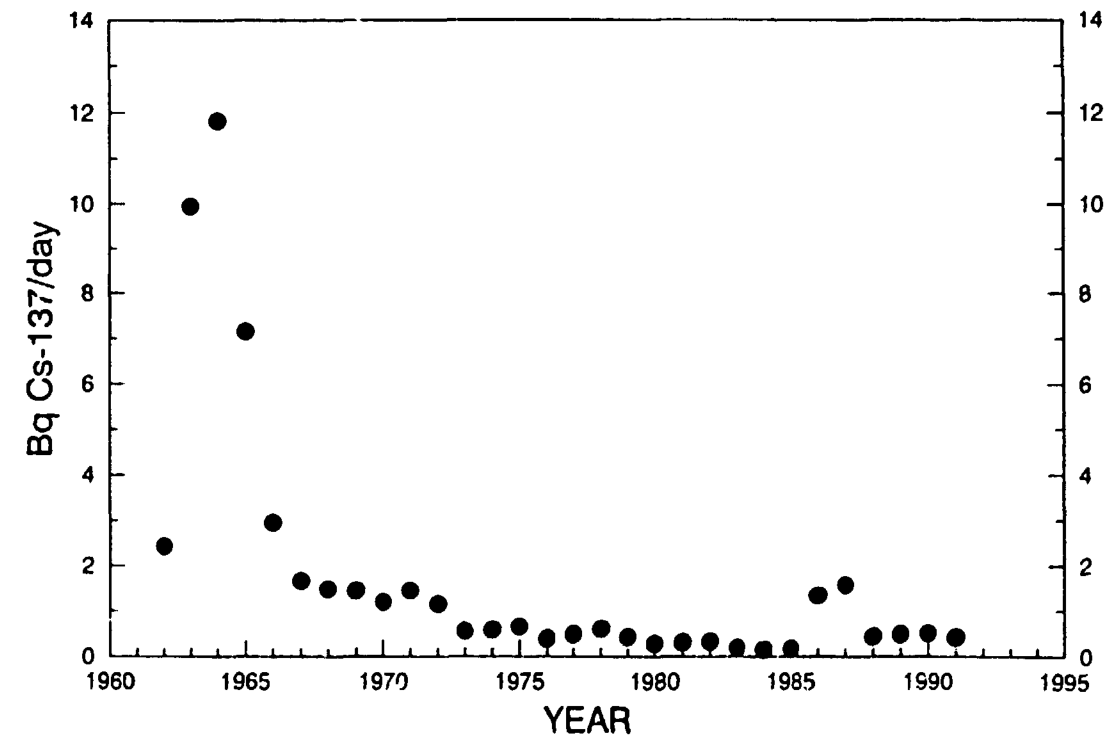


Table 5.10.1.1.A. Strontium-90 in grass collected at Risø weekly in 1990

Periods	Bq ^{90}Sr (kg ash)$^{-1}$	Bq ^{90}Sr (kg Ca)$^{-1}$	Bq ^{90}Sr m^{-2}
Jan-March	10.5	220	0.101
April-June	15.3	260	0.170
July-Sept	16.0	199	0.22
Oct-Dec	16.3	250	0.199
1990: Geometric mean	14.3	230	0.166
1990: Arithmetic mean	14.5	230	0.173

Table 5.10.1.1.B. Strontium-90 in grass collected at Risø weekly in 1991

Periods	Bq ^{90}Sr (kg ash)$^{-1}$	Bq ^{90}Sr (kg Ca)$^{-1}$	Bq ^{90}Sr m^{-2}
Jan-March	12.3	220	0.125
April-June	17.8	310	0.175
July-Sept	17.3	240	0.192
Oct-Dec	16.5	230	0.194
1991: Geometric mean	15.8	250	0.169
1991: Arithmetic mean	16.0	250	0.172

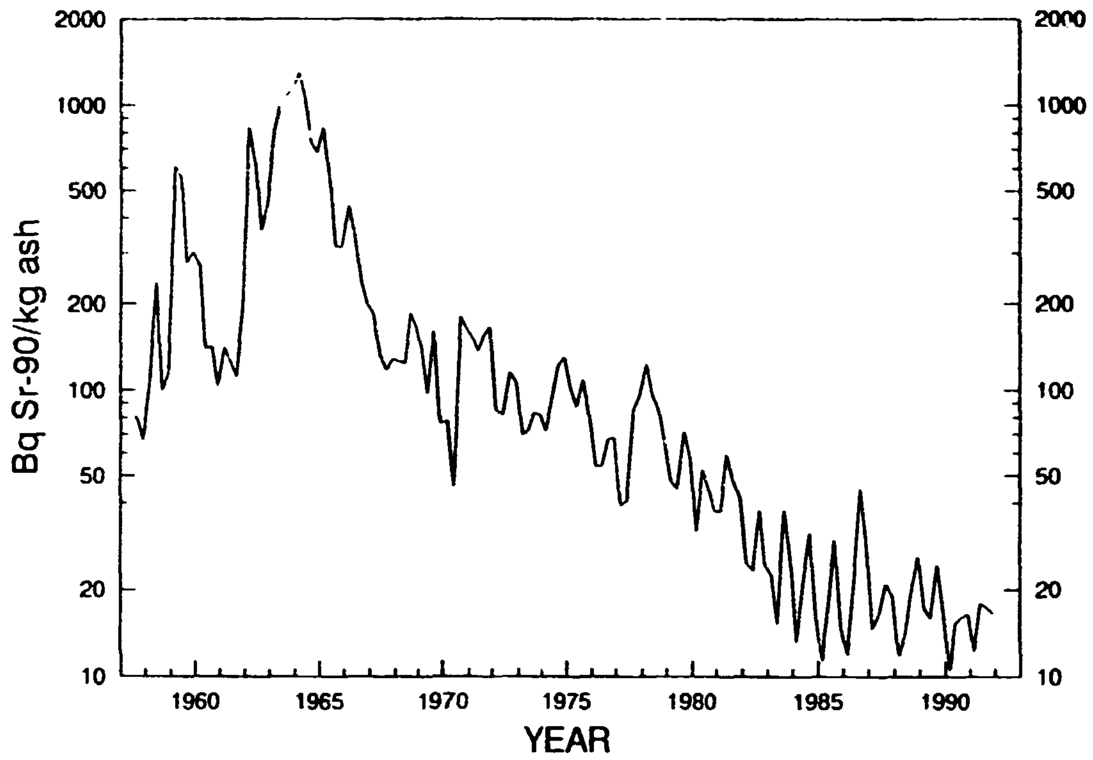


Figure 5.10.1. Quarterly ^{90}Sr levels in grass, 1957-1991. (Unit: Bq (kg ash)$^{-1}$).

Figure 5.10.2. Cesium-137 in grass samples collected at Risø, Denmark in the period April 1986 - December 1991. (Unit: Bq kg^{-1} fresh weight).

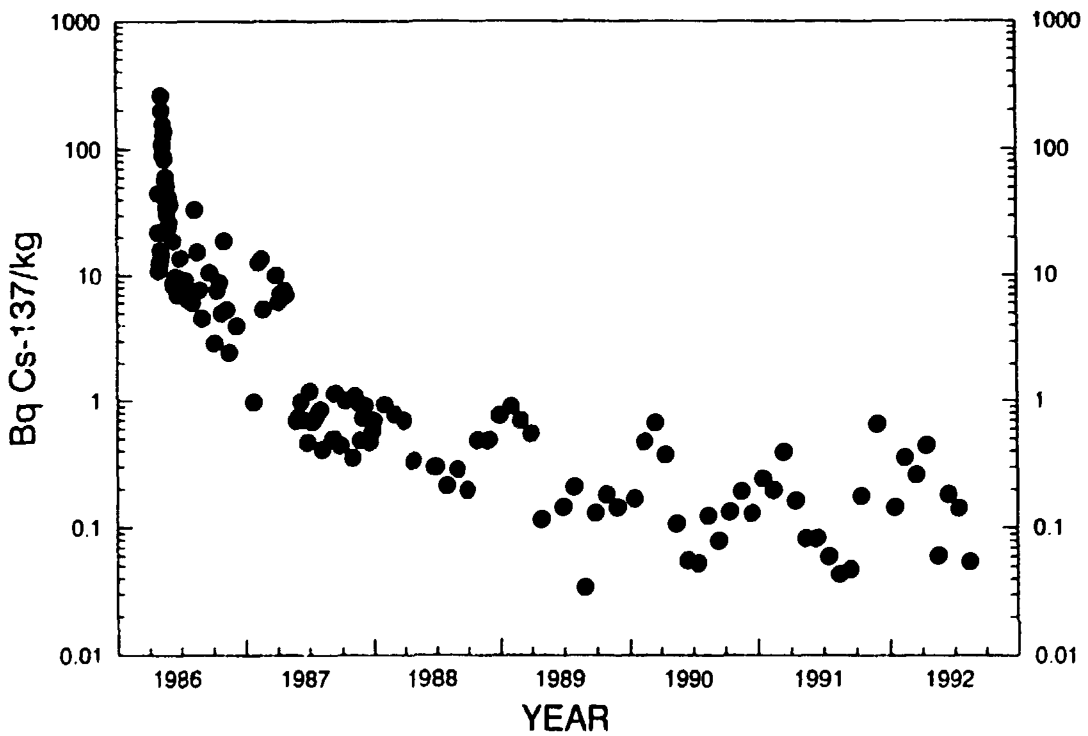


Table 5.10.1.2.A. Radiocesium in grass collected at Risø weekly in 1990

Month	Bq ^{137}Cs kg^{-1} fresh weight	Bq ^{137}Cs m^{-2}	g K kg^{-1} fresh weight	^{134}Cs/^{137}Cs
Jan	0.168	0.044	1.86	-
Feb	0.47	0.071	2.57	0.27 A
March	0.66	0.125	2.37	0.14 A
April	0.37	0.086	5.16	0.17
May	0.107	0.049	4.92	0.45
June	0.055	0.033	5.75	-
July	0.052 A	0.026 B	7.47	-
Aug	0.124 A	0.054 A	8.22	-
Sept	0.078 B	0.034 B	4.96	-
Oct	0.132	0.063	4.77	0.33 A
Nov	0.189	0.086	2.72	0.07 A
Dec	0.128	0.042	2.49	-
1990: Geometric mean	0.154	0.054	4.0	
1990: Arithmetic mean	0.21	0.059	4.4	

Table 5.10.1.2.B. Radiocesium in grass collected at Risø weekly in 1991

Month	Bq ^{137}Cs kg^{-1} fresh weight	Bq ^{137}Cs m^{-2}	g K kg^{-1} fresh weight	^{134}Cs/^{137}Cs
Jan	0.24	0.084	4.16	-
Feb	0.195	0.044	1.79	-
March	0.39	0.058	2.71	-
April	0.161	0.044	5.36	-
May	0.082 A	0.035 A	6.30	-
June	0.082 A	0.053 A	5.56	-
July	0.059 B	0.027 B	5.55	-
Aug	0.043 A	0.0161 A	5.72	-
Sept	0.047 A	0.022 A	5.57	-
Oct	0.176	0.067	5.14	-
Nov, Dec	0.65	0.28	4.71	0.129
1991: Geometric mean	0.154	0.056	4.5	
1991: Arithmetic mean	0.23	0.084	4.8	

Table 5.10.2.A. Radiocesium in grass collected at the state experimental farms in June 1990 (fresh weight samples)

Location	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs m^{-2}	^{134}Cs / ^{137}Cs	g K kg^{-1}
Tylstrup	0.123	0.063	-	6.4
Kalø	0.174	0.081	0.161 A	5.2
Borris	0.20	0.141	0.088 A	4.5
Askov	0.83	0.47	0.123	4.7
St. Jyndevad	0.34	0.23	0.079 A	5.1
Årslev	0.164	0.073	-	6.1
Tystofte	0.063	0.044	0.29 A	7.2
Ledreborg	0.094	0.138	0.22 A	4.0
Abed	0.031 B	0.026 B	-	8.9
Tornbygård	0.028 A	0.025 A	-	6.1
1990: Geometric mean	0.126	0.086	0.144	5.7
S.D. factor	2.83	2.55	1.67	1.27
1990: Arithmetic mean	0.20	0.129	0.160	5.8
S.D.	0.24	0.135	0.082	1.46
N	10	10	6	10

Table 5.10.2.B. Cesium-137 in grass collected at the state experimental farms in June 1991 (fresh weight samples)

Location	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs m^{-2}	g K kg^{-1}
Tylstrup	0.109	0.071	4.6
Kalø	0.083	0.059	5.0
Borris	0.20	0.169	4.4
Askov	0.25	0.[illegible]1	6.3
St. Jyndevad	0.26	0.173	5.6
Årslev	0.150	0.149	4.7
Tystofte	0.036	0.038	6.8
Ledreborg	0.121	0.062	5.9
Abed	0.073	0.045	6.6
Tornbygård	0.086 A	0.046 A	6.9
1991: Geometric mean	0.118	0.083	5.6
S.D. factor	1.84	1.87	1.19
1991: Arithmetic mean	0.137	0.099	5.7
S.D.	0.076	0.060	0.96
N	10	10	10

Table 5.10.3.A. Strontium-90 in grass collected at the state experimental farms in June 1990 (fresh weight samples)

Location	Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr m^{-2}	Bq ^{90}Sr $(kg\ Ca)^{-1}$
Jutland	0.83	0.48	710
The Islands	0.31	0.27	270
1990: Geometric mean	0.51	0.36	440
1990: Arithmetic mean	0.57	0.38	490

Table 5.10.3.B. Strontium-90 in grass collected at the state experimental farms in June 1991 (fresh weight samples)

Location	Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr m^{-2}	Bq ^{90}Sr $(kg\ Ca)^{-1}$
Jutland	1.04	0.73	960
The Islands	0.41	0.30	331
1991: Geometric mean	0.65	0.47	560
1991: Arithmetic mean	0.73	0.52	650

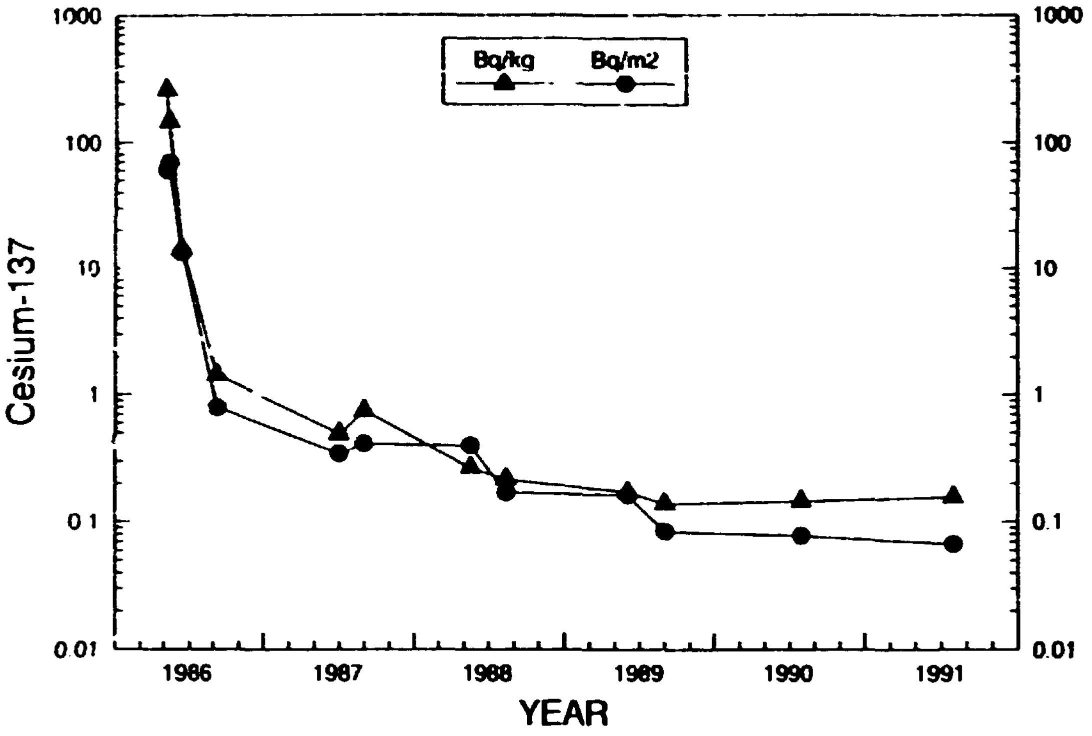
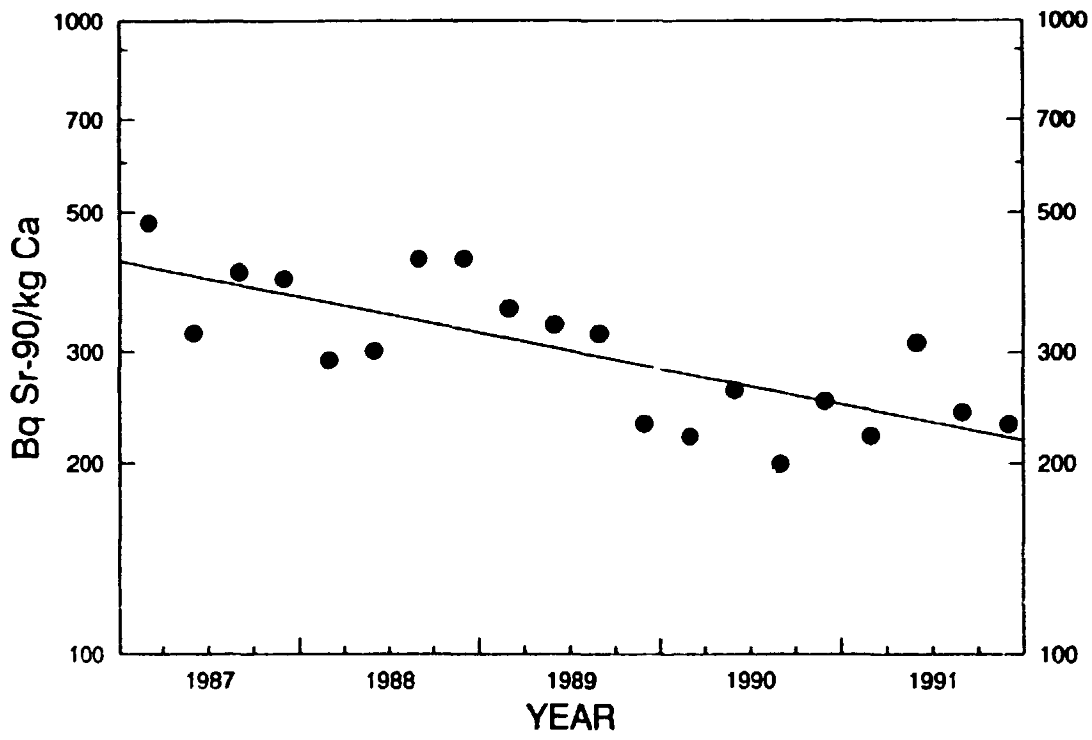


Figure 5.10.3. Cesium-137 median values in grass from the 10 Danish State experimental farms 1986-1991.

Figure 5.10.4. Quarterly Sr-90 levels in grass collected at Risø environment 1987-1991. (Unit: Bq (kg Ca)$^{-1}$).



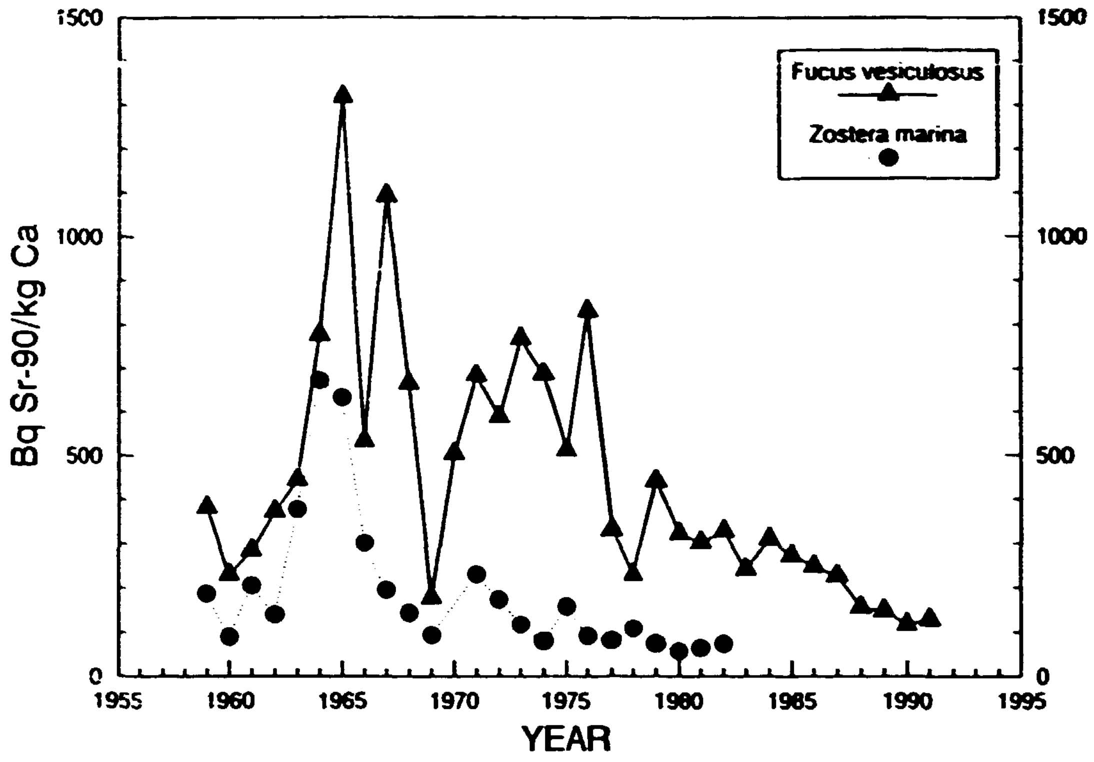


Figure 5.11.1. Strontium-90 in sea plants from Roskilde Fjord, 1959-1991. (Unit: Bq (kg Ca)$^{-1}$).

