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Environmental Radioactivity in Denmark in 1986

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Risø National Laboratory, DK-4000 Roskilde, Denmark

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+International Laboratory for Marine Radioactivity, Monaco

Abstract. Strontium-90, radiocesium and other radionuclides were determined in samples from all over the country of air, precipitation, stream water, lake water, ground water, drinking 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 of the mean contents of radiostrontium and radiocesium in the human diet in Denmark during 1986 are given. Tritium was determined in atmospheric precipitation, ground water, other fresh waters and sea water. The γ-background was measured regularly by TLD, ionization chamber and on site γ-spectroscopy at locations around Risø, at ten of the State experimental farms, along the coasts of the Great Belt and around Gylling Næs. The marine environments at Barsebäck and Ringhals were monitored for ^{137}Cs (Cesium 137) and corrosion products (^{58}Co, ^{60}Co, ^{65}Zn, ^{54}Mn) (Cobalt 58, Cobalt 60, Zn 65, Manganese 54). The Chernobyl accident caused a substantial expansion of the environmental monitoring activities in Denmark. The programme was expanded to an extent similar to that in the sixties.

Keywords: Russian reactor accidents, Radiation monitors, Radioactive fallout, Radioactive isotopes, Background radiation, Food chains, Data tables, Aquatic ecosystems, Environmental impact. (edc)

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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: mikro: 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.

cpm: counts per minute
dpm: disintegrations per minute
OR: observed ratio
CF: concentration factor
FP: fission products
μR: micrc-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

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 between the variance in question and 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 deviation >33%, such results are not considered significantly different from zero activity
B.D.L.: below detection limit

In the significance test the following symbols were used:
* : probably significant (P > 95%)
** : significant (P > 99%)
***: highly significant (P > 99.9%)

1. INTRODUCTION

1.1.

The present report is the thirtieth of a series of periodic reports (cf. ref. 1) dealing with measurements of radioactivity in Denmark. The organization of the material in the present report corresponds to that of last years report. After the introduction and a chapter on organization and facilities there follows a chapter on environmental monitoring around nuclear facilities (Risø, Barsebäck and Ringhals). Chapter four deals with fallout nuclides in the abiotic environment, i.e. air, water and soil. Chapters five and six comprise fallout nuclides in the human diet, 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.

Although the programme was expanded substantially after the Chernobyl accident in Ukraine in April 1986, we have not found it necessary to change the organization of the material. We have, however, removed some of the very detailed tables for air, precipitation, grass and milk collected at Risø to the Appendix.

1.2.

The methods of radiochemical analysis[2-4] and the statistical treatment of the results[5,12] are still based on the principles established in previous reports[1].

1.3.

The detailed tables of the environmental monitoring programme for Risø National Laboratory appear in the two semiannual reports: Radioactivity in the Risø district January-June 1986 and July-December 1986, which are available from the Risø Library.

1.4.

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

1.5.

In 1986 the personnel of the Environmental Control Section of the Health Physics Department consisted of two chemists, one biologist, one physicist, ten laboratory technicians, three sample collectors, and two laboratory assistants. The group for Electronics Development and Maintenance gave assistance with the maintenance of counting equipment.

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.

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

By S.P. Nielsen

2.1. Detectors

The samples are measured as follows:

Alpha (^{239}Pu, ^{241}Am): 22 solid-state surface barrier detectors connected to multichannel analyzers (512 channels per detector) and another two for total alpha counting.

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

Gamma (natural and fallout isotopes): A total of 9 germanium detectors in 10 cm lead shields are used for gamma spectrometric measurements. 5 detectors are connected to hard-wired multichannel analyzers and 4 to MCA-cards in a personal computer. The efficiencies of the detectors are in the range 12-40% relative to a 3" × 3" NaI (Tl) detector. A 8" × 4" NaI(Tl) in an underground shielded room is used for gamma-spectrometric whole-body measurements.

2.2. Data treatment

Measured spectra are transferred to a Burroughs B7800 computer for evaluation.

A program system STATDATA[16] is developed for registration and treatment of environmental measurements including multichannel analyzer spectra. To date, approximately 90 000 sets of results have been registered covering the period from 1957.

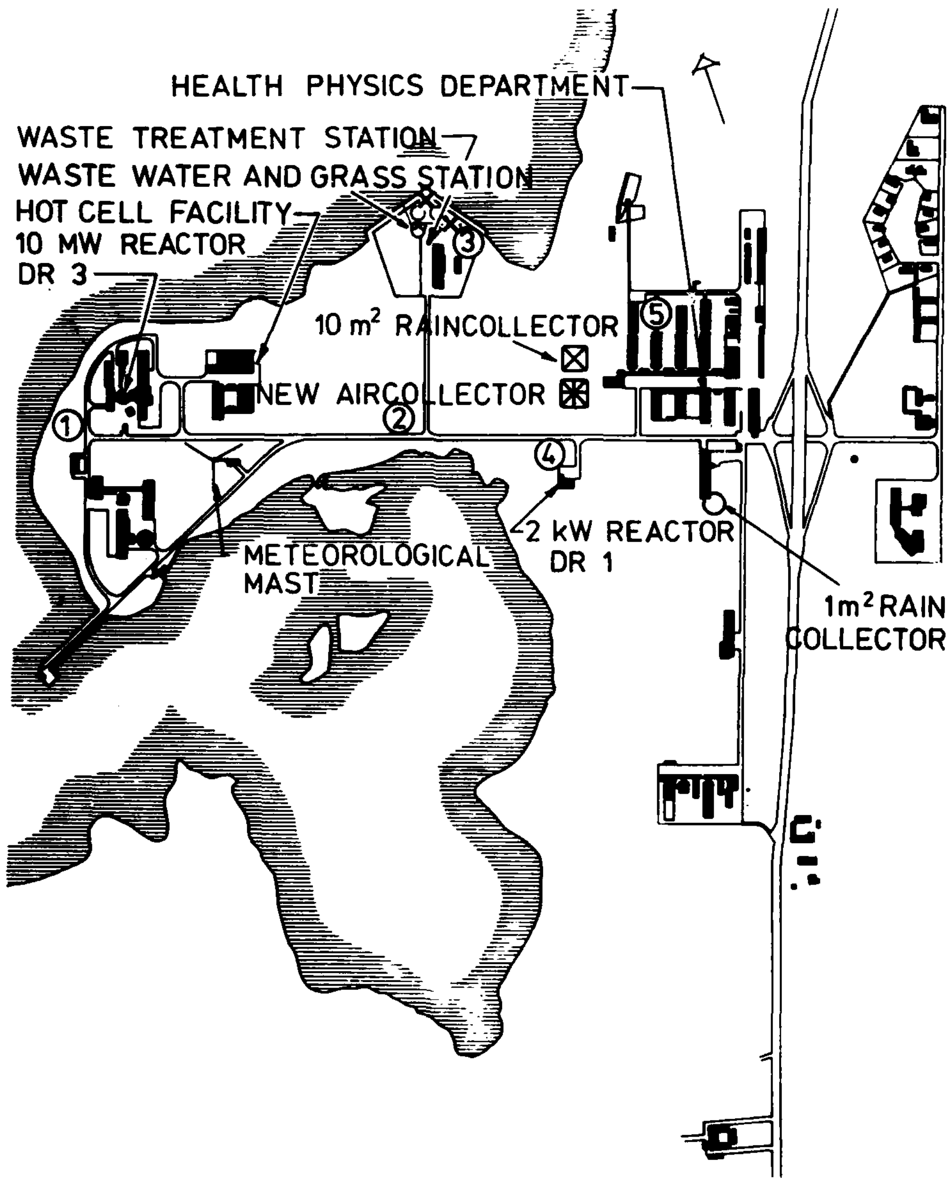


Fig. 3.1.1. Sampling locations at Risø National Laboratory. 1-5: locations for rain bottles (0.03 m^2 each), ion-exchange columns (0.06 m^2 each) and grass samples.

3. ENVIRONMENTAL MONITORING AT RISØ, BARSEBÄCK AND RINGHALS IN 1986

by H. Dahlgaard

3.1 Environmental monitoring at Risø

From the two semiannual reports: Radioactivity in the Risø district January-June 1986 and July-December 1986 the results of the environmental monitoring at Risø are presented. The reports are available from the Risø Library.

The various anthropogenic radionuclides measured outside the Risø area came from non-Risø sources, preferentially from the Chernobyl accident.

3.2. Marine environmental monitoring at Barsebäck and Ringhals

The radiological monitoring of the marine environment around the two nuclear power plants at Barsebäck and Ringhals in Sweden[1)] was continued in 1986.

Figures 3.2.1.1 and 3.2.1.2 show the sampling locations.

3.2.1. γ-emitting radionuclides in brown algae

Table 3.2.1.1 shows the radionuclide concentrations found by γ-spectrometric analysis in brown algae sampled near Ringhals in 1986. Monthly data on radionuclides in seaweed from Barsebäck and Ringhals are reported from the experimental programme in chapter 3.2.5. The data are expressed on the basis of dry weight. Dry matter contents are given.

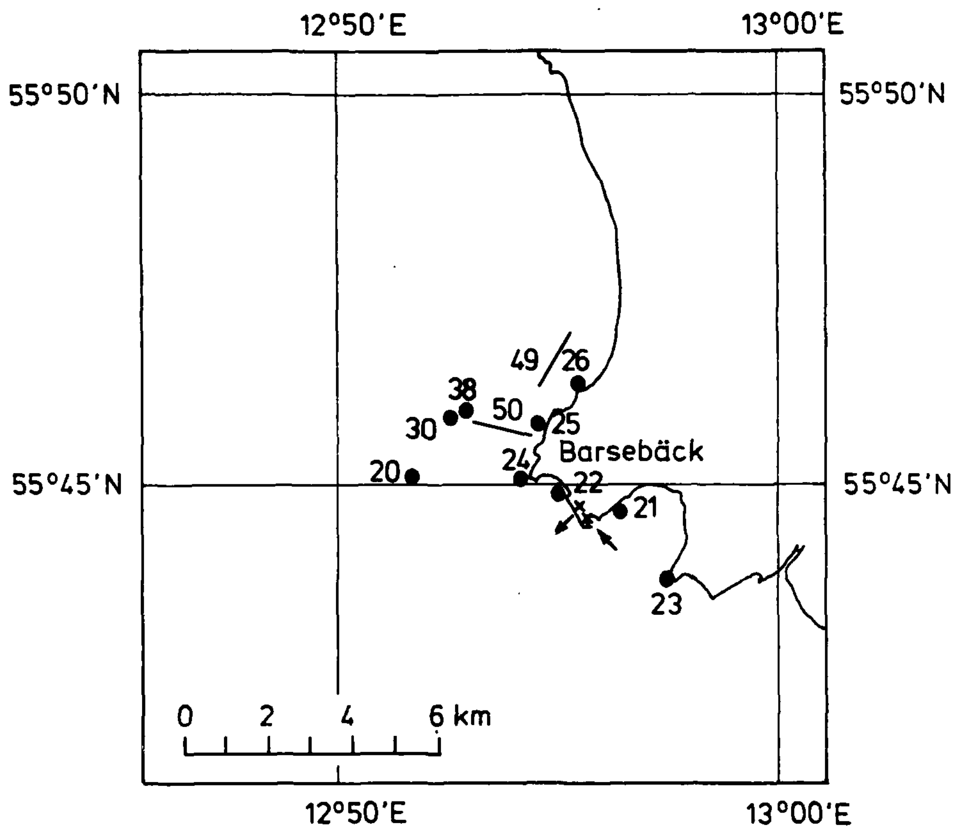


Fig. 3.2.1.1. Sampling locations at Barsebäck. 49 and 50 indicate fishing tracks. Arrows indicate cooling water intake and outlet.

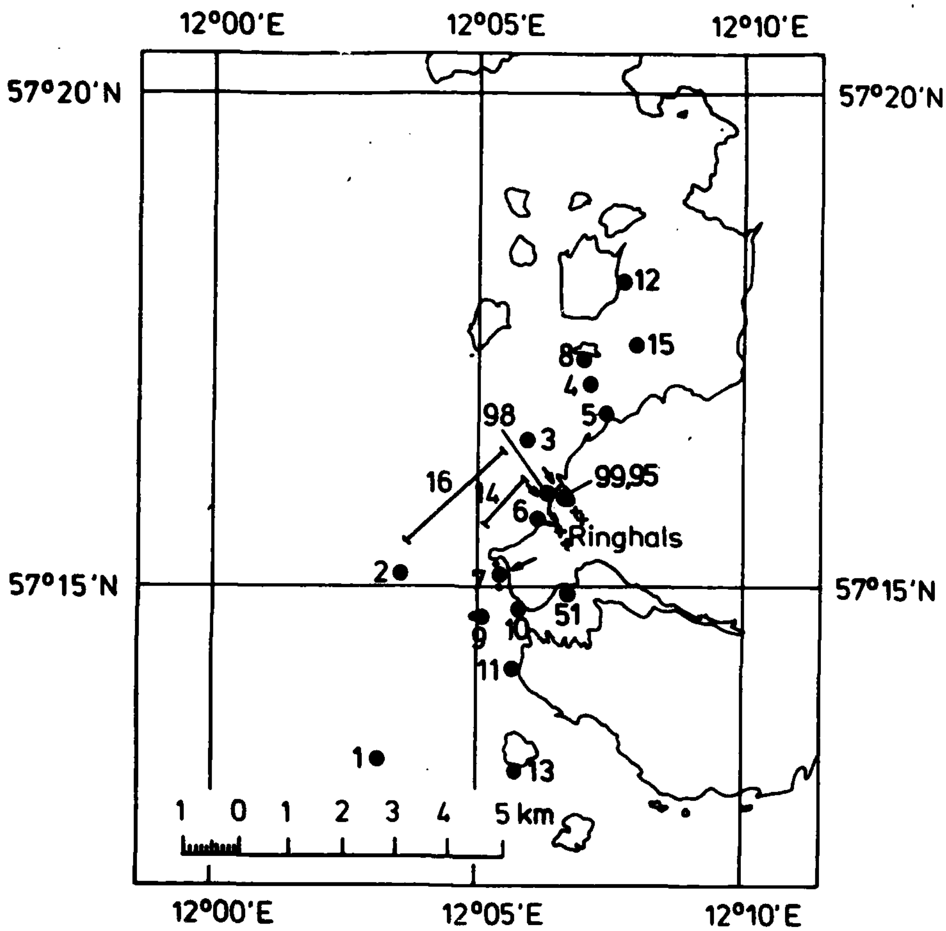


Fig. 3.2.1.2. Sampling locations at Ringhals. 14 and 16 indicate fishing tracks. Arrows indicate cooling water intake and outlet.

Table 3.2.1.1. Radionuclides in Fucus vesiculosus (Fu.ve.), Fucus serratus (Fu.se.) and Ascophyllum nodosum (As.no.) collected at Ringhals 10 June 1986 (Unit: Bq kg^{-1} dry matter)

Station No.**	7	7	6	6	5	5	8	8	10*	10*	9*	13*	13*	13*
% dry matter	20.3	20.5	13.9	16.6	20.5	21.3	16.1	16.3	12.4	16.6	17.6	16.8	14.8	22.0
Species	Fu.ve.	As.no.	Fu.ve.	Fu.se.	Fu.ve.	Fu.se.	Fu.ve.	Fu.se.	Fu.ve.	Fu.se.	. Fu.se	Fu.ve.	Fu.se.	As.no.
Distance from outlet in km	0.2	0.2	1.9	1.9	4.1	4.1	4.8	4.8	0.9	0.9	1.1	4.1	4.1	4.1
^{54}Mn	34		9.5	10 A	7.8			6.6 A	23	13.9	12 A	5.0 A		
^{57}Co	2.7 A													
^{58}Co	620	300	138	179	63	74	73	75	410	350	210	28	25	
^{60}Co	390	300	79	112	48	47	57	59	150	138	107	56	44	25
^{65}Zn	22	33	13 B											
^{103}Ru	290	210	350	290	280	167	310	270	640	330	189	290	590	78
^{106}Ru	149	78 A	156	118 A	133	96	150 A	135	320	157 A	104	136	330	51 A
^{110m}Ag	34	32	28	16.5	23	20 A	23	13 A	40	25	24	19.9	24	17.6
^{134}Cs	19.7	13.3	13.8	14.6	21	17.5	20	18.6	25	23	19.3	18.1	21	11.6
^{137}Cs	43.4	29.1	47	33	48	56	43	44	55	51	45	51	41	28
^{144}Ce						52		21 B				18 A	38 A	

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

**Cf. Fig. 3.2.1.2.

Table 3.2.1.3 shows a comparison of the 3 fucoids Fucus vesiculosus, Fucus serratus and Ascophyllum nodosum. The levels of significance of differences from unity are indicated.

Table 3.2.1.3.. Ratios of activity concentrations on dry weight basis in Fucus vesiculosus (Fu.ve.), Fucus serratus (Fu.se.) and Ascophyllum nodosum (As.no.) collected at Ringhals 1978-1986

Isotope	Fu.ve./Fu.se.			Fu.ve./As.no.		
^{60}Co	0.81***	±0.046	(n=30)	1.3*	±0.13	(n=17)
^{58}Co	0.82***	±0.040	(n=29)	2.4***	±0.27	(n=15)
^{54}Mn	0.98	±0.068	(n=25)	3.5***	±0.33	(n=8)
^{65}Zn	0.80***	±0.058	(n=25)	1.2	±0.17	(n=16)
^{110m}Ag	1.52**	±0.159	(n=18)	1.2	±0.18	(n=11)
^{137}Cs	1.04	±0.032	(n=29)	1.4***	±0.05	(n=15)
^{131}I	0.94		(n=1)	1.2		(n=1)
^{95}Zr	0.89		(n=1)			
^{124}Sb	0.70		(n=1)	1.3		(n=1)
^{57}Co				0.8		(n=1)
^{134}Cs	1.03	±0.059	(n=5)	1.5	±0.04	(n=2)
^{103}Ru	1.29	±0.249	(n=5)	2.5	±1.17	(n=2)
^{106}Ru	1.25	±0.261	(n=5)	2.3	±0.38	(n=2)
^{144}Ce	0.47		(n=1)			

The error term was 1 S.E.

In Figures 3.2.1.3-3.2.1.11 we have compared the discharges of various radionuclides with the calculated transfer factors for the period 1983-1987. It is evident that the transfer factors are not constant (as we would have liked them to be). In case of ^{110m}Ag (Fig. 3.2.1.7) the Chernobyl accident evidently influenced the transfer factors in 1986.

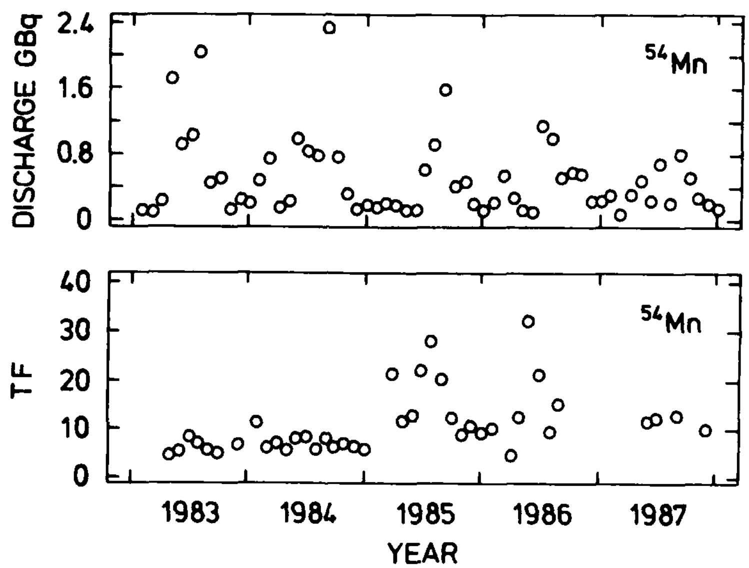


Fig. 3.2.1.3. Monthly discharge and transfer factors (TF) to Fucus from Ringhals for ^{54}Mn.
The TF is calculated as the ratio between activity concentration in Fucus (Bq kg^{-1} dry) and the monthly discharge (GBq $month^{-1}$) average over 6 months previous to the Fucus sampling.

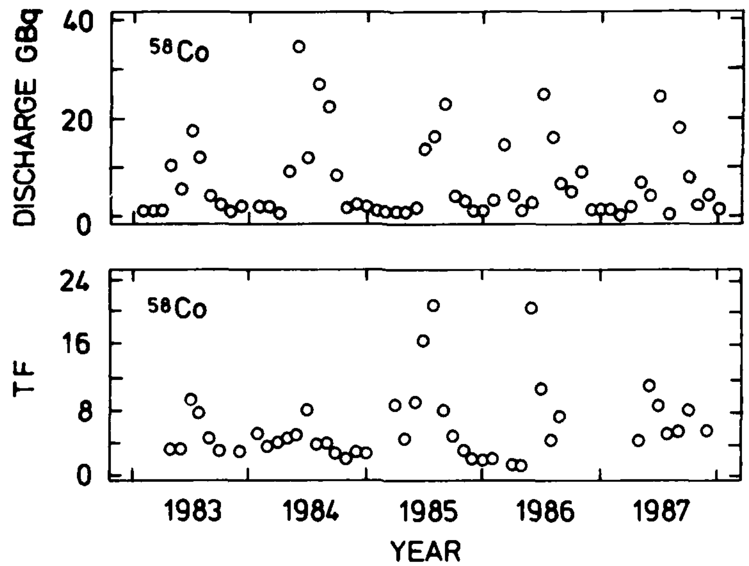


Fig. 3.2.1.4. Discharge and TF to Fucus from Ringhals (cf. Fig. 3.2.1.3).

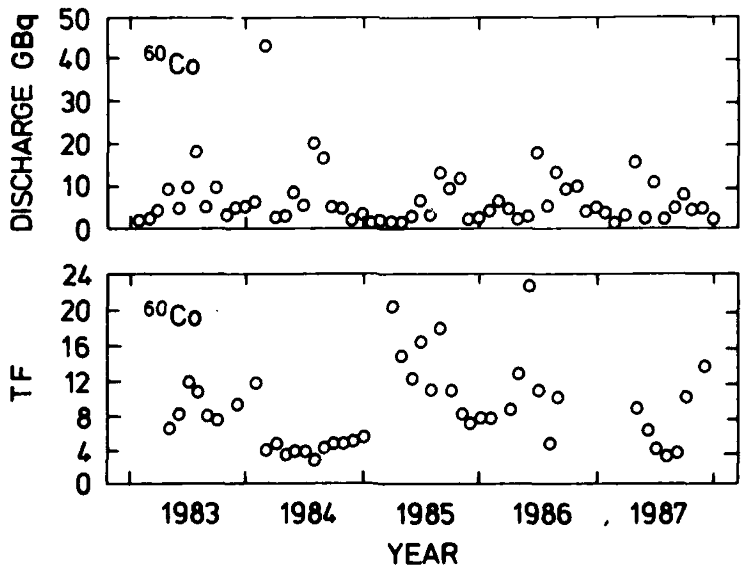


Fig. 3.2.1.5. Discharge and TF to Fucus from Ringhals (cf. Fig. 3.2.1.3).

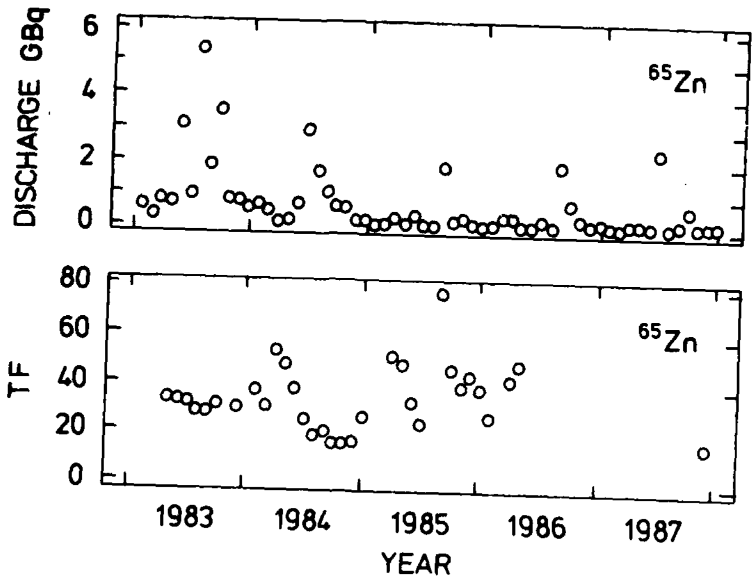


Fig. 3.2.1.6. Discharge and TF to Fucus from Ringhals (cf. Fig. 3.2.1.3).

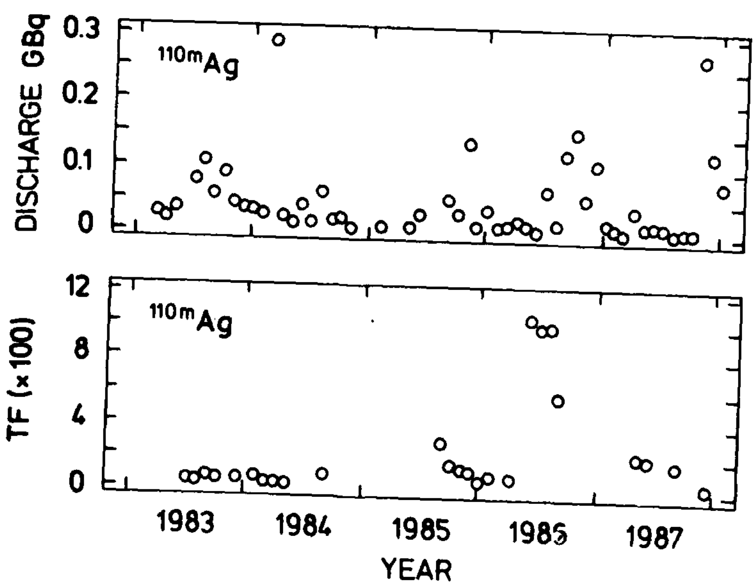


Fig. 3.2.1.7. Discharge and TF to Fucus from Ringhals (cf. Fig. 3.2.1.3).

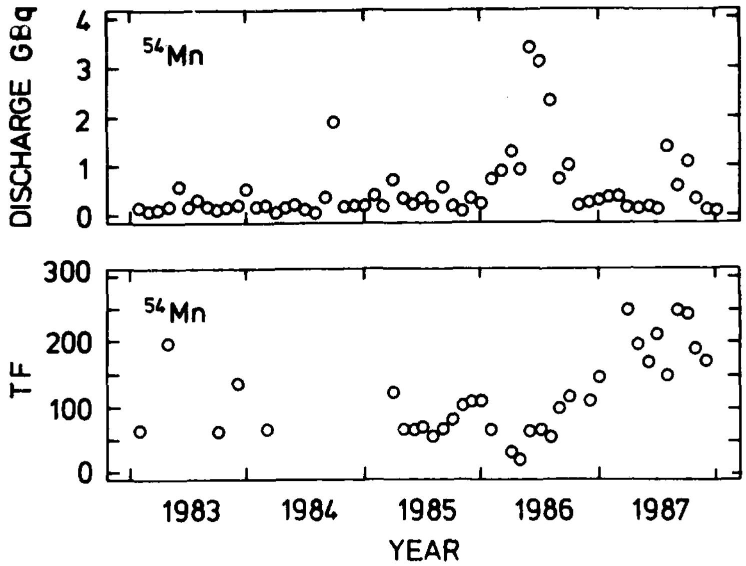


Fig. 3.2.1.8. Discharge and TF to Fucus from Barsebäck (cf. Fig. 3.2.1.3).

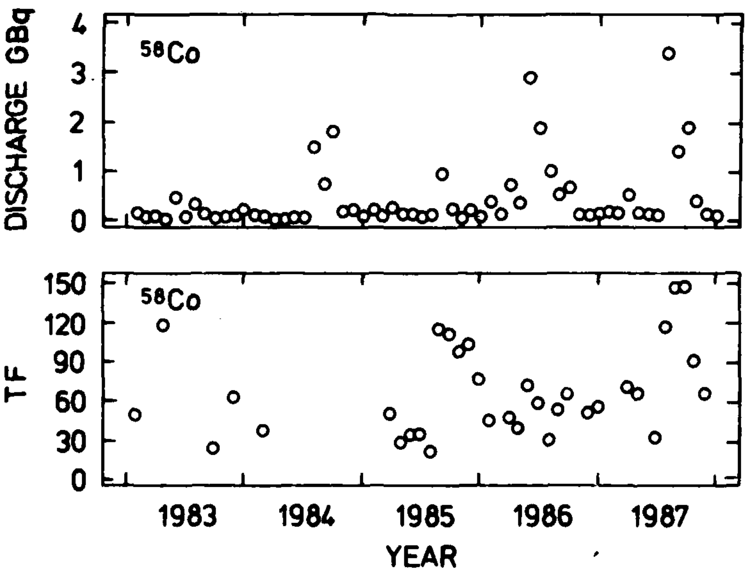


Fig. 3.2.1.9. Discharge and TF to Fucus from Barsebäck (cf. Fig. 3.2.1.3).

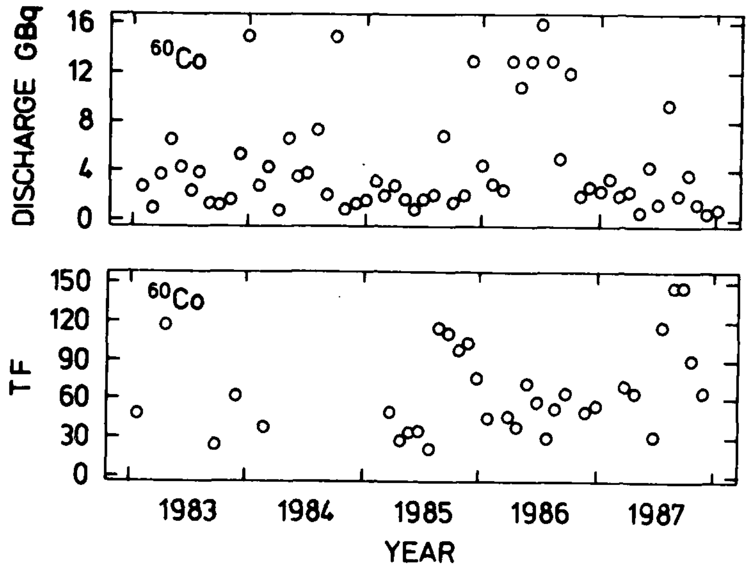


Fig. 3.2.1.10. Discharge and TF to Fucus from Barsebäck (cf. Fig. 3.2.1.3).

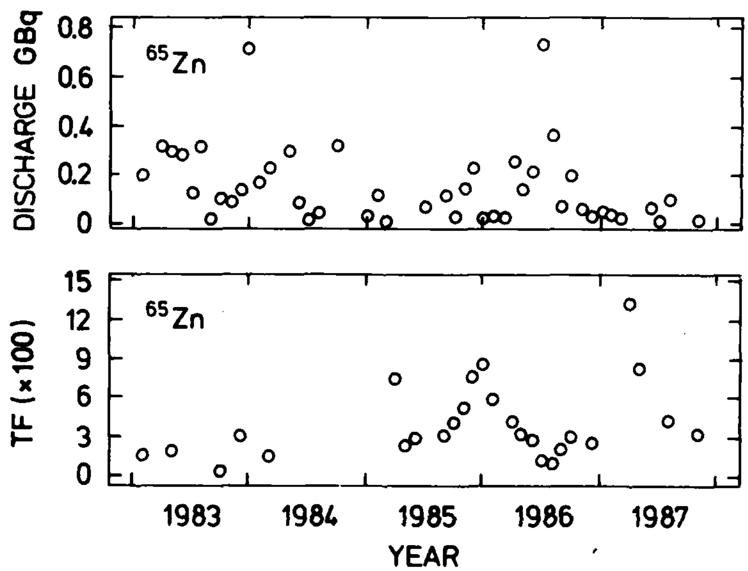


Fig. 3.2.1.11. Discharge and TF to Fucus from Barsebäck (cf. Fig. 3.2.1.3).

3.2.2. γ-emitting radionuclides in benthic invertebrates and fish

Table 3.2.2.1 shows results of the γ-countings on benthic animals and fish from Ringhals and Barsebäck in 1986. The dose commitment to a hypothetical critical individual consuming 20 kg Mytilus edulis soft parts (fresh weight) yearly would be approximately 1.9 µSv y^{-1} based on mussels from Table 3.2.2.1. This is < 0.1% of the background radiation dose (≃ 2 mSv yr^{-1}).

Table 3.2.2.1. Gamma-emitting radionuclides in benthic animals and fish collected at Ringhals and Barsebäck in 1986. (Unit: Bq kg^{-1} fresh)

Species	Fish meat	Plaice meat	Dab meat	Edible crab total$^{\Delta}$	Mytilus edulis meat	Mytilus edulis meat
Date	30/5	31/5	10/6	10/6	28/2	31/1
Location	Barsebäck	Barsebäck	Ringhals	Ringhals	Ringhals	Ringhals
Station No.*	25	30	14	14	95	98
% dry matter	-	-	-	32.5	19.0	21.2
Depth in m	0.3	~20	17	17	-	-
^{60}Co	-	-	-	1.77	4.9	4.5
^{65}Zn	-	-	-	-	-	4.1 A
^{110m}Ag	-	-	-	-	3.9 A	-
^{134}Cs	-	-	0.3	-	-	-
^{137}Cs	2.8	3.1	2.9	3.5	2.6 A	2.5

*Cf. Figs. 3.2.1.1 and 3.2.1.2.

$^{\Delta}$Unit: Bq kg^{-1} dry.

3.2.4. γ-emitting radionuclides in sea sediments

Results from sediment samples collected at Barsebäck and Ringhals with the HAPS bottom corer are shown in Tables 3.2.4.1 and 3.2.4.2. At both sites ^{60}Co from the power plants is seen to have accumulated in the sediments.

Table 3.2.4.1. Gamma-emitting radionuclides in sediment samples collected at Barsebäck, 55°45'N 12°52'E, location 38, in 1986. (Area: 0.0145 m^2)

Date	Layer in cm	^{60}Co Bq kg^{-1} dry	^{60}Co Bq m^{-2}	^{137}Cs Bq kg^{-1} dry	^{137}Cs Bq m^{-2}
30/5	0-3	13.4	66	64	310
	3-15	4.8	210	35	1490
	0-15		Σ 280		Σ1800
19/11	0-3	11.0	59	79	420
	3-6	-	-	48	400
	6-15	-	-	10.8	350
	0-15		Σ 59		Σ 1170

Table 3.2.4.2. Gamma-emitting radionuclides in sediment samples collected at Ringhals, 57°15'N 12°04'E. location 2, in 1986. (Area: 0.0145 m^2)

Date	Layer in cm	^{60}Co Bq kg^{-1} dry	^{60}Co Bq m^{-2}	^{134}Cs Bq kg^{-1} dry	^{134}Cs Bq m^{-2}	^{137}Cs Bq kg^{-1} dry	^{137}Cs Bq m^{-2}
11/6	0-3	14.0	194	2.1 A	29 A	25	350
	3-6	14.3	330	-	-	27	620
	6-15	1.25	137	-	-	7.8	850
	0-15		Σ 660		Σ 29		Σ 1820

3.2.5. Field experiments at Ringhals, Barsebäck and Forsmark

For 1986 the time-integrated water samplings were only carried out at Forsmark. At Barsebäck and Ringhals the monthly sampling programme had (as in 1985) 3 parts: 1) Local Fucus vesiculosus plants and at Ringhals also Fucus serratus; 2) uncontaminated Fucus vesiculosus transplanted to the contaminated areas one month prior to sampling and 3) contaminated plants transplanted to an uncontaminated area, where they should be sampled monthly for 6 months. The loss-measurements were initiated every 3 months. The overall idea of this programme was to gather data to support a model on especially seasonal variation in bioindicator response.

Ringhals results

Tables 3.2.5.1-3.2.5.7 give the Ringhals data. In Figure 3.2.5.1 the relations between monthly values for discharge, local Fucus vesiculosus from the cooling water channel and plants transplanted to the same site from a low level location: Varberg, one month prior to sampling has been shown. The "background" at Varberg can be seen in Table 5.11.3.

The transfer factors obtained during one month of accumulation (Table 3.2.5.6) was expected to show a distinct seasonal variation with a summer maximum, as in 1985 this was not observed - maybe because of other variables. One cause of variation might be differences in current patterns leading a variable amount of activity to the site. Compared to 1985 the mean transfer factors in 1986 were nearly the same except that for ^{110m}Ag, which due to Chernobyl was much higher in 1986.

As seen previously[1] the level in the cooling water intake channel (Table 3.2.5.4) is higher than just outside the channel (Table 3.2.5.3), except for the Chernobyl fallout nuclides (^{95}Zr, ^{103}Ru, ^{106}Ru, ^{110m}Ag, ^{134}Cs, ^{137}Cs, ^{140}Ba, ^{140}La, ^{141}Ce and ^{144}Ce) for which it was opposite.

Table 5.3.2.7 and Figure 5.3.2.1 show activity in Fucus after translocation from Ringhals to the low-active area, Varberg.

Table 3.2.5.1. Reported monthly liquid discharges from Ringhals in 1986, reference 36.
(Unit: Bq month^{-1})

Isotope	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
^{51}Cr	5.2×10^{8}	4.0×10^{8}	1.2×10^{8}	1.3×10^{8}	2.1×10^{9}	3.4×10^{9}	9.2×10^{8}	9.9×10^{8}	7.8×10^{8}	4.2×10^{8}	1.5×10^{8}	2.5×10^{7}
^{54}Mn	2.2×10^{8}	5.4×10^{8}	2.7×10^{8}	1.1×10^{8}	9.0×10^{7}	1.2×10^{9}	1.0×10^{9}	5.1×10^{8}	5.8×10^{8}	5.6×10^{8}	2.4×10^{8}	2.3×10^{8}
^{57}Co	7.6×10^{6}	3.8×10^{7}	1.8×10^{7}	5.1×10^{6}	8.9×10^{6}	7.8×10^{7}	4.7×10^{7}	2.3×10^{7}	2.2×10^{7}	3.9×10^{7}	8.8×10^{6}	1.2×10^{7}
^{58}Co	3.4×10^{9}	1.5×10^{10}	4.2×10^{9}	9.5×10^{8}	2.8×10^{9}	2.5×10^{10}	1.6×10^{10}	6.7×10^{9}	5.0×10^{9}	9.0×10^{9}	1.2×10^{9}	1.2×10^{9}
^{59}Fe	2.0×10^{7}	9.8×10^{6}	1.4×10^{7}	2.7×10^{6}	1.3×10^{7}	2.4×10^{8}	3.3×10^{8}	5.6×10^{7}	6.9×10^{7}	4.7×10^{7}	4.4×10^{6}	1.3×10^{6}
^{60}Co	4.0×10^{9}	6.7×10^{9}	4.4×10^{9}	2.0×10^{9}	2.9×10^{9}	1.8×10^{10}	5.6×10^{9}	1.3×10^{10}	9.5×10^{9}	1.0×10^{10}	4.2×10^{9}	4.9×10^{9}
^{65}Zn	1.2×10^{8}	4.5×10^{8}	3.4×10^{9}	7.7×10^{7}	8.7×10^{7}	2.3×10^{8}	6.5×10^{7}	1.9×10^{9}	7.8×10^{8}	3.0×10^{8}	1.2×10^{8}	1.9×10^{8}
^{110m}Ag	1.0×10^{7}	1.3×10^{7}	2.2×10^{7}	1.1×10^{7}	3.2×10^{6}	6.7×10^{7}	1.5×10^{7}	1.2×10^{8}	1.6×10^{8}	5.6×10^{7}	1.1×10^{8}	1.8×10^{7}
^{131}I	0	0	0	4.8×10^{8}	0	2.3×10^{6}	2.1×10^{6}	0	8.0×10^{7}	1.8×10^{7}	2.6×10^{7}	8.2×10^{6}
^{134}Cs	2.5×10^{9}	2.8×10^{8}	2.4×10^{8}	2.0×10^{8}	1.3×10^{8}	4.0×10^{8}	1.4×10^{8}	1.8×10^{8}	2.7×10^{8}	2.1×10^{9}	1.0×10^{9}	4.8×10^{8}
^{137}Cs	2.4×10^{9}	7.5×10^{8}	7.2×10^{8}	3.6×10^{8}	2.8×10^{8}	4.2×10^{8}	2.4×10^{8}	6.3×10^{8}	7.3×10^{8}	6.5×10^{9}	1.4×10^{9}	8.0×10^{8}

Table 3.2.5.2. Reported annual liquid discharges from Ringhals 1975–1986 reference 36.
(Unit: Bq year^{-1})

Isotope	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
^{51}Cr		2.3×10^{9}	1.3×10^{11}	3.9×10^{10}	7.5×10^{9}	6.0×10^{9}	1.6×10^{10}	5.5×10^{9}	1.4×10^{10}	8.1×10^{9}	1.9×10^{10}	1.0×10^{10}
^{54}Mn		3.4×10^{9}	3.3×10^{10}	1.1×10^{10}	5.2×10^{9}	5.4×10^{9}	4.0×10^{9}	2.2×10^{9}	7.8×10^{9}	8.1×10^{9}	5.1×10^{9}	5.5×10^{9}
^{57}Co						1.6×10^{8}	1.1×10^{8}	2.2×10^{7}	4.9×10^{7}	1.1×10^{8}	2.6×10^{8}	3.1×10^{8}
^{58}Co	0	1.5×10^{10}	3.1×10^{11}	5.1×10^{10}	2.7×10^{10}	1.8×10^{10}	2.6×10^{10}	1.8×10^{10}	5.9×10^{10}	1.2×10^{11}	6.7×10^{10}	9.1×10^{10}
^{59}Fe		0	1.1×10^{9}	1.1×10^{10}	1.3×10^{9}	9.9×10^{8}	1.1×10^{9}	1.1×10^{8}	6.5×10^{8}	6.6×10^{9}	2.7×10^{9}	8.0×10^{8}
^{60}Co	4.4×10^{5}	2.2×10^{10}	1.1×10^{11}	9.8×10^{10}	5.2×10^{10}	9.3×10^{10}	6.5×10^{10}	3.3×10^{10}	7.8×10^{10}	1.2×10^{11}	5.7×10^{10}	8.6×10^{10}
^{65}Zn		8.1×10^{9}	3.8×10^{10}	4.0×10^{10}	8.5×10^{10}	4.2×10^{10}	8.8×10^{10}	2.2×10^{10}	2.0×10^{10}	9.7×10^{9}	3.6×10^{9}	4.6×10^{9}
^{110m}Ag		3.0×10^{8}	9.3×10^{8}	4.6×10^{9}	1.1×10^{9}	1.1×10^{9}	9.8×10^{8}	6.0×10^{8}	5.2×10^{8}	5.1×10^{8}	3.1×10^{8}	6.0×10^{8}
^{131}I		2.4×10^{9}	0	3.6×10^{7}	0	2.4×10^{9}	1.8×10^{9}	3.0×10^{9}	3.4×10^{9}	4.8×10^{8}	951	6.1×10^{8}
^{134}Cs			6.2×10^{9}	1.2×10^{10}	4.9×10^{10}	1.5×10^{10}	1.5×10^{10}	2.5×10^{10}	8.8×10^{9}	2.8×10^{9}	1.8×10^{9}	7.9×10^{9}
^{137}Cs			8.4×10^{9}	2.6×10^{10}	6.6×10^{10}	2.1×10^{10}	2.0×10^{10}	3.3×10^{10}	1.5×10^{10}	6.2×10^{9}	3.8×10^{9}	1.5×10^{10}

Table 3.2.5.3. Gamma-emitting radionuclides in Fucus vesiculosus (Fu.ve.) and Fucus serratus (Fu.se.) outside the northern cooling-water intake at Ringhals (location 98, 2.3 km north of the outlet) in 1986. (Unit: Bq kg^{-1} dry weight)

Date		2/1	31/1	1/4	1/5	2/6	1/7	2/8	1/9	1/10	1/11	1/12	2/1-87	Mean	S.E.	n
% dry matter	Fu.ve.	18.2	23.3	21.6	20.1	13.1	13.3	12.2	17.4							
	Fu.se.		21.5	23.3	16.0	19.6	21.3	19.6	22.3	21.2	19.4	22.1	18.8			
^{54}Mn	Fu.ve.	5.4	4.7	1.2 A	2.8	6.6	8.1	4.6	7.5 A							
	Fu.se.		3.8		4.2	7.3	9.1	7.8		4.1	6.9	4.8	4.7			
	Fu.ve./Fu.se.		1.24		0.68	0.91	0.89	0.59						0.86	0.113	5
^{57}Co	Fu.se.							0.73A			0.7 B					
^{58}Co	Fu.ve.	14.7	11.8	6.5	5.1	71	92	47	67							
	Fu.se.		12.5	7.8	18.4	122	88	94	40	36	70	45	34			
	Fu.ve./Fu.se.		0.95	0.83	0.28	0.58	1.05	0.50	1.69					0.84	0.174	7
^{60}Co	Fu.ve.	54	56	45	46	79	69	32	78							
	Fu.se.		51	49	72	91	79	71	59	55	108	98	92			
	Fu.ve./Fu.se.		1.08	0.91	0.64	0.87	0.88	0.46	1.32					0.88	0.106	7
^{65}Zn	Fu.ve.	16.5	11.8	8.8	8.4											
	Fu.se.		10.4		11.5			4.7 A		10.8	16.0	12.9	11.9			
	Fu.ve./Fu.se.		1.14		0.73									0.93	0.206	2
^{95}Zr	Fu.ve.				11.1											
	Fu.se.				41											
	Fu.ve./Fu.se.				0.27									0.27		1
^{103}Ru	Fu.ve.				7.2	550	160	87								
	Fu.se.				10.3	174	97 A	65			9 B	7.5 A				
	Fu.ve./Fu.se.				0.70	3.2	1.66	1.34						1.71	0.521	4

Table 3.2.5.3. (continued)

Date		2/1	31/1	1/4	1/5	2/6	1/7	2/8	1/9	1/10	1/11	1/12	2/1-87	Mean	S.E.	n
% dry matter	Fu.ve.	18.2	23.3	21.6	20.1	13.1	13.3	12.2	17.4							
	Fu.se.		21.5	23.3	16.0	19.6	21.3	19.6	22.3	21.2	19.4	22.1	18.8			
^{106}Ru	Fu.ve.					250	128	105	76							
	Fu.se.					79	70 A			33	41	35	33			
	Fu.ve./Fu.se.					3.2	1.82							2.51	0.688	2
^{110m}Ag	Fu.ve.	2.3 B	3.7 A	2.9		18.6	21	22	23							
	Fu.se.				2.6 A	14.8	16.0	17.2	18.9	16.5	16.2	13.1	13.1			
	Fu.ve./Fu.se.					1.26	1.33	1.27	1.22					1.27	0.023	4
^{131}I	Fu.se.				169											
^{134}Cs	Fu.ve.					29	17.1	9.9	9.5							
	Fu.se.					19.8	17.9	10.8		3.8	6.5	5.4	5.2			
	Fu.ve./Fu.se.					1.49	0.96	0.92						1.12	0.184	3
^{137}Cs	Fu.ve.	7.5	8.0	2.1	6.1	69	35	32	21							
	Fu.se.		7.2	3.5	7.9	44	45	29	19.2	13.3	18.1	22	15.3			
	Fu.ve./Fu.se.		1.11	0.59	0.78	1.57	0.77	1.11	1.11					1.00	0.122	7
^{140}Ba	Fu.se.				32 A											
^{140}La	Fu.ve.				15.6											
	Fu.se.				33											
	Fu.ve./Fu.se.				0.47									0.47		1
^{141}Ce	Fu.ve.				10.8											
	Fu.se.				44											
	Fu.ve./Fu.se.				0.24									0.24		1
^{144}Ce	Fu.ve.				8.1		11.8 A	7.5 A								
	Fu.se.				34											
	Fu.ve./Fu.se.				0.24									0.24		1

Table 3.2.5.4. Gamma-emitting radionuclides in Fucus vesiculosus collected from the northern cooling-water intake channel at Ringhals in 1986 (location 95 (local), 2.5 km north of the outlet). (Unit: Bq kg^{-1} dry weight)

Date	2/1	31/1	28/2	1/4	1/5	2/6	1/7	2/8	1/9	1/12	2/1-87
% dry matter	13.1	14.2	21.9	24.6	14.6	18.7	18.5	20.1	20.5	16.2	13.8
^{54}Mn	13.8	8.3	6.5		9.6	17.1	13.4	12.8		12.2	6.5
^{57}Co							1.5 A				
^{58}Co	30.6	18.9	21.3	13.6	26.5	136	164	106	94	67	36
^{60}Co	138	78	78	59	82	164	158	98	101	170	114
^{65}Zn		9.4 A			8.3A		5 B				6.5 A
^{95}Zr					112						
^{103}Ru					36	1940	490	167	54 A	22 A	8.5 A
^{106}Ru						790	320	210		183	94
^{110m}Ag						33	28	23		15.6	17.7
^{125}Sb						18 A	6 A				
^{134}Cs					2.0A	75	29	18.0	18.0A	18.6	12.8
^{137}Cs	22.5	17.0	11.4	12.1	18.8	152	69	45	44	56	39
^{140}Ba					103 A						
^{140}La					98						
^{141}Ce					88						
^{144}Ce					66		40				

Table 3.2.5.5. Gamma-emitting radionuclides in *Fucus vesiculosus* transplanted from Stora Näss, Varberg (57°07'N 12°11'E) to the northern cooling-water intake channel at Ringhals one month before sampling. (Unit: Bq kg^{-1} dry weight)

Period of accumulation	31/1-28/2	1/4-1/5	1/5-2/6	2/6-1/7	1/7-2/8	2/8-1/9	1/9-1/10	1/10-1/11	1/11-1/12	1/12-2/1-87*
% dry matter	-	23.5	17.2	22.0	18.5	15.7	23.7	18.4	17.4	18.6
^{54}Mn			10.7	8.3	4.2	21		12.2	3.7 A	
^{57}Co								2 B		
^{58}Co			121	109	43	158		90	7.2 A	2.5 B
^{60}Co	6.9	7.5	105	72	25	320	10.5	119	34	11.1
^{95}Zr			144							
^{103}Ru			1400	270	66	125		27		
^{106}Ru			600	181	79	240	71 A	104	41 A	29
^{110m}Ag			30	21	14.8	25	8.9 A	14.8	11.6	10.9
^{134}Cs			61	24	13.0	21		18.4	10.1	10.2
^{137}Cs	3.9 A	6.6	128	60	31	56	6.7 A	56	34	32
^{144}Ce				22	8 B					

**Fucus serratus*

Table 3.2.5.6. Fucus vesiculosus. Transfer factors obtained during one month of accumulation after transplantation to Ringhals. (Unit: Bq kg^{-1} dry Fucus/GBq discharged) (cf. Tables 3.2.5.1 and 3.2.5.5)

	Feb	April	May	June	July	Aug	Sept	Oct	Nov	Dec	$\bar{x}$	S.E.	n
^{54}Mn			119	6.92	4.20	41.18		21.8	15.42		35	17.7	6
^{58}Co			43.21	4.36	2.69	23.58		10.0	6.0	2.08	13.1	5.7	7
^{60}Co	1.03	3.75	36.21	4.00	4.46	24.62	1.11	11.9	8.10	2.27	9.7	3.7	10
^{110m}Ag			9400	313	987	208	56	264	105	606	1490	1130	8

Table 3.2.5.7. Gamma-emitting radionuclides in Fucus vesiculosus transplanted from outside the cooling-water intake channel (Table 3.2.5.3) to Stora Näss, Varberg (57°07'N 12°11'E) in 1986. (Unit: Bq kg^{-1} dry weight)

Transplanting date	2 January					1 April		1 July			
Sampling date	2/1	31/1	1/4	1/5	2/6	1/4	1/5	1/7	2/8	1/9	1/10
% dry matter	18.2	20.4	22.4	22.2	25.0	21.6	18.2	13.3	21.3	19.3	28.6
^{54}Mn	5.4	5 B			4 B	1.2 A		8.1	5.3	6.9 A	
^{58}Co	14.7	12 B	11 B			6.5		92	32	33	
^{60}Co	54	51	70	19.7	6.0 A	45	22	69	32	42	6.2
^{65}Zn	16.5	17 A	19.8 A			8.8					
^{95}Zr				270			630				
^{103}Ru					480		300 A	160	82	37 B	
^{106}Ru					210		61 B	128	68	34 B	40 A
^{110m}Ag	2 B				12 A	2.9		21	10.6	17.8	5 B
^{134}Cs					40		14.4	17.1	15.3	14.4	7.1
^{137}Cs	7.5	10.4	10.2 A	7.5	84	2.1	23	35	41	38	25
^{144}Ce					22 B		360				

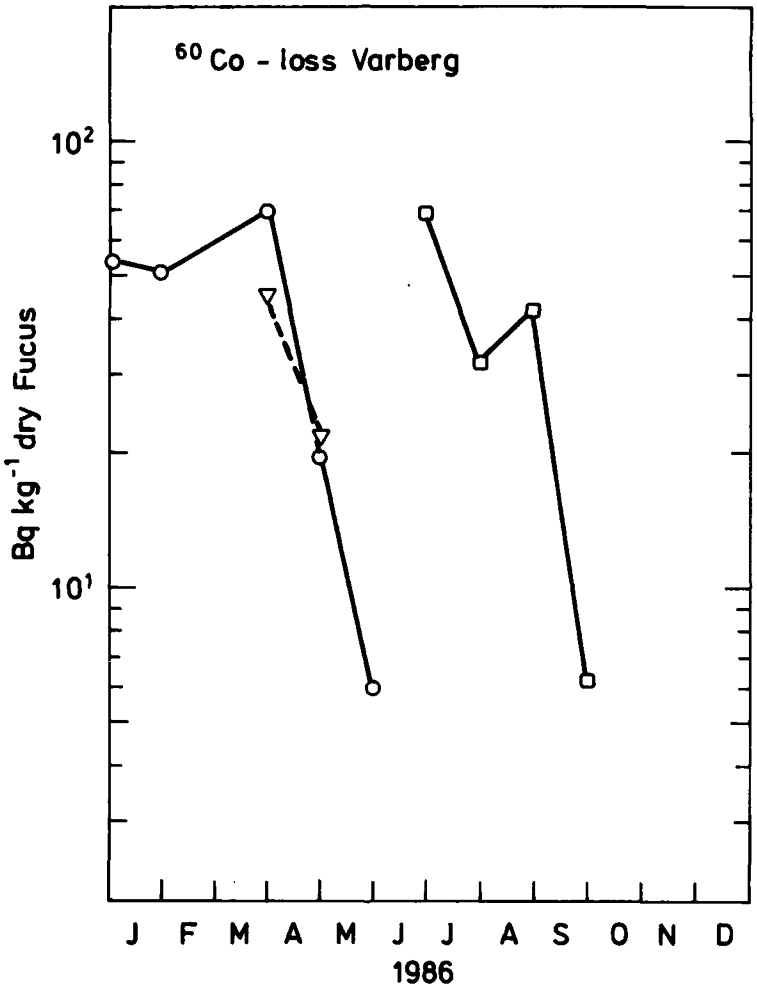


Figure 3.2.5.1. Concentration of ^{60}Co in Fucus vesiculosus translocated from Ringhals to Varberg (low activity). Data from Table 3.2.5.7.

The material is far less complete than planned, but for the winter (Jan 2) as well as for the summer (July 1) translocation we observed steep decreases in activity 3 months after the translocation to Varberg.

Barsebäck results

Tables 3.2.5.8-3.2.5.13 and Figures 3.2.5.3 and 3.2.5.4 give the Barsebäck data. Also here lost data perturbed the project. For this site Limhamn was used as low-level site for Fucus transplants (cf. Fig. 3.2.5.2). The background at Limhamn is seen in Table 5.11.3.

Neither at Barsebäck could any seasonal variation be quantified from the one-month accumulation experiments (Tables 3.2.5.11 and 3.2.5.12). But in case of ^{60}Co the variation in transfer factors from month to month was nearly the same in 1986 as in 1985 and so was the annual mean.