Table 5.11.1. Radionuclides in Fucus vesiculosus from Bolund (55°42'N 12°05'E) in Roskilde Fjord in 1990 and 1991

Date	% dry matter	Bq ^{90}Sr (kg Ca)$^{-1}$	Bq ^{90}Sr kg^{-1} d.w.	Bq ^{137}Cs kg^{-1} d.w.	^{134}Cs / ^{137}Cs	Salinity in ‰
Jan 17, 1990	17.1	-	-	13.9	0.068 A	13.7
June 14, 1990	18.2	116	2.8	18.7	0.119	14.6
July 31, 1991	20.0	127	3.7	16.0	0.101	13.1

Table 5.11.2.A. Radionuclides in Fucus vesiculosus (Fu.ve.) and Fucus serratus (Fu.se.) collected at Klint (55°58'N, 11°35'E) in 1990. (Unit: Bq kg^{-1} dry matter)

Species	Date	^{60}Co	^{137}Cs	^{134}Cs / ^{137}Cs	^{99}Tc	% dry matter	Salinity in ‰
Fu.ve.	Jan 15	1.60	10.7	0.098	79	19.0	20.3
Fu.se.	Jan 15	2.1	11.3	0.159	-	20.2	
Fu.ve.	Feb 15	1.80	7.3	0.114	85	18.9	25.8
Fu.ve.	March 22	1.30	9.3	0.118	73	18.4	23.0
Fu.ve.	April 17	1.01	15.4	0.136	52	17.5	13.9
Fu.ve.	May 15	0.85	23	0.132	51	16.4	13.6
Fu.ve.	June 14		25	0.131	49	19.5	13.5
Fu.ve.	July 20		19.2	0.137	42	14.9	18.1
Fu.ve.	Aug 15		16.7	0.131	39	18.7	16.6
Fu.ve.	Sep 17		16.8	0.111	47	17.7	17.2
Fu.ve.	Oct 15		13.7	0.103	59	18.4	22.1
Fu.ve.	Nov 12	1.65	13.3	0.094	66	19.8	19.2

Table 5.11.2.B. Radionuclides in Fucus vesiculosus (Fu.ve.) and Fucus serratus (Fu.se.) collected at Klint (55°58'N, 11°35'E) in 1991. (Unit: Bq kg^{-1} dry matter)

Species	Date	^{60}Co	^{137}Cs	^{134}Cs / ^{137}Cs	^{99}Tc	% dry matter	Salinity in ‰
Fu.ve.	Jan 16	1.68	16.9	0.077	109	17.7	24.8
Fu.se.	Jan 16	1.89	12.6	0.118	-	17.9	
Fu.ve.	March 14	1.21	12.6	0.098	129	17.2	13.2
Fu.ve.	April 16	0.96 A	9.9	0.161	72	19.4	18.0
Fu.ve.	May 15	0.75 A	9.4	0.095	48	18.9	17.2
Fu.ve.	June 14	1.44	13.5	0.127	60	15.9	19.7
Fu.ve.	July 15	1.38	15.9	0.097	31	17.2	17.1
Fu.ve.	Aug 14	1.25 A	26	0.105	39	17.9	15.7
Fu.ve.	Sep 16	1.51	23	0.089	lost	15.4	17.8
Fu.ve.	Oct 15	1.20	17.3	0.110	46	22.5	19.8
Fu.ve.	Nov 14	1.15	14.8	0.089	49	19.6	22.4
Fu.ve.	Dec 16	1.29	13.0	0.066	52	18.8	19.9

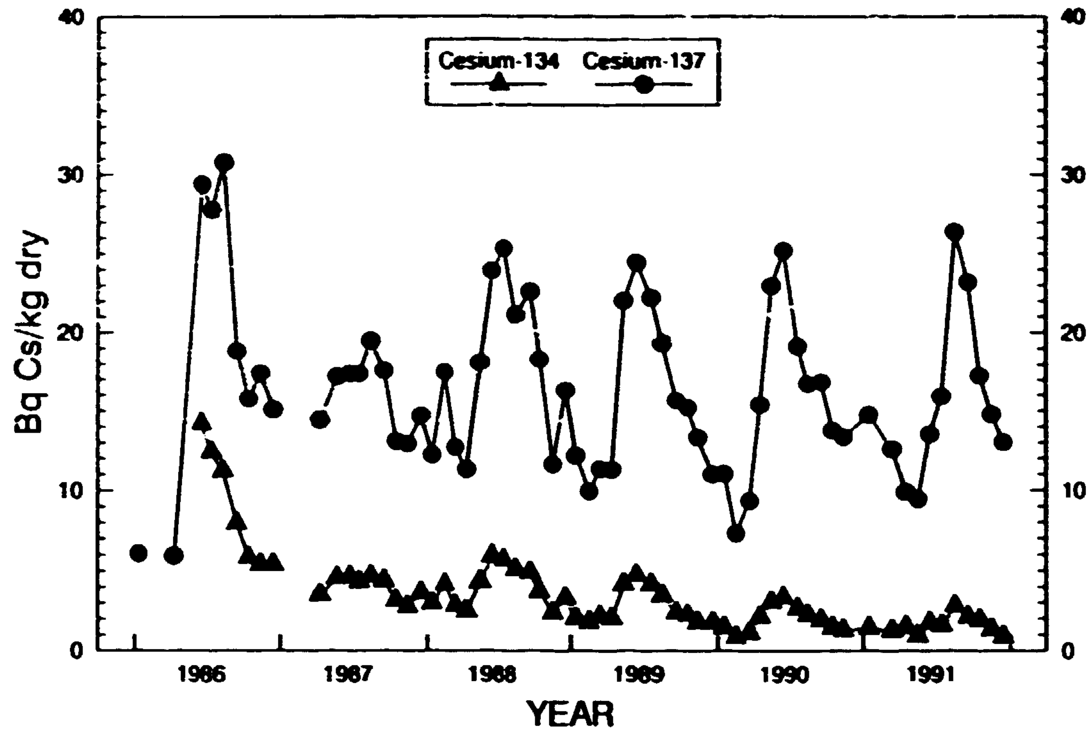


Figure 5.11.2. Cesium-137 and cesium-134 in Fucus vesiculosus and Fucus serratus from April 1986 to November 1990 collected at Klint, Zealand (55°58'N, 11°35'E). (Unit: Bq kg^{-1} dry matter).

Figure 5.11.3. Cesium-137, cesium-134 and salinity in surface sea water from April 1986 to December 1991 collected at Klint, Zealand (55°58'N, 11°35'E).

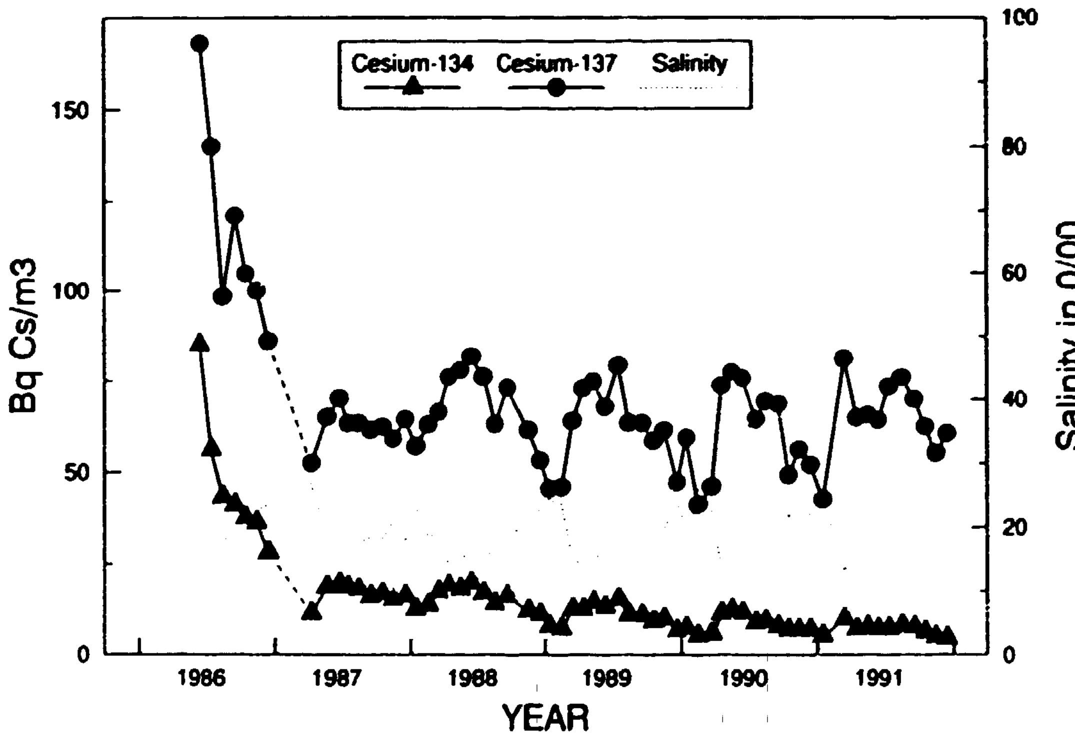


Table 5.11.3 Radionuclides in Fucus vesiculosus collected in Danish waters in 1990 and 1991. (Unit: Bq kg⁻¹ dry matter)

Location	Position N E	Date	^{60}Co	^{137}Cs	$^{134}Cs/^{137}Cs$	% dry matter	Salinity in ‰
Nysted	54°40' 11°44'	Jan 16, 1990		24	0.153	17.4	10.5
-"-	-"-	Feb 16, 1990		22	0.137	17.4	14.7
-"-	-"-	March 23, 1990		19.0	0.129	16.7	14.7
-"-	-"-	April 18, 1990		32	0.132	16.5	11.8
-"-	-"-	May 16, 1990		48	0.139	17.8	10.2
-"-	-"-	June 13, 1990		46	0.149	17.4	11.0
-"-	-"-	July 19, 1990		40	0.143	16.7	15.4
-"-	-"-	Aug 16, 1990		45	0.124	20.0	12.0
-"-	-"-	Sep 18, 1990		43	0.134	15.2	11.6
-"-	-"-	Oct 16, 1990		39	0.127	15.6	13.1
-"-	-"-	Nov 13, 1990		37	0.109	16.3	11.2
-"-	-"-	Dec 12, 1990		30	0.106	17.6	11.8
-"-	-"-	Aug 14, 1991		45	0.106	11.2	10.1
Strøby Egede	55°25' 12°15'	Jan 16, 1990	1.21	28	0.164	17.9	20.5
-"-	-"-	Feb 16, 1990		25	0.139	15.3	15.4
-"-	-"-	March 23, 1990		26	0.152	13.4	12.9
-"-	-"-	April 18, 1990		39	0.140	11.9	10.5
-"-	-"-	May 16, 1990		43	0.148	12.6	9.0
-"-	-"-	June 13, 1990		53	0.142	13.5	9.2
-"-	-"-	July 19, 1990	0.5 B	42	0.137	19.4	10.1
-"-	-"-	Aug 16, 1990		41	0.132	22.3	11.0
-"-	-"-	Sep 18, 1990	0.90 A	44	0.135	17.5	8.8
-"-	-"-	Oct 16, 1990	1.14 A	39	0.132	17.6	11.2
-"-	-"-	Nov 13, 1990	1.14	38	0.127	17.6	8.8
-"-	-"-	Dec 12, 1990	1.46 A	35	0.114	17.5	11.0
-"-	-"-	Aug 14, 1991		57	0.103	17.3	10.6
Reersø	55°31' 11°07'	Jan 15, 1990		15.3	0.169	16.7	14.7
-"-	-"-	Feb 15, 1990		15.4	0.144	16.6	17.6
-"-	-"-	March 22, 1990		14.5	0.126	15.4	16.9
-"-	-"-	April 17, 1990		24	0.143	13.8	11.8
-"-	-"-	May 15, 1990		38	0.139	14.2	10.8
-"-	-"-	June 13, 1990		26	0.129	19.8	13.2
-"-	-"-	July 19, 1990		24	0.128	19.0	22.5
-"-	-"-	Aug 15, 1990		30	0.137	20.9	13.5
-"-	-"-	Sep 18, 1990		29	0.107	17.8	18.4
-"-	-"-	Oct 16, 1990		22	0.104	14.4	20.3
-"-	-"-	Nov 12, 1990		21	0.109	17.9	15.6
-"-	-"-	Dec 12, 1990		21	0.101	17.1	18.2
-"-	-"-	Aug 14, 1991		37	0.093	16.6	14.4
Nakkehoved	56°07' 12°21'	Jan 15, 1990	2.0 A	10.8	0.138	19.0	19.5
-"-	-"-	Feb 15, 1990		10.5	0.136	19.6	23.2
-"-	-"-	April 17, 1990	0.96 A	10.0	0.106	14.5	17.0
-"-	-"-	May 15, 1990		18.4	0.137	15.5	14.1
-"-	-"-	June 14, 1990	1.13 A	23	0.146	15.8	12.1
-"-	-"-	July 20, 1990		16.5	0.132	15.7	15.8
-"-	-"-	Aug 15, 1990	1.07 A	20	0.122	16.8	15.6

Table 5.11.3. Continued

Location	Position N	Position E	Date	^{60}Co	^{137}Cs	^{134}Cs/^{137}Cs	% dry matter	Salinity in ‰
Nakkehoved	56°07'	12°21'	Sep 17, 1990	1.3 A	19.6	0.130	15.9	17.7
-"-	-"-		Oct 15, 1990	1.82	12.8	0.121	17.5	21.7
-"-	-"-		Nov 12, 1990	1.90	11.9	0.090	18.6	19.1
-"-	-"-		Aug 14, 1991	2.1	18.5	0.105	[illegible].9	14.9
Svenskehavn	55°05'	15°09'	May 17, 1990		51	0.160	13.9	8.1
-"-	-"-		May 22, 1991		60	0.122	16.0	7.4
-"-	-"-		Aug 12, 1991		76	0.114	16.7	
Grenå	56°23	10°56'	Aug 21, 1991	0.46	13.0	0.096	23.9	18.7
Udbyhøj	56°36'	10°20'	Aug 21, 1991		8.5		16.2	17.6
Ø. Hurup	56°48'	10°19'	Aug 21, 1991		6.4	0.039	21.4	26.0
Hals	57°00'	10°20'	Aug 21, 1991		7.4		23.7	27.2
Bangsbo	57°25'	10°32'	Aug 21, 1991	0.8 A	11.1		15.6	30.1
Ålbæk	57°36'	10°26'	Aug 21, 1991	1.11	4.9	0.057	18.2	31.2

*^{54}Mn: 0.4 Bq kg^{-1} dry weight.

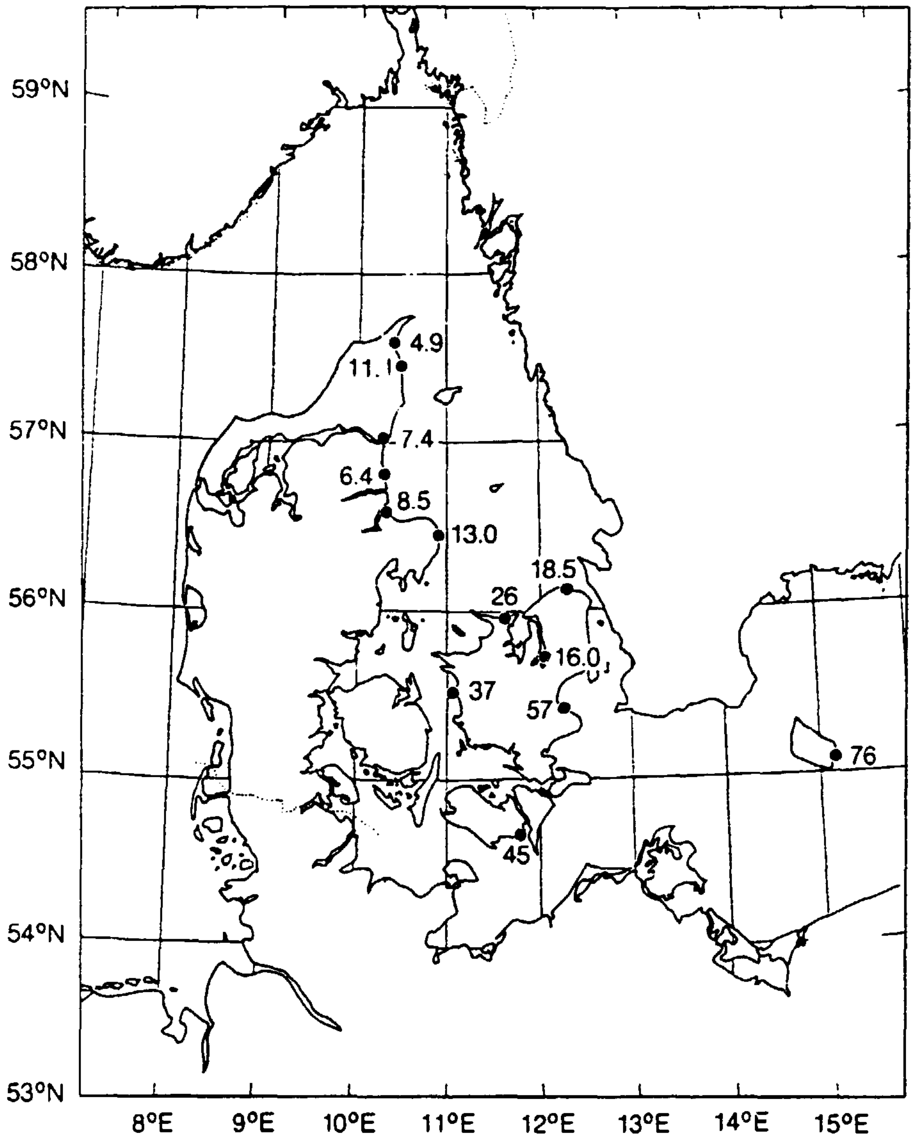


Figure 5.11.4. Cesium-137 in Fucus vesiculosus collected in Denmark, August 1991. (Unit: Bq kg⁻¹ dry matter).

Table 5.12.1. Radiocesium in lichen (Cladina portentosa) collected at Oustrup Heather October 4, 1990, by Ulrik Søchting, Institute of Sporeplants, University of Copenhagen

Sample	^{137}Cs Bq kg^{-1} d.w.	^{137}Cs Bq m^{-2}	^{134}Cs Bq kg^{-1} d.w.	^{134}Cs Bq m^{-2}	^{134}Cs/^{137}Cs	% Chernobyl ^{137}Cs
Top layer No. 1	230	220	34	33	0.149	
Top layer No. 2	400	430	52	57	0.130	
Top layer No. 3	230	210	26	24	0.114	
Top layer No. 4	300	500	35	58	0.117	
Top layer No. 5	210	210	20	21	0.100	
Bottom layer No. 1	29	1030	1.15	41	0.039	
Bottom layer No. 2	11.7	330	0.75 A	21 A	0.065 A	
Bottom layer No. 3	10.8	340	0.70 A	22 A	0.065 A	
Bottom layer No. 4	17.6	610	0.78 A	27 A	0.044 A	
Bottom layer No. 5	9.9	380	0.36 B	14 A	0.036 A	
x̄ Top ±1 S.D.	270 ±78	310±140	33±12	39±18		58
x̄ Bottom ±1 S.D.	15.8±8.0	540±300	0.75±0.28	25±10		34
Top + Bottom ±1 S.D.		850±310		64±22		55

Table 5.12.2.A. Radionuclides in lichen (Cladina portentosa) collected in Denmark in 1990

Location	Date	^{137}Cs Bq m^{-2}	^{106}Ru/^{137}Cs	^{125}Sb/^{137}Cs	^{134}Cs/^{137}Cs	kg d.w. m^{-2}
*Bornholm	May 17	81			0.116	0.83
Hvide Sande	Sep 13	800	0.032 A	0.0012 A	0.144	0.98
Skagen 1	Oct 22	163			0.130	0.82
Skagen 2	Oct 22	250			0.128	1.06
Skagen 3	Oct 22	200			0.132	0.98

*27% Cladonia stellaris.

Table 5.12.2.B. Radiocesium in lichen (Cladina portentosa) collected in Denmark in 1991

Location	Date	^{137}Cs Bq m^{-2}	^{134}Cs/^{137}Cs	kg d.w. m^{-2}
Dueodde (Bornholm)	May 22	66	0.076	1.07
Hvide Sande	June 13	480	0.116	1.04
Skagen 1	Sep 14	128	0.069	1.19
Skagen 2	Sep 14	66	0.085	0.58
Skagen 3	Sep 14	68	0.095	0.63

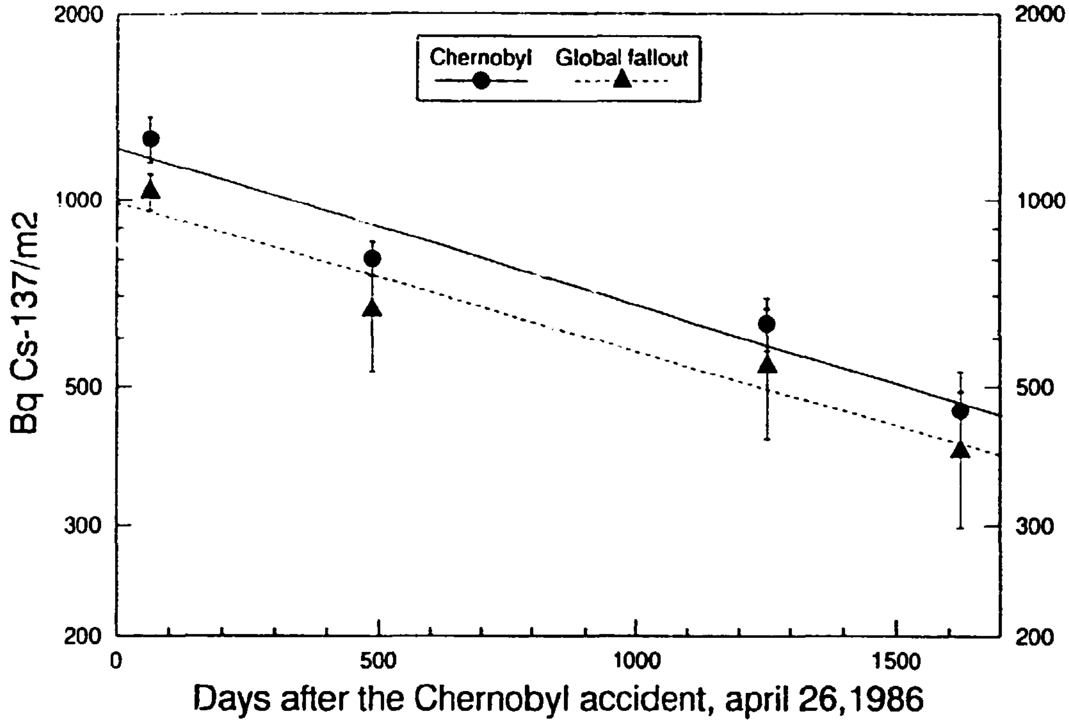
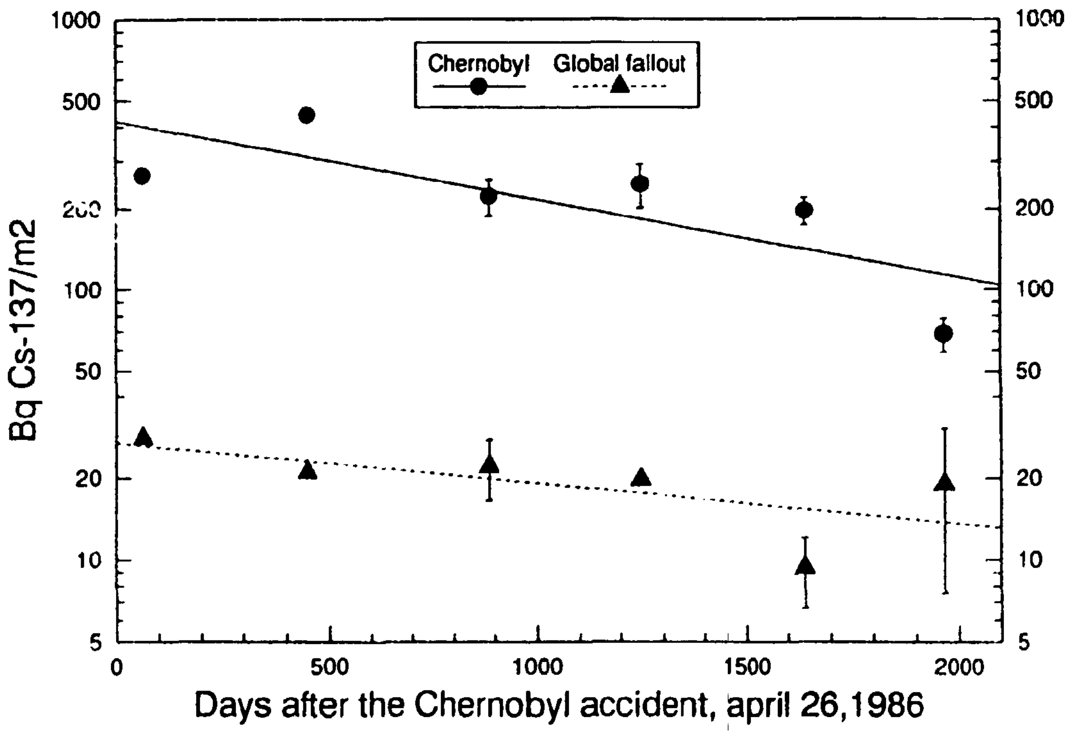


Figure 5.12.1. The ecological decay of ^{137}Cs from Chernobyl and from global fallout in Danish lichen (Cladina portentosa)collected at Oustrup Heather 1986-1990.

Figure 5.12.2. The ecological decay of ^{137}Cs from Chernobyl and from global fallout in Danish lichen (Cladina portentosa)collected at Skagen 1986-1991.



6. Strontium-90 and Radiocesium in Humans

6.1. Strontium-90 in Human Bone

(by A. Aarkrog)

Tables 6.1.1-6.1.2 A & B summarize the results from 1990 and 1991.

6.2. Radiocesium in the Human Body

by B. Lauridsen and J. Søgaard-Hansen

Whole-body measurements of radiocesium were initiated at Risø in July 1963 (cf. 2.3 in Risø Report No. 85). The initial program stopped in 1977 due to very low body contents. The Chernobyl accident resulted in elevated radiocesium levels in foodstuff and the whole-body measurements were resumed in September 1986.

The new control group comprises a large fraction of the old supplemented with a few newcomers. In total there are about 20 persons in the group including 2 children.

Results from the early whole-body measurements are shown in Figure 6.2.1. The figure shows the average yearly radiocesium contents (± 1 S.E.) in the period 1963 to 1977. The measurements are compared with calculated values based on foodstuff data. For comparison the average values for 1986, 1987, 1988, 1989 and 1990 are given.