Table 3.2.5.8. Reported monthly liquid discharges from Barsebäck in 1986, reference 36.
(Unit: Bq $month^{-1}$)

Isotope	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
^{51}Cr	1.7×10^{9}	9.9×10^{8}	2.7×10^{9}	2.9×10^{9}	5.6×10^{9}	1.7×10^{9}	1.1×10^{9}	3.6×10^{8}	3.0×10^{8}	4.5×10^{7}	2.6×10^{8}	6.5×10^{8}
^{54}Mn	7.0×10^{8}	8.8×10^{8}	1.3×10^{9}	9.2×10^{8}	3.4×10^{9}	3.1×10^{9}	2.3×10^{9}	7.2×10^{8}	1.0×10^{9}	1.9×10^{8}	2.6×10^{8}	3.2×10^{8}
^{58}Co	4.0×10^{8}	1.4×10^{8}	7.4×10^{8}	3.7×10^{8}	2.9×10^{9}	1.9×10^{9}	1.0×10^{9}	5.4×10^{8}	6.9×10^{8}	1.2×10^{8}	1.1×10^{8}	1.3×10^{8}
^{59}Fe	0	0	0	0	4.8×10^{8}	4.3×10^{8}	9.3×10^{7}	5.5×10^{7}	0	0	0	0
^{60}Co	3.0×10^{9}	2.5×10^{9}	1.3×10^{10}	1.1×10^{10}	1.3×10^{10}	1.6×10^{10}	1.3×10^{10}	5.0×10^{9}	1.2×10^{10}	2.1×10^{9}	2.7×10^{9}	2.4×10^{9}
^{65}Zn	3.3×10^{7}	2.5×10^{7}	2.6×10^{8}	1.4×10^{8}	2.2×10^{8}	7.4×10^{8}	3.7×10^{8}	7.2×10^{7}	2.0×10^{8}	6.0×10^{7}	3.4×10^{7}	5.1×10^{7}
^{110m}Ag	1.3×10^{7}	0	0	0	0	0	0	0	0	0	0	0
^{131}I	0	0	8.5×10^{7}	0	0	0	0	0	0	3.1×10^{7}	0	0
^{134}Cs	0	4.7×10^{7}	2.3×10^{8}	1.7×10^{8}	2.0×10^{8}	1.9×10^{8}	1.1×10^{8}	0	2.6×10^{8}	2.6×10^{7}	0	1.6×10^{7}
^{137}Cs	1.6×10^{8}	2.2×10^{8}	1.1×10^{9}	9.0×10^{8}	7.5×10^{8}	4.2×10^{8}	3.9×10^{8}	2.4×10^{8}	7.5×10^{8}	7.9×10^{7}	5.0×10^{7}	5.9×10^{7}

Table 3.2.5.9. Reported annual liquid discharges from Barsebäck 1975-1986 reference 36.
(Unit: Bq year^{-1})

Isotope	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
^{51}Cr	1.2×10^{10}	1.7×10^{10}	1.3×10^{10}	3.2×10^{10}	1.7×10^{10}	4.2×10^{9}	2.7×10^{10}	6.7×10^{9}	7.2×10^{9}	4.7×10^{9}	6.6×10^{9}	1.8×10^{10}
^{54}Mn	5.6×10^{7}	2.0×10^{9}	2.1×10^{9}	3.9×10^{9}	2.0×10^{9}	1.7×10^{9}	2.0×10^{9}	3.3×10^{9}	2.7×10^{9}	3.7×10^{9}	3.7×10^{9}	1.5×10^{10}
^{58}Co	6.6×10^{9}	2.6×10^{10}	1.3×10^{10}	3.4×10^{10}	7.8×10^{9}	7.2×10^{9}	6.3×10^{9}	4.0×10^{9}	1.8×10^{9}	4.9×10^{9}	2.6×10^{9}	9.0×10^{9}
^{59}Fe					2.4×10^{8}	9.3×10^{7}	1.5×10^{8}	1.2×10^{8}	1.3×10^{8}	5.5×10^{8}	7.8×10^{7}	1.1×10^{9}
^{60}Co	2.6×10^{8}	1.4×10^{10}	2.8×10^{10}	5.4×10^{10}	2.2×10^{10}	3.7×10^{10}	4.3×10^{10}	7.3×10^{10}	4.9×10^{10}	5.0×10^{10}	4.2×10^{10}	9.6×10^{10}
^{65}Zn	3.7×10^{7}	3.1×10^{9}	7.0×10^{9}	1.0×10^{10}	5.5×10^{9}	5.8×10^{9}	5.5×10^{9}	7.7×10^{9}	2.6×10^{9}	1.2×10^{9}	7.5×10^{8}	2.2×10^{9}
^{110m}Ag	0	2.2×10^{9}	1.8×10^{9}	3.6×10^{9}	8.6×10^{8}	2.9×10^{8}	2.4×10^{8}	1.3×10^{8}	3.8×10^{7}	5.7×10^{7}	0	1.3×10^{7}
^{131}I									7.5×10^{8}	2.2×10^{8}	3.7×10^{7}	1.2×10^{8}
^{134}Cs					0	0	4.6×10^{9}	1.9×10^{10}	6.5×10^{9}	4.0×10^{9}	4.7×10^{8}	1.2×10^{9}
^{137}Cs	0	0	6.5×10^{8}	1.9×10^{7}	0	0	6.1×10^{9}	2.6×10^{10}	1.2×10^{10}	9.2×10^{9}	1.9×10^{9}	5.1×10^{9}

Table 3.2.5.10. Gamma-emitting radionuclides in Fucus vesiculosus collected at Barsebäck, location 25 ($55^{o}48'80N$ $12^{o}54'45E$) in 1986. (Unit: Bq kg^{-1} dry weight)

Sampling date	3/1	31/1	1/4	1/5	30/5	2/6	1/7	1/8	1/9	1/10	1/11	1/12	2/1-87
% dry matter	21.7	17.6	19.6	20.6	14.1	10.5	16.9	17.9	16.3	16.9	17.1	17.6	17.8
^{54}Mn	29	23	18.9	15.4	69	92	115	106	171	220	200	138	116
^{58}Co	21	14.3	12.3	11.8	52 A	56	61	34	42 A	78	77	36	23
^{60}Co	1190	1010	980	710	680	640	930	780	860	1980	1510	1440	1160
^{65}Zn	79	57	50	39		32	30	28	28 A	86	81	63	
^{95}Zr				390		200							
^{103}Ru				320	410	660	118						
^{106}Ru				69	166 A	260	91						
^{125}Sb						8 B	8 B						
^{134}Cs				9.6	41	45	22	12.2	11.4	7.5	6.8	6.3	
^{137}Cs	8.0	6.5	6.0	21.4	87	99	54	29	32	23	19.9	18.6	17.2
^{140}Ba				430									
^{140}La				420									
^{141}Ce				350									
^{144}Ce				240		166							

Table 3.2.5.11. Gamma-emitting *radionuclides* in Fucus vesiculosus transplanted *from* Limhamn (55°35'N 12°55'E) to Barsebäck, location 25, one month before sampling. (Unit: Bq kg^{-1} dry weight)

Period of accumulation	3/1-31/1	1/4-1/5	1/5-2/6	2/6-1/7	1/7-1/8	1/10-1/11	1/11-1/12	1/12-2/1-87
% dry matter	20.0	17.7	19.5	17.9	18.4	22.3	18.4	16.3
^{54}Mn	6.6 A	15.0	118	87	77	23	21	
^{58}Co			77 A	38 A	24 B		8 B	
^{60}Co	42	164	590	510	350	250	200	74
^{65}Zn				19 B	14 B			
^{95}Zr		340						
^{103}Ru		148 A	230					
^{106}Ru			107	92 A				
^{134}Cs			32	31	16.9			
^{137}Cs	6.0 B	18.6	66	73	39	14 A	20	17 A

Table 3.2.5.12. Fucus vesiculosus. Transfer-factors obtained during one month of accumulation after transplantation to Barsebäck. (Unit: Bq kg^{-1} dry Fucus/GBq discharged) (cf. Tables 3.2.5.8 and 3.2.5.11)

Isotope	Jan	April	May	June	July	Oct	Nov	Dec	$\bar{x}$	S.E.	n
^{54}Mn	9.4	17.0	35	28	33	121	81		46	15	7
^{58}Co			27	20	24		73		36	12	4
^{60}Co	14.0	14.9	45	32	27	119	74	31	45	13	8
^{65}Zn				26	38				32	6	2

Table 3.2.5.13. Gamma-emitting radionuclides in Fucus vesiculosus transplanted from Barsebäck (Table 3.2.5.10) to Limhamn (55°35'N 12°55'E) in 1986. (Unit: Bq kg^{-1} dry weight)

Transplanting date	1 November 1985						31 January					1 May		1 August				1 November		
Sampling date	1/11-85	3/12-85	3/1	31/1	1/4	1/5	31/1	1/4	1/5	2/6	1/7	1/5	2/6	1/8	1/9	1/10	1/11	1/11	1/12	2/1-87
% dry matter	21.6	21.5	24.0	19.5	17.4	17.3	17.6	19.2	21.4	18.5	16.9	20.6	20.0	17.9	15.5	21.6	23.6	17.6	19.3	20.2
^{54}Mn	27	25	4.0 A	15.5	15.7 A	5.1 A	23	25	11.8		8.7	15.4	17 B	106	29	47	15.6	200	66	44
^{58}Co	26						14.3					11.8		34				77	18 B	
^{60}Co	490	570	114	340	320	164	1010	1180	510	460	270	710	580	780	200	600	188	1510	720	440
^{65}Zn	33	28 A	5 B		23 B		57	59	27		13 B	39		28					37 A	
^{95}Zr												390								
^{103}Ru										390 A	210	320	420 B							
^{106}Ru										166	111	69	137 B							
^{134}Cs										68	33	9.6	61	12.2				6.8		
^{137}Cs	11.5	7 B	2.2 A	8.5 A		9.5	6.5	8 B	10.7	144	80	21.4	127	29	20	20	13.9	19.9	18.1	21
^{140}Ba												430								
^{140}La												420								
^{141}Ce												350								
^{144}Ce									18.1	30 B	19 B	240								

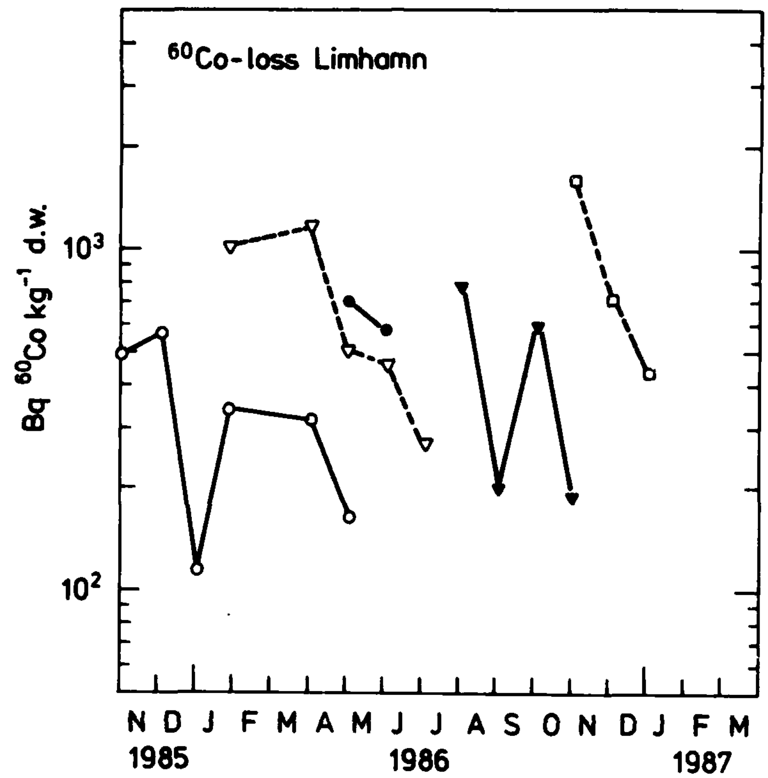


Figure 3.2.5.2. Concentration of ^{60}Co in Fucus vesiculosus translocated from Barsebäck to Limhamn (low activity). Data from Table 3.2.5.13.

Forsmark results

Tables 3.2.5.14-17 show data on radionuclides in water from the Biotest area, discharge from Forsmark and calculated transfer factors from discharge to water. The time-integrated water sampling procedure was described in the 1983-report[1].

The water samplings at Forsmark were performed by the National Swedish Environmental Protection Board, and the results should be compared with their measurements on biota and sediments. A map of the location is shown in Figure 3.2.5.3.

Table 3.2.5.14. Reported monthly liquid discharges from Forsmark I and II in 1986, reference 36.
(Unit: Bq month^{-1})

Isotope	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
^{51}Cr	1.4×10^{8}	0	1.9×10^{8}	1.2×10^{9}	1.9×10^{9}	1.9×10^{9}	3.3×10^{9}	2.1×10^{9}	2.3×10^{9}	6.0×10^{8}	4.0×10^{9}	1.0×10^{9}
^{54}Mn	2.8×10^{8}	3.0×10^{8}	2.0×10^{8}	3.0×10^{8}	2.2×10^{8}	1.0×10^{8}	1.8×10^{9}	2.2×10^{9}	7.1×10^{8}	6.7×10^{8}	6.1×10^{8}	4.1×10^{8}
^{57}Co	0	0	0	0	0	0	1.5×10^{7}	1.5×10^{7}	1.2×10^{7}	0	2.4×10^{7}	2.8×10^{7}
^{58}Co	7.6×10^{8}	8.1×10^{8}	3.9×10^{8}	8.7×10^{8}	7.6×10^{8}	5.5×10^{8}	6.2×10^{9}	6.2×10^{9}	3.6×10^{9}	3.5×10^{9}	3.4×10^{9}	1.3×10^{9}
^{59}Fe	0	0	0	0	0	0	0	0	0	0	0	0
^{60}Co	2.1×10^{10}	2.4×10^{10}	1.1×10^{10}	1.5×10^{10}	1.6×10^{10}	6.4×10^{9}	7.1×10^{10}	7.7×10^{10}	2.9×10^{10}	4.3×10^{10}	2.1×10^{10}	1.9×10^{10}
^{65}Zn	1.6×10^{9}	2.7×10^{9}	1.5×10^{9}	1.6×10^{9}	1.4×10^{9}	6.4×10^{8}	6.9×10^{9}	6.6×10^{9}	2.8×10^{9}	4.7×10^{9}	2.7×10^{9}	2.0×10^{9}
^{95}Zr	0	0	0	0	0	0	0	0	0	0	0	0
^{95}Nb	0	0	0	0	0	0	0	0	0	0	0	0
^{103}Ru	0	0	0	0	0	0	0	0	0	0	0	0
^{110m}Ag	2.4×10^{8}	1.6×10^{8}	2.0×10^{8}	2.7×10^{8}	3.5×10^{8}	1.5×10^{8}	1.1×10^{9}	1.2×10^{9}	1.2×10^{9}	6.7×10^{8}	1.4×10^{9}	6.2×10^{8}
^{124}Sb	0	9.5×10^{8}	0	0	6.1×10^{8}	0	1.8×10^{9}	1.7×10^{9}	0	0	1.3×10^{9}	0
^{125}Sb	0	7.7×10^{8}	0	0	3.4×10^{8}	0	0	0	0	0	0	5.5×10^{7}
^{131}I	0	0	0	0	0	1.5×10^{8}	0	0	4.4×10^{8}	3.2×10^{8}	2.4×10^{8}	3.3×10^{8}
^{134}Cs	0	0	0	0	0	0	0	2.6×10^{8}	0	0	0	0
^{137}Cs	0	0	0	0	0	0	2.8×10^{8}	3.1×10^{8}	0	0	6.2×10^{7}	0
^{140}Ba	0	0	0	0	0	0	0	0	0	0	0	0
^{140}La	0	0	0	0	0	0	0	0	2.4×10^{8}	0	0	0
^{141}Ce	0	1.4×10^{7}	8.9×10^{6}	4.7×10^{7}	2.0×10^{7}	1.1×10^{7}	6.0×10^{7}	0	1.7×10^{8}	1.9×10^{7}	8.5×10^{7}	3.4×10^{7}

Table 3.2.5.15. Reported annual liquid discharges from Forsmark I and II in 1984-1986 from reference 36

Isotope	1984	1985	1986
^{51}Cr	4.9×10^{11}	3.3×10^{10}	1.9×10^{10}
^{54}Mn	4.7×10^{9}	6.1×10^{9}	7.8×10^{9}
^{57}Co	9.0×10^{8}	4.1×10^{7}	9.4×10^{7}
^{58}Co	3.8×10^{10}	5.2×10^{10}	2.8×10^{10}
^{59}Fe	4.7×10^{7}	0	0
^{60}Co	9.2×10^{10}	2.0×10^{11}	3.5×10^{11}
^{65}Zn	2.4×10^{10}	3.1×10^{10}	3.5×10^{10}
^{95}Zr	1.8×10^{8}	0	0
^{95}Nb	5.3×10^{8}	0	0
^{103}Ru	2.9×10^{8}	0	0
^{110m}Ag	5.6×10^{9}	4.8×10^{9}	7.6×10^{9}
^{124}Sb	8.1×10^{9}	2.2×10^{10}	5.2×10^{9}
^{125}Sb	1.4×10^{9}	6.4×10^{8}	1.2×10^{9}
^{131}I	1.7×10^{10}	4.4×10^{9}	1.5×10^{9}
^{134}Cs	8.6×10^{7}	3.6×10^{9}	2.6×10^{8}
^{137}Cs	3.7×10^{8}	4.4×10^{9}	6.5×10^{8}
^{140}Ba	5.2×10^{9}	0	0
^{140}La	2.8×10^{9}	6.1×10^{7}	2.4×10^{8}
^{141}Ce	1.6×10^{12}	1.6×10^{8}	4.7×10^{8}

Table 3.2.5.16. Radiocobalt and Zinc-65 in time-integrated water samples collected at the outlet from the biotest-area, Forsmark in 1986. (Unit: Bq m^{-3})

Isotope	2/1-4/2	5/2-4/3	4/3-1/4	5/5-1/6	1/6-2/7	July	Aug	12/9-8/10	6/11-1/12	5/12-7/1-87
^{58}Co						22	26	21 A		
^{60}Co	71	101	127	123	27	250	230	194	68	60
^{65}Zn	25	22	22	13.9	6 A	25	22	26	9.1 A	13.7

Table 3.2.5.17. Transfer-factor from reported monthly discharge (GBq) to monthly time-integrated mean water concentration (Bq m^{-3}) at the outlet from the biotest-area, Forsmark in 1986 (Bq m^{-3}/GBq $month^{-1}$ or $10^{-9} \times month\ m^{-3}$)

Isotope	Jan	Feb	March	May	June	July	Aug	Sept	Nov	Dec	$\bar{x}$	S.E.	n
^{58}Co						3.5	4.2	5.8			4.5	0.7	3
^{60}Co	3.4	4.2	11.5	7.7	4.2	3.5	3.0	6.7	3.2	3.2	5.1	0.9	10
^{65}Zn	15.6	8.1	14.7	9.9	9.4	3.6	3.3	9.3	3.4	6.8	8.4	1.4	10

Table 3.2.5.18. Radiocobalt and Zinc-65 in time-integrated water samples collected at the intake to the biotest-area, Forsmark in 1986 (Unit: Bq m^{-3})

Isotope	12/9-6/10	6/11-1/12
^{58}Co	12 A	-
^{60}Co	134	38
^{65}Zn	20	8.7

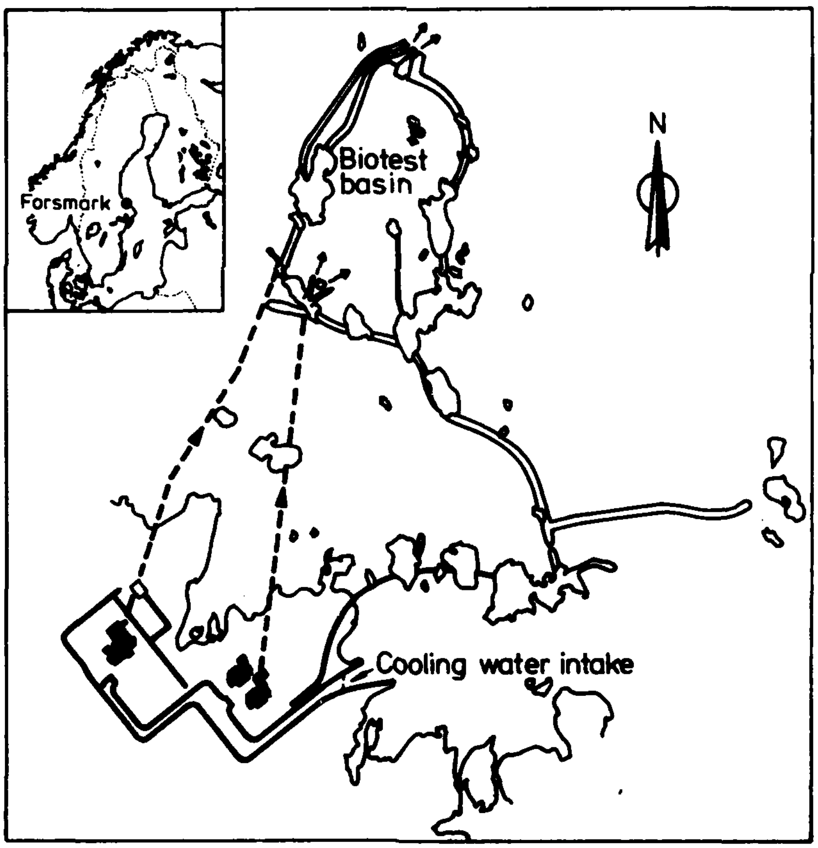


Figure 3.2.5.3. The biotest basin at Forsmark. The water samples were taken at the outlet from the basin.

4. FALLOUT NUCLIDES IN THE ABIOTIC ENVIRONMENT

by A. Aarkrog and Heinz Hansen

4.1. Air

4.1.1. Radiostrontium

The mean air activity for 1986 was 26 μBq ^{90}Sr m^{-3} mean of big and small air samplers and glass fibre filters. This is an increase by two orders of magnitude since last year due to the Chernobyl accident. The ^{90}Sr disappeared more rapidly from the air than the radiocesium. Already by September the ^{90}Sr levels were back to fallout background again.

For the period May-Sept 1986 the integral air activity was 5.7 mBq m^{-3} days in Bornholm (Table 4.1.1.2), while we on the two

Table 4.1.1.1. Strontium-90 in air collected at Risø in 1986. (Unit: μBq m^{-3})

Month	Big sampler, glass fibre filter, shunt	$^{89}Sr/^{90}Sr^{+}$	Small sampler glass fibre	$^{89}Sr/^{90}Sr^{+}$
Jan 1 - April 26	0.48 B		0.53	
April 27-28 (1 day)	5700	19.7	(5700)	
May	145 ±51	12.8	84 ±6	16.0
June	4.1±1.9		1.89±0.23	
July	0.97 B		0.83 A	
Aug	0.53 B		0.31 B	
Sept	0.32 B		1.24	
Oct-Dec	-0.24 B		0.61 B	
1986	28.6		(23.5)*	

*The annual mean for the small sampler included the peak value from April 27-28 obtained from the big sampler.

The error terms are 1 S.E. of double determinations.

+Decay corrected to April 26, 1986.

samples at Risø measured 4.7 and 2.7 mBq ^{90}Sr m^{-3} days, respectively. The small sampler, however, did not include the first 4 days of May. The mean of $^{89}Sr/^{90}Sr$ (on April 26) was 16±3.5 (N = 3; ±1 S.D.).

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

Table 4.1.1.2. Strontium-90 in air collected at Bornholm May-Sept 1986 (Unit: μBq m^{-3})

Month	Big sampler, glass fibre filter, shunt
May	172
June	4.6 A
July	2.0 A
Aug	2.6 B
Sept	2.8 B

4.1.2. Radiocesium

The Chernobyl accident was first of all characterized by its release of radiocesium. It has been estimated that approximately 100 PBq ^{137}Cs and about 50 PBq ^{134}Cs were released[20]. One third of this was deposited within the European part of the USSR, i.e. about 1 MCi ^{137}Cs and 0.5 MCi ^{134}Cs[22].

The peak air activity at Risø occurred between April 27 noon and April 28 noon, when the air concentrations were 0.24 Bq ^{137}Cs m^{-3} and 0.13 Bq ^{134}Cs m^{-3}.

The mean concentration of ^{137}Cs in air in 1986 increased by a factor of nearly 2000 compared to 1985.

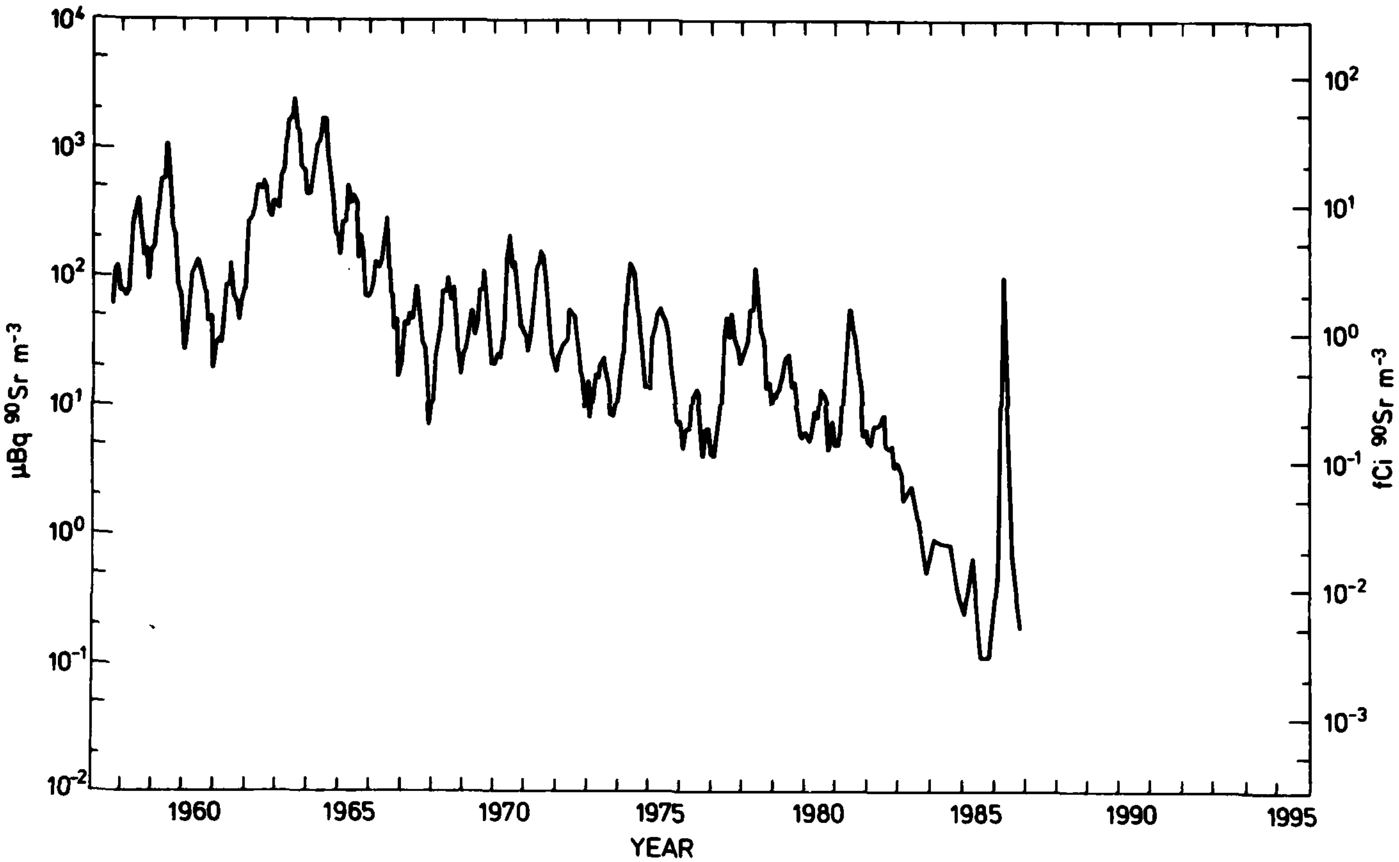


Fig. 4.1.1. Strontium-90 in ground level air at Risø, 1957-1986.

For the period May-Sept 1986 the integrated air activity at Risø was 0.25 Bq ^{137}Cs m^{-3} days and at Bornholm we measured 0.51 Bq ^{137}Cs m^{-3} days. The $^{90}Sr/^{137}Cs$ in this period was 0.019 at Risø and 0.011 at Bornholm. In the Risø "peak sample" from 27-28 April the $^{90}Sr/^{137}Cs$ was 0.024.

Table 4.1.2.1. Radiocesium in air collected in glass-fibre filters by the big air sampler at Risø in 1986. (Unit: μBq m^{-3})

Month	^{137}Cs	^{134}Cs
January	0.47 A	-
February	0.94	-
March	1.00	-
April	8000	4500
May	7700	4400
June	160	87
July	65	33
August	30	15
September	19	9.6
October	21	10
November	13.3	5.8
December	23	10
1986	1340	

Table 4.1.2.2. Radiocesium in air collected at the big air sampler in Bornholm May-Dec 1986 (Unit: μBq m^{-3})

Month	^{137}Cs	^{134}Cs
May	16100	9000
June	153	84
July	28	13.9
August	16.5	8.4
September	10.3	5.0
October	17.9	8.1
November	9.1	4.2
December	14.5	7.3

Figures 4.1.2.1-4.1.2.4 show the concentrations of ^{137}Cs in air collected at Risø and Bornholm since the Chernobyl accident. Figure 4.1.2.1 shows that the air concentration decreased rapidly after the first peak on 27-28 April: but a new maximum occurs in the first days of May with a peak on May 7. Then the ^{137}Cs activity disappears from the air with a halflife of approximately 1 week. However, when we come to July a peculiar pattern appears from Fig. 4.1.2.2: In the first days of the week (Monday-Thursday) the air concentrations are an order of magnitude higher than in the weekend (Friday-Sunday). This pattern continued until the last half of August, when the situation became more blurred. However, the air activity decreased much more slowly than in the first two months after the accident. From July to December the ^{137}Cs concentrations thus only decreased by a factor of two or three.

What we see is a substantial resuspension of the deposited Chernobyl radiocesium. Furthermore, this resuspension seems to have been strongly influenced by the human activities in the working days of the week. At Risø it may during July-August have been due to the more intense traffic on the roads during the working days than in the weekends. When the phenomenon disappears after a few months it may be because the Chernobyl dust then has been removed from the roads and their neighbourhood and thus no more can be influenced by the traffic. The broader peak seen in Fig. 4.1.2.2 at the beginning of September may be due to the burning of the fields after harvest. We may compare the total integrated ^{137}Cs air activity from Chernobyl measured at Risø with that measured from global fallout. Chernobyl released 100 PBq ^{137}Cs and resulted in 1.3 mBq ^{137}Cs m^{-3} year. Global fallout has released 740 PBq ^{137}Cs (UNSCEAR, 1982) and gave 7.4 mBq ^{137}Cs m^{-3} year. Normalized to a release of 1 PBq ^{137}Cs, global fallout thus gives 10 μBq ^{137}Cs m^{-3} year while Chernobyl gave 13 μBq m^{-3} year. It is, however, important to notice that while essentially all the activity from Chernobyl was delivered within a few months the global fallout of ^{137}Cs will disappear from the atmosphere with an effective half-life of 10 months. That is due to the fact that the Chernobyl debris was injected in the troposphere only, while global fallout comes mostly from the stratosphere.

Table 4.1.2.3. Cesium-137 in air collected at Risø 1958-1986

Year	fCi m^{-3}	$\mu Bq\ m^{-3}$
1958	4.2	155
1959	13.1	480
1960	1.98	73
1961	2.3	84
1962	23	850
1963	66	2400
1964	31	1150
1965	10.6	390
1966	5.7	210
1967	2.1	79
1968	2.4	88
1969	2.4	91
1970	3.4	127
1971	2.7	98
1972	1.37	51
1973	0.47	17.3
1974	1.96	73
1975	1.30	48
1976	0.42	15.5
1977	1.62	60
1978	1.70	63
1979	0.62	23
1980	0.24	8.7
1981	0.81	30
1982	0.146	5.4
1983	0.053	1.97
1984	0.036	1.35
1985	0.0184	0.68
1986	36	1340

Chernobyl has, however, shown us that after the deposition of the debris there is a period with resuspension which may last more than a year after the deposition.

Figure 4.1.2.5 shows the air concentrations at various locations in Denmark during the passage of the first and second clouds from Chernobyl. The samples were obtained from a sampling network operated for other purposes by the Air Pollution

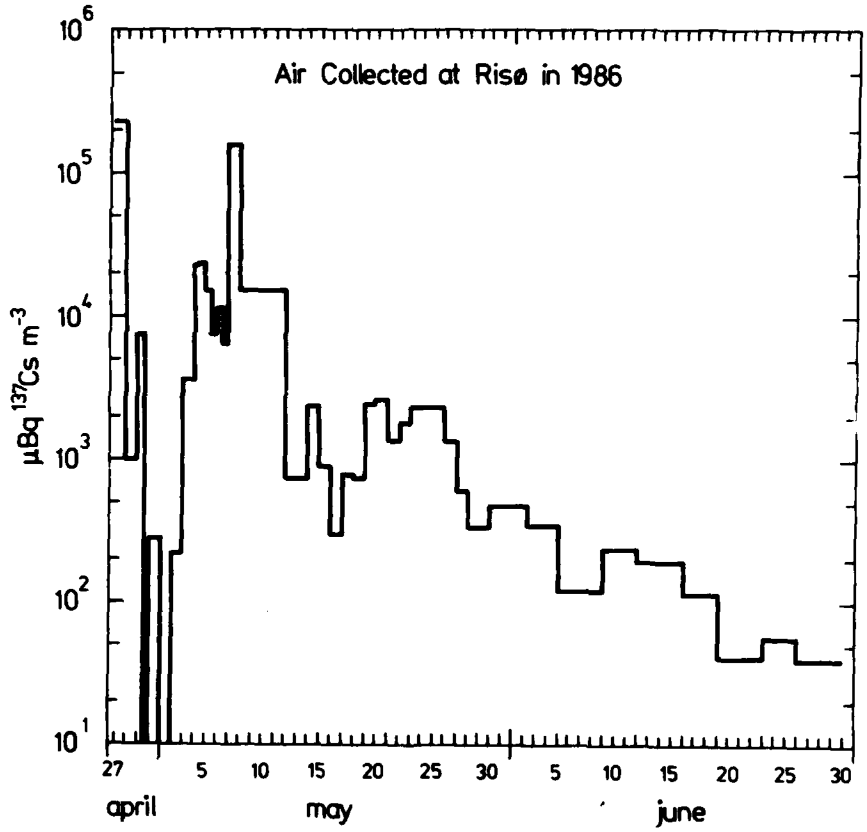


Fig. 4.1.2.1. Cesium-137 in air collected at Risø, Denmark, in the period April 27-June 30, 1986 (cf. also Fig. 4.1.2.2).

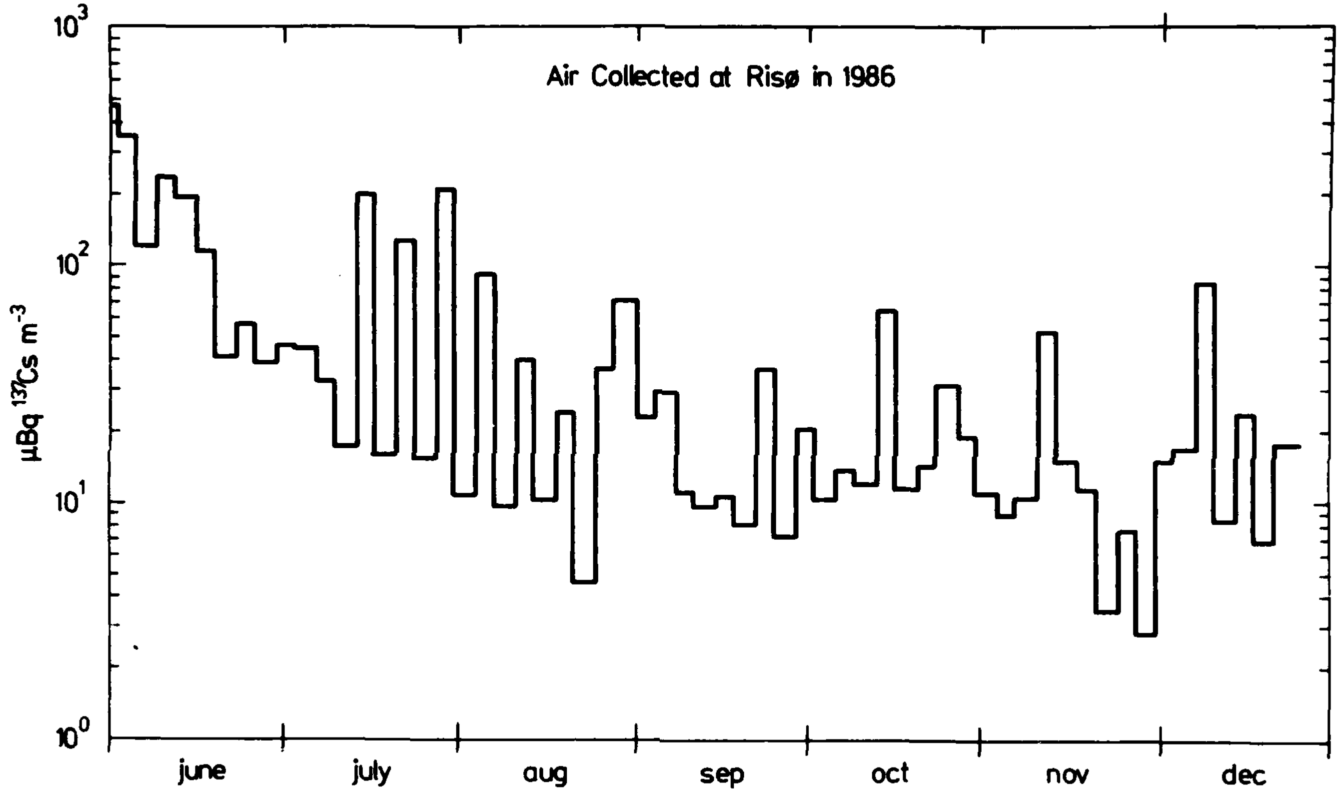


Fig. 4.1.2.2. Cesium-137 in air collected at Risø, Denmark, in the period June 1-Dec 31, 1986 (cf. also Fig. 4.1.2.1).

Laboratory of the National Agency of Environmental Protection in Denmark*). It is remarkable that the first cloud on 27-28 April did not hit the southwestern part of the country. The second cloud on 4-5 May was, however, most prominent in the southern and western parts of Denmark.

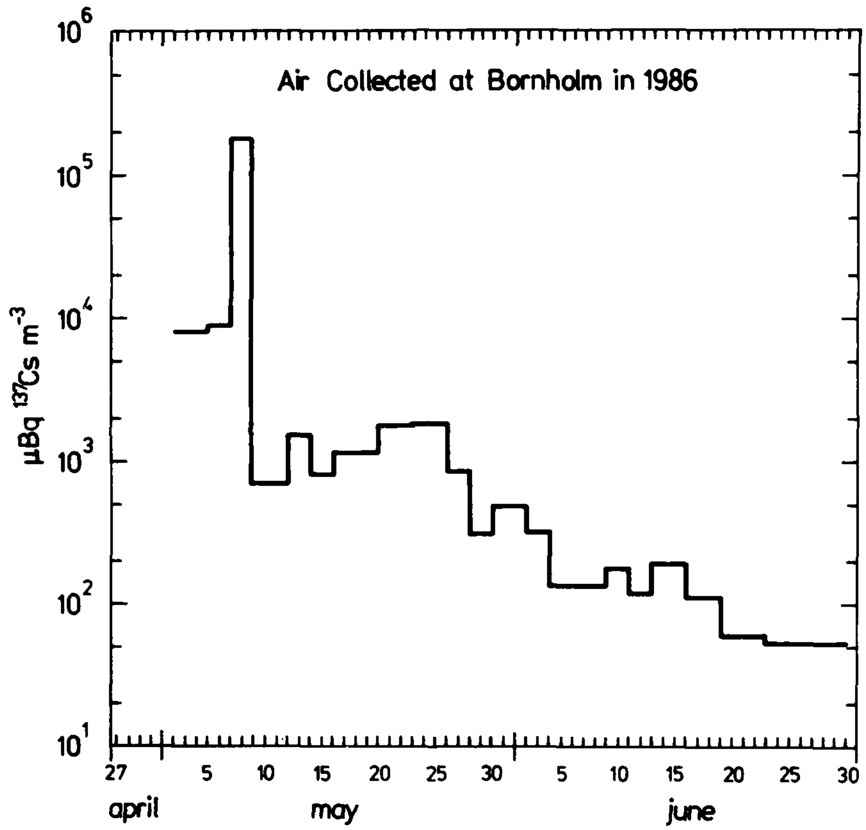


Fig. 4.1.2.3. Cesium-137 in air collected at Bornholm, Denmark, in the period May-June 1986 (cf. also Fig. 4.1.2.4).

*The filters collected only particulates and they filtered approximately 60 m^3 in 24 hours.

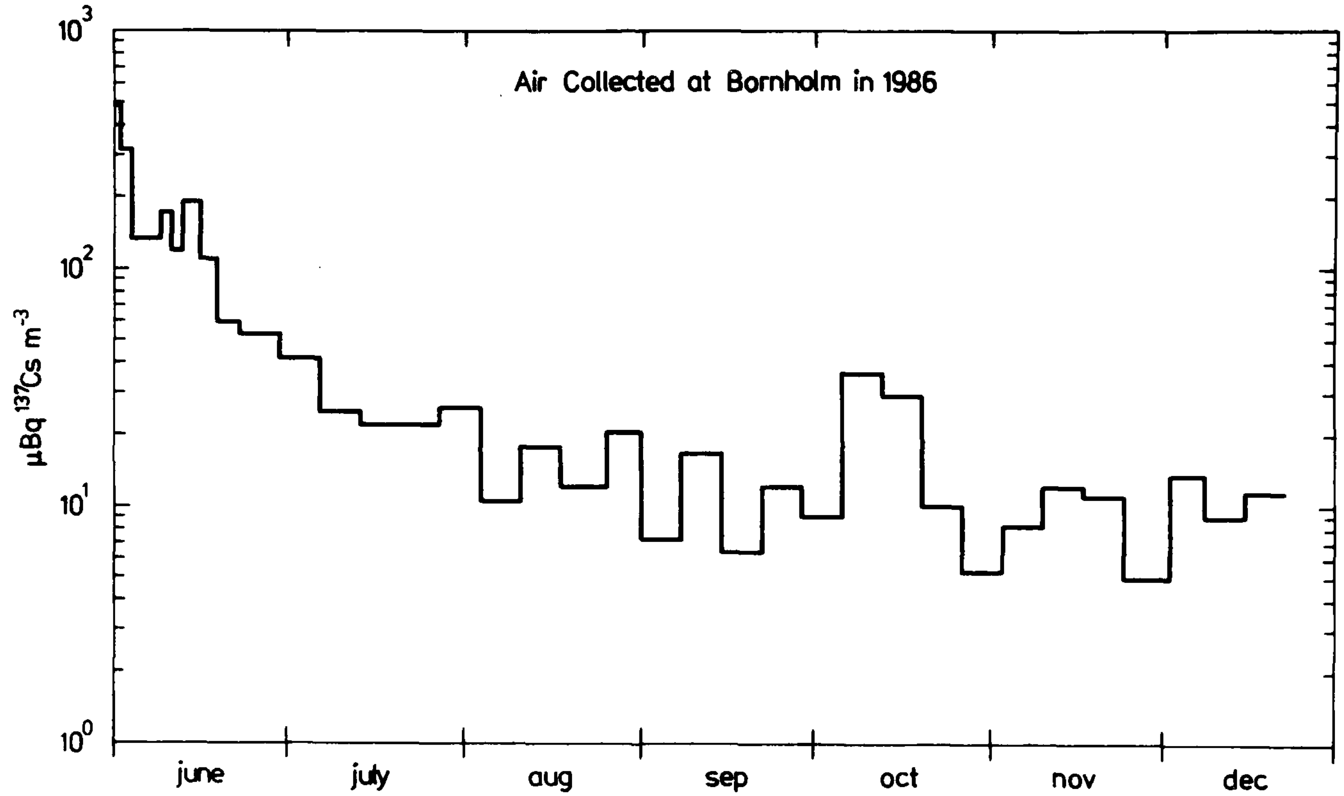
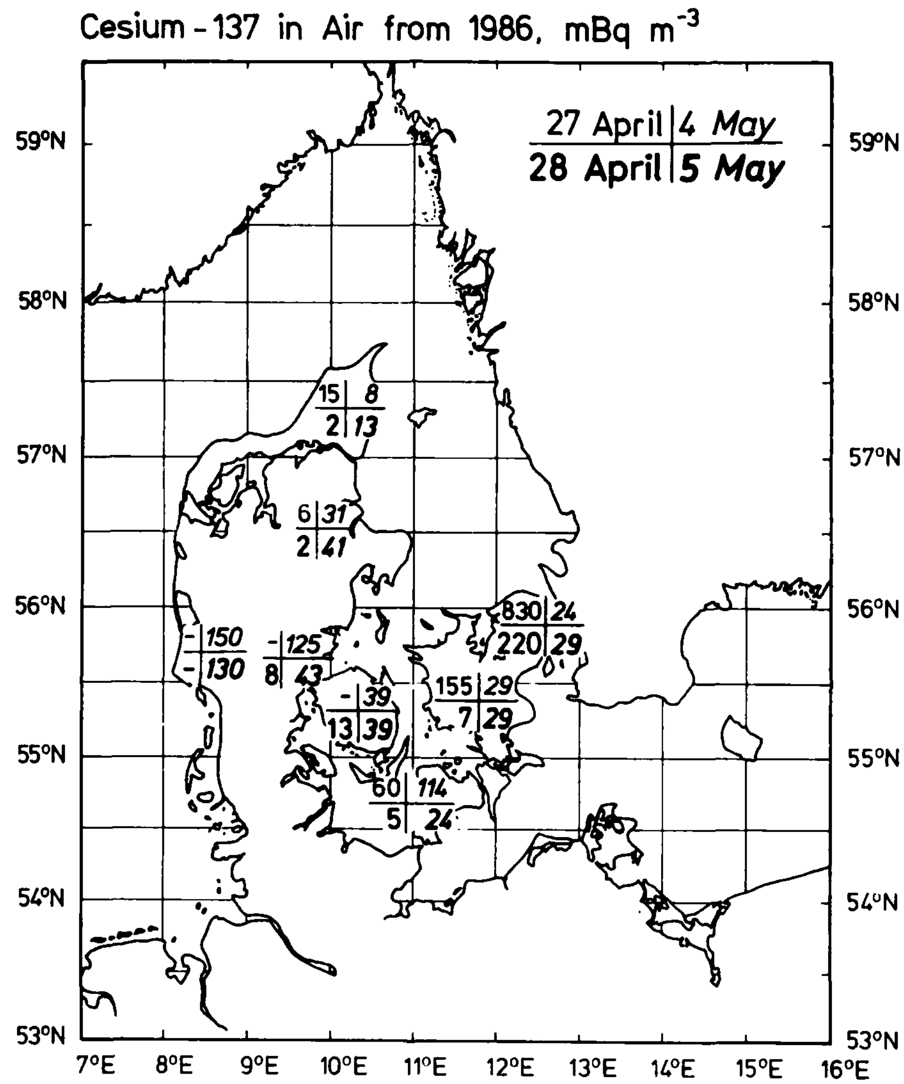


Fig. 4.1.2.4. Cesium-137 in air collected at Bornholm, Denmark, in the period June-December, 1986 (cf. also Fig. 4.1.2.3).



<u>Figure 4.1.2.5</u>. Cesium-137 in ground level air collected at stations operated by the Air Pollution Laboratory of the National Agency of Environmental Protection in Denmark in April-May 1986.

The mean $^{137}Cs/^{90}Sr$ ratio in Risø air was 52 in 1986. Risø rain showed a ratio of 35 (Tables 4.2.1.6 and 4.2.2.4). Table 4.1.2.3 shows the annual ^{137}Cs concentrations in air collected at Risø since 1958.

Table 4.1.3.1. Short-lived isotopes in Chernobyl debris

Date (at 12:00)	$^{132}Tc/^{131}I$ λ=0.127 d^{-1}	$^{133}I/^{131}I$ λ=0.714 d^{-1}	Sample type	Location	
26 April	0.67	-	Lorry dust	Brest, Ukraine	
27 April	0.46	-	Air	Charlottenlund	DK Zealand
-"-	0.45	-	-"-	Næstved	-"-
28 April	0.46	0.33	-"- 24-28/4	Risø	-"-
-"-	0.59	-	-"-	Charlottenlund	-"-
-"-	0.71	0.25	Cutter filter	Baltic Sea	DK Bornholm
-"-	0.077	0.26	Grass	Risø	DK Zealand
-"-	0.068	0.38	-"-	-"-	-"-
-"-	0.061	0.38	-"-	Vindinge	-"-
-"-	0.050	0.29	-"-	Tune	-"-
-"-	0.086	0.30	-"-	Himmelev	-"-
29 April	0.38	0.129	Air 28-29/4	Risø	-"-
-"-	0.29	0.143	-"- 29/4	-"-	-"-
-"-	0.082	0.134	Grass	-"-	-"-
-"-	0.51	0.22	Dry fallout 1-29/4	Risø	-"-
-"-	0.062	-	Grass	Tylstrup	DK N-Jutland
30 April	0.072	0.077	-"-	Risø	DK Zealand
1 May	0.109	0.038	-"-	-"-	-"-
2 May	0.102	0.048 B	-"-	-"-	-"-
-"-	0.123	-	-"-	Ledreborg	-"-
3 May	0.058	-	-"-	Grevinge	-"-
-"-	0.068	-	-"-	S-Jutland	DK S-Jutland
4 May	0.048	-	-"-	S-Halland	Sweden
-"-	0.034	0.0088	Dandelion	Risø	DK Zealand
5 May	0.040	0.0030	Air	Risø	-"-
-"-	0.031	0.012 B	Grass	-"-	-"-
-"-	0.043	-	-"-	Smidstrup	-"-
-"-	0.73	-	-"-	Årslev	DK Funen

4.1.3. Short-lived γ-emitters in air

4.1.3.1. Radioiodine. Figure 4.1.3.1 shows the ^{131}I concentrations in air collected at Risø in the first months after the Chernobyl accident. The maximum occurred 27 April, when the first cloud passed over the eastern part of the country. The samples were collected on glass fibre filters and thus did not contain all the iodine. The total iodine activity may have been 1.5-2 times higher than that actually measured.

Figure 4.1.3.2 shows the countrywide pattern of the ^{131}I activity in air during the passage of the two clouds after the accident (cf. also Fig. 4.1.2.5). The maximum: 3 Bq ^{131}I m^{-3} was observed at Charlottenlund in NE-Zealand on April 27. As for ^{137}Cs the first cloud was not detectable in Western Denmark, while the second cloud on 4-5 May was most prominent here.

The countrywide mean ratio: $^{131}I/^{137}Cs$ in particulate air debris was 3.8 ± 0.66 (N = 5; ± 1 S.D.) on 27 April. On 5 May we found 11 ± 3.9 (N = 8; ± 1 S.D.). This may suggest that the particulate fraction of iodine increased from the first to the second cloud.

The efficiency of our glass fibre filters for the various chemical forms of iodine is not known. We believe, however, from simultaneous measurements with carbon beds that our glass fibre filter have collected between 40-80% of the total ^{131}I activity from Chernobyl. Finnish measurements[23] have shown that between 76 and 97% of the ^{131}I penetrated through the glass fibre filter in Nurmijärvi in the period April 29-June 30, 1986. We have found that our glass fibre filters were more efficient than that. This may, however, be a result of a heavier load with dust (and carbon particles from coal-fired power plants) in the Risø environment.

If we look at refractory elements such as ^{95}Zr and ^{141}Ce the $^{95}Zr/^{137}Cs$ and $^{141}Ce/^{137}Cs$ decreased by nearly an order of magnitude from the first to the second cloud. This shows that fractionation has played an important role.

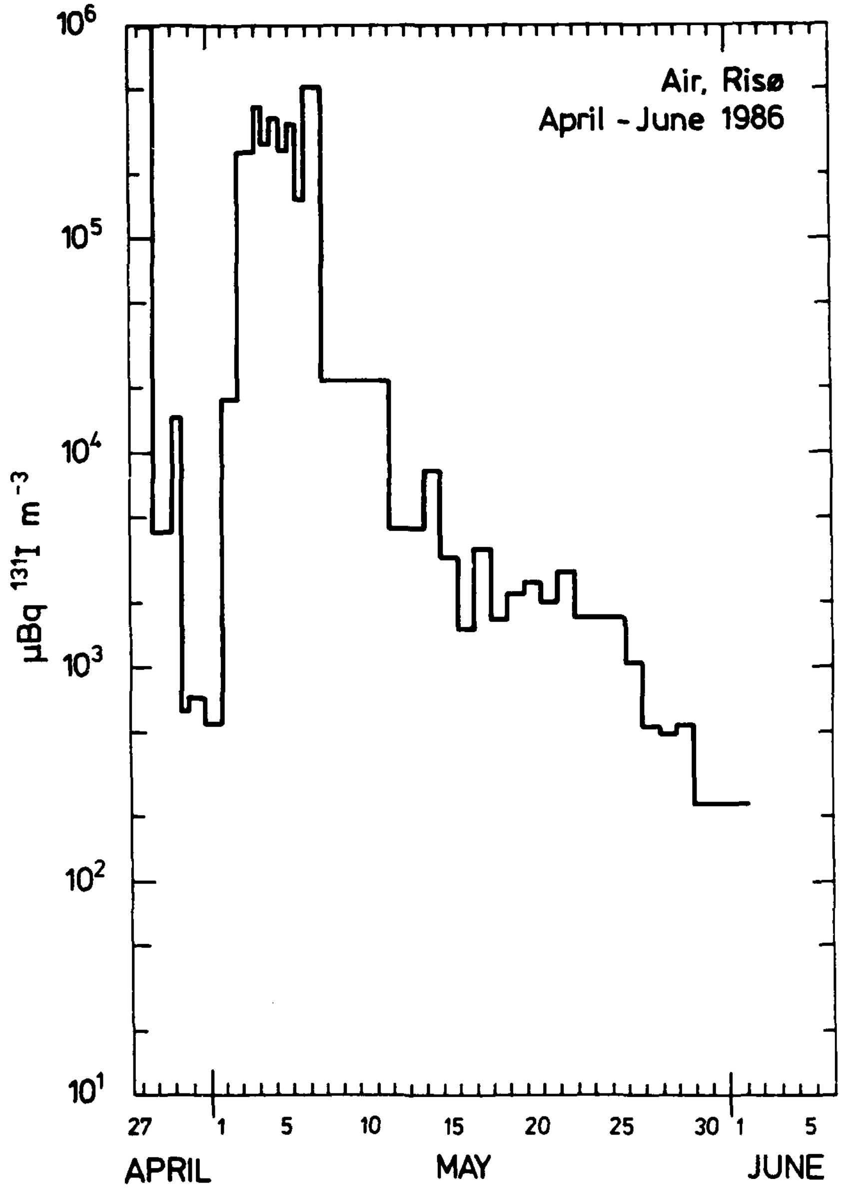


Fig. 4.1.3.1. Iodine-131 in ground level air collected at Risø in April-June 1986.

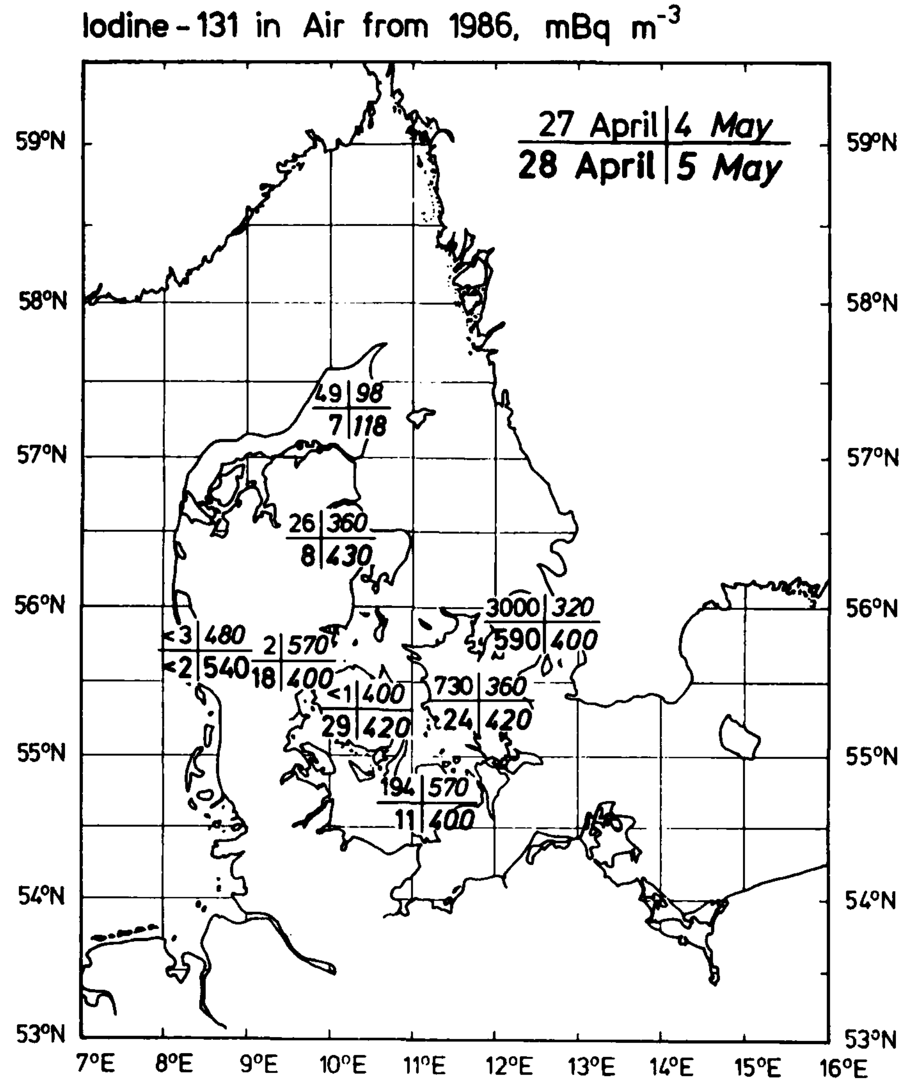


Fig. 4.1.3.2. Iodine-131 in ground level air collected at stations operated by the Air Pollution Laboratory of the National Agency of Environmental Protection in Denmark in April-May 1986.

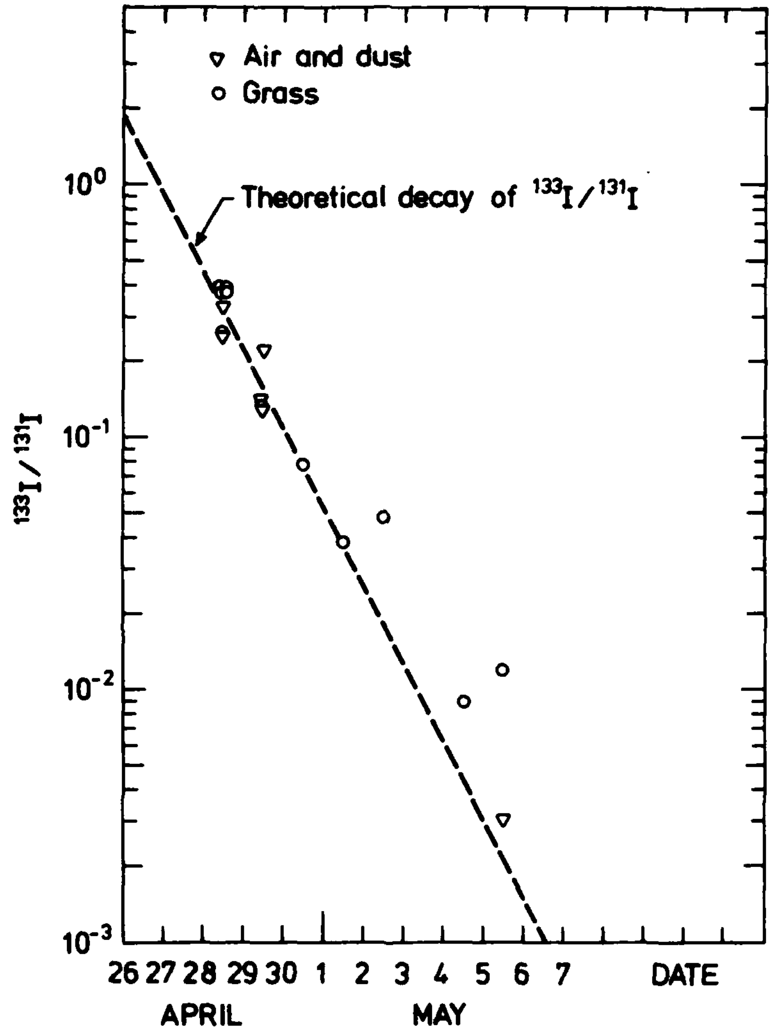


Fig. 4.1.3.3. $^{133}I/^{131}I$ in air and dust samples collected in Denmark in 1986.

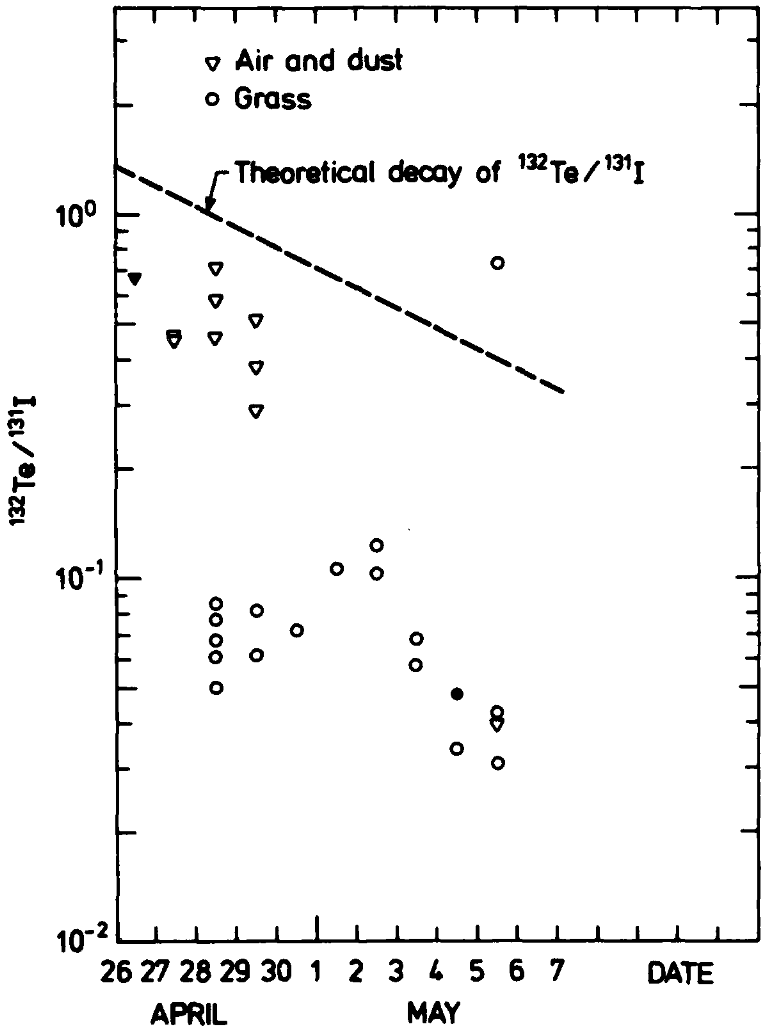


Fig. 4.1.3.4. $^{132}Te/^{131}I$ in air, dust and grass samples collected in Denmark in 1986.

▼ Lorry dust from Ukraine, ● grass from S-Sweden.

The $^{132}Te/^{131}I$ did not follow the theoretical ratio. In air the observed ratio was approximately half of the theoretical one and in grass the ratio was nearly an order of magnitude lower than that in air. The reason is that Te is less volatile than Iodine and furthermore, that the deposition of Te on grass is lower than that of Iodine. It should be noticed that the dry deposition of Te in our 10 m^2 rain collector at Risø was approximately 8 times higher than that observed in grass samples. A single grass sample collected May 5, 1986 at Årslev, Funen, showed a much higher $^{132}Te/^{131}I$ than seen in other grass samples. This sample may, however, have been the only one representing wet deposition as it rained over Funen April 30.

Around May 7, 1986, when the second Chernobyl cloud over Denmark showed its peak concentrations of radiocesium short-lived radionuclides appeared again. In Sweden, Ingemansson[14] found an increase in the $^{133}I/^{131}I$ and $^{132}Te/^{131}I$ ratios, and he concluded that fission reaction had taken place again in the damaged case. We were not able to detect ^{133}I (Fig. 4.1.3.3) in our air filters from Risø and Bornholm, but we found ^{132}Te. As shown in Fig. 4.1.3.4 the $^{132}Te/^{131}I$ increased by more than an order of magnitude. Tellurium may, however, behave otherwise than Iodine and some of the increase could be due to fractionation phenomena. If we consider the ratio: $^{239}Np/^{141}Ce$ (Fig. 4.1.4.1) we notice again a steep increase in the ratio. In this case it is less likely that fractionation should be the explanation. We may also have a look at the $^{239}Np/^{137}Cs$ ratio; in this case we cannot see any increase around May 7, it rather looks like a drop in the ratio. This may be due to fractionation by which Cesium has been enriched relative to Neptunium, but this enrichment was even more pronounced relative to ^{141}Ce (cf. also 4.1.3.2).

4.1.3.2. Other γ-emitters. In the appendix the detailed measurements of the air filters collected at Risø and Bornholm are reported. Table 4.1.3.2 shows the $^{95}Nb/^{95}Zr$ ratios in some of these air filters and in a few other samples. It appears that air collected between 9 and 12 May showed a strong depletion of

Table 4.1.3.2. $^{95}Nb/^{95}Zr$ in samples of air, rain, grass and dry deposit collected April-July 1986

	Lorry E-Poland 26-28 Apr	Boat filt. Baltic Sea 27-28 Apr	Air filter Risø 27-28 Apr	Air filter Risø 4 May	Air filter Risø 4-5 May	Air filter Risø 7-8 May	Air filter Bornholm 7-9 May	Air filter Risø 8-12 May	Dry fallout△ Risø 26-29 Apr	Rain△ Risø 30 Apr-9 May	Rain△ Risø 9-31 May	Rain△ Risø June	Grass Risø 28 Apr	Grass Risø 4 May	Grass Risø 8 May
Date of measurement	May 1	May 1	April 29	May 5		May 8	May 11			May 10			Apr 28	May 4	May 8
Theoretical	1.04	1.04	1.03	1.06		1.13	1.15			1.14			1.03	1.08	1.13
Found	0.92	1.24	1.17	1.07		2.90	2.92			2.33			1.01	0.95	1.05
Date of measurement	July 29	July 9	July 7		July 14		July 7	July 14	July 20		June 27	July 11			
Theoretical	1.58	1.58	1.57		1.61		1.56	1.61	1.66		1.68	1.59			
Found	1.68	1.67	1.59		1.84		2.76	7.1	1.60		1.74	1.28			
$^{95}Zr/^{137}Cs$*	2.83/0.77	0.19/0.24	0.78	0.22	0.12	0.15	0.020	0.0040	14.9		0.044	0.22	1.31	4.4	0.10

*Decay corrected to 26 Apr.

△Collected in a 10 m^2 rain sampler connected with an ion exchange column.

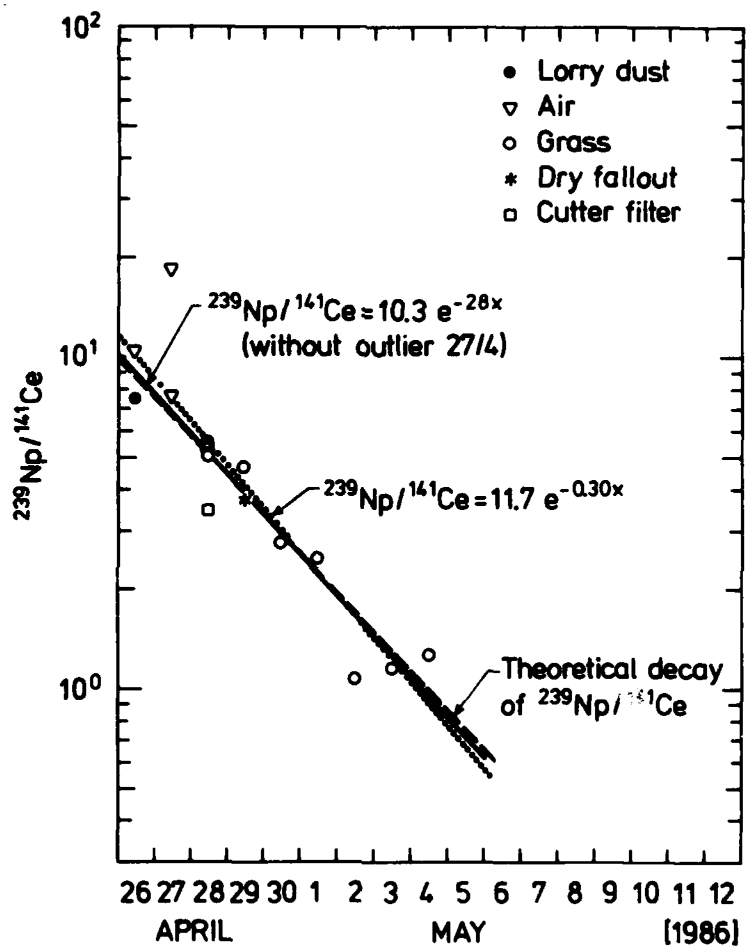
^{95}Zr compared to ^{95}Nb. The $^{95}Nb/^{95}Zr$ was significantly higher than the theoretical ratio. This phenomenon was perhaps due to some scavenging process in the reactor, where the Zr-cladding of the fuel elements may have retained the Zr more efficiently than the Nb.

The $^{141}Ce/^{95}Zr$ is as the $^{95}Nb/^{95}Zr$ also usually rather insensitive to fractionation, but again we notice a depletion of ^{95}Zr around 9-12 May when the ratio increases by a factor of 2-4.

4.1.4. Transuranics and uranium-237 in air

4.1.4.1. Neptunium-239 and uranium-237. The first samples collected after the accident in Chernobyl all contained ^{239}Np and ^{237}U. These radionuclides were determined from their γ-peaks at 277.6 keV and 208.0 keV, respectively. In the Risø air filter collected from 24 April to 28 April the time integrals were 1.82 Bq ^{239}Np $m^{-3}d$ and 0.23 Bq ^{237}U $m^{-3}d$ referred to April 26; 12.00. In the lorry dust sample from Brest in Ukraine the $^{239}Np/^{137}Cs$ ratio was 19, i.e. 25 times higher than in the Risø air filter. The $^{237}U/^{137}Cs$ was 1.11 in the lorry dust and 0.96 in the Risø filter, all ratios referred to April 26; 12.00. The USSR[22]) has reported a $^{239}Np/^{137}Cs$ in the release on April 26 of 9.

We found that ^{239}Np and ^{141}Ce behaved very similar in the various environmental samples (lorry dust, air debris, dry deposit and grass) (Fig. 4.1.4.1). The dry deposition velocity of ^{239}Np on grass was higher than for ^{137}Cs (Fig. 4.1.4.2) and probably also than for ^{132}Te (Fig. 4.1.4.3). However, ^{237}U possibly showed a higher dry deposition velocity than ^{239}Np (Fig. 4.1.4.4).



<u>Fig. 4.1.4.1</u>. Comparison of $^{239}Np/^{141}Ce$ ratio in various samples.

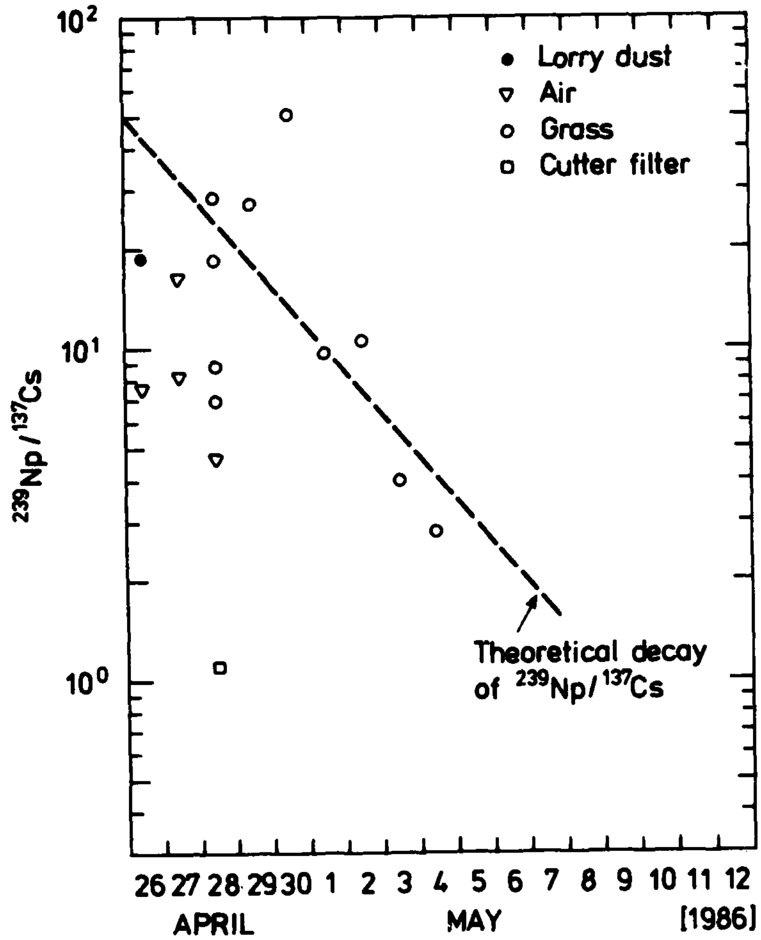


Fig. 4.1.4.2. Comparison of $^{239}Np/^{137}Cs$ ratio in various samples.

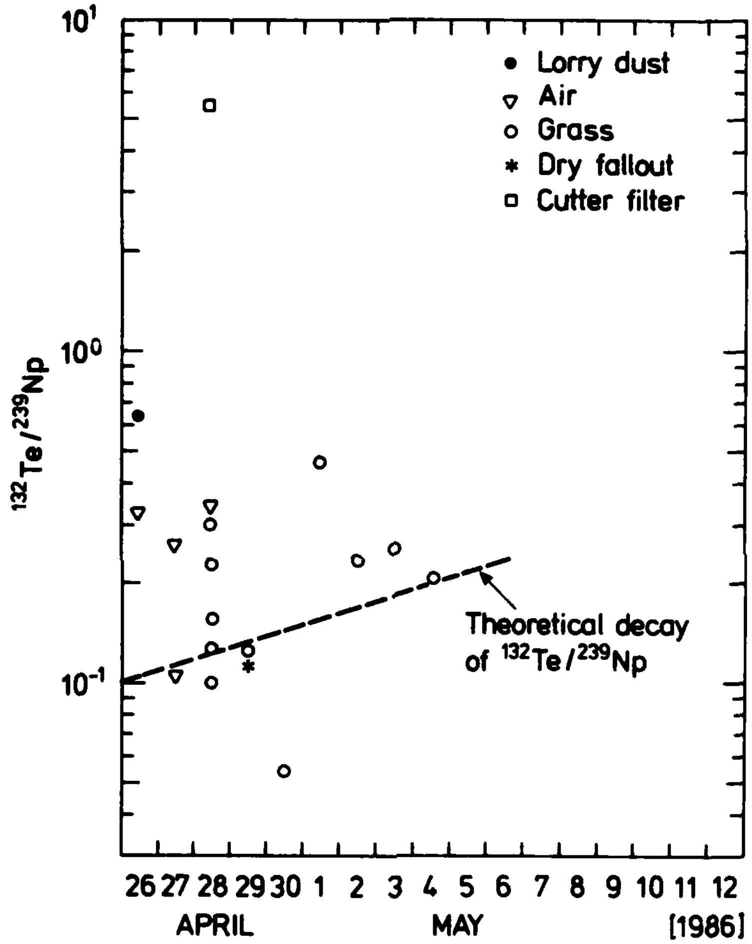


Fig. 4.1.4.3. Comparison of $^{132}Te/^{239}Np$ ratio in various samples.

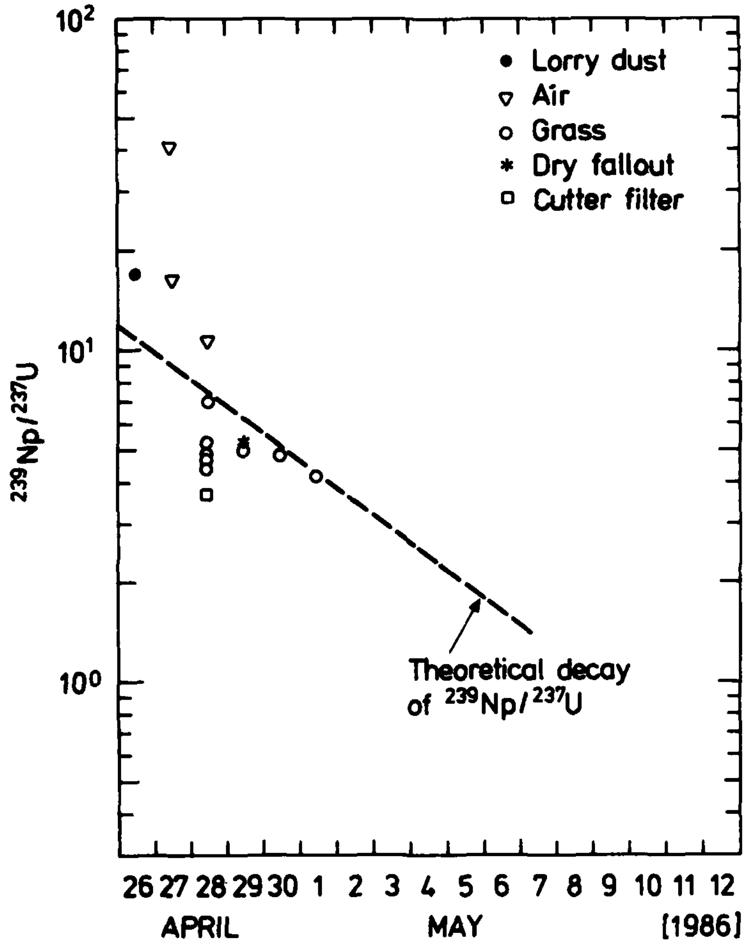


Fig. 4.1.4.4. Comparison of $^{239}Np/^{237}U$ ratio in various samples.

<u>4.1.4.2. Longer-lived transuranics: Pu, Am, Cm</u>. Some of the more radioactive samples collected after Chernobyl were analysed radiochemically for plutonium, americium and curium. The radiochemical analysis for Am does not separate for curium isotopes and these are thus determined along with Am by the α-spectroscopy. Curium-242 (half-life 162.8 d) has a peak in 6.11 MeV. Curium-243 (half-life 28.5 y) and Curium-244 (half-life 18.1 y) both have peaks around 5.8 MeV, and could not be separated from each other.

In Tables 4.1.4.1 and 4.1.4.2 we have summarized all Pu, Am and Cm data on Chernobyl debris measured at our laboratory. Besides air filters (Table 4.1.4.1) we have included the above-mentioned lorry dust sample, the Cutter filter, and a few other samples (see Table 4.1.4.2). Most of the samples were analysed twice.

It is evident that the samples were very inhomogeneous. The two aliquots differed in some cases by nearly an order of magnitude. Already around the middle of May Pu and Am had practically disappeared from the air. We may estimate the *inhalation* dose from $^{239,240}Pu$ from the air integral: $\sim$ 50 μBq $m^{-3}d$ received by the first cloud from Chernobyl and the daily respiration rate 20 $m^{-3}d^{-1}$. This gives an intake of 1 mBq $^{239,240}Pu$. The actual intake is lower because the air concentration is lower indoors than outdoors. The dose from 1 mBq $^{239,240}Pu$ is 0.03 μSv.

If we limit ourselves to the most radioactive samples for which the counting errors are relatively low we may calculate the ratios between the transuranics in Chernobyl debris. This has been done in Table 4.1.4.3. We find the following mean ratios: $^{238}Pu/^{239,240}Pu$ = 0.5, $^{241}Am/^{239,240}Pu$ = 0.1 and $^{242}Cm/^{239,240}Pu$ = 14. There is no systematic difference between the same ratio measured in various samples, except for $^{241}Am/^{239,240}Pu$, which probably (P > 95%) was lower in the lorry dust than in the other samples. The $^{238}Pu/^{239,240}Pu$ and $^{242}Cm/^{239,240}Pu$ were reported as 0.47 and 12.4 by the USSR[22] at the Vienna conference about Chernobyl in August 1986, i.e. in good agreement with our observations.

Table 4.1.4.1. Transuranics in air $\mu Bq\ m^{-3}$ collected in 1986

Location	Sampling period	Aliquot	$^{239,240}Pu$	^{238}Pu	^{241}Am	^{242}Cm on 26 April 1986	$^{243,244}Cm$	^{137}Cs
Risø	24-28 April	I	6.4	3.7	0.76	195	2.3	63600
"	- " -	II	19.0	8.8	1.81	287	2.4	
Risø	4 May 10 a.m.-7 p.m.	I	0.50	0.37	0.48 A	6.9	0.54 A	22700
"	- " -	II	0.40	0.29	0.21 B	6.1	B.D.L.	
Risø	4-5 May 7 p.m.-9 a.m.	I	2.2	1.32	0.26 A	6.7	0.47 A	24000
"	- " -	II	0.29	0.21	B.D.L.	3.7	0.15 A	
Risø	7-8 May 9 a.m.-9 a.m.	I	0.66	0.30	B.D.L.	5.7	0.37	154400
"	- " -	II	0.37	0.28	0.68	7.1	0.68	
Risø	8-12 May 9 a.m.-9 a.m.	I	0.005A	B.D.L.	B.D.L.	0.29 A	B.D.L.	14400
"	- " -	II	0.148	B.D.L.	B.D.L.	0.15 B	B.D.L.	
Risø	19-20 May 9 a.m.-9 a.m.	I	B.D.L.	B.D.L.	B.D.L.	0.19 B	B.D.L.	2420
"	- " -	II	0.07 B	B.D.L.	B.D.L.	0.20 B	B.D.L.	
Bornholm	7-9 May	I	0.75	0.28	0.34	7.4	0.16 A	183400
"	- " -	II	1.72	0.73	0.033	14.4	0.11 A	

Table 4.1.4.2. Transuranics in various samples collected in 1986

Sample	Location	Date	Aliquot	$^{239,240}Pu$	^{238}Pu	^{241}Pu	^{241}Am	^{242}Cm on 26 April 1986	$^{243,244}Cm$	Unit	^{137}Cs
Motor filter	Bornholm	28 April	I	0.123	0.073		0.0164	2.07	0.027	Bq l^{-1} extract*	2730
	- " -	- " -	II	0.123	0.059		0.0146	1.81	0.017	- " -	
Lorry dust	Brest Ukraine	27 April	I	3.0	0.90		0.22	23	0.40	Bq kg^{-1}	13700
	- " -	- " -	II	17.6	8.7		1.01	190	1.31	- " -	
Rain	Risø	8 May		-	-	-	0.53	39	0.29	mBq l^{-1}	115600
Grass	Askov	27 May	I	0.051	0.034		0.0152A	0.68	0.055 A	Bq kg^{-1} dry w.	147
	- " -	- " -	II	0.079	0.048		0.0137A	1.05	0.017 A	- " -	
Grass turf	Kiev USSR	26 Sept	I	3.9	1.71	308	0.51	55	0.48	Bq kg^{-1} dry w.+	2040
	- " -	- " -	II	10.4	3.8	655	1.09	100	0.65	- " -	
Wheat grain	Greece	6 Aug	I	0.030	0.015		0.0053	0.32	0.0043	Bq kg^{-1} dry w.	1140
	- " -	- " -	II	-	-		0.0016	0.020	0.0029	- " -	
Wheat grain	Greece	7 July	I	0.0008A	B.D.L.		0.0007B	0.0072	0.0007B	Bq kg^{-1} dry w.	650
	- " -	- " -	II				0.0008A	0.0157	0.0033	- " -	
Sun-flower seeds	Greece		I	-	-		0.0014A	0.0047A	0.0005B	Bq kg^{-1} dry w.	24.4
	- " -		II	-	-		0.0024A	0.0082A	0.003 A	- " -	

*1.94 g filter was dissolved in 1 l. Two aliquots of 100 ml each were analysed.

+The deposition was I: 190 Bq $^{239,240}Pu\ m^{-2}$ and II: 510 Bq $^{239,240}Pu\ m^{-2}$.

Table 4.1.4.3. Transuranic ratios (referred to April 26, 1986) in Chernobyl debris

Sample	Location	Date	Aliquot	$\frac{^{241}Pu}{^{239,240}Pu}$	$\frac{^{238}Pu}{^{239,240}Pu}$	$\frac{^{241}Am}{^{239,240}Pu}$	$\frac{^{242}Cm}{^{243,244}Cm}$	$\frac{^{242}Cm}{^{239,240}Pu}$	$\frac{^{242}Cm}{^{241}Am}$	$\frac{^{243,244}Cm}{^{241}Am}$	$\frac{^{239,240}Pu}{^{137}Cs}$
Lorry dust	Brest Ukraine	27 April	I		0.30	0.073	58	7.7	105	1.82	0.75×10^{-3}
		- " -	II	97	0.49	0.057	145	10.8	188	1.30	
Motor filter	Bornholm	28 April	I		0.59	0.133	77	16.8	126	1.64	0.045×10^{-3}
		- " -	II	91	0.48	0.119	106	14.7	124	1.16	
Air	Risø	24-28 April	I		0.58	0.119	85	30	257	3.0	0.21×10^{-3}
		- " -	II	101	0.46	0.095	120	15.1	159	1.33	
Grass turf	Kiev USSR	26 Sept	I	79	0.44	0.131	115	14.1	108	0.94	3.5×10^{-3}
		- " -	II	63	0.37	0.105	154	9.6	92	0.60	
Wheat grain	Greece	6 Aug	I		0.50	0.177	74	10.7	60	0.81	
			$\bar{x}$	86	0.47	0.112	104	14.4	135	1.40	
			S.D.	15	0.09	0.035	33	6.6	59	0.71	
			n	0.18	0.20	0.32	0.32	0.46	0.43	0.51	

4.2. Precipitation

4.2.1. Radiostrontium in precipitation

Samples of rain water were collected in 1986 from the State experimental farms (cf. fig. 4.2) in accordance with the principles laid down in Risø Report No. 63, p. 51[1].

Tables 4.2.1.1 and 4.2.1.2 show the results of the ^{90}Sr determinations and Tables 4.2.1.3 and 4.2.1.4 the analysis of variance of the results.

The mean levels for ten State experimental farms were 38 Bq ^{90}Sr m^{-2} and 63 Bq ^{90}Sr m^{-3}. The fallout rate in 1986 was 47 times that observed in 1985. The ^{90}Sr mean deposition in 1986 was the same in Jutland as in the Islands. Although ^{90}Sr only was a minor contributor to the Chernobyl contamination, the signal was nevertheless very significant. We have not had a higher fallout rate of ^{90}Sr in a single year since 1971.

Table 4.2.1.5 shows the ^{89}Sr/^{90}Sr in precipitation samples from 1986. The mean was 13.5$\pm$5.2 ($\pm$1 S.D.; N = 26) decay corrected to April 26, 1986. The USSR[22] has reported a ratio of 10. Finnish measurements[33] agreed with our ratio. The ^{90}Sr concentration in rain water decayed in 1986 with an effective half-life of 3 weeks.

Table 4.2.1.6 shows the ^{90}Sr in precipitation collected at Risø partly by the 10 m^2 ion exchange sampler, partly in the 8 rain bottles located at Risø and in the environment[21]. The total sampling area of these bottles is 0.23 m^2.

The mean concentrations of ^{90}Sr in the Risø rain samples were in good agreement with that from the state experimental farms. The deposition differed significantly between the two Risø sample systems; the bottles collected 32 Bq m^{-2} (503 mm) while the 10 m^2 ion exchange sampler gave 23 Bq m^{-2} (395 mm). In case of ^{137}Cs (cf. 4.2.2) we found agreement between deposition for the two systems, but in this case the concentrations found in the ion exchange sampler were higher than those in the rain bottles.

The grand mean of $^{89}Sr/^{90}Sr$ in Risø rain (Table 4.2.1.7) was 13.0 ± 4.5 (± 1 S.D.; N = 5), i.e. in good agreement with the countrywide mean. The $^{90}Sr/^{137}Cs$ ratio was significantly higher in deposition than in air (cf. 4.1.2). Probably because the rain samples did not represent the same air masses as the air samples.

Table 4.2.1.1. Strontium-90 fall-out in Denmark in 1986 (Unit: Bq m^{-3})

Location	Jan-March	April	May	June	July-Aug	Sept-Oct	Nov-Dec	Weighted mean
Tylstrup		330	410	9.0	5.6	2.9	1.52	50
Kale		8.0	(600)	75	15.0	5.7	5.5	(53)
Borris	1.01	5.1	(450)	33	9.9	2.5	0.50	(40)
Askov		830	430	154	39	4.8	2.41	88
St. Jyndevad		7.1	500	65	13.9	5.0	1.36	56
Aarslev		2200	1030	51	30	6.7	4.1	180
Tystofte	0.96	9.9	970	51	6.9	1.10	1.12	83
Ledreborg		7.8	340	31	8.3	3.1	0.82	36
Abed		(7.3)	145	25	13.9	5.6	3.5	28
Bornholm	2.0	83	480	46	23	15.2	5.7	47
Weighted mean	1.08	320	480	55	16.2	4.9	2.4	63
$\bar{x}$ mm	117	32	51	19	117	133	133	

Table 4.2.1.2. Strontium-90 fall-out in Denmark in 1986 (Unit: Bq m^{-2})

Location	Jan-March	April	May	June	July-Aug	Sept-Oct	Nov-Dec	1986
Tylstrup		7.8	22	0.16	0.72	0.30	0.23	31
Kale		0.10	(23)	1.38	1.84	0.58	0.55	(28)
Borris	0.140	0.23	(29)	0.57	1.57	0.40	0.11	(32)
Askov		42	18.5	3.15	4.8	1.08	0.46	70
St. Jyndevad		0.22	35	0.82	1.33	0.75	0.27	39
Aarslev		45	36	0.83	2.04	0.82	0.47	85
Tystofte	0.092	0.24	38	0.97	0.60	0.15	0.09	40
Ledreborg		0.23	14.8	0.36	0.74	0.28	0.08	16.6
Abed		(0.24)	13.2	0.54	2.14	0.78	0.28	17.3
Bornholm	0.188	3.7	15.1	1.65	3.3	1.34	0.68	26
Mean	0.126	10.0	24.5	1.04	1.91	0.65	0.32	38

Values in brackets estimated from ^{137}Cs data (Table 4.2.2.2) because the samples were lost.

Table 4.2.1.3. Analysis of variance of ln Bq ^{90}Sr m^{-3} precipitation, April-December 1986 (from Table 4.2.1.1)

Variation	SSD	f	s^2	v^2	P
Between months	164.623	5	32.925	30.380	> 99.95%
Between locations	24.472	9	2.719	2.509	> 97.5%
Remainder	45.518	42	1.084		

Table 4.2.1.4. Analysis of variance of ln Bq ^{90}Sr m^{-2} precipitation, April-December 1986 (from Table 4.2.1.2)

Variation	SSD	f	s^2	v^2	P
Between months	94.566	5	18.913	17.459	> 99.95%
Between locations	26.556	9	2.951	2.724	> 97.5%
Remainder	45.499	42	1.083		

Table 4.2.1.5. Sr-89/Sr-90 in precipitation (decay corrected to April 26) in 1986

Location	May	June	July-Aug	Sept-Oct
Tylstrup	-	10	11	-
Kalø	-	21	-	24
Borris	-	16	7	-
Askov	-	15	5	12
St. Jyndevad	-	16	16	16
Aarslev	12	15	7	9
Tystofte	12		8	16
Ledreborg	14		-	-
Abed	8	20	7	-
Bornholm	-	25	13	15
Mean	11.5	17.2	9.2	15.3
1 S.D.	2.5	4.6	3.7	5.0

Table 4.2.1.6. Strontium-90 in precipitation collected at Risø in 1986

Month	10 m^2 ion exchange sampler Bq m^{-2}	Bq m^{-3}	Eight 0.23 m^2 rain bottles Bq m^{-2}	Bq m^{-3}
Jan	0.007	0.18		
Feb	0.017	0.66	0.019	0.21
March				
April	0.48±0.00	17.9±0.1	0.073	2.1
May	21.4 ±0.8	520 ±20	31.1	640
June	0.54±0.03	39 ±2	0.23	12.8
July	0.173±0.006	3.1±0.1	0.29	2.9
Aug	0.038	1.17		
Sep	0.034	1.02	0.076	0.72
Oct	0.060	1.01		
Nov	0.113	3.7	0.052	0.47
Dec	0.015	0.41		
1986 (395 mm)	Σ 23	$\bar{x}$ 58	(503 mm) Σ32	$\bar{x}$ 63

The error terms are ±1 S.E. of the mean of double determinations.

Table 4.2.1.7. Sr-89/Sr-90 in Risø rain 1986 (decay corrected to April 26, 1986)

Month	10 m^2 ion exchange sampler	Eight 0.23 m^2 rain bottles
April	17.2	-
May	15.2±0.0	6.0
June	11.2	-

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

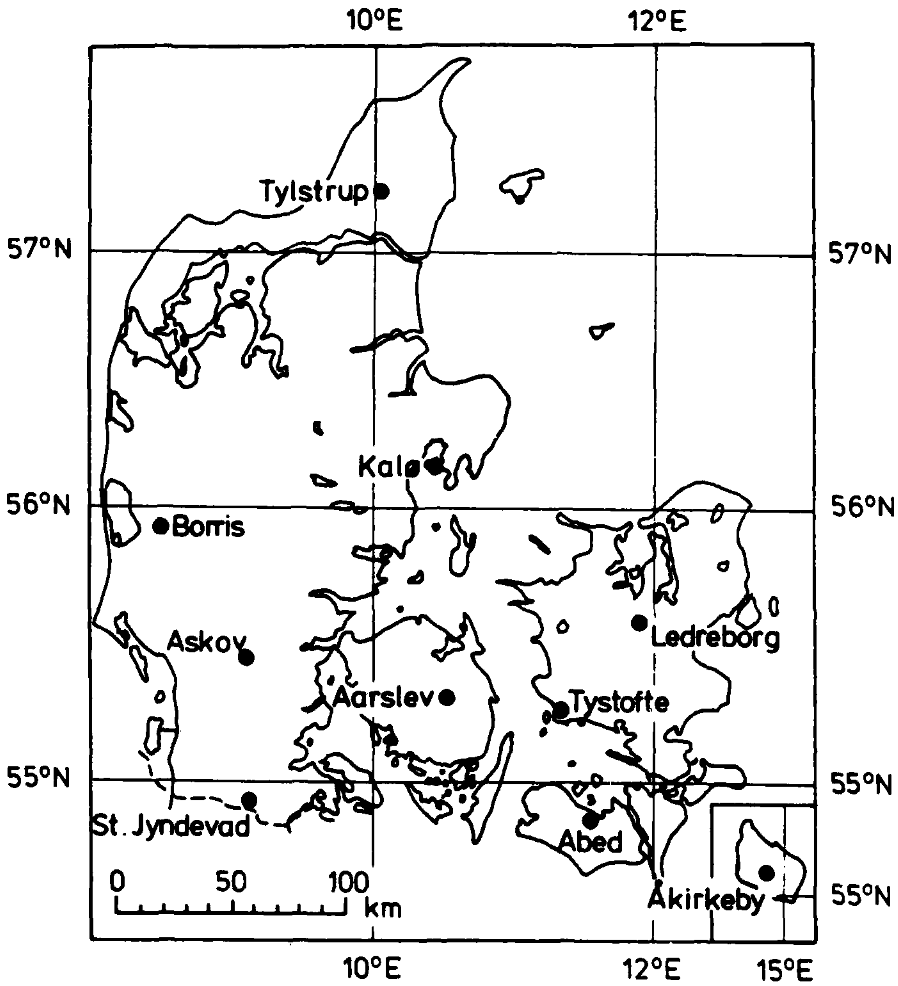


Fig. 4.2. State experimental farms in Denmark.

4.2.2. Radiocesium in precipitation

The most important longer-lived radionuclides from the Chernobyl accident were ^{137}Cs and ^{134}Cs. The measurements of these isotopes in precipitation collected at the Danish State Experimental farms are shown in Tables 4.2.2.1 and 4.2.2.2. The mean deposition was 1070 Bq ^{137}Cs m^{-2} (cf. also 4.5) and the mean concentration was 1780 Bq ^{137}Cs m^{-3}. From the $^{134}Cs/^{137}Cs$ found in the precipitation samples we may estimate this ratio on April 26, 1986 to 0.553 ± 0.004 (mean of 50 determinations; ± 1 S.E.).

The $^{90}Sr/^{137}Cs$ mean ratios in May, June and July-Aug were 0.041 ± 0.004 (± 1 S.E.; N = 8), 0.016 ± 0.003 (± 1 S.E.; N = 10) and 0.026 ± 0.005 (± 1 S.E.; N = 10), respectively. In the last four months of the year the $^{90}Sr/^{137}Cs$ was approximately 0.03. This may, however, be a little too high for Chernobyl debris, because the fallout background of ^{90}Sr may play a role in this period, due to the decreasing Chernobyl levels. In the first months after the accident the rain water concentrations of ^{137}Cs decreased with an effective halflife of approximately 3 weeks as also observed for ^{90}Sr (cf. 4.2.1), but from October the decrease becomes slower. We notice that the concentrations are highest at those stations with the highest deposition in May-June from Chernobyl, i.e. Askov and Årslev. We assume that we deal with local resuspension of Chernobyl radiocesium. The two rain collector systems at Risø (10 m^2 ion exchange collector and 0.23 m^2 or 1 m^2 rain bottles) both gave a ^{137}Cs deposition about 800 Bq m^{-2} (cf. also 4.2.1), which is in agreement with the observations in Table 4.2.2.2 for Zealand (Tystofte and Ledreborg). The mean $^{90}Sr/^{137}Cs$ ratio was 0.034 in Risø rain which is in good agreement with the countrywide mean of 0.036 in 1986 (Tables 4.2.1.2 and 4.2.2.2).

Table 4.2.2.1. Cesium-137 (Bq m^{-3}) and $^{134}Cs/^{137}Cs$ in precipitation in Denmark in 1986

Location	Jan-March		April*		May		June		July-Aug		Sept-Oct		Nov-Dec		1986
	^{137}Cs	134/137	^{137}Cs	134/137	^{137}Cs	134/137	^{137}Cs	134/137	^{137}Cs	134/137	^{137}Cs	134/137	^{137}Cs	134/137	^{137}Cs
Tylstrup			(8300)		7100	0.51	2300	0.53	390	0.46	105	0.53	49	0.47	1130
Kalø			(230)		15000	0.52	3300	0.52	580	0.49	178	0.48	171	0.42	1390
Borris			(130)		11200	0.54	3000	0.58	560	0.49	62	0.51	7.5	0.50	1080
Askov			(22000)		15200	0.53	12200	0.52	1680	0.51	270	0.50	440	0.47	2900
St. Jyndevad			(190)		10500	0.54	2400	0.52	520	0.48	132	0.51	53	0.49	1220
Aarslev			(60000)		32000	0.55	9200	0.53	1650	0.52	270	0.47	220	0.49	5600
Tystofte			(250)		21000	0.53	2700	0.52	760	0.49	94	0.47	89	0.49	2000
Ledreborg			(200)		10700	0.53	2700	0.53	390	0.53	98	0.51	75	0.48	1230
Abed			(180)		4900	0.54	1630	0.52	300	0.56	144	0.51	121	0.52	890
Bornholm			(2200)		9400	0.53	1550	0.54	420	0.53	153	0.46	66	0.48	940
Mean	(1.7)	-	(8100)	-	12400	0.53 S.D.:0.01	3900	0.53 S.D.:0.02	680	0.51 S.D.:0.03	159	0.50 S.D.:0.02	96	0.48 S.D.:0.03	1780

*The April samples were not analysed for radiocesium. The concentrations were estimated from the ^{90}Sr determinations assuming $^{137}Cs/^{90}Sr$ = 26.3, i.e. the ratio measured in *May*.

Table 4.2.2.2. Radiocesium fallout in Denmark in 1986 (Bq m^{-2})

Location	Jan-March		April*		May		June		July-Aug		Sept-Oct		Nov-Dec		1986
	^{137}Cs	^{134}Cs	^{137}Cs	^{134}Cs	^{137}Cs	^{134}Cs	^{137}Cs	^{134}Cs	^{137}Cs	^{134}Cs	^{137}Cs	^{134}Cs	^{137}Cs	^{134}Cs	^{137}Cs
Tylstrup			(200)		380	191	41	21	50	23	11	5.7	7.2	3.4	690
Kalø			(3)		570	290	60	31	72	35	18	8.7	17	7.2	740
Borris			(6)		710	380	51	30	88	43	10	5.0	1.7	0.85	870
Askov			(1100)		660	350	250	130	210	106	61	30	39	18.6	2320
St. Jyndevad			(6)		730	390	30	15	50	24	20	10.3	10.5	5.2	850
Aarslev			(1200)		1110	600	150	79	112	58	34	15.9	25	12.1	2630
Tystofte			(6)		820	430	52	27	67	33	13	6.0	7.0	3.5	970
Ledreborg			(6)		470	250	31	17	34	18	9	4.6	9.0	4.7	560
Abed			(6)		440	240	35	18	45	25	20	10.4	7.9	3.8	550
Bornholm			(100)		290	155	55	30	59	31	13	6.2	7.0	3.4	520
Mean	(0.2)		(260)		620	330	75	40	79	40	21	10	13	6.3	1070

*The ^{137}Cs deposition in April was calculated from the ^{90}Sr deposition in Table 4.2.1.2 assuming the same mean $^{137}Cs/^{90}Sr$ as observed in May, i.e. 26.3.

Table 4.2.2.3. mm precipitation at the State Experimental farms in 1986 measured in the fallout collectors

Location	Jan-March	April until May 4	May from May 5	June	July-Aug	Sept-Oct	Nov-Dec	1986 Σ
Tylstrup		24	53	17	129	103	148	613
Kalø		13	38	18	123	102	100	533
Borris	139	45	63	17	158	161	226	809
Askov		51	43	20	124	226	192	795
St. Jyndevad		31	69	13	96	153	197	698
Aarslev		20	34	16	68	122	114	470
Tystofte	96	24	39	19	87	136	76	477
Ledreborg		30	44	12	89	92	94	457
Abed		34	91	21	154	141	80	617
Bornholm	94	45	31	36	140	88	119	553
Mean	117	32	50	19	117	132	135	602

Table 4.2.2.4. Radiocesium in precipitation collected at Risø in 1986

Month	10 m^2 ion exchange sampler Bq ^{137}Cs m^{-2}		Bq ^{137}Cs m^{-3}	1 m^2 rain sampler*) Bq ^{137}Cs m^{-2}		Bq ^{137}Cs m^{-3}
Jan	0.01 A		0.3 A			
Feb	0.019		0.74			
March						
April	0.48	(0.55)	18			
May	740	(0.53)	17900	760	(0.57)	18500
June	28	(0.52)	2060	30	(0.52)	2100
July	18.7	(0.52)	340	19.2	(0.50)	192
Aug	4.4	(0.51)	134			
Sept	3.2	(0.48)	96	5.0	(0.44)	48
Oct	2.4	(0.47)	41			
Nov	1.94	(0.44)	63	0.98	(0.59)	9.0
Dec	1.25	(0.45)	33			
1986	Σ800		Σ 2030	Σ815		Σ 1780

*)July-Dec: 0.23 m^2 rain bottles

Values in brackets are the ratios: $^{134}Cs/^{137}Cs$.

4.2.3. Short-lived γ-emitters in precipitation

The first rain at Risø after the Chernobyl accident occurred on May 7. In the following days rain was collected in the 1 m^2 rain collector and analysed for γ-emitters (Table 4.2.3). In these early precipitation samples the mean $^{131}I/^{137}Cs$ was 14 (decay corrected to April 26). This ratio was higher than those found in air samples from Risø (cf. 4.1.3.1), probably reflecting that rain retains more of the non-particulate iodine fraction than glass fibre filters. There may, however, also have been an increase in the particulate $^{131}I/^{137}Cs$ ratio with time as suggested from measurements of the air filters.

Table 4.2.3. Early rain samples with Chernobyl debris collected 7-10 May 1986 at Risø (Bq m^{-2})

	7-8 May	8 May	9 May	10 May	Σ on April 26, 1986
Zr-95	55 A				
Nb-95	59	5.9			
Ru-103	1900	250	61	49	2760
Ru-106	970	113			
I-131	2600	640	210	98	9530
Te-132	1350	250	32	43	18700
Cs-134	260	48	13.9	35	357
Cs-136	81	15			
Cs-137	490	86	23	73	672
La-140	250	35	10.6	9.0	560
Ce-141	46				
mm precipitation	4.2	2.9	2.1	5.0	14.2

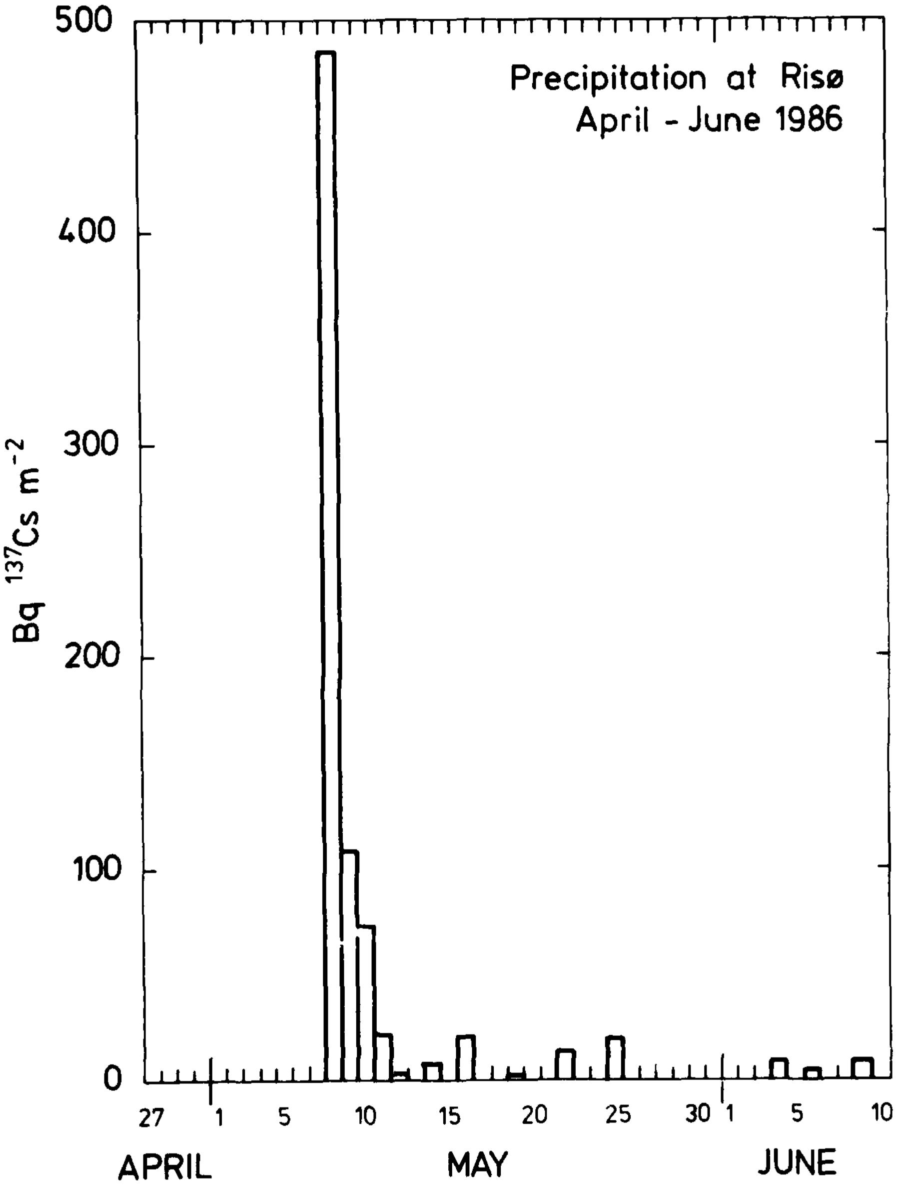


Fig. 4.2.2.4. Cesium-137 in precipitation at Risø in May-June 1986.

The $^{132}Te/^{131}I$ (on 26 April) was 2.0 in the above-mentioned early precipitation samples. This was somewhat higher than the ratio found in air samples from Risø, but not incompatible with Finnish deposition measurements[33].

A comparison between the yearly amounts of precipitation found in the rain gauges used by the Danish Meteorological Institute[9] and the amounts collected in our rain bottles at the same ten locations in 1986 showed a mean ratio of 1.06±0.09 (1 S.D.) between the two sampling systems.

The washout ratios (Bq m^3 rain/μBq m^3 air) calculated for Risø was 60.5/28.6 = 2.1 for ^{90}Sr and 1905/1340 = 1.42 for ^{137}Cs (Table 4.2.6). These values were somewhat higher than the usually observed washout ratio of 1.0[21] perhaps suggesting a more efficient washout of Chernobyl debris than of global fallout.

4.2.4. Tritium in precipitation

Despite the Chernobyl accident, the tritium content of rain-water collected at Risø in 1986 (cf. Table 4.2.8.) was lower by nearly a factor of 2, than in 1985.

Table 4.2.9 shows the tritium concentrations in rain-water from three other locations in Denmark. Compared with Risø the average concentration for these three stations was approx. 3 times lower than that from Risø. The concentrations from Bornholm were higher than those at the stations in Jutland. As earlier mentioned (Risø-R-487[1]) this may reflect the five times higher tritium concentrations in the Baltic Sea as compared with those in the North Sea (cf. Eq. 4.4). There may be a small tritium contribution from the Chernobyl accident, however, enhanced levels in April-July have also been observed in earlier years and may reflect global fallout tritium coming from the stratosphere.

Table 4.2.8. Tritium in precipitation collected at Risø in 1986

Month	m	1 m^2 rain collector		10 m^2 rain collector	
		kBq m^{-3}	kBq m^{-2}	kBq m^{-3}	kBq m^{-2}
Jan	0.038	4.6±0.5	0.175	2.5±0.2	0.095
Feb	0	-	-	-	-
March	0.033	0.9±0.1	0.030	-	-
April	0.025	1.8±0.2	0.045	1.0±0.0	0.025
29/4 - 9/5	0.009	-	-	9.0±0.0	0.081
9/5 - 1/6	0.032	-	-	3.0±0.1	0.096
May	0.041	2.4±0.3	0.098	1.6±0.1	0.066
June	0.014	3.4±0.1	0.048	7.1±0.0	0.099
July	0.055	1.6±0.2	0.088	1.6±0.2	0.088
Aug	0.033	2.6±0.1	0.086	11.2±0.7	0.37
Sept	0.033	6.2±0.3	0.20	19.1±0.1	0.63
Oct	0.059	0.7±0.3	0.041	3.3±0.2	0.195
Nov	0.031	3.1±0.2	0.096	1.6±0.0	0.050
Dec	0.038	1.4±0.0	0.053	0.7±0.1	0.027
1986	Σ0.400	$\bar{x}$ 2.2	Σ0.866	$\bar{x}$4.2	Σ1.675

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

Table 4.2.9. Tritium in precipitation collected in Denmark in 1986. (Unit: kBq m^{-3})

Date	Tylstrup	Jyndevad	Bornholm
January	B.D.L.	0.9±0.5	0.9±0.2
February	-	-	-
March	B.D.L.	B.D.L.	1.0±0.1
April	4.2±0.2	3.0±0.1	0.9±0.3
May	1.2±0.0	1.4±0.0	2.0±0.1
June	2.2±0.1	2.9±0.0	2.6±0.1
July	1.6±0.3	1.7±0.1	2.4±0.2
August	1.4±0.3	1.4±0.1	1.2±0.2
September	B.D.L.	B.D.L.	1.1±0.1
October	B.D.L.	B.D.L.	1.0±0.0
November	B.D.L.	2.6±0.2	1.8±0.6
December	B.D.L.	B.D.L.	B.D.L.
Precipitation weighted mean	0.7	1.0	1.2

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

4.3. Fresh water

4.3.1. Radionuclides in ground water

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

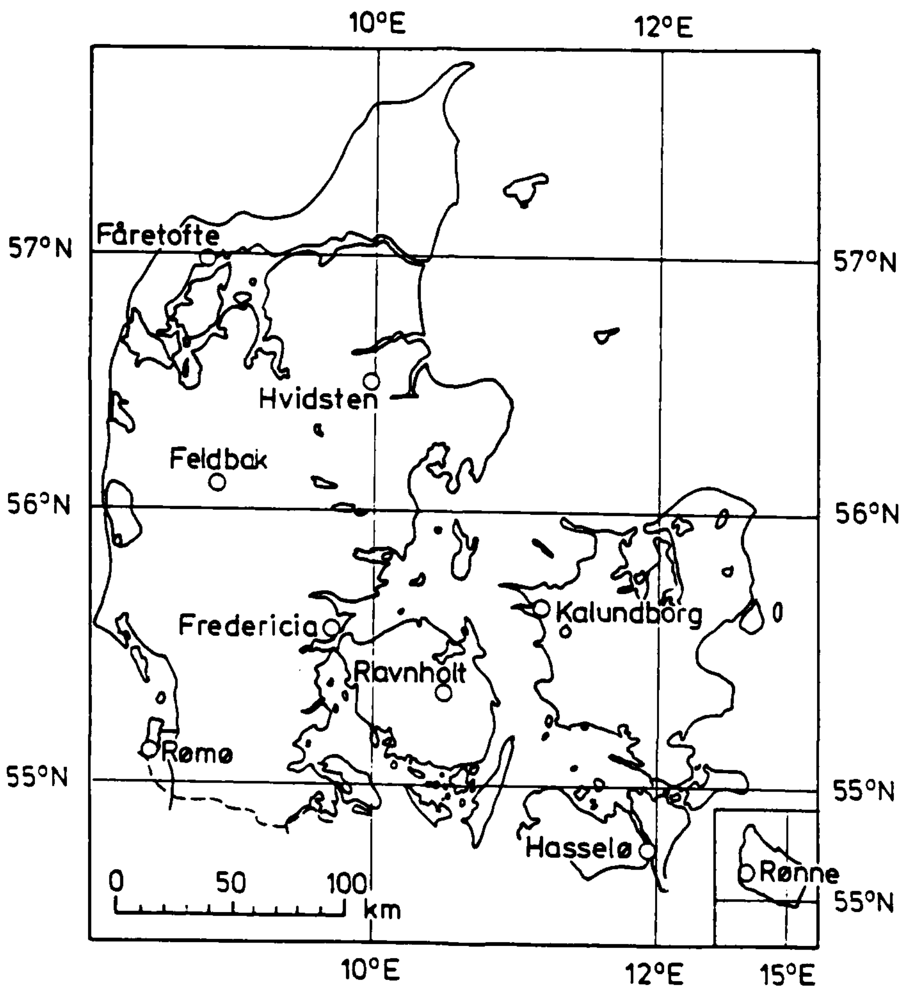


Fig. 4.3.1.1. Ground water sampling locations in Denmark.

Table 4.3.1. Radionuclides in ground water collected in 1986

Location	Date	Bq ^{90}Sr m^{-3}	kg Ca m^{-3}	kBq ^{3}H m^{-3}
Hvidsten	March	0.034 B	0.070	B.D.L.
Feldbak	"	57	0.035	1.1±0.2
Rømø	"	0.36	0.033	B.D.L.
Rønne new	22/5	0.012 B	0.023	B.D.L.
Rønne old	22/5	0.072 A	0.019	B.D.L.
Hasselø	March	0.113	0.056	B.D.L.
Fåretofte	"	0.048 B	0.126	4.2±0.3
Kalundborg	"	0.43	0.023	1.1±0.3
Ravnholt	"	0.134	0.100	2.8±0.0
Fredericia	"	0.26	0.069	1.4±0.3
Geometric mean		0.098*	0.055**	1.0**
Median		0.124	0.046	0.6

A sample of ground water from Maglekilde in Roskilde contained 1.50 Bq ^{90}Sr m^{-3}, 3.1±0.3 kBq ^{3}H m^{-3} and 0.094 kg Ca m^{-3}.

* Feldbak was not included in the geometric mean.

**Arithmetic mean.

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

The median level of ^{90}Sr in 1986 was compatible with the values found since 1967 (cf. Fig. 4.3.1.2).

The tritium concentrations in 1986 were a little lower than the 1985 levels. The tritium content of ground water has been decreasing since 1977.

As appears from Fig. 4.3.1.3, the ^{90}Sr levels in ground water from Feldbak have been in the order of 50-100 Bq m^{-3} in later years. The arithmetic mean of ^{90}Sr in Danish ground water in 1986 (excluding Feldbak and including Maglekilde) was 0.30 Bq m^{-3}. The predicted mean (cf. Appendix C.1) was 0.28 Bq m^{-3}.

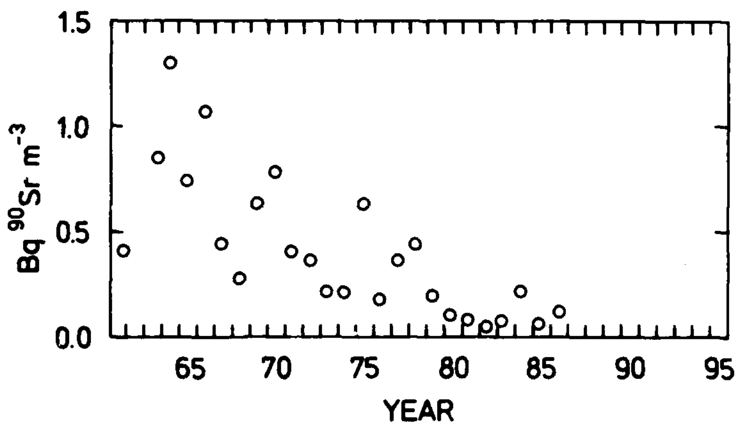


Fig. 4.3.1.2. Median ^{90}Sr levels in Danish ground water, 1961-1986.

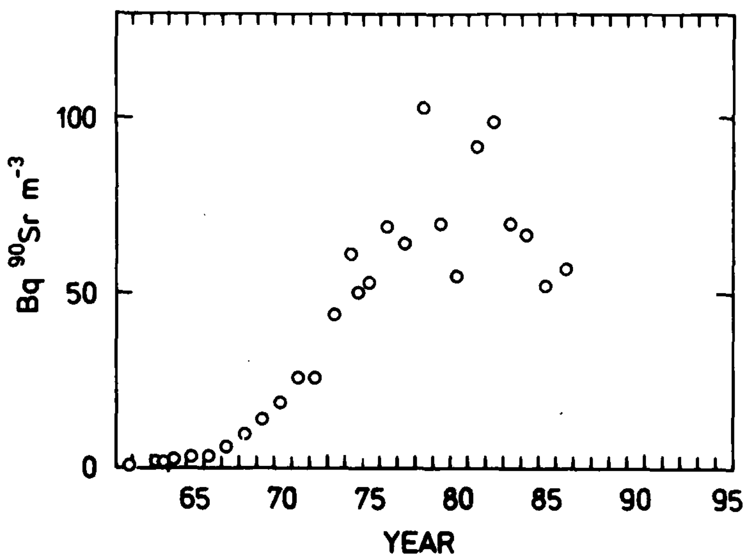


Fig. 4.3.1.3. Strontium-90 in ground water at Feldbak 1961-1986.

4.3.2. Strontium-90, radiocesium and tritium in fresh water from Danish lakes and streams

The mean levels in 1986 were 9.7 Bq ^{90}Sr m^{-3} in streams and 27.7 Bq ^{90}Sr m^{-3} in lakes. The levels in lakes in 1986 were 78% higher than in 1985, and streams were 8% higher (Tables 4.3.2.1 and 4.3.2.2).

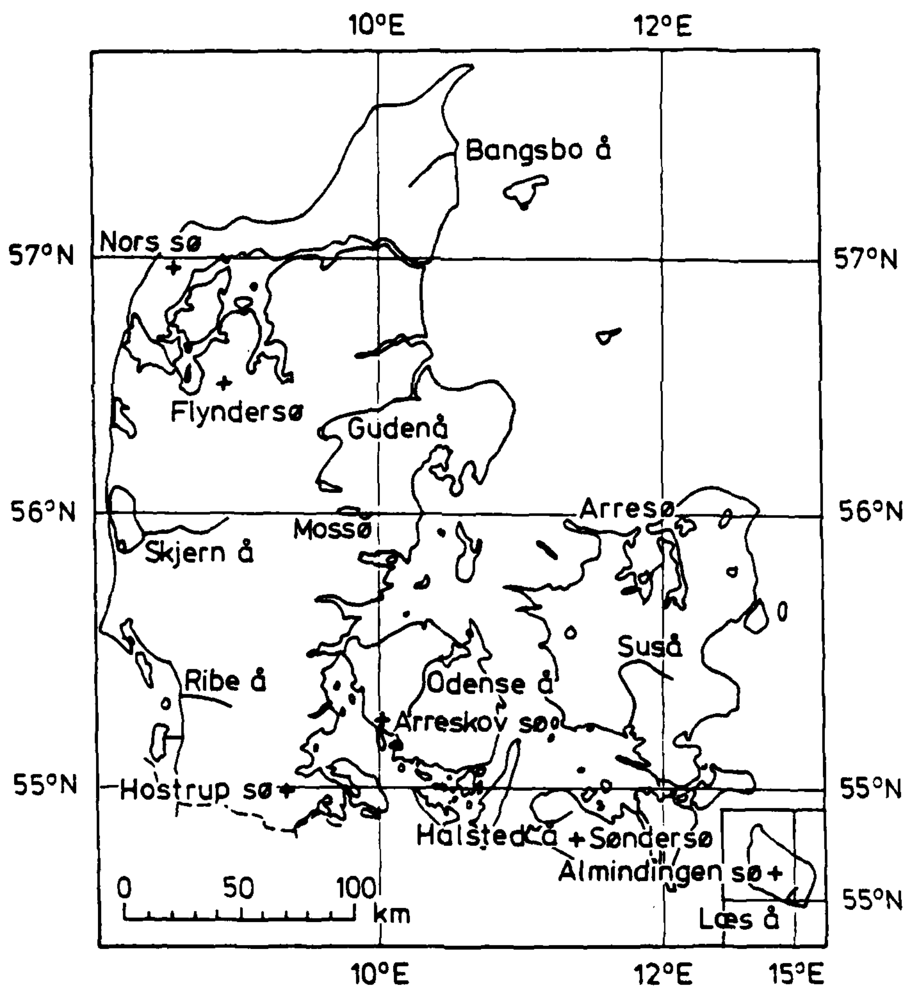


Fig. 4.3.2.1. Sample locations for fresh water from Danish streams (å) and lakes (sø).

Table 4.3.2.1. Strontium-90 in Danish stream water collected in 1986.

Stream	Date	Bq ^{90}Sr m^{-3}	Date	Bq ^{90}Sr m^{-3}
Bangsbo å	June 11	7.4	Oct 14	7.3
Gudenå	May 27	12.4	Oct 14	5.6
Skjern å	May 28	9.5	Oct 15	8.2
Ribe å	May 28	9.5	Oct 2	4.1
Odense å	June 3	9.8	Oct 1	4.1
Suså	May 21	15.6	Oct 17	13.0
Halsted å	June 4	14.5	Oct 2	9.5
Læs å	May 23	17.6	-	-
Mean		12.0		7.4
Relative S.E.		10%		16%

Two samplings were carried out in 1986, one in May-June and one in October. From the first to the second sampling the ^{90}Sr levels in streams decreased by a factor of 1.7 ± 0.60 (N=7; ± 1 S.D.) and in the lakes the factor was 1.5 ± 1.0 (N=7; ± 1 S.D.). The relative standard deviation was greater for the lakes than the streams. Some lakes actually increased in ^{90}Sr concentrations from June to October.

In case of ^{137}Cs (Tables 4.3.2.3 and 4.3.2.4) the mean level in streams was 18 Bq m^{-3} and in lakes we found 66 Bq m^{-3}. The ^{134}Cs/^{137}Cs ratios suggest that all ^{137}Cs found in Danish streams and lakes in 1986 was coming from the Chernobyl accident.

From the first to the second sampling the stream waters ^{137}Cs content decreased by a factor of 4.8 ± 1.34 (N=6; ± 1 S.D.), while lakes decreased by a factor of 2.8 ± 0.95 (N=7; ± 1 S.D.).

Hence the decrease in ^{137}Cs concentrations was more rapid than that of ^{90}Sr. Streams showed a more rapid decrease than lakes. The difference between ^{90}Sr and ^{137}Cs is due to the preferential absorption and sedimentation of radiocesium by particulates (and organisms) in the water.

The tritium contents were not significantly different from those observed in 1985. We may thus conclude that the Chernobyl accident did not contribute significantly to the tritium levels in Danish streams and lakes in 1986.

Appendix C1 shows that the observed level in streams is 0.77 times the predicted, and in the case of lakewater the observed mean concentration is 2.9 times that predicted.

Table 4.3.2.2. Strontium-90 in Danish lake water collected in 1986.

Lake	Date	Bq ^{90}Sr m^{-3}	Date	Bq ^{90}Sr m^{-3}
Norssø	June 11	47	Oct 14	38
Mossø	June 11	13	Oct 16	14
Flyndersø	June 11	22	Oct 15	19
Hostrupsø	June 10	55	Oct 2	56
Arreskovsø	June 12	34	Oct 1	18
Arresø	June 9	22	Oct 13	23
Søndersø	June 4	24	Oct 3	6.6
Almindingen sø	May 22	26	-	-
Mean		30		25
Relative S.E.		16%		24%

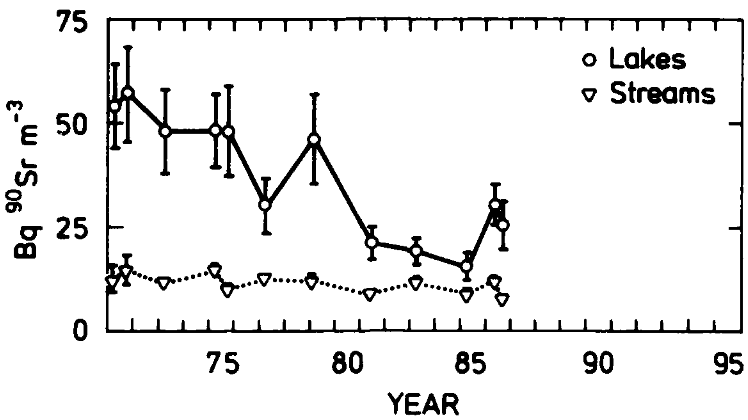


Fig. 4.3.2.2. Strontium-90 concentrations (±1 S.E.) in 8 Danish Streams and 8 Danish lakes collected every second year since 1971.