In Figure 6.2.2 the measured mean values of ^{134}Cs + ^{137}Cs body content are shown for men, women and children (only up to 1989). The figure, furthermore, shows the calculated levels based upon estimated intake of radiocesium with food. In Figure 6.2.2 persons in the control group were omitted if they have been on official travel to countries with relatively high contamination levels. The measured body contents in 1990 are well below the 1987 peak values and are approaching the pre-Chernobyl level. The calculated levels appear to be in good agreement with the observed values. At the beginning of 1991 several persons had body contents below the lower level of detection, hence it was decided to cease the measurements. The mean concentration in 1990 was 415 Bq ^{134}Cs + $^{137}Cs/(kg\ K)^{-1}$ (rel. S.D.: 19%).

6.3. Radionuclides in Human Milk

(by A. Aarkrog)

No samples.

6.4. Human Urine

Since the Chernobyl accident in 1986 ^{137}Cs has been measured in urine from a Risø control group. The results have been compared with the ^{137}Cs levels in diet and body (Figure 6.4). The urine showed a peak in April 1991 (Table 6.4) not explainable from the diet data. This suggests that members of the Risø group have received diet higher in ^{137} Cs than normal average Danish diet, perhaps during a stay abroad.

Table 6.1.1.A. Strontium-90 in human bone in 1990

Zone/Location	Age*	Month of death	Sex	Bq (kg Ca)$^{-1}$
Jutland	3 m	6	F	10 B
II	1 y 4 m	5	F	8 B
II	22 y	5	M	12.9
I	24 y	5	F	10.5
II	40 y	6	M	11.1
Jutland	48 y	5	M	23
II	50 y	5	M	10.5
III	53 y	5	F	24
II	53 y	5	M	12.2
II	53 y	5	M	9.0 A
II	54 y	6	M	30
Jutland	60 y	5	M	13.2
III	64 y	6	M	11.4
I	67 y	5	M	18.8
II	71 y	5	M	12.6 A
II	81 y	5	M	25

*y = year, m = month

Table 6.1.1.B. Strontium-90 in human bone in 1991

Zone	Age*	Month of death	Sex	Bq (kg Ca)$^{-1}$
III	1 y 11 m	9	F	13.8
I	23 y	8	M	14.4
II	39 y	9	F	18.0
III	47 y	8	M	16.7
II	61 y	12	M	15.9
II	63 y	9	F	13.1
I	72 y	8	M	13.0
I	74 y	9	M	25
I	76 y	8	F	22
II	82 y	9	M	17.8

*y = year, m = month

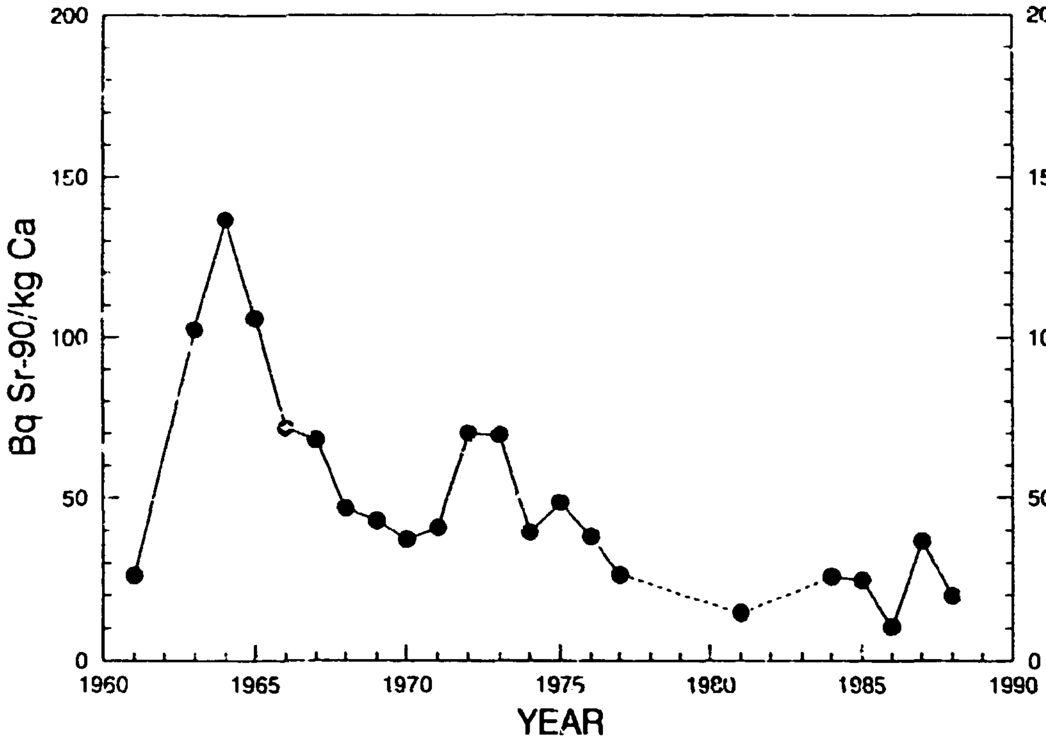
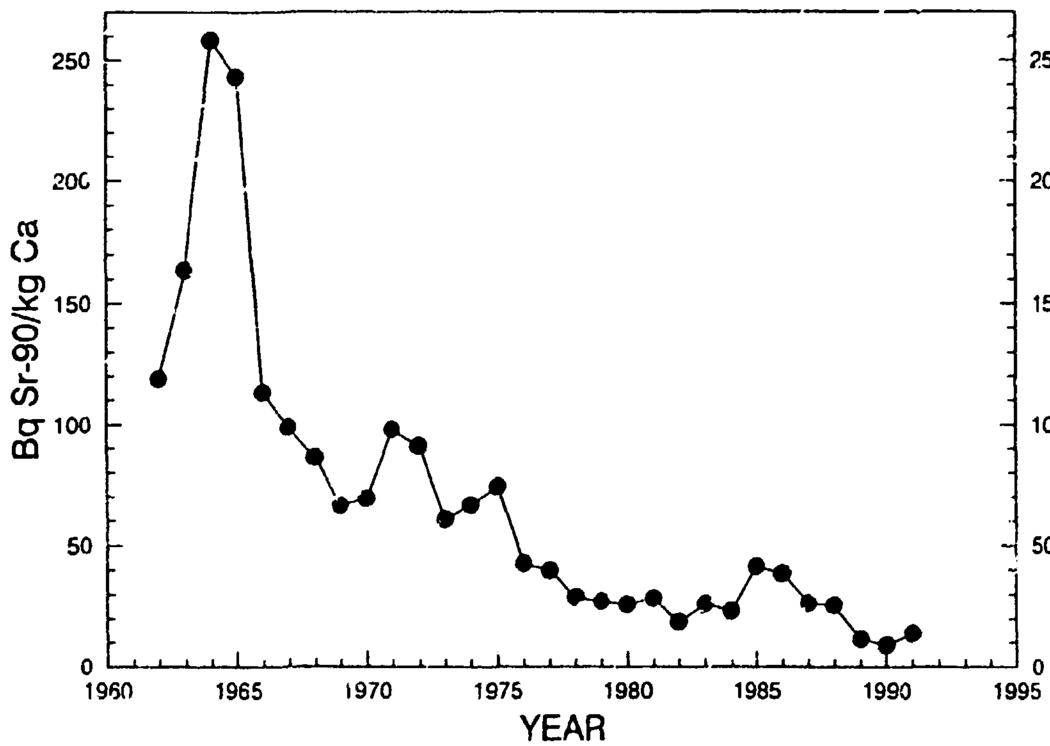


Figure 6.1.1. Strontium-90 levels in bone from new-born (< 1 month) 1961-1991.

Figure 6.1.2. Strontium-90 levels in bone from infants (> 1 month ≤ 4 years) 1961-1991.



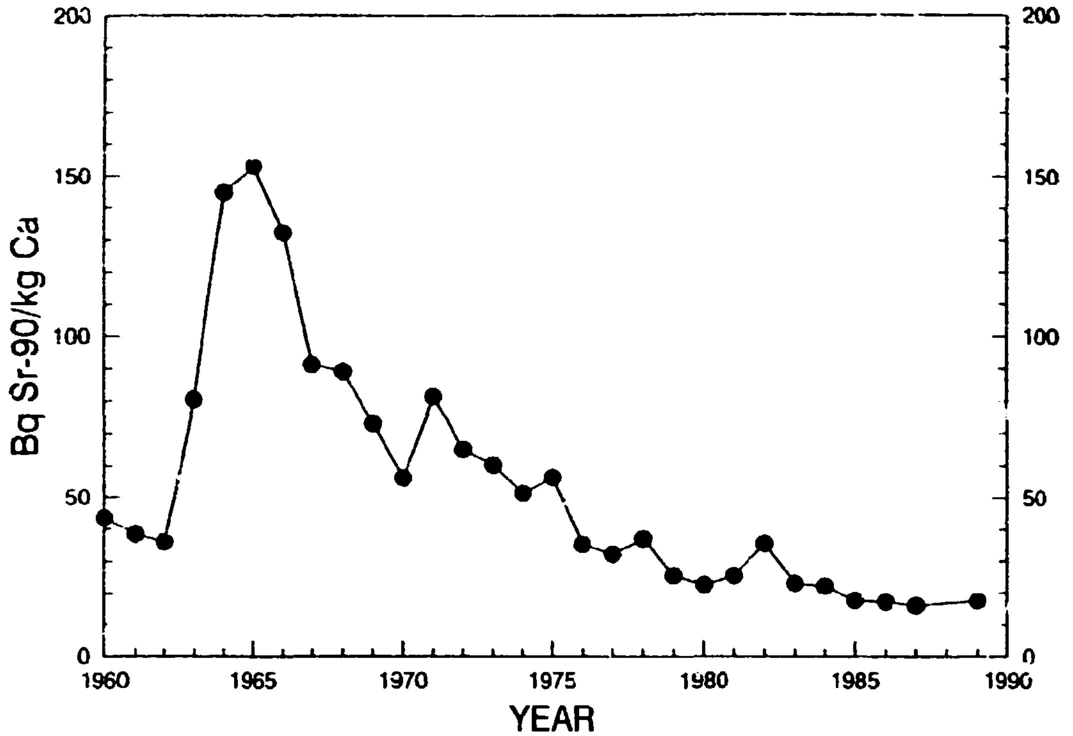
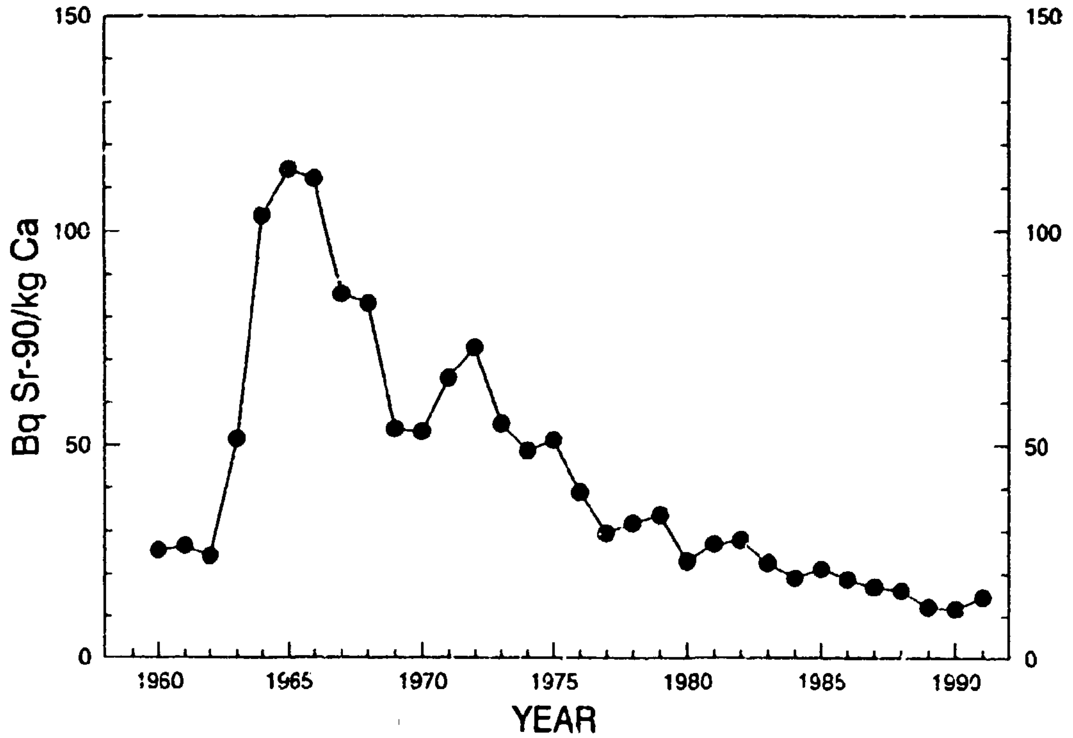


Figure 6.1.3. Strontium-90 levels in bone from children (> 4 years ≤ 19 years) 1960-1991.

Figure 6.1.4. Strontium-90 levels in bone from adults (> 19 years ≤ 29 years) 1960-1991.



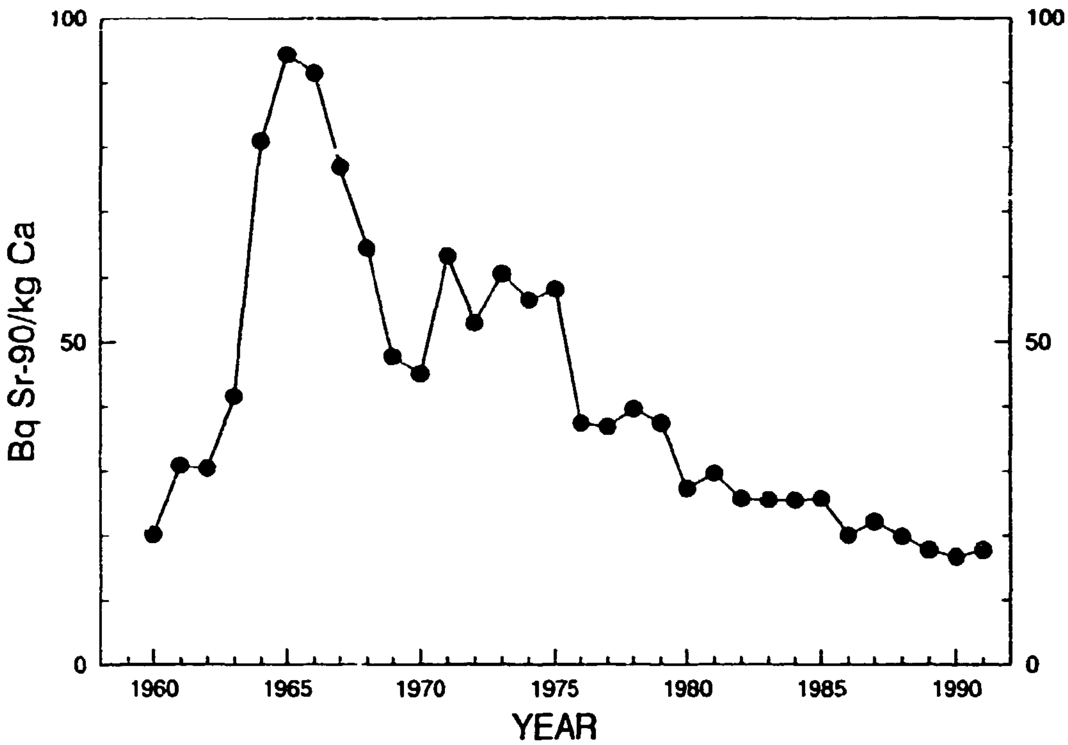


Figure 6.1.5. Strontium-90 levels in bone from adults (> 29 years) 1960-1991).

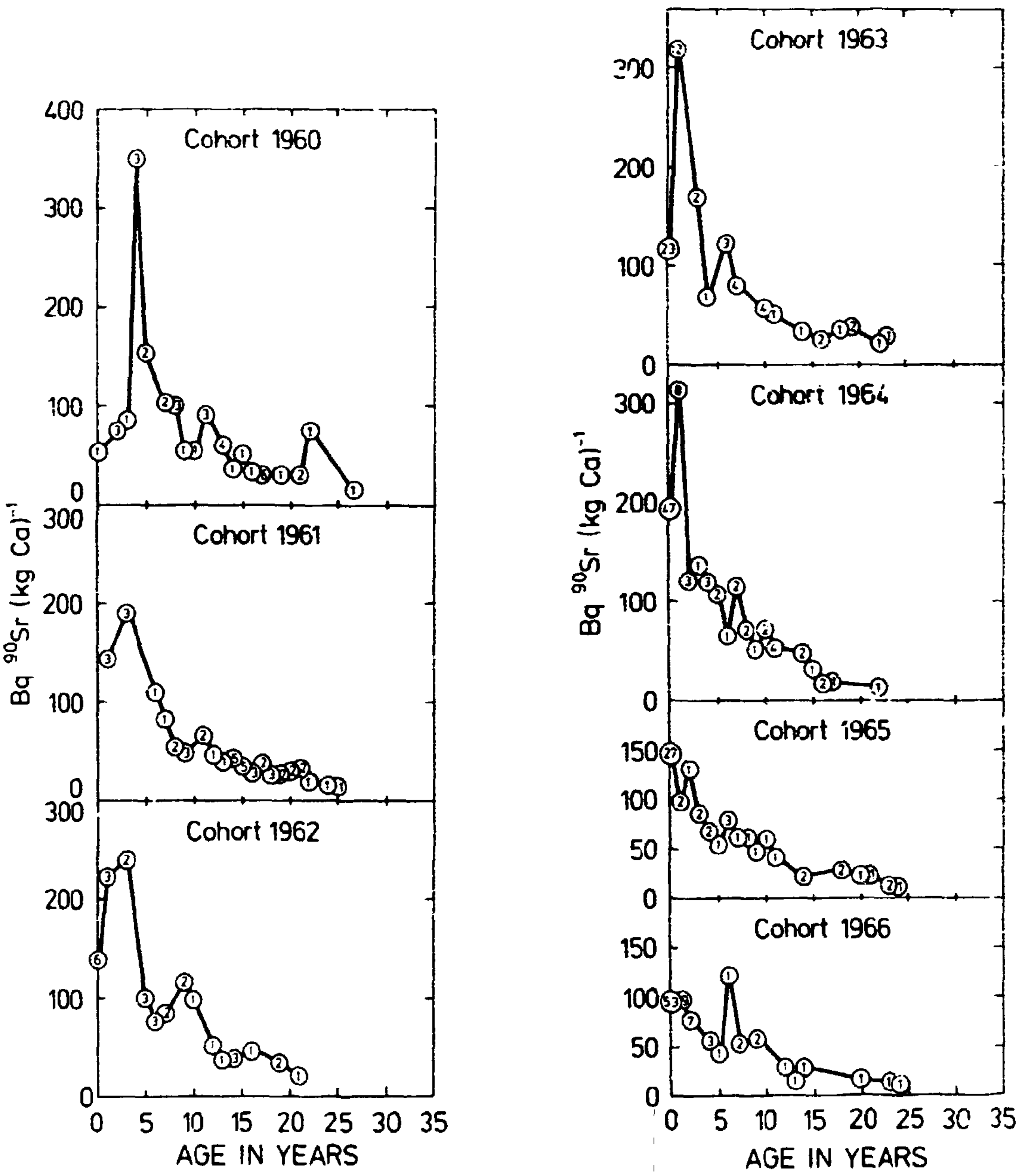


Figure 6.1.6. Strontium-90 in human bone from Danish cohorts 1960-1966. Abscissa: age in years. Ordinate: bone level in Bq ^{90}Sr (kg Ca)$^{-1}$.

Table 6.1.2.A. Strontium-90 in human vertebrae collected in Denmark (Jutland only) in 1990. (Unit: Bq (kg Ca)$^{-1}$)

Age group	Number of samples	Min.	Max.	Median	Arithmetic mean	Geometric mean
New-born (< 1 month)	0	-	-	-	-	-
Infants (≤ 4 years)	2	8	10	9	9	9
Children (≤ 19 years)	0	-	-	-	-	-
Adults (≤ 29 years)	2	10.5	12.9	11.7	11.7	11.6
Adults (> 29 years)	12	9.0	30	12.9	16.7	15.5

Table 6.1.2.B. Strontium-90 in human vertebrae collected in Denmark (Jutland only) in 1991. (Unit: Bq (kg Ca)$^{-1}$)

Age group	Number of samples	Min.	Max.	Median	Arithmetic mean	Geometric mean
New-born (< 1 month)	0	-	-	-	-	-
Infants (≤ 4 years)	1	13.8	13.8	13.8	13.8	13.8
Children (≤ 19 years)	0	-	-	-	-	-
Adults (≤ 29 years)	1	14.4	14.4	14.4	14.4	14.4
Adults (> 29 years)	8	13.0	25	17.3	17.7	17.3

Table 6.2 Radiocesium ($^{134+137}Cs$) in humans from Risø and environment measured in 1990

No.	Date	Sex	Age	Bq Cs $(kg K)^{-1}$	g K $(kg)^{-1}$
2	January 25	F	46	570	2.13
2	May 2	F	46	540	2.27
3	January 25	F	57	764	2.14
3	September 17	F	57	920	1.43
4	January 26	M	57	577	1.79
4	May 7	M	57	512	2.02
6	January 22	M	58	398	1.85
6	May 2	M	58	362	2.04
6	September 6	M	58	244	1.65
7	January 25	F	50	474	1.62
7	September 7	F	51	269	1.51
9	January 23	F	61	629	1.77
11	January 23	F	53	221	1.46
11	May 9	F	53	378	1.68
14	January 24	M	47	255	2.33
15	January 22	F	48	255	1.46
15	September 12	F	49	145	1.45
18	January 25	F	53	172	1.50
19	January 22	F	51	501	1.61
19	May 21	F	51	658	1.67
20	January 23	M	47	393	1.82
20	May 14	M	47	353	1.87
20	September	M	47	239	1.62
22	January 23	F	8	480	1.30
24	January 30	F	15	402	1.79
24	May 10	F	15	284	2.15
27	January 22	M	48	1062	1.68
27	May 15	M	48	451	1.74
27	September 6	M	48	265	1.48
31	January 23	M	74	426	1.74
31	September 13	M	75	180	1.54

Mean*	January 1990	474± 56
	May 1990	442± 43
	September 1990	323±101

*Monthly mean values (adults) $^{134+137}Cs$ Bq $(kg K)^{-1}$±1 S.E.

An approximate estimate of the ^{137}Cs content may be obtained by multiplying the Bq Cs $(kg K)^{-1}$ by 0.87.

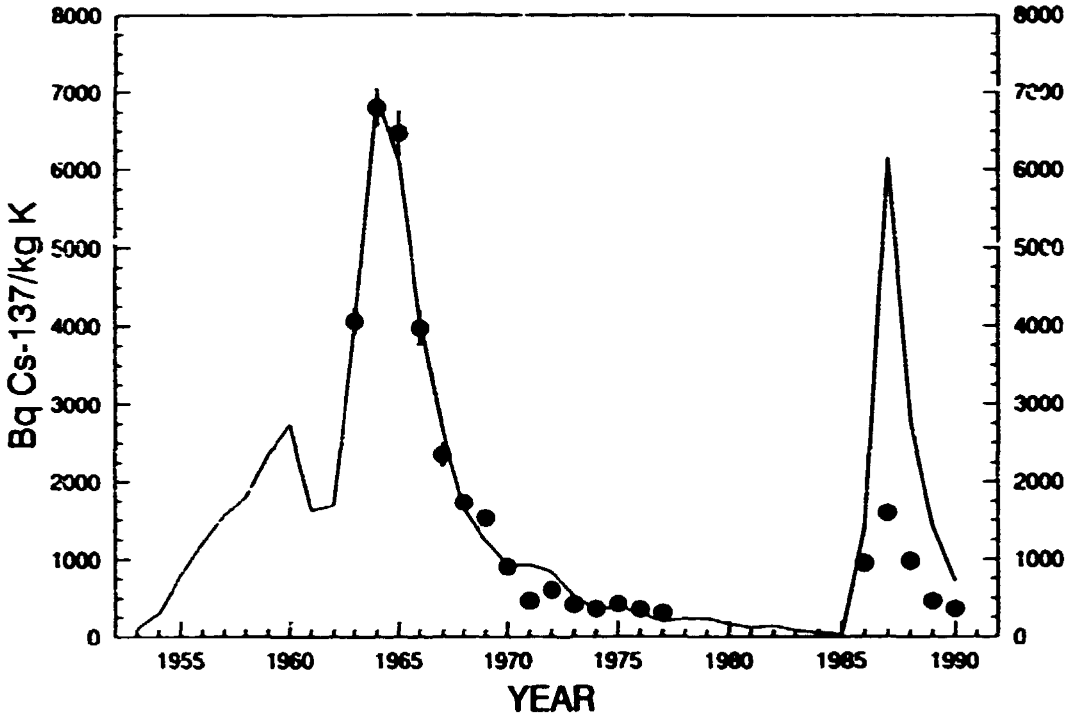
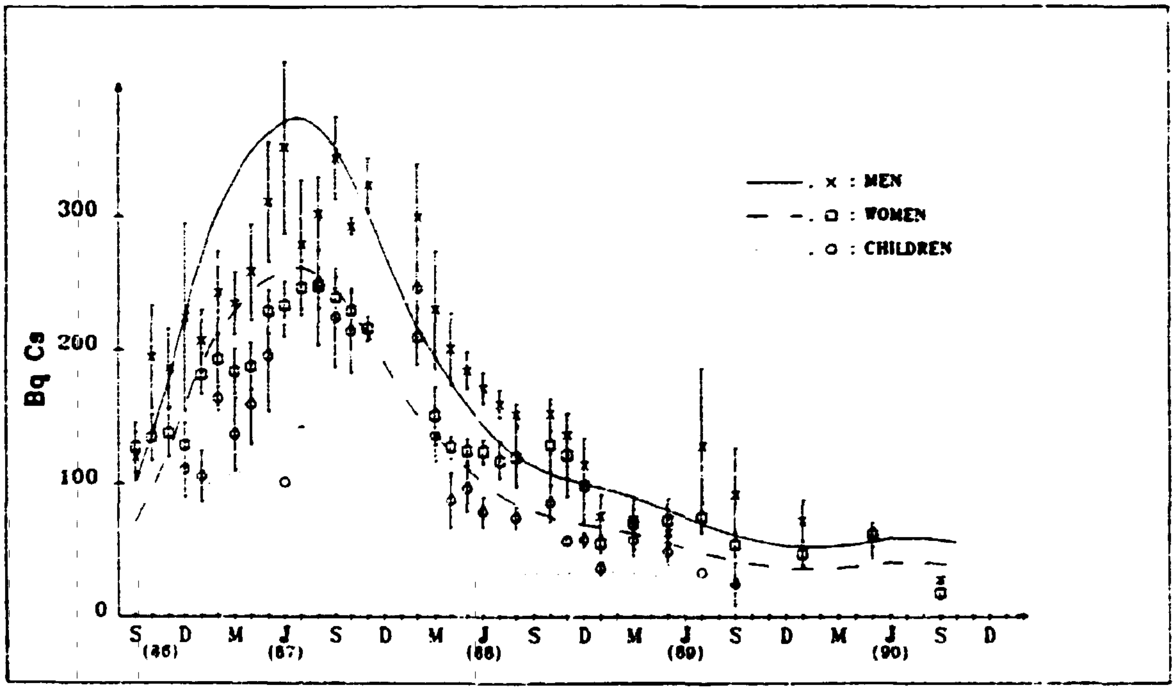


Figure 6.2.1. A comparison between observed (±1 S.E.) and calculated (Aarkrog 1979) Bq ^{137}Cs (kg K)$^{-1}$ levels in persons from Zealand.

Figure 6.2.2. Radiocesium in Danish men, women and children from Zealand in 1986-1990. The curves represent the calculated levels based upon calculated diet measurements.



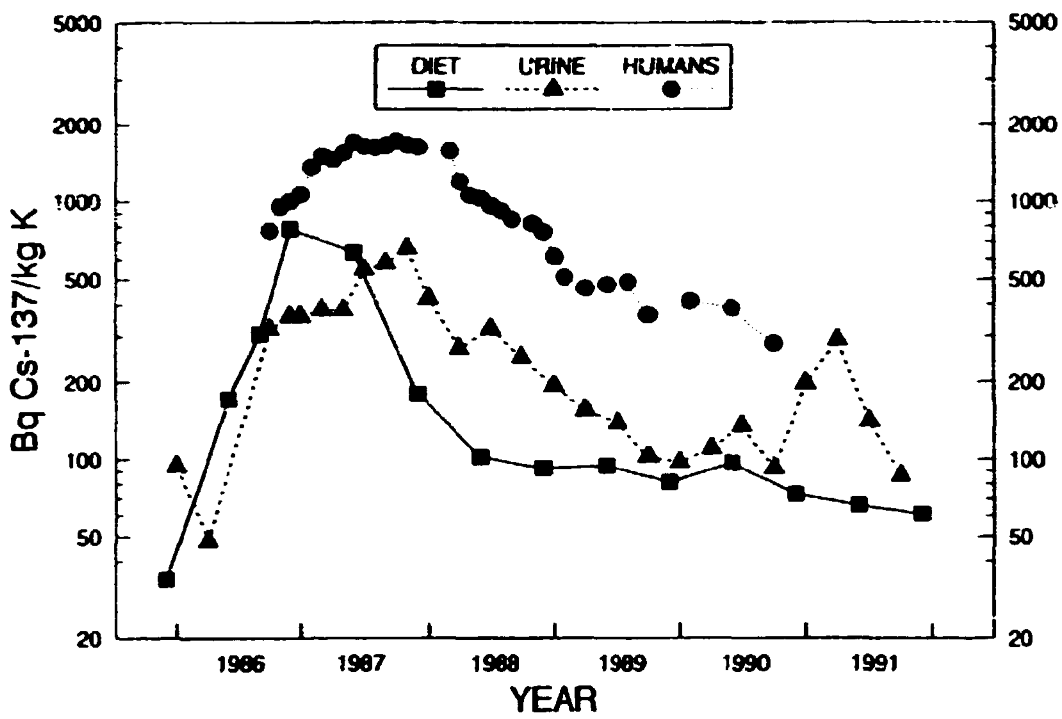


Figure 6.4. Radiocesium (Bq ^{137}Cs (kg K)$^{-1}$ in diet, urine, and humans from Zealand in 1986-1991. (The human data were calculated from whole-body measurements of (^{134}Cs + ^{137}Cs) by multiplication with 0.67 in 1986, 0.72 in 1987, 0.78 in 1988 and 0.83 in 1989 and 0.87 in 1990.

Table 6.4. Cesium-137 in urine samples from a control group at Risø. 1990-1991

Quarters	^{40}K g l^{-1}	Bq ^{137}Cs (kg K)$^{-1}$
January 1990	0.74	97
April 1990	1.50	110
July 1990	0.68	135
October 1990	0.85	92
January 1991	0.64	197
April 1991	0.97	290
July 1991	1.19	140
October 1991	1.01	86

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 0.4 kBq m^{-3} from this source (UNSCEAR 1982). 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 (UNSCEAR 1982). Finally, tritium is produced as a by-product of the peaceful uses of atomic energy: it is released both during reactor operation and fuel reprocessing.

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 as previously described (Risø Reports Nos. 386 etc. (Risø Reports 1957-1991)).

We have found that the tritium background in the air in our laboratory makes it impossible to produce reliable results if the concentrations are below 2 kBq m^{-3}. (Personal Communication G. *Östlund*, 1984). Previously we have applied a constant background correction by subtraction of 1.2 kBq ^3H m^{-3} from our measured values (cf. Appendix in Risø-R-527) (Risø Reports 1957-1991). This is not done any longer. Instead a blank is following the samples analysed and the ^3H level in this blank is used for the correction.

7.3. Summary of Results

The tritium results are shown in detail in the chapters where the samples belong.

Tables 4.2.3 and 4.2.4 give the results for precipitation. The annual mean concentrations in rain in 1990 were: 6.0 kBq m^{-3} at Risø, 2.3 at Tylstrup, 2.1 at Jyndevad, and 2.7 at Bornholm. In 1991 the levels were 5.5, 1.9, 2.2, and 2.6, respectively. The enhanced tritium levels at Risø were due to discharges of the DR 3 reactor at the site.

The tritium concentrations in Danish streams and lakes were 2.4 and 2.1 kBq m^{-3}, respectively (Tables 4.3.2.1 and 4.3.2.2).

The levels were in general unchanged compared with those seen in 1988 and 1989.

8. Measurements of Background Radiation in 1990 and 1991

by L. Bøtter-Jensen and S.P. Nielsen

8.1. Instrumentation

Measurements of the background radiation were made with thermoluminescence dosimeters (TLD's), and a NaI(Tl) detector.

8.2. State Experimental Farms

The State experimental farms are situated as shown in Figure 4.2. The results of the TLD measurements are shown in Table 8.2.1.A. The results of the NaI(Tl) detector measurements are shown in Tables 8.2.2.A and B.

The γ-background measured with the NaI(Tl) detector in four groups of sampling stations is shown in Figure 8.2.1 from 1962 to 1991.

8.3. Risø Environment

The five zones around Risø are located as shown in Figure 8.3.1. The results of the TLD measurements are shown in Tables 8.3.1.A and B, and the results of the NaI(Tl) detector measurements are shown in Tables 8.3.2.A and B.

8.4. Gylling Næs Environment

The Gylling Næs environment is routinely monitored with TLDs, and the results from the site are given in Table 8.4.1.A. The locations are shown in Figure 8.4.1.

8.5. Great Belt and Langeland Belt Areas

Locations on both shores of the Great Belt and the Langeland Belt (an international shipping route) are routinely monitored with TLDs; the results and locations are shown in Table 8.5.1.A and Figure 8.5.1, respectively.

8.6. The Baltic Island of Bornholm

Locations on the island of Bornholm have been monitored with TLDs in the period May 1989 - May 1990 and May 1990 - May 1991. The results and locations are shown in Tables 8.6.1.A and B and Figure 8.6.1, respectively.

Table 8.2.1.A. TLD-measurements of the background radiation (integrated over 12 months and normalized to μR h⁻¹) at the State experimental farms in 1989/90

Location	Sep 1989 - Sep 1990 $\mu R\,h^{-1}$
Tylstrup	7.7
Borris	6.9
Ødum	7.1
Askov	7.7
St. Jyndevad	6.6
Årslev	8.6
Tystofte	8.8
Abed	8.5
Mean	7.7

Table 8.2.1.B. TLD-measurements of the background radiation (integrated over 12 months and normalized to $\mu R\,h^{-1}$) at the State experimental farms in 1990/91

Lost.

Table 8.2.2.A. Terrestrial exposure rates at the state experimental farms measured with the NaI(Tl) detector in 1990 ($\mu R\ h^{-1}$)

Location	March	June	October	Mean
Tylstrup	3.3	3.2	3.2	3.2
Borris	3.5	3.5	3.5	3.5
Kalø	3.8	4.0	4.0	3.9
Askov	3.8	3.8	3.8	3.8
St. Jyndevad	2.3	2.2	2.3	2.3
Årslev	4.6	4.6	4.6	4.6
Ledreborg	5.0	4.8	5.0	5.0
Tystofte	4.9	4.8	5.0	4.9
Abed	5.0	5.0	5.0	5.0
Tornbygård	(5.9)	5.9	(5.9)	5.9
Mean	4.2	4.2	4.2	4.2

Figures in brackets were calculated from VAR3 (*Vestergaard* 1964).

Table 8.2.2.B. Terrestrial exposure rates at the state experimental farms measured with the NaI(Tl) detector in 1991 ($\mu R\ h^{-1}$)

Location	March	June	October	Mean
Tylstrup	3.1	3.2	3.1	3.1
Borris	3.2	3.5	3.1	3.3
Kalø	3.7	3.5	3.8	3.7
Askov	3.5	3.9	3.6	3.7
St. Jyndevad	2.1	2.1	2.0	2.1
Årslev	4.5	4.8	5.4	4.9
Ledreborg	4.8	4.6	4.8	4.7
Tystofte	4.9	4.9	4.8	4.8
Abed	4.9	5.3	5.6	5.3
Tornbygård	(5.9)	6.0	(6.1)	6.0
Mean	4.1	4.2	4.2	4.1

Figures in brackets were calculated from VAR3 (*Vestergaard* 1964).

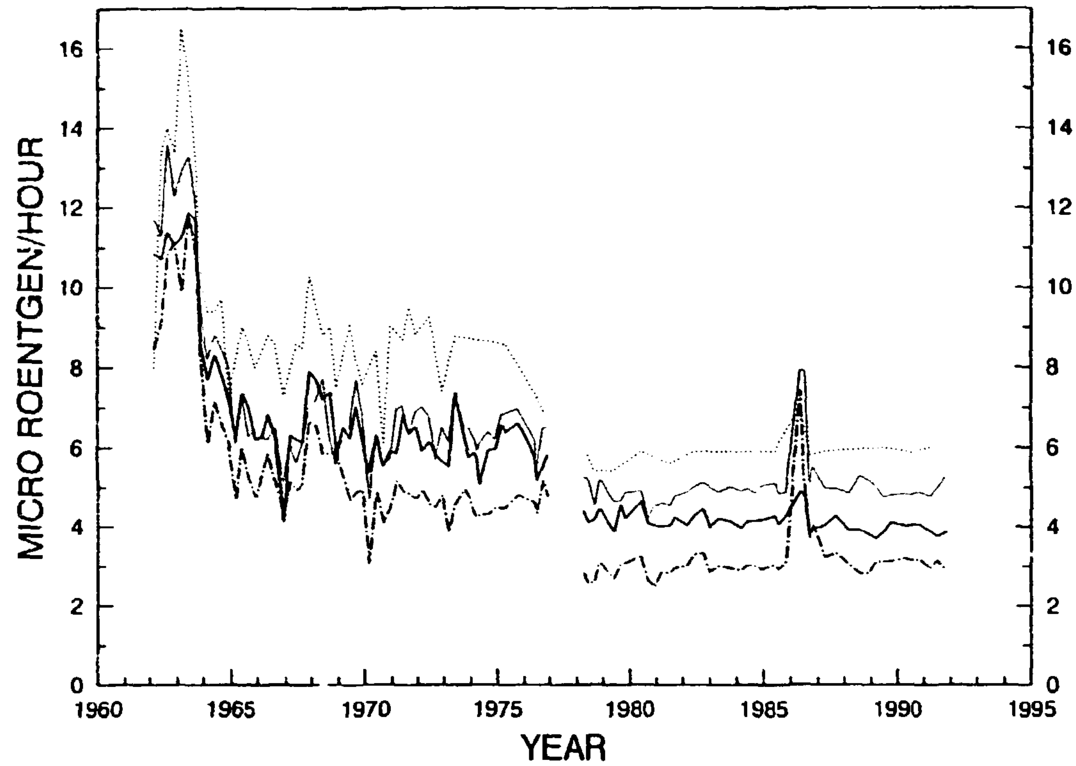


Figure 8.2.1. Terrestrial exposure rates at the State experimental farms in 1962-1976 and 1978-1991 measured with the NaI(Tl) detector (μR h⁻¹).

......	*Åkirkeby/Tornbygård*
———	*Abed. Blangstedgård/Årslev, Tystofte*
━━━	*Virumgård/Ledreborg, Ødum/Kalø, Tylstrup*
—·—	*Jyndevad, Askov, Studsgård/Borris*

Figure 8.3.1. The environment of Risø. Locations for measurements of the background radiation.

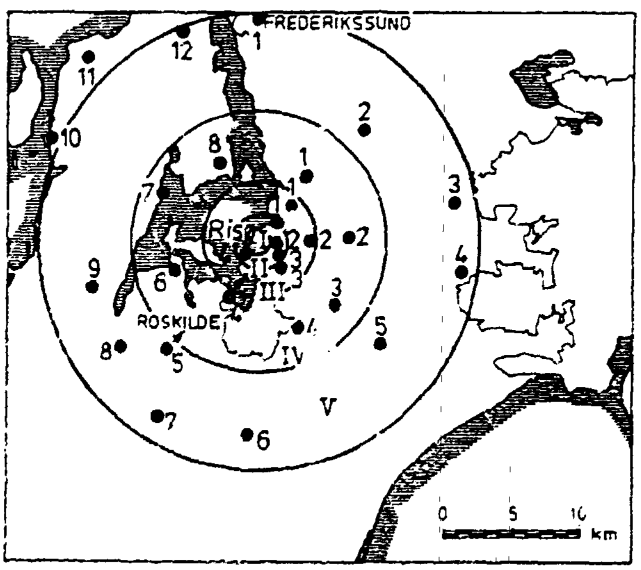


Table 8.3.1 A. TLD-measurements of the background radiation (mean of 2 × 6 months integration periods and normalized to μR h⁻¹) in five zones (I-V) around Risø in 1989/90

Risø zone	Location	Oct 1989 - Oct 1990 $\mu R\ h^{-1}$
I	1	8.5
I	2	9.0
I	3	19.2
I	4	8.2
I	5	9.3
Mean		10.8
II	1	7.6
II	2	8.4
II	3	7.1
II	4	7.6
Mean		7.7
III	1	8.3
III	2	8.0
III	3	7.8
Mean		8.0
IV	1	6.8
IV	2	7.6
IV	3	8.2
IV	4	6.7
IV	5	6.9
IV	6	7.3
IV	7	9.0
Mean		7.5
V	1	7.9
V	2	9.1
V	3	8.6
V	4	7.4
V	5	8.0
V	6	8.4
V	7	9.0
V	8	9.7
V	9	6.5
V	10	7.9
Mean		8.5

Table 8.3.1.B. TLD-measurements of the background radiation (12-month integration period and normalized to μR h⁻¹) in five zones (I-V) around Risø in 1990/91

Risø zone	Location	Oct 1990 - Oct 1991 μR h^{-1}
I	1	8.2
I	2	9.1
I	3	17.1
I	4	8.6
I	5	8.9
Mean		10.4
II	1	7.8
II	2	8.9
II	3	8.4
II	4	8.0
Mean		8.3
III	1	8.1
III	2	8.4
III	3	8.0
Mean		8.2
IV	1	7.4
IV	2	8.6
IV	3	8.3
IV	4	7.6
IV	5	6.6
IV	6	7.7
IV	7	9.1
Mean		7.9
V	1	8.1
V	2	8.9
V	3	8.7
V	4	7.6
V	5	8.3
V	6	8.6
V	7	8.8
V	8	8.4
V	9	8.5
V	10	7.8
Mean		8.4

Table 8.3.2 A. Terrestrial exposure rates at the Risø zones in 1990 measured with the NaI(Tl) detector ($\mu R\ h^{-1}$)

Risø zone	Location	January	April	July	October
I	1	5.7	5.6	6.2	6.0
I	2	7.1	7.1	7.4	7.6
I	3	73	70	69	71
I	4	5.6	5.6	5.2	5.9
I	5	10.7	10.0	10.3	9.8
Mean		20	19.6	20	20
II	1	4.9	4.5	4.4	4.9
II	2	5.2	5.2	4.9	4.9
II	3	4.4	4.4	4.3	4.5
II	4	4.6	4.5	4.5	4.8
Mean		4.8	4.6	4.5	4.8
III	1		5.2		5.5
III	2		4.8		4.9
III	3		4.2		4.4
Mean			4.7		4.9
IV	1		4.5		4.5
IV	2		4.7		4.9
IV	3		4.8		4.8
IV	4		4.5		4.6
IV	5		3.0		3.1
IV	6		3.8		4.1
IV	7		4.5		4.9
Mean			4.2		4.4
V	1		4.5		4.6
V	2		5.2		5.4
V	3		5.0		5.2
V	4		5.2		5.0
V	5		5.4		5.2
V	6		5.0		5.0
V	7		5.0		5.0
V	8		4.1		4.5
V	9		4.[illegible]		4.5
V	10		3.7		4.2
Mean			4.7		4.9

Table 8.3.2.B. Terrestrial exposure rates at the Risø zones in 1991 measured with the NaI(Tl) detector (μR h^{-1})

Risø zone	Location	January	April	July	October
I	1	5.6	5.8	5.5	3.6
I	2	6.3	6.6	6.4	6.8
I	3	67	69	67	68
I	4	5.6	5.8	5.4	5.6
I	5	7.4	7.4	7.6	8.1
Mean		18.4	18.9	18.4	18,4
II	1	4.8	4.6	4.6	4.6
II	2	4.7	4.8	4.9	4.7
II	3	4.4	4.4	4.3	4.2
II	4	4.6	4.7	4.7	4.5
Mean		4.6	4.6	4.6	4.5
III	1		5.5		5.3
III	2		4.7		4.8
III	3		4.3		4.3
Mean			4.8		4.8
IV	1		4.6		4.5
IV	2		4.8		4.7
IV	3		4.6		4.6
IV	4		4.6		3.4
IV	5		3.0		2.9
IV	6		3.8		3.8
IV	7		4.6		4.6
Mean			4.3		4.1
V	1		4.7		4.5
V	2		5.2		5.2
V	3		5.3		5.2
V	4		5.1		5.0
V	5		5.2		5.1
V	6		4.8		4.9
V	7		4.8		4.7
V	8		4.4		4.4
V	9		4.4		4.4
V	10		4.2		4.0
Mean			4.8		4.7

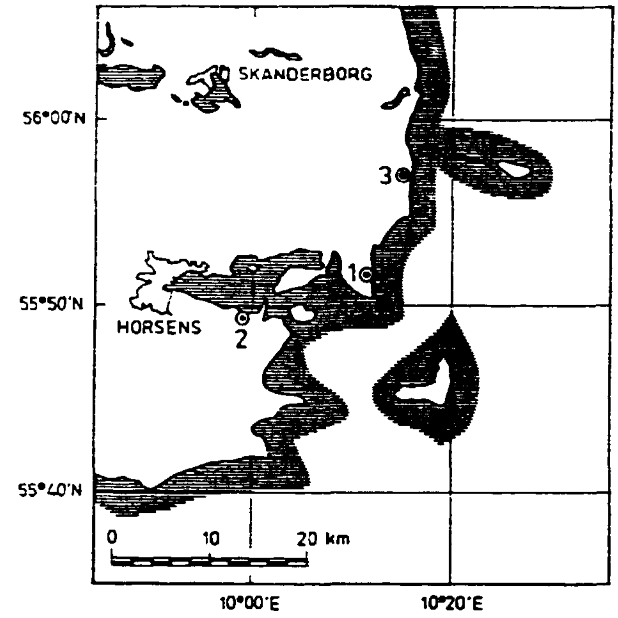


Figure 8.4.1. The environment of Gylling Næs. Locations for measurements of the background radiation.

Figure 8.5.1. The coasts of the Great Belt. Locations for measurements of the background radiation.

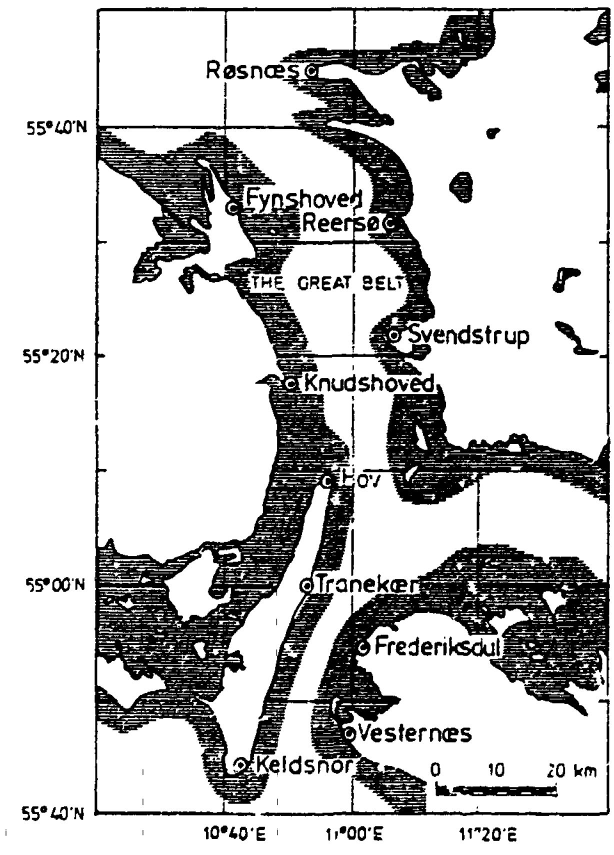


Table 8.4.1.A. TLD-measurements of the background radiation (integrated over 12 months and normalized to μR h^{-1}) at the Gylling Næs site in 1989/90

Location	Sep 1989 - Sep 1990 μR h^{-1}
1	8.2
2	-
3	8.3
Mean	8.2

Table 8.4.1.B. TLD-measurements of the background radiation (integrated over 12 months and normalized to μR h^{-1}) at the Gylling Næs site in 1990/91

Lost.