Table 4.3.2.3. Radiocesium in Danish stream water collected in 1986

Stream	Date	Bq ^{137}Cs m^{-3}	^{134}Cs/^{137}Cs	Date	Bq ^{137}Cs m^{-3}	^{134}Cs/^{137}Cs
Bangsbo å	June 11	6.4 A	-	Oct 14	B.D.L.	-
Gudenå	May 27	53	0.56	Oct 14	8.3	0.55 A
Skjern å	May 28	25	0.59	Oct 15	4.2 A	-
Ribe å	May 28	37	0.64	Oct 2	7.6	0.44 B
Odense å	June 3	37	0.60	Oct 1	14.0	0.51 A
Suså	May 21	44	0.58	Oct 17	10.0	0.52 A
Halsted å	June 4	15	0.58	Oct 2	3.1 B	-
Læs å	May 23	12	0.69	-	-	-
Mean		29	0.61		7.9	0.51
Relative S.E.		21%	3%		21%	5%

Table 4.3.2.4 Radiocesium in Danish lake water collected in 1986

Lake	Date	Bq ^{137}Cs m^{-3}	$^{134}Cs/^{137}Cs$	Date	Bq ^{137}Cs m^{-3}	$^{134}Cs/^{137}Cs$
Norssø	June 11	145	0.54	Oct 14	97	0.47
Mossø	June 11	42	0.68	Oct 16	18	0.36 A
Flyndersø	June 11	130	0.51	Oct 15	38	0.56
Hostrupsø	June 10	108	0.55	Oct 2	34	0.48
Arreskovsø	June 12	32	0.44	Oct 1	8.3	0.60 B
Arresø	June 9	76	0.55	Oct 13	40	0.51
Søndersø	June 4	143	0.53	Oct 3	38	0.53
Almindingen sø	May 22	61	0.51	-	-	-
Mean		92	0.54		39	0.50
Relative S.E.		17%	4%		27%	6%

Table 4.3.2.5. Tritium in Danish stream water collected in 1986

Stream	Date	kBq ^{3}H m^{-3}	Date	kBq ^{3}H m^{-3}
Bangsbo å	June 11	1.8±0.1	Oct 14	2.2±0.1
Gudenå	May 27	2.4±0.3	Oct 14	1.7±0.1
Skjern å	May 28	2.3±0.1	Oct 15	1.7±0.0
Ribe å	May 28	0.8±0.3	Oct 2	1.5±0.1
Odense å	June 3	1.2±0.0	Oct 1	1.4±0.2
Suså	May 21	1.7±0.1	Oct 17	1.7±0.1
Halsted å	June 4	0.9±0.3	Oct 2	1.5±0.1
Læs å	May 23	2.1±0.0	-	-
Mean		1.65		1.67
Relative S.E.		13%		6%

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

Table 4.3.2.6. Tritium in Danish lake water collected in 1986

Lake	Date	kBq ^{3}H m^{-3}	Date	kBq ^{3}H m^{-3}
Norssø	June 11	1.2±0.0	Oct 14	1.6±0.2
Mossø	June 11	1.3±0.0	Oct 16	1.5±0.3
Flyndersø	June 11	1.3±0.1	Oct 15	1.3±0.1
Hostrupsø	June 10	1.2±0.3	Oct 2	B.D.L.
Arreskovsø	June 12	1.0±0.2	Oct 1	B.D.L.
Arresø	June 9	1.6±0.1	Oct 13	1.8±0.2
Søndersø	June 4	1.4±0.1	Oct 3	1.8±0.3
Almindingen sø	May 22	1.7±0.2	-	-
Mean		1.34		1.1
Relative S.E.		6%		27%

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

4.3.3. Radionuclides in Danish drinking water

The ^{90}Sr and tritium concentrations were lower than those in 1985 when drinking water was examined last time. Cesium-137 has not earlier been determined in drinking water. Chernobyl resulted in measurable levels, but the concentrations were very low. We assume that the levels found either were due to contamination during the sampling or due to a content of surface water.

The median ^{90}Sr level was 2-3 times higher in drinking water than in ground water and the arithmetic mean was 1.8 times higher. The tritium mean level in drinking water was not significantly different from that in ground water.

Table 4.3.3. Strontium-90, Cesium-137 and tritium in drinking water collected in June 1986

Zone		Bq ^{90}Sr m^{-3}	Bq ^{137}Cs m^{-3}	kBq ^{3}H m^{-3}	kg Ca m^{-3}
I:	N. Jutland	0.37	0.52	1.1±0.2	0.060
II:	E. Jutland	0.21	0.25 B	B.D.L.	0.092
III:	W. Jutland	0.95	0.03 B	B.D.L.	0.055
IV:	S. Jutland	0 B	0.37 A	B.D.L.	0.081
V:	Funen	0.1 A	0.61	B.D.L.	0.103
VI:	Zealand	0.05 B	2.47	B.D.L.	0.091
VII:	Lolland-Falster	0.07 B	0.62	B.D.L.	0.110
VIII:	Bornholm	0.54	0.06 B	1.5±0.1	0.074
Mean		0.29	0.62	0.3	0.083
Risø		0.14 A	0.11 B	-	0.125
Median of zones		0.14	0.45	B.D.L.	0.086

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

4.4. Radionuclides in sea water in 1986

As in previous years, sea water samples were collected by M/S Fyrholm from inner Danish waters (cf. Tables 4.4.1-4.4.4 and Figs. 4.4.1, 4.4.2 and 4.4.3). Furthermore, sea water samples were collected at Barsebäck in the Sound, and at Ringhals in the Kattegat (Table 4.4.5). Samples were obtained from the research vessel DANA, which in 1986 have collected samples from the Danish straits as well as from the North and the Baltic Seas (Table 4.4.5). The research vessel GAUSS from the German Hydrographic Institute in Hamburg hosted us on a cruise to the Baltic Sea in Oct 1986. (Table 4.4.5.)

The Chernobyl debris was not detectable in the surface water samples collected in the German Bight during the DANA 4 cruise at 29-30 April 1986. (Table 4.4.5) This observation is in aggrement with the distribution of the first radioactive cloud over Denmark from Chernobyl (Fig. 4.1.2.5).

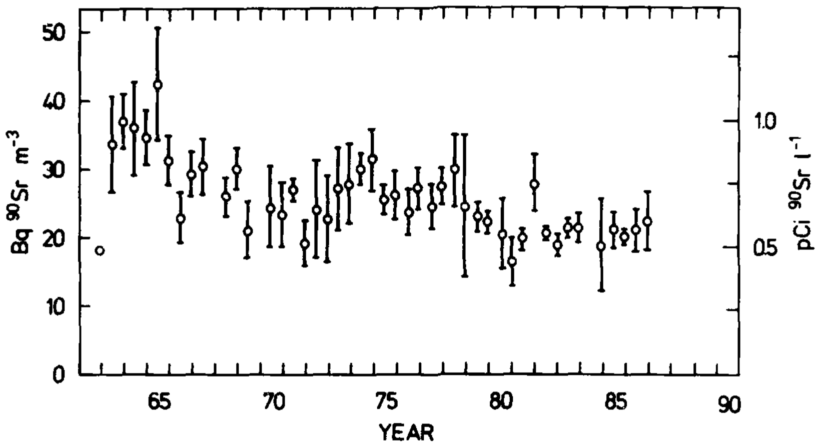


Fig. 4.4.1. Strontium-90 in surface sea water from inner Danish waters, 1962-1986. (1 S.D. indicated) (from Table 4.4.1).

In the samples collected around Zealand in May (table 4.4.1) ^{137}Cs from Chernobyl amounted to 86% of the total ^{137}Cs activity in the surface water, but only to 29% of the ^{137}Cs found in bottom water. At four stations no Chernobyl had yet showed up in the bottom water.

An extra sampling was made in August 1986 (Table 4.4.2). At that time 80% of the ^{137}Cs in surface water was from Chernobyl and 69% of the ^{137}Cs in bottom water.

In Nov 1986 (Table 4.4.3) 72% of the ^{137}Cs in surface water and 68% in bottom water came from Chernobyl. We may conclude that it took approximately half a year before the Chernobyl radiocesium had become totally mixed in the water column of the Danish Straits.

We may furthermore conclude that Chernobyl tripled the ^{137}Cs inventory in the Danish Straits found prior to the accident (Fig. 4.4.2).

Tables 4.4.1 and 4.4.3 and Fig. 4.4.1 furthermore show that Chernobyl did not contribute measurable to the ^{90}Sr concentrations in Danish sea water.

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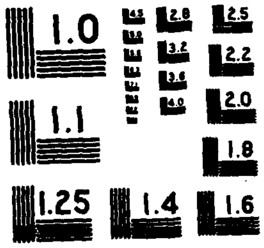
1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0

The perturbation from Chernobyl has made it impossible to continue the validation of the model for transfer of radiocesium from Sellafield to the Danish Straits (cf. Risø-R-540 Fig. 4.4.6)[1]. It has also become meaningless to relate the ^{137}Cs activities in the Danish Straits to the salinity (cf. Risø-R-540 p. 57-59)[1].

Table 4.4.5 shows that the mean ^{137}Cs concentration in the central North Sea (~ 54°-59°N and ~ 0°-8°E) in February was 47±26 Bq m^{-3} (±1 SD; N=11). In June we found: 104±18 (±1 SD; N=7). The $^{134}Cs/^{137}Cs$ in the June sampling suggested that 35% of the ^{137}Cs at that time should have come from Chernobyl. The increase from February to June was however greater probably because the ^{137}Cs from Sellafield (and La Hague) is unevenly distributed, and as the two samplings did not cover exactly the same areas we may get a discrepancy.

The monthly samples collected at Klint (table 4.4.5) represent surface water in the southern Cattegat. From June to December the concentration of ^{137}Cs decreased by a factor of 2 and the contribution of Chernobyl ^{137}Cs changed from 99% to 74% reflecting the vertical mixing of the activity.

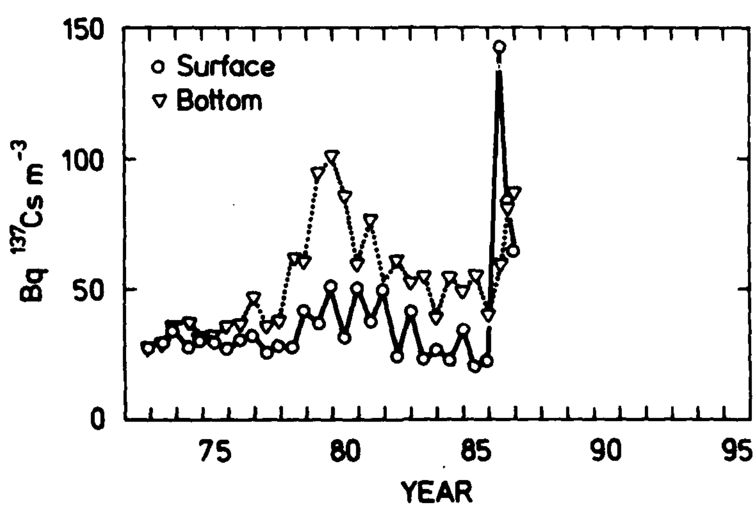

Fig. 4.4.2. Cesium-137 in surface and bottom water collected in inner Danish waters 1972-1986.

In the German Bight the mean ^{137}Cs in April 1986 was 22.6±6.0 (±1 SD; N=10). Half a year later in October we found 60±28 (± 1 SD; N=8) The $^{134}Cs/^{137}Cs$ at the two samplings was 0.076±0.050 and 0.28±0.12 respectively. In April the $^{134}Cs/^{137}Cs$ indicated La Hague radiocesium, but in October the Chernobyl signal was evident. If we assume that the "pre-Chernobyl" radiocesium

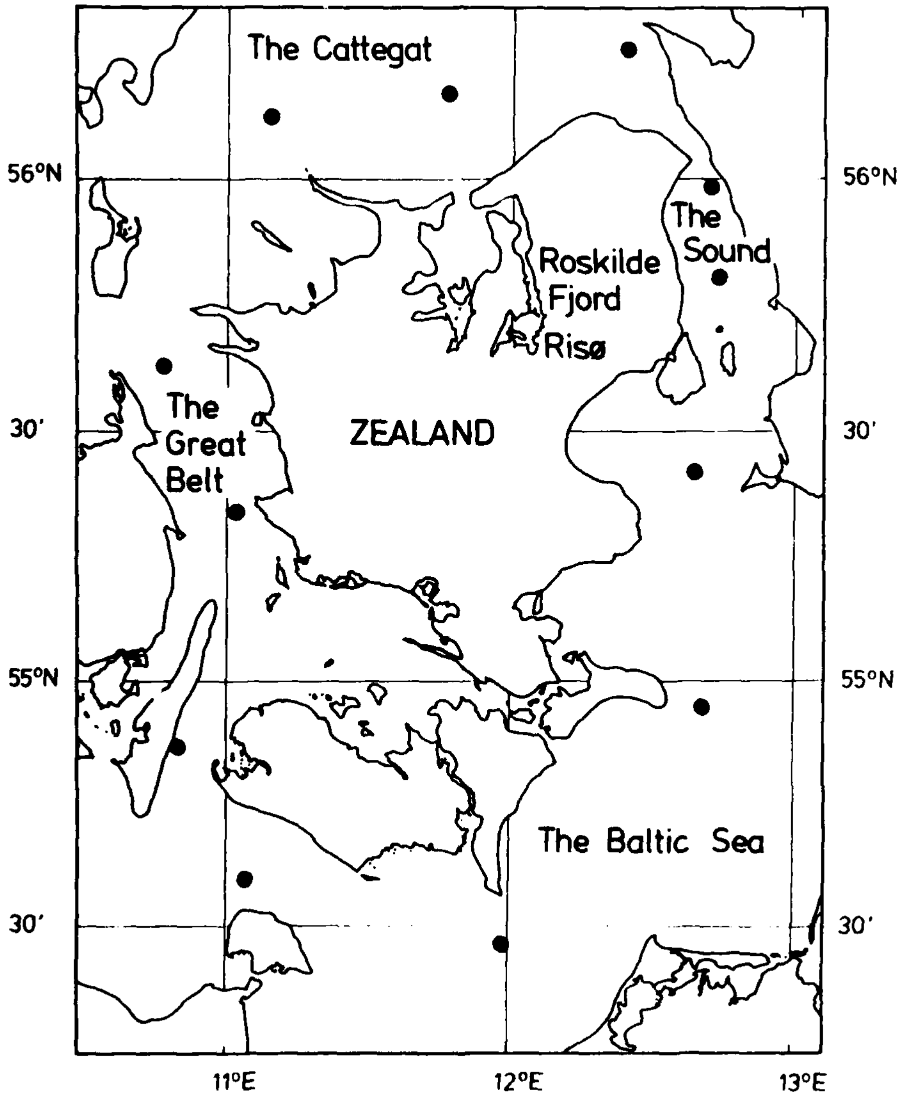

Fig. 4.4.3. Sea water locations around Zealand.

Table 4.4.1. Radionuclides in sea water collected around Zealand in May 1986

Location	Date in May	Position N	Position E	Depth in m	^{90}Sr Bq m^{-3}	^{137}Cs Bq m^{-3}	$^{134}Cs/^{137}Cs$	Salinity o/oo
Kullen	31	56°15'	12°25'	2	21.7	158	0.48	18.7
"				25	-	49	0.07	34.2
Hesselø	29	56°10'	11°47'	2	19.6	140	0.43	18.7
"				23	-	40	0	34.5
Kattegat SW	29	56°07'	11°10'	2	22.9	156	0.45	18.6
"				34	-	41	0	34.1
Asnæs rev	29	55°39'	10°46'	2	25.2	157	0.46	17.7
" "				41	-	40	0.08	33.7
Halskov rev	29	55°23'	11°03'	2	24.8	173	0.43	17.6
" "				24	-	43	0	33.1
Langeland belt	29	54°52'	10°50'	2	24.8	188	0.48	14.4
" "				19	-	61	0.24	31.0
Femern belt	30	54°36'	11°04'	2	21.4	243	0.51	14.3
" "				25	-	73	0.29	29.3
Gedser odde	30	54°28'	11°59'	2	20.2	55	0.37	8.3
" "				17	16.1	38	0.12	24.2
Møen	30	54°57'	12°41'	2	19.4	89	0.45	8.0
"				21	16.9	104	0.48	10.0
The Sound - South	30	55°25'	12°36'	2	13.6	58	0.45	8.2
" " "				13	13.6	124	0.39	14.4
The Sound - North A	31	55°48'	12°44'	2	21.4	147	0.45	17.7
" " "				18	-	46	0.13	33.4
The Sound - North B	31	55°59'	12°42'	2	20.4	157	0.47	19.4
" " "				26	-	51	0	33.5
Mean				Surface	21.2	143	0.45	15.1
S.D.					3.2	54	0.03	4.5
S.E.					0.9	15	0.01	1.3
Mean				Bottom	15.5	59	0.15	28.8
S.D.					1.7	28	0.16	8.3
S.E.					1.0	8	0.05	2.4

Table 4.4.2. Radionuclides in sea water collected around Zealand in August 1986

Location	Date in Aug.	Position N	Position E	Depth in m	^{137}Cs Bq m^{-3}	$^{134}Cs/^{137}Cs$	Salinity o/oo
Kullen	25	56°15'	12°25'	2	108	0.38	18.5
"				23	77	0.27	31.7
Hesselø	25	56°10'	11°47'	2	115	0.37	19.5
"				24	90	0.34	31.8
Kattegat SW	27	56°07'	11°10'	2	101	0.43	14.7
"				38	85	0.36	30.0
Asnæs rev	27	55°39'	10°46'	2	86	0.41	19.4
" "				31	77	0.33	28.7
Halskov rev	26	55°23'	11°03'	2	95	0.38	14.7
" "				23	91	0.38	26.2
Langeland bælt	26	54°52'	10°50'	2	100	0.43	17.2
" "				34	95	0.34	25.3
Femern bælt	26	54°36'	11°04'	2	111	0.37	13.4
" "				26	103	0.35	22.9
Gedser odde	26	54°28'	11°59'	2	42	0.38	8.7
" "				17	98	0.38	18.2
Møen	26	54°57'	12°41'	2	41	0.39	7.9
"				22	68	0.35	11.1
The Sound - South	25	55°25'	12°36'	2	42	0.32	8.2
" " "				16	43	0.28	8.8
The Sound - North A	25	55°48'	12°44'	2	72	0.35	14.9
" " "				19	80	0.38	24.9
The Sound - North B	25	55°59'	12°42'	2	81	0.43	17.6
" " "				27	66	0.29	31.8
Mean				Surface	83	0.39	14.6
S.D.					28	0.03	4.3
S.E.					8	0.01	1.2
Mean				Bottom	81	0.34	24.3
S.D.					17	0.04	7.8
S.E.					5	0.01	2.3

Table 4.4.3. Radionuclides in sea water collected around Sealand in November 1986

Location	Date in Nov.	Position N	Position E	Depth in m	^{90}Sr Bq m^{-3}	^{137}Cs Bq m^{-3}	$^{134}Cs/^{137}Cs$	salinity o/oo
Kullen	19	56°15'	12°25'	2	27.2	49	0.32	12.0
"				24		95	0.27	32.0
Hesselø	17	56°10'	11°47'	2		84	0.32	22.0
"				24	15.7	93	0.29	28.8
Kattegat SW	17	56°07'	11°10'	2		94	0.29	23.4
"				38	15.3	97	0.31	27.8
Asnæs rev	17	55°39'	10°46'	2		87	0.34	20.2
" "				43	16.4	89	0.31	26.7
Halskov rev	17	55°23'	11°03'	2		76	0.33	16.0
" "				23	18.1	80	0.31	18.5
Langeland bælt	18	54°52'	10°50'	2		82	0.35	15.8
" "				31		88	0.35	17.2
Femern bælt	18	54°36'	11°04'	2	25.0	70	0.35	14.0
" "				32		91	0.34	22.0
Gedser odde	28	54°28'	11°59	2		58	0.33	12.2
" "					-	-	-	-
Møen	28	54°57'	12°41'	2	19.5	40	0.31	9.6
"					-	-	-	-
The Sound - South	18	55°25'	12°36'	2		51	0.30	12.3
" " "				14	17.5	51	0.32	12.3
The Sound - North A	19	55°48'	12°44'	2		41	0.33	10.1
" " "				18		95	0.28	30.8
The Sound - North B	19	55°59'	12°42'	2	18.3	41	0.34	10.4
" " "				26		93	0.27	31.6
Mean				Surface	22.5	64	0.33	14.8
S.D.					4.3	20	0.02	4.7
S.E.					2.1	6	0.01	1.4
Mean				Bottom	16.6	87	0.31	24.8
S.D.					1.2	14	0.03	6.9
S.E.					0.5	4	0.01	2.2

Table 4.4.4. Tritium in sea water collected around Zealand in 1986 (unit: kBq m^{-3})

Location	Position N	Position E	Depth in m	May	Nov
Kullen	56°15'	12°25'	2	4.8± 0.0	-
"			24	2.0± 0.0	-
Hesselø	56°10'	11°47'	2	3.9± 0.4	2.7± 0.1
"			23	2.7± 0.3	2.0± 0.8
Kattegat SW	56°07'	11°10'	2	2.7± 0.3	2.4± 0.1
"			34	B.D.L.	1.6± 0.2
Asnæs rev	55°39'	10°46'	2	3.9± 0.4	3.4± 0.2
" "			41	B.D.L.	2.2± 0.1
Halskov rev	55°23'	11°03'	2	1.9± 0.7	3.2± 0.2
" "			24	B.D.L.	3.3± 0.1
Langeland bælt	54°52'	10°50'	2	3.1± 0.2	3.2± 0.2
" "			19	B.D.L.	3.0± 0.2
Femern bælt	54°36'	11°04'	2	3.3± 0.1	3.8± 0.0
" "			25	1.0± 0.3	1.9± 0.1
Gedser odde	54°29'	11°59'	2	4.0± 0.5	
" "			17	1.9± 0.1	
Møen	54°57'	12°41'	2	5.1± 0.5	
"			21	4.0± 0.1	
The Sound - South	55°25'	12°36'	2	4.7± 1.0	4.1± 0.0
" " "			13	5.4± 0.0	4.3± 0.4
The Sound - North A	55°48'	12°44'	2	5.7± 0.6	5.0± 0.1
" " "			18	1.6± 0.1	1.1± 0.6
The Sound - North B	55°59'	12°42'	2	2.3± 0.0	1.3± 0.5
" " "			29	1.8± 0.1	4.1± 0.3
Mean			Surface	3.8	3.2
S.D.				1.2	1.0
S.E.				0.3	0.3
Mean			Bottom	1.7	2.6
S.D.				1.7	1.1
S.E.				0.5	0.3

The salinities are shown in tables 4.4.1 - 4.4.3

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

Table 4.4.5 Radionuclides in sea water collected in the Danish Straits, the North and the Baltic Seas in 1986.

Location/Cruise	Position N	Position E or W	Date	Depth in m	Salinity o/oo	^{90}Sr Bq m^{-3}	^{137}Cs Bq m^{-3}	$^{134}Cs/^{137}Cs$	^{99}Tc Bq m^{-3}	^{3}H kBq m^{-3}
North Sea/Dana 1	57°10'	6°20'E	20/2	0	35.0	-	30.8	-	-	BDL
" " "	57°44'	5°16'E	19/2	0	35.2	-	27.6	0.031B	-	BDL
" " "	58°08'	4°56'E	19/2	0	35.2	-	25.9	-	-	BDL
" " "	58°48'	2°50'E	18/2	0	35,3	-	11.0	-	-	BDL
" " "	57°38'	2°12'E	18/2	0	33.4	-	53.6	-	-	BDL
" " "	55°10'	0°17'E	11/2	0	34.7	7.17	90.2	0.037	-	BDL
" " "	54°26'	4°36'E	10/2	0	34.6	-	89.2	0.033A	-	BDL
" " "	54°14'	5°31'E	9/2	0	34.5	-	66.3	-	-	BDL
" " "	57°05'	7°23'3E	4/2	0	35.1	-	38.4	0.038B	-	BDL
" " "	58°05'	3°30'E	19/2	0	34.8	7.90	38.1	0.039	-	BDL
" " "	55°06'	6°09'E	19/2	0	34.5	-	41.9	0.078A	-	BDL
Baltic Sea/Dana 2	55°18'	15°58'E	18/3	0	7.6	16.7	11.9	-	-	4.5±0.2
" " "	53°22'	18°37'E	16/3	0	7.8	-	12.7	-	-	4.4±0.4
" " "	55°51'	18°22'E	16/3	0	7.5	-	13.3	-	-	4.6±0.0
Danish Straits/Dana 3	56°14'	12°21'E	21/3	0	9.3	-	14.2	-	-	-
" " "	56°59'	12°02'E	21/3	0	14.8	25.6	24.2	-	-	-
" " "	57°22'	10°46'E	21/3	0	14.8	-	19.2	-	-	-
" " "	57°32'	11°31'E	21/3	0	17.4	-	24.0	-	-	-
" " "	57°48'	10°52'E	22/3	0	30.0	-	35.2	-	-	-
German Bight/Dana 4	55°00'	8°16'E	29/4	0	30.6	-	15.7	0.040A	-	-
" " "	55°00'	7°58'E	29/4	0	31.5	26.0	19.7	-	-	-
" " "	55°00'	7°36'E	29/4	0	32.0	-	19.0	-	-	-
" " "	55°00'	7°13'E	29/4	0	33.0	22.0	19.9	0.086	-	-
" " "	55°00'	6°50'E	29/4	0	34.2	-	35.6	0.064A	-	-
" " "	53°56'	6°50'E	29/4	0	31.8	20.8	21.6	0.145	-	-
" " "	54°01'	6°50E	29/4	0	32.4	-	18.9	0.124	-	-

Table 4.4.5 Continued

Location/Cruise	Position N	Position E or W	Date	Depth in m	Salinity o/oo	^{90}Sr Bq m^{-3}	^{137}Cs Bq m^{-3}	$^{134}Cs/^{137}Cs$	^{99}Tc Bq m^{-3}	^{3}H kBq m^{-3}
German Bight/Dana 4	54°12'	7°28E	30/4	0	32.6	16.2	22.2	0.114	-	-
" " "	54°20'	6°50'E	30/4	0	33.6	-	22.7	0.104	-	-
" " "	54°31'	6°50'E	30/4	0	33.8	12.7	30.4	0.083	-	-
Barsebäck	55°45'	12°53'E	30/5	2,5	16.7	22.1	147	0.48	-	2.7±0.2
"	"	"	"	19	32.8	-	44.8	0.118	-	1.0±0.4
Bornholm East	55°05'	15°09E	22/5	0	-	19.5	30.6	0.29	-	-
Anholt	56°40'	12°06'E	10/6	47	34.4	12.8	39.4	0	-	-
Ringhals	57°15'	12°04'E	11/6	2.5	19.7	-	141	0.47	-	-
"	"	"	"	20	32.4	-	86	0.33	-	-
Læsø	57°19'	11°07'E	11/6	2.5	24.7	16.5	115	0.44	-	-
Læsø	57°18'	10°56'E	11/6	0.5	19.8	-	141	0.45	-	-
Læsø	57°20'	11°24'E	11/6	52	34.0	11.6	52.5	0.19	-	-
Anholt	56°43'	11°30'E	12/6	2.5	19.2	-	130	0.46	-	-
Hesselø	56°12'	11°42'E	12/6	2.5	18.1	33.3	135	0.45	-	-
Hesselø	56°10'	11°48'E	12/6	27	34.1	-	39.9	0	-	-
Risø	55°42'	12°05'E	12/5	2.5	11.1	13.6	207	0.46	-	-
Klint	55°58'	11°35'E	20/6	0	16.0	-	168	0.51	-	-
Klint	"	"	15/7	0	19.4	-	140	0.40	-	-
Klint	"	"	14/8	0	17.1	-	98	0.44	-	-
Klint	"	"	15/9	0	22.2	-	121	0.34	-	-
Klint	"	"	15/10	0	22.6	-	105	0.36	-	-
Klint	"	"	14/11	0	22.6	-	100	0.36	-	-
Klint	"	"	15/12	0	21.8	-	86	0.33	-	-
North Sea/Dana	56°04'	8°08'E	13/6	0	34.3	-	86	0.17	-	-
" " "	56°01'	2°30'E	31/5	0	34.7	11.3	98	0.21	-	-

Table 4.4.5 Continued

Location/Cruise	Position N	Position E or W	Date	Depth in m	Salinity o/oo	^{90}Sr Bq m^{-3}	^{137}Cs Bq m^{-3}	$^{134}Cs/^{137}Cs$	^{99}Tc Bq m^{-3}	^{3}H kBq m^{-3}
North Sea/Dana	56°30'	2°30'E	31/5	0	34.9	-	108	0.25	-	-
" " "	55°59'	5°23'E	2/6	0	34.5	14.0	136	0.24	-	-
" " "	55°30'	1°37'E	1/6	0	34.8	-	89	0.11	-	-
" " "	55°31'	1°51'E	10/6	0	34.2	11.0	94	0.11	-	-
" " "	56°26'	6°23'E	4/6	0	34.5	-	115	0.20	-	-
Nystsj	54°40'	11°44'E	5/8	0	11.9	-	81.6	0.39	-	-
Cattegat/Dana	57°22'	10°46'E	24/10	0	22.3	25.9	98	0.33	-	-
" "	56°14'	12°22'E	23/10	0	21.7	-	100	0.34	-	-
" "	56°40'	12°07'E	23/10	0	23.2	15.7	106	0.36	-	-
" "	56°10'	11°20'E	23/10	0	21.3	-	92	0.35	-	-
" "	57°12'	11°40'E	23/10	0	25.7	12.3	103	0.33	-	-
" "	57°33'	11°31'E	22/10	0	33.2	24.6	94	0.29	-	-
" "	57°52'	11°19'E	22/10	0	33.0	13.8	93	0.31	-	-
" "	57°00'	12°03'	23/10	0	24.5	-	102	0.34	-	-
German Bight/Dana	55°00'	6°50'E	27/10	0	34.0	16.9	28	0.26	-	-
" " "	54°08'	6°50'E	28/10	0	34.0	13.0	68	0.12	-	-
" " "	55°00'	7°12'E	27/10	0	33.4	13.1	30.8	0.30	-	-
" " "	55°00'	8°15'E	27/10	0	29.9	13.0	103	0.47	-	-
" " "	53°45'	6°53'E	28/10	0	32.1	16.4	37.2	0.21	-	-
" " "	55°00'	7°36'E	27/10	0	32.8	17.4	54.2	0.31	-	-
" " "	55°00'	6°27'E	27/10	0	31.7	19.3	74.1	0.14	-	-
" " "	55°00'	7°57'E	27/10	0	30.9	19.1	88.4	0.41	-	-
Danish Straits/Gauss	56°45'	11°00'E	15/10	4	24.3	22.9	100	0.32	1.26	-
" " "	57°00'	12°00'E	15/10	4	23.3	11.7	106	0.35	2.10	-
" " "	57°00'	12°00'E	15/10	40	32.7	-	84*	0.35*	1.15	-
" " "	56°30'	11°30'E	15/10	40	22.6	-	96*	0.39*	1.09	-

Table 4.4.5 Continued

Location/Cruise	Position N	Position E or W	Date	Depth in m	Salinity o/oo	^{90}Sr Bq m^{-3}	^{137}Cs Bq m^{-3}	$^{134}Cs/^{137}Cs$	^{99}Tc Bq m^{-3}	^{3}H kBq m^{-3}
Danish Straits/Gauss	56°30'	12°00'E	16/10	4	21.9	17.2	97	0.36	1.23	-
" " "	55°17'	12°33'E	16/10	4	8.2	19.5	33.4	0.24	-	-
Baltic Sea/Gauss	55°34'	15°09'E	17/10	4	7.7	19.4	37.1	0.35	0.040	-
" " "	"	"	17/10	~50	10.0	-	36*	0.36*	0.160	-
" " "	"	"	17/10	~70	13.6	-	43*	0.30*	0.160	-
" " "	57°00'	17°30'E	17/10	4	6.8	20.6	265	0.51	0.017	-
" " "	"	"	17/10	4	6.8	-	259*	0.52*	0.055	-
" " "	"	"	17/10	~50	7.3	-	55*	0.45*	0.031	-
" " "	"	"	17/10	~90	7.5	-	18*	0.11*	0.028	-
" " "	58°53'	19°50'E	18/10	4	6.4	27.7	753	0.51	0.016	-
" " "	"	"	18/10	50	7.1	-	132*	0.53*	0.025	-
" " "	"	"	18/10	130	10.1	-	18*	0.10*	0.061	-
" " "	58°45'	18°30'E	18/10	4	6.8	29.5	449	0.42	0.043	-
" " "	"	"	18/10	120	9.9	-	16*	0*	0.072	-
" " "	"	"	18/10	250	10.2	-	19*	0*	0.049	-
" " "	[illegible]	[illegible]	21/10	4	5.5	37.4	963	0.51	0.047	-
" " "	"	"	21/10	120	7.2	-	152*	0.47*	0.055	-
" " "	"	"	21/10	240	7.4	-	70*	0*	0.041	-
" " "	61°30'	17°59'E	22/10	4	5.5	29.1	592	0.50	0.082	-
" " "	62°40'	19°33'E	23/10	4	5.8	27.2	523	0.52	0.038	-
" " "	"	"	23/10	~50	5.8	-	464*	0.54*	0.069	-
" " "	"	"	23/10	~130	6.8	-	60*	0.47*	0.069	-
" " "	64°05'	21°56'E	23/10	4	3.6	21.2	112	0.48	0.183	-
" " "	"	"	23/10	90	4.2	-	37[illegible]*	0.46*	0.054	-
" " "	64°44'	23°06'E	24/10	4	3.7	20.2	152	0.51	0.036	-
" " "	62°00'	20°30'E	25/10	4	6.0	28.0	721	0.50	0.036	-
" " "	61°04'	19°42'E	26/10	4	6.0	-	550	0.46	0.033	-

Table 4.4.5 Continued

Location/Cruise	Position N	Position E or W	Date	Depth in m	Salinity o/oo	^{90}Sr Bq m^{-3}	^{137}Cs Bq m^{-3}	$^{134}Cs/^{137}Cs$	^{99}Tc Bq m^{-3}	^{3}H kBq m^{-3}
Baltic Sea/Gauss	61°04'	19°42'E	26/10	80	-	-	104*	0.46*	0.023	-
" " "	"	"	26/10	130	-	-	126*	0.49*	0.039	-
" " "	60°10'	26°35'E	28/10	4	5.5	26.7	399	0.50	-	-
" " "	59°30'	23°20'E	30/10	4	6.9	20.5	85.2	0.43	0.039	-
" " "	56°05'	17°42'E	1/11	4	7.4	20.3	38.0	0.31	-	-
" " "	"	"	1/11	50	-	-	21*	0.27*	0.073	-
" " "	54°48'	19°19'E	1/11	4	7.5	21.4	42.9	0.37	-	-
" " "	"	"	1/11	100	-	-	22*	0.19*	0.140	-
Barsebäck	55°45'	12°52'E	19/11	2.5	9.9	-	43.8	0.34	-	5.1±0.2
"	"	"	19/11	19	23.8	-	78.9	0.28	-	2.5±0.2

*Analysed by German Hydrographic Institute.

background is given by the April sampling and that this background still exists in the October samples we may calculate that the ^{137}Cs from Chernobyl in October was 60 - 22.6 = 37.4 Bq m^{-3} and the ^{134}Cs was (0.28x60) - (0.076x22.6) = 15.1 Bq m^{-3}. The theoretical $^{134}Cs/^{137}Cs$ in pure Chernobyl debris was 0.466 in October. Hence the relative contribution of ^{137}Cs from Chernobyl in October in the German Bight was (15.1x100)/(0.466x60) = 54%. The increase in ^{137}Cs here is thus a little lower than in the Danish Straits.

Prior to Chernobyl in March 1986 (Table 4.4.5.1) the Baltic Sea contained 12.8±0.64 Bq ^{137}Cs m^{-3} (±1 SD: N=4). At the Gauss cruise in the last half of October the surface water of the Baltic Sea contained: 379±301 (±1 SD: N=15) Bq ^{137}Cs m^{-3}. The concentration varied a factor of nearly 30. The highest levels were found in the Gulf of Bothnia around 59°-62°N and 18°-20°E. The lowest concentration were seen in the southern part of the Baltic Sea. The $^{134}Cs/^{137}Cs$ showed that nearly 100% of the 137Cs seen in the Baltic samples came from Chernobyl.

During the Gauss cruise in the Baltic we filtered eleven large volume (2-3 m^3) sea water samples through a millipore (0.45 μm) cartridge filters and determined the particulate γ-emitters and plutonium and americium (Table 4.4.6). Radiocesium and ^{110m}Ag were measurable in nearly all samples. The ruthenium isotopes were detectable in approximately half of the samples. The particulate fraction of ^{137}Cs in Baltic Sea surface water varied between 0.08% to 4.3%. The median level was 0.5%. The high percentage was found in the northern part of the Bothnian Bay where the salinity is very low due to river run off (3.6 o/oo). The $^{110m}Ag/^{137}Cs$ ratio in particulate matter was inversely proportional to the particulate fraction of ^{137}Cs in the sea water. If we calculated the percentage of particulate ^{110m}Ag compared to total ^{137}Cs in the sea water we got a mean of $(0.23 \pm 0.09) \times 10^{-2}$ (± 1 S.D.; N=9). This may be compared with the ratio found in Chernobyl debris which is 5-10 times higher.

We assume that ^{110m}Ag is mainly present as particulates and that most of it has sedimented. This means that the surface water is depleted with respect to ^{110m}Ag compared with a soluble nuclide such as ^{137}Cs. If ^{137}Cs to a large extent had been associated with particulate matter we would have expected the $^{110m}Ag/^{137}Cs$ in particles to have shown a ratio with a significantly smaller relative standard deviation than that found between ^{110m}Ag and total ^{137}Cs in the water: we found relative SD's of 110% and 41%, respectively, for the 9 samples. Three sediment samples (cf. Table 4.6.2) from the Gauss cruise contained ^{110m}Ag in the 0-3 cm layer. The mean ratio between ^{110m}Ag and Chernobyl-derived ^{137}Cs was 0.020 ± 0.0071 (± 1 S.D.; N = 3). This ratio is 0.020/0.0021 $\sim$ 9 times higher than the ratio found between ^{110m}Ag and ^{137}Cs in the surface water. This supports our hypothesis that most of the ^{110m}Ag has sedimented. Five 1.8 m^3 samples of Baltic surface sea water from the Gauss cruise has been analysed for ^{241}Am. The mean content was 0.29 ± 0.09 mBq m^{-3} (± 1 S.E.; N=5). A detailed table will appear in the 1987 report. None of the samples contained measurable amounts of ^{242}Cm.

Table 4.4.6. Particulate activity in Baltic Sea surface water collected at the Gauss cruise in October 1986. (cf. also table 4.4.5) (Unit: Bq m^{-3})

Position N	Position E	Date in Oct	Volume filtered m^3	^{103}Ru	^{106}Ru	^{110m}Ag	^{125}Sb	^{134}Cs	^{137}Cs	$^{239,240}Pu$*	^{241}Am*	% particulate ^{137}Cs
56°30'	11°30'	15	1.8	-	-	-	-	0.114	0.22	0.0829	0.29	0.21
55°17'	12°33'	16	2.3	-	-	-		-	-	-	-	-
57°00'	17°30'	17	2.6	0.06B	0.44A	0.63	-	0.124	0.25	0.118A	-	0.09
58°45'	18°30'	18	2.7	0.12A	-	1.04	-	0.35	0.62	-	-	0.14
58°53'	19°50'	18	2.6	0.24	0.85	1.90	-	1.16	3.5	0.185	-	0.46
61°30'	17°59'	22	2.1	0.50	1.85A	1.53	-	4.2	8.5	0.41	-	1.44
64°05'	21°56'	23	2.7	0.14A	-	0.20	-	2.3	4.8	0.55	-	4.3
61°04'	19°42'	26	3.2	0.36	1.16	1.67	0.14B	2.1	4.8	0.169	0.049A	0.87
59°30'	23°20'	30	1.85	-	-	0.073	-	0.22	0.47	0.40	0.123	0.55
56°05'	17°42'	Nov.1	2.7	-	-	0.098	-	0.153	0.37	0.154	-	0.97
54°48'	19°:9'	Nov.1	3.0	-	-	0.048A	-	-	0.035A	0.046A	-	0.08

*Unit: mBq m^{-3}

▲At these locations sediment collumns were collected and analysed (cf. 4.6).

4.5. Strontium-90 and radiocesium in soil samples

In order to determine the total fallout of ^{90}Sr, ^{137}Cs and ^{134}Cs deposited after the Chernobyl accident two soil samplings were performed. The first one took place in the period 15-27 May. At each of the 10 state experimental farms three samples were collected from grass fields which had been undisturbed since the Chernobyl accident. Each sample was 10 × 10 × 5 cm (the depth was 5 cm). Table 4.5.1 shows the results of this sampling. From 15-17 September a new sampling was carried out. This time the samples were collected to a depth of 10 cm (cf. Table 4.5.2 and Fig. 4.5.1). Finally, a special sampling was made in South Jutland at 5 locations where the Institute of Radiation Hygiene in Copenhagen had identified relatively high depositions in grass samples (Table 4.5.3).

Table 4.5.1. Soil collected at the 10 state experimental farms in May 1986. 0-5 cm layer. (Unit: Bq m^{-2}) (untreated soil samples)

Location	^{103}Ru	^{131}I	^{134}Cs	^{137}Cs	^{140}La	Date in May
Tylstrup	970	620	340	990	167	27
Kalø	1350	620	470	1100	270	27
Borris	1360	1440	450	1200	520	16
Askov	5000	4200	1650	3300	2400	17
St. Jyndevad	1330	1460	480	1370	520	16
Årslev	3400	3500	1060	2100	1120	17
Tystofte	1630	1670	450	1020	410	15
Ledreborg	1660	830	450	1140	160 A	26
Abed	1600	1800	390	970	290 A	15
Tornbygård	1120	890	290	610	220	22
Mean	1940	1690	600	1390	600	
Rel. S.E. %	21	23	22	18	36	

Table 4.5.2.1. Soil collected at the 10 state experimental farms 15-17 September 1986. 0-10 cm layer

Location	^{90}Sr	^{103}Ru	^{106}Ru	^{134}Cs	^{137}Cs	Estimated (from deposition data) Chernobyl ^{90}Sr	Calculated Chernobyl ^{137}Cs ($^{134}Cs/^{137}Cs$ = 0.48)
			Bq m^{-2}				
Tylstrup	173	-	-	310	1030	31	650
Kalø	300	500	980 A	780	4400	(26)	1620
Borris	250	280	-	420	1750	(31)	880
Askov	310	1530	2500	1820	4300	70	3800
St. Jyndevad	180	370	750	500	1940	38	1040
Årslev	230	600	-	970	2400	83	2000
Tystofte	153	300 B	-	390	1230	40	810
Ledreborg	170	490	980 A	630	1650	16.4	1310
Abed	185	370	-	400	1380	16.7	830
Tornbygård	185	220 A	-	300	990	25	620
Mean	214	-	-	652	2110	37.7	1356
Rel. S.E. %	8	-	-	22	19	19	23

Table 4.5.2.2. Soil collected at the 10 state experimental farms 15-17 September 1986. 0-10 cm layer

Location	^{90}Sr	^{103}Ru	^{106}Ru	^{134}Cs	^{137}Cs	^{40}K
			Bq kg^{-1}			g kg^{-1}
Tylstrup	1.59	-	-	2.8	9.5	12.8
Kalø	4.8	7.8	15.3	12.2	69	10.3
Borris	2.5	3.1	-	4.7	17.5	9.8
Askov	3.3	16.6	27	19.8	46.8	10.6
St. Jyndevad	1.72	3.5	7.0 A	4.8	18.4	8.8
Årslev	2.2	5.8	-	9.3	24	16.7
Tystofte	1.54	3.0 B	-	3.9	12.3	17.8
Ledreborg	1.96	5.6	11.3 A	7.2	19.0	18.2
Abed	1.97	3.9	-	4.2	14.7	16.6
Tornbygård	2.1	2.5 A	-	3.4	11.0	18.4
Mean	2.37			7.2	24.2	14.0
Rel. S.E. %	13			23	25	9

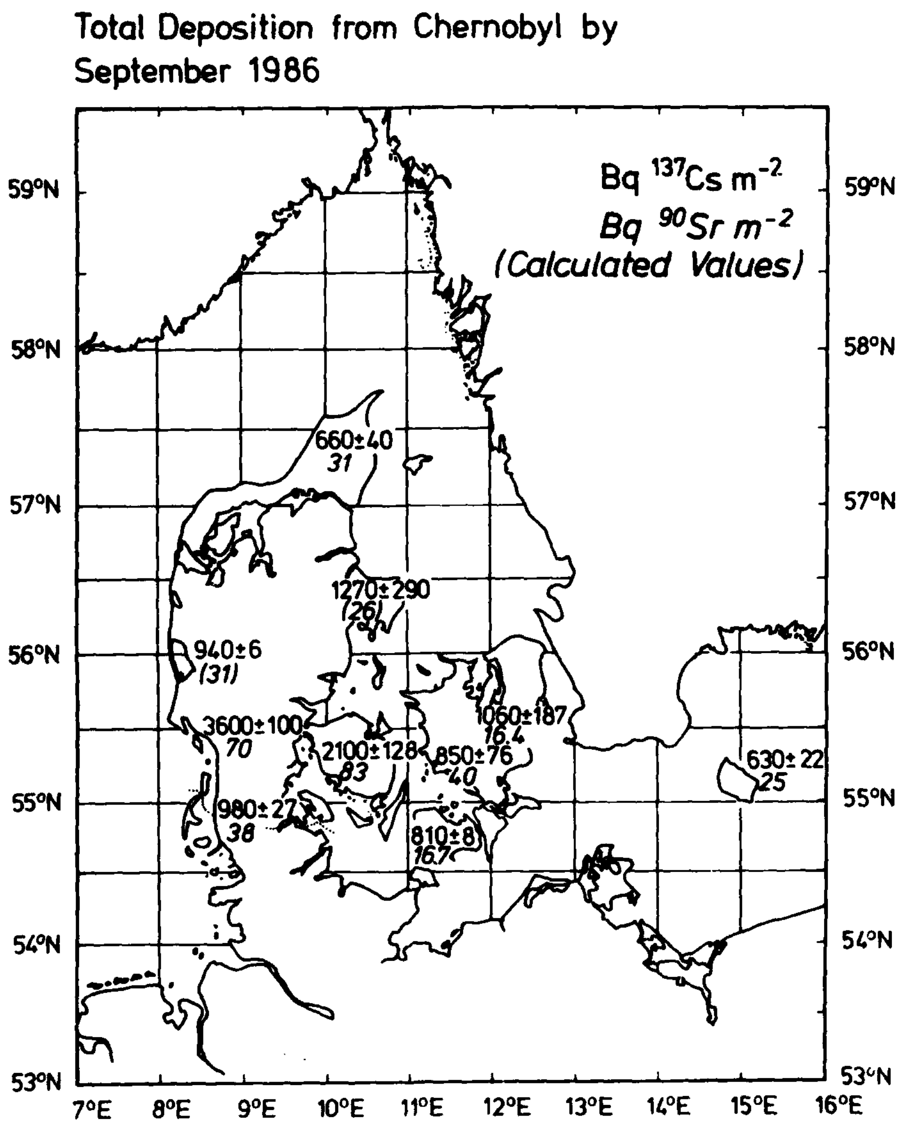

Fig. 4.5.1. The deposits of ^{137}Cs and ^{90}Sr from Chernobyl at the 10 State experimental farms in Denmark by September 1986. The error terms for ^{137}Cs are 1 S.E. of the mean of the soil measurements in September and of the soil measurements in June plus the fallout from June to September. The ^{137}Cs contribution in soil samples were calculated from ^{134}Cs measurements and the ^{134}Cs/^{137}Cs ratio of 0.55 at April 26, 1986 in Chernobyl debris. The Sr-90 deposition was based upon precipitation samples only.

The results of the soil sampling may be compared with the deposition measured in precipitation samples. In this respect it is a problem that the systematic measurements of ^{137}Cs and ^{134}Cs in precipitation samples from the state experimental farms first started May 5, 1986. We have thus not been able to include the dry deposition of radiocesium in the last days of April and the first ones of May. We neither have a direct measure of the deposit with the few showers occurring before May 5. We have, however, calculated the ^{137}Cs deposition from ^{90}Sr data assuming a $^{137}Cs/^{90}Sr$ ratio in Chernobyl debris of 26.3, i.e. the ratio observed in May (cf. Table 4.2.2.2). The mean ratio: Bq ^{137}Cs m^{-2} (precipitation by 1986)/Bq ^{134}Cs m^{-2}/0.48 (soil in September 1986): 0.84 ± 0.30 (± 1 S.D.; N = 10); (0.48 is the $^{134}Cs/^{137}Cs$ ratio in Chernobyl debris in September 1986). Half of the stations showed a significantly higher Chernobyl ^{137}Cs in the soil samples than in precipitation: Kalø, Askov, Ledreborg, Abed and Tornbygaard; but a few: Årslev and Tystofte showed lower soil values. The soil data may be the most reliable, because they best represent what actually has been deposited on the fields - including dry fallout, for which we suspect the rain funnels to have been less efficient. On the other hand, the rain funnels cover a larger area than the soil samples. In our prediction model calculations (cf. Appendix C2) we have used the mean of precipitation and soil data for the estimation of the deposition of ^{137}Cs in 1986.

Tables 4.5.2.1 and 4.5.2.2 show that the contribution from Chernobyl in the 0-10 cm soil layer in Denmark was 18% for ^{90}Sr and 64% for ^{137}Cs. The relative high Chernobyl contribution for ^{90}Sr compared with ^{137}Cs reflects the fact that global fallout ^{90}Sr migrates more rapidly than ^{137}Cs down through the soil layers.

The highest deposition from Chernobyl was found in South Jutland. Five locations (cf. Fig. 4.5.2) were selected and two sets of samples were collected. One set, 0-10 cm, was treated as normal soil samples, i.e. it was blended and crushed and stones were removed. The other set was collected to 5-cm depth and was not treated at all, but the total sample was measured.

Tables 4.5.3.1 and 4.5.3.2 show the results. It appears that the 0-5 cm sample set contained a 35% higher Chernobyl deposit of ^{134}Cs than the 0-10 cm set. The other nuclides did also show a higher deposition in the 0-5 cm samples. We have no explanation for this difference for the time being, but we will return to the problem in next year's report.

In case of ^{103}Ru there was no significant difference between the 0-5 cm and 0-10 cm sample sets.

The $^{103}Ru/^{134}Cs$ ratio mean (decay corrected to 26 April 1986) was 5.79±0.33 (±1 S.D.; N = 5) in the 0-10 cm set and 4.56±0.23 in the 0-5 cm set (Tables 4.5.31 and 4.5.3.2).

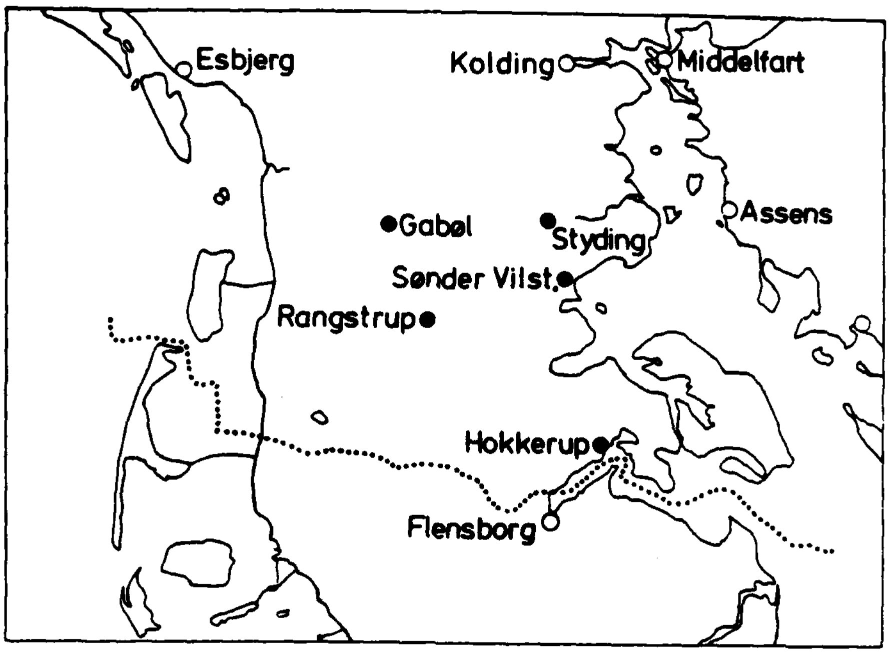

Fig. 4.5.2. Special soil sampling in South-Jutland in 1986.

Table 4.5.3.1. Soil collected 15-17 September 1986 in South-Jutland (0-10 cm layer)

Location	^{90}Sr	^{103}Ru	^{106}Ru	^{134}Cs	^{137}Cs	Calculated Chernobyl ^{137}Cs ($^{134}Cs/^{137}Cs$ = 0.48)
	Bq m^{-2}					
Hokkerup	280	670	1010 A	1330	4200	2800
Sønder Vilstrup	230	430	-	770	2100	1600
Gabøl	500	1055	1720 A	1820	4700	3800
Rangstrup	400	920	1510	1680	4300	3500
Styding	290	430	930 A	740	2100	1550
Mean	340	700	-	1270	3500	2650
Rel. S.E. %	14	18		18	17	18

Table 4.5.3.2. Soil collected 15-17 September 1986 in South-Jutland (0-5 cm layer) (untreated soil, cf. text)

Location	^{103}Ru	^{106}Ru	^{134}Cs	^{137}Cs	Calculated Chernobyl ^{137}Cs ($^{134}Cs/^{137}Cs$ = 0.48)
	Bq m^{-2}				
Hokkerup	650	1530	1450	3600	3000
Sønder Vilstrup	360	780	800	2000	1670
Gabøl	1000	2300	2500	5300	5200
Rangstrup	990	2100	2300	5100	4800
Styding	670	1650	1480	3200	3100
Mean	730	1670	1710	3800	3600
Rel. S.E. %	16	16	18	16	18

Table 4.5.4. Radionuclide ratios in soil samples collected in Denmark 15-17 September 1986. Decay corrected to April 26, 1986 (0-10 cm layer)

	Mean ± 1 S.D. Without decay	Mean ± 1 S.D. At 26 April 1986	Number of results	% of ^{137}Cs by 26/4
$^{95}Nb/^{134}Cs$	0.66±0.30	2.66±1.21	6	144
$^{103}Ru/^{134}Cs$	0.71±0.12	7.42±1.25	12	400
$^{106}Ru/^{134}Cs$	1.29±0.32	1.48±1.37	5	80
$^{95}Zr/^{134}Cs$	0.21	0.85	1	46

From Table 4.5.1 we find a countrywide mean ratio in the 0-5 cm soil layer from May 1986 of 4.89±0.74 (±1 S.D.; N = 10) and Table 4.5.2 gives us a mean ratio for the 0-10 cm layer in September of 7.79±1.04 (±1 S.D.; N = 9). It thus seems that ^{134}Cs has not penetrated as deep as ^{103}Ru in the soil. This was to be expected if Ru is on an anionic form, which will not be retained as easily as the cationic ^{134}Cs by the soil minerals.

4.6. Sediments

An extended sediment sampling took place in 1986, in order to see how rapidly the Chernobyl debris appeared in the sediments. Unfortunately ^{134}Cs has to be determined on an enhanced background of naturally occurring radionuclides in sediments. This

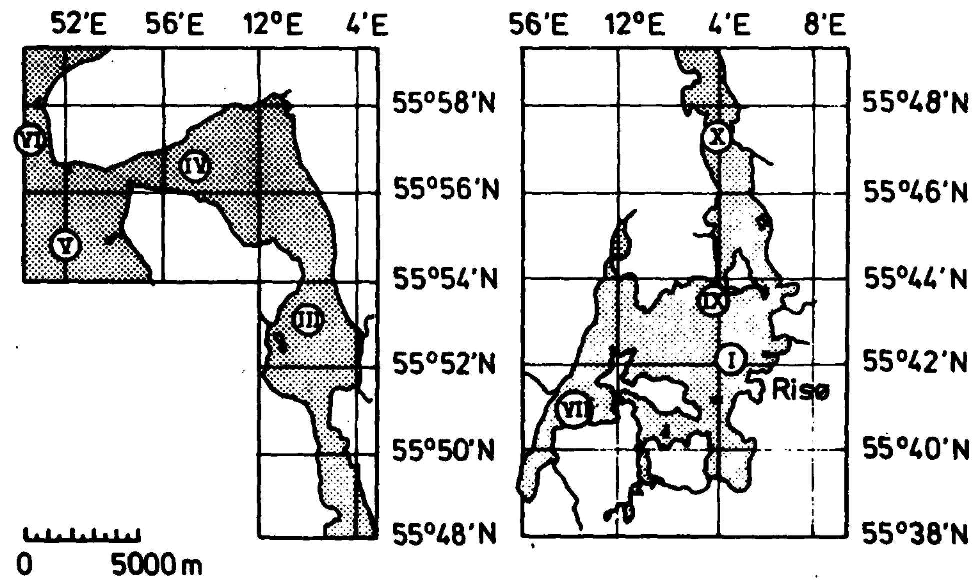

Fig. 4.6.1. Roskilde fjord.