Table 8.5.1.A. TLD-measurements of the background radiation (integrated over 12 months and normalized to μR h^{-1}) along the coasts of the Great Belt and Langeland Belt in 1989/90

Location	Sep 1989 - Sep 1990 μR h^{-1}
Røsnæs	7.5
Reersø	8.7
Svendstrup	7.5
Vesternæs	8.7
Frederiksdal	8.4
Kelds Nor	9.9
Tranekær	12.2
Hov	8.3
Fyns Hoved	9.1
Knuds Hoved	10.1
Mean	9.0

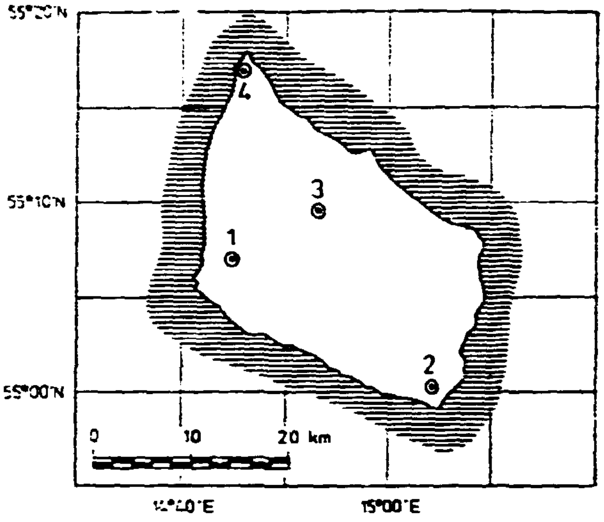


Figure 8.6.1. Locations for measurements on Bornholm.

Table 8.5.1.B. TLD-measurements of the background radiation (integrated over 12 months and normalized to μR h^{-1}) along the coasts of the Great Belt and Langeland Belt in 1990/91

Lost.

Table 8.6.1.A. TLD-measurements of the background radiation (integrated over 12 months and normalized to μR h^{-1}) on the island of Bornholm in 1989/90

Location	May 1989 - May 1990 μR h^{-1}
1	9.5
2	9.4
3	9.7
4	15.1
Mean	10.9

Table 8.6.1.B. TLD-measurements of the background radiation (integrated over 13 months and normalized to μR h^{-1}) on the island of Bornholm in 1990/91

Location	May 1990 - May 1991 μR h^{-1}
1	11.6
2	11.5
3	12.9
4	16.5
Mean	13.1

9. Conclusion

9.1. Environmental Monitoring at Risø

No radioactive contamination of the environment originating from the operation of Risø National Laboratory was ascertained outside its boundaries in 1990 and 1991.

9.2. Fallout in the Abiotic Environment

The mean content of ^{90}Sr in air collected in 1990 and 1991 were 0.3 $\mu Bq\ m^{-3}$.

The mean concentrations of ^{137}Cs in air from 1990 and 1991 were 1.0 and 0.9 $\mu Bq\ m^{-3}$, respectively.

The depositions of ^{90}Sr at the ten State experimental farms in Denmark were 0.5 $Bq\ m^{-2}$ in 1990 and 0.6 $Bq\ m^{-2}$ in 1991. The corresponding depositions for ^{137}Cs were 2.6 and 1.6 $Bq\ m^{-2}$.

The concentrations of ^{90}Sr and ^{137}Cs in the surface sea water of inner Danish waters have been nearly unchanged since 1987, i.e. about 16 Bq $^{90}Sr\ m^{-3}$ and 76 Bq $^{137}Cs\ m^{-3}$.

9.3. Fallout Nuclides in the Human Diet

The mean concentrations in Danish milk were 0.05 Bq $^{90}Sr\ l^{-1}$ and 0.10 Bq $^{137}Cs\ l^{-1}$ in 1990 and in 1991 the levels were 0.046 and 0.076, respectively. The effective halflife of ^{90}Sr in Danish milk was 10 years and for global fallout ^{137}Cs it was 6 years. The halflife of Chernobyl ^{137}Cs has shown an increasing tendency in all samples. During 1987-1989 it was 1 year in Danish milk, during 1989 to 1991 it had increased to 3 years.

Danish grain from 1990-1991 contained 0.3 Bq $^{90}Sr\ kg^{-1}$ and 0.09 Bq $^{137}Cs\ kg^{-1}$.

Danish vegetables (cabbage and carrots) contained 0.2 Bq $^{90}Sr\ kg^{-1}$ and 0.05 Bq $^{137}Cs\ kg^{-1}$ in 1990 and 1991. Potatoes showed mean concentrations of 0.03 Bq $^{90}Sr\ kg^{-1}$ and 0.06 Bq $^{137}Cs\ kg^{-1}$.

The intake of ^{90}Sr with total diet was 0.13 $Bq\ d^{-1}$ in 1990 and 1991, and the ^{137}Cs intake was 0.3. The effective halflife of Chernobyl ^{137}Cs in Danish total diet is 3 years, while global fallout ^{137}Cs decays with approx. 5 years halflife. Strontium-90 has decayed with an effective halflife similar to the radiological halflife.

9.4. Strontium-90 and Cesium-137 in Humans

The ^{90}Sr mean content in adult human bone (vertebrae) collected in 1990 was 17 Bq (kg Ca)$^{-1}$ and in 1991 the level was 18.

Whole-body measurements of ^{137}Cs were resumed after the Chernobyl accident. The measured mean level in 1990 was 359 Bq ^{137}Cs (kg K)$^{-1}$.

9.5. Tritium in Environmental Samples

The tritium mean concentrations in 1990 and 1991 in stream and lake water were around 2 $kBq\ m^{-3}$. The mean content of precipitation in 1990 and 1991 was 2.3 $kBq\ m^{-3}$.

9.6. Background Radiation

The average total background exposure rate measured with TLDs at the State experimental farms was 7.7 μR h^{-1}. The mean of the terrestrial exposure rates at the State experimental farms measured with the NaI(Tl) detector was 4.2 μR h^{-1}. The annual means in 1990-1991 are not different from the levels prior to the Chernobyl accident.

Acknowledgements

The authors wish to thank the staff of the Ecology Section for their conscientious performance of their work of this report.

We are specially indebted to the staffs of the ten State experimental farms at Tylstrup, Kalø, Borris, Askov, St. Jyndevad, Årslev, Tystofte, Ledreborg, Abed, Kannikegård and Tornbygård, who have continued to supply us with a number of the most important samples dealt with in this report.

R/V DANA belonging to the Ministry of Fisheries have collected surface water samples from the North Sea, the Danish Straits, and the Baltic Sea.

R/V GAUSS and other vessels from the Bundesamt für Seeschiffahrt und Hydrographie, formerly the German Hydrografic Institute, in Hamburg, collected a substantial number of the sea water samples in this report.

DMU (National Environmental Research Institute) assisted with the collection of sea water samples from the inner Danish waters.

Part of this work was supported by the CEC Radiation Protection Programme (contract no. B17-0044) by the CEC MAST Programme (contract MAST-052-c) and by the Nordic Nuclear Safety Research Programme.

Appendix A

Revised Models for ^{137}Cs in Danish Grain

(Cf. Risø-R-570) (Risø Reports, 1957-1991).

Rye	Jutland	:	$Bq\ kg_{(i)} = 0.074\ d_{i(May\text{-}Aug)} + 0.032 \cdot 10^{-3}\ A_i\ (30)$
Rye	Islands	:	$Bq\ kg_{(i)} = 0.078\ d_{i(May\text{-}Aug)} + 0.005 \cdot 10^{-3}\ A_i\ (30)$
Barley	Jutland	:	$Bq\ kg_{(i)} = 0.063\ d_{i(May\text{-}Aug)} + 0.017 \cdot 10^{-3}\ A_i\ (30)$
Barley	Islands	:	$Bq\ kg_{(i)} = 0.052\ d_{i(May\text{-}Aug)} + 0.001 \cdot 10^{-3}\ A_i\ (30)$
Wheat	Jutland	:	$Bq\ kg_{(i)} = 0.063\ d_{i(May\text{-}Aug)} + 0.017 \cdot 10^{-3}\ A_i\ (30)$
Wheat	Islands	:	$Bq\ kg_{(i)} = 0.045\ d_{i(May\text{-}Aug)} + 0.006 \cdot 10^{-3}\ A_i\ (30)$
Oats	Jutland	:	$Bq\ kg_{(i)} = 0.052\ d_{i(May\text{-}Aug)} + 0.064 \cdot 10^{-3}\ A_i\ (30)$
Oats	Islands	:	$Bq\ kg_{(i)} = 0.049\ d_{i(May\text{-}Aug)} + 0.005 \cdot 10^{-3}\ A_i\ (30)$

where $d_{i(May\text{-}Aug)}$ is the fallout rate in Bq ^{137}Cs m^{-2} in May-Aug in year (i) and A_i is the accumulated fallout by year (i) in Bq ^{137}Cs m^{-2} according to Appendix D.3.

Appendix B

Statistical information

Zone		ΔΔΔ Area in km²	ΔΔPopulation in thousands	ΔAnnual milk production in mega-kg	ΔAnnual wheat production in mega-kg	ΔAnnual rye production in mega-kg	ΔAnnual potato production in mega-kg	ΔGrass and green fodder production in mega-kg
I:	North Jutland	6,171	482	893				
II:	East Jutland	7,561	909	1,427	980	425	980	17,649
III:	West Jutland	12,104	711	1,326				
IV:	South Jutland	3,929	250	663				
V:	Funen	3,486	455	357				
VI:	Zealand	7,435	2,115*	306	992	140	120	2,536
VII:	Lolland-Falster	1,795	141	76				
VIII:	Bornholm	588	47	51				
Total		43,069	5,110	5,099	1,972	565	1,100	20,185

*1,170,000 people were living in Greater Copenhagen and 945,000 in the remaining part of Zealand.

Δ (ref. Danmarks Statistik 1986)
ΔΔ (ref. Danmarks Statistik 1988)
ΔΔΔ (ref. Danmarks Statistik 1972)

Appendix C

A Comparison Between Observed and Predicted Levels in the Human Food Chain in Denmark in 1990 and 1991

Table C.1. A Comparison between observed and predicted ^{90}Sr levels in environmental samples collected in 1990

Sample	Location	Unit	Number observations in mean	Observed ±1 S.E. (Arithmetic mean)	Predicted	Obs./pred.	Model in reference (*Aarkrog* 1979)
Dried milk	Jutland	Bq ^{90}Sr (kg Ca)$^{-1}$	3	50 ±4	100	0.50	a)
-"-	Islands	-"-	3	34 ±2	31	1.10	a)
Rye	Jutland	Bq ^{90}S. .g^{-1}		0.38	0.37	1.03	C.2.2.1 No. 1
"	Islands	-"-		0.168	0.102	1.64	C.2.2.1 No. 3
Barley	Jutland	-"-	2	0.57 ±0.11	0.63	0.90	C.2.2.1 No. 4
"	Islands	-"-	2	0.19 ±0.01	0.198	0.96	C.2.2.1 No. 6
Wheat	Jutland	-"-	2	0.62 ±0.21	0.45	1.38	C.2.2.1 No. 8
"	Islands	-"-	2	0.20 ±0.05	0.160	1.25	C.2.2.1 No. 10
Oats	Jutland	-"-		0.63	1.29	0.49	C.2.2.1 No 12
"	Islands	-"-		0.22	0.58	0.38	C.2.2.1 No. 13
Potatoes	Jutland	-"-		0.027	0.091	0.30	C.2.5.1 No. 8
"	Islands	-"-		0.038	0.083	0.46	C.2.5.1 No. 10
Cabbage	Jutland	-"-		0.21	0.29	0.72	C.2.5.1 No. 1
"	Islands	-"-		0.111	0.25	0.44	C.2.5.1 No. 3
Carrot	Jutland	-"-		0.43	0.49	0.88	C.2.5.1 No. 5
"	Islands	-"-		0.22	0.13	1.69	C.2.5.1 No. 6
Apples	Denmark	-"-	2	0.022±0.012	0.011	2.00	C.2.5.1 No. 13
Pork	"	-"-		0.002	0.021	0.10	C.3.4.1 No. 3
Beef	"	-"-		0.0074	0.031	0.24	C.3.4.1 No. 1
Eggs	"	-"-		-	0.0091	-	C.3.6.1 No. 6
Total diet C	"	Bq ^{90}Sr (kg Ca)$^{-1}$		122	127	0.96	C.4.2.1 No. 1
Total diet P	"	-"-		104	96	1.08	C.4.2.1 No. 7
Human bone > 29 yr	"	-"-	12	16.7 ±2.0	36	0.46	C.4.3.1 No. 13
Whole year grass	Islands	-"-	4	230 ±14	332	0.69	C.2.4.1 No. 1
Fucus vesiculosus	"	-"-		116	401	0.29	C.2.7.1 No. 3
Ground water*	Denmark	Bq ^{90}Sr m^{-3}		-	0.20	-	C.1.4.1 No. 1
Stream water*	"	-"-		-	5.75	-	C.1.4.1 No. 3
Lake water*	"	-"-		-	33	-	C.1.4.1 No. 6

* No samples in 1990.

a) New prediction models from Table C.3.1 in Risø-R-540.

Table C.1.B. Comparison between observed and predicted ^{90}Sr levels in environmental samples collected in 1991

Sample	Location	Unit	Number observations in mean	Observed ±1 S.E. (Arithmetic mean)		Predicted	Obs./pred.	Model in reference (*Aarkrog* 1979)
Dried milk	Jutland	Bq ^{90}Sr (kg Ca)$^{-1}$	3	43	±2	96	0.45	a)
-"-	Islands	-"-	3	34	±2	29	1.17	a)
Rye	Jutland	Bq ^{90}Sr kg^{-1}		0.32		0.35	0.91	C.2.2.1 No. 1
"	Islands	-"-		0.169		0.112	1.51	C.2.2.1 No. 3
Barley	Jutland	-"-	2	0.36	±0.03	0.53	0.68	C.2.2.1 No. 4
"	Islands	-"-	2	0.29	±0.02	0.196	1.48	C.2.2.1 No. 6
Wheat	Jutland	-"-	2	0.35	±0.10	0.35	1.00	C.2.2.1 No. 8
"	Islands	-"-	2	0.24	±0.09	0.157	1.53	C.2.2.1 No. 10
Oats	Jutland	-"-		0.55		1.20	0.42	C.2.2.1 No. 12
"	Islands	-"-		0.30		0.57	0.53	C.2.2.1 No. 13
Potatoes	Jutland	-"-		0.031		0.089	0.35	C.2.5.1 No. 8
"	Islands	-"-		0.027		0.031	0.33	C.2.5.1 No. 10
Cabbage	Jutland	-"-		0.22		0.28	0.79	C.2.5.1 No. 1
"	Islands	-"-		0.077		0.24	0.32	C.2.5.1 No. 3
Carrot	Jutland	-"-		0.29		0.48	0.60	C.2.5.1 No. 5
"	Islands	-"-		0.21		0.12	1.75	C.2.5.1 No. 6
Apples	Denmark	-"-		0.0128±0.0028		0.011	1.16	C.2.5.1 No. 13
Pork	"	-"-		0.0020		0.020	0.10	C.3.4.1 No. 3
Beef	"	-"-		0.0069		0.030	0.23	C.3.4.1 No. 1
Eggs	"	-"-		0.0109		0.0083	1.31	C.3.6.1 No. 6
Total diet C	"	Bq ^{90}Sr (kg Ca)$^{-1}$		123		123	1.00	C.4.2.1 No. 1
Total diet P	"	-"-		88		92	0.96	C.4.2.1 No. 7
Human bone > 29 yr	"	-"-	8	17.7	±1.46	34	0.52	C.4.3.1 No. 13
Whole year grass	Islands	-"-	4	250	±20	307	0.81	C.2.4.1 No. 1
Fucus vesiculosus	"	-"-	1	127		388	0.33	C.2.7.1 No. 3
Ground water*	Denmark	Bq ^{90}Sr m^{-3}		-		0.19	-	C.1.4.1 No. 1
Stream water	"	-"-	8	7.0	±0.9	5.6	1.25	C.1.4.1 No. 3
Lake water	"	-"-	8	11.3	±2.0	32	0.35	C.1.4.1 No. 5

*No samples in 1991.

a) See note to Table C.1.A.

Table C.2.A. Comparison between observed and predicted ^{137}Cs levels in environmental samples collected in 1990

Sample	Location	Unit	Number observations in mean	Observed ±1 S.E. (Arithmetic mean)	Predicted	Obs./pred.	Model in reference (*Aarkrog* 1979)	
Dried milk	Jutland	Bq ^{137}Cs (kg K)$^{-1}$	48	106 ±7	112	0.95	a)	
-"-	Islands	-"-	36	35 ±2	34	1.03	a)	
Rye	Jutland	Bq ^{137}Cs kg^{-1}		0.36	0.22	1.64	Appendix A	This report
"	Islands	-"-		0.096	0.64	1.50	Appendix A	
Barley	Jutland	-"-		0.116	0.150	0.77	Appendix A	
"	Islands	-"-		0.024	0.035	0.69	Appendix A	
Wheat	Jutland	-"-		0.186	0.150	1.24	Appendix A	
"	Islands	-"-		0.020	0.046	0.43	Appendix A	
Oats	Jutland	-"-		0.23	0.31	0.74	Appendix A	
"	Islands	-"-		0.054	0.046	1.17	Appendix A	
Potatoes	Jutland	-"-		0.113	0.161	0.70	C.2.5.3 No. 5	
"	Islands	-"-		0.069	0.005	13.8	C.2.5.3 No. 7	
Cabbage	Denmark	-"-	2	0.092±0.067	0.060	1.53	C.2.5.3 No. 1	
Carrot	"	-"-	2	0.087±0.070	0.038	2.29	C.2.5.3 No. 3	
Apples	"	-"-	2	0.038±0.0065	0.157	0.24	C.2.5.3 No. 11	
Pork	"	-"-		0.165	0.29	0.57	C.3.4.2 No. 3	
Beef	"	-"-		3.5	0.60	5.83	C.3.4.2 No. 1	
Eggs*	"	-"-		-	0.041	-	C.3.6.2 No. 6	
Total diet C	"	Bq ^{137}Cs (kg K)$^{-1}$		106	21	5.05	C.4.2.2 No. 1	
Total diet P	"	-"-		130	74	1.76	C.4.2.2 No. 6	
Persons	Zealand	-"-		359	719	0.50	C.4.5.1 No. 1	

*No samples in 1990.
a) Cf. Table C.1.A.

Table C.2.B. Comparison between observed and predicted ^{137}Cs levels in environmental samples collected in 1991

Sample	Location	Unit	Number observations in mean	Observed ±1 S.E. (Arithmetic mean)	Predicted	Obs./pred.	Model in reference (*Aarkrog* 1979)
Dried milk	Jutland	Bq ^{137}Cs (kg K)$^{-1}$	48	77±1	85	0.91	a)
-"-	Islands	-"-	36	26±2	32	0.81	a)
Rye	Jutland	Bq ^{137}Cs kg^{-1}		0.157	0.187	0.84	Appendix A (This report)
"	Islands	-"-		0.052	0.056	0.93	Appendix A
Barley	Jutland	-"-		0.088	0.122	0.72	Appendix A
"	Islands	-"-		0.079	0.031	2.55	Appendix A
Wheat	Jutland	-"-		0.086	0.122	0.70	Appendix A
"	Islands	-"-		0.027	0.042	0.64	Appendix A
Oats	Jutland	-"-		0.35	0.29	1.21	Appendix A
"	Islands	-"-		0.073	0.041	1.78	Appendix A
Potatoes	Jutland	-"-		0.113	0.152	0.74	C.2.5.3 No. 5
"	Islands	-"-		0.042	0.004	10.5	C.2.5.3 No. 7
Cabbage	Denmark	-"-		0.058	0.054	1.07	C.2.5.3 No. 1
Carrot	"	-"-		0.034	0.030	1.13	C.2.5.3 No. 3
Apples	"	-"-		0.044	0.082	0.54	C.2.5.3 No. 11
Pork	"	-"-		0.49	0.169	2.90	C.3.4.2 No. 3
Beef	"	-"-		0.44	0.42	1.05	C.3.4.2 No. 1
Eggs	"	-"-		0.030	0.036	0.83	C.3.6.2 No. 6
Total diet C	"	Bq ^{137}Cs (kg K)$^{-1}$		66	10.3	6.41	C.4.2.2 No. 1
Total diet P	"	-"-		107	59	1.81	C.4.2.2 No. 6

a) Cf. Table C.1.A.

Appendix D

Fallout Rates and Accumulated Fallout in Denmark 1950-1991

d_i

Annual fallout rate in mCi ^{90}Sr km^{-2} y^{-1} or Bq ^{90}Sr m^{-2} y^{-1}. Accumulated fallout by the end of the year (i) assuming effective half-lives of ^{90}Sr of 28.8 y. Unit: mCi ^{90}Sr km^{-2} or Bq ^{90}Sr m^{-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} or Bq ^{90}Sr m^{-2} period^{-1}. The fallout rate (d_i) was based on precipitation data collected for all Denmark in the period 1962-1984 (cf. Table 4.2.1) (Risø Reports 1957-1989). Before 1962 the levels in the table were estimated from the HASL data for New York (HASL Appendix 291, 1975) (HASL 1958-1978) 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 4.2 (Risø Reports 1957-1991) for the period 1962-1984. 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.

Table D.1 shows the mCi ^{90}Sr km^{-2} figures and Table D.2 gives the Bq m^{-2} values.

Table D.3 (Bq ^{137}Cs m^{-2}) was until 1986 based upon Table D.2 (the ^{137}Cs fallout was assumed to be 1.6 times the ^{90}Sr). Since 1986 the ^{137}Cs fallout has been based on actual measurements.