Table 4.6.1. Sediment samples collected in the Danish Straits in 1986

Location N	Location E	Date	Depth in m	Sediment layer in cm	^{137}Cs Bq kg^{-1} dry	^{137}Cs Bq m^{-2}	$^{134}Cs/^{137}Cs$	^{134}Cs Bq kg^{-1} dry	^{134}Cs Bq m^{-2}	g K kg^{-1}
54°36'	11°04'	Aug 26	26	0-3	16.7	280	-	-	-	13.8
				3-6	6.9	129	-	-	-	15.5
				6-9	3.3	70	-	-	-	18.5
				9-12	1.6	43	-	-	-	16.9
				12-14	1.0 B	14.8 B	-	-	-	21.5
				0-14		Σ 537				
55°23'	11°03'	Aug 26	24	0-3	46	270	0.10 B	4.6 B	26 B	21.1
				3-6	20	270	-	-	-	21.5
				6-9	6.2	61	-	-	-	21.7
				9-12	2.4 A	24 A	-	-	-	21.9
				12-14	0.9 B	11 B	-	-	-	21.0
				0-14		Σ 636			Σ 26	
55°23'	11°03'	Nov 17	24	0-3	44	530	-	-	-	21.1
				3-6	19	240	-	-	-	20.8
				6-9	4.4	54	-	-	-	19.3
				9-12	4.5	60	-	-	-	19.9
				12-15	4.8	59	-	-	-	20.9
				0-15		Σ 943				
57°19'	11°27'	June 11	67	0-3	59	290	-	-	-	25
				3-6	59	560	-	-	-	25
				6-9	63	690	-	-	-	24
				9-12	74	1040	-	-	-	25
				0-12		Σ 2480				
56°10'	11°47'	Aug 25	25	0-3	7.5	210	0.14	1.0	28	13.7
				3-6	5.4	240	-	-	-	13.8
				6-9	3.1	110	-	-	-	13.0
				0-9		Σ 560			Σ 28	
56°10'	11°47'	Nov 17	25	0-3	4.8	230	0.15	0.7 A	34 A	15.2
				3-6	3.2	142	-	-	-	14.3
				6-9	1.6 A	55	-	-	-	14.9
				0-9		Σ 427			Σ 34	
54°57'	12°41'	Aug 26	23	0-3	4.4	155	0.30	1.3	46	15.5
				3-6	3.2	113	-	-	-	11.5
				6-9	1.6	56	-	-	-	11.0
				0-9		Σ 324			Σ 46	
55°42'	12°06'	Dec 6	-	0-3	23	152	0.20	4.6	31	12.2
				3-6	11.2	190	-	-	-	11.9
				6-9	3.8	108	-	-	-	12.0
				9-12	2.1	29	-	-	-	11.6
				0-12		Σ 479			Σ 31	

Table 4.6.2.1. Radionuclides in sediment samples collected at the Gauss cruise to the Baltic Sea in October 1986. (HAPS) (Area: 0.0145 m^2) (see also Table 4.4.2.2)

Position N E	Date	Depth in m	Layer in cm	^{137}Cs Bq kg^{-1} dry	^{137}Cs Bq m^{-2}	^{134}Cs Bq kg^{-1} dry	^{134}Cs Bq m^{-2}	$^{134}Cs/^{137}Cs$	^{238}Pu Bq kg^{-1} dry	^{238}Pu Bq m^{-2}	$^{239,240}Pu$ Bq kg^{-1} dry	$^{239,240}Pu$ Bq m^{-2}	^{241}Am Bq kg^{-1} dry	^{241}Am Bq m^{-2}	$^{238}Pu/^{239}Pu$	$^{241}Am/^{239}Pu$	g E ha^{-1}	kg dry m^{-2}
56°45' 11°00' Gauss No. 10	Oct 15	12	0-3	1.60	60	0.80	37	0.55	-	-	0.064	2.7	-	-	-	-	11.0	42.25
			3-6	1.79	75	-	-	-	-	-	0.073	3.1	-	-	-	-	11.0	41.90
			6-9	1.93	82	-	-	-	-	-	0.074	3.1	0.015	0.64	-	0.20	10.0	42.54
			0-9		Σ 230		Σ 37					8.9		0.64		Σ:0.20		
57°00' 12°00' Gauss No. 17	Oct 15	45	0-3	21	400	1.41	27	0.068	0.020	0.39	0.37	7.2	0.12	2.3	0.054	0.32	24	19.32
			3-6	20	410	1.16 A	24 A	0.059 A	0.015	0.31	0.38	7.9	0.15	3.1	0.039	0.39	23	20.74
			6-9	18.8	420	-	-	-	0.028	0.63	0.34	7.6	-	-	0.083	-	23	22.34
			9-12	15.8	400	-	-	-	0.015	0.38	0.28	7.1	-	-	0.054	-	24	25.31
			12-15	9.4	270	-	-	-	0.0084	0.24	0.16	4.6	0.045	1.29	0.053	0.28	22	28.62
			15-18	5.9	134	-	-	-	-	-	0.045	1.02	-	-	-	-	24	22.66
			0-18		Σ 2000		Σ 51			Σ 1.95		Σ 35		Σ 6.7	Σ:0.057	Σ:0.33		
56°30' 12°00' Gauss No. 18	Oct 16	30	0-3	12.7	350	1.6 A	44 A	0.13 A	-	-	0.26	7.1	0.066	1.8	-	0.25	17.6	27.39
			3-6	10.9	380	-	-	-	0.020	0.70	0.26	9.1	0.073	2.6	0.077	0.28	17.5	34.99
			6-9	6.3	250	-	-	-	0.014	0.55	0.20	7.9	0.052	2.0	0.070	0.26	17.2	39.37
			0-9		Σ 900		Σ 44			Σ ..25		Σ 24		Σ 6.4	Σ:0.074	Σ:0.26		
55°17' 12°33' Gauss No. 22	Oct 16	23	0-3	13.7	410	2.2	67	0.16	0.019	0.57	0.40	11.9	0.15	4.5	0.048	0.38	13.3	29.79
			3-6	4.4	189	-	-	-	0.039	1.68	0.49	21	0.17	7.3	0.081	0.35	13.4	43.04
			6-9	1.7	65	-	-	-	-	-	0.15	5.8	-	-	-	-	12.4	38.52
			0-9		Σ 660		Σ 67			Σ 2.2		Σ 39		Σ 11.8	Σ:0.064	Σ:0.36		
55°34' 15°00' Gauss No. 25	Oct 17	72	0-3	38	250	-	-	-	0.11	0.72	2.45	16.0	0.83	5.4	0.043	0.34	27	6.55
			3-6	29	230	-	-	-	0.084	0.66	2.45	19.2	0.82	6.4	0.034	0.33	27	7.83
			6-9	24	210	-	-	-	-	-	3.70	34.5	0.83	7.3	-	0.30	27	8.81
			9-12	5.9	70	-	-	-	-	-	0.36	4.3	0.11	1.3		0.30	24	11.91
			12-15	2.7 A	48 A	-	-	-	-	-	-	-	-	-	-	-	22	17.87
			0-15		Σ 810					Σ 1.38		Σ 64		Σ 20	Σ:0.038	Σ:0.32		
57°00' 17°30' Gauss No. 28	Oct 17	109	0-3	73.8	88	-	-	-	-	-	0.64	6.1	0.25	1.60	-	0.39	35	6.40
			3-6	4.5	37	-	-	-	-	-	-	-	-	-	-	-	37	8.14
			6-9	-	-	-	-	-	-	-	-	-	-	-	-	-	37	8.00
			9-12	-	-	-	-	-	-	-	-	-	-	-	-	-	37	8.41
			12-15	-	-	-	-	-	-	-	-	-	-	-	-	-	37	8.76
			0-15		Σ 125							Σ 6.1		Σ 1.6		Σ:0.39		
58°00' 18°00' Gauss No. 30	Oct 18	159	0-3	19.7	71	-	-	-	0.047	0.169	0.74	2.7	0.30	1.08	0.063	0.40	37	3.60
			3-6	3.7	36	-	-	-	-	-	0.018	0.18	-	-	-	-	33	9.90
			6-9		-	-	-	-	-	-	-	-	-	-	-	-	37	8.24
			9-12	-	-	-	-	-	-	-	0.026	0.22	-	-	-	-	38	8.90
			12-15	-	-	-	-	-	-	-	-	-	-	-	-	-	38	8.90
			15-18	-	-	-	-	-	-	-	-	-	-	-	-	-	37	6.92
			0-18		Σ 107					Σ 0.169		Σ 3.0		Σ 1.08	Σ:0.063	Σ:0.40		

Table 4.6.2.1. continued

Position N E	Date	Depth in m	Layer in cm	^{137}Cs Bq kg^{-1} dry	^{137}Cs Bq m^{-2}	^{134}Cs Bq kg^{-1} dry	^{134}Cs Bq m^{-2}	$^{134}Cs/^{137}Cs$	^{238}Pu Bq kg^{-1} dry	^{238}Pu Bq m^{-2}	$^{239,240}Pu$ Bq kg^{-1} dry	$^{239,240}Pu$ Bq m^{-2}	^{241}Am Bq kg^{-1} dry	^{241}Am Bq m^{-2}	$^{238}Pu/^{239}Pu$	$^{241}Am/^{239}Pu$	φ % kg^{-1}	kg dry m^{-2}
58°45' 18°30' Gauss No. 12	Oct 18	276	0-3	9.1	41	-	-	-	0.070	0.32	1.52	6.8	0.56	2.5	0.047		35	4.58
			3-6	2.2	14	-	-	-	-	-	0.027	0.10	-	-	-	-	37	6.56
			6-9	-	-	-	-	-	-	-	-	-	-	-	-	-	38	7.31
			9-12	-	-	-	-	-	-	-	-	-	-	-	-	-	40	8.37
			12-15	-	-	-	-	-	-	-	-	-	-	-	-	-	38	10.87
			0-15		Σ 55					Σ 0.32		Σ 7.0		Σ 2.5	R:0.047			
58°53' 19°50' Gauss No. 68	Oct 18	142	0-3	37	88	-	-	-	0.068	0.196	3.05	8.2	0.71	2.0	0.024	0.24	35	2.68
			3-6	7.1	64	-	-	-	-	-	0.084	0.76	0.014	0.126	-	0.17	40	9.00
			6-9	-	-	-	-	-	-	-	-	-	0.014	0.150	-	-	39	10.74
			9-12	-	-	-	-	-	-	-	0.0092	0.073	-	-	-	-	38	7.00
			12-15		-	-	-	-	-	-	-	-	-	-	-	-	39	7.41
			0-15		Σ 152					Σ 0.196		Σ 9.0		Σ 2.3	R:0.024	R:0.24		
60°13' 19°84' Gauss No. 35	Oct 21	260	0-3	112	740	12.4	82	0.11	0.048	0.33	2.50	16.6	-	-	0.019	-	34	6.62
			3-6	101	670	-	-	-	0.12	0.08	3.10	27.2	-	-	0.038	-	34	6.66
			6-9	101	780	-	-	-	-	-	3.64	25.4	1.02	7.11	-	0.28	34	6.97
			9-12	104	720	-	-	-	0.20	1.39	4.27	29.7	1.24	8.62	0.047	0.29	35	6.95
			12-15	108	900	-	-	-	0.15	1.25	5.06	40.9	1.73	14.43	0.025	0.30	35	8.34
			15-18	106	820	-	-	-	0.28	2.17	6.71	53.1	-	-	0.042	-	34	7.76
			0-18		Σ 4600		Σ 82			Σ 5.9		Σ 194		Σ 30	R:0.034	R:0.29		
61°30' 17°58' Gauss No. 39	Oct 22	40	0-3	290	7400	147	3700	0.50	-	-	0.18-0.05	4.4±1.3	0.053	1.34	-	0.29	30	25.38
			3-6	17.7	410	12.1	200	0.68	-	-	0.063	1.48	-	-	-	-	35	23.27
			6-9	-	-	-	-	-	-	-	0.035	0.82	-	-	-	-	35	23.46
			0-9		Σ 7800		Σ 4000					Σ 6.9		Σ 1.3		R:0.29		
62°40' 19°33' Gauss No. 43	Oct 23	140	0-3	470	8080	164	2880	0.35	-	-	0.82	13.9	0.31	5.2	-	0.37	29	16.90
			3-6	4.4	54	-	-	-	-	-	0.03	0.4	-	-	-	-	34	12.27
			6-9	-	-	-	-	-	-	-	-	-	-	-	-	-	37	12.07
			9-12	-	-	-	-	-	-	-	-	-	-	-	-	-	34	11.60
			12-15	-	-	-	-	-	-	-	-	-	-	-	-	-	36	13.42
			0-15		Σ 8100		Σ 2900					Σ 14.3		Σ 5.2		R:0.37		
64°05' 21°54' Gauss No. 47	Oct 23	99	0-3	930	3100	460	1560	0.50	0.30	1.0	9.1	31	2.8	9.5	0.033	0.31	24	3.30
			3-6	41	230	5.2	29	0.13	0.12	0.67	5.1	28	-	-	0.024	-	26	5.59
			6-9	6.1	56	-	-	-	-	-	0.019	0.2	-	-	-	-	27	9.10
			9-12	-	-	-	-	-	-	-	-		-	-	-	-	29	8.13
			0-12		Σ 3400		Σ 1590			Σ 1.7		Σ 59		Σ 9.5	R:0.028	R:0.31		
62°00' 20°30' Gauss No. 59	Oct 25	114	0-3	200	1850	73	480	0.26	0.123	0.83	4.46	29.5	1.34	8.9	0.028	0.30	32	6.62
			3-6	91	930	-	-	-	0.159	1.63	5.11	52.5	1.79	10.4	0.031	0.35	34	10.27
			6-9	34	310	-	-	-	0.050	0.46	2.21	20.5	0.69	6.4	0.023	0.31	35	9.26
			9-12	4.6	39	-	-	-	-	-	-	-	-	-	-	-	34	8.55
			12-15	-	-	-	-	-	-	-	0.050	0.49	-	-	-	-	35	9.80
			0-15		Σ 3100		Σ 480			Σ 2.9		Σ 103		Σ 34	R:0.027	R:0.32		

Table 4.6.2.1. continued

Position N E	Date	Depth in m	Layer in cm	^{137}Cs, Bq kg^{-1} dry	^{137}Cs, Bq m^{-2}	^{134}Cs, Bq kg^{-1} dry	^{134}Cs, Bq m^{-2}	^{134}Cs/^{137}Cs	^{238}Pu, Bq kg^{-1} dry	^{238}Pu, Bq m^{-2}	^{239,240}Pu Bq kg^{-1} dry	^{239,240}Pu Bq m^{-2}	^{241}Am, Bq kg^{-1} dry	^{241}Am, Bq m^{-2}	^{238}Pu/^{239}Pu	^{241}Am/^{239}Pu	g K kg^{-1}	kg dry m^{-2}
61°04' 19°42'	Oct 26	137	0-3	490	2800	210	1180	0.43	0.13	0.73	3.38	19.0	1.20	6.7	0.038	0.36	33	5.61
Gauss No. 63			3-6	100	810	-	-	-	0.17	1.38	3.95	32.0	1.22	9.9	0.043	0.31	35	8.09
			6-9	49	480	-	-	-	0.17	1.65	4.68	45.4	1.51	14.6	0.036	0.32	38	9.70
			9-12	86	900	-	-	-	-	-	-	-	1.05	11.0	-	-	34	10.48
			12-15	6.8	60	-	-	-	-	-	0.14	1.24	-	-	-	-	35	8.83
			0-15		5100		1180			Σ 3.8		98		42	$\bar{x}$:0.039	$\bar{x}$:0.33		
60°10' 26°35'	Oct 28	52	0-3	680	1620	300	750	0.44	0.19	0.45	4.13	9.9	-	-	0.045	-	28	2.39
Gauss No. 74			3-6	124	750	-	-	-	0.17	1.03	5.44	33.0	-	-	0.031	-	31	6.06
			6-9	66	520	-	-	-	0.12	0.95	4.07	32.1	-	-	0.030	-	31	7.89
			9-12	5.7	53	-	-	-	-	-	0.067	0.62	-	-	-	-	34	9.24
			12-15	0.8 A	12 A	-	-	-	-	-	0.012	0.17	-	-	-	-	30	14.58
			0-15		3000		750			Σ 2.4		76			$\bar{x}$:0.035			
56°05' 17°42'	Nov 1	57	0-3	22	450	-	-	-	0.039	0.79	0.81	16.4	0.28	5.7	0.048	0.35	20	20.26
Gauss No. 95			3-9	1.8 A	62	-	-	-	-	-	0.039	1.36	-	-	-	-	34	34.80
			9-12	-	-	-	-	-	-		-	-	-	-	-	-	32	32.31
			0-12		510					Σ 0.79		16.3		5.7	$\bar{x}$:0.048	$\bar{x}$:0.35		
54°48' 19°19'	Nov 1	115	0-3	38	118	-	-	-	0.065	0.20	2.08	6.5	0.83	2.6	0.031	0.40	30	3.11
Gauss No. 85			3-6	6.2	30	-	-	-	0.010	0.05	0.25	1.22	-	-	0.040	-	34	4.88
			6-9	1.7 B	10 B	-	-	-	-	-	0.017	0.095	-	-	-	-	32	5.60
			9-12	-	-	-	-	-	-	-	0.0096	0.06	-	-	-	-	33	6.41
			12-15	-	-	-	-	-	-	-	-	-	-	-	-	-	32	6.87
			0-15		158					Σ 0.25		7.9		2.6	$\bar{x}$:0.036	$\bar{x}$:0.40		

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

raises the limit of detection in such samples. In the Danish straits (Table 4.6.1) only three samples showed indication of ^{134}Cs. The ^{137}Cs levels did neither indicate a significant contribution from Chernobyl debris. The two samples displaying a ^{134}Cs content indicate a deposit of Chernobyl ^{137}Cs in the order of 60 Bq m^{-1}, i.e. 5-10% of the actual deposit.

At the Gauss cruise to the Baltic Sea 18 HAPS cores were collected, 11 of these showed a ^{134}Cs content. The highest radiocesium levels were found in samples collected at 61°30'N, 17°59'E and at 62°40'N, 19°33'E. These samples contained approximately 7 kBq ^{137}Cs m^{-2} from Chernobyl. This may be compared with a coastal deposition in Eastern Sweden at the same lattitudes in the order of 60-80 kBq ^{137}Cs m^{-2} [38]. Hence the sediments contained about 10% of the radiocesium deposit in October 1986). Three samples contained ^{110m}Ag; the mean $^{110m}Ag/^{137}Cs$ ratio in these samples was 0.021 ± 0.008 (± 1 S.D.; N = 3). The theoretical ratio in October 1986 was estimated at 0.009 [38]. Hence we may conclude that ^{110m}Ag from Chernobyl was sedimented easier than radiocesium (cf. also 4.4). The conclusion from the observations of radiocesium in the Baltic Sea is that the Chernobyl cesium was not associated with particulate matter to any significant extent, it behaved as we would have expected it from our global fallout studies of ^{137}Cs.

<u>Table 4.6.2.2.</u> Radionuclides in sediment samples (0-3 cm) collected at the Gauss cruise to the Baltic Sea in October 1986. (HAPS) (AREA: 0.0145 m^2) (supplement to Table 4.6.2.1)

Gauss No. (cf. Table 4.6.2.1)	^{60}Co Bq kg^{-1} dry	^{60}Co Bq m^{-2}	^{106}Ru Bq kg^{-1} dry	^{106}Ru Bq m^{-2}	^{110m}Ag Bq kg^{-1} dry	^{110m}Ag Bq m^{-2}	^{144}Ce Bq kg^{-1} dry	^{144}Ce Bq m^{-2}
17	1.10	21						
18			17 A	480 A				
39					8.9 A	220 A		
47			50 A	170 A	13.5	46		
63			107	600	9 B	50 B		
95							21	420

Table 4.6.2.3. Radionuclides in Ferro-Manganese nodules from surface sediments collected at the Gauss cruise to the Baltic Sea (position: 61°30'N 17°59'E) October 22, 1986). The activity per m^2 of the first sample should be added to the corresponding result for 0-3 cm in Table 4.6.2.1.

Gauss No. 39 (cf. Table 4.6.2.1)	^{137}Cs Bq kg^{-1} dry	^{137}Cs Bq m^{-2}	^{134}Cs Bq kg^{-1} dry	^{134}Cs Bq m^{-2}	$^{239,240}Pu$ Bq kg^{-1} dry	$^{239,240}Pu$ Bq m^{-2}	^{241}Am Bq kg^{-1} dry	$^{241}Am/^{239}Pu$
HAPS, 0-3 cm 0.0145 m^2 (cf. Table 4.6.2.1)	270	2100	128	990	0.48	3.7	0.10	0.21
*Box-corer, same position	80	-	34	-	0.42	-	0.056	0.28

*1.4 (A) Bq ^{54}Mn kg^{-1} dry.

5. DANISH FOOD AND VARIOUS VEGETATION

by A. Aarkrog

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

As compared with 1985 the countrywide mean ^{90}Sr level in dried milk increased by 7% in 1986. The locations in South (Åbenrå) and West Jutland (Videbæk) increased by 22 and 16%, respectively. Funen (Nyborg) increased by 5%. The other locations were unchanged except Hjørring (N-Jutland) which decreased a little. The milk levels reflect the distribution of the Chernobyl fallout over Denmark (cf. Fig. 4.5.1).

The ^{137}Cs content increased in 1986 by a factor of 14 compared to 1985. The maximum occurred in June (2120 Bq ^{137}Cs (kg K)$^{-1}$).

Table 5.1.1. Strontium-90 in dried milk in 1986. (Unit: Bq (kg Ca)$^{-1}$)

Month	Hjørring	Randers	Videbæk	Åbenrå	Nyborg	Ringsted	Nakskov	Mean
Jan	67	66	61	59	64	42	45	58
March	68	67	73	67	68	44	47	62
May	62	63	105	89	73	52	65	73
June	80	94	107	106	103	39	53	83
July	59	67	86	77	51	36	37	59
Aug	69	70	79	75	46	40	40	60
Sept	61	81	76	81	58	37	38	62
Oct	60	72	80	86	56	32	37	60
Nov	69	70	73	79	65	38	48	63
Dec	62	76	73	79	68	49	41	64
Mean*	66	72	79	77	65	41	45	64

Jan and Mar each counted twice in the mean.

As 1 cubic meter of milk contains 1.2 kg Ca, the mean ^{90}Sr content in Danish milk produced in 1986 was 77 Bq m^{-3} (or 0.077 Bq ^{90}Sr l^{-1}).

Table 5.1.2. Analysis of variance of ln Bq ^{90}Sr (kg Ca)$^{-1}$ in Danish dried milk in 1986 (from Table 5.1.1) (milk year)

Variation	SSD	f	s^2	v^2	P
Between months	0.949	11	0.086	5.444	> 99.95%
Between locations	6.061	6	1.010	63.712	> 99.95%
Month × loc.	1.046	66	0.016		

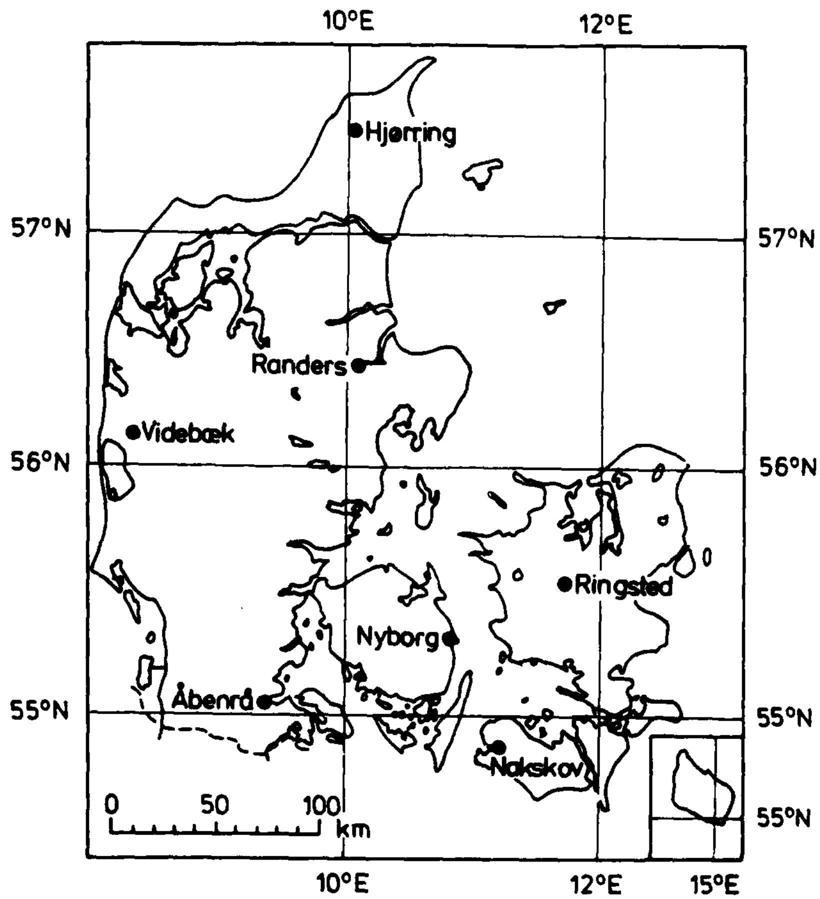

Fig. 5.1.1. Dried milk sampling locations in Denmark.

By December the ^{137}Cs had decreased by a factor of 4.4. As for ^{90}Sr we observed the highest levels in the milk from Videbæk, Åbenrå and Nyborg.

The $^{134}Cs/^{137}Cs$ ratio indicates that since June all radiocesium in Danish milk came from Chernobyl.

Table 5.1.3 shows the results of the ^{137}Cs determinations and Table 5.1.4 the analysis of variance of the results. Figures 5.1.2 and 5.1.3 show the ^{90}Sr and ^{137}Cs levels in dried milk compared with the predicted values (cf. Appendix C). The observed ^{90}Sr levels in 1986 were 0.52 times the predicted, while the observed ^{137}Cs levels were 0.27 times the predicted ones (means of Jutland and the Islands). It is thus evident that the models were not able to predict the Chernobyl milk levels better than with a factor of two to four.

Table 5.1.3. Radiocesium in Danish dried milk in 1986. Unit: Bq ^{137}Cs (kg K)$^{-1}$ ($^{134}Cs/^{137}Cs$)

Month	Hjerring	Randers	Videbæk	Åbenrå	Nyborg	Ringsted	Nakskov	Mean	Theoretical ($^{134}Cs/^{137}Cs$)	% Chernobyl ^{137}Cs
Jan	------------	46	------------		----------	31	----------	40		
Feb	------------	44	------------		----------	24	----------	35		
March	------------	39	------------		----------	20	----------	31		
April	------------	55	------------		----------	66	----------	60		
May	133	42	2200	1520	450	940	1420	960		
	(0.48)	(0)	(0.52)	(0.56)	(0.48)	(0.50)	(0.57)	(0.44)	0.54	81
June	1480	2400	2900	3500	3400	470	700	2120		
	(0.53)	(0.54)	(0.54)	(0.52)	(0.48)	(0.51)	(0.55)	(0.52)	0.52	100
July	870	1240	2100	1620	890	440	330	1070		
	(0.50)	(0.53)	(0.53)	(0.54)	(0.55)	(0.48)	(0.50)	(0.52)	0.51	98
Aug	620	1080	1490	1550	970	280	260	890		
	(0.53)	(0.51)	(0.50)	(0.49)	(0.50)	(0.51)	(0.52)	(0.51)	0.50	98
Sep	1140	640	1220	1280	1260	270	171	850		
	(0.48)	(0.44)	(0.50)	(0.49)	(0.45)	(0.49)	(0.49)	(0.48)	0.48	100
Oct	610	490	1000	1260	790	260	150	650		
	(0.47)	(0.44)	(0.47)	(0.53)	(0.44)	(0.42)	(0.51)	(0.47)	0.47	100
Nov	380	630	930	690	520	230	111	530		
	(0.43)	(0.42)	(0.41)	(0.43)	(0.47)	(0.48)	(0.46)	(0.44)	0.46	105
Dec	410	660	610	840	490	230	142	480		
	(0.44)	(0.45)	(0.47)	(0.42)	(0.44)	(0.39)	(0.49)	(0.44)	0.45	102
Mean	490	610	1050	1050	740	270	285	640		

As 1 cubic meter of milk contains approx. 1.66 kg K, the mean ^{137}Cs content in Danish milk produced in 1986 was estimated at 1062 Bq m^{-3} (or 1.06 Bq ^{137}Cs l^{-1}).

Table 5.1.4. Analysis of variance of ln Bq ^{137}Cs (kg K)$^{-1}$ in Danish dried milk in 1986 (from Table 5.1.3) (milk year)

Variation	SSD	f	s^2	v^2	P
Between months	15.858	11	1.442	4.570	> 99.95%
Between locations	29.258	6	4.876	15.456	> 99.95%
Remainder	20.507	65	0.315		

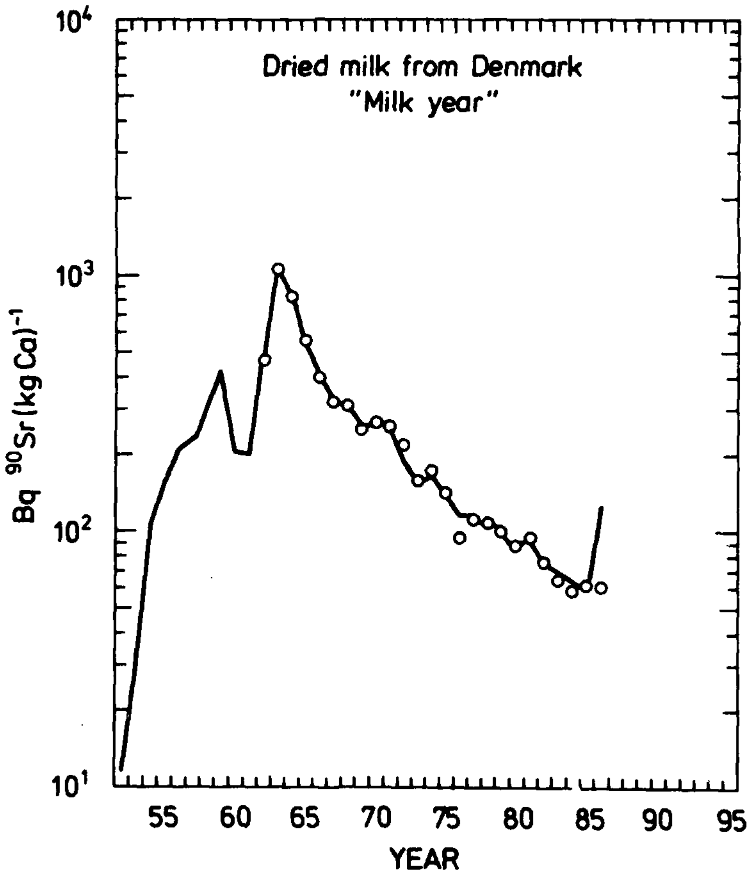

Fig. 5.1.2. Predicted (curve) and observed $^{90}Sr/Ca$ levels in dried milk from Denmark (May 1962-April 1987).

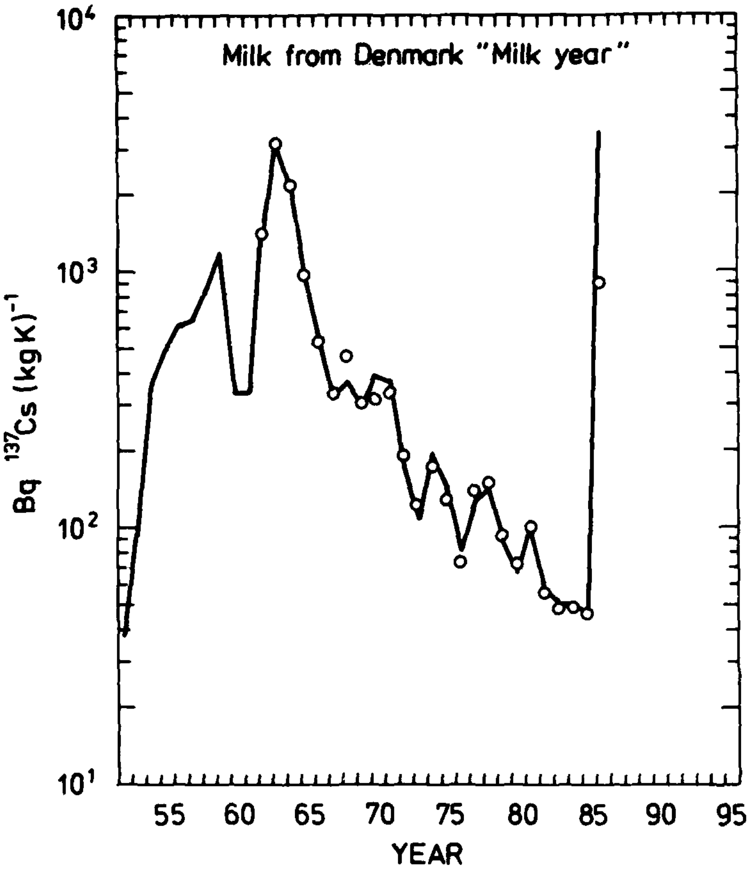

Fig. 5.1.3. Predicted (curve) and observed $^{137}Cs/K$ levels in dried milk from Denmark (May 1962-April 1987).

5.2. Fresh milk

5.2.1. Radiostrontium and radiocesium in total milk

In June and September milk and grass (cf. 5.10.2) samples were collected at the state experimental farms in Denmark. If we assume that a cow producing 11 l milk per day needs 9 feed units and that it gets them as grass, this corresponds to a daily grass consumption of 50 kg fresh weight. From this and from

Table 5.2.1. Strontium-90 and radiocesium in whole milk collected at the 10 State experimental farms in 1986

Location	Date	Bq ^{90}Sr $(kg\ Ca)^{-1}$	Bq ^{137}Cs $(kg\ K)^{-1}$	Bq ^{137}Cs l^{-1}	$^{134}Cs/^{137}Cs$	Date	Bq ^{90}Sr $(kg\ Ca)^{-1}$	Bq ^{137}Cs $(kg\ K)^{-1}$	Bq ^{137}Cs l^{-1}	$^{134}Cs/^{137}Cs$
Tylstrup	June 11	88	2600	5.1	0.53	Sep 12	72±1	470	0.80	0.34
Kalø	June 11	59	1200	1.77	0.56	Sep 12	42	580	1.05	0.45
Borris	June 10	172	4200	6.8	0.56	Sep 12	97	1620	2.66	0.49
Askov	June 10	189	3300	6.0	0.52	Sep 12	141	1170	2.13	0.50
St. Jyndevad	June 10	105	3800	5.9	0.54	Sep 12	72	3700	7.26	0.41
Årslev	June 10	59	2800	3.9	0.58	Sep 12	43	290	0.50	0.49
Tystofte	June 13	85	2200	3.1	0.49	Sep 8	40±1	1320	2.00	0.49
Ledreborg	June 16	35	740	1.18	0.65	Sep 8	27	610	0.99	0.50
Abed	June 12	44	149 B	0.27 B	0.93 B	Sep 12	36	77	0.13	0.52
Tornbygård	May 9	-	690 B	0.98 B	0.89 B	Sep 2	38	1400	2.11	0.50
$\bar{x}$	June	93	2200	3.5	0.55+	Sep	61	1130	1.96	0.47

^{131}I was detected in four of the June samples: Borris: 1.75 Bq l^{-1} A; St. Jyndevad: 1.06 Bq l^{-1} A; Tystofte: 0.51 Bq l^{-1} A; Ledreborg: 0.25 Bq l^{-1} B.

+Except Abed and Tornbygård, due to high counting errors.

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

Table 5.2.2. Strontium-90 and radiocesium in consumers milk collected in the 8 zones and Copenhagen in 1986 (cf. Figs. 5.4.1 and 5.4.2)

Country part	Date	Bq ^{90}Sr (kg Ca)$^{-1}$	Bq ^{137}Cs (kg K)$^{-1}$	Bq ^{137}Cs l^{-1}	^{134}Cs/^{137}Cs	Date	Bq ^{90}Sr (kg Ca)$^{-1}$	Bq ^{137}Cs (kg K)$^{-1}$	Bq ^{137}Cs l^{-1}	^{134}Cs/^{137}Cs
N-Jutland	May 24	66	1290	2.16	0.53	Nov/Dec	68	630	1.01	0.45
E-Jutland	May 26	95	2700	4.64	0.53	Nov/Dec	66	560	0.89	0.45
W-Jutland	May 26	101	2500	4.09	0.58	Nov/Dec	67	640	1.04	0.44
S-Jutland	June 2	113	4400	7.10	0.55	Nov/Dec	73	670	1.12	0.45
Funen	June 2	100	4900	8.23	0.58	Nov/Dec	78	730	1.22	0.44
Zealand	June 9	69	1700	2.66	0.50	Nov/Dec	58	350	0.51	0.43
Lolland-Falster	June 2	47	870	1.45	0.58	Nov/Dec	58	300	0.48	0.46
Bornholm	May 17	47	940	1.56	0.56	Nov/Dec	51	260	0.51	0.45
Mean		80	2400	3.99	0.55		65	520	0.85	0.45
Copenhagen	June 2	45	830	1.36	0.63					

Tables 5.2.1, 5.10.2 and 5.10.4 it is possible to calculate the percentage of the daily intakes of ^{90}Sr and ^{137}Cs excreted in the milk. For ^{90}Sr we found that 1.5% of the intake were excreted in the milk both in June and September. In case of ^{137}Cs the June excretion was $7 \pm 1\%$ (N = 9; ± 1 S.E.), but in September the excretion was as high as $22 \pm 5\%$ (N = 10; ± 1 S.E.) (cf. also Figs. 5.10.2.1 and 5.10.2.2). The cows may in September have received some stored fodder from May-June with a high ^{137}Cs content. We have earlier[21)] found excretions of 1.9% for ^{90}Sr and 7.6% for ^{137}Cs.

5.2.2. Radiostrontium and radiocesium in consumers milk

Milk was purchased in the 8 zones and Copenhagen (Figs. 5.4.1 and 5.4.2) in May-June and in November-December 1986. The results are shown in Table 5.2.2 and were similar to those in the dried milk samples (cf. Table 5.1.3).

5.2.3. Radiostrontium and radiocesium in Danish cheese

Cheese samples were obtained monthly from dairies in West and South Jutland in 1986. Table 5.2.3 shows that the Bq ^{137}Cs (kg K)$^{-1}$ levels in cheese were higher than those in dried milk samples from the same areas (cf. Table 5.1.3) and so were the Bq ^{90}Sr (kg Ca)$^{-1}$ levels (Table 5.1.1). The reasons for these discrepancies may be due to higher ^{137}Cs and ^{90}Sr concentrations in the milk used for cheese production than that used for dried milk.

Table 5.2.3. Strontium-90 and radiocesium in cheese collected in West and South Jutland in 1986

Month	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
June	1.24	164	3.9	5300	0.49
July	1.22	167	3.2	4500	0.45
Aug	0.86	112	1.74	2100	0.53
Sept	1.11	122	1.58	1760	0.38 A
Oct	-	-	1.39	1740	0.50
Oct, Nov, Dec	0.91	120	1.43	3500	0.47
June-Dec mean	1.02	132	2.1	3200	-

For ^{90}Sr the values for Oct, Nov, Dec counted three times in the means.

For ^{137}Cs they counted twice, because we already had one value from Oct.

5.2.4. Iodine-131 in Danish milk after Chernobyl

In the first days after the Chernobyl accident a number of milk samples were analysed for ^{131}I. As Danish cows had not started grazing when the Chernobyl fallout arrived, we would not have expected ^{131}I in Danish milk in general, and most of the samples received were in fact below the detection limit. We received, however, also some samples from farms where the cows had begun grazing. Furthermore, we collected grass from these farms for a comparison between ^{131}I concentrations in milk and grass (see Table 5.10.7). The mean ratio: Bq ^{131}I l^{-1} milk/Bq ^{131}I kg^{-1} grass (dry matter) was 0.015$\pm$0.007 (N = 4; $\pm$1 S.E.), dry matter content of grass was 20%. This ratio is compatible with earlier observations[21], where we found a ratio of 0.01.

In consumers milk collected countrywide in May-June 1986 (Table 5.2.4) we found 1.65 Bq ^{131}I l^{-1} milk. In Table 5.10.3 we have ^{131}I data on countrywide collected grass samples from May 12 and approximately June 11. If we decay-correct (effective half-life of ^{131}I on grass is 5 days) these two sets of grass samples to May 27, which was the mean date for the milk sampling (and

Table 5.2.4. Iodine-131 in consumer milk collected in the 8 zones and Copenhagen in May-June 1986

Zone		Date	$Bq\ l^{-1}$
I:	North Jutland	24/5	1.56
II.	East Jutland	26/5	1.60
III.	West Jutland	26/5	1.72
IV.	South Jutland	2/6	1.34
V.	Funen	2/6	1.38
VI.	Zealand	21/5 9/6	1.74 (0.46)A
VII.	Lolland-Falster	2/6	0.46 A
VIII.	Bornholm	17/5 22/5	(5.5) 3.4
Mean			1.65
Copenhagen		2/6	0.56

Figures in brackets not included in the mean.

also the mean date of the grass sampling) we find a mean ^{131}I concentration in Danish grass of 29 $Bq\ kg^{-1}$ fresh weight or 145 $Bq\ kg^{-1}$ dry weight. Hence the milk/grass ratio becomes 1.65/145 = 0.011 which again is compatible with earlier observations. We may thus conclude that the Chernobyl ^{131}I showed nearly the same transfer from grass to milk as observed earlier for global fallout iodine. In such calculations it is always a problem what the cows may have eaten beside the grass.

The Danish authorities asked the farmers to keep their cows on staple until about 10 May. This reduced the ^{131}I content in Danish milk just after the accident from a calculated level of about 50-100 $Bq\ l^{-1}$ to a few $Bq\ l^{-1}$. When the cows began grazing a countrywide surveillance of the milk were carried out. Approximately 100 milk samples were measured daily. Figure 5.2.4 shows the daily median concentrations of this monitoring programme.

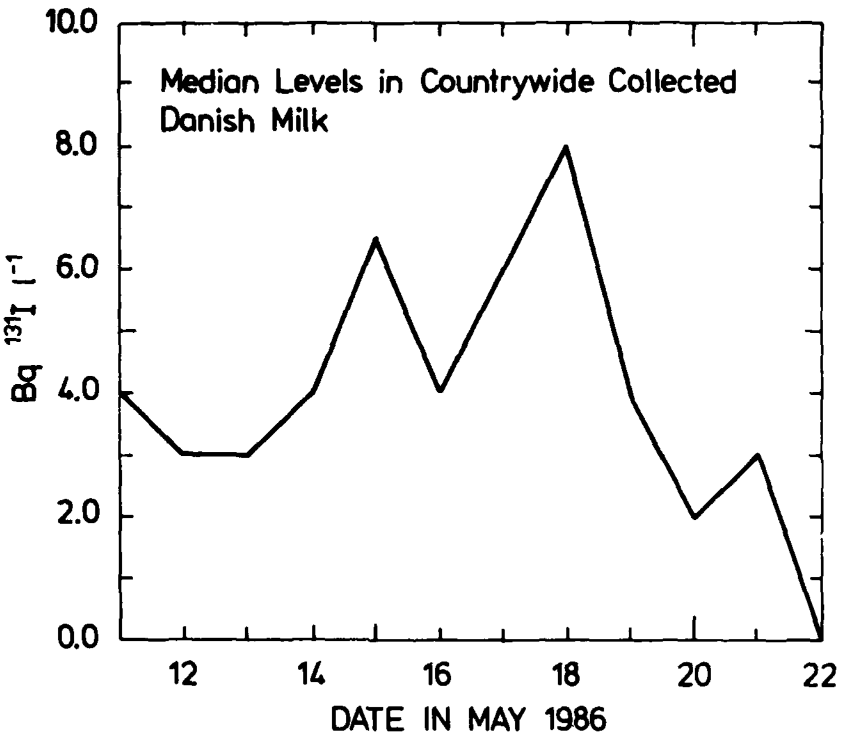

Fig. 5.2.4. Iodine-131 in Danish milk collected countrywide in May 1986.

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

As in previous years, grain samples were obtained from the State experimental farms (cf. Fig. 4.2). Strontium-90 was determined as previously (Risø Report No. 63[1]), and ^{137}Cs and ^{134}Cs were measured on ashed samples by γ-spectrometry on a Ge(Li) detector.

Tables 5.3.1 and 5.3.2 show the measurements of ^{90}Sr in grain in 1986. Table 5.3.4 gives the analysis of variance of the Bq ^{90}Sr (kg Ca)$^{-1}$ figures and Table 5.3.3 that of the Bq ^{90}Sr kg^{-1} grain figures.

Table 5.3.1. Strontium-90 in Danish grain in 1986. (Unit: Bq kg^{-1})

Location	Rye Winter	Barley Spring	Barley Winter	Wheat Winter	Wheat Spring	Oats Spring	Triticale
Tylstrup	0.44	0.55	0.59	0.40	0.69	0.75	-
Kalø	0.46±0.02	0.30±0.10*	0.42	0.32±0.03*	-	1.05	-
Askov	0.79	0.63	0.63±0.01	0.41±0.03	0.72±0.06	1.12±0.08	0.30
Borris	0.47±0.02	0.63	0.47	0.42	0.29	0.77±0.09	1.08
St. Jyndevad	0.41	0.38±0.03	0.53±0.03	0.34	-	0.65	-
Årslev	0.51	0.39±0.05	-	0.174	-	1.01	-
Tystofte	0.26	0.45±0.03	0.22±0.02	0.25	0.25	0.48	-
Ledreborg	0.32±0.01	0.28	0.34	0.30	0.62±0.27	0.41	-
Abed	-	0.164	0.29±0.00	0.30	0.27±0.04	0.0186±0.003	-
Tornbygård	0.167	0.23±0.05	0.22±0.03	0.129	-	0.23	-
Mean	0.42	0.40	0.41	0.30	0.48	0.67	-

*Mean of Kalø and Ødum ±1 S.E.

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

Table 5.3.2. Strontium-90 in Danish grain in 1986. (Unit: Bq (kg Ca)$^{-1}$)

Location	Rye Winter	Barley Spring	Barley Winter	Wheat Winter	Wheat Spring	Oats Spring	Triticale
Tylstrup	1060	1490	1100	1200	1580	920	-
Kalø	510±63	680±138*	860	940±55*	-	1050	-
Askov	1880	1420	1010±4	1190±45	1650±131	1200±41	900
Borris	1070±194	1500	960	1410	770	970±98	2300
St. Jyndevad	1470	1000±101	1110±121	1020	-	870	-
Årslev	1340	1180±152	-	440	-	1170	-
Tystofte	740	940±76	400±41	820	670	560	-
Ledreborg	800±49	810	620	980	1530±570	440	-
Abed	-	330	480±64	740	440±42	240±8	-
Tornbygård	470	510±88	360±67	470	-	290	-
Mean	1040	980	770	920	1110	770	-

*Mean of Kalø and Ødum ±1 S.E.

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

Table 5.3.3. Analysis of variance of ln Bq ^{90}Sr kg^{-1} in grain in 1986 (from Table 5.3.1)

Variation	SSD	f	s^2	v^2	P
Between species	2.174	3	0.725	5.372	-
Between locations	10.455	9	1.162	8.611	> 99.95%
Spec. × loc.	3.508	26	0.135	1.726	-
Remainder	2.970	38	0.078		

Table 5.3.4. Analysis of variance of ln Bq ^{90}Sr $(kg\ Ca)^{-1}$ in grain in 1986 (from Table 5.3.2)

Variation	SSD	f	s^2	v^2	P
Between species	0.799	3	0.266	2.232	-
Between locations	12.716	9	1.413	11.835	> 99.95%
Spec. × loc.	3.104	26	0.119	1.502	-
Remainder	3.021	38	0.080		

Table 5.3.3 shows that the variation in Bq ^{90}Sr kg^{-1} between species was significant. Oats showed the highest Bq ^{90}Sr kg^{-1} levels. The ^{90}Sr levels in grain from 1986 were 18% higher than those found in 1985. All species except barley were higher in 1986.

As in previous years, the variation with location was highly significant; the mean Bq ^{90}Sr kg^{-1} level for grain from Jutland was 1.8 times that in eastern Denmark. The observed Bq ^{90}Sr kg^{-1} levels in grain from 1986 were 0.86 ± 0.22 (1 S.D., N = 8) times those predicted (cf. Appendix C).

Tables 5.3.5 and 5.3.6 show the measurements of ^{137}Cs and ^{134}Cs in grain in 1986. The ^{137}Cs mean level in grain from 1986 was 43 times the level in 1985. The fallout in May-August 1986 was 1630 times that of the fallout in May-August 1985.

The ANOVA's (Tables 5.3.7 and 5.3.8) showed significant variation between locations but Jutland was as a whole not significantly different from the Islands.

Due to the early arrival of the Chernobyl fallout, the crops were in general very small and most of the activity was thus not intercepted by the plants. Only in the case of rye the plants were sufficiently developed for a significant uptake. Hence the radiocesium concentrations in rye were at least an order of magnitude higher than those of the other species.

Our prediction models (cf. Appendix C.2) which assume that the radiocesium found in grain is solely dependent upon the fallout coming in May-August, overestimated the actually found radio-

Table 5.3.5. Radiocesium in Danish grain in 1986. (Unit: Bq ^{137}Cs kg^{-1})

Location	Rye Winter	Barley Spring	Barley Winter	Wheat Winter	Wheat Spring	Oats Spring	Triticale
Tylstrup	1.95	0.41	0.84	0.35	0.35	0.33	-
	-	(0.44)	(0.43)	(0.37 A)	(0.50)	-	-
Kalø	6.5	0.26 ±0.05	0.61	0.59 0.11	-	1.04	-
	(0.49)	-	(0.78)	(0.60)	-	-	-
Askov	19.1	0.25	1.37	0.55	0.96	1.11	2.6
	(0.58)	-	(0.49)	(0.80 A)	(0.53)	(0.37)	(0.52)
Borris	12.0	0.39	1.71	0.47	0.28	0.27	0.98
	(0.45)	(0.67)	(0.55)	(0.46 A)	-	-	(0.53)
St. Jyndevad	12.0	0.48	1.70	0.98	-	1.07	-
	(0.52)	(0.39 B)	(0.45)	(0.49)	-	(0.43)	-
Årslev	14.0	0.24	-	1.54	-	2.5	-
	(0.51)	(0.58 A)	-	(0.41)	-	(0.48)	-
Tystofte	17.9	0.22	0.66	0.49	0.159	0.21	-
	(0.50)	-	(0.48)	(0.42)	(0.66 A)	-	-
Ledreborg	9.9	0.179	0.68	0.71	0.23	0.23	-
	(0.49)	(0.76 B)	(0.60)	(0.52)	-	-	-
Abed	-	0.43	4.8	1.44	0.26	0.31	-
	-	-	(0.52)	(0.48)	(0.84 A)	-	-
Tornbygård	6.8	0.41	1.28	0.87	-	0.30	-
	(0.50)	(0.40 B)	(0.44)	(0.47)	-	-	-
Mean	11.1	0.33	1.52	0.80	0.37	0.74	-

*Mean of Kalø and Ødum ±1 S.E.

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

Table 5.3.6. Cesium-137 in Danish grain in 1986. (Unit: Bq ^{137}Cs (kg K)$^{-1}$)

Location	Rye Winter	Barley		Wheat		Oats Spring	Triticale
		Spring	Winter	Winter	Spring		
Tylstrup	460	92	188	99	94	83	-
Kalø	1490	61±13	173	168±42	-	290	-
Askov	4500	77	480	182	300	320	660
Borris	3600	101	380	131	73	89	187
St. Jyndevad	2400	112	380	250	-	230	-
Årslev	2900	54	-	380	-	570	-
Tystofte	3500	47	166	111	40	53	-
Ledreborg	1900	39	135	145	43	60	-
Abed	-	64	1030	350	40	73	-
Tornbygård	1640	76	320	220	-	97	-
Mean	2500	72	360	200	98	200	-

*Mean of Kalø and Ødum ±1 S.E.

Table 5.3.7. Analysis of variance of ln Bq ^{137}Cs kg^{-1} in grain in 1986 (from Table 5.3.5)

Variation	SSD	f	s^2	v^2	P
Between species	72.354	5	14.471	46.212	> 99.95%
Between locations	7.136	9	0.793	2.532	> 97.5%
Spec. × loc.	12.213	39	0.313	3.559	-
Remainder	0.176	2	0.088		

Table 5.3.8. Analysis of variance of ln Bq ^{137}Cs (kg K)$^{-1}$ in grain in 1986 (from Table 5.3.6)

Variation	SSD	f	s^2	v^2	P
Between species	69.630	5	13.926	47.771	> 99.95%
Between locations	7.874	9	0.875	3.001	> 99%
Spec. × loc.	11.369	39	0.292	2.523	-
Remainder	0.231	2	0.116		

cesium concentrations by 1-2 orders of magnitude, because these models assume an approximately constant fallout rate during the growing period.

From experimental uptake studies at Risø we have earlier proposed a model for the contamination of barley grain, which takes the time of contamination into consideration[27]:

$$\mu(t) = 0.098\ e^{-0.0013(t-34)^2} \qquad \text{(Eq. 1)}$$

where $\mu(t)$ is the activity in Bq ^{137}Cs kg^{-1} in the mature barley grain at harvest
(t) is the time in days before harvest when the crop has received 1 Bq ^{137}Cs per m^2 barley field.

The equation was calculated for a crop density of 0.8 kg dry matter m^{-2} at harvest, which is the average agricultural yield in a mature Danish barley field. In a similar way we have proposed a model for the initial uptake % of the barley crops at various times t before harvest:

$$\% = 36\ e^{-0.00052(t-30)^2} \qquad \text{(Eq. 2)}$$

We tested these two models at Risø for a field with winter barley. Model (Eq. 2) was in agreement with observations if we assumed a field loss half-life of 2 days for days with rain and of 14 days during dry periods. This is a more rapid field loss than observed under the experimental conditions, for which the two equations were developed. In that case the field loss half-life was 20 days. We may thus expect that much of the ^{137}Cs deposited after Chernobyl has been lost from the crops before it could be translocated to the grain. Equation (Eq. 1) would thus overestimate the actual levels in mature grain. This was also the case. From Equation (Eq. 1) we calculated a grain level of 4.2 Bq ^{137}Cs kg^{-1} but we found only 0.3 Bq kg^{-1}.

In Tables 5.3.12.1 and 5.3.12.2 we have made the calculations of grain from the various state experimental farms. The periods for deposition measurements are here longer than for Risø and

Table 5.3.9. Harvest dates for Danish grain in 1986

Location	Rye Winter	Barley Spring	Barley Winter	Wheat Winter	Wheat Spring	Oats Spring	Triticale
Tylstrup	26/8	13/8	13/8	5/9	8/9	26/8	-
Kalø	Sept	21/8	4/9	9/9	-	26/8	-
Askov	17/9	17/9	17/9	17/9	17/9	17/9	17/9
Borris	4/9	18/8	7/8	4/9	5/9	5/9	16/9
St. Jyndevad	14/8	16/8	11/8	14/8	-	14/8	-
Årslev	26/8	21/8	-	26/8	-	21/8	-
Tystofte	19/8	21/8	13/8	25/8	21/8	4/9	-
Ledreborg	20/8	18/8	11/8	21/8	4/9	29/8	-
Abed	-	29/8	6/8	3/9	29/8	29/8	-
Tornbygård	21/8	18/8	18/8	25/8	-	25/8	-

Table 5.3.10. Radiocesium and Strontium-90 in barley samples collected at Risø in 1986

Date	Sample	kg m^{-2}	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs $(kg\ K)^{-1}$	Bq ^{137}Cs m^{-2}	$^{134}Cs/^{137}Cs$	Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr $(kg\ Ca)^{-1}$	Variety
4/5	Total plant	0.16	5.1		0.82	0.57 A			Winter barley
14/5	- " -	0.48	10.5	2300	5.0	0.61			- " -
2/6	- " -	1.82	1.6 B	400 B	2.9 B	1.1 B			- " -
30/6	- " -	3.02	1.10 A	280 A	3.3 A	-			- " -
12/8	- " -		1.64	133		0.49 B			- " -
"	Grain		0.30 A	73 A		-	0.183	360	- " -
"	Husks		3.5	500		0.51 B			- " -
"	Straw		7.7	670		0.49	1.83	520	- " -
"	Grain		0.13 B	34			0.11 B	300 B	Spring barley
"	Straw		1.84	151	0.6		2.55	390	- " -

Table 5.3.11. Radiocesium in spring barley samples collected at Grevinge, W-Zealand in 1986

Date	Sample	kg m^{-2}	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs $(kg\ K)^{-1}$	Bq ^{137}Cs m^{-2}	$^{134}Cs/^{137}Cs$
14/5	Total plant	0.071	16.6 A	3500	1.18 A	0.81 A
20/6	- " -	1.24	0.92 A	195	1.14 A	-
15/7	- " -	~1.0	~0.7 B	160 B	~0.7 B	-
4/8	- " -	0.74	1.08±0.20	165±25	0.8	-
15/8	- " -	0.98	1.8 ±0.8	250±20	1.8	-
1/9	- " -	1.21	0.76 0.16	280±120	0.9	-
9/9	Grain		0.33	63		0.46

The error term is 1 S.E. from double determinations.

Table 5.3.12.1. Model* predictions of ^{137}Cs from Chernobyl in Danish mature spring barley grain at harvest 1986

Location	Wet deposition (Bq ^{137}Cs m^{-2})			Harvest	Barley, mature grain predicted (Bq ^{137}Cs kg^{-1})
	5-12 May	12 May-1 June	1 June-1 July		
Tylstrup	200	177	41	13 Aug	2.68
Kalø	220	350	60	21 Aug	1.97
Borris	471	237	51	18 Aug	2.21
Askov	1230	467	248	20 Aug	7.44
St. Jyndevad	397	333	30	16 Aug	2.19
Årslev	637	470	150	21 Aug	4.35
Tystofte	6	810	52	21 Aug	2.40
Ledreborg	314	159	31	18 Aug	1.38
Abed	26	417	35	29 Aug	0.55
Åkirkeby	92	202	55	29 Aug	2.15

*Heuristic barley model from ref. 27: $\mu(t) = 9.9 \cdot 10^{-2}\, e^{-0.0013(t-34)^2}$
(t is the time in days before harvest and $\mu(t)$ is the concentration (Bq ^{137}Cs kg^{-1}) in mature grain for a deposition of 1 Bq ^{137}Cs m^{-2} barley field at time (t)).

Table 5.3.12.2. Comparison of measured and predicted concentrations of ^{137}Cs in Danish mature barley grain at harvest 1986

Location	Winter barley			Spring barley		
	meas. (Bq kg^{-1})	pred. (Bq kg^{-1})	meas./pred. (%)	meas. (Bq kg^{-1})	pred. (Bq kg^{-1})	meas./pred. (%)
Tylstrup	0.84	2.68	31	0.41	2.68	15
Kalø				0.20	1.97	10
Borris	1.71	6.01	28	0.39	2.21	18
Askov	1.31	7.44	18	0.25	7.44	3
St. Jyndevad	1.70	3.69	46	0.48	2.19	22
Årslev				0.24	4.35	6
Tystofte	0.66	1.49	44	0.22	2.40	9
Ledreborg	0.68	2.69	25	0.18	1.38	13
Abed	4.81	6.43	75	0.43	0.55	78
Åkirkeby	1.28	2.15	60	0.41	2.15	19

the uncertainty on model calculations may thus be larger. It is evident that the contributions from July-August play an important role in the models. This contribution may, however, not be so important in reality because the fallout in July-August was mostly due to local resuspension. This means that the radiocesium was attached to soil particles, which may retain the radiocesium so efficiently that the plants cannot get hold of it. The field loss of resuspended matter may also be higher than of primary fallout.

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

In 1986, samples of white bread (75% extraction) and dark rye bread (100% extraction) were collected all over the country (cf. Figs. 5.4.1 and 5.4.2) in November, and ^{90}Sr, ^{137}Cs and ^{134}Cs were determined. Samples from Copenhagen were analysed separately. The ^{137}Cs determinations were carried out on the ash by Ge(Li) γ-spectroscopy.

Tables 5.4.1 and 5.4.2 show the results. It is assumed that 1 kg flour yields approximately 1.35 kg bread[11] and that wheat flour of 75% extraction contains 20% of the ^{90}Sr and 50% of the ^{137}Cs found in wheat grain[1], while rye flour is 100% extraction. Hence we can compare the 1986 bread levels with the 1985 grain levels (cf. Table 5.4.3). The above assumptions for transfer of ^{137}Cs and ^{90}Sr from grain to bread seem justified for rye but not for wheat. This has in fact been envisaged in Risø-R-437 p. 86[21] where it is predicted that the transfer from wheat to white bread will increase from 20 to 33% for ^{90}Sr. The discrepancy for ^{137}Cs on white bread/wheat may be due to import of Chernobyl-contaminated wheat from Southern Europe, where the contamination of wheat was higher than in Denmark.

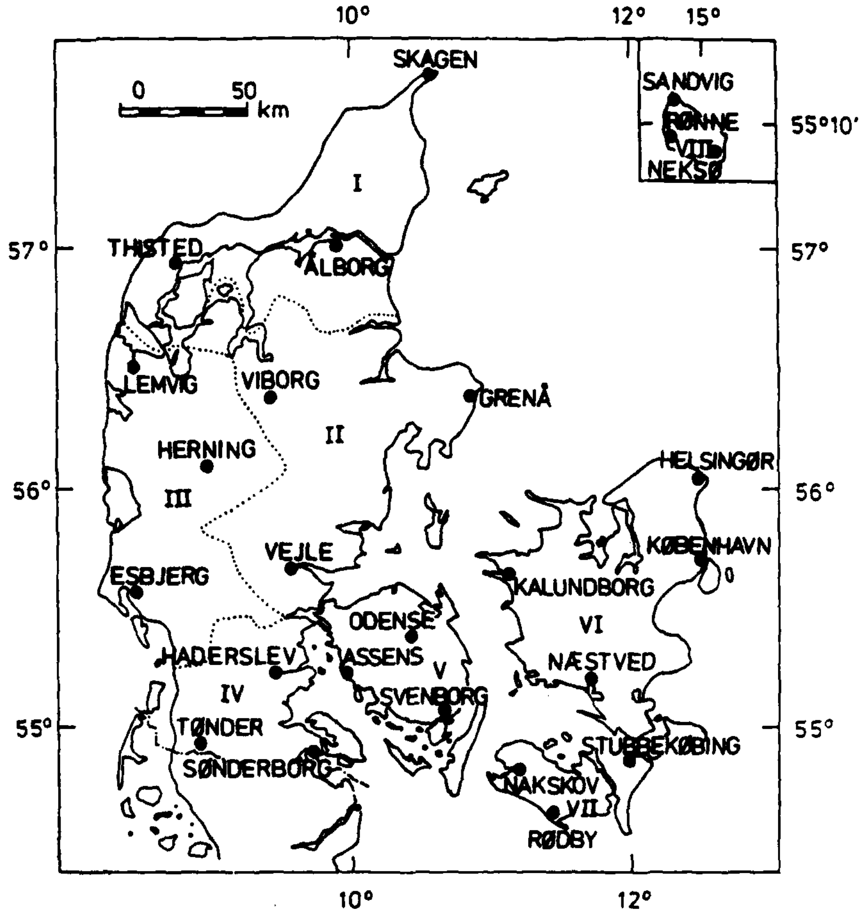

Fig. 5.4.1. "A"-towns in the 8 zones in Denmark used for diet, bread and milk sampling (these towns were used in 1961-1972 and in 1986).
I: North-Jutland; II: East-Jutland; III: West-Jutland; IV: South-Jutland; V: Funen; VI: Sealand; VII: Lolland-Falster; VIII: Bornholm.

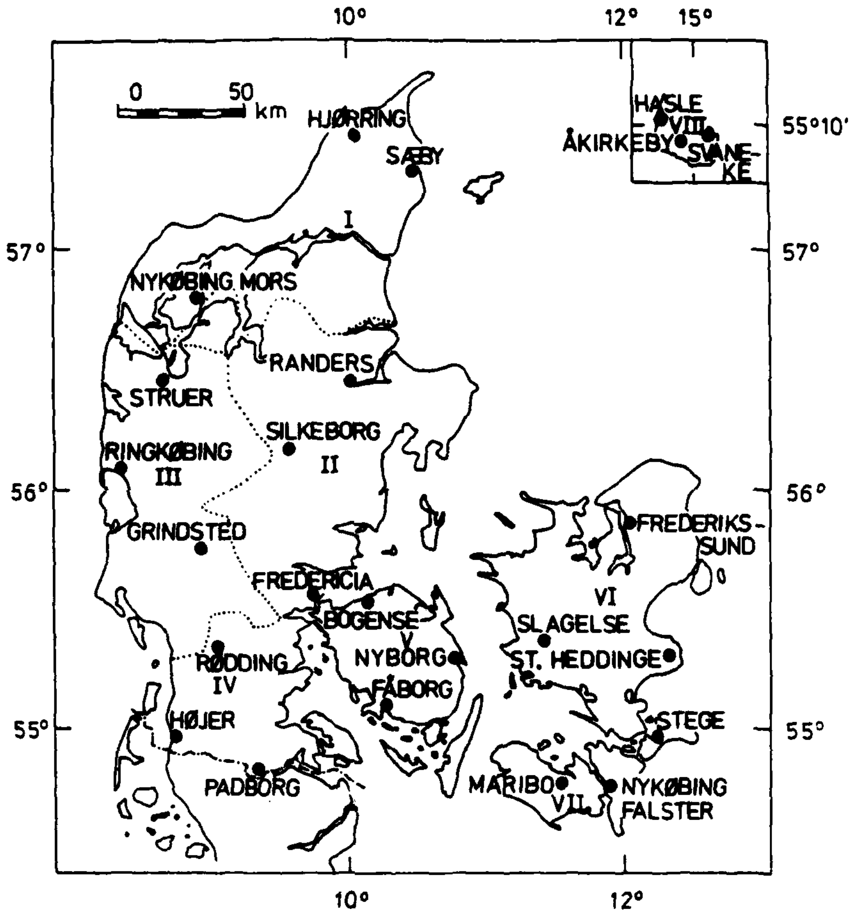

Fig. 5.4.2. "B"-towns in the 9 zones in Denmark used for diet, bread and milk sampling (these towns were used in 1961-1972 and in 1986).

Table 5.4.1. Strontium-90 in Danish bread collected in Nov 1986

Location	Rye bread		White bread	
	Bq kg^{-1}	Bq $(kg\ Ca)^{-1}$	Bq kg^{-1}	Bq $(kg\ Ca)^{-1}$
I. North Jutland	0.43	148	0.182	98
II. East Jutland	0.27	580	0.135	74
III. West Jutland	0.31	940	0.099	340
IV. South Jutland	0.38	153	0.155	128
V. Funen	0.23	210	0.108	112
VI. Zealand	0.27	184	0.094	42
VII. Lolland-Falster	0.24	166	0.117	71
VIII. Bornholm	0.21	103	0.097	182
Mean	0.29	310	0.123	131
Copenhagen	0.24	720	0.166	69
Population-weighted mean	0.28	480	0.132	113

Table 5.4.2. Radiocesium in Danish bread collected in Nov 1986

Location	Rye bread			White bread		
	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs $(kg\ K)^{-1}$	$^{134}Cs/^{137}Cs$	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs $(kg\ K)^{-1}$	$^{134}Cs/^{137}Cs$
I. North Jutland	11.3	3300	0.48	0.95	590	0.38
II. East Jutland	10.0	3200	0.45	0.59	400	0.54
III. West Jutland	7.5	2600	0.48	1.81	1300	0.49
IV. South Jutland	9.2	2800	0.46	0.88	610	0.46
V. Funen	10.8	3800	0.49	0.66	560	0.48
VI. Zealand	6.3	2100	0.47	0.30	220	0.52
VII. Lolland-Falster	1.9	530	0.48	1.48	930	0.44
VIII. Bornholm	4.7	1980	0.48	0.181	135	0.54 A
Mean	7.6	2500	0.47	0.86	590	0.48
Copenhagen	4.5	1420	0.46	0.26	184	0.51 A
Population-weighted mean	7.6	2500	0.47	0.71	500	0.50

Table 5.4.3. A comparison between ^{90}Sr and ^{137}Cs levels in bread and grain 1986

Nuclide	Species	Bread activity in Nov 1986 calculated as grain in Bq kg^{-1} (cf. text)	Activity in grain from harvest 1986[1)] Bq kg^{-1}	"Bread"/grain ratio
^{90}Sr	Wheat	0.89	0.39	2.3
	Rye	0.38	0.43	0.9
^{137}Cs	Wheat	1.92	0.63	3.0
	Rye	10.3	11.2	0.9

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

The samples of potatoes were collected in September from ten of the State experimental farms (cf. Fig. 4.2) and analysed for ^{90}Sr, ^{137}Cs and ^{134}Cs (γ-spectroscopy of the ash).