Appendix D.1. Fallout rates and accumulated fallout (mCi ^{90}Sr km^{-2}) in Denmark 1950-1991

	Denmark		Jutland		Islands	
Year	di	$Ai_{(28.82)}$	di	$Ai_{(28.82)}$	di	$Ai_{(28.82)}$
1950	0.021	0.020	0.022	0.021	0.020	0.020
1951	0.101	0.118	0.114	0.132	0.088	0.105
1952	0.198	0.309	0.224	0.347	0.172	0.270
1953	0.500	0.789	0.566	0.891	0.434	0.687
1954	1.901	2.623	2.152	2.967	1.650	2.279
1955	2.501	4.997	2.831	5.655	2.171	4.340
1956	3.101	7.898	3.510	8.939	2.692	6.858
1957	3.101	10.728	3.510	12.142	2.692	9.313
1958	4.302	14.658	4.869	16.591	3.734	12.725
1959	6.102	20.247	6.908	22.918	5.297	17.576
1960	1.140	20.859	1.291	23.610	0.990	18.107
1961	1.481	21.787	1.676	24.661	1.285	18.913
1962	7.428	28.493	7.976	31.830	6.880	25.155
1963	16.695	44.071	18.453	49.041	14.937	39.101
1964	10.412	53.136	11.685	59.225	9.139	47.048
1965	3.954	55.679	4.204	61.861	3.704	49.497
1966	2.145	56.395	2.166	62.445	2.124	50.345
1967	1.047	56.023	1.176	62.048	0.918	49.997
1968	1.403	56.006	1.568	62.045	1.237	49.968
1969	1.035	55.632	1.241	61.721	0.829	49.542
1970	1.647	55.863	1.993	62.140	1.301	49.586
1971	1.506	55.951	1.726	62.288	1.286	49.615
1972	0.435	54.993	0.457	61.194	0.413	48.792
1973	0.192	53.821	0.215	59.891	0.168	47.750
1974	0.710	53.183	0.779	59.171	0.643	47.197
1975	0.414	52.272	0.452	58.150	0.376	46.397
1976	0.103	51.082	0.116	56.826	0.090	45.339
1977	0.384	50.204	0.405	55.827	0.362	44.581
1978	0.463	49.426	0.538	54.985	0.388	43.867
1979	0.166	48.379	0.174	53.810	0.156	42.947
1980	0.095	47.244	0.114	52.556	0.078	41.932
1981	0.451	46.358	0.309	51.559	0.269	41.159
1982	0.046	45.257	0.048	50.332	0.043	40.184
1983	0.036	44.174	0.036	49.123	0.037	39.227
1984	0.029	43.110	0.033	47.941	0.026	38.283
1985	0.022	42.067	0.020	46.776	0.023	37.360
1986	1.041	42.042	1.081	46.674	1.000	37.412
1987	0.039	42.022	0.038	46.649	0.040	37.396
1988	0.027	41.049	0.024	45.564	0.030	36.537
1989	0.0147	40.088	0.0112	44.492	0.0183	35.687
1990	0.0137	39.149	0.0113	43.445	0.0160	34.854
1991	0.0151	38.233	0.0056	42.418	0.0095	34.035

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	2.01	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	0.590	0.42
4.223	1.857	4.566	2.052	3.880	1.562
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
0.232	0.096	0.275	0.098	0.188	0.093
0.086	0.030	0.087	0.031	0.084	0.029
0.051	0.022	0.064	0.025	0.038	0.0180
0.175	0.060	0.176	0.058	0.174	0.061
0.022	0.0071	0.024	0.0085	0.020	0.0058
0.013	0.0048	0.015	0.0055	0.0114	0.0043
0.013	0.0075	0.016	0.0090	0.0106	0.0059
0.0086	0.0054	0.0075	0.0046	0.0088	0.0062
0.74	0.052	0.78	0.055	0.70	0.048
0.0159	0.0068	0.0178	0.0068	0.0141	0.0070
0.0121	0.0075	0.0125	0.0074	0.0117	0.0076
0.0077	0.0042	0.0059	0.0025	0.0095	0.0060
0.0069	0.0037	0.0070	0.0034	0.0068	0.0041
0.0081	0.0052	0.0059	0.0026	0.0102	0.0078

Appendix D.2. Fallout rates and accumulated fallout (Bq ^{90}Sr m^{-2}) in Denmark 1950-1991

	Denmark		Jutland		Islands	
Year	di	$Ai_{(28.82)}$	di	$Ai_{(28.82)}$	di	$Ai_{(28.82)}$
1950	0.777	0.759	0.814	0.795	0.740	0.722
1951	3.737	4.389	4.218	4.894	3.256	3.884
1952	7.326	11.436	8.288	12.868	6.364	10.004
1953	18.500	29.225	20.942	33.007	16.058	25.443
1954	70.337	97.196	79.624	109.954	61.050	84.438
1955	92.537	185.224	104.747	209.599	80.327	160.849
1956	114.737	292.833	129.870	331.402	99.604	254.264
1957	114.737	397.884	129.870	450.310	99.604	345.458
1958	159.174	543.820	180.153	615.481	138.158	472.124
1959	225.774	751.306	255.596	850.377	195.989	652.236
1960	42.180	774.629	47.767	876.800	36.630	672.495
1961	54.797	809.716	62.012	916.502	47.545	702.929
1962	274.836	1058.779	295.112	1182.821	254.560	934.736
1963	617.715	1636.653	68[illegible].761	1821.249	552.669	1452.058
1964	385.244	1973.849	4[illegible]2.345	2200.039	338.143	1747.659
1965	146.298	2069.764	155.548	2299.609	137.048	1839.918
1966	79.365	2098.057	80.142	2323.199	78.588	1872.915
1967	38.739	2086.017	43.512	2310.468	33.966	1861.566
1968	51.911	2087.122	58.016	2312.200	45.769	1862.009
1969	38.295	2074.909	45.917	2302.078	30.673	1847.704
1970	60.939	2085.092	73.741	2319.360	48.137	1850.789
1971	55.722	2089.939	63.862	2326.587	47.582	1853.258
1972	16.095	2055.987	16.909	2287.806	15.281	1824.135
1973	7.104	2014.063	7.955	2241.204	6.216	1786.854
1974	26.270	1991.847	28.823	2216.082	23.791	1767.617
1975	15.318	1959.467	16.724	2179.746	13.912	1739.193
1976	3.811	1916.622	4.292	2132.136	3.330	1701.114
1977	14.208	1884.946	14.985	2096.097	13.394	1673.764
1978	17.131	1856.876	19.906	2065.718	14.356	1648.004
1979	6.142	1818.745	6.438	2022.914	5.772	1614.475
1980	3.504	1778.945	4.229	1979.966	2.869	1577.924
1981	10.662	1747.079	11.447	1944.499	9.967	1549.659
1982	1.691	1707.212	1.782	1900.127	1.601	1514.297
1983	1.344	1667.954	1.329	1856.433	1.359	1479.475
1984	1.094	1629.385	1.209	1813.506	0.980	1445.264
1985	0.806	1591.452	0.744	1771.286	0.868	1411.618
1986	38.5	1591.218	40	1766.622	37	1415.882
1987	1.44	1554.810	1.41	1726.017	1.47	1383.670
1988	0.989	1518.827	0.874	1685.853	1.105	1351.867
1989	0.544	1483.265	0.413	1646.193	0.677	1320.402
1990	0.506	1448.510	0.418	1607.481	0.593	1289.603
1991	0.560	1414.635	0.207	1569.483	0.353	1259.302

	Denmark		Jutland		Islands	
Year	$di_{(May-Aug)}$	$di_{(July-Aug)}$	$di_{(May-Aug)}$	$di_{(July-Aug)}$	$di_{(May-Aug)}$	$di_{(July-Aug)}$
1950	0.370	0.370	0.370	0.370	0.370	0.370
1951	1.850	0.740	2.220	1.110	1.850	0.740
1952	4.070	1.850	4.440	1.850	3.330	1.480
1953	9.990	4.440	11.470	5.180	8.510	3.700
1954	38.110	17.020	42.920	19.240	32.930	14.800
1955	49.950	22.200	56.610	25.160	43.290	19.240
1956	61.790	27.380	70.300	31.080	53.650	24.050
1957	61.790	27.380	70.300	31.080	53.650	24.050
1958	85.840	38.110	97.310	43.290	74.740	33.300
1959	92.500	25.160	102.120	27.750	82.880	22.570
1960	17.390	11.470	19.240	12.580	15.540	10.360
1961	24.420	17.390	27.010	19.240	21.830	15.540
1962	156.251	68.709	168.942	75.924	143.560	61.494
1963	368.705	208.273	397.861	219.484	339.549	197.099
1964	230.695	95.016	265.290	107.670	196.063	82.362
1965	75.073	31.450	77.478	31.524	72.668	31.376
1966	38.813	15.466	36.408	18.352	41.218	12.580
1967	13.579	5.217	14.060	4.958	13.098	5.476
1968	31.376	15.762	33.670	17.020	29.082	14.504
1969	22.718	10.212	26.751	11.803	18.685	8.621
1970	33.596	20.239	39.812	23.384	27.380	17.094
1971	36.704	14.985	42.698	19.092	30.710	10.878
1972	9.361	3.108	9.694	3.108	9.028	3.108
1973	2.775	1.221	3.441	1.443	2.109	0.999
1974	15.577	7.030	17.131	8.103	13.986	5.994
1975	5.883	2.775	6.623	3.367	5.809	2.220
1976	1.184	0.370	1.184	0.407	1.184	0.333
1977	6.586	3.959	6.068	3.145	7.030	4.773
1978	8.584	3.552	10.175	3.626	6.956	3.441
1979	3.182	1.110	3.219	1.147	3.108	1.073
1980	1.903	0.816	2.386	0.936	1.420	0.664
1981	6.464	2.205	6.494	2.144	6.433	2.265
1982	0.816	0.263	0.876	0.314	0.755	0.215
1983	0.453	0.178	0.544	0.202	0.423	0.160
1984	0.488	0.277	0.581	0.336	0.395	0.216
1985	0.318	0.200	0.276	0.169	0.326	0.230
1986	27.4	1.91	28.8	2.05	26.0	1.76
1987	0.59	0.25	0.66	0.25	0.52	0.26
1988	0.447	0.276	0.462	0.272	0.432	0.280
1989	0.285	0.157	0.219	0.093	0.351	0.221
1990	0.255	0.138	0.259	0.126	0.253	0.151
1991	0.298	0.193	0.218	0.097	0.378	0.289

Appendix D.3. Fallout rates and accumulated fallout (Bq ^{137}Cs m^{-2}) in Denmark 1950-1991

Year	Denmark		Jutland		Islands	
	d_i	$Ai_{(30.02)}$	d_i	$Ai_{(30.02)}$	d_i	$Ai_{(30.02)}$
1950	1.243	1.215	1.302	1.273	1.184	1.157
1951	5.979	7.030	6.749	7.838	5.210	6.221
1952	11.722	18.323	13.261	20.618	10.182	16.029
1953	29.600	46.830	33.507	52.889	25.693	40.770
1954	112.539	155.731	127.398	176.173	97.680	135.290
1955	148.059	296.857	167.595	335.922	128.523	257.792
1956	183.579	469.471	207.792	531.304	159.366	407.637
1957	183.579	638.145	207.792	722.227	159.366	554.062
1958	254.678	872.445	288.245	987.409	221.053	757.424
1959	361.238	1205.526	408.954	1364.492	313.582	1046.561
1960	67.488	1243.959	76.427	1408.032	58.608	1079.940
1961	87.675	1301.241	99.219	1472.849	76.072	1129.632
1962	439.738	1701.242	472.179	1900.635	407.296	1501.849
1963	988.344	2628.199	1092.418	2924.739	884.270	1331.659
1964	616.390	3170.535	691.752	3533.949	541.029	2807.121
1965	234.077	3326.905	248.877	3696.486	219.277	2957.324
1966	126.984	3375.057	128.227	3737.418	125.741	3012.697
1967	61.982	3358.593	69.619	3720.145	54.346	2997.040
1968	83.058	3363.098	92.826	3725.944	73.230	3000.195
1969	61.272	3346.212	73.467	3712.693	49.077	2979.675
1970	97.502	3365.115	117.986	3743.247	77.019	2986.928
1971	89.155	3375.430	102.179	3757.659	76.131	2993.148
1972	25.752	3323.554	27.054	3698.331	24.450	2948.724
1973	11.366	3258.804	12.728	3626.358	9.946	2891.141
1974	42.032	3225.498	46.117	3588.654	38.066	2862.350
1975	24.509	3175.328	26.758	3532.894	22.259	2818.771
1976	6.098	3109.302	6.867	3458.970	5.328	2759.642
1977	22.733	3060.549	23.976	3403.451	21.430	2717.597
1978	27.410	3017.479	31.650	3356.893	22.970	2678.016
1979	9.827	2958.211	10.301	3290.341	9.235	2625.917
1980	5.606	2896.171	6.766	3221.854	4.591	2570.470
1981	17.059	2846.738	18.316	3165.216	15.948	2527.385
1982	2.706	2784.409	2.851	3096.736	2.561	2472.203
1983	2.151	2722.959	2.126	3028.134	2.175	2417.902
1984	1.751	2662.521	1.935	2960.911	1.567	2364.247
1985	1.290	2603.012	1.191	2894.495	1.388	2311.642
1986	1210.000	3725.984	1340.000	4137.847	1080.000	3314.232
1987	29.000	3669.280	32.000	4074.674	26.000	3263.994
1988	11.900	3597.161	13.400	3994.768	10.300	3199.562
1989	3.500	3518.480	4.510	3907.998	2.530	3129.007
1990	2.63	3440.744	3.85	3822.564	1.41	3058.968
1991	1.63	3363.805	1.92	3737.194	1.36	2990.480

	Denmark		Jutland		Islands	
Year	$di_{(May-Aug)}$	$di_{(July-Aug)}$	$di_{(May-Aug)}$	$di_{(July-Aug)}$	$di_{(May-Aug)}$	$di_{(July-Aug)}$
1950	0.592	0.592	0.592	0.592	0.592	0.592
1951	2.960	1.184	3.552	1.776	2.960	1.184
1952	6.512	2.960	7.104	2.960	5.328	2.368
1953	15.984	7.104	18.352	8.288	13.616	5.920
1954	60.976	27.232	68.672	30.784	52.688	23.680
1955	79.920	35.520	90.576	40.256	69.264	30.784
1956	98.864	43.808	112.480	49.728	85.840	38.480
1957	98.864	43.808	112.480	49.728	85.840	38.480
1958	137.344	60.976	155.696	69.264	119.584	53.280
1959	148.000	40.256	163.392	44.400	132.608	36.112
1960	27.824	18.352	30.784	20.128	24.864	16.576
1961	39.072	27.824	43.216	30.784	34.928	24.864
1962	250.062	109.934	270.307	121.478	229.696	98.390
1963	589.928	333.237	636.578	351.174	543.278	315.358
1964	369.112	152.026	424.464	172.272	313.701	131.779
1965	120.117	50.320	123.965	50.438	116.269	50.202
1966	62.101	24.746	58.253	29.363	65.949	20.129
1967	21.726	8.347	22.496	7.933	20.957	8.762
1968	50.202	25.219	53.872	27.232	46.531	23.206
1969	36.349	16.339	42.802	18.885	29.696	13.794
1970	53.754	32.382	63.599	37.414	43.808	27.350
1971	58.726	23.976	68.317	30.547	49.136	17.405
1972	14.978	4.973	15.510	4.973	14.445	4.973
1973	4.440	1.954	5.506	2.309	3.374	1.598
1974	24.923	11.248	27.410	12.965	22.378	9.590
1975	9.413	4.440	10.597	5.387	9.294	3.552
1976	1.894	0.592	1.894	0.551	1.894	0.533
1977	10.538	6.334	9.709	5.032	11.249	7.637
1978	13.734	5.683	16.280	5.802	11.130	5.506
1979	5.091	1.776	5.150	1.835	4.973	1.717
1980	3.045	1.305	3.818	1.498	2.271	1.063
1981	10.342	3.528	10.390	3.431	10.291	3.624
1982	1.305	0.420	1.401	0.503	1.208	0.345
1983	0.773	0.285	0.870	0.324	0.677	0.256
1984	0.781	0.443	0.929	0.538	0.632	0.347
1985	0.508	0.320	0.441	0.270	0.522	0.368
1966	772.000	78.000	790.000	94.000	754.000	63.000
1987	12.000	5.400	12.500	5.500	11.400	5.300
1988	4.800	2.400	5.310	2.620	4.160	2.080
1989	1.110	0.570	1.490	0.730	0.740	0.410
1990	0.99	0.40	1.35	0.54	0.62	0.27
1991	0.73	0.31	0.93	0.44	0.53	0.175

Appendix E

Transfer of Radiocesium in the Soil-Grass-Lamb Food Chain

by A. Aarkrog and S.P. Nielsen

This work is part of a Nordic comparative study carried out in all the Nordic countries (Denmark, The Faroe Islands, Finland, Iceland, Norway and Sweden). The purpose is to compare the radioecological sensitivity of radiocesium (Bq kg^{-1} year per Bq m^{-2}) in the soil-grass-lamb foodchain for a number of Nordic locations. As a first step the observed ratios between the levels in lamb and soil (0-5 cm layer), lamb and grass, and grass and soil are compared for the samples collected in 1990 and 1991.

A location in Southwest Denmark, Vester Vedsted 7 km SW of Ribe, was selected for the Danish samples. Lambs meat is only a marginal constituent of the average Danish diet (about 1% of the total meat consumption), but in the West Jutland there are a number of herds grazing lowland fallows behind the dikes to the North Sea.

Tables E.1-E.3 show the results of soil, grass and lamb analysis.

Conclusions

- There is no significant difference between $^{134}Cs/^{137}Cs$ in lamb, »grass« and soil (0-5 cm layer).
- The mean ratio in the samples at September 1, 1991, was 0.078±0.001 corresponding to 76% Chernobyl ^{137}Cs.
- The transfer of Chernobyl and global fallout ^{137}Cs does thus not differ significantly in this foodchain.
- The transfer of ^{137}Cs from soil (0-5 cm layer) to lamb meat (fresh weight) was 0.6 Bq kg^{-1} per kBq m^{-2} (rel. S.D.: ±40%).
- The transfer of ^{137}Cs from soil (0-5 cm layer) to »grass« (dry weight) was 0.7 Bq kg^{-1} per kBq m^{-2} (rel. S.D.: ±20%).
- The observed ratio between ^{137}Cs in lamb and grass (Bq kg^{-1} f.w./Bq kg^{-1} d.w.) was 0.8 (relative S.D.: ±30%).
- The observations were based upon 5 soil, 2 grass and 3 lamb samples collected from the same field at Ribe in SW Jutland in the summer of 1991.

Table E.1.A. Radiocesium in untreated, uncultivated soil (0-5 cm) collected in South Jutland (near Ribe) June 26, 1990. (Unit: Bq m^{-2})

No.	^{137}Cs	$^{134}Cs/^{137}Cs$	Chernobyl ^{137}Cs*
1	2179	0.122	1784
2	2133	0.102	1460
3	2327	0.114	1780
Mean	2213		1675
Relative S.D.	5%		11%

*Calculated from $^{134}Cs/^{137}Cs$ assuming that this ratio was 0.55 in pure Chernobyl debris on April 26, 1986.

Table E.1.B. Radiocesium in uncultivated soil collected in South Jutland (near Ribe) June 3, 1991. (Unit: Bq ^{137}Cs m^{-2}) ($^{134}Cs/^{137}Cs$)

Collection No.	0-5	5-10	10-20	Σ 0-10	Σ 0-20	Chernobyl ^{137}Cs* 0-5 cm
91018	2221 (0.092)	1593	948	3814	4762	1824
91019	1994 (0.076)	1683	-	3677	-	1353
91020	1694 (0.091)	1360	-	3054	-	1376
91021	2473 (0.086)	1232	-	3705	-	1899
91022	1799 (0.078)	1228	-	3027	-	1253
Mean	2036	1419	948	3455	4762	1541
Relative S.D.	16%	15%		11%		19%

*Calculated from $^{134}Cs/^{137}Cs$ assuming that this ratio was 0.55 in pure Chernobyl debris on April 26, 1986.

Table E.2.A Radiocesium in grass collected in South Jutland (near Ribe) in 1990

Date	^{137}Cs Bq kg^{-1} fresh	^{137}Cs Bq m^{-2}	^{134}Cs Bq kg^{-1} fresh	^{134}Cs Bq m^{-2}	^{40}K g kg^{-1} fresh
June 26	1.08	0.90	0.148	0.122	8.0

Table E.2.B Radiocesium in grass collected in South Jutland (near Ribe) in 1991

Date	Remarks	^{137}Cs Bq kg^{-1} fresh	^{137}Cs Bq kg^{-1} dry	^{137}Cs Bq m^{-2}	^{134}Cs Bq kg^{-1} fresh	^{134}Cs Bq kg^{-1} dry	^{134}Cs Bq m^{-2}	^{40}K g kg^{-1} fresh	^{40}K g kg^{-1} dry
3 June	Low	2.8	9.0	0.32	0.176	0.56	0.0198	6.3	20.3
3 June	High	1.18	4.8	1.06	0.120	0.49	0.108	8.5	34.9
10 July		1.172	1.51	0.144	<0.035			7.9	69.5
30 August		0.38	1.43	1.186	<0.052			11.6	44.2

Table E.3.A. Radiocesium in lamb meat collected in South Jutland (near Ribe) in 1990. (Unit: Bq kg^{-1} fresh)

Date	^{137}Cs	^{134}Cs	^{40}K*
June 26	5.0	0.68	3.4

*g K kg^{-1} fresh.

Table E.3.B. Radiocesium in lamb meat (neck) collected in South Jutland (near Ribe) August 27, 1991. (Unit: Bq kg^{-1} fresh)

Collection	^{137}Cs	^{134}Cs	^{40}K*
1	1.13	0.071 A	3.3
2	1.69	0.140 A	3.3
3	0.91	0.094 A	3.3
1+2+3 bulked	1.22	0.096	3.2

*g K kg^{-1} fresh.

Appendix F

by M. Strandberg

Radiocesium in a Danish Forest Ecosystem

Results from simultaneous samplings of soil and biota from a Danish forest are presented. Most samples are from a stand of Scotch pine (*Pinus silvestris*) in Tisvilde Hegn in North Zealand (NZ), Figure F.1, but a few results from Gribskov (NZ), Figure F.1, will also be presented here.

The Locality »Tisvilde Hegn«

Tisvilde Hegn is a marine influenced forest on sandy ground. Climatically Tisvilde Hegn belongs to the northern part of the ' 'mperate zone.

The site quality of the soil is low. The soil is m. '' sand covered by an approximately 5 cm thick layer of decomposed o._. ic matter. The clay content is low between 0 & 2 %, and pH about 5 (Nielsen & Strandberg 1989).

The composition of trees are mainly Scotch pine (*Pinus silvestris*), Norway spruce (*Pices abies*), Beech (*Fagus silvaticus*) and Oak (*Quercus robur*). Birch (*Betula pendula*) is common as upgrowth whereever light conditions allows it. The coniferous parts of the forest are very Scandinavian as regards composition of understorey species e.g. Linnaea borealis, Goodyera repens and Vaccinium vitis-idaea. Also the fungi species are widely distributed in Scandinavian coniferous forests e.g. Rozites caperatus and Russula decolorans. Lichen heath is often developed in areas with Scotch pine, where soil quality is low.

The sampling site is old seafloor, which gives a very plain topography. The area where sampling took place was mainly under Scotch pine, but some samples of fungi were c llected in other forest types.

Radiocesium in the Forest Soil

Both Chernobyl debris and global fallout cesium is still (1991) concentrated in the upper soil layers, see Table F.1 and Figure F.2.

From the ratio $^{134}Cs/^{137}Cs$ the Cs-contribution from Chernobyl can be calculated.

In the autumn of 1991 there is totally in the soil (down to 20 cm) and litter 3135 Bq ^{137}Cs m^{-2}, 923 Bq ^{137}Cs m^{-2} deriving from Chernobyl and 2212 Bq ^{137}Cs m^{-2} deriving from weapon testing, Table F.1. The Chernobyl cesium is distributed with 20% in the litter layer and 80% in the upper 5 cm of the soil column. The distribution of global fallout cesium in the soil column shows that 3% is in the litter layer, 56% is in the upper 5 cm, 27% in the 5-10 cm and 14% in the 10-20 cm layer (Figure F.2).

The occurrence of a higher proportion of ^{137}Cs to K in the upper soil layers might be part of an explanation of the availability of cesium in the forest ecosystems.

The observed low penetration of radiocesium in the soil layers is of course due to some kind of fixation or binding to soil compounds. The relative high bio-availability shows that the binding is reversible to some degree. This indicates that a part of the soil cesium in the forest ecosystem is bound in such a way that release to roots, rhizoids and mycelia of plants, mosses and fungi is possible. The low penetration and the high bioavailability from soil to plant of cesium, also constitutes the main differences between forest soil and agricultural soil. The very low clay content in the Tisvilde soil (*Nielsen & Strandberg* 1989) might be one explanation of the low fixation observed. The results indicate a higher availability of Chernobyl cesium than of fallout. Maybe the most likely explanation is that Chernobyl cesium is concentrated in the surface soil, where it to a large degree can be supposed to be associated with humus.

It can be calculated that 95% of the cesium in the system is in the soil and only 5% in above ground parts (*Strandberg* 1992). On the other hand if 20% or more of the soil cesium is situated in below ground parts of mycelia of fungi (Brückmann 1992), we can conclude that more than 25% of the cesium in the forest system are in the biosphere.

Differences in cesium and potassium distribution in the soil profile might explain some of the reason of the enlarged uptake of cesium in the forest ecosystem. A complete answer to this question demands further and more detailed studies of cesium and potassium distribution in the soil profile as well as studies of the feeding depths of the investigated plant species. The mechanisms and velocity of uptake immediately after deposition must also be of great importance, this could be an interesting object of a future experimental study.

Radiocesium in the Living Parts of the Forest Ecosystem

In plants, mosses and lichens in Tisvilde Hegn we rarely see observed ratios (OR) higher than 0.1 $m^2\ kg^{-1}$ (Table F.10 and Figure F.4) - while in the fungi OR is often higher than 1.0 $m^2\ kg^{-1}$ and as high as 6.55 $m^2\ kg^{-1}$ (Table F.11). The highest values are seen in the genus Cortinarius and in the closely related species Rozites caperatus. In this group we see total observed ratios (TOR) ranging from 0.75 $m^2\ kg^{-1}$ to 6.55 $m^2\ kg^{-1}$ see Table F.11. Although Cortinarius anomalus have the highest total uptake 20543 Bq ^{137}Cs, some of the samples of Rozites caperata have a higher uptake of Chernobyl cesium but a much lower of fallout cesium (Table F.11 and Figure F.5).