Table 5.5.1 shows the ^{90}Sr and radiocesium contents in potatoes. The mean contents for the country were 0.039 Bq ^{90}Sr kg^{-1}, or 820 Bq ^{90}Sr (kg Ca)$^{-1}$, and 0.197 Bq ^{137}Cs kg^{-1} or 46 Bq ^{137}Cs (kg K)$^{-1}$. The ^{90}Sr levels were 70% of those in 1985, and the ^{137}Cs concentrations were 3.4 times the 1985 values.

The mean ratio between observed and predicted ^{90}Sr concentrations in potatoes was 0.41 and for ^{137}Cs we found 0.05 (cf. Appendix C).

Table 5.5.1. Strontium-90 and radiocesium in Danish potatoes in 1986

Location	Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr (kg Ca)$^{-1}$	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs (kg K)$^{-1}$	$^{134}Cs/^{137}Cs$
Tylstrup	0.033	890	0.075	22	0.48 A
Kalø	0.041	1110	0.66	149	0.43
Borris	0.043	930	0.180	40	
Askov	0.062	1340	0.54	137	0.32 A
St. Jyndevad	0.020	560	0.30	64	0.28 A
Årslev	0.040	660	0.076	16	
Tystofte	0.058	1140	0.063	15	
Ledreborg	0.033	540	0.029	6.3	
Abed	0.029	460	0.020	4.0	
Bornholm	0.035	540	0.020	3.7	
Mean	0.039	820	0.197	46	

5.6. Strontium-90 and radiocesium in vegetables and fruits from the entire country

In 1986, as in previous years, vegetables and fruit were collected in the autumn from eight larger provincial towns, one in each of the eight zones (cf. Fig. 5.4). The programme was, however, expanded considerably compared to previous years. Tables 5.6.1-5.6.14 show the results.

Table 5.6.1. Strontium-90 and radiocesium in cabbage collected in Aug-Sept 1986

Zone		Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr (kg Ca)$^{-1}$	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs (kg K)$^{-1}$	$^{134}Cs/^{137}Cs$
I.	North Jutland	0.173	600	0.29	154	0.20 A
II.	East Jutland	0.143	340	0.183 A	69 A	
III.	West Jutland	0.28	780	0.51	280	0.42
IV.	South Jutland	0.21	390	0.56	200	0.45
V.	Funen	0.069	120	0.044 A	27 A	
VI.	Zealand	0.139	310	0.03 B	10 B	
VII.	Lolland-Falster	0.24	370	0.131	50	
VIII.	Bornholm	0.53	780	0.03 B	10 B	
Mean		0.22	460	0.21	100	

Table 5.6.2. Strontium-90 and radiocesium in carrot collected in Aug-Sept 1986

Zone		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
I.	North Jutland	0.155	510	0.042	22	
II.	East Jutland	0.28	790	0.24	197	0.29
III.	West Jutland	0.31	1130	0.137	56	0.37
IV.	South Jutland	0.189	800	0.24	210	0.21
V.	Funen	0.187	640	0.024	11.5	
VI.	Zealand	0.23	790	0.035	16.4	
VII.	Lolland-Falster	0.194	510	0.044	22	
VIII.	Bornholm	0.45	870	0.065	13.4	
Mean		0.25	760	0.103	69	

Table 5.6.3. Strontium-90 and radiocesium in beans collected in Aug-Sept 1986

Zone		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
I.	North Jutland	0.34	410	0.082 A	23 A	
II.	East Jutland	0.25	410	0.088 A	28 A	
III.	West Jutland	0.30	550	0.22	101	0.46
IV.	South Jutland	0.61	1780	0.20	79	0.48
V.	Funen	0.33	660	0.27	114	0.48 A
VI.	Zealand	0.64	950	0.116	33	
VII.	Lolland-Falster	0.133	350	0.039 B	17 B	
VIII.	Bornholm	0.157	320	0.016 B	6 B	
Mean		0.34	680	0.130	50	

Table 5.6.4. Strontium-90 and radiocesium in peas collected in July 1986

Zone		Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr $(kg\ Ca)^{-1}$	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs $(kg\ K)^{-1}$	$^{134}Cs/^{137}Cs$
I:	North Jutland	0.23	1160	0.22	69	
II:	East Jutland	0.35	1130	0.130 A	36 A	
III:	West Jutland	0.28	1120	0.38	99	0.45 A
IV:	South Jutland	0.068	280	0.179 A	42 A	
V:	Funen	0.196	770	0.37	147	0.36
VI:	Zealand	0.085	560	0.052 B	17 B	
VII:	Lolland-Falster	0.38	280	0.128 B	27 B	
VIII:	Bornholm	0.34	400	0.087 A	36 A	
Mean		0.24	710	0.194	59	

Table 5.6.5. Strontium-90 and radiocesium in lettuce collected in July 1986

Zone		Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr $(kg\ Ca)^{-1}$	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs $(kg\ K)^{-1}$	$^{134}Cs/^{137}Cs$
I:	North Jutland	0.62	1350	0.31	79	0.32
II:	East Jutland	0.195	870	0.085	33	
III:	West Jutland	0.028	790	1.22	360	0.49
IV:	South Jutland	0.20	1030	0.74	177	0.31
V:	Funen	0.181	240	1.00	220	0.51
VI:	Zealand	0.20	380	0.195	44	
VII:	Lolland-Falster	0.181	270	0.55	220	0.45
VIII:	Bornholm	0.38	480	0.192	43	
Mean		0.25	680	0.54	147	

Table 5.6.6. Strontium-90 and radiocesium in onion collected in Aug-Sept 1986

Zone		Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr (kg Ca)$^{-1}$	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs (kg K)$^{-1}$
I:	North Jutland	0.20	510	0.040 B	21 B
II:	East Jutland	0.28	890	0.079 A	29 A
III:	*West Jutland*	0.45	1170	0.090	42
IV:	South Jutland	0.24	610	0.015 B	10 B
V:	Funen	0.20	900	0.032 B	18 B
VI:	Zealand	0.43	1070	0.031 B	15 B
VII:	Lolland-Falster	0.26	730	0.026 B	13 B
VIII:	Bornholm	0.37	1300	0.008 B	6 B
Mean		0.30	900	0.04	19

Table 5.6.7. Strontium-90 and radiocesium in tomatoes collected in July-Aug 1986

Zone		Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr (kg Ca)$^{-1}$	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs (kg K)$^{-1}$
I:	North Jutland			0.038 B	16 B
II:	East Jutland			0.022 B	10 B
III:	West Jutland			0.142	45
IV:	South Jutland			0.044 A	18 A
V:	Funen			0.032 B	13 B
VI:	Zealand			0.037 B	14 B
VII:	*Lolland-Falster*			0.062 B	20 B
VIII:	Bornholm			0.058 B	20 B
Mean		0.0081	73	0.054	20

Table 5.6.8. Strontium-90 and radiocesium in strawberries collected in July 1986

Zone	Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr $(kg\ Ca)^{-1}$	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs $(kg\ K)^{-1}$	$^{134}Cs/^{137}Cs$
I: North Jutland			1.38	750	0.52
II: East Jutland			4.0	2100	0.49
III: West Jutland			4.3	2300	0.54
IV: South Jutland			4.2	2200	0.49
V: Funen			2.7	1320	0.55
VI: Zealand			0.31	156	0.48 A
VII: Lolland-Falster			0.71	370	0.38 A
VIII: Bornholm			1.26	890	0.55
Mean	0.30	1250	2.3	1260	0.50

Table 5.6.9. Strontium-90 and radiocesium in gooseberries collected in July-Aug 1986

Zone	Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr $(kg\ Ca)^{-1}$	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs $(kg\ K)^{-1}$	$^{134}Cs/^{137}Cs$
I: North Jutland			4.0	2500	0.52
II: East Jutland			11.8	8600	0.55
III: West Jutland			19.8	10900	0.54
IV: South Jutland			8.2	4100	0.50
V: Funen			8.2	6100	0.53
VI: Zealand			6.9	4800	0.50
VII: Lolland-Falster			5.0	2400	0.47
VIII: Bornholm			4.1	2100	0.54
Mean	0.083	410	8.5	5200	0.52

Table 5.6.10. Strontium-90 and radiocesium in red currants collected in July-Aug 1986

Zone	Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr $(kg\ Ca)^{-1}$	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs $(kg\ K)^{-1}$	$^{134}Cs/^{137}Cs$
I: North Jutland			3.6	1670	0.55
II: East Jutland			13.5	6000	0.53
III: West Jutland			39	12100	0.51
IV: South Jutland			27	9200	0.49
V: Funen			12.9	4800	0.48
VI: Zealand			13.7	5100	0.54
VII: Lolland-Falster			6.6	2800	0.52
VIII: Bornholm			4.4	1790	0.50
Mean	0.45*	1100	15.1	5400	0.52

*$^{89}Sr/^{90}Sr$: 2.2

Table 5.6.11. Strontium-90 and radiocesium in black currants collected in July-Aug 1986

Zone	Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr $(kg\ Ca)^{-1}$	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs $(kg\ K)^{-1}$	$^{134}Cs/^{137}Cs$
I: North Jutland			6.8	2600	0.47
II: East Jutland			16.8	3800	0.51
III: West Jutland			25	11200	0.50
IV: South Jutland			26	7400	0.51
V: Funen			23	5100	0.48
VI: Zealand			6.7	2400	0.50
VII: Lolland-Falster			15.4	4200	0.51
VIII: Bornholm			3.9	1010	0.56
Mean	0.57	840	15.5	4700	0.51

Table 5.6.12. Strontium-90 and radiocesium in raspberries collected in July-Aug 1986

Zone	Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr $(kg\ Ca)^{-1}$	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs $(kg\ K)^{-1}$	$^{134}Cs/^{137}Cs$
I: North Jutland			1.24	500	0.60
II: East Jutland			3.5	1290	0.53
III: West Jutland			13.2	4500	0.49
IV: South Jutland			8.2	3700	0.50
V: Funen			5.0	2300	0.59
VI: Zealand			2.2	1240	0.52
VII: Lolland-Falster			4.7	1760	0.54
VIII: Bornholm			1.88	710	0.50
Mean	0.040	139	5.0	2000	0.53

Table 5.6.13. Strontium-90 and radiocesium in cherries collected in July-Aug 1986

Zone	Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr $(kg\ Ca)^{-1}$	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs $(kg\ K)^{-1}$	$^{134}Cs/^{137}Cs$
I: North Jutland			4.5	1640	0.49
II: East Jutland			8.3	3200	0.52
III: West Jutland			12.0	6200	0.54
IV: South Jutland			6.4	3400	0.51
V: Funen			12.8	5100	0.51
VI: Zealand			3.1	1590	0.49
VII: Lolland-Falster			2.7	1090	0.46
VIII: Bornholm			2.5	700	0.51
Mean	0.164	940	6.5	2900	0.50

Table 5.6.15 shows a calculation of the mean contents of ^{90}Sr and ^{137}Cs in Danish vegetables collected in 1986. The ^{90}Sr levels were similar to the 1985 concentrations.

The ^{137}Cs concentrations in 1986 were 3.2 times higher than those in 1985.

The 1986 levels in Danish fruit were calculated from apples (80%) and strawberries (20%). The mean levels in Danish fruit were thus 0.067 Bq ^{90}Sr kg^{-1} and 1.82 Bq ^{137}Cs kg^{-1}. The observed Bq ^{90}Sr kg^{-1} levels in vegetables and fruit in 1986 were 0.74±0.54 (1 S.D.) times those predicted (cf. Appendix C). In the case of ^{137}Cs, the observed values were 0.33±0.34 times the predicted ones. Apples were the only one which came close to the predicted value for ^{137}Cs in 1986.

Table 5.6.14. Strontium-90 and radiocesium in apples collected in Aug-Sept 1986

Zone		Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr $(kg\ Ca)^{-1}$	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs $(kg\ K)^{-1}$	$^{134}Cs/^{137}Cs$
I:	North Jutland			0.65	500	0.49
II:	East Jutland			1.47	1230	0.54
III:	West Jutland			2.8	2500	0.46
IV:	South Jutland			1.93	1340	0.48
V:	Funen			1.85	1440	0.58
VI:	Zealand			2.0	1580	0.49
VII:	Lolland-Falster			2.5	1210	0.46
VIII:	Bornholm			0.46	300	0.47
Mean		0.0088	176	1.70	1260	0.50

Table 5.6.15. Calculated ^{90}Sr and ^{137}Cs mean levels in vegetables in 1986

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)	0.22	460	0.21	100
30 root vegetables (carrot)	0.25	760	0.103	69
40 peas and beans	0.29	695	0.162	55
120 g	0.25	610	0.167	77

The Chernobyl accident did not influence the ^{90}Sr levels in vegetables and fruits. In case of ^{137}Cs the influence was strongest for berries such as red and black currants. The countrywide mean value for these berries was 15 Bq ^{137}Cs kg^{-1}. Root vegetables in particular onion were very little affected by the radiocesium from Chernobyl. The ^{137}Cs content in most onion samples was in fact below the limit of detection.

The high ^{137}Cs concentration in berries was due to translocation of ^{137}Cs (and ^{134}Cs) to the berries. This is demonstrated by the $^{103}Ru/^{137}Cs$ and $^{106}Ru/^{137}Cs$ ratios in Table 5.6.16 which both are a factor of two lower than those seen in the air in July-August 1986 (cf. Appendix).

Table 5.6.17 shows that ^{131}I was present in the fresh contaminated vegetables. The concentrations relative to ^{137}Cs corresponded to those seen in air and precipitation. A spinach sample was measured before and after washing. The ^{131}I content

Table 5.6.16. Radionuclide concentrations relative to those of ^{137}Cs in various fruit samples

Species	Zone	Date	^{95}Zr	^{95}Nb	^{103}Ru	^{106}Ru	^{141}Ce	^{144}Ce
Red currant	III	Aug 4	0.039	0.081	0.163	0.25	-	0.083
- " -	VI	July 23	-	0.027	0.22	0.23	-	-
- " -	VIII	July 24	0.21	0.46	0.41	-	0.102	0.34
Black currant	V	Aug 5	0.093	0.25	0.35	0.37 A	0.050 A	0.22
- " -	VI	July 23	0.031 A	0.064	0.119	-	-	-
- " -	VII	July 29	0.195	0.39	0.26	-	0.072	0.27
Gooseberry	I	July 10	-	0.114	0.31	-	-	-
- " -	II	July 10	-	0.069	0.28	-	-	-
- " -	III	July 10	-	-	0.165	0.118 A	-	-
- " -	IV	July 10	-	-	0.33	-	-	-
- " -	V	July 10	-	-	0.29	-	-	-
- " -	VI	July 14	-	-	0.124	0.089 A	-	-
- " -	VII	July 10	-	-	0.29	-	-	-
- " -	VIII	July 7	0.45	0.76	0.23	0.32 A	0.23	0.67
Strawberry	III	July 10	0.082	0.113	0.078	-	0.039	-
- " -	IV	July 10	-	-	0.120	-	-	-

after washing was 91% of that before washing and the radiocesium was 78%. Thus ^{131}I may be more difficult to remove by washing than ^{137}Cs.

Table 5.6.17. Radionuclides in some vegetable samples collected just after the Chernobyl accident (Unit: Bq kg^{-1})

Sample	Location	Date 1986	^{131}I	^{134}Cs	^{137}Cs
Rhubarb	Ganløse (Zealand)	9/5	6.8	-	-
Radish	Ganløse (Zealand)	9/5	42	6.1	10.5
Chive	Hedehusene (Zealand)	9/5	113	8 B	21.5
Parsley	Roskilde (Zealand)	8/5	500	116	230
Spinach (unwashed)	Svendborg (Funen)	9/5	810	189	330
Spinach (washed)	Svendborg (Funen)	9/5	740	144	260

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

In 1986 total-food samples representing an average Danish diet according to E. Hoff-Jørgensen (cf. Appendix B in Risø Report No. 63[1])9 were collected from 48 towns, 6 from each of the eight zones (cf. Figs. 5.4.1 and 5.4.2) and from Copenhagen. The sampling took place in June, September and December.

Tables 5.7.1-5.7.6 show the results. The ^{90}Sr levels in Jutland was 6% higher than those in the Islands in 1986. The ^{137}Cs levels were 17% higher in Jutland than those from the Islands.

Table 5.7.1. Strontium-90 in Danish total diet collected in June 1986

Zone	Bq (kg Ca)$^{-1}$	Bq day^{-1} cap^{-1}	g Ca day^{-1}
I: North Jutland	96	0.145	1.51
II: East Jutland	126	0.189	1.50
III: West Jutland	138	0.173	1.25
IV: South Jutland	111	0.173	1.56
V: Funen	128	0.166	1.29
VI: Zealand	107	0.156	1.46
VII: Lolland-Falster	109	0.174	1.60
VIII: Bornholm	88	0.142	1.61
Mean	113	0.165	1.47
Copenhagen	100	0.149	1.49
Population-weighted mean	114	0.164	1.44

Table 5.7.2. Strontium-90 in Danish total diet collected in September 1986

Zone	Town group	Bq (kg Ca)$^{-1}$	Bq day^{-1} cap^{-1}	g Ca day^{-1}
I: North Jutland	A	105	0.158	1.50
	B	94	0.143	1.52
II: East Jutland	A	100	0.143	1.43
	B	122	0.174	1.43
III: West Jutland	A	117	0.183	1.56
	B	113	0.184	1.63
IV: South Jutland	A	103	0.159	1.54
	B	101	0.164	1.62
V: Funen	A	100	0.151	1.51
	B	80	0.130	1.63
VI: Zealand	A	86	0.128	1.49
	B	101	0.130	1.29
VII: Lolland-Falster	A	110	0.163	1.48
	B	78	0.135	1.73
VIII: Bornholm	A	93	0.144	1.55
	B	91	0.151	1.66
Mean		100	0.153	1.54
Copenhagen		77	0.120	1.56
Population-weighted mean		101	0.145	1.44

Table 5.7.3. Strontium-90 in Danish total diet collected in December 1986

Zone	Town group	Bq (kg Ca)$^{-1}$	Bq day^{-1} cap^{-1}	g Ca day^{-1}
I: North Jutland	A	120	0.185	1.54
	B			
II: East Jutland	A			
	B	149	0.20	1.36
III: West Jutland	A	116	0.172	1.48
	B			
IV: South Jutland	A			
	B	160	0.24	1.50
V: Funen	A	135	0.180	1.33
	B			
VI: Zealand	A			
	B	113	0.161	1.42
VII: Lolland-Falster	A	95	0.157	1.65
	B			
VIII: Bornholm	A			
	B	117	0.161	1.38
Mean		126	0.182	1.46
Copenhagen		103	0.174	1.69
Population-weighted mean		122	0.180	1.49

Table 5.7.4. Radiocesium in Danish total diet collected in June 1986

Zone	Bq (kg K)$^{-1}$	Bq day^{-1} cap^{-1}	g K day^{-1}	$^{134}Cs/^{137}Cs$
I: North Jutland	620	2.40	3.87	0.52
II: East Jutland	640	2.32	3.62	0.50
III: West Jutland	700	2.57	3.67	0.48
IV: South Jutland	1480	5.53	3.74	0.54
V: Funen	1320	4.76	3.61	0.51
VI: Zealand	171	0.60	3.51	0.46
VII: Lolland-Falster	240	0.90	3.75	0.50
VIII: Bornholm	630	2.35	3.73	0.51
Mean	725	2.68	3.69	0.50
Copenhagen	240	0.85	3.54	0.47
Population-weighted mean	560	2.04	3.62	0.49

Table 5.7.5. Radiocesium in Danish total diet collected in September 1986

Zone		Town group	Bq (kg K)$^{-1}$	Bq day^{-1} cap^{-1}	g K day^{-1}	$^{134}Cs/^{137}Cs$
I:	North Jutland	A	610	2.32	3.80	0.43
		B	550	2.02	3.67	0.49
II:	East Jutland	A	450	1.65	3.67	0.44
		B	570	2.19	3.84	0.48
III:	West Jutland	A	760	2.91	3.83	0.35
		B	590	2.18	3.69	0.50
IV:	South Jutland	A	750	3.08	4.11	0.50
		B	980	3.67	3.74	0.42
V:	Funen	A	800	3.09	3.86	0.53
		B	650	2.42	3.72	0.46
VI:	Zealand	A	290	1.11	3.83	0.53
		B	320	1.22	3.81	0.42
VII:	Lolland-Falster	A	310	1.18	3.81	0.46
		B	350	1.33	3.80	0.35
VIII:	Bornholm	A	370	1.50	4.05	0.50
		B	400	1.54	3.85	0.49
Mean			550	2.09	3.82	0.46
Copenhagen			390	1.53	3.92	0.38
Population-weighted mean			500	1.93	3.80	0.44

The ^{90}Sr 1986 levels (mean of June and December values) in the total diet were equal to the 1985 levels, while the ^{137}Cs levels were 13.8 times higher in 1986 than in 1985.

From the total-diet sampling it is possible to estimate the mean levels of ^{90}Sr and ^{137}Cs in the Danish diet in 1986. For the period January-April 1986, the ^{90}Sr level in the total diet is assumed to have been equal to that measured in December 1985, Risø Report No. 549[1)]. For the period May-July we assume the level to have corresponded to that measured in June 1986. For the months August-October we used the September 1986 figures and the December 1986 figures are taken to represent the last two months of the year. Hence the mean content in the total diet in 1986 was 109 Bq ^{90}Sr (kg Ca)$^{-1}$, or 0.16 Bq ^{90}Sr (day)$^{-1}$.

Similarly, the ^{137}Cs content in the Danish diet in 1986 was estimated to be 1.45 Bq ^{137}Cs $(day)^{-1}$ or 390 Bq ^{137}Cs $(kg\ K)^{-1}$. The daily mean intake of ^{134}Cs was 0.63 Bq cap^{-1} corresponding to a total intake of 230 Bq ^{134}Cs in 1986. The observed ^{137}Cs fallout level in total diet was 0.21 times that predicted (cf. Appendix C.2).

Figure 5.7.1 show the zone mean Bq ^{90}Sr $(kg\ Ca)^{-1}$ levels (not population-weighted) in total diet compared with the predicted values (cf. Appendix C), the observed value was 0.65 times that predicted.

Table 5.7.6. Radiocesium in Danish total diet collected in December 1986

Zone		Town group	Bq $(kg\ K)^{-1}$	Bq day^{-1} cap^{-1}	g K day^{-1}	$^{134}Cs/^{137}Cs$
I:	North Jutland	A	680	2.54	3.74	0.41
		B	540	2.05	3.80	0.41
II:	East Jutland	A	690	2.59	3.75	0.43
		B	760	2.70	3.55	0.41
III:	West Jutland	A	790	3.01	3.81	0.42
		B	810	3.02	3.73	0.43
IV:	South Jutland	A	700	2.77	3.96	0.43
		B	580	2.26	3.90	0.40
V:	Funen	A	740	2.83	3.82	0.45
		B	680	2.61	3.84	0.41
VI:	Zealand	A	660	2.41	3.65	0.44
		B	920	3.41	3.71	0.38
VII:	Lolland-Falster	A	380	1.45	3.82	0.45
		B	430	1.60	3.72	0.47
VIII:	Bornholm	A	290	1.21	4.17	0.40
		B	270	1.10	4.07	0.40
Mean			620	2.34	3.82	0.42
Copenhagen			420	1.56	3.71	0.44
Population-weighted mean			650	2.42	3.72	0.42

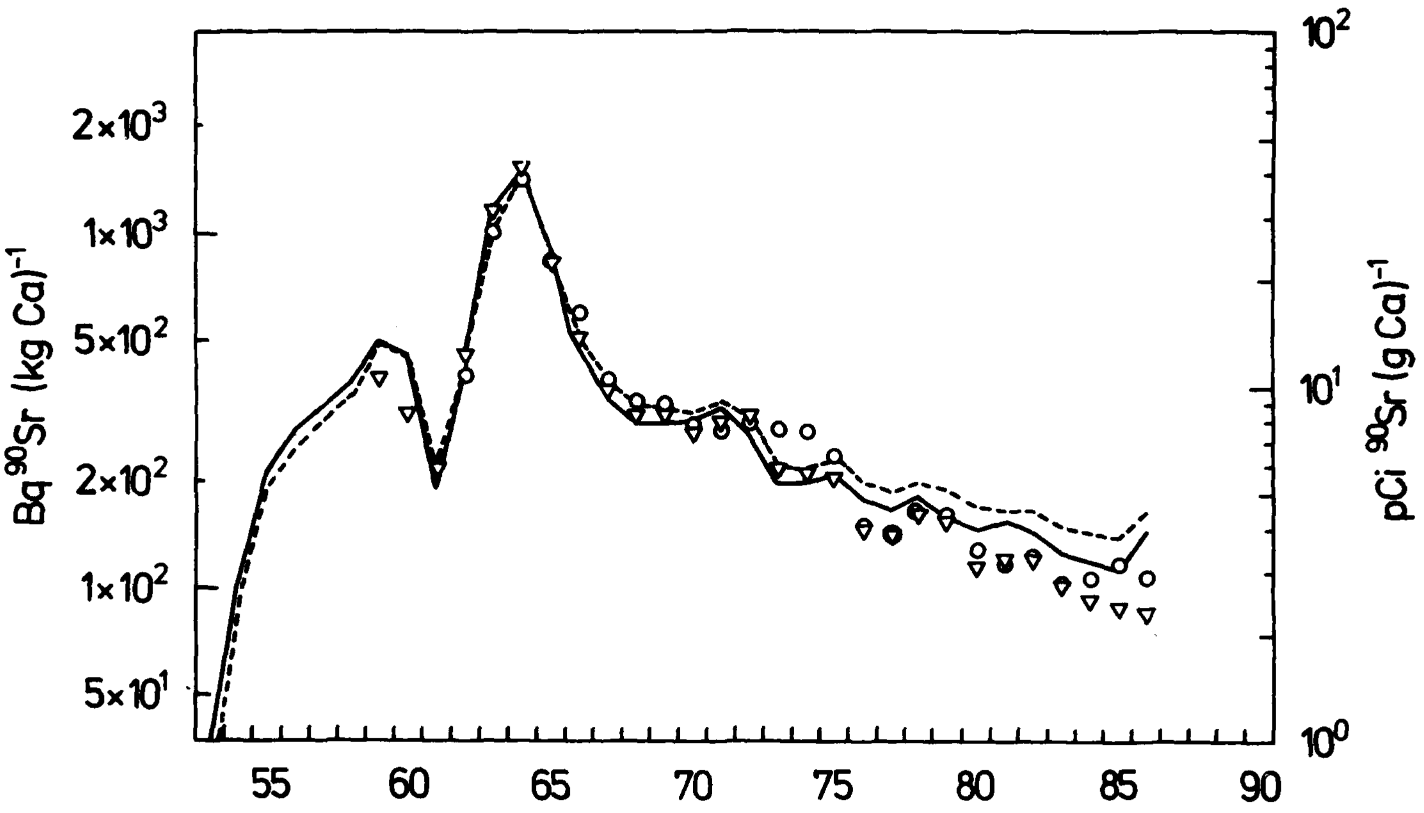

Fig. 5.7.1. Predicted and observed ^{90}Sr levels in the Danish total diet. The dotted curve represents the predicted values for "Diet C" (*cf.* Tables 5.7.1 and 5.7.2) and the circles are the corresponding observed values. The unbroken curve represents the predicted values for "Diet P" (*cf.* Table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

5.8. Radionuclides in meat, fish, eggs and various vegetable foodstuffs

5.8.1. Strontium-90 and radiocesium in meat

Pork and beef samples were collected in Copenhagen in three large shops in March and September. Tables 5.8.1.1 and 5.8.1.2 show the results. Due to the Chernobyl accident meat samples were furthermore collected from all parts of the country in June (Table 5.8.1.3) and from major slaughter houses in August and December (Table 5.8.1.4).

Table 5.8.1.1. Strontium-90 in Danish meat collected in Copenhagen in 1986

	Pork		Beef	
Month	Bq kg^{-1}	Bq (kg Ca)$^{-1}$	Bq kg^{-1}	Bq (kg Ca)$^{-1}$
March	0.005 B	65 B	0.04 B	340 B
Aug	B.D.L.	B.D.L.	0.01 B	95 B

Table 5.8.1.2. Radiocesium in Danish meat collected in Copenhagen in 1986

	Pork			Beef		
Month	Bq kg^{-1}	Bq (kg K)$^{-1}$	$^{134}Cs/^{137}Cs$	Bq kg^{-1}	Bq (kg K)$^{-1}$	$^{134}Cs/^{137}Cs$
March	0.25	73	-	0.159	43	-
Aug	2.0	520	0.61	17.1	4700	0.52

Table 5.8.1.3. Radiocesium in beef and pork collected countrywide in June 1986

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	0.50	147	-	0.17 B	50 B	-
II:	East Jutland	0.50	212	-	0.42 A	140 A	-
III:	West Jutland	0.63	213	0.51 A	0.77	280	0.31 B
IV:	South Jutland	1.38	380	0.40	0.87	250	0.56
V:	Funen	3.7	1240	0.48	0.16 B	50 B	-
VI:	Zealand	0.28±0.04	90	-	0.2 B	74 B	-
VII:	Lolland-Falster	0.81	270	0.63	0.3 A	120 A	-
VIII:	Bornholm	0.43±0.01	132	-	0.53±0.15	173±22	0.50 A
Mean		1.03	340	-	0.43	142	-
Copenhagen		3.15	1040	-	0.2 B	50 B	-

Table 5.8.1.4. Radiocesium and Strontium-90 in combined beef and pork samples from Danish slaughterhouses collected in August and December 1986

Month	Sample	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs (kg K)$^{-1}$	^{134}Cs/^{137}Cs	Bq ^{90}Sr kg^{-1}
August	Beef	5.5	1640	0.50	0.03 B
- " -	Pork	1.42	440	0.47	0.008 B
December	Beef	2.4	780	0.48	
- " -	Pork	0.89	340	0.44	

In order to calculate the mean level of ^{137}Cs in Danish meat in 1986 we use a similar model as that for total diet (cf. 5.7): January-April is for meat represented by March (Table 5.8.1.2), May-July by June (Table 5.8.1.3), August-October by August (Table 5.8.1.4) and November-December by December (Table 5.8.1.4). We assume that the data from August 1986 in Table 5.8.1.4 represent the countrywide mean better than those in Table 5.8.1.2, where the samples were from Copenhagen only.

Hence the mean ^{137}Cs content in Danish beef in 1986 becomes 2.1 Bq kg^{-1} and in pork we get 0.69 Bq ^{137}Cs kg^{-1}. Compared to 1985 the ^{137}Cs level in beef increased by a factor of 7.5 and that in pork by a factor of 3. The difference in increase reflects the differences in the contamination of grass (cow fodder) and grain (pig fodder).

It is evident that it takes a longer time after Chernobyl for the meat to obtain the maximum ^{137}Cs values than for the milk.

The mean ratio between observed and predicted (cf. Appendix C) ^{137}Cs levels in meat was 0.05 and for ^{90}Sr the mean ratio was 0.44.

5.8.2. Radionuclides in fish

Fish samples were collected in the North Sea and in inner Danish waters. Tables 5.8.2 show the results. The mean levels were 0.014 Bq ^{90}Sr kg^{-1} and 4.75 Bq ^{137}Cs kg^{-1}.

Table 5.8.2.1. Strontium-90 and radiocesium in fish (flesh) collected in Danish waters in 1986

Location	Date	Species	Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr $(kg\ Ca)^{-1}$	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs $(kg\ K)^{-1}$	$^{134}Cs/^{137}Cs$	Bone Bq ^{90}Sr $(kg\ Ca)^{-1}$
Hundested (Cattegat,	Sept 30	Cod	0.0021	32	7.9	2000	0.35	23
"	"	Plaice	0.030	31	4.9	1240	0.29	28
"	"	Herring	0.002 B	7 B	3.8	1230	0.26	5.7
"	Nov 7	Cod	0.032	47	4.1	1160	0.27	4.6
"	"	Plaice	0.024	31	7.0	1820	0.26	23
"	"	Herring	0.0031	8.8	3.8	1040	0.27	6.8
Ringkøbing (North Sea)	Oct 7	Cod	0.016	16.4	3.4	840	0.36	11.8
"	"	Plaice	0.0064	14.5	2.3	650	0.34	16.8
"	"	Herring	0.014	34	8.1	2100	0.36	7.1
"	Nov 15	Cod	0.0156	19	4.0	1030	0.28	14
"	"	Plaice	0.0144	30	3.3	940	0.48	14
"	"	Herring	0.0061 A	17	4.4	1380	0.25	-
Mean			0.014	24	4.75	1290	0.31	14

The mean ^{137}Cs content in fish from Cattegat was 1.24 times that in fish from the North Sea, but the contribution from Chernobyl was 74% in the North Sea fish while it was 60% in the fish from Cattegat. Hence the ^{137}Cs concentrations in Cattegat fish became $5.25 \times 0.6 = 3.15$ Bq kg^{-1} and in North Sea fish $4.25 \times 0.74 = 3.15$ Bq kg^{-1}, i.e. the same level. This implies that the mean content of non Chernobyl ^{137}Cs in Danish fish from the autumn of 1986 became 1.6 Bq kg^{-1}, which is half of the 1985 level in fish. The marked reduction in the discharges of ^{137}Cs from Sellafield in the later years have thus reduced the ^{137}Cs concentrations in fish significantly. In 1985 we estimated that 80% of the ^{137}Cs in Danish fish came from non fallout sources, i.e. mostly from Sellafield. In 1986 only 1 Bq ^{137}Cs kg^{-1} fish was from Sellafield and similar sources (e.g. La Hague) this is 27% of the total ^{137}Cs in fish in 1986. In this calculation we assumed that 1/3 of the 1986 consumption of fish was free of Chernobyl ^{137}Cs, i.e. it contained 1.6 Bq ^{137}Cs kg^{-1}, while 2/3 contained 4.75 Bq ^{137}Cs kg^{-1} of which 3.15 Bq kg^{-1} came from Chernobyl.

We also followed the monthly radiocesium concentrations in eels caught in the Baltic Sea near Oscarshamn in Sweden in 1986 (Table 5.8.2.2).

The Chernobyl signal was most evident in the sample from July. The Baltic eel samples contained less Chernobyl ^{137}Cs than the fish from the Cattegat and the North Sea (cf. Table 5.8.2.1).

Table 5.8.2.2. Radiocesium in eels from the Baltic Sea (Oscarshamn, Sweden) in 1986

Month	Bq ^{137}Cs kg^{-1}	$^{134}Cs/^{137}Cs$
April 15	1.48	0
June 17	2.3	0.16
June	2.7	0.22
July	3.9	0.33
Aug	3.2	0.21
Sept	3.5	0.18
Oct	3.2	0.28
Nov-Dec	3.1	0.17

5.8.3. Strontium-90 and radiocesium in eggs

Eggs were collected countrywide in September 1986. The ^{90}Sr concentrations were a little lower than in 1985, i.e. not influenced by the Chernobyl accident. The ^{137}Cs concentrations increased by a factor of 3 compared to 1985.

Furthermore we analysed countrywide collected egg samples in August and December. They contained 0.144 and 0.22 Bq ^{137}Cs kg^{-1}, respectively, and the $^{134}Cs/^{137}Cs$ were 0.44 and 0.48.

The observed ^{90}Sr levels in eggs were (cf. Appendix C) 0.46 times those predicted, but the observed ^{137}Cs concentration was 10 times those predicted. This indicates that our prediction model for ^{137}Cs in eggs has significantly underestimated the importance of the deposition of ^{137}Cs in the year when the eggs are produced.

Table 5.8.3. Strontium-90 and radiocesium in Danish eggs collected countrywide in September 1986

Zone		Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr $(kg\ Ca)^{-1}$	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs $(kg\ K)^{-1}$	$^{134}Cs/^{137}Cs$
I:	North Jutland	0.0186	34	0.175	121	0.54
II:	East Jutland	0.0168	31	0.154	100	0.87
III:	West Jutland	0.0169	30	0.181	121	0.53
IV:	South Jutland	0.022	39	0.170	114	0.70
V:	Funen	0.021	39	0.184	127	0.46
VI:	Zealand	0.0157	28	0.21	143	0.32
VII:	Lolland-Falster	0.0128	23	0.111	78	-
VIII:	Bornholm	0.0157	29	0.126	92	0.53 B
Mean		0.0174	32	0.164	112	-
Copenhagen		0.0169	31	0.068	45	-

5.8.4 Strontium-90 and radiocesium in the variety of vegetable food

In the imported vegetable products there was a significant "Chernobyl signal" in hazelnuts and in oranges.

Table 5.8.4. Strontium-90 and radiocesium in various imported vegetable food purchased in Copenhagen in November 1986

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	0.0139	44	0.035	44	-
Oats	0.40	163	0.160	40	-
Hazel nuts	2.5	950	280	40000	0.47
Banana	0.0060	55	0.009 B	2.3 B	-
Orange	0.128	340	0.127	92	0.46
Coffee	0.42	740	0.53	33	-
Tea	0.41	3000	2.8	184	-

5.9. Estimate of the mean contents of ^{90}Sr and radiocesium in the human diet in Denmark in 1986

5.9.1. The annual quantities

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

5.9.2. Milk and cream

The ^{90}Sr and ^{137}Cs contents per kg milk were calculated from the annual mean values for dried milk (cf. Tables 5.1.1 and 5.1.3). 1 kg ~ 1 l milk, containing approximately 1.2 g Ca and 1.66 g K. Hence the mean contents in milk were 0.077 Bq ^{90}Sr kg^{-1} and 1.062 Bq ^{137}Cs kg^{-1}.

5.9.3. Cheese

One kg of cheese contains approximately 8.5 g Ca and 1.2 g K. The ^{90}Sr and ^{137}Cs contents in cheese were calculated from these figures and from the $^{90}Sr/Ca$ and $^{137}Cs/K$ ratios in dried milk (cf. Tables 5.1.1 and 5.1.3). One kg of cheese appeared to contain 0.54 Bq ^{90}Sr and 0.768 Bq ^{137}Cs.

5.9.4. Grain products

Tables 5.9.1 and 5.9.2 show the estimates of ^{90}Sr and ^{137}Cs, respectively, in grain products consumed in 1986. From these tables, the activity levels in grain products were estimated at 0.197 Bq ^{90}Sr kg^{-1} and 1.106 Bq ^{137}Cs kg^{-1}.

Table 5.9.1. Estimate of the ^{90}Sr content in grain products consumed pro capite in 1986

Type	Fraction from harvest 1985			Fraction from harvest 1986			Total Bq
	kg flour	Bq kg^{-1}	Bq	kg flour	Bq kg^{-1}	Bq	
Rye flour 100% extraction	21.9	0.38	8.32	7.3	0.43	3.14	11.46
Wheat flour 75% extraction	32.9	0.06	1.97	10.9	0.084	0.92	2.89
Grits	5.5	0.19	1.04	1.8	0.23	0.41	1.45
Total	60.3	0.19	11.33	20.0	0.22	4.47	15.80

Table 5.9.2. Estimate of the ^{137}Cs content in grain products consumed pro capite in 1986

Type	Fraction from harvest 1985			Fraction from harvest 1986			Total Bq
	kg flour	Bq kg^{-1}	Bq	kg flour	Bq kg^{-1}	Bq	
Rye flour 100% extraction	21.9	0.090	1.97	7.3	11.2	81.76	83.73
Wheat flour 75% extraction	32.9	0.028	0.92	10.9	0.29	3.16	4.08
Grits	5.5	0.061	0.34	1.8	0.37	0.67	1.01
Total	60.3	0.054	3.23	20.0	4.28	85.59	88.82

5.9.5. Potatoes

The figures in Table 5.5.1 were used, i.e. 0.039 Bq ^{90}Sr kg^{-1} and 0.197 Bq ^{137}Cs kg^{-1}.

5.9.6. Vegetables

Table 5.6.15 shows the calculation of ^{90}Sr and ^{137}Cs in Danish vegetables consumed in 1986. The mean contents were 0.25 Bq ^{90}Sr kg^{-1} and 0.167 Bq ^{137}Cs kg^{-1}.

5.9.7. Fruit

The levels in imported fruit in 1986 are assumed to be equal to the mean levels found in oranges and bananas collected in Copenhagen in 1986, i.e. 0.067 Bq ^{90}Sr kg^{-1} and 0.068 Bq ^{137}Cs kg^{-1}. The mean levels in Danish fruit (cf. 5.6) in 1986 were 0.067 Bq ^{90}Sr kg^{-1} and 1.82 Bq ^{137}Cs kg^{-1}. The daily mean consumption of fruit consisted of 100 g of Danish and 40 g of foreign origin. Hence the mean contents in fruit were 0.067 Bq ^{90}Sr kg^{-1} and 1.32 Bq ^{137}Cs kg^{-1}.

5.9.8. Meat

The annual mean values of ^{90}Sr and ^{137}Cs in meat were calculated from 5.8.1: 0.010 Bq ^{90}Sr kg^{-1} and 1.16 Bq ^{137}Cs kg^{-1}. (In a Danish diet meat comprises 2/3 pork and 1/3 beef).

5.9.9. Fish

The ^{90}Sr and ^{137}Cs contents in fish are estimated from 5.8.2 at 0.014 Bq ^{90}Sr kg^{-1} and 4.75 Bq ^{137}Cs kg^{-1}.

5.9.10. Eggs

The contents of activity in eggs were estimated from 5.8.3. The levels were 0.017 Bq ^{90}Sr kg^{-1} and 0.164 Bq ^{137}Cs kg^{-1}.

5.9.11. Coffee and tea

One third of the total consumption consists of tea and two thirds of coffee. We use the mean contents from 1986 (5.8.4): 0.41 Bq ^{90}Sr kg^{-1} and 1.29 Bq ^{137}Cs kg^{-1} 1).

5.9.12. Drinking water

The ^{90}Sr level (population-weighted mean) found in drinking water collected in June 1986 (4.3.3) was used as the mean level for drinking water, i.e. $0.29 \cdot 10^{-3}$ Bq ^{90}Sr kg^{-1}. The ^{137}Cs content in drinking water was measured to $0.62 \cdot 10^{-3}$ Bq kg^{-1}.

5.9.13. Discussion

Tables 5.9.3 and 5.9.4 show the estimates of ^{90}Sr and ^{137}Cs in the Danish diet in 1986. The figures should be compared with

Table 5.9.3. Estimate of the mean content of ^{90}Sr in the human diet in 1986

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	0.077	12.63	23.5
Cheese	9.1	0.54	4.91	9.1
Grain products	80.3	0.197	15.80	29.3
Potatoes	73.0	0.039	2.85	5.3
Vegetables	43.8	0.25	10.95	20.3
Fruit	51.1	0.067	3.42	6.3
Meat	54.7	0.010	0.55	1.0
Eggs	10.9	0.017	0.19	0.4
Fish	10.9	0.014	0.15	0.3
Coffee and tea	5.5	0.41	2.26	4.2
Drinking water	548	0.0003	0.16	0.3
Total			53.87	

The mean Ca intake was estimated at 0.62 kg y^{-1} (approx. 0.2-0.25 kg creta praeparata). Hence the ^{90}Sr/Ca ratio in total diet was 87 Bq ^{90}Sr (kg Ca)$^{-1}$ (2.3 S.U.) in 1986.

Table 5.9.4. Estimate of the mean content of ^{137}Cs in the human diet in 1986

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	1.062	174.17	36.0
Cheese	9.1	0.768	6.99	1.4
Grain products	80.3	1.106	88.82	18.4
Potatoes	73.0	0.197	14.38	3.0
Vegetables	43.8	0.167	7.31	1.5
Fruit	51.1	1.32	67.45	13.9
Meat	54.7	1.16	63.45	13.1
Eggs	10.9	0.164	1.79	0.4
Fish	10.9	4.75	51.78	10.7
Coffee and tea	5.5	1.29	7.10	1.5
Drinking water	548	0.0006	0.33	0.1
Total			483.57	

As the approximate intake of potassium was 1.365 kg y^{-1} the $^{137}Cs/K$ ratios were 354 Bq ^{137}Cs (kg K)$^{-1}$ or 9.6 M.U. in 1986.

the levels calculated from the total-diet samples (cf. 5.7). The ^{90}Sr estimates obtained by the two methods (cf. also fig. 5.7.1) were 87 Bq (kg Ca)$^{-1}$ and 109 Bq (kg Ca)$^{-1}$, respectively, or 0.15 and 0.16 Bq ^{90}Sr (day)$^{-1}$, and the ^{137}Cs estimates were 1.32 Bq ^{137}Cs (day)$^{-1}$ and 1.45 Bq ^{137}Cs (day)$^{-1}$.

The ratio between observed and predicted (cf. Appendix C) diet levels was 0.59 for ^{90}Sr and 0.17 for ^{137}Cs.

The relative contribution of ^{90}Sr from milk products (32%) was nearly similar to those in 1978-1985. The contribution from potatoes, other vegetables, and fruit was 32%, and that from cereals was 29%. The relative contribution of ^{137}Cs in the total diet changed from 1985 to 1986 as follows: milk products

(16 to 37%), grain products increased from 8 to 18%, and meat decreased (16 to 13%). Fruit increased from 1 to 14% and was thus the diet group which was relatively most influenced by the Chernobyl debris. Fish contributed 11% to the total ^{137}Cs intake in 1986.

5.10. Grass and fodder samples

5.10.1. Grass collected around Risø

Table 5.10.1.1 shows the ^{90}Sr content in grass ash from Zealand in 1986. The mean ^{90}Sr activity was 27 Bq ^{90}Sr (kg ash)$^{-1}$, or 460 Bq ^{90}Sr (kg Ca)$^{-1}$, i.e. the 1986 level was approximately 30% higher than 1985 level. Figure 5.10.1 shows the ^{90}Sr concentration in grass since 1957. The ratio between observed and predicted (cf. Appendix C.1) ^{90}Sr level in grass in 1986 was 0.32.

In Table 5.10.1.2 the ^{90}Sr levels in grass collected weekly at Risø since Chernobyl are shown. The samples were combined to monthly samples for June-September before analysis. In the sample collected on April 28, the $^{89}Sr/^{90}Sr$ was determined. In the air sample from this date the ratio was 19.7 and from this we estimate that 1/3 of the ^{90}Sr in the grass was from Chernobyl.

Table 5.10.1.1. Strontium-90 in grass from Zealand, 1986

Periods	Bq ^{90}Sr (kg ash)$^{-1}$	Bq ^{90}Sr (kg Ca)$^{-1}$
Jan-March	11.9	370
April-June	20.8	460
July-Sept	45	540
Oct-Dec	29	480
Mean	27	460

A number of grass samples were collected around Risø on April 28 when the Chernobyl debris was detected. Table 5.10.1.3 shows radionuclide ratios (relative to ^{137}Cs) in 3 of these samples. The ratios were in general higher than those seen in the Risø air filter from 28 April. This may indicate that ^{137}Cs was not retained as efficiently as the other radionuclides by the grass. In case of radioiodine it may furthermore be because iodine is not retained by the air filter to the same extent as by the grass. The variations in ratios between the 3 grass samples indicate that the debris has been of an inhomogeneous composition.

Figure 5.10.2 shows the variation of the ^{137}Cs in Risø grass since Chernobyl. In May we see a steep decrease due to growth dilution but also to some extent influenced by the wash off by rain showers. From June 1986 to March 1987 the levels were rather constant around 10 Bq ^{137}Cs kg^{-1} fresh weight, since May 1987 the levels have decreased to about 0.5-1 Bq ^{137}Cs kg $^{-1}$.

Table 5.10.1.2. Radiostrontium in grass samples collected at Risø after the Chernobyl accident in 1986

Date		Bq ^{90}Sr kg^{-1} fresh w.	Bq ^{90}Sr (kg Ca)$^{-1}$	$^{89}Sr/^{90}Sr$
April 28	1986	4.2	810	6.5
Maj 5	-	1.59	780	
June	-	1.24	720	
July	-	1.27	490	
Aug	-	1.48	450	
Sep	-	1.15	350	

Table 5.10.1.3. Radionuclide ratios relative to Cs-137 in grass collected around Risø April 28, 1986

		^{95}Zr	^{95}Nb	^{103}Ru	^{131}I	^{132}Te	^{133}I	^{134}Cs	^{140}Ba	^{140}La	^{141}Ce	^{239}Np
Risø	9 a.m.	1.31	1.32	0.79	21	1.61	5.4	0.56	2.0	1.85	1.40	7.0
Vindinge	3 p.m.	1.88	2.03	1.23	44	2.7	17	0.42 A	2.3	2.6	1.58	14
Risø	11 a.m.	5.4	8.7	2.7	42	2.8	16	0.52	5.8	5.7	5.3	29

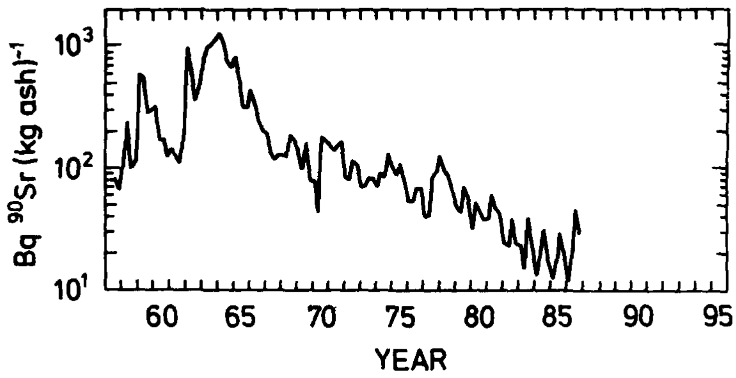

Fig. 5.10.1. Quarterly ^{90}Sr levels in grass, 1957-1586.

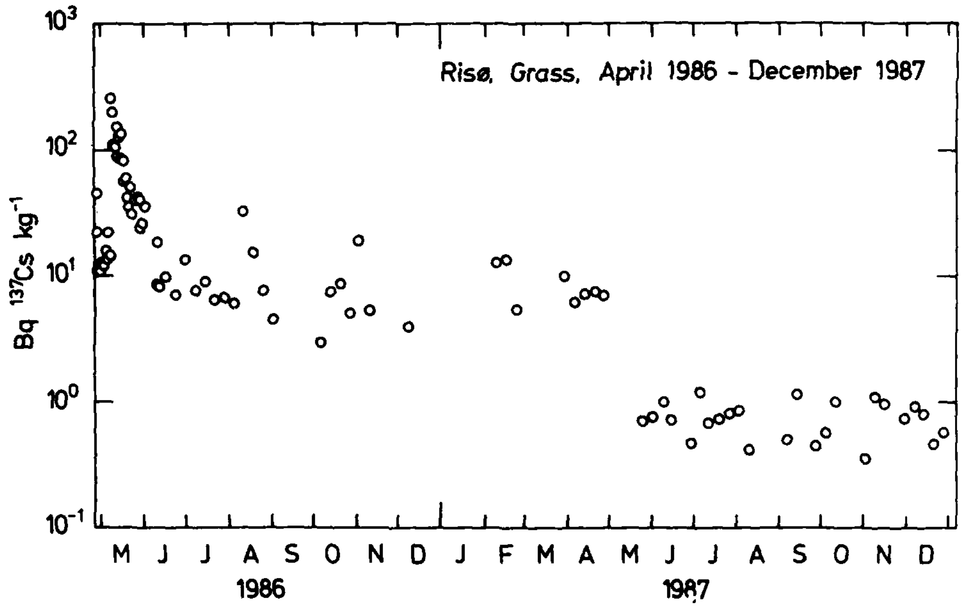

Fig. 5.10.2. Cesium-137 in grass samples collected at Risø, Denmark in the period April 1986-December 1987.

5.10.2. Radionuclides in grass collected at the state experimental farms

Grass samples were collected countrywide 5 times after the Chernobyl accident at the 10 state experimental farms (Tables 5.10.2 - 5.10.6). From May 12 to September 8 the ^{137}Cs levels in grass decreased by two orders of magnitude at the state experimental farms. This is another picture than seen in the Risø samples. The explanation is that the Risø grass samples are from a permanent grass field which is not grazed by cows, which is the case for the state experimental farm samples. If all ^{137}Cs had been deposited on May 12 the field loss seen for ^{137}Cs at the state experimental farms would have corresponded to a half-life of 18 days. This is, however, an overestimate because deposition of ^{137}Cs on grass also occurred after May 12. In a similar way the effective half-life of ^{131}I was estimated to 4.8 days corresponding to a field loss half-life of 12 days ($\frac{1}{8} + \frac{1}{12} = \frac{1}{4.8}$) but that was for the period May 12-June 11. If the field loss half-life for ^{137}Cs for this period was calculated it became only 8.6 days. Hence we see an increasing field loss half-life for ^{137}Cs with time. This was to be expected due to the decreasing growth of the grass with time and thus a reduced growth dilution with time.

If we compare the radionuclide ratios in Table 5.10.6 with those in Table 5.10.5 after having corrected for decay, we notice that all ratios except the $^{131}I/^{137}Cs$ agrees. In case of this ratio we found in June twice of that expected from the May ratio. We see two possible explanations for this. First, the field loss from grass of iodine may be less than that of ^{137}Cs and the other radionuclides studied (cf. Table 5.6.17). Secondly, some of the iodine deposited on the soil may be volatized and thus be transferred to the grass (once more).

In samples containing radiostrontium from Chernobyl only, the $^{89}Sr/^{90}Sr$ on 26 April 1986 was determined to 16.8 ± 2.5 (N = 4; ± 1 S.D.)[20]. In Table 5.10.4 the mean ratios in countrywide collected grass samples were determined. From this we calculate that approx. 40% of the ^{90}Sr in grass collected from 29/4-9/5 was from Chernobyl. Around June 11 30% was from Chernobyl and

Table 5.10.2. Radiocesium in grass collected at the State experimental farms in 1986 (fresh weight samples)

Location	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs m^{-2}	$^{134}Cs/^{137}Cs$	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs m^{-2}	$^{134}Cs/^{137}Cs$	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs m^{-2}	$^{134}Cs/^{137}Cs$	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs m^{-2}	$^{134}Cs/^{137}Cs$	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs m^{-2}	$^{134}Cs/^{137}Cs$
Tylstrup	3.0 (29/4)	1.36	0.55	3.3 B (5/5)	1.8 B	-	153 (12/5)	110	0.53	7.8 (11/6)	10.3	0.56	0.95 (8/9)	0.76	0.38
Kalø	<5 B (29/4)	<2 B	-	17.5 B (5/5)	1.4 B	-	164 (12/5)	16.9	0.61	24 (11/6)	30	0.55	1.38 (8/9)	0.81	0.54
Borris	B.D.L. (30/4)	B.D.L.	-	380 (6/5)	400	0.57	125 (12/5)	38	0.58	19.2 (10/6)	12.5	0.54	4.5 (9/9)	1.30	0.36
Askov	B.D.L. (1/5)	B.D.L.	-	2300 (5/5)	1650	0.55	620 (12/5)	310	0.57	18.4 (10/6)	13.9	0.55	5.3 (9/9)	1.86	0.35
St. Jyndevad	B.D.L. (1/5)	B.D.L.	-	220 (6/5)	87	0.58	83 (12/5)	32	0.61	22 (10/6)	14.5	0.57	5.6 (10/9)	2.1	0.51
Årslev	B.D.L. (1/5)	B.D.L.	-	670 (5/5)	132	0.56	270 (12/5)	150	0.56	18.3 (10/6)	19.7	0.55	1.95 (10/9)	0.55	0.55
Tystofte	4 A (2/5)	0.87 A	-	12.6 (5/5)	3.2	0.52 A	135 (12/5)	-	0.61	9.8 (13/6)	13.9	0.60	1.47 (8/9)	0.91	0.58
Ledreborg	9.7 A (2/5)	3.3 A	-	290 (8/5)	150	0.59	80 (12/5)	35	0.56	2.8 (16/6)	3.6	0.60	0.61 A (8/9)	0.52 A	-
Abed	4.2 (2/5)	1.09	0.55 A	340 (6/5)	33	0.55	550 (12/5)	280	0.57	8.0 (12/6)	5.7	0.52	0.49 (11/9)	0.193	-
Tornbygård	- (-)	-	-	35 (7/5)	18	0.50	137 (12/5)	100	0.53	- (-)	-	-	0.88 (2/9)	0.26	-
Mean	5.4	1.72	0.55	430	250	0.55	230	119	0.57	14.5	13.8	0.56	2.3	0.93	0.47
S.D.	2.7	0.98	0	690	510	0.03	194	109	0.03	7.5	7.8	0.03	2.0	0.64	0.10
N	5	5	2	10	10	8	10	9	10	9	9	9	10	10	7

Table 5.10.3. Iodine-131 in grass collected at the State experimental farms in 1986 ($^{132}I/^{131}I$) (fresh weight samples)

Location	Date	Bq kg^{-1}	Bq m^{-2}	Date	Bq kg^{-1}	Bq m^{-2}	Date	Bq kg^{-1}	Bq m^{-2}	Date	Bq kg^{-1}	Bq m^{-2}
Tylstrup	29/4 (0.06 A)	48	22	5/5 (0.04)	195	103	12/5	200	146	11/6	1.5 B	1.9 B
Kalø	29/4	59	22	5/5	630	49	12/5	220	22	11/6	2.5 A	3.1 A
Borris	30/4	4 B	2 B	6/5	760	800	12/5	220	69	10/6	3.6 A	2.4 A
Askov	1/5	5 B	2 B	5/5	3800	2800	12/5	560	280	10/6	-	-
St. Jyndevad	1/5	6 B	2 B	6/5	390	151	12/5	97	37	10/6	4.3	2.9
Årslev	1/5	9.4	1.71	5/5 (0.79)	2100	410	12/5	187	103	10/6	3.7	4.0
Tystofte	2/5	61	13.5	5/5	470	119	12/5	121	-	13/6	1.8 A	2.6 A
Ledreborg	2/5 (0.11)	210	70	8/5	860	450	12/5	117	51	16/6	0.9 A	1.1 A
Abed	2/5	18.6	4.7	6/5	1180	113	12/5	960	480	12/6	2.4 A	1.7 A
Tornbygård	-	-	-	7/5	570	290	12/5	260	190	-	-	-
Mean		47	16		1100	530		290	153		2.6	2.5
S.D.		66	22		1090	830		270	148		1.2	0.9
N		9	9		10	10		10	9		8	8

Figures in brackets is the $^{132}I/^{131}I$ ratio.

Table 5.10.4. Radiostrontium in grass collected at the State experimental farms in 1986
(Fresh weight samples) ($^{89}Sr/^{90}Sr$ decay corrected to April 26, 1986)

Location	Date ($^{89}Sr/^{90}Sr$)	Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr m^{-2}	Bq ^{90}Sr $(kg\ Ca)^{-1}$	Date ($^{89}Sr/^{90}Sr$)	Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr m^{-2}	Bq ^{90}Sr $(kg\ Ca)^{-1}$	Date ($^{89}Sr/^{90}Sr$)	Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr m^{-2}	Bq ^{90}Sr $(kg\ Ca)^{-1}$
Tylstrup	29/4 (3.7)	0.67	0.30	560	11/6 (1.9)	0.90	1.18	1090	8/9	0.96	0.77	910
Kalø	29/4 (0.5)	0.62	0.24	1140	11/6	1.79	2.3	1880	8/9	0.79	0.47	480
Borris	30/4 (0.3)	0.46	0.26	580	10/6 (6.2)	1.89	1.23	3200	9/9	1.61	0.46	1150
Askov	1/5	0.70	0.27	490	10/6 (7.1)	2.7	2.1	3100	9/9 (0.7 B)	2.6	0.90	1960
St. Jyndevad	1/5	4.0	1.08	3100	10/6 (3.7)	2.7	1.82	2500	10/9	1.57	0.59	1660
Årslev	1/5 (12.6)	0.44	0.080	260	10/6 (6.8)	2.4	2.6	2400	10/9 (5.0 B)	1.20	0.34	570
Tystofte	2/5 (2.8)	0.62	0.136	182	13/6 (3.0)	1.04	1.49	1040	8/9 (2.3 B)	0.54	0.33	530
Ledreborg	2/5	2.1	0.69	1070	16/6	0.50	0.65	520	8/9 (4.5 B)	0.36	0.31	300
Abed	2/5 (9.2)	1.01	0.26	390	12/6 (4.6)	0.43	0.30	440	11/9 (4.6 B)	0.34	0.134	430
Tornbygård	9/5 (14.3)	2.4	1.22	3400	-	-	-	-	2/9	0.74	0.21	470
Mean	(7.2)	1.30	0.45	1120	(4.8)	1.59	1.52	1800	(3.4)	1.07	0.45	850
S.D.	(5.7)	1.17	0.40	1170	(2.0)	0.91	0.76	1070	(1.9)	0.70	0.24	570
N	(6)	10	10	10	(7)	9	9	9	(5)	10	10	10

Table 5.10.5. Radionuclide ratios (relative to ^{137}Cs) in grass collected May 12, 1986 at the State experimental farms.