Observed ratios for Chernobyl cesium (COR) are higher than the other observed ratios for nearly all species thereby indicating a higher availability of cesium from Chernobyl. A species like Tricholoma portentosum, which have a fairly high uptake of ^{137}Cs (610 Bq kg^{-1}), makes an exception by not having detectable amounts of ^{134}Cs. The most likely reason is that its mycelia is placed at deeper levels than is reached by penetrating Chernobyl cesium until now.

The lowest value of TOR observed is 0.002 $m^2\ kg^{-1}$ which is Lactarius vellereus. Most of the mykorhizal fungi lie in the range from 0.2 - 1.3 $m^2\ kg^{-1}$. The saprophytes investigated range between 0.004 and 0.11 $m^2\ kg^{-1}$. This indicates that the symbiotic fungi generally have a higher uptake of cesium than the saprophytes.

Why do we observe these differences? Do some fungi have some specialised physiological capability of reversing cesium fixation to soil compounds like clay or maybe any other than clay? Or is the cesium situated in the mycelia of the fungi, and how did it come there? The high uptake of potassium seen in most fungi, compared to other plant species, might explain part of the enlarged levels of cesium seen (Tables G.2-G.9). However at the same time it raise new questions. How do some fungi with a high potassium uptake avoid taking up cesium e.g. Agaricus, Russula xerampelina, Lactarius vellereus.

One assumption claims that the ratio $^{134}Cs/^{137}Cs$ in the fungi reflects the ratio in the soil layer from which it is taken up (e.g. Byrne, 1988, Battiston, 1989). The species of Russula and Lactarius should after this assumption get most of the cesium from layers just beyond the litter layer, while the species of Cortinarius have their main uptake from the upper soil layers. A more exact investigation of the distribution of cesium in the upper soillayers is necessary to establish a more exact relationship between the ratio in fungi and that in the corresponding soil layers. According to the above mentioned assumption the fixation of fallout cesium and Chernobyl cesium is equal.

Figure F.3 shows that concentrations are highest in the endshoots of Scotch pine and decreasing by a factor 30 to the new wood and by a factor 3 from the new wood to the old wood. Looking at potassium it is seen that the corresponding factors are 10 and 3. The picture is the same but the decline in concentration is not so high for potassium from endshoots to new wood as it is for cesium (Figure F.3).

From the results in Table F.2 it is seen that the concentration of cesium in endshoots of Scotch pine is 4 times higher than it is in leaves of birch. The samples of pine and birch are taken very close to each other from a mixed stand. This indicates a higher uptake rate for Scotch pine than for Birch. A comparison of Observed Ratios (OR) for the plant and lichen samples are given in Table F.10.

The relative high levels of ^{137}Cs found in the roedeer (Table F.8) is interesting, this ought to be taken into account when assessing total doses. The problem concerning the cesium transfer from soil to roe deer need more investigation. In Sweden it has been observed (*Karlén, Johansson & Bergström* 1991) that the ^{137}Cs levels in roedeer show a peak in the autumn due to the consumption of mushrooms. Such a maximum could also be expected in Danish roedeer as fungi also here is part of the roedeer's diet in autumn (*Petersen & Strandgaard* 1992).

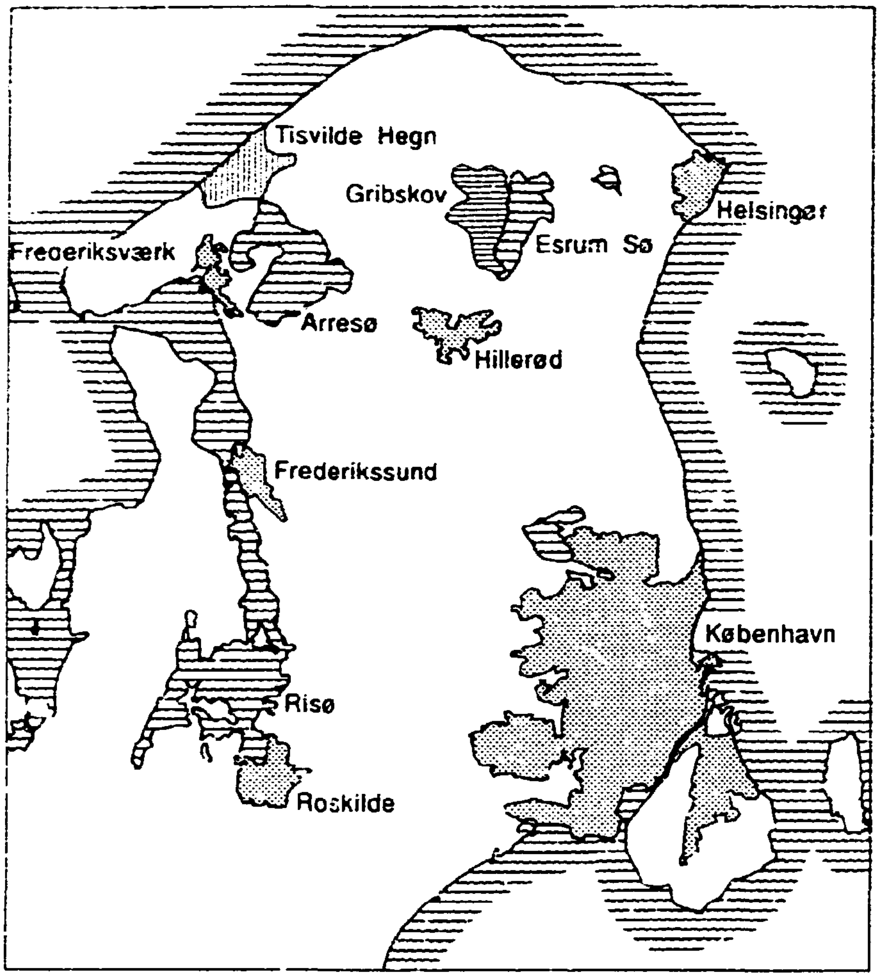


Figure F.1. Map of Zealand showing the situation of Tisvilde Hegn and Gribskov.

Table F.1. Content of radiocesium and potassium in soil under Scotch pine in Tisvilde Hegn in the autumn of 1991. (Bq is given per kg of dry weight)

	^{134}Cs		^{137}Cs		$\frac{^{134}Cs}{^{137}Cs}$	K
	Bq kg^{-1}	Bq m^{-2}	Bq kg^{-1}	Bq m^{-2}		g kg^{-1}
Litter						
Mean of 3	10.0	15.4	156	235	0.071	3.28
± S.D.	3.1	3.2	92	115	0.018	0.96
Soil 0-5 cm						
Mean of 3	4.75	69	109	1989	0.038	8.06
± S.D.	4.56	13	65	634	0.015	5.94
Soil 5-10 cm						
Mean of 3	-	-	23.5	602		11.48
± S.D.			29.5	366		3.64
Soil 10-20 cm						
Mean of 3			2.6	309		12.14
± S.D.			2.7	325		1.32
Total	15	84		3135		
Fallout				2212		
Chernobyl				923		
Total - Litter	10	69		2900		
Litter + 0-5 cm	-	84		2224		
Soil 0-5 cm	10	69	109	1989		

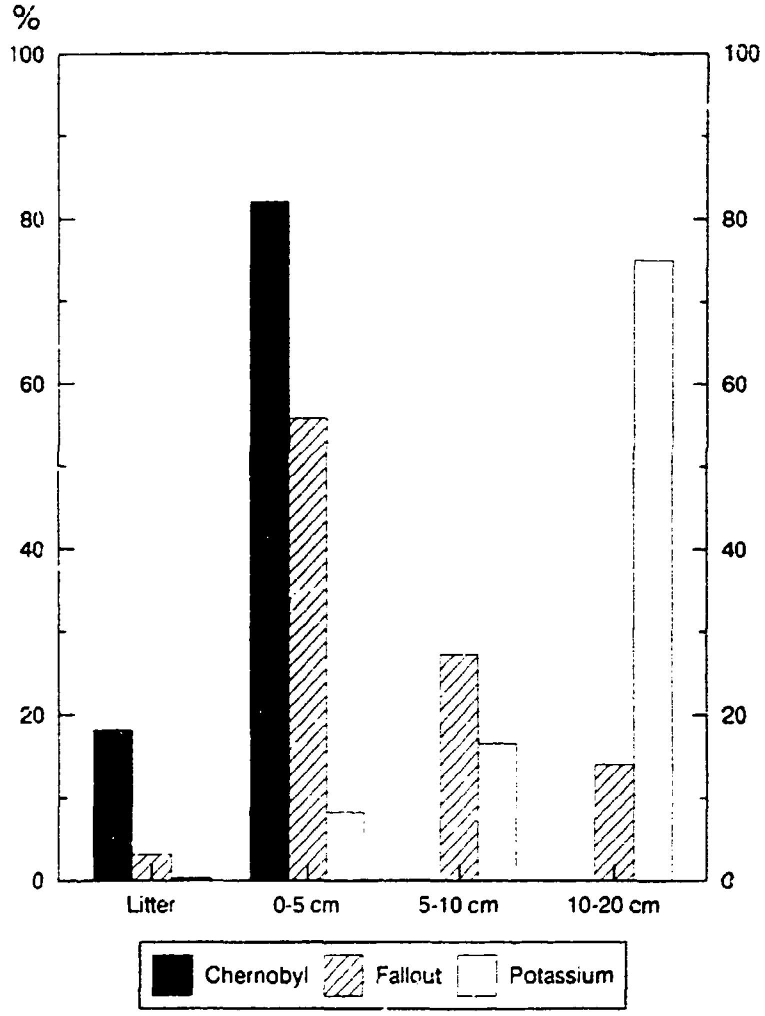


Figure F.2. The distribution of ^{137}Cs and K in the soil layers in Tisvilde Hegn 1991. It is seen that the penetration of cesium is slow in the forest soil.

Trees

Table F.2. Content of radiocesium and potassium in Scotch pine (Pinus silvestris) and Birch (Betula pendula) from Tisvilde 1991. (Bq is given per kg of dry weight)

	^{134}Cs Bq kg^{-1}	^{137}Cs Bq kg^{-1}	^{134}Cs/^{137}Cs	K g kg^{-1}
Pinus silvestris				
Year-shoot				
Mean of 3	5.39	105.5	0.050	5.78
± S.D.	3.38	65.4	0.004	0.56
Wood after 1986				
Mean of 3		3.11		0.56
± S.D.		0.57		0.17
Wood before 1986				
Mean of 3	1.05		0.19	
± S.D.		0.30		0.04
Birch leaves				
Mean of 3	0.85	27.43	0.029	6.13
± S.D.	0.50	4.84	0.011	2.01

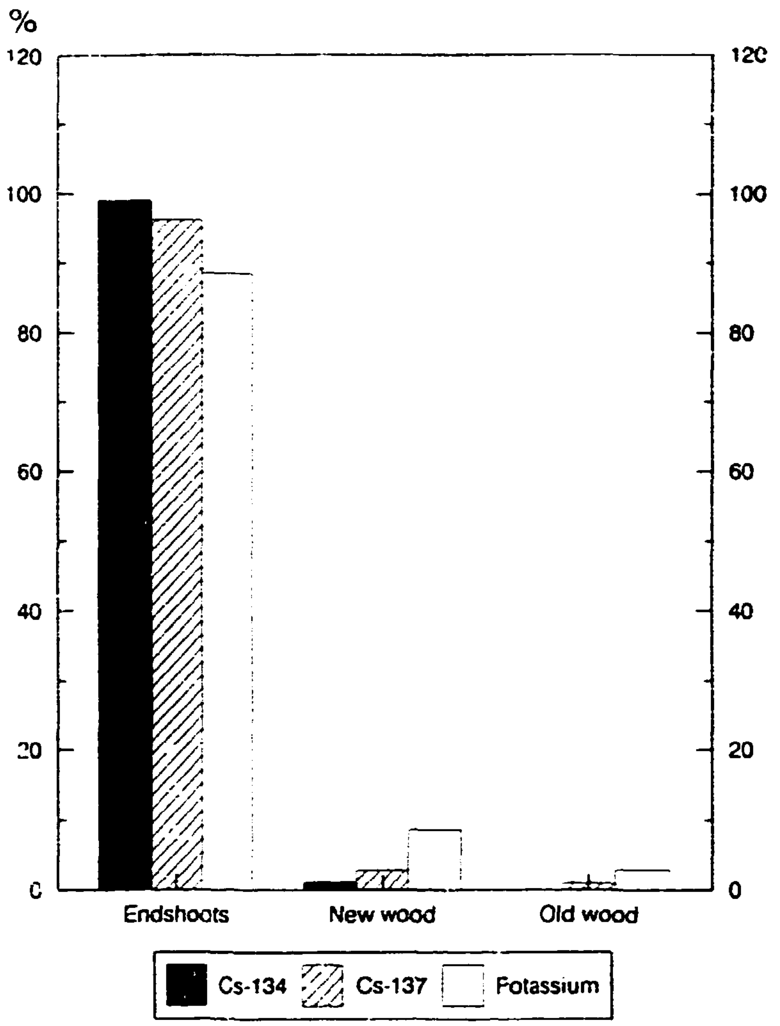


Figure F.3. The distribution of concentrations of cesium and potassium in shoots and wood of Scotch pine in Tisvilde Hegn autumn 1991.

Shrubs

Table F.3. Content of radiocesium and potassium in shrub species from Tisvilde hegn 1991. (Bq is per kg of dry weight)

	^{134}Cs Bq kg^{-1}	^{134}Cs Bq m^{-2}	^{137}Cs Bq kg^{-1}	^{137}Cs Bq m^{-2}	^{134}Cs/^{137}Cs	K g kg^{-1}
Calluna vulgaris						
Mean of 3	12.97	3.4	213.9	55.8	0.058	4.05
± S.D.	6.93	1.8	96.8	23.7	0.01	0.98
Empetrum nigrum						
Mean of 3	1.80		23.74		0.076	4.45
± S.D.	0.46		6.3		0.004	0.79
	^{134}Cs Bq kg^{-1}		^{137}Cs Bq kg^{-1}		^{134}Cs/^{137}Cs	K g kg^{-1}
Vaccinium vitis-idaea						
Mean of 2	9.52		147.69		0.066	5.04
± S.D.	1.09		37.5		0.01	0.42
Vaccinium uliginosum						
V.uliginosum	4.64		56.83		0.082	5.12

Grasses

Table F.4. Content of radiocesium and potassium in species of grass in Tisvilde Hegn 1991. (Bq is per kg of dry weight)

	^{134}Cs Bq kg^{-1}	^{134}Cs Bq m^{-2}	^{137}Cs Bq kg^{-1}	^{137}Cs Bq m^{-2}	^{134}Cs/^{137}Cs	K g kg^{-1}
Molinea caerulea						
Mean of 3	1.807		34.06		0.051	13.47
± S.D.	0.1		16.9		0.022	2.48
	^{134}Cs Bq kg^{-1}	^{134}Cs Bq m^{-2}	^{137}Cs Bq kg^{-1}	^{137}Cs Bq m^{-2}	^{134}Cs/^{137}Cs	K g kg^{-1}
Deschampsia flexuosa						
Mean of 3	3.9	0.38	44	4.4	0.082	8.13
± S.D.	2.5	0.24	23	2.3	0.019	3.06

Mosses

Table F.5. Content of radiocesium and potassium in species of moss (Hylocomium splendens & Polytrichum commune) from Tisvilde Hegn 1991. (Bq is per kg of dry weight)

	^{134}Cs Bq kg^{-1}	^{137}Cs Bq kg^{-1}	$\frac{^{134}Cs}{^{137}Cs}$	K g kg^{-1}
H. splendens				
Mean of 3	8.74	104.75	0.082	4.53
± S.D.	2.93	17.29	0.015	1.31
P. commune	10.31	116.78	0.088	5.82

Lichens

Table F.6. Content of radiocesium and potassium in species of lichens in Tisvilde Hegn 1991. (Bq is per kg of dry weight)

	^{134}Cs Bq kg^{-1}	^{137}Cs Bq kg^{-1}	$\frac{^{134}Cs}{^{137}Cs}$	K g kg^{-1}
Cladina portentosa				
Mean of 4	17.59	196.28	0.0899	2.05
± S.D.	7.84	85.16	0.0061	0.56
Hypogymnia physodes				
Mean of 3	22.46	250.31	0.0897	3.02
± S.D.	3.59	38.50	0.0015	0.68
Cetraria islandica				
C. islandica	9.31	103.31	0.0902	2.60

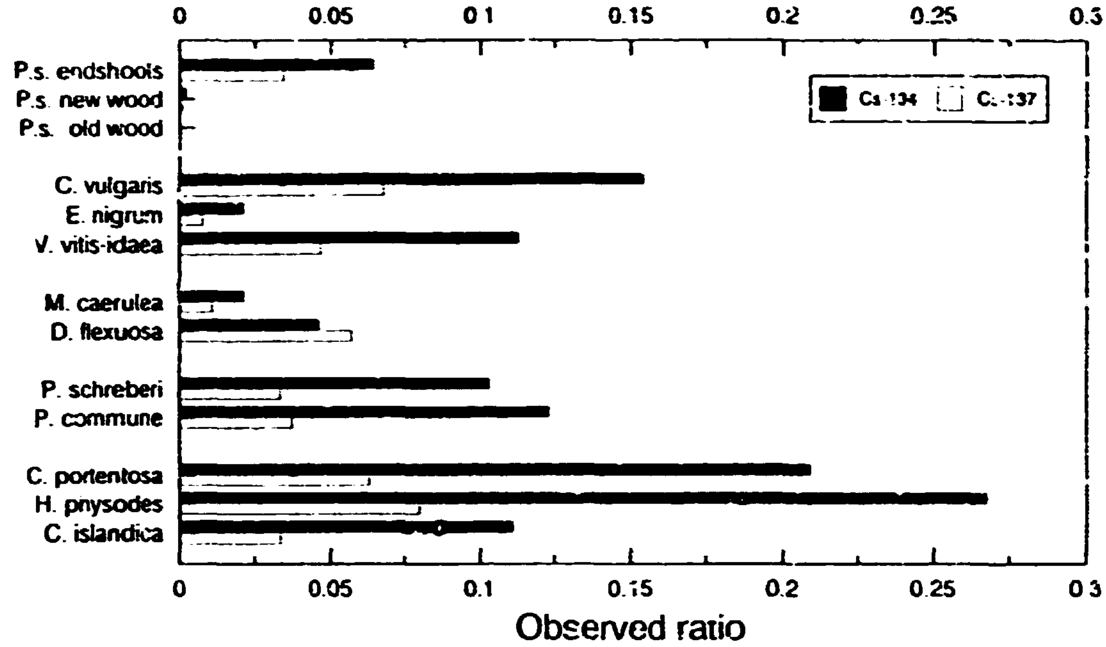


Figure F.4. Observed Ratios$_{plant/soil}$ (m^2 kg^{-1}) for plants, mosses and lichens in Tisvilde hegn, autumn 1991.

Fungi

The replicate samples of fungi represents species that in some connection have been selected as species suited for sampling and international comparison, or species suited for collection and use in characterization of this particular forest ecosystem. Other samples is taken in order to determine differences on the level of genus and ecotype.

Table F 7.1. Content of radiocesium and potassium in replicate samples in Tisvilde Hegn, collected in the autumn of 1991. (Bq is per kg of dry weight)

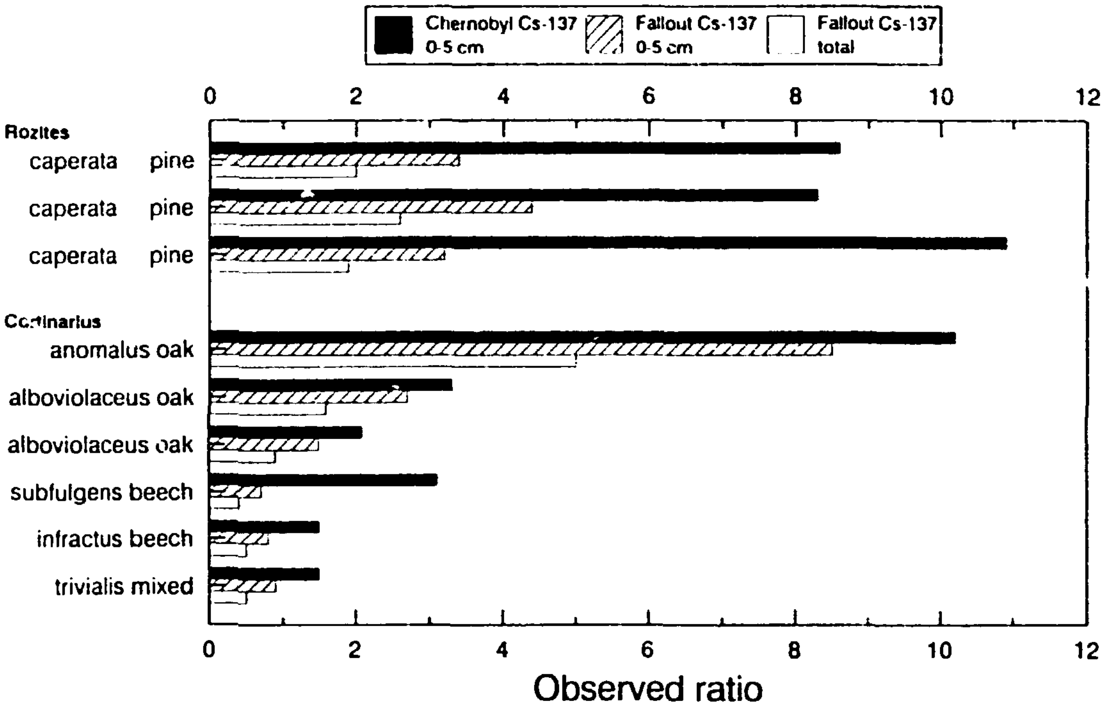
	^{134}Cs Bq kg^{-1}	^{137}Cs Bq kg^{-1}	$\frac{^{134}Cs}{^{137}Cs}$	K g kg^{-1}
R.caperatus				
Mean of 3	869.4	13343	0.065	45.57
± S.D.	131.8	876	0.007	0.98
C. alboviol.				
Mean of 3	257.9	5241	0.050	52.00
± S.D.	77.4	1928	0.004	6.79
S.variegatus				
Mean of 3	55.35	892	0.063	25.79
± S.D.	15	245	0.01	0.96
B.badius				
Mean of 3	69.55	1300	0.054	33.61
± S.D.	3.1	200	0.01	3.23
L.rufus				
Mean of 3	159.3	2205	0.072	30.00
± S.D.	88.1	1206	0.004	3.12
C. cibarius				
Mean of 2	< 14.84	212	0.071	47.46
± S.D.	3.59	71	0.007	9.12
C.tubaeformis				
Mean of 4	76.1	1366	0.057	39.60
± S.D.	18.11	493	0.007	5.79

(The species listed in the table are Rozites caperatus, Cortinarius alboviolaceus, Suillus variegatus, Boletus badius, Lactarius rufus, Cantharellus cibarius, and Cantharellus tubaeformis).

Table F.7.2 Content of radiocesium and potassium in fungi in Tisvilde Hegn in the autumn of 1991. (Bq is per kg of dry weight)

	^{134}Cs Bq kg^{-1}	^{137}Cs Bq kg^{-1}	^{134}Cs / ^{137}Cs	K g kg^{-1}
Cortinarius				
C.anomalus	962.1	20543	0.047	33.40
C.subfulgens	291.7	3736	0.078	31.09
C.infractus	142.9	2442	0.059	44.48
C.trivialis	121.9	2400	0.051	39.01
C.alboviolaceus	312.6	6604	0.047	56.80
C.alboviolaceus	203.2	3877	0.052	47.20
Mean	339.1	6600	0.056	42.00
± S.D.	314.7	6999	0.012	9.53
Russula				
R.decolorans	56.45	906	0.062	35.05
R.flava	49.56	679	0.072	35.26
R.ochroleuca	16.77	230	0.073	43.48
R.paludosa	38.16	669	0.057	32.62
R.sardonia	153.2	2021	0.076	32.46
R.vesca	< 3	31	-	31.92
R.vinosa	78.26	982	0.079	30.99
R.virescens	B.D.L.	9	-	30.01
R.xerampelina	4.40	54	0.081	22.12
Mean	51.22	620	0.071	32.66
± S.D.	49.43	649	0.009	5.60
Lactarius				
L.vietus	101.5	1482	0.069	26.57
L.pubescens	80.8	1033	0.078	28.58
L.vellereus	< 1.5	6	-	34.42
L.necator	31.25	491	0.064	43.48
L.deliciosus	140.4	1778	0.079	22.30
L.rufus	67.70	997	0.068	26.50
L.rufus	243.4	3409	0.071	31.01
L.rufus	166.7	2209	0.075	32.49
Mean	104.16	1425	0.072	30.67
± S.D.	77.78	1062	0.0055	6.44
Saprophytes (wooddecomposers)				
A.obscura	5.28	81	0.065	48.15
M.platyphylla	28.77	337	0.085	27.63
K.mutabilis	18.67	311	0.060	43.39
T.purpurea	4.04	55	0.074	31.07
Mean	14.19	196	0.071	37.56
± S.D.	11.76	149	0.011	9.78
Saprophytes (leaves and twig decomposers)				
A.silvaticus	< 1.31	< 13		103.6
C.maculata	24.24	308	0.078	23.31
L.fumosum	< 4.0	140		64.20

The investigated saprophytes are Armillaria obscura, Megacollybia platyphylla, Kuehneromyces mutabilis, Tricholomopsis purpurea, Agaricus silvaticus, Collybia maculata & Lyophyllum fumosum.