	^{95}Zr	^{95}Nb	^{103}Ru	^{106}Ru	^{131}I	^{132}I	^{134}Cs	^{136}Cs	^{140}Ba	^{140}La	^{141}Ce	^{144}Ce
Tylstrup	0.24	0.26	1.77	0.80	1.33	0.26	0.52	-	0.75	0.77	0.26	0.33A
Kalø	-	0.12A	1.85	-	1.33	0.29	0.61	-	0.80A	0.97	0.13B	-
Borris	-	0.17	2.4	0.91B	1.79	0.50	0.58	-	0.89	1.15	0.12A	-
Askov	0.14	0.18	1.47	-	0.90	0.21	0.57	0.12	0.96	1.12	0.21	-
St. Jyndevad	0.28	0.36	3.4	-	1.17	0.30	0.61	0.18A	-	1.35	0.43	-
Årslev	0.07A	0.08	2.2	-	0.69	0.31	0.56	0.13	0.86	0.92	0.13	-
Tystofte	-	0.05A	1.59	-	0.89	0.15	0.61	0.12	0.55	0.61	-	-
Ledreborg	0.10B	0.22	2.7	1.13A	1.47	0.23	0.56	-	0.76	0.70	-	-
Abed	0.25	0.30	1.92	0.60	1.74	0.29	0.57	0.12	0.74	0.79	0.24	0.25A
Tornbygård	0.52	0.58	2.6	1.19	1.91	0.52	0.53	0.12A	0.67	0.63	0.32	0.39A
Mean	0.23	0.23	2.2	0.93	1.32	0.31	0.57	0.13	0.78	0.90	0.23	0.32
S.D.	0.15	0.16	0.59	0.24	0.41	0.12	0.03	0.02	0.12	0.25	0.11	0.07
n	65%	68%	27%	26%	31%	38%	6%	18%	16%	27%	47%	22%
N	7	10	10	5	10	10	10	7	9	10	8	3

Table 5.10.6. Radionuclide ratios (relative to ^{137}Cs) in grass collected around June 11, 1986 at the State experimental farms.

	Date	^{95}Zr	^{95}Nb	^{103}Ru	^{106}Ru	^{131}I	^{134}Cs	^{140}Ba	^{140}La	^{141}Ce	^{144}Ce
Tylstrup	11/6	-	-	0.79	-	0.19B	0.56	-	-	-	-
Kalø	11/6	0.04B	0.06	1.104	0.61	0.10A	0.55	-	0.15	0.06A	-
Borris	10/6	-	-	0.91	0.41A	0.19A	0.54	0.29A	0.12	-	-
Askov	10/6	-	-	1.31	-	-	0.55	-	-	-	-
St. Jyndevad	10/6	0.09A	0.13	1.62	0.83	0.20	0.57	-	0.14	0.06B	-
Årslev	10/6	0.17	0.25	1.81	0.88	0.20	0.55	-	0.14	0.14	0.25B
Tystofte	13/6	0.64	0.89	1.93	1.23A	0.19A	0.59	-	0.23	0.42	0.76
Ledreborg	16/6	-	-	2.2	-	0.32A	0.60	-	-	-	-
Abed	12/6	0.83	1.25	3.1	1.76	0.29A	0.52	-	-	0.27	0.74A
Mean	11/6	0.35	0.52	1.64	0.95	0.21	0.56	0.29	0.16	0.19	0.58
S.D.		0.36	0.53	0.73	0.48	0.07	0.02	-	0.04	0.15	0.29
rel. S.D.		102%	101%	44%	51%	32%	4%	-	27%	81%	50%
N		5	5	9	6	8	9	1	5	5	3

at the beginning of September 20% of the ^{90}Sr in Danish grass was from Chernobyl. This shows the decreasing contribution of direct contamination and the increasing contribution from root uptake in the course of the growing season for grass.

In the early days of the Chernobyl accident a number of plants other than grass was collected and analysed for radiocesium and ^{131}I (Table 5.10.7). Two samples of stinging nettle were collected before and after the rain came on May 7. The rain reduced the ^{131}I content by 20% but it increased the radiocesium level by a factor of nearly 8. Iodine has thus been deposited to a relatively larger extent by dry deposition than by wet compared with radiocesium.

Table 5.10.8 shows a number of grass samples partly collected along with milk samples in order to study the transfer of ^{131}I from grass to milk (cf. 5.2.4). Three samples of grass were collected at Grevinge from grass fields 1 year, 2 years and 3 years old, respectively. The retention of radioiodine was apparently higher in the 2-year old grass, but the differences between the 3 samples were not greater than 30%.

Table 5.10.7. Radionuclides in various plants collected in the first days after the Chernobyl accident

Sample	Location	Date 1986	Bq ^{131}I		Bq ^{132}I		Bq ^{134}Cs		Bq ^{137}Cs	
			kg^{-1}	m^{-2}	kg^{-1}	m^{-2}	kg^{-1}	m^{-2}	kg^{-1}	m^{-2}
Dandelion	Risø (Zealand)	4/5	530	-	17.8	-	4.5	-	7.8	-
Stinging nettle (before rain)	Roskilde (Zealand)	7/5	670	-			16	-	24	-
Stinging nettle (after 20 mm rain)	Roskilde (Zealand)	7/5	530	-			112	-	200	-
Moss	Stinesminde 56°14'N 9°58'E	12/5	122	3500	-		19.6	570	48	1390
Moss	Dueodde Bornholm	22/5	55	470	-		23	193	46	400
Moss	20 km north of Märkaryd, Sweden	11/5	220	690	-		26	84	71	230
Moss	- " -	20/5	179	890	-		57	280	200	1000
Lichen	- " -	20/5	119	450	-		-	-	81	300

Table 5.10.8. Radionuclides in various grass samples collected in the first days after the Chernobyl accident

Location		Date 1986	Bq ^{131}I kg^{-1}	Bq ^{131}I m^{-2}	Bq ^{132}I kg^{-1}	Bq ^{132}I m^{-2}	Bq ^{134}Cs kg^{-1}	Bq ^{134}Cs m^{-2}	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs m^{-2}	Bq ^{131}I per litre of milk
Grevinge (Zealand)	1 yr crop	3/5	75	20	-	-	-	-	< 4	-	
- " -	2 yr crop	3/5	85	20	4.9A	1.2A	-	-	-	-	
- " -	3 yr crop	3/5	65	15	-	-					
Smidstrupgård Munkebjerg (Zealand)		5/5	700	-	-	-	-	-	24	-	30
Gundsømagle (Zealand)		6/5	475	175	-	-	11.0	4.0	15.3	5.6	88
Søndersted, Tølløse (Zealand)		7/5	750	210	-	-	45	12.6	79	22	32
Hvorvarp Års, (E-Jutland)		6/5	830	-	-	-	152	-	270	-	
Stinesminde 56°14'N 9°58'E		11/5	300	169	-	-	81	46	140	80	7.9
South Halland (Sweden)		4/5	1160	400	49A	17A	51	18	96	33	
7 km west of Svaneke (Bornholm)		22/5	21.5	27			4.0	5.0	6.9	8.8	
Askov (S-Jutland)	5 cm stubbles	27/5	19.9	31			35	54	69	107	
- " -	0 cm stubbles	27/5	36	81			89	200	157	360	

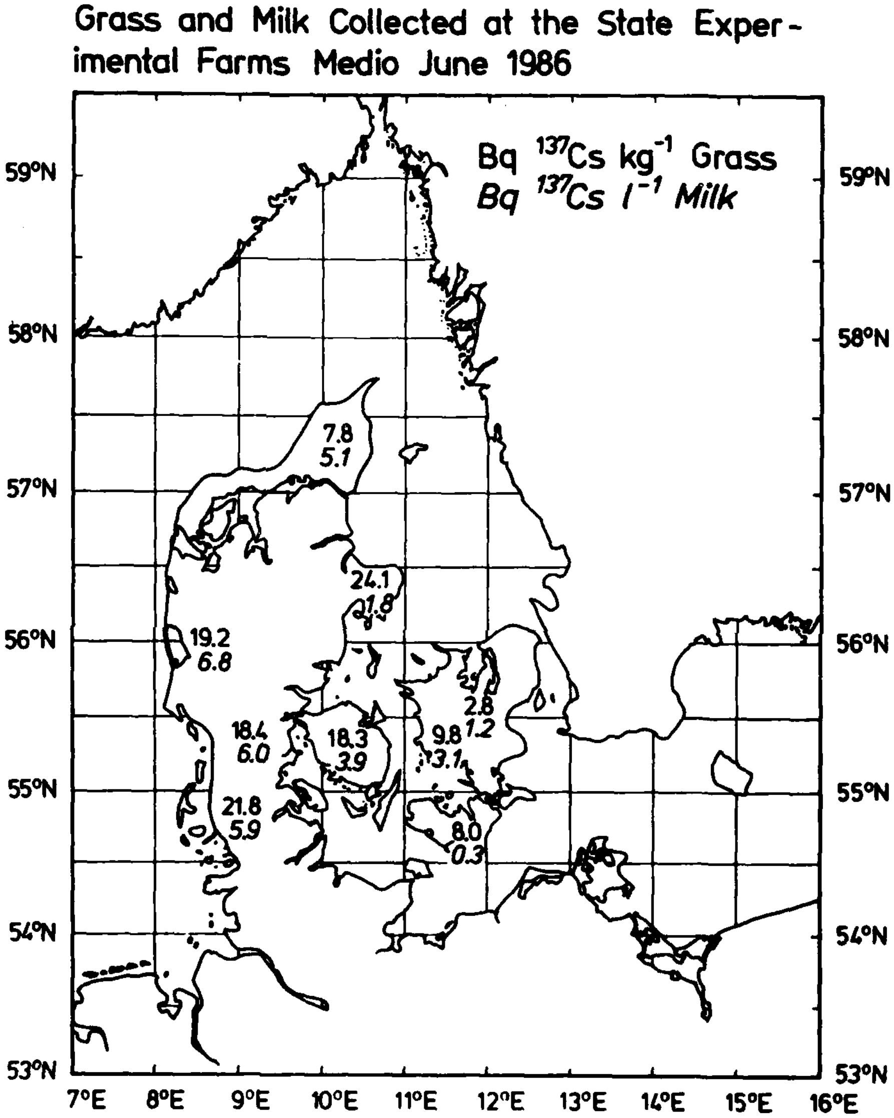

Fig. 5.10.2.1. A comparison between ^{137}Cs in milk and in grass collected at the state experimental frams in Denmark in June 1986.

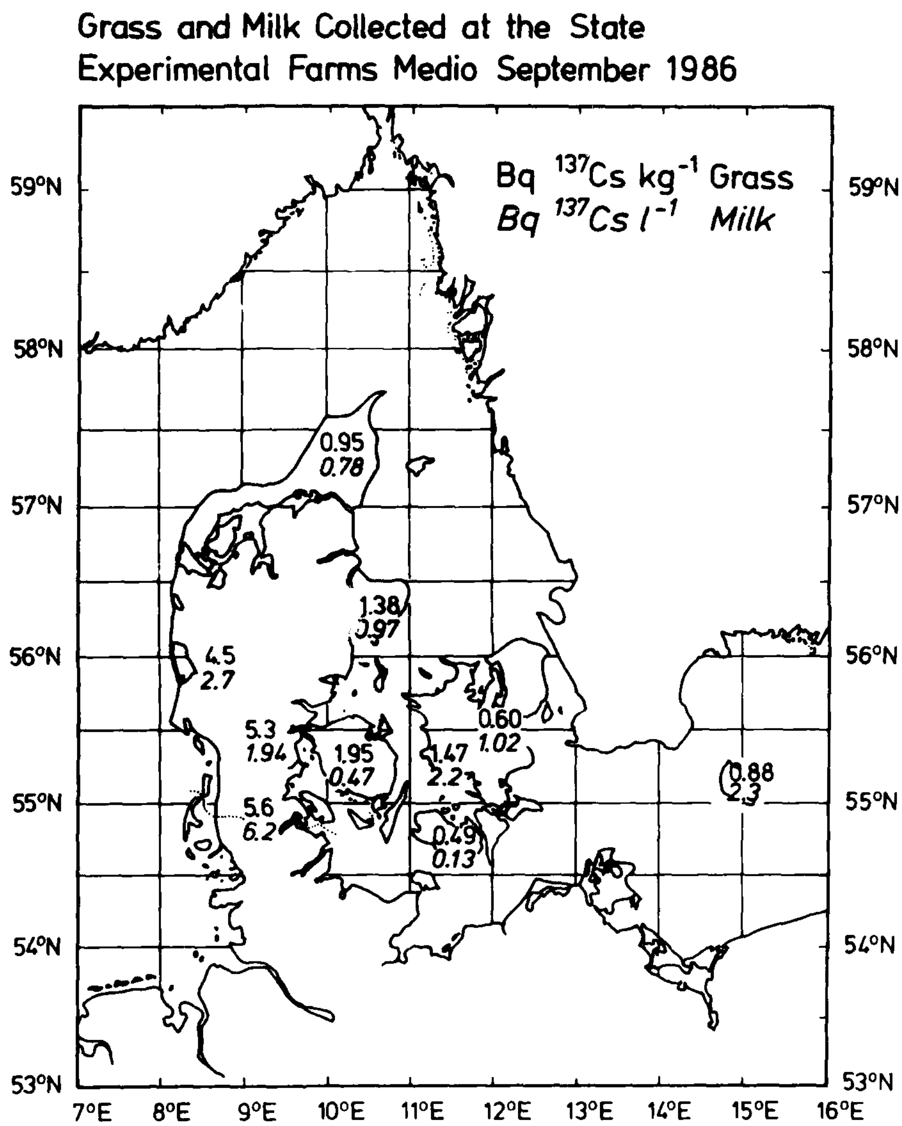

Fig. 5.10.2.2. Cesium-137 in grass and milk collected at the 10 Danish state experimental farms in September 1986.

5.11. Sea plants

5.11.1. Sea plants collected in Roskilde Fjord

Figure 5.11.1 shows the Bq ^{90}Sr (kg Ca)$^{-1}$ levels in sea plants since 1959 and Table 5.11.1 the results for 1986. The mean level in Fucus vesiculosus was 250 Bq ^{90}Sr (kg Ca)$^{-1}$ (7.3 Bq kg^{-1} dry weight). We got no samples of Zostera marina in 1986. The mean ratio between observed and predicted ^{90}Sr levels in fucus was 0.53 (cf. Apendix C.1).

Fucus contained 22 Bq ^{137}Cs kg^{-1} dry weight.

Tabel 5.11.1. Strontium-90 and Cesium-137 in Fucus vesiculosus from Roskilde Fjord in 1986

Location	Date	% dry matter	Bq ^{90}Sr (kg Ca)$^{-1}$	Bq ^{90}Sr kg^{-1} dry weight	Bq ^{137}Cs (kg K)$^{-1}$	Bq ^{137}Cs kg^{-1} dry weight	$\frac{^{134}Cs}{^{137}Cs}$
At Bolund	7/4	17.0	240	3.8	190	6.5	-
- " -	18/6	20*	350	13.8	2500	78	0.48
- " -	2/10	19.5	109	7.3	1500	47	0.44
- " -	15/12	18.0	350	6.6	950	36	0.41
IX	6/6	20*	220	5.9	3400	74	0.52
X	6/6	20*	220	6.5	2800	73	0.51

*Measured on fresh weight. We have used 20% dry matter as the best estimate.

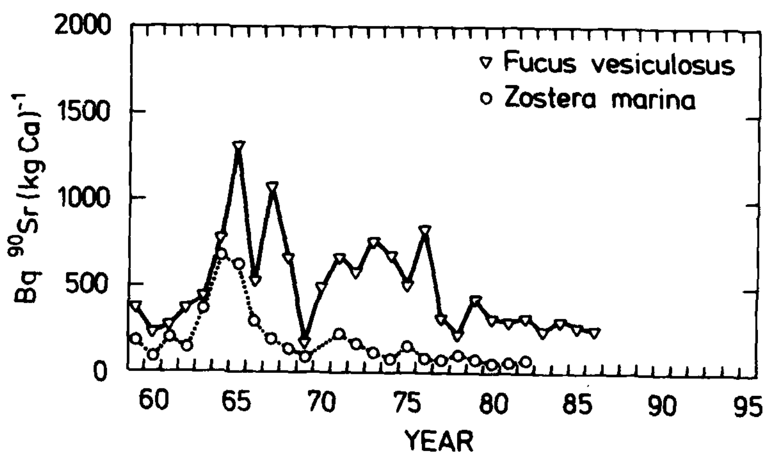

Fig. 5.11.1. Strontium-90 in sea plants from Roskilde fjord, 1959-1986.

5.11.2. Sea plants collected at Klint ($55^{o}58$'N, $11^{o}35$'E)

The two Fucus species most often found in Denmark, Fucus vesiculosus and Fucus serratus, had been collected monthly to test the difference between the two species and to get data of the important seasonal variation. All samples have been analysed for γ-emitting radionuclides (Table 5.11.2).

Fucus serratus contained significantly higher ^{60}Co concentrations than Fucus vesiculosus.

There was no significant difference between the ^{137}Cs levels in the two fucoids.

The Chernobyl fallout increased the radiocesium levels by a factor of five. From June to December the levels decreased again by a factor of two. This is compatible with the decrease seen in surface water in this period. If we look at the ^{110m}Ag/^{134}Cs (Fig. 5.11.2) in fucoids, it seems that this ratio increases from June to December rather than decreases. This may reflect that ^{110m}Ag is accumulated in fucoids without any appreciable excretion, whereas ^{134}Cs has a relatively high excretion. In case of ^{106}Ru/^{134}Cs (Fig. 5.11.3) this ratio may decrease more rapidly than expected from the radiological half-lives of the two isotopes. The reason for this may be that ^{106}Ru disappears relatively more rapidly than radiocesium from the water column due to sedimentation. But it may also be explained by differences in the excretion from fucoids of the two radionuclides.

Table 5.11.2. Radionuclides in Fucus vesiculosus (Fu.ve.) and Fucus serratus (Fu.se.) collected at Klint (55°58'N 11°35'E) in 1986. (Unit: Bq kg^{-1} dry matter)

Species	Date	^{54}Mn	^{60}Co	^{99}Tc	^{137}Cs	$\frac{^{95}Zr}{^{137}Cs}$	$\frac{^{95}Nb}{^{137}Cs}$	$\frac{^{103}Ru}{^{137}Cs}$	$\frac{^{106}Ru}{^{137}Cs}$	$\frac{^{110m}Ag}{^{137}Cs}$	$\frac{^{131}I}{^{137}Cs}$	$\frac{^{125}Sb}{^{137}Cs}$	$\frac{^{134}Cs}{^{137}Cs}$	$\frac{^{140}Ba}{^{137}Cs}$	$\frac{^{140}La}{^{137}Cs}$	$\frac{^{141}Ce}{^{137}Cs}$	$\frac{^{144}Ce}{^{137}Cs}$
Fu.ve.	10/1		2.2		5.8												
Fu.se.	"		2.8		6.3												
Fu.ve.	11/4		1.77		5.5												
Fu.se.	"		2.4		6.3												
Fu.ve.	20/6	1.20	2.1		30	0.09 B	0.50	3.7	2.1	0.53	3.2	0.11 A	0.46	0.62 A	0.63	0.22 A	0.53
Fu.se.	"	1.14 A	2.3		28	0.22	-	4.9	2.9	0.53	4.1	0.07 B	0.47	-	-	0.19 A	0.40
Fu.ve.	15/7	1.48	3.0		29	0.06 A	-	2.1	1.95	0.62	-	-	0.43	-	0.32 B	0.12 A	0.27
Fu.se.	"	1.46	4.4		26	0.10 A	-	2.1	1.69	0.62	-	0.10	0.46	-	0.36 B	0.11 A	0.32
Fu.ve.	12/8	1.27	2.8		33	0.05 B	-	0.64	0.80	0.43	-	-	0.35	-	-	-	0.15 A
Fu.se.	"	1.17	3.4		29	-	-	0.62	0.78	0.35	-	0.05 B	0.37	-	-	0.08 A	-
Fu.ve.	15/9	0.81 A	2.7		19.1	-	-	0.82	1.66	0.57	-	0.09 B	0.43	-	-	-	0.16 A
Fu.se.	"	1.10	4.1		18.5	-	-	0.70	1.50	0.67	-	0.15	0.42	-	-	-	-
Fu.ve.	15/10	0.71 A	2.7		16.7	-	-	0.36	1.36	0.49	-	0.09 A	0.33	-	-	-	-
Fu.se.	"	0.92	3.9		14.8	-	-	0.51	1.56	0.90	-	0.16	0.41	-	-	-	0.23 A
Fu.ve.	14/11	-	-		13.7	-	-	0.20	0.93	0.42	-	-	0.32	-	-	-	-
Fu.se.	"	-	5.3		21	-	-	0.15	0.84	0.40	-	0.10	0.30	-	-	-	-
Fu.ve.	15/12	0.82 B	3.5	141	13.4	-	-	0.11 A	0.84 A	0.44	-	-	0.29	-	-	-	-
Fu.se.	"	0.96	5.8		16.8	-	-	0.11	1.29	0.43	-	0.25	0.41	-	-	-	0.13 A

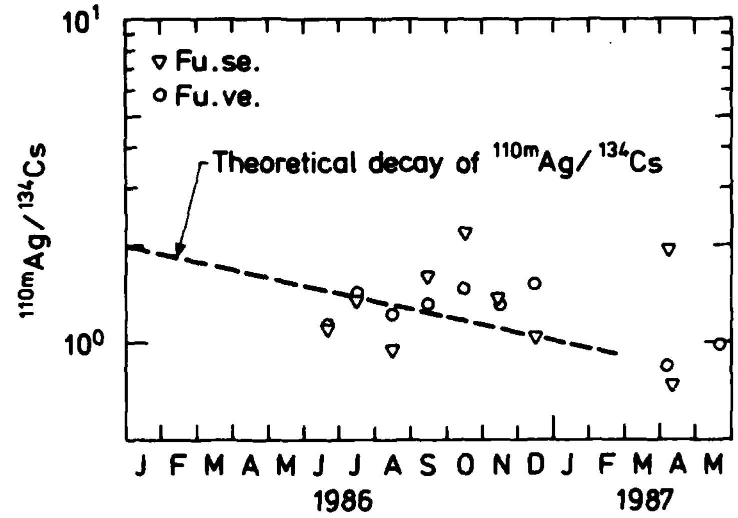

Fig. 5.11.2. The ratio: $^{110m}Ag/^{134}Cs$ in fucoids collected at Klint 1986-1987.

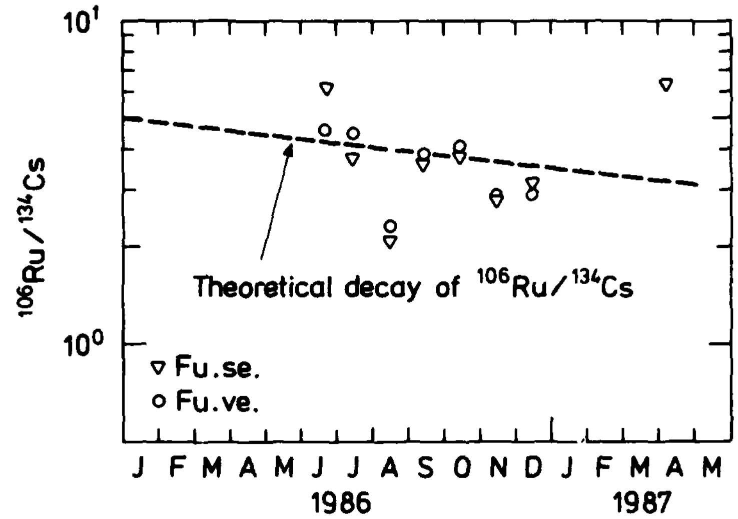

Fig. 5.11.3. The ratio: $^{106}Ru/^{134}Cs$ in fucoids collected at Klint 1986-1987.

5.11.3. Sea plants collected in Danish waters

Apart from the Klint collection, 15 other samples were taken in 1986, which consist of 1 sample of Fucus serratus, and 14 of Fucus vesiculosus. All samples have been analysed for γ-emitters (Table 5.11.3).

Two samples were collected in the very early days of the Chernobyl accident (May 1, 1986). These samples have not attained their maximum ^{137}Cs yet, but they show remarkably high contents of ^{95}Zr, ^{103}Ru, ^{140}La, ^{141}Ce and ^{144}Ce. These nuclides have been deposited as dry fallout but their ratio to ^{137}Cs was much higher in the sea plants than in the air. In fact the observed ratios in fucoids came close to those observed in the sample collected in our 10 m^2 rain collector at Risø on April 29, 1986. Here we found: $^{95}Zr/^{137}Cs = 15$; $^{103}Ru/^{137}Cs = 10$; $^{140}Ba/^{137}Cs = 23$; $^{141}Ce/^{137}Cs = 15$. This may suggest that deposition velocity of the radiocesium on the sea surface was less than that of the other radionuclides. We do not think that it is differences in metabolism which are reflected so shortly after the arrival of the fallout.

Table 5.11.3. Radionuclides in *Fucus vesiculosus* (Fu.ve.) and *Fucus serratus* (Fu.se.) collected at various locations in the inner Danish waters in 1986. (Unit: Bq kg^{-1} dry matter)

Position N	Position E	Location	Species	Date	^{54}Mn	^{60}Co	^{137}Cs	$\frac{^{95}Zr}{^{137}Cs}$	$\frac{^{103}Ru}{^{137}Cs}$	$\frac{^{106}Ru}{^{137}Cs}$	$\frac{^{110m}Ag}{^{137}Cs}$	$\frac{^{131}I}{^{137}Cs}$	$\frac{^{125}Sb}{^{137}Cs}$	$\frac{^{134}Cs}{^{137}Cs}$	$\frac{^{140}La}{^{137}Cs}$	$\frac{^{141}Ce}{^{137}Cs}$	$\frac{^{144}Ce}{^{137}Cs}$
55°05'	15°09'	Svenskehavn	Fu.ve.	22/5	-	-	63	1.79	6.0	2.0	-	-	-	0.49	1.37	1.36	1.59
*56°43'	11°31'	Anholt	Fu.ve.	11/6	-	-	40	0.36	3.7	1.81	-	6.7	-	0.45	0.79	-	-
*57°18'	10°56'	Læsø	Fu.ve.	11/6	-	-	28	-	3.3	-	-	17.6	-	0.51	1.00	-	-
*57°19'	11°08'	Læsø	Fu.ve.	11/6	-	1.9 A	55	-	2.0	1.0	-	2.6	-	0.47	0.31	-	-
*56°12'	11°43'	Hesselø	Fu.ve.	12/6	-	5.0 A	46	-	2.2	2.0	-	8.2	-	0.42	0.71	-	-
* "	"	"	Fu.se.	"	3 B	3.4 B	35	0.39 A	2.0	1.23 A	0.28	10.4	-	0.45	1.38	0.23 A	-
55°35'	12°55'	Limhamn	Fu.ve.	1/5	-	3.6	13.1	8.9	4.2	1.83	-	11.5	-	0.32	10.0	7.7	5.9
"	"	"	Fu.ve.	1/7	3.1 A	3.7	74	0.11 A	2.1	1.36	0.13	-	-	0.48	-	-	0.15 B
"	"	"	Fu.ve.	1/8	4.8	7.6	45	-	0.84	0.98	0.14	-	-	0.40	-	-	-
"	"	"	Fu.ve.	1/11	2.3	11.4	21	-	-	-	0.24	-	-	0.31	-	-	-
57°07'	12°11'	Varberg	Fu.ve.	1/5	-	3.2	8.2	28	19.6	4.0	-	6.2	-	0.22	31	27	17.4
"	"	"	Fu.ve.	1/7	1.6 B	5.1	51	0.84 A	4.9	3.4	0.34	-	-	0.42	-	0.18 A	0.36
"	"	"	Fu.ve.	2/8	2.6 B	5.9	38	-	1.57	1.52 A	0.27	-	-	0.44		0.15 B	0.29 B
"	"	"	Fu.ve.	1/9	-	4.9	22	-	1.90	3.5	0.53	-	-	0.35	-	-	-
54°40'	11°44'	Nysted	Fu.ve.	5/8	-	-	57	-	0.31	0.35 A	0.05 A	-	-	0.41	-	-	-

*Measured on fresh weight. We have used 20% dry matter as the best estimate.

5.12. Moss and lichens

The Chernobyl was as expected easily detectable in moss and lichen samples collected after the accident. It was, however, interesting that in the samples where both top and bottom (the old plants) were collected, it was only the top which showed a significant Chernobyl radiocesium signal; but ^{103}Ru had penetrated into the old layer of lichen at Asserbo (N-Zealand). The average depositions from Chernobyl was 940 ± 122 Bq ^{137}Cs m^{-2} at Asserbo and 1000 ± 130 Bq ^{137}Cs m^{-2} at Oustrup Heath (W-Jutland) (± 1 S.D.; N = 5). These depositions were in agreement with deposition estimates made from soil measurements (Fig. 4.5.1). At Asserbo the total ^{137}Cs deposit (including old global fall-out) was 2800 ± 290 Bq m^{-2} and at Oustrup Heath we found 2300 ± 260 Bq ^{137}Cs m^{-2}; Chernobyl thus contributed with 34% and 43%, respectively, of the total ^{137}Cs at the two locations.

The lichen samples were collected by Ulrik Søchting, Institute of Spore Plants, University of Copenhagen.

Table 5.12. Radionuclides in moss and lichen collected in Denmark in 1986

Sample	Location	Date in 1986	^{90}Sr, Bq m^{-2}	^{137}Cs, Bq m^{-2}	$\frac{^{95}Zr}{^{137}Cs}$	$\frac{^{103}Ru}{^{137}Cs}$	$\frac{^{106}Ru}{^{137}Cs}$	$\frac{^{131}I}{^{137}Cs}$	$\frac{^{134}Cs}{^{137}Cs}$	$\frac{^{140}La}{^{137}Cs}$	$\frac{^{141}Ce}{^{137}Cs}$	$\frac{^{144}Ce}{^{137}Cs}$	kg d.w. m^{-2}		
Moss	Bornholm	May 22	21	450	-	1.88	0.87	1.03	0.50	-	-	-	-		
Moss	Bornholm	Sep 2	-	460	-	0.17	0.36A	-	0.32	-	-	-	0.92		
Lichen	Bornholm	Sep 2	-	680	0.046	0.22	0.33A	-	0.46	-	-	0.18 A	1.05	Cladina Portentosa	
Lichen	Skagen (Jutland)	June 28	8.5	440	0.050	0.56	0.38	-	0.48	0.03A	0.05A	0.11 B	0.93	- " -	
Lichen	Skagen (Jutland)	June 28	-	370	0.095	0.61	0.38	0.03	0.50	0.04	0.06	0.13 A	0.91	- " -	
Top: Lichen*	Asserbo (Zealand)	June 2	26	940	-	0.77	-	-	0.44	-	-	-	2.48	Cladina Portentosa	top
"	"	June 2	-	1030	-	0.96	-	-	0.45	-	-	-	1.81	- " -	"
"	"	June 2	-	1200	-	0.96	0.40A	0.36B	0.45	0.15B	-	-	2.80	- " -	"
"	"	June 2	-	1170	-	0.93	0.41	-	0.47	0.11A	-	-	2.36	- " -	"
"	"	June 2	-	1290	-	0.89	0.33	0.35B	0.44	0.11A	-	-	2.75	- " -	"
Bottom: Lichen*	Asserbo (Zealand)	June 2	-	1440	-	0.21	-	-	-	-	-	-	34.8	- " -	bottom
"	"	June 2	-	1590	-	0.22	-	-	-	-	-	-	18.3	- " -	"
"	"	June 2	-	1660	-	0.25	-	-	-	-	-	-	37.0	- " -	"
"	"	June 2	-	1690	-	0.15	-	-	-	-	-	-	47.5	- " -	"
"	"	June 2	-	1850	-	0.24	-	-	-	-	-	-	52.2	- " -	"
Top: Lichen*	Oustrup Heather (Jutland)	June 28	-	1470	-	0.44	0.30	-	0.42	-	-	-	1.80	- " -	top
"	"	June 28	-	1230	-	0.06A	-	-	0.47	-	-	-	1.63	- " -	"
"	"	June 28	-	1470	-	0.52	-	-	0.35	-	-	-	2.37	- " -	"
"	"	June 28	-	1060	-	0.22	-	-	0.42	-	-	-	1.34	- " -	"
"	"	June 28	-	1020	-	0.64	-	-	0.48	-	-	-	1.10	- " -	"
Bottom: Lichen*	Oustrup Heather (Jutland)	June 28	-	930	-	-	-	-	-	-	-	-	38.6	- " -	bottom
"	"	June 28	-	940	-	-	-	-	-	-	-	-	19.7	- " -	"
"	"	June 28	-	800	-	-	-	-	-	-	-	-	11.6	- " -	"
"	"	June 28	-	890	-	-	-	-	0.06B	-	-	-	9.5	- " -	"
"	"	June 28	-	1620	-	0.21B	-	-	0.19B	-	-	-	10.5	- " -	"

*Collected by Ulrik Søchting, Institut for Sporeplanter, University of Copenhagen.

6. STRONTIUM-90 AND RADIOCESIUM IN MAN IN 1986

6.1. Stronium-90 in human bone (by A. Aarkrog)

The collection of human vertebrae from the institutes of forensic medicine in Copenhagen and Århus was continued in 1986. As in the total-diet survey (cf. 5.7), the country was divided into eight zones. The samples were divided into five age groups: new-born (< 1 month), infants (1 month-4 years), children and teenagers (5-19 years), adults ($\leq$ 29 years), and adults (> 29 years).

Tables 6.1.1-6.1.5 show the results for the five groups. The ^{90}Sr concentrations in human bone collected in 1986 were nearly unchanged from those observed in 1979-1985.

The observed mean concentration in adults ($\geq$ 30 years) was 0.54 times that predicted (cf. Appendix C).

Table 6.1.1. Strontium-90 in vertebrae from new-born children (< 1 month old) in 1986

Zone	Age in days	Month of death	Sex	Bq (kg Ca)$^{-1}$
VI	19	8	M	10.2

Table 6.1.2. Strontium-90 in bone from infants (≤ 4 years) in 1986

Zone	Age in months	Month of death	Sex	Bq (kg Ca)$^{-1}$
I	2	11	M	15 B
I	3	2	M	20 B
I	6	6	M	41
II	2	12	M	91 A
II	2	12	M	15.4
II	2	9	M	150
II	2	10	M	29 A
II	5	12	M	79 B
II	8	7	M	22
II	8	11	M	32 A
II	11	11	M	34
II	40	9	M	22
II	3	7	F	18 A
II	4	12	F	25
II	18	2	F	13.1
III	6	12	M	32
IV	3	11	M	35 A
VI	3	10	M	40
VI	4	11	M	18.1
VI	7	12	M	30 B
VI	3	10	F	47 A

Table 6.1.3. Strontium-90 in bone from children and teenagers (≤ 19 years) in 1986

Zone	Age in years	Month of death	Sex	Bq (kg Ca)$^{-1}$
VI	19	9	M	17.2

Table 6.1.4. Strontium-90 in vertebrae from adults (≤ 29 years) in 1986

Zone	Age in years	Month of death	Sex	Bq (kg Ca)$^{-1}$
II	23	3	M	28
VI	20	10	F	15.4
VI	21	6	F	22
VI	22	5	M	13.4 A
VI	25	6	M	14.0 A
VI	28	6	M	19.3

Table 6.1.5. Strontium-90 in vertebrae from adults (> 29 years) in 1986

Zone	Age in years	Month of death	Sex	Bq (kg Ca)$^{-1}$
I	45	2	M	18.3
I	47	2	M	19.8
I	54	6	M	11.0 A
I	65	3	M	17.4
I	74	7	M	16.3
II	33	6	F	19.3
II	51	3	F	18.3
II	60	3	F	30
II	33	6	M	18.9
II	42	6	M	22
II	44	8	M	17.7
II	45	8	M	20.6
II	48	3	M	25
II	50	6	M	13.2
II	52	7	M	25
II	58	8	M	17.9
II	66	8	M	13.4
II	79	3	M	11.2
III	51	2	F	24
III	37	7	M	18.8
VI	31	5	F	16.9
VI	37	8	F	12 B
VI	39	10	F	21
VI	46	6	F	46 B
VI	49	9	F	18.4

Table 6.1.5. continued

Zone	Age in years	Month of death	Sex	Bq (kg Ca)$^{-1}$
VI	50	8	F	19.9
VI	66	6	F	19.8
VI	70	10	F	2.8
VI	76	10	F	31
VI	31	2	M	15.9
VI	31	11	M	29
VI	33	8	M	15.6
VI	36	5	M	27
VI	37	9	M	25
VI	41	11	M	18.2
VI	44	10	M	54 A
VI	45	6	M	15.4 A
VI	45	6	M	12.6
VI	45	10	M	14.3
VI	45	9	M	34
VI	49	11	M	24
VI	50	9	M	12.8
VI	51	8	M	13.6
VI	52	6	M	16.2
VI	53	6	M	11.0
VI	54	8	M	13.4
VI	57	6	M	31 A
VI	58	6	M	12.5
VI	59	6	M	18.8
VI	59	10	M	18.0 A

Table 6.1.5. continued

Zone	Age in years	Month of death	Sex	Bq (kg Ca)$^{-1}$
VI	61	6	M	14.2
VI	61	6	M	14.3
VI	61	10	M	24
VI	62	8	M	14.3
VI	62	9	M	38
VI	70	8	M	26 B
VI	71	9	M	13.1 A
VI	72	10	M	14.6 A
VI	77	10	M	20 A

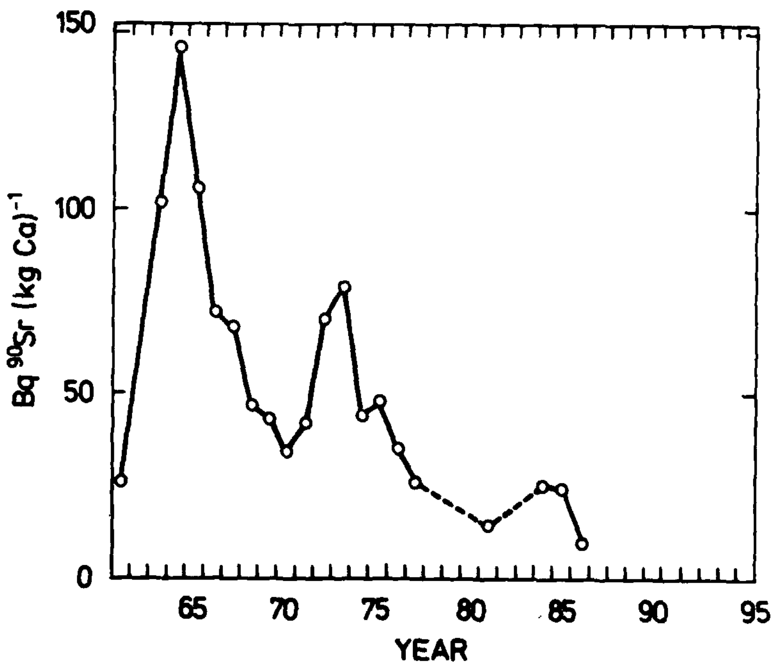

Fig. 6.1.1. Strontium-90 levels (sample number weighted mean) in bone from newborn (< 1 month) 1961-1986.

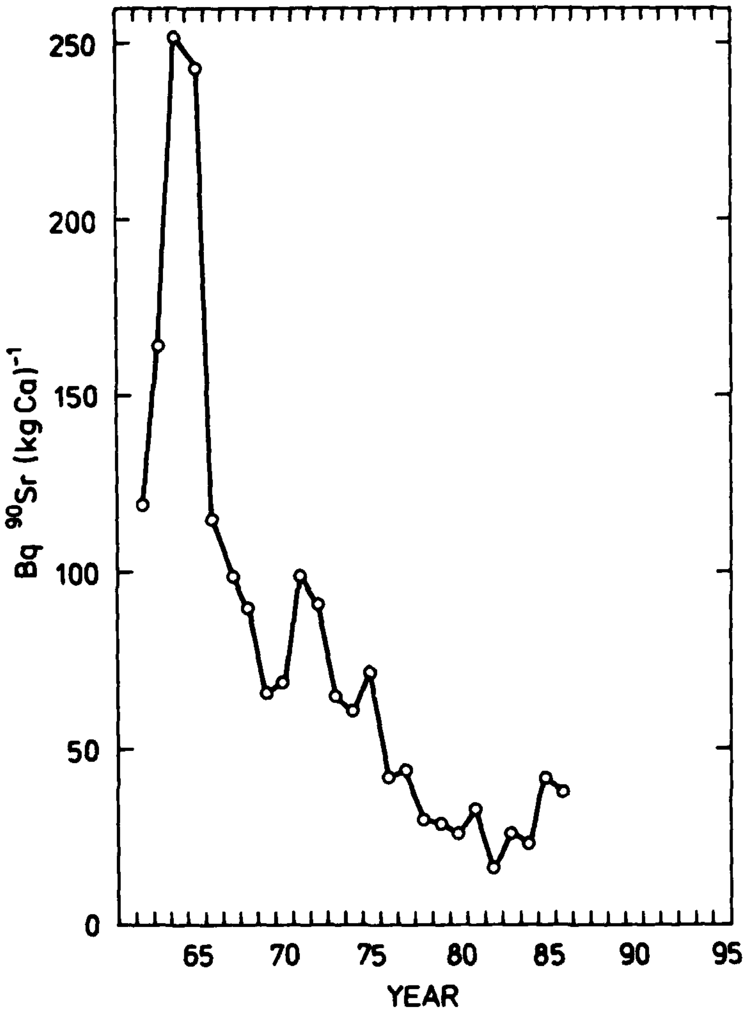

Fig. 6.1.2. Strontium-90 levels (sample number weighted Mean) in bone from infants (> 1 month ≤ 4 years) 196?-1986.

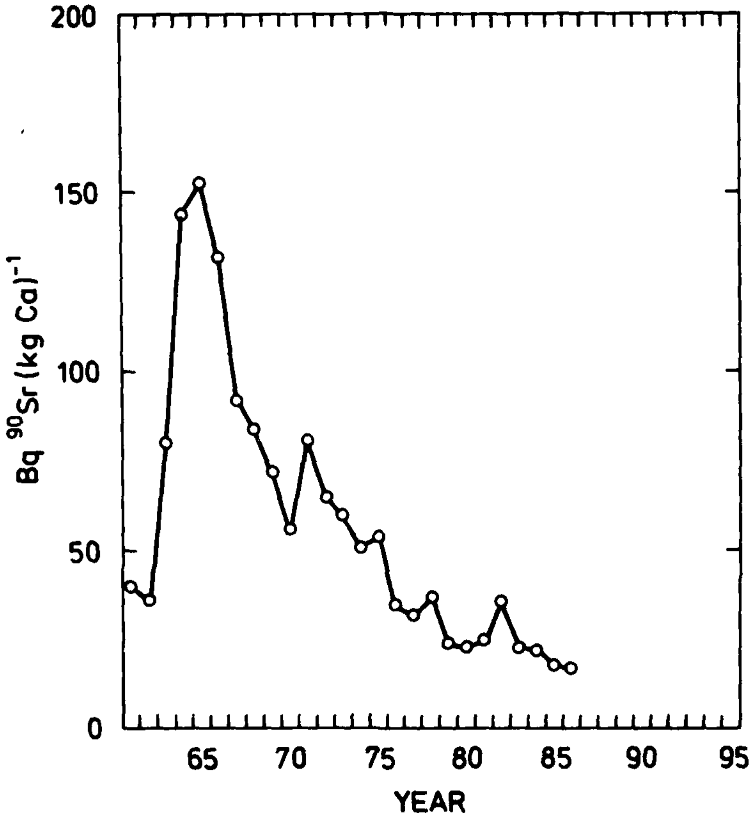

Fig. 6.1.3. Strontium-90 levels (sample number weighted mean) in bone from children (> 4 years ≤ 19 years) 1961-1986.

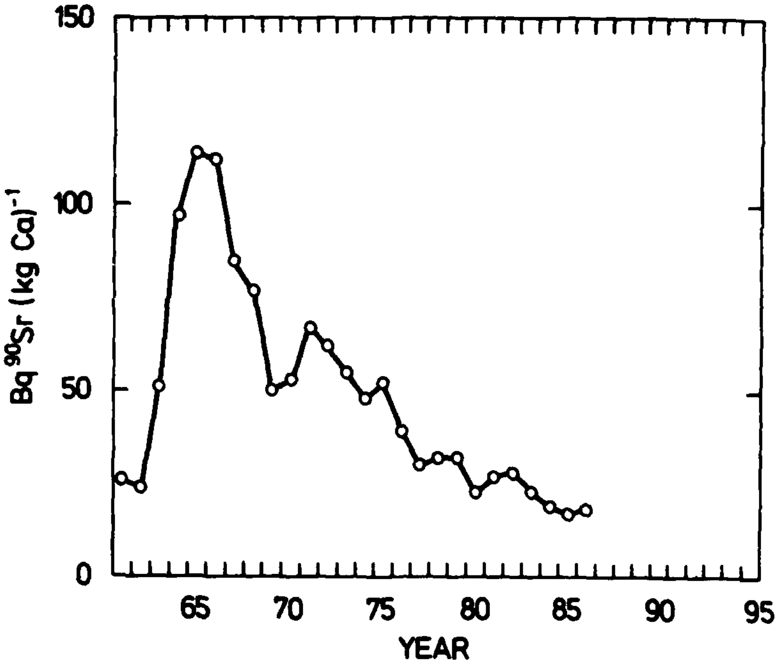

Fig. 6.1.4. Strontium-90 levels (sample number weighted mean) in bone from adults (> 19 years ≤ 29 years) 1961-1986.

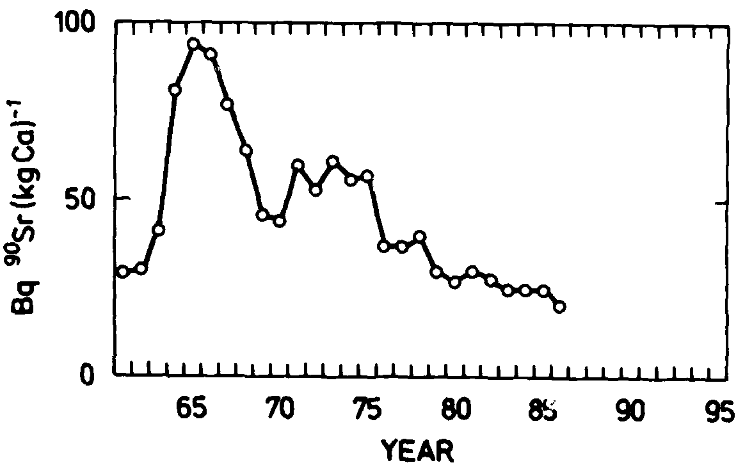

Fig. 6.1.5. Strontium-90 levels (sample number weighted mean) in bone from adults (> 29 years) 1961-1986.

Table 6.1.6. Strontium-90 in human vertebrae collected in Denmark in 1986. (Unit: Bq (kg Ca)$^{-1}$)

Age group	Number of samples	Min.	Max.	Median	Mean
New-born (< 1 month)	1	10.2	10.2	10.2	10.2
Infants (≤ 4 years)	21	13.1	150	30	38
Children (≤ 19 years)	1	17.2	17.2	17.2	17.2
Adults (≤ 29 years)	6	13.4	28	17	18.7
Adults (> 29 years)	59	2.8	54	18.3	20

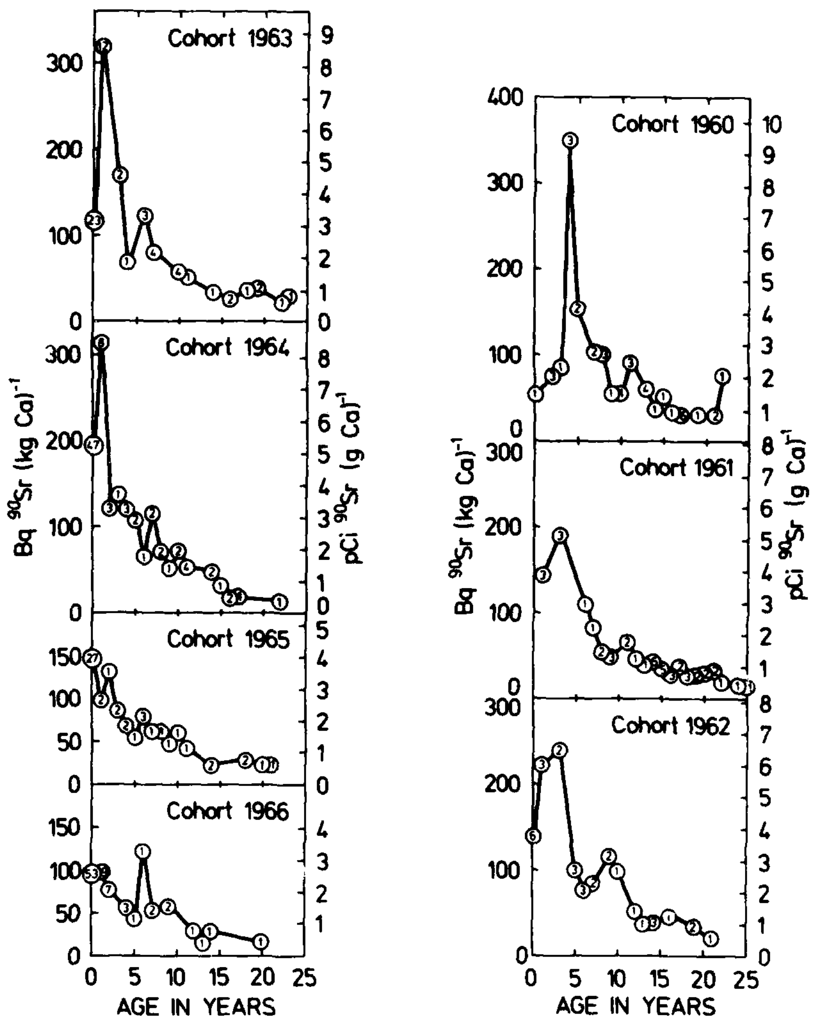

Fig. 6.1.6. Strontium-90 in human bone from Danish cohorts 1960-1966. Abscissa: age in years. Ordinate: bone level in Bq ^{90}Sr (kg Ca)$^{-1}$.

6.2. Radiocesium in the human body (by J. Søgaard-Hansen and B. Lauridsen)

Whole-body measurements were initiated at Risø in July 1963 (cf. 2.3 in Risø Report No. 85[1]). A control group from the Health Physics Department was selected and was measured three times a year.

However, due to the decreasing ^{137}Cs content in the body the contribution from interfering radionuclides to the γ-spectra has made the determination of ^{137}Cs unreliable and since 1978 we have not published whole-body measurements.

After the Chernobyl accident the whole-body measurements were resumed. The control group was essentially the old one but a few newcomers were added so that the group consisted of about 20 persons, among them were a few children.

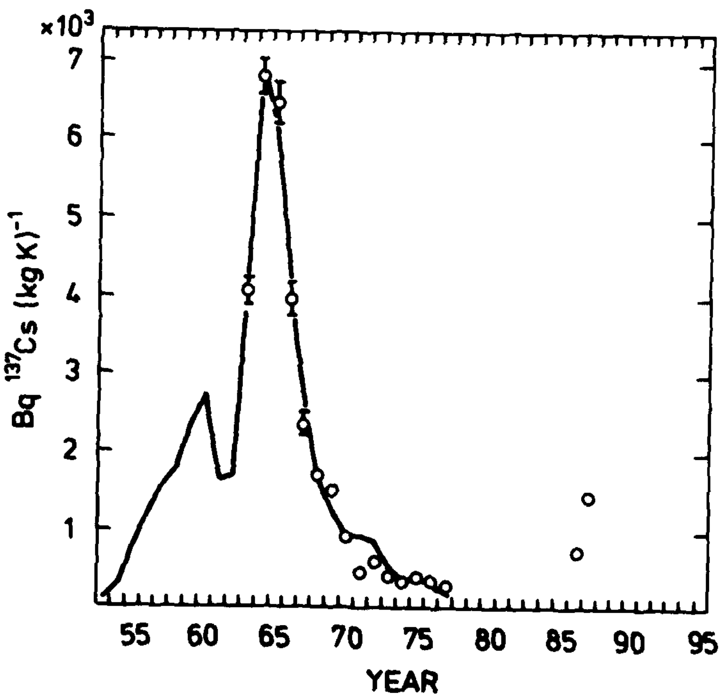

Fig. 6.2.1. A comparison between observed (±1 S.E.) and calculated[21] Bq ^{137}Cs (kg K)-1 levels in persons from the Islands.

In Figure 6.2.2 the monthly mean values of ^{134}Cs + ^{137}Cs body content are shown for men, women and children. The figure furthermore shows the calculated levels based upon the intake of radiocesium with food. In Figure 6.2.2 we omitted those persons in the control group who had been on official travels to countries with relatively high contamination levels. It appears that the calculated levels are in good agreement with those observed. The mean concentration in the period September 1986 - December 1986 was 1410 Bq ^{134}Cs + ^{137}Cs (kg K)$^{-1}$ (relative S.D.: 35%).

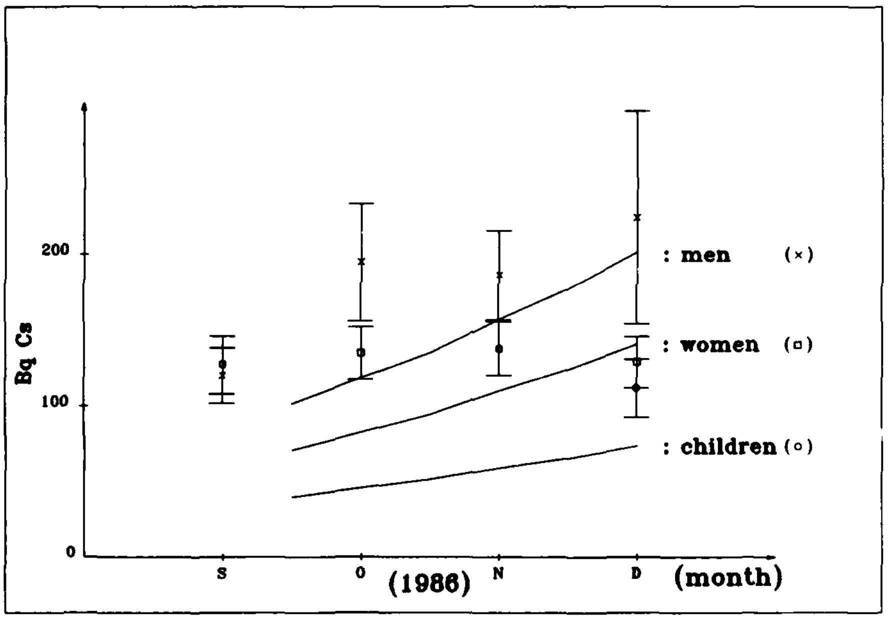

Fig. 6.2.2. Radiocesium in Danish men, women and children from Sealand in 1986-1987. The ^{137}Cs content is approx. 0.7 times the total radiocesium (^{134}Cs + ^{137}Cs). The curves represent the calculated levels based upon diet measurements (cf. Fig. 6.2.1).

Table 6.2. Radiocesium ($^{134+137}Cs$) in humans from Risø and environment measured in 1986

No.	Date	Sex	Age	Bq Cs $(kg\ K)^{-1}$	g K $(kg)^{-1}$
2	9/9 -86	F	43	951	1.85
"	13/10-86	F	"	1661	1.72
"	14/11-86	F	"	1351	1.70
"	9/12-86	F	"	1859	1.63
3	15/9 -86	F	53	1859	1.75
"	14/10-86	F	"	1772	1.95
"	20/11-86	F	"	2107	1.80
"	16/12-86	F	"	1732	1.51
5	11/9 -86	M	36	2442	1.64
6	8/9 -86	M	54	491	1.50
"	21/10-86	M	"	770	1.73
"	19/11-86	M	"	1083	1.65
"	18/12-86	M	"	1480	1.76
7	16/9 -86	F	47	1166	1.35
"	23/10-86	F	"	842	1.48
"	18/11-86	F	"	1174	1.48
"	5/12-86	F	"	1150	1.31
9	9/9 -86	F	58	1568	1.41
"	23/10-86	F	"	1722	1.45
"	11/11-86	F	"	1773	1.58
"	16/12-86	F	"	2139	1.48
11	11/9 -86	F	49	1928	1.28
"	13/10-86	F	"	2340	1.34
"	11/11-86	F	"	2076	1.34
14	16/9 -86	M	44	866	1.84
"	14/10-86	M	"	962	2.01
"	19/11-86	M	"	950	1.82
"	18/12-86	M	"	969	1.82
15	11/9 -86	F	45	883	1.22
"	23/10-86	F	"	1028	1.47
"	12/11-86	F	"	1353	1.35
"	11/12-86	F	"	1290	1.38

Table 6.2. continued

No.	Date	Sex	Age	Bq Cs (kg K)$^{-1}$	g K (kg)$^{-1}$
16	12/9 -86	M	39	838	1.74
17	5/9 -86	M	27	827	2.36
"	15/10-86	M	"	2141	2.07
"	13/11-86	M	"	2011	2.18
"	9/12-86	M	"	2107	2.42
18	11/9 -86	F	50	1204	3.02
"	23/10-86	F	"	1153	1.66
"	18/11-86	F	"	966	1.42
"	17/12-86	F	"	1144	1.35
19	18/9 -86	F	47	915	1.34
"	21/10-86	F	"	1058	1.38
"	20/11-86	F	"	1218	1.42
"	17/12-86	F	"	1120	1.41
20	9/9 -86	M	43	1069	1.48
"	15/10-86	M	"	1385	1.68
"	13/11-86	M	"	1445	1.52
"	16/12-86	M	"	1719	1.60
22	16/12-86	F	5	1120	2.26
24	22/12-86	F	11	1838	1.61
25	22/12-86	M	10	1686	1.58
26	22/12-86	F	7	2401	1.77

Mean*	September 1986	1155	115
Mean	October 1986	1430	140
Mean	November 1986	1505	120
Mean	December 1986	1595	140

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

An approximate estimate of the ^{137}Cs content may be obtained by multiplying the Bq Cs (kg K)$^{-1}$ with 0.7.

6.3. Radionuclides in human milk (by A. Aarkrog)

A few samples of mothers milk were obtained after the Chernobyl accident. Table 6.3 shows the results obtained.

Table 6.3. Radionuclides in human milk collected in Zealand in 1986. Unit: Bq l^{-1}

Date	Location	^{90}Sr	^{131}I	^{137}Cs	$^{134}Cs/^{137}Cs$
May 11	Copenhagen	-	1.86	-	-
July	N-Zealand	0.0027 A	-	0.21	0.59
Nov	Roskilde	-	-	0.64	0.52

Compared with cows milk from Zealand collected in July, the human milk concentrations were 1/5 for ^{137}Cs and 1/15 for ^{90}Sr. The levels in human milk agreed with those expected from diet measurements from Zealand in June, September and December 1986 (cf. Tables 5.7.1-5.7.6). We have earlier found[21] that for a daily production of 1 l human milk, 20-33% of the daily ^{137}Cs intake and 2-3% of the daily ^{90}Sr intake are excreted in the milk.

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[25]. Tritium is also produced and injected into the stratosphere as the result of thermonuclear explosions. At present, this latter source has enhanced the natural inventory by about a factor of ten[25]. Finally, tritium is produced as a by-product of the peaceful uses of atomic energy: it is released both during reactor operation and 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. [1]).

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). Hence we have discarded such results. We have furthermore applied a background correction by subtraction of 1.2 kBq ^3H m^{-3} from our measured values (cf. Appendix E in Risø-R-527[1])).

7.3. Summary of results

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

Tables 4.2.8 and 4.2.9 give the results for precipitation. The annual mean concentrations in rain in 1986 were: 3.2 kBq m^{-3} at Risø, 0.7 at Tylstrup, 1.0 at Jyndevad and 1.2 at Bornholm. The concentrations at Risø were approximately 50% of those observed in 1985, while the tritium levels at the 3 experimental farms were approximately 1.3 times those seen in 1985. The enhanced tritium levels at Risø were due to discharges of the DR-3 reactor at the site. The median concentration of tritium in Danish ground water (cf. Table 4.3.1) was 0.6 kBq ^3H m^{-3} or approximately 50% of the 1985 level.

The tritium concentrations in Danish streams and lakes were 1.7 and 1.2 kBq ^{3}H m^{-3}, respectively (Table 4.3.2), i.e. nearly the same as in 1985. Danish drinking water contained 0.3 kBq ^{3}H m^{-3} in 1986 (Table 4.3.3).

The tritium concentration in Danish straits was as earlier observed inversely proportional to the salinity.

The Chernobyl accident did not contribute significantly to the environmental levels of tritium in Denmark in 1986.

8. MEASUREMENTS OF BACKGROUND RADIATION IN 1986

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 Fig. 4.2. The results of the TLD measurements are shown in Table 8.2.1. The results of the NaI(Tl) detector measurements are shown in Table 8.2.2. The impact of the Chernobyl fallout is evident from the latter table, especially from the measurements made in May. With the exception of the Askov location the TLD results do not show significant changes compared to last year. This is due to the relatively low contamination levels, except for Askov, the annual averaging and the sensitivity of the TL detectors to the cosmic component. The NaI(Tl) detector has a very limited sensitivity to the secondary cosmic radiation.

Table 8.2.1. TLD-measurements of the background radiation (integrated over 12 months and normalized to μR h^{-1}) at the State experimental farms in 1985/86

Location	Oct 1985 - Sept 1986 μR h^{-1}
Tylstrup	7.3
Borris	7.1
Ødum	8.3
Askov	8.7
St. Jyndevad	6.4
Blangstedgård	-
Tystofte	8.5
Abed	8.4
Mean	7.8

Table 8.2.2. Terrestrial exposure rates at the State experimental farms measured with the NaI(Tl) detector in 1986 (μR h^{-1})

Location	May	July	September	November	Mean
Tylstrup	4.0	3.8	3.3	3.1	3.6
Borris	5.8	4.0	3.3	3.4	4.1
Kalø	4.9	4.7	3.0	3.8	4.1
Askov	12.1	6.6	5.0	6.3	7.5
St. Jyndevad	4.4	3.5	2.8	2.4	3.3
Årslev	9.3	9.3	5.3	5.5	7.4
Ledreborg	5.8	5.7	5.2	4.9	5.4
Tystofte	7.4	7.3	5.2	5.4	6.3
Abed	7.1	7.1	4.8	5.6	6.2
Tornbygård	7.0	(6.7)	5.8	(5.4)	6.2
Mean	6.8	5.9	4.4	4.6	5.4

Figures in brackets were calculated from VAR3[12].