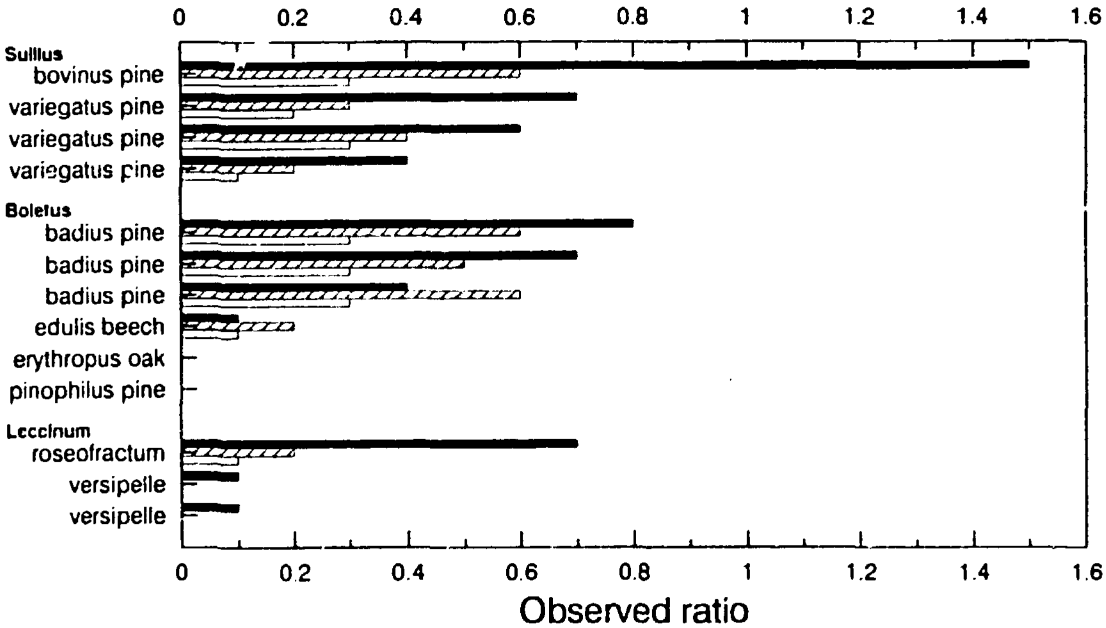
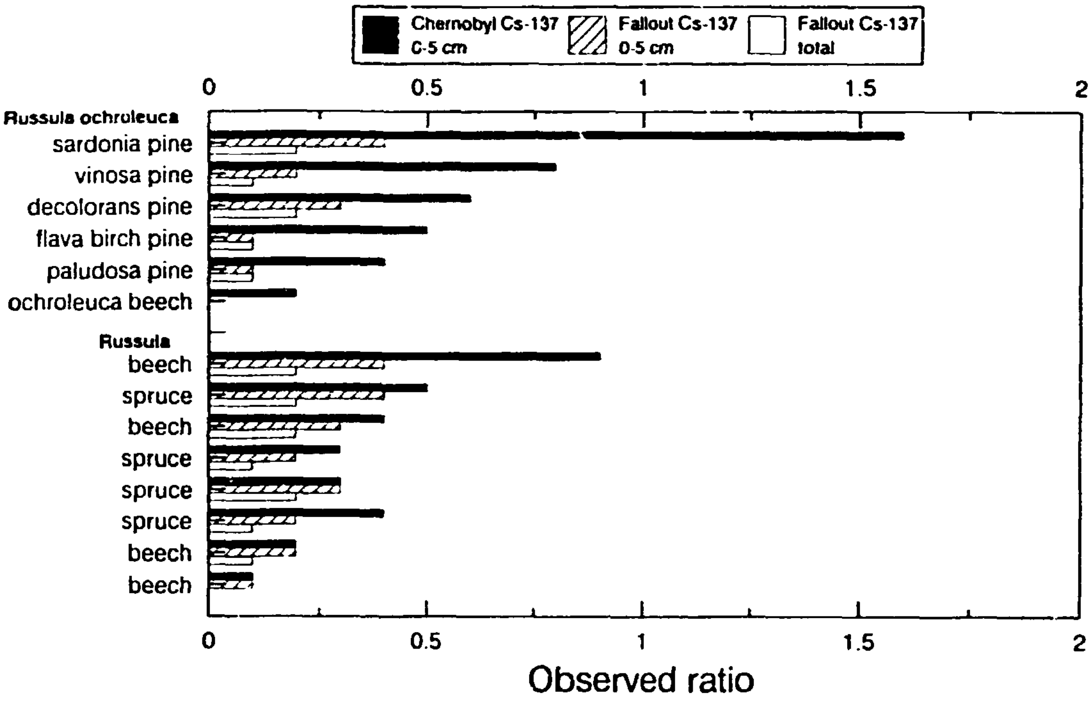


Figure F.5. See text nest page

Figure F.5 continued



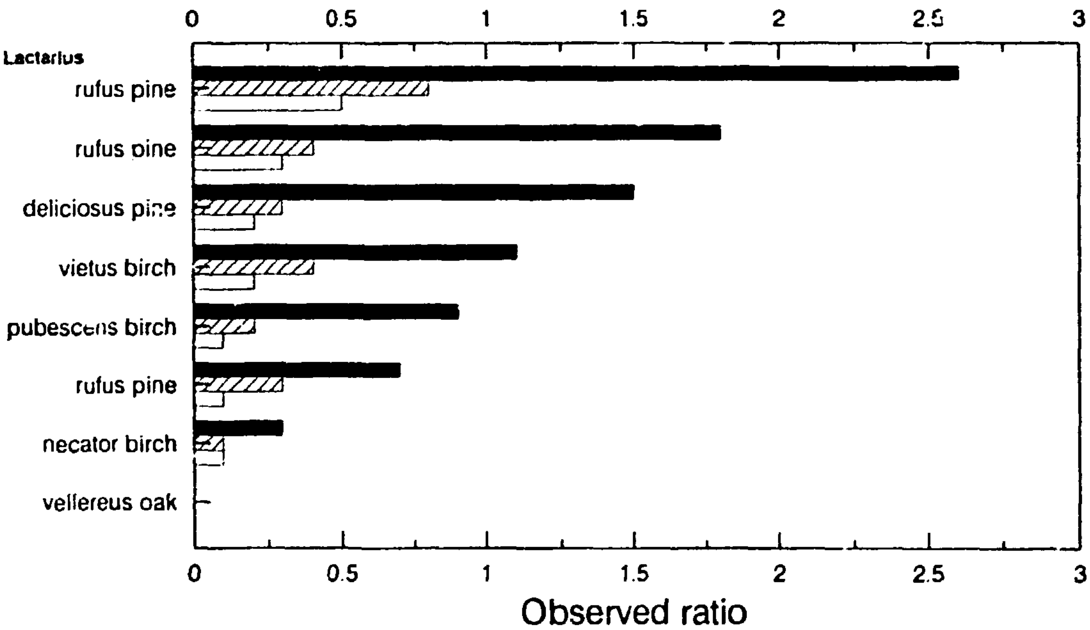


Figure F.5. Observed ratios ($m^2\ kg^{-1}$) COR and FOR for fungi in Tisvilde hegn in the autumn of 1991. FOR (Observed Ratio$_{fungi/soil}$ of Fallout cesium) is illustrated both for the fraction in the upper 5 cm and totally. a. Cortinarius, b. Boletales, c. Russula d. Lactarius.

Roedeer

Table F.8. Radiocesium and potassium in three specimens of Roedeer (Capreolus capreolus) collected in Tisvilde Hegn in October 1991. (Bq is per kg of dry weight)

	^{134}Cs Bq kg^{-1}	^{137}Cs Bq kg^{-1}	^{134}Cs / ^{137}Cs	K g kg^{-1}
Roe	3.72	49.25	0.076	12.60
Roebuck	31.05	627.2	0.050	10.98
Fawn	3.96	66.65	0.059	8.24
Arithmetical Mean per kg	15 Bq ±21 Bq	298 Bq = 313 Bq ±432 Bq		
(Bq/kg Fresh weight)				
Roe 9 kg	0.95	12.60		
Roebuck 11 kg	8.22	166.1		
Fawn 6 kg	1.04	17.47		
Arithmetical Mean per kg	(4.05	78.67)	× 700000 = 57904000 Bq	
± S.D.	5.53	114.45		
Mean/animal	(11.69	681.77)	× 70000 = 56553700 Bq	
± S.D.	15.98	991.89		
Geometrical Mean/animal	(16.90	279.00)	× 70000 = 20713000 Bq	
S.E.	4.3	5.1		
Mean per kg	(1.95	32.19)	× 700000 = 23898000 Bq	

The yearly consumption of deer in Denmark is 70000, which equals 700000 kg usable meat. Below and right in the table it is calculated how much cesium is transferred to man through roedeer in Denmark.

Table F.9. Results from Gribskov 28-10/1991. Samples of Common yellow Russula (Russula ochroleuca) from stands of Norway spruce (Picea abies) and Beech (Fagus silvaticus) (Bq is per kg of dry weight)

	n	^{134}Cs Bq kg^{-1}	^{137}Cs Bq kg^{-1}	Ratio	K g kg^{-1}
Fagus silvaticus stand					
Russula ochroleuca	4	37.95	670.9	0.055	39.94
± S.D.		32.21	504.5	0.005	5.83
Picea abies stand					
Russula ochroleuca	4	33.19	688.5	0.048	41.00
± S.D.		8.09	176.3	0.005	3.81
	n	**^{134}Cs Bq m^{-2}**	**^{137}Cs Bq m^{-2}**	**Ratio**	**K g kg^{-1}**
Litter 1-0 cm	1	17.06	180.9	0.094	5.78
Soil 0-5 cm	2	104.8	2055	0.061	19.87
Soil 5-10 cm	2	-	659		21.60
Soil 10-20 cm	2	-	373	-	22.55

Table F.10. Observed Ratios $OR_{(plant/Soil)}$ (m^2/kg) for the species investigated in Tisvilde Hegn 1991. (Bq is per kg of dry weight)

Sample type	Number	^{134}Cs Bq kg^{-1}	^{137}Cs Bq kg^{-1}	^{134}Cs / ^{137}Cs	OR ^{134}Cs	OR ^{137}Cs	Chernobyl % ^{137}Cs
P.s. endsh.	3	5.39	105.5	0.051	0.064	0.034	53.0
P.s. new wood	3	0.17	3.6	0.047	0.002	0.001	50.1
P.s. old wood	3	> 0	1.0	> 0	0.000	0.0003	> 0
C. vulgaris	3	12.97	213.90	0.058	0.154	0.068	61.5
E. nigrum	3	1.80	23.74	0.076	0.021	0.008	80.5
V. vitis-idaea	3	9.52	147.69	0.066	0.113	0.047	69.9
M. caerulea	3	1.81	34.06	0.051	0.021	0.011	54.0
D. flexuosa	3	3.90	44.00	0.082	0.046	0.057	86.9
P. schreberi	3	8.72	104.75	0.083	0.103	0.033	88.0
P. commune	1	10.31	116.78	0.088	0.123	0.037	93.3
C. portentosa	4	17.59	196.28	0.090	0.209	0.063	88.2
H. physodes	3	22.46	250.31	0.090	0.267	0.080	90.3
C. islandica	1	9.32	103.31	0.090	0.111	0.033	86.5

Table F.11. Observed Ratios$_{(fungi/soil)}$ (m^2 kg) for fungi in Tisvilde Hegn 1991. (COR is the observed ratio of Chernobyl cesium, FOR is the observed ratio of fallout cesium. In the table it is split into what is present in the upper 5 centimeters and what is present in total and TOR is the observed ratio of all present Cs-137

Name	Forest type	^{137}Cs %	Chern. %	Fallout %	COR	FOR 0-5cm	FOR Total	TOR	TOR weight
Cortinarius									
anomalus	oak	20543	46	54	10.2	8.5	5	6.6	188.5
albovioiaceus	oak	6604	46	54	3.3	2.7	1.6	2.1	60 6
alboviolaceus	oak	3877	51	49	2.1	1.5	0.9	1.2	35.6
subfulgens	beech	3736	77	23	3.1	0.7	0.4	1.2	34.3
infractus	beech	2442	58	42	1.5	0.8	0.5	0.8	22.4
trivialis	mixed	2400	50	50	1.3	0.9	0.5	0.8	22.0
Rozites									
caperatus	pine	14186	71	29	10.9	3.2	1.9	4.5	130.1
caperatus	pine	13406	57	43	8.3	4.4	2.6	4.3	123.0
caperatus	pine	12438	64	36	8.6	3.4	2	4.0	114.1
Amanita									
rubescens	pine	4093	51	49	2.3	1.5	0.9	1.3	37.6
virosa	pine	2252	50	50	1.2	0.9	0.5	0.7	20.7
fulva	beech	600	48	52	0.3	0.2	0.1	0.2	5.5
rubescens	oak	36						0.0	0.3
Lactarius									
rufus	pine	3409	70	30	2.6	0.8	0.5	1.1	31.3
rufus	pine	2209	74	26	1.8	0.4	0.3	0.7	20.3
deliciosus	pine	1778	78	22	1.5	0.3	0.2	0.6	16.3
vietus	birch	1482	68	32	1.1	0.4	0.2	0.5	13.6
pubescens	birch	1033	77	23	0.9	0.2	0.1	0.3	9.5
rufus	pine	997	67	33	0.7	0.3	0.1	0.3	9.1
necator	birch	491	63	37	0.3	0.1	0.1	0.2	4.5
vellereus	oak	6						0.0	0.1
Russula									
sardonia	pine	2021	75	25	1.6	0.4	0.2	0.6	18.5
vinosa	pine	982	79	21	0.8	0.2	0.1	0.3	9.0
decolorans	pine	906	61	39	0.6	0.3	0.2	0.3	8.3
flava birch	pine	579	72	28	0.5	0.1	0.1	0.2	6.2
paludosa	pine	669	56	44	0.4	0.1	0.1	0.2	6.1
ochroleuca	beech	230	72	28	0.2			0.1	2.1
Russula ochroleuca									
	beech	1369	61	39	0.9	0.4	0.2	0.4	12.6
	spruce	953	46	54	0.5	0.4	0.2	0.3	8.7
	beech	684	49	51	0.4	0.3	0.2	0.2	6.3
	spruce	602	46	54	0.3	0.2	0.1	0.2	5.5
	spruce	600	43	57	0.3	0.3	0.2	0.2	5.5
	spruce	599	54	46	0.4	0.2	0.1	0.2	5.5
	beech	425	50	50	0.2	0.2	0.1	0.1	3.9
	beech	206	56	44	0.1	0.1	-	0.1	1.9

Table F.11. (Continued)

Name	Forest type	^{137}Cs %	Chern. %	Fallout %	COR	FOR 0-5cm	FOR Total	TOR	TOR weight
Russula									
xerampelina	pine	54	79	21				0.0	0.5
vesca	mixed	31						0.0	0.3
virescens	beech	9						0.0	0.1
Cantharellus									
tubaeformis	spruce	1382	56	44	0.8	0.5	0.3	0.4	12.7
tubaeformis	pine	1067	65	35	0.8	0.3	0.2	0.3	9.8
tubaeformis	beech	959	57	43	0.6	0.3	0.2	0.3	8.8
cibarius	pine	262	65	35	0.2	0.1		0.1	2.4
cibarius	pine	162						0.1	1.5
Suillus									
bovinus	pine	2095	65	35	1.5	0.6	0.3	0.7	19.2
variegatus	pine	1035	66	34	0.7	0.3	0.2	0.3	9.5
variegatus	pine	1033	53	47	0.6	0.4	0.3	0.3	9.5
variegatus	pine	609	65	35	0.4	0.2	0.1	0.2	5.6
Boletus									
badius	pine	1483	51	49	0.8	0.6	0.3	0.5	13.6
badius	pine	1330	49	51	0.7	0.5	0.3	0.4	12.2
badius	pine	1087	33	67	0.4	0.6	0.3	0.3	10.0
edulis	beech	363	36	64	0.1	0.2	0.1	0.1	3.3
erythropus	oak	43						0.0	0.4
pinophilus	pine	15						0.0	0.1
Leccinum									
roseofractum	birch	856	73	37	0.7	0.2	0.1	0.3	7.9
versipelle	birch	117	83	17	0.1			0.0	1.1
versipelle	birch	84	68	32	0.1			0.0	0.8
Tricholoma	pine	621						0.2	5.7
Gyroporus	pine	25						0.0	0.2
Hygrophorus	beech	19						0.0	0.2
Saprophytes									
Megacoll. platyphylla		337	83	17	0.3			0.1	3.1
Kuehnero. mutabilis		311	59	41	0.2	0.1	0.1	0.1	2.9
Collybia maculata		308	78	22	0.3	0.1		0.1	2.8
Lyophyllum fumosum		140	28	72		0.1		0.0	1.3
Armillaria obscura		81	64	36	0.1			0.0	0.7
Tricholomopsis rutilans		55	73	37				0.0	0.5
Agaricus silvaticus		13						0.0	0.1

References

Aarkrog, A. (1979). Environmental Studies on Radioecological Sensitivity and Variability with Special Emphasis on the Fallout Nuclides ^{90}Sr and ^{137}Cs. Risø-R-437.

Aarkrog, A. (1988). Studies of Chernobyl Debris in Denmark, Environment International **14**, 149-155.

Aarkrog, A. (1989). Radioecological Lessons Learned from Chernobyl, Proceeding of the XVeth Regional Congress of IPRA, Visby, Gotland, Sweden, 10-14 Sept., 1989, 129-134.

Battiston, G.A. (1989). Radioactivity in mushrooms in Northeast italy following the Chernobyl accident. *J. Environ. Radioactivity* **9** (1989) pp.53-60.

Bryant, F.J., Morgan,A. and Spicer, G.S. (1959). The Determination of Radiostrontium in Biological Materials. AERE-R 3030.

Danmarks statistik. Statistisk årbog 1972 (Statistical Yearbook) (Copenhagen, 1972).

Brückmann, A. (1992). Personal communication on radiocesium in underground parts of fungi. Axel Brückmann Institut für Bodenkole + Waldernähr, Büsgenweg 2, 3400 Göttingen.

Byrne, A.R. (1989). Radioactivity in fungi in Slovenia, Yugoslavia, following the Chernobyl accident. *J. Environ. Radioactivity* **6**, 177-183.

Danmarks statistik. Landbrugsstatistik 1985. (Statistical Yearbook) (Copenhagen, 1986).

Danmarks statistik. Statistisk årbog 1987 (Statistical Yearbook) (Copenhagen 1988).

Hald, A. (1958). Private communication.

Harley, John H. (1972). Manual of Standard Procedures. HASL-300.

HASL (1958-1978). General reference to: Environmental quarterly. Quarterly reports from Health and Safety Laboratory, U.S. Atomic Energy Commission, later U.S. Energy Research and Development Administration and latest Environmental Measurements Laboratory, Department of Energy (New York).

Karlén, G.; Johansson, K.J. & Bergström, R. (1991). Seasonal variation in the activity concentration of ^{137}Cs in Swedish roedeer and in their daily intake. *J. Environ. Radioactivity* **14**, 91-103.

Lippert, J. (1975). Statdata, Risø-M-1780.

Nielsen, B. & Strandberg, M. (1989). Cæsium i græsningsfødekæden. Thesis from Risø National Laboratory (MIL-ECO) 1989.

Petersen, M.R. and Strandgaard, H. (1992). Roe deer's food selection in two different Danish roe deer biotopes. CIC Symposium »Capreolus« in Salzburg, April 1992.

Osmond, R.G., Owers, M.J., Healy, C. and Mead, A.P. (1959). The Determination of Radioactivity due to Caesium, Strontium, Barium and Cerium in Waters and Filters. AERE-R 2899.

Quittner, P. (1969). Nucl. Instr. and Methods **76**, 115-124.

Risø National Laboratory (1957-91). Risø Reports Nos. 1, 3, 9, 14, 23, 41, 63, 85, 107, 130, 154, 180, 201, 220, 245, 265, 291, 305, 323, 345, 361, 386, 403, 421, 447, 469, 487,509, 527, 540, 549, 563 and 570.

Strandberg, M. (1992). Radiocesium in a Danish pineforest ecosystem. Information presented at »Seminar on The dynamic behaviour of radionuclides in forests« in Stockholm May 18-22. 1992. To be published.

UNSCEAR. (1982). United Nations Scientific Committee on the Effects of Atomic Radiation.. Ionizing Radiation: Sources and biological effects. (New York) 773 pp.

Vestergaard, J. (1964). Analysis of Variance with Unequal Numbers in Group. GIER System Library No. 211 (A/S Regnecentralen, Copenhagen, 1964).

Bibliographic Data Sheet **Risø-R-621(EN)**

Title and author(s)

Environmental Radioactivity in Denmark in 1990 and 1991

A. Aarkrog, L. Bøtter-Jensen, Chen Qing Jiang, H. Dahlgaard, Heinz Hansen, Elis Holm, Bente Lauridsen, S.P. Nielsen, Morten Strandberg and J. Søgaard-Hansen

ISBN	ISSN
87-550-1802-5	0106-2840 0106-407X

Dept. or group	Date
Health Physics Department	December 1992

Groups own reg. number(s)	Project/contract no.

Pages	Tables	Illustrations	References
174	164	76	23

Abstract (Max. 2000 characters)

Strontium-90, radiocesium, and other radionuclides were determined in samples from all over the country of air, precipitation, stream water, lake water, sea water, soil, sediments, dried milk, fresh milk, meat, fish, cheese, eggs, grain, bread, potatoes, vegetables, fruit, grass, moss, lichen, sea plants, total diet, and humans. Estimates are given of the mean contents of radiostrontium and radiocesium in the human diet in Denmark during 1990 and 1991. Tritium was determined in precipitation, fresh waters, and sea water. The γ-background was measured regularly by TLD's and a NaI detector. Tc-99 determinations were carried out on various marine samples, first of all sea water.

Descriptors INIS/EDB

AIR; ANTIMONY 125; AQUATIC ECOSYSTEMS; ATMOSPHERIC PRECIPITATIONS; BACKGROUND RADIATION; BONE TISSUES; CESIUM 134; CESIUM 137; CHERNOBYLSK-4 REACTOR; COBALT 60; DENMARK; DIET; ENVIRONMENT; FALLOUT DEPOSITS; FISHES; FOOD; FOOD CHAINS; FORESTS; FRESH WATER; FUNGI; GLOBAL FALLOUT; LOCAL FALLOUT; MAN; MILK; NUMERICAL DATA; PLANTS; POLONIUM 210; POTASSIUM; POTASSIUM 40; RADIOACTIVITY; REACTOR ACCIDENTS; RISOE NATIONAL LABORATORY; RUTHENIUM 106; SEAWATER; SEAWEEDS; SEDIMENTS; SOILS; STRONTIUM 90; TECHNETIUM 99; TERRESTRIAL ECOSYSTEMS; TRITIUM; VEGETABLES

Available on request from Risø Library, Risø National Laboratory, (Risø Bibliotek, Forskningscenter Risø), P.O.Box 49, DK-4000 Roskilde, Denmark.
Telephone +45 42 37 12 12, ext. 2268/2269
Telex 43 116. Telefax +45 46 75 56 27.

Available on request from:
Risø Library
Risø National Laboratory,
P.O. Box 49, DK-4000 Roskilde, Denmark
Phone +45 42 37 12 12, ext. 2268/2269
Telex 43116, Telefax +45 46 75 56 27

ISBN 87-550-1802-5
ISSN 0106-2840
0106-407X