The γ-background measured with the NaI(Tl) detector in four groups of sampling stations is shown in Fig. 8.2.1 from 1962 to 1986. The influence from the Chernobyl fallout is shown to affect the groups differently, according to their geographical location.

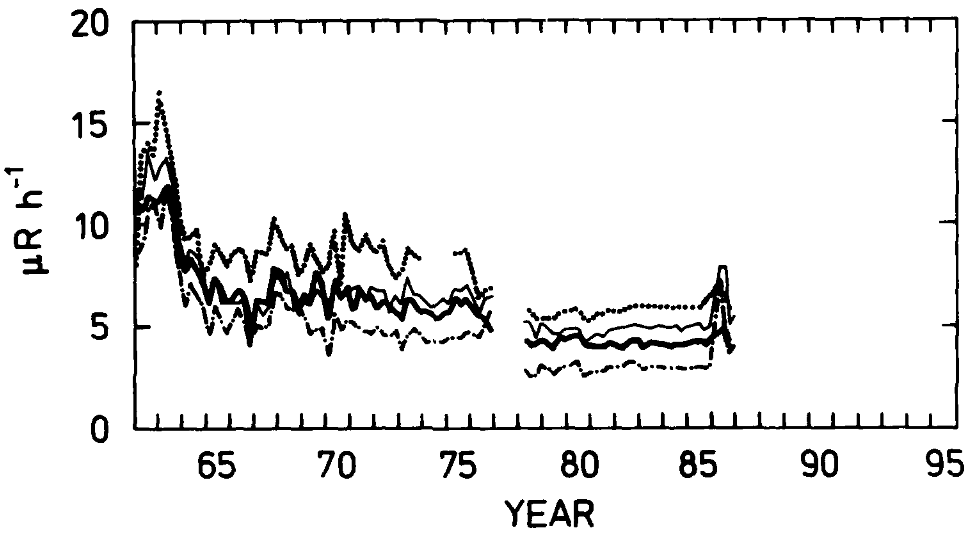

Fig. 8.2.1. Terrestrial exposure rates at the State experimental farms in 1962-1976 and 1978-1986 measured with the NaI(Tl) detector ($\mu R\ h^{-1}$).

..... Åkirkeby/Tornbygård

____ Abed, Blangstedgård/Årslev, Tystofte

____ Virumgård/Ledreborg, Ødum/Kalø, Tylstrup

—·—·— Jyndevad, Askov, Studsgård/Borris

8.3. Risø environment

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

Table 8.3.1. TLD-measurements of the background radiation (7-month integration period and normalized to $\mu R\ h^{-1}$) in five zones (I-V) around Risø in 1985/86

Risø zone	Location	Oct 1985/Sept 1986 $\mu R\ h^{-1}$
I	1	8.8
"	2	8.9
"	3	17.4
"	4	8.7
"	5	10.6
Mean		10.9
II	1	7.8
"	2	8.4
"	3	7.5
"	4	8.4
Mean		8.0
III	1	8.2
"	2	8.6
"	3	8.0
Mean		8.3
IV	1	7.6
"	2	8.5
"	3	8.4
"	4	8.1
"	5	7.0
"	6	8.0
"	7	9.3
Mean		8.1
V	1	8.1
"	2	9.8
"	3	9.7
"	4	7.6
"	5	8.3
"	6	8.3
"	7	8.8
"	8	9.2
"	9	9.0
"	10	7.9
Mean		8.6

Table 8.3.2. Terrestrial exposure rates at the Risø zones in 1986 measured with the NaI(Tl) detector ($\mu R\ h^{-1}$)

Risø zone	Location	February	April	August	November
I	1	5.7	5.0	6.2	5.5
"	2	5.9	6.2	8.1	7.1
"	3	66.1	54.4	56.7	62.2
"	4	5.6	5.7	6.8	5.8
"	5	10.1	9.2	11.6	10.7
Mean		18.7	16.1	17.9	18.3
II	1	5.0	4.6	5.9	5.1
"	2	5.4	5.0	6.1	5.3
"	3	4.9	5.1	6.1	4.6
"	4	4.7	4.5	5.3	4.6
Mean		5.0	4.8	5.8	4.9
III	1		5.2		5.4
"	2		4.7		5.1
"	3		4.3		4.4
Mean			4.7		5.0
IV	1		4.0		4.4
"	2		4.5		4.5
"	3		5.1		4.9
"	4		4.3		4.3
"	5		2.6		2.9
"	6		4.0		4.3
"	7		5.0		4.6
Mean			4.2		4.3
V	1		4.8		4.6
"	2		5.1		5.4
"	3		4.5		5.1
"	4		4.4		5.1
"	5		4.0		5.6
"	6		4.8		4.4
"	7		4.8		5.0
"	8		4.9		4.5
"	9		4.8		4.8
"	10		3.5		3.8
Mean			4.6		4.8

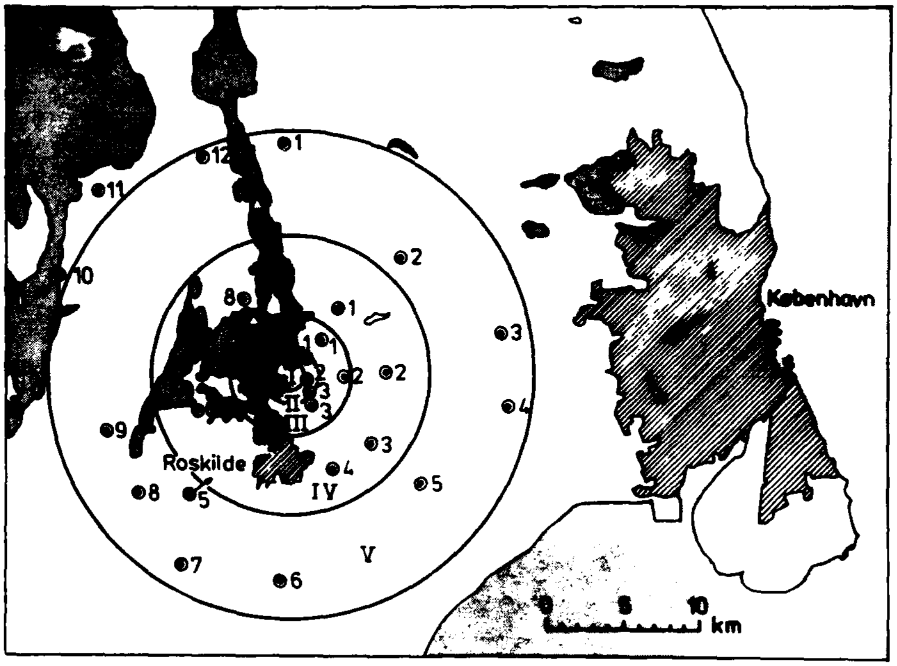

Fig. 8.3.1. The environment of Risø. Locations for measurements of the background radiation.

8.4. Gylling Næs environment

The Gylling Næs environment (a potential nuclear power plant site) is routinely monitored with TLD's, and the results from the site are given in Table 8.4.1. The locations are shown in Fig. 8.4.1.

Table 8.4.1. TLD-measurements of the background radiation (integrated over 12 months and normalized to $\mu R\ h^{-1}$) around the Gyllingnæs site in 1985/86

Location	Oct 1985 - Sept 1986 $\mu R\ h^{-1}$
1	8.2
2	8.8
3	8.8
Mean	8.6

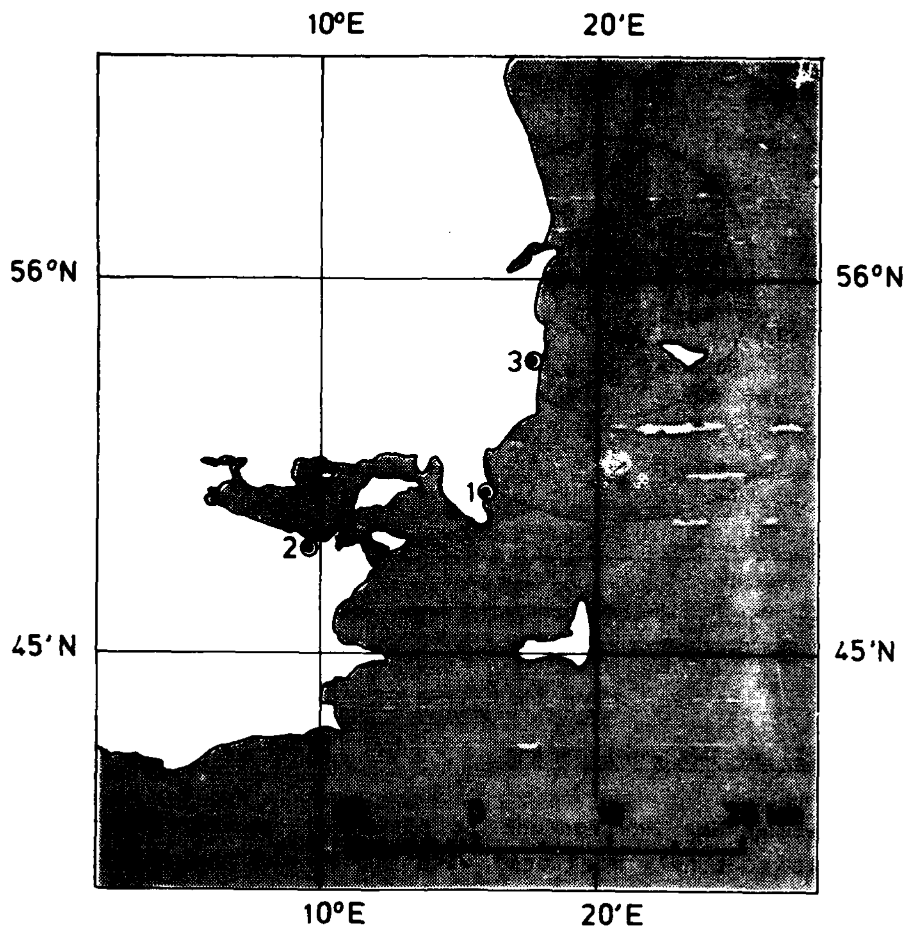

Fig. 8.4.1. The environment of Gylling Næs. Locations for measurements of the background radiation.

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 likewise routinely monitored with TLD's; the results and locations are shown in Table 8.5.1 and Fig. 8.5.1, respectively.

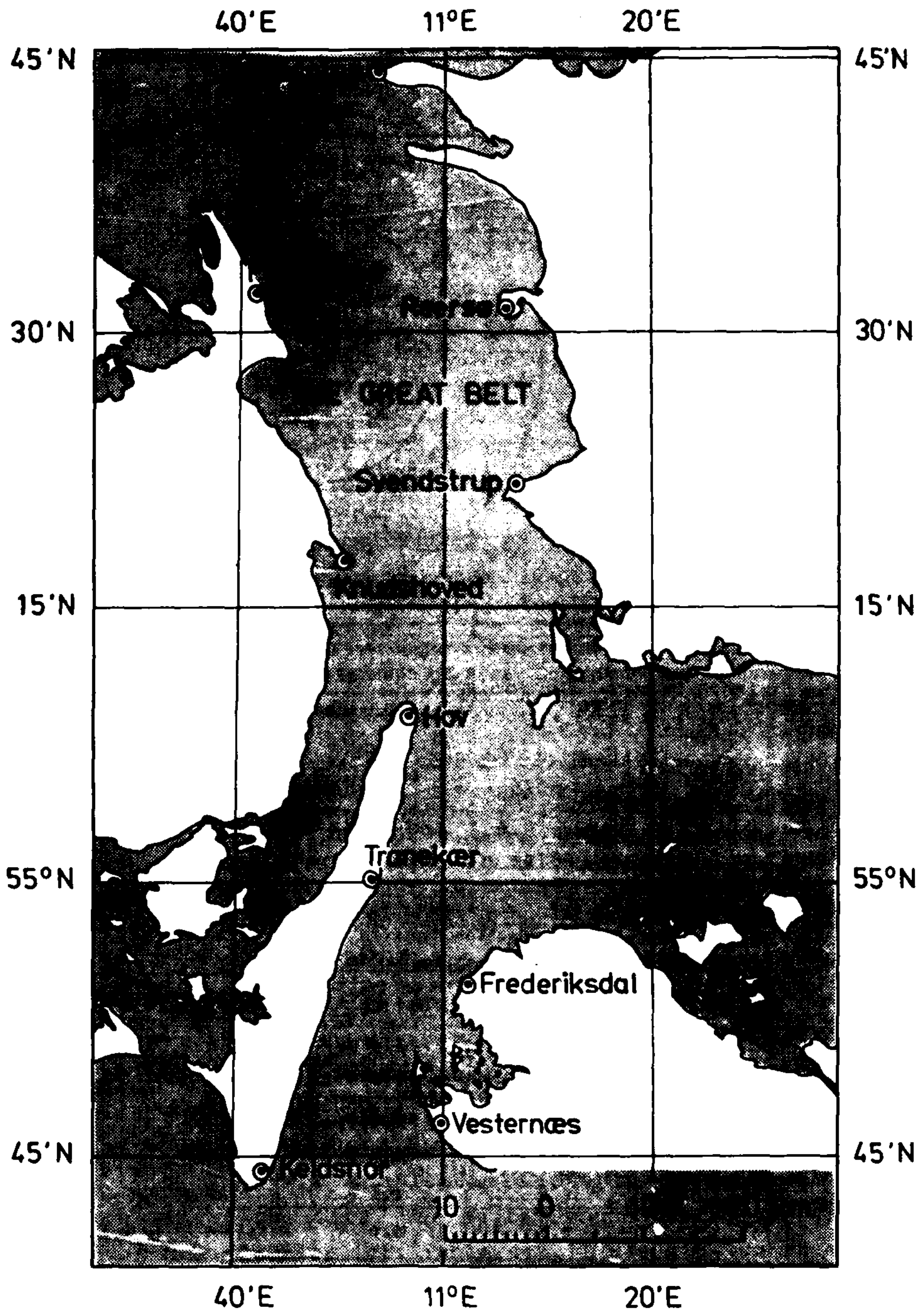

Fig. 8.5.1. The coasts of the Great Belt. Locations for measurements of the background radiation.

Table 8.5.1. TLD-measurements of the background radiation (integrated over 12 months and normalized to $\mu R\ h^{-1}$) along the coasts of the Great Belt and Langeland Belt in 1985/86

Location	Oct 1985 - Sept 1986 $\mu R\ h^{-1}$
Røsnæs	7.8
Reersø	9.1
Svendstrup	7.6
Vesternæs	9.5
Frederiksdal	8.7
Kelds Nor	12.3
Tranekær	9.8
Hov	8.7
Fyns Hoved	8.2
Knuds Hoved	-
Mean	9.1

8.6. The Baltic island, Bornholm

Locations on the island of Bornholm have been monitored with TLD's in the period April 1985-May 1986. The results and locations are shown in Table 8.6.1 and Fig. 8.6.1, respectively.

Table 8.6.1. TLD-measurements of the background radiation (integrated over 11 months and normalized to $\mu R\ h^{-1}$) on the island Bornholm in 1985/86

Location	April 1985 - May 1986 $\mu R\ h^{-1}$
1	9.8
2	9.8
3	9.2
4	16.0
Mean	11.2

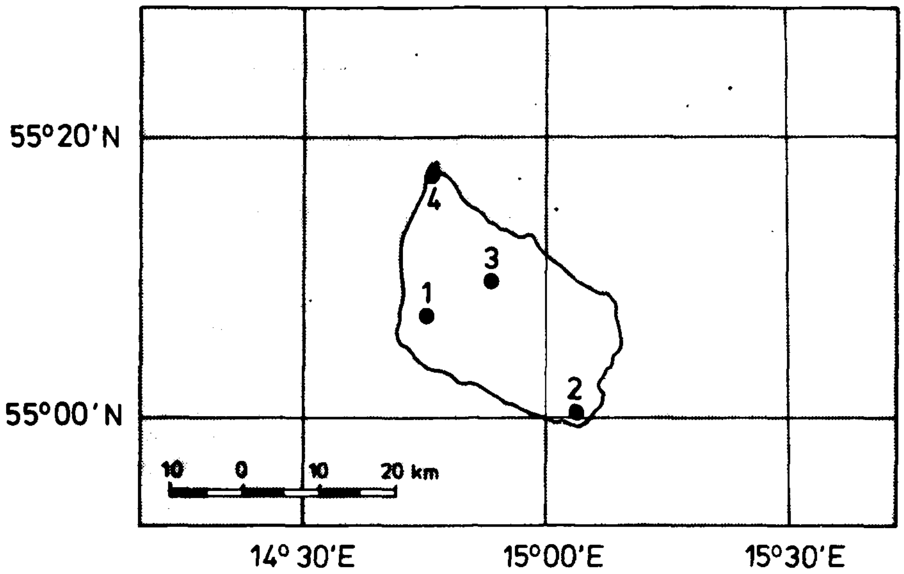

Fig. 8.6.1. Locations for measurements on Bornholm.

8.7. Estimating the external dose from Chernobyl fallout in Denmark

The environmental gamma-ray exposure rate has been measured at the 10 State experimental farms in May 1986, July 1986, September 1986, November 1986, April 1987 and September 1987. The natural levels were subtracted from these measurements. The natural levels were the means of the measurements in August 1985 and December 1985, i.e. prior to the Chernobyl accident.

The net exposure rates in May 1986 were related to the accumulated ^{137}Cs from Chernobyl at the various locations (by September 1986). The following relationship was found:

$$\mu R\ h^{-1} = 0.0025\ Bq\ ^{137}Cs\ m^{-2} - 0.44 \qquad (Eq.\ 1)$$

The net exposure rate due to Chernobyl debris at the State experimental farms decayed after a power function. This function was determined from the data obtained from Askov, St. Jyndevad, Årslev and Ledreborg.

The data were normalized to those observed in May 1986:

$$\text{relative exp. rate: } 0.1274\ X^{-0.7328} \qquad \text{(Eq. 2)}$$

where X is the time in years.

We may now assume that all locations in Denmark follow this time dependence when normalized to the exposure rates in May 1986. The mean deposition of ^{137}Cs from Chernobyl was determined to 1290 Bq $^{137}Cs\ m^{-2}$ by September 1986. If this level is inserted in Eq. 1 we get the countrywide mean exposure rate in May 1986 of 2.785 $\mu R\ h^{-1}$ corresponding to 24.4 $mR\ yr^{-1}$. Eq. 2 has a value of 1.348 in the middle of May 1986 ($X = 0.04$ yr) and this value corresponds to 24.4 $mR\ yr^{-1}$ in absolute terms. Hence Eq. 2 becomes:

$$mR\ yr^{-1} = \frac{24.4 \times 0.1274}{1.348} X^{-0.7328} \qquad \text{(Eq. 3)}$$

or

$$mR\ yr^{-1} = 2.3\ X^{-0.73}$$

In order to calculate the total air exposure from γ-emitters deposited in Denmark after Chernobyl we may integrate Eq. 3:

$$\int_{0.02}^{43} 2.3\ X^{-0.73}\ dx = \left[\frac{2.3}{0.27} X^{0.27}\right]_{0.02}^{43}$$

$$= 8.52\ [2.76-0.35] = 20.5\ mR$$

The integration period chosen is from the data when the Chernobyl fallout arrived with the rain over Denmark (7-8 May 1986) to the radiological mean-life of ^{137}Cs (43 years).

UNSCEAR (1982) assumes that the air dose may be transferred to an organ dose by multiplication with 0.3. This factor includes a factor of 0.7 taking account for the change of material (air to tissue) and for back-scatter and shielding by other tissues of the body. Furthermore, the factor of 0.3 includes the shielding from buildings assumed to be 20%.

The factor finally takes account for the time spent indoors (80%). However, if the air dose is measured in rural districts as it is in Denmark, the factor of 0.3 is an overestimate of the dose encountered in urban areas where the deposition is significantly lower and the removal of the activity is higher than in rural districts. Furthermore, the shielding effects of buildings are higher in urban areas and the time spent indoors is longer than in the country site. Thus we will assume that urban organ doses are only 0.1 times those received in rural sites. In Denmark about 20% of the population lives in urban sites and the rest in rural districts. Hence the external dose commitment from Chernobyl becomes:

$$0.80\ [0.205\times0.3] + 0.20\ [0.205\times0.3\times0.1] = 0.050\ \text{mSv}$$

The first-year dose can be estimated by integrating Eq. 3 from 0.02 to 1 year, which gives a value of 5.6 mR. Thus the external first-year dose from Chernobyl can be estimated at:

$$0.80\ [0.056\times0.3] + 0.20\ [0.056\times0.3\times0.1] = 0.014\ \text{mSv}$$

9. CONCLUSION

9.1. Environmental monitoring at Risø, Barsebäck and Ringhals

No radioactive contamination of the environment originating from the operation of the National Laboratory was ascertained outside Risø in 1986 except minor amounts of tritium in the fjord water collected close to Risø. For a person eating 100 kg fish per year caught just outside Risø, and containing 0.2 kBq ^{3}H from Risø, the annual dose becomes 3.3×10^{-9} Sv or 1.5×10^{-6} times the dose from the natural background radiation.

Benthic brown algae, mussels and fish collected at the Swedish nuclear plants at Barsebäck and Ringhals were analysed for radioactive pollution. Transfer factors from releases of various radionuclides to Fucus were calculated. The radioactive contamination of the marine environment due to the operation of the Swedish nuclear power plants resulted into doses of less than 1% of the background radiation to any individual eating 20 kg mussel and 100 kg fish per year.

9.2. Fallout in the abiotic environment

The mean content of ^{90}Sr in air collected in 1986 was 26 μBq m^{-3} (0.7 fCi ^{90}Sr m^{-3}), i.e. 87 times of the 1985 level. The mean concentration of ^{137}Cs in air was 1340 μBq m^{-3} in 1986, i.e. nearly 2000 times more than in 1985. The average fallout at the State experimental farms in 1986 was 38 Bq ^{90}Sr m^{-2} (1.03 mCi ^{90}Sr km^{-2}) or 48 times the 1985 figure, and the mean concentration of ^{90}Sr in rain water was 63 Bq ^{90}Sr m^{-3} (1.70 pCi ^{90}Sr l^{-1}). The deposition of ^{137}Cs was 1070 Bq m^{-2} (measured in precipitation) and 1360 Bq ^{137}Cs m^{-2} measured in soil samples.

By the end of 1986 the accumulated fallout was approximately 1570 Bq ^{90}Sr m^{-2} (42 mCi ^{90}Sr km^{-2}). The corresponding ^{137}Cs

was estimated at 3760 Bq m^{-2}. Hence the Chernobyl accident increased the accumulated ^{137}Cs fallout in Denmark by 50%.

The median level of ^{90}Sr in Danish ground water was 0.12 Bq m^{-3} (3.3 fCi ^{90}Sr l^{-1}).

Inner Danish surface waters (salinity ~ 16 o/oo) contained 22 Bq ^{90}Sr m^{-3} (0.59 pCi ^{90}Sr l^{-1}) and 97 Bq ^{137}Cs m^{-3} (2.6 pCi ^{137}Cs l^{-1}). Compared with 1985 the ^{90}Sr level was nearly unchanged in 1986, but the ^{137}Cs concentration increased by a factor of 4.6.

9.3. Fallout nuclides in the human diet

The mean level of ^{90}Sr in Danish milk was 64 Bq (kg Ca)$^{-1}$ (1.7 S.U.), and the mean content of ^{137}Cs was approximately 1060 Bq m^{-3} (28.6 pCi ^{137}Cs l^{-1}).

The 1986 ^{90}Sr level was 1.07 times the level found in milk produced in 1985, but the ^{137}Cs was 14 times higher. The ^{90}Sr mean content in grain from the 1986 harvest was 0.47 Bq kg^{-1} (13 pCi ^{90}Sr kg^{-1}). The ^{137}Cs mean content in grain was 3.3 Bq kg^{-1} (90 pCi ^{137}Cs kg^{-1}). The ^{90}Sr level in grain from the 1986 harvest was 1.15 times the level found in the 1985 harvest, and ^{137}Cs was 41 times the 1985 level.

The mean contents of ^{90}Sr and ^{137}Cs in Danish vegetables collected in 1986 were 0.25 Bq ^{90}Sr kg^{-1} (6.8 pCi kg^{-1}) and 0.17 Bq ^{137}Cs kg^{-1} (4.5 pCi kg^{-1}), respectively, and in fruit 0.067 Bq ^{90}Sr kg^{-1} (1.8 pCi kg^{-1}) and 0.068 Bq ^{137}Cs kg^{-1} (1.8 pCi kg^{-1}); potatoes contained 0.039 Bq ^{90}Sr kg^{-1} (1.0 pCi kg^{-1}) and 0.20 Bq ^{137}Cs kg^{-1} (5.3 pCi kg^{-1}).

The mean levels of ^{90}Sr and ^{137}Cs in Danish total diet in 1986 were 98 Bq ^{90}Sr (kg Ca)$^{-1}$ (2.6 S.U.) and 370 Bq ^{137}Cs (kg K)$^{-1}$ (10 M.U.), respectively. The levels of ^{90}Sr and ^{137}Cs in the Danish total diet in 1986 were respectively 0.94 and 7 times those observed in 1985.

Grain products contributed 29% and milk products 33% to the total ^{90}Sr intake; 18% of the ^{137}Cs in the diet originated from grain products, 13% from meat, and 37% from milk products. Fish contributed with 11% to the ^{137}Cs diet intake.

The predicted levels of ^{137}Cs in Danish food products based on global fallout models were in general much higher than those actually observed in 1986. This was because nearly all the Chernobyl fallout arrived in May, when the crops were just beginning to appear. Hence only little of the Chernobyl debris was retained by the vegetation. A prerequisite for using the models based on global fallout data is that the fallout has an annual distribution similar to that of global fallout and this was not the case for the Chernobyl fallout.

9.4. Strontium-90 and Cesium-137 in humans

The ^{90}Sr mean content in human bone (vertebra) collected in 1986 was about 20 Bq (kg Ca)$^{-1}$ (0.5 S.U.).

Whole-body measurements of ^{137}Cs were resumed after the Chernobyl accident. The measured mean level in 1986 was 950 Bq ^{137}Cs (kg K)$^{-1}$ (16.1 pCi ^{137}Cs (g K)$^{-1}$).

9.5. Tritium in environmental samples

The tritium mean concentration in ground, stream, lake and drinking water was approximately 1 kBq m^{-3} in 1986. The mean content of precipitation was also 1.0 kBq m^{-3}.

9.6. Background radiation

The average total background exposure rate measured with TLD's at the State experimental farms was 7.8 μR h^{-1}. This is only slightly higher than last year (7.5 μR h^{-1}) and illustrates the low level of contamination in Denmark from the Chernobyl accident. The annual mean of the terrestrial exposure rates at the State experimental farms measured with the NaI(Tl) detector was 5.4 $\mu R\ h^{-1}$, which is significantly higher than last year (4.2 $\mu R\ h^{-1}$). It must be noted that these measurements were all made after the Chernobyl accident and they are not representative for the true annual means as the TLD results are.

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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 in 1986.

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APPENDICES

Appendix A

Foreign Chernobyl samples

After the Chernobyl accident we received a few samples from other countries collected by Danish visitors. The results of the analysis are shown in Tables A.1-A.3.

The lorry dust from Brest (Table A.1) was the only sample young enough to contain very short-lived radionuclides, such as the iodine isotopes and ^{239}Np. The concentrations of the various radionuclides in the dust are not very informative; but the activity ratios between the different nuclides are useful and therefore reported. They may be compared with those found in Denmark, in Bukarest (Table A.2) and in Kiev (Table A.3). It appears that the isotopic ratios are very similar for the 4 locations. But the relative ratios to ^{137}Cs vary with the distance from Chernobyl as discussed in Reference 20.

In the soil sample from Bukarest in Romania (Table A.2) it appears that 95% of ^{137}Cs comes from Chernobyl. The sample was collected to a depth of 5 cm. In case of ^{239,240}Pu 10% were from Chernobyl. As we have no ^{89}Sr determination on this sample we do not know how much of the ^{90}Sr was from Chernobyl; but if we assumed ^{137}Cs/^{90}Sr in global fallout equal to 1.6, we can estimate the ^{90}Sr global fallout: $\frac{10200-9700}{1.6}$ = 310 Bq m^{-2}. As ^{90}Sr moves faster in the soil than ^{137}Cs the ^{137}Cs/^{90}Sr in global fallout may probably be higher than 1.6. Hence 310 Bq m^{-2} is an upper estimate of the global fallout derived ^{90}Sr. A lower limit for ^{90}Sr coming from Chernobyl in Bukarest should then be 1040-310 = 730 Bq m^{-2}, and ^{90}Sr/^{137}Cs in Chernobyl debris in Bukarest should have been at least 0.08. This is higher than seen in Denmark, but lower than found in the USSR. The ratio between Chernobyl derived ^{239,240}Pu and ^{137}Cs became 2x10^{-4} in the Bukarest soil, which is lower than seen in the Kiev soil

(35×10^{-4}) and in the Brest lorry dust (7.5×10^{-4}) but higher than seen in Baltic Sea air dust (0.45×10^{-4}) (cf. Table 4.1.4.3).

The grass turf from Kiev (Table A.3) showed inhomogeneities with respect to transuranic elements. The sample contains in general higher relative amounts of refractory elements such as ^{95}Zr, radiocerium and transuranics than the other Chernobyl samples in this report. This is explained by the proximity of Kiev to the accident site (~ 100 km).

Appendix A.1. Dust from Danish lorry passing Brest, Ukraine 26-27 April 1986. All data are decay corrected to April 26, 1986

$^{95}Sr/^{137}Cs$	0.28
$^{95}Zr/^{137}Cs$	1.7
$^{103}Ru/^{137}Cs$	3.3
$^{140}Ba/^{137}Cs$	3.9
$^{141}Ce/^{137}Cs$	1.6
$^{239,240}Pu/^{137}Cs$	0.75×10^{-3}
$^{89}Sr/^{90}Sr$	17
$^{103}Ru/^{106}Ru$	4.3
$^{134}Cs/^{137}Cs$	0.53
$^{141}Ce/^{144}Ce$	1.35
$^{238}Pu/^{239,240}Pu$	0.40
$^{242}Cm/^{243,244}Cm$	91
$^{241}Am/^{239,240}Pu$	0.061
$^{242}Cm/^{239,240}Pu$	8.0
$^{131}I/^{137}Cs$	18
$^{132}Te/^{137}Cs$	12
$^{239}Np/^{137}Cs$	19
$^{237}U/^{137}Cs$	1.1
$^{136}Cs/^{137}Cs$	0.26

Table A.2. Soil sample collected in Bukarest, June 10, 1986. All data are decay corrected to April 26, 1986

	Bq m^{-2}	Bq kg^{-1}	N
^{90}Sr	1040±210	17 ± 3.4	3
^{95}Zr	1160	19	
^{103}Ru	28000	460	
^{106}Ru	7000	114	
^{134}Cs	5300	86	
^{137}Cs	10200*	168	
^{140}Ba	41000	680	
^{141}Ce	3100	52	
^{144}Ce	2400	40	
^{238}Pu	1	0.016±0.001	2
$^{239,240}Pu$	20⁺	0.33 ±0.01	2
^{241}Am	6	0.10 ±0.01	2
^{242}Cm	21	0.34	

*If $^{134}Cs/^{137}Cs$ in Chernobyl debris is 0.54[20] the deposition of ^{137}Cs from Chernobyl becomes 9700 Bq m^{-2}.

⁺If the $^{242}Cm/^{239,240}Pu$ in Chernobyl debris is 10.6[20] the deposition of $^{239,240}Pu$ from Chernobyl becomes 1.96 Bq m^{-2}.

The error term is 1 S.D.

Table A.3. Grass turf collected in Kiev September 1986. All data are decay corrected to April 26, 1986

	1st determination	2nd determination
^{89}Sr	505 kBq m^{-2}	
^{90}Sr	36 - " -	
^{95}Zr	1880 - " -	
^{103}Ru	1370 - " -	
^{106}Ru	290 - " -	
^{110m}Ag	1.5- " -	
^{125}Sb	6.9- " -	
^{134}Cs	49 - " -	
^{137}Cs	100 - " -	
^{140}Ba	2400 - " -	
^{141}Ce	1820 - " -	
^{144}Ce	1260 - " -	
^{238}Pu	84 Bq m^{-2}	190 Bq m^{-2}
$^{239,240}Pu$	190 - " -	510 - " -
^{241}Pu	14900 - " -	32000 - " -
^{241}Am	25 - " -	52 - " -
^{242}Cm	2600 - " -	4600 - " -
$^{243,244}Cm$	24 - " -	31 - " -

Appendix B. Statistical information

Zone		Area in km^2 15)	Population in thousands 28) 1985	Annual milk production in mega-kg 13) 1985	Annual wheat production in mega-kg 13) 1985	Annual rye production in mega-kg 13) 1985	Annual potato production in mega-kg 13) 1985	Grass and green fodder production in mega-kg 13) 1985
I:	North Jutland	6,171	482	893	980	425	980	17,649
II:	East Jutland	7,561	909	1,427				
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.

APPENDIX C

For the calculation of the ^{137}Cs levels before 1986 we have assumed the $^{137}Cs/^{90}Sr$ ratio equal to 1.6 because that was the ratio used in reference 21.

Appendix C.1. Comparison between observed and predicted ^{90}Sr levels in environmental samples collected in 1986

Sample	Location	Unit	Observed	Predicted	Obs./pred.	Model in reference (21)
Dried milk	Jutland	Bq ^{90}Sr (kg Ca)$^{-1}$	75	166	0.45	C.3.2.1 No. 1
" "	Islands	- " -	47	81	0.58	- " - No. 3
Rye	Jutland	Bq ^{90}Sr kg^{-1}	0.51	0.55	0.93	C.2.2.1 No. 1
"	Islands	- " -	0.31	0.25	1.24	- " - No. 3
Barley	Jutland	- " -	0.51	0.73	0.70	- " - No. 4
"	Islands	- " -	0.29	0.31	0.94	- " - No. 6
Wheat	Jutland	- " -	0.45	0.59	0.76	- " - No. 8
"	Islands	- " -	0.29	0.28	1.04	- " - No. 10
Oats	Jutland	- " -	0.87	1.41	0.62	- " - No. 12
"	Islands	- " -	0.43	0.69	0.62	- " - No. 13
Potatoes	Jutland	- " -	0.040	0.101	0.40	C.2.5.1 No. 8
"	Islands	- " -	0.039	0.093	0.42	- " - No. 10
Cabbage	Jutland	- " -	0.20	0.32	0.63	- " - No. 1
"	Islands	- " -	0.24	0.28	0.86	- " - No. 3
Carrot	Jutland	- " -	0.23	0.52	0.44	- " - No. 5
"	Islands	- " -	0.27	0.17	1.59	- " - No. 6
Apples	Denmark	- " -	0.0088	0.054	0.16	- " - No. 13
Pork	"	- " -	0.025	0.031	0.81	C.3.4.1 No. 3
Beef	"	- " -	0.003	0.051	0.06	- " - No. 1
Eggs	"	- " -	0.017	0.037	0.46	C.3.6.1 No. 6
Total diet C	"	Bq ^{90}Sr (kg Ca)$^{-1}$	109	168	0.65	C.4.2.1 No. 1
" " P	"	- " -	87	148	0.59	- " - No. 7
Human bone > 29 yr	"	- " -	20	37	0.54	C.4.3.1 No. 13
Whole year grass	Islands	- " -	460	1430	0.32	C.2.4.1 No. 1
Fucus vesiculosus	"	- " -	250	470	0.53	C.2.7.1 No. 3
Ground water**	Denmark	Bq ^{90}Sr m^{-3}	0.30	0.28	1.07	C.1.4.1 No. 1
Stream water	"	- " -	9.7	12.6	0.77	- " - No. 3
Lake water	"	- " -	27.5	9.6	2.86	- " - No. 6

**Mean of all ground water samples except Feldbak (cf. 4.3.1).

Appendix C.2. Comparison between observed and predicted ^{137}Cs levels in environmental samples collected in 1986

Sample	Location	Unit	Observed	Predicted	Obs./pred.	Model in reference (21)
Dried milk	Jutland	Bq ^{137}Cs (kg K)$^{-1}$	1010	4700	0.21	C.3.2.2 No. 1
" "	Islands	- " -	790	2400	0.33	- " - No. 3
Rye	Jutland	Bq ^{137}Cs kg^{-1}	10.4	58	0.18	C.2.2.4 No. 1
"	Islands	- " -	12.2	59	0.21	- " - No. 3
Barley	Jutland	- " -	0.80	50	0.02	- " - No. 4
"	Islands	- " -	0.99	40	0.02	- " - No. 5
Wheat	Jutland	- " -	0.57	50	0.01	- " - No. 6
"	Islands	- " -	0.71	34	0.02	- " - No. 7
Oats	Jutland	- " -	0.76	41	0.02	- " - No. 8
"	Islands	- " -	0.71	37	0.02	- " - No. 9
Potatoes	Jutland	- " -	0.35	4.5	0.08	C.2.5.3 No. 5
"	Islands	- " -	0.042	3.6	0.01	- " - No. 7
Cabbage	Denmark	- " -	0.21	1.01	0.21	- " - No. 1
Carrot	"	- " -	0.103	1.85	0.06	- " - No. 3
Apples	"	- " -	1.70	2.4	0.71	C.2.5.3 No. 11
Pork	"	- " -	0.69	20	0.03	C.3.4.2 No. 3
Beef	"	- " -	2.1	30	0.07	- " - No. 1
Eggs	"	- " -	0.164	0.016	10.3	C.3.6.2 No. 6
Total diet C	"	Bq ^{137}Cs (kg K)$^{-1}$	390	1890	0.21	C.4.2.2 No. 1
" " P	"	- " -	354	2090	0.17	- " - No. 6

Appendix C.3. Deposition in 1986 in Bq m^{-2}

	Jutland	Islands	Denmark
^{90}Sr Jan-Dec	40	37	38.5
^{137}Cs*Jan-Dec	1340	1080	1210
^{90}Sr July-Aug	2.05	1.76	1.91
^{90}Sr May-Aug	28.8	26.05	27.41
^{137}Cs July-Aug	(94)	(63)	(78)
^{137}Cs May-Aug	790	754	772

*Mean of precipitation and soil measurements.

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APPENDIX D

$\underline{d_i}$:

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

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

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[1]). Before 1962 the levels in the tables were estimated from the HASL data for New York (HASL Appendix 291, 1975)[29] considering that the mean ratio between ^{90}Sr fallout in Denmark and New York was 0.7 in the period 1962-1974.
The $d_{i(May-Aug)}$ and $d_{i(July-Aug)}$ values were also obtained from 4.2[1] 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.

Appendix D.1. Fallout rates and accumulated fallout (mCi ^{90}Sr km^{-2}) in Denmark 1950-1986

	Denmark		Jutland		Islands	
Year	di	$A_{i(28.82)}$	di	$A_{i(28.82)}$	di	$A_{i(28.82)}$
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

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	1.662
9.965	5.629	10.753	5.932	9.177	5.327
6.235	2.568	7.170	2.910	5.299	2.226
2.029	0.850	2.094	0.852	1.964	0.848
1.049	0.418	0.984	0.496	1.114	0.340
0.367	0.141	0.380	0.134	0.354	0.148
0.848	0.426	0.910	0.460	0.786	0.392
0.614	0.276	0.723	0.319	0.505	0.233
0.908	0.547	1.076	0.632	0.740	0.462
0.992	0.405	1.154	0.516	0.830	0.294
0.253	0.084	0.262	0.084	0.244	0.084
0.075	0.033	0.093	0.039	0.057	0.027
0.421	0.190	0.463	0.219	0.378	0.162
0.159	0.075	0.179	0.091	0.157	0.060
0.032	0.010	0.032	0.011	0.032	0.009
0.178	0.107	0.164	0.085	0.190	0.129
0.232	0.096	0.275	0.098	0.188	0.093
0.086	0.030	0.087	0.031	0.084	0.029
0.031	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

Appendix D.2. Fallout rates and accumulated fallout (Bq $^{90}Sr\ m^{-2}$) in Denmark 1950-1986

	Denmark		Jutland		Islands	
Year	di	$A_{i(28.82)}$	di	$A_{i(28.82)}$	di	$A_{i(28.82)}$
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	682.761	1821.249	552.669	1452.058
1964	385.244	1973.849	432.345	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

	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	0.483	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

APPENDIX E

Detailed Chernobyl air, precipitation and grass data

Contents

LOCATION : RISOE
UNIT : MICRO BQ/M3

ISOTOP	DATE	SPECIES	SD %	RESULTS	
95-ZR	1986 APR 24-1986 APR 28	NEW SAMPLER 6 FILTER	1	50581.447	
103-RU	-	-	1	52753.832	
106-RU	-	-	10	10344.227	
131-I	-	-	18	232622.749	
132-I	-	-	1	152000.000	
133-I	-	-	-	350000.000	
134-CS	-	-	0	35370.493	
137-CS	-	-	0	63608.520	
140-BA	-	-	18	92611.833	
140-LA	-	-	2	87001.534	
141-CE	-	-	1	49780.987	
144-CE	-	-	1	32706.973	
238-PU	-	-	2	3.692	8.813
239,240-PU	-	-	1	6.400	18.988
241-AM	-	-	7	0.761	1.812
242-CM	-	-	1	119.960	176.730
244-CM	-	-	6	2.251	2.419
90-SR	-	NEW SAMPLER SHUNT	1	1436.735	
89-SR/90-SR	-	-	3	19.700	
95-ZR	1986 APR 28-1986 APR 29	NEW SAMPLER 6 FILTER	18	560.000	
103-RU	-	-	16	460.000	
131-I	-	-	2	4600.000	
132-I	-	-	4	1580.000	
133-I	-	-	15	540.000	
134-CS	-	-	10	540.000	
137-CS	-	-	8	980.000	
140-BA	-	-	29	1000.000	
140-LA	-	-	4	3300.000	
141-CE	-	-	25	470.000	
95-ZR	1986 APR 29	-	23	700.000	
103-RU	-	-	25	420.000	
131-I	-	-	1	14700.000	
132-I	-	-	3	4200.000	
133-I	-	-	13	2100.000	
134-CS	-	-	4	4300.000	
137-CS	-	-	2	7400.000	
140-LA	-	-	10	910.000	
141-CE	-	-	21	610.000	
131-I	1986 APR 29-1986 APR 30	-	7	610.000	
132-I	-	-	22	190.000	
137-CS	-	-	99	90.000	
131-I	1986 APR 30-1986 MAY 01	-	6	750.000	
132-I	-	-	12	310.000	
134-CS	-	-	38	100.000	
137-CS	-	-	15	280.000	
140-LA	-	-	2	3460.000	
131-I	1986 MAY 01-1986 MAY 02	-	22	530.000	
132-I	-	-	-	490.000	
137-CS	-	-	99	200.000	
7-BE	1986 MAY 01-1986 JUN 02	NEW SAMPLER SHUNT	17	5654.230	
90-SR	-	-	5	93.878	195.918
95-ZR	-	-	6	1537.806	
103-RU	-	-	1	30315.835	
106-RU	-	-	6	9688.146	

134-CS	-	-	1	5738.412		
137-CS	-	-	1	10534.425		
140-LA	-	-	22	3679.576		
141-CE	-	-	12	1408.512		
144-CE	-	-	22	1126.121		
89-SR/90-SR	-	-	15	12.800		
103-RU	1986 MAY 02-1986 MAY 03	NEW SAMPLER 6 FILTER	35	130.000		
131-I	-	-	1	17600.000		
132-I	-	-	25	210.000		
137-CS	-	-	22	220.000		
95-ZR	1986 MAY 03-1986 MAY 04	-	27	570.000		
103-RU	-	-	7	1880.000		
131-I	-	-	1	223900.000		
132-I	-	-	15	5100.000		
133-I	-	-	20	1400.000		
134-CS	-	-	7	2120.000		
137-CS	-	-	4	3560.000		
140-BA	-	-	24	2300.000		
95-ZR	1986 MAY 04	-	14	4650.000		
103-RU	-	-	4	15300.000		
131-I	-	-	1	410000.000		
132-I	-	-	2	30500.000		
134-CS	-	-	4	14200.000		
137-CS	-	-	3	22700.000		
140-BA	-	-	19	9100.000		
140-LA	-	-	6	8700.000		
141-CE	-	-	17	4460.000		
238-PU	-	-	15	0.373	0.295	
239,240-PU	-	-	11	0.497	0.400	
241-AM	-	-	26	0.484	0.213	
242-CM	-	-	9	4.413	3.940	1.424
244-CM	-	-	20	0.529	0.548	
7-BE	1986 MAY 04-1986 MAY 05	-	8	8097.708		
95-ZR	-	-	2	2582.946		
103-RU	-	-	1	11605.702		
106-RU	-	-	8	3292.109		
131-I	-	-	5	264302.697		
132-I	-	-	3	17100.000		
134-CS	-	-	0	14342.357		
137-CS	-	-	0	23965.937		
140-LA	-	-	5	8377.138		
141-CE	-	-	4	2451.123		
144-CE	-	-	6	2077.188		
238-PU	-	-	6	1.321	0.212	
239,240-PU	-	-	4	2.241	0.291	
241-AM	-	-	28	0.264		
242-CM	-	-	2	43.004	2.439	
244-CM	-	-	21	0.467	0.159	
95-ZR	1986 MAY 05	-	4	6480.000		
103-RU	-	-	2	9470.000		
131-I	-	-	1	362000.000		
132-I	-	-	-	14400.000		
133-I	-	-	39	1100.000		
134-CS	-	-	3	9650.000		
137-CS	-	-	2	15440.000		
140-BA	-	-	9	8700.000		
140-LA	-	-	3	9000.000		
141-CE	-	-	5	6800.000		
95-ZR	1986 MAY 05-1986 MAY 06	-	7	3800.000		
103-RU	-	-	2	12260.000		
131-I	-	-	3	280000.000		
132-I	-	-	1	12100.000		
134-CS	-	-	3	4600.000		
137-CS	-	-	-	7410.000		
140-BA	-	-	15	5600.000		
140-LA	-	-	4	7600.000		

141-CE	-	-	38	520.000	
90-SR	1986 MAY 05-1986 JUN 02	LT SAMPLER GLASS	2	77.551	89.796
89-SR/90-SR	-	-	6	16.000	
95-ZR	1986 MAY 06	NEW SAMPLER 6 FILTER	13	3700.000	
103-RU	-	-	1	40700.000	
131-I	-	-	-	334000.000	
134-CS	-	-	5	7300.000	
137-CS	-	-	3	12400.000	
140-BA	-	-	17	8500.000	
140-LA	-	-	5	7500.000	
95-ZR	1986 MAY 06-1986 MAY 07	-	15	1990.000	
103-RU	-	-	3	7800.000	
131-I	-	-	1	164000.000	
134-CS	-	-	5	3900.000	
137-CS	-	-	4	6400.000	
140-BA	-	-	23	4100.000	
140-LA	-	-	5	6100.000	
95-ZR	1986 MAY 07-1986 MAY 08	-	40	3200.000	
103-RU	-	-	1	644000.000	
131-I	-	-	-	496000.000	
134-CS	-	-	-	82400.000	
137-CS	-	-	-	154400.000	
140-BA	-	-	4	64500.000	
140-LA	-	-	1	50300.000	
141-CE	-	-	19	3500.000	
238-PU	-	-	12	0.302	0.282
239,240-PU	-	-	8	0.665	0.374
241-AM	-	-	30	0.682	
242-CM	-	-	6	3.660	4.638
244-CM	-	-	18	0.373	0.682
7-BE	1986 MAY 08-1986 MAY 12	-	4	4677.004	
95-ZR	-	-	28	49.262	
103-RU	-	-	0	62117.504	
106-RU	-	-	1	18758.728	
131-I	-	-	13	17902.270	
134-CS	-	-	0	7964.493	
136-Cs	-	-	22	1642.893	
137-CS	-	-	0	14449.212	
140-BA	-	-	19	4655.938	
140-LA	-	-	2	4992.985	
141-CE	-	-	19	194.474	
144-CE	-	-	22	230.854	
239,240-PU	-	-	13	0.005	0.148
242-CM	-	-	24	0.195	0.095
131-I	1986 MAY 12-1986 MAY 14	-	1	4299.062	
134-CS	-	-	6	463.838	
137-CS	-	-	5	739.376	
103-RU	1986 MAY 14-1986 MAY 15	-	2	4350.000	
131-I	-	-	2	8251.830	
134-CS	-	-	5	1235.727	
137-CS	-	-	4	2272.353	
103-RU	1986 MAY 15-1986 MAY 16	-	5	880.000	
131-I	-	-	2	3245.429	
134-CS	-	-	6	487.152	
137-CS	-	-	5	880.622	
103-RU	1986 MAY 16-1986 MAY 17	-	6	310.000	
131-I	-	-	3	1505.162	
134-CS	-	-	8	168.856	
137-CS	-	-	7	292.279	
140-LA	-	-	23	80.000	
103-RU	1986 MAY 17-1986 MAY 18	-	5	530.000	
131-I	-	-	2	2771.549	
134-CS	-	-	4	451.452	
137-CS	-	-	4	783.461	
140-LA	-	-	15	160.000	
103-RU	1986 MAY 18-1986 MAY 19	-	4	680.000	

131-I	-	-	2	1663.992	
134-CS	-	-	6	388.275	
137-CS	-	-	5	744.968	
103-RU	1986 MAY 19-1986 MAY 20	-	4	2220.000	
131-I	-	-	4	2248.152	
134-CS	-	-	5	1367.364	
137-CS	-	-	4	2421.003	
239,240-PU	-	-	45	0.070	
242-CM	-	-	32	0.127	0.140
244-CM	-	-	16	0.546	
103-RU	-	-	3	2173.496	
131-I	-	-	3	2507.328	
132-I	-	-	3	94344.410	
134-CS	-	-	3	1438.880	
136-Cs	-	-	17	267.557	
137-CS	-	-	3	2598.644	
7-BE	1986 MAY 21-1986 MAY 22	-	14	3142.718	
103-RU	-	-	4	1601.783	
131-I	-	-	3	2006.858	
134-CS	-	-	5	782.936	
137-CS	-	-	5	1322.503	
140-LA	-	-	29	590.627	
7-BE	1986 MAY 22-1986 MAY 23	-	15	4614.205	
103-RU	-	-	3	2747.069	
131-I	-	-	4	2809.772	
134-CS	-	-	6	1022.112	
137-CS	-	-	5	1772.712	
7-BE	1986 MAY 23-1986 MAY 26	-	3	5153.000	
103-RU	-	-	1	3783.206	
131-I	-	-	1	1805.169	
134-CS	-	-	1	1221.249	
136-Cs	-	-	28	114.257	
137-CS	-	-	1	2275.187	
140-LA	-	-	7	190.253	
7-BE	1986 MAY 26-1986 MAY 27	-	11	3352.038	
103-RU	-	-	3	1700.081	
106-RU	-	-	39	965.968	
131-I	-	-	5	1029.120	
134-CS	-	-	5	748.740	
137-CS	-	-	4	1300.118	
140-LA	-	-	38	453.882	
7-BE	1986 MAY 27-1986 MAY 28	-	10	2575.941	
95-ZR	-	-	39	92.791	
103-RU	-	-	4	794.525	
131-I	-	-	7	517.007	
134-CS	-	-	7	314.819	
137-CS	-	-	6	593.957	
141-CE	-	-	33	108.931	
7-BE	1986 MAY 28-1986 MAY 29	-	26	1216.446	
103-RU	-	-	6	735.281	
131-I	-	-	10	481.501	
134-CS	-	-	14	195.620	
137-CS	-	-	11	330.033	
7-BE	1986 MAY 29-1986 MAY 30	-	37	700.856	
103-RU	-	-	4	927.222	
131-I	-	-	9	533.149	
134-CS	-	-	17	145.561	
137-CS	-	-	12	330.422	
7-BE	1986 MAY 30-1986 JUN 02	-	5	2108.147	
103-RU	-	-	2	678.511	
106-RU	-	-	26	377.886	
131-I	-	-	7	225.311	
134-CS	-	-	4	257.319	
137-CS	-	-	3	472.401	
7-BE	1986 JUN 02-1986 JUN 05	-	3	1875.315	
103-RU	-	-	2	518.568	

106-RU	-	-	18	217.925	
131-I	-	-	6	144.475	
134-CS	-	-	3	194.207	
137-CS	-	-	2	348.180	
140-LA	-	-	18	26.901	
90-SR	1986 JUN 02-1986 JUN 30	LT SAMPLER GLASS	30	1.621	2.069
7-BE	-	NEW SAMPLER SHUNT	6	4191.051	
90-SR	-	-	19	5.944	
103-RU	-	-	10	335.747	
134-CS	-	-	12	166.574	
137-CS	-	-	9	279.561	
7-BE	1986 JUN 05-1986 JUN 09	NEW SAMPLER 6 FILTER	5	1502.228	
103-RU	-	-	2	540.243	
106-RU	-	-	19	282.765	
131-I	-	-	11	86.634	
134-CS	-	-	8	69.867	
137-CS	-	-	7	120.460	
140-LA	-	-	19	45.627	
7-BE	1986 JUN 09-1986 JUN 12	-	2	6933.916	
103-RU	-	-	3	447.918	
106-RU	-	-	31	278.227	
131-I	-	-	13	103.137	
134-CS	-	-	6	111.226	
137-CS	-	-	5	236.094	
7-BE	1986 JUN 12-1986 JUN 16	-	6	2925.777	
103-RU	-	-	8	292.192	
131-I	-	-	37	73.856	
134-CS	-	-	13	108.498	
137-CS	-	-	11	193.601	
7-BE	1986 JUN 16-1986 JUN 19	-	3	3248.560	
103-RU	-	-	7	162.046	
131-I	-	-	31	44.084	
134-CS	-	-	13	52.318	
137-CS	-	-	9	114.382	
140-LA	-	-	8	225.859	
7-BE	1986 JUN 19-1986 JUN 23	-	3	2805.043	
103-RU	-	-	11	79.513	
137-CS	-	-	20	40.723	
7-BE	1986 JUN 23-1986 JUN 26	-	2	2829.303	
103-RU	-	-	8	49.922	
134-CS	-	-	9	31.798	
137-CS	-	-	7	57.112	
140-LA	-	-	38	6.973	
7-BE	1986 JUN 26-1986 JUN 30	-	4	2958.751	
137-CS	-	-	29	39.086	
7-BE	1986 JUN 30-1986 JUL 03	-	3	4333.064	
103-RU	-	-	21	43.979	
137-CS	-	-	21	46.006	
7-BE	1986 JUL 03-1986 JUL 07	-	3	2843.895	
103-RU	-	-	15	38.572	
134-CS	-	-	19	18.602	
137-CS	-	-	12	45.019	
7-BE	1986 JUL 07-1986 JUL 10	-	1	2447.069	
103-RU	-	-	15	16.892	
134-CS	-	-	10	17.987	
137-CS	-	-	9	32.605	
7-BE	1986 JUL 10-1986 JUL 14	-	1	1711.182	
103-RU	-	-	5	10.252	
134-CS	-	-	4	9.682	
137-CS	-	-	3	17.187	
7-BE	1986 JUL 14-1986 JUL 17	-	1	2835.883	
95-ZR	-	-	36	3.118	
103-RU	-	-	3	36.454	
106-RU	-	-	26	31.396	
134-CS	-	-	1	101.560	
137-CS	-	-	1	201.046	

7-BE	1986 JUL 17-1986 JUL 21	-	0	3453.660
103-RU	-	-	3	14.713
106-RU	-	-	26	13.111
134-CS	-	-	4	8.267
137-CS	-	-	3	16.164
7-BE	1986 JUL 21-1986 JUL 24	-	1	2739.551
95-ZR	-	-	16	5.993
103-RU	-	-	7	12.660
134-CS	-	-	1	67.489
137-CS	-	-	1	127.483
7-BE	1986 JUL 24-1986 JUL 28	-	1	1951.938
103-RU	-	-	4	10.676
106-RU	-	-	27	12.224
134-CS	-	-	4	7.342
137-CS	-	-	3	15.435
7-BE	1986 JUL 28-1986 JUL 31	-	1	2330.194
103-RU	-	-	19	5.136
134-CS	-	-	1	108.618
137-CS	-	-	1	211.246
7-BE	1986 JUL 31-1986 AUG 04	-	1	1751.396
103-RU	-	-	9	4.923
134-CS	-	-	6	6.091
137-CS	-	-	5	10.827
141-CE	-	-	34	1.882
7-BE	1986 AUG 04-1986 AUG 07	-	1	2834.058
103-RU	-	-	16	5.100
134-CS	-	-	2	47.968
137-CS	-	-	1	91.578
7-BE	1986 AUG 07-1986 AUG 11	-	0	3506.442
103-RU	-	-	9	4.057
134-CS	-	-	6	4.708
137-CS	-	-	4	9.725
7-BE	1986 AUG 11-1986 AUG 14	-	1	2101.748
95-ZR	-	-	9	10.344
103-RU	-	-	10	7.138
106-RU	-	-	33	18.356
134-CS	-	-	3	20.014
137-CS	-	-	2	40.403
141-CE	-	-	28	3.172
144-CE	-	-	22	16.790
7-BE	1986 AUG 14-1986 AUG 18	-	1	2256.735
103-RU	-	-	10	4.376
134-CS	-	-	7	5.026
137-CS	-	-	5	10.288
7-BE	1986 AUG 18-1986 AUG 21	-	1	1918.817
95-ZR	-	-	36	2.676
103-RU	-	-	13	4.985
134-CS	-	-	4	12.662
137-CS	-	-	3	23.936
7-BE	1986 AUG 21-1986 AUG 25	-	1	1598.419
103-RU	-	-	25	1.439
134-CS	-	-	13	2.571
137-CS	-	-	10	4.589
7-BE	1986 AUG 25-1986 AUG 28	-	1	2105.291
65-ZN	-	-	11	12.573
95-ZR	-	-	5	17.716
103-RU	-	-	7	9.616
106-RU	-	-	39	14.160
134-CS	-	-	3	17.268
137-CS	-	-	2	37.016
141-CE	-	-	26	3.436
144-CE	-	-	19	17.875
7-BE	1986 AUG 28-1986 SEP 01	-	1	2496.133
95-ZR	-	-	3	32.007
103-RU	-	-	3	32.961
134-CS	-	-	2	33.358

137-CS	-	-	1	71.904
141-CE	-	-	10	9.341
144-CE	-	-	11	34.045
7-BE	1986 SEP 01-1986 SEP 04	-	1	1451.120
95-ZR	-	-	39	2.523
103-RU	-	-	23	2.441
134-CS	-	-	5	10.998
137-CS	-	-	3	23.198
7-BE	1986 SEP 04-1986 SEP 08	-	1	1685.094
60-CO	-	-	23	1.687
103-RU	-	-	6	9.227
106-RU	-	-	23	17.253
134-CS	-	-	3	14.179
137-CS	-	-	2	29.771
7-BE	1986 SEP 08-1986 SEP 11	-	1	1154.865
103-RU	-	-	15	64.365
134-CS	-	-	7	5.887
137-CS	-	-	5	11.237
7-BE	1986 SEP 11-1986 SEP 15	-	1	1789.682
103-RU	-	-	19	2.406
134-CS	-	-	8	4.717
137-CS	-	-	5	9.920
7-BE	1986 SEP 15-1986 SEP 18	-	1	1693.058
103-RU	-	-	17	65.106
134-CS	-	-	8	5.726
137-CS	-	-	6	10.768
7-BE	1986 SEP 18-1986 SEP 22	-	1	2242.544
103-RU	-	-	22	1.719
134-CS	-	-	8	4.083
137-CS	-	-	6	8.230
7-BE	1986 SEP 22-1986 SEP 25	-	1	1641.141
103-RU	-	-	27	1.915
134-CS	-	-	3	18.622
137-CS	-	-	2	37.501
7-BE	1986 SEP 25-1986 SEP 29	-	1	2047.825
103-RU	-	-	19	1.826
134-CS	-	-	12	3.954
137-CS	-	-	6	7.309
7-BE	1986 SEP 29-1986 OCT 02	-	1	2229.846
103-RU	-	-	35	1.459
134-CS	-	-	5	9.500
137-CS	-	-	4	20.900
7-BE	1986 OCT 02-1986 OCT 06	-	1	1695.777
103-RU	-	-	12	3.449
106-RU	-	-	36	7.447
134-CS	-	-	7	5.130
137-CS	-	-	5	10.554
7-BE	1986 OCT 06-1986 OCT 09	-	1	1132.058
103-RU	-	-	36	1.223
134-CS	-	-	6	6.647
137-CS	-	-	4	13.708
7-BE	1986 OCT 09-1986 OCT 13	-	1	1997.742
103-RU	-	-	16	2.267
134-CS	-	-	6	5.808
137-CS	-	-	4	12.019
7-BE	1986 OCT 13-1986 OCT 16	-	1	2988.326
103-RU	-	-	18	3.933
134-CS	-	-	2	32.358
137-CS	-	-	2	65.302
7-BE	1986 OCT 16-1986 OCT 20	-	1	2370.685
103-RU	-	-	17	2.408
134-CS	-	-	7	5.399
137-CS	-	-	4	11.556
7-BE	1986 OCT 20-1986 OCT 23	-	1	1995.386
134-CS	-	-	6	6.866
137-CS	-	-	5	14.178

7-BE	1986 OCT 23-1986 OCT 27	-	1	1140.389
103-RU	-	-	16	2.724
106-RU	-	-	34	12.121
134-CS	-	-	3	15.056
137-CS	-	-	2	31.456
7-BE	1986 OCT 27-1986 OCT 30	-	1	1462.714
134-CS	-	-	5	9.063
137-CS	-	-	4	19.115
7-BE	1986 OCT 30-1986 NOV 03	-	1	1902.807
134-CS	-	-	7	5.017
137-CS	-	-	5	11.286
7-BE	1986 NOV 03-1986 NOV 06	-	1	1840.976
134-CS	-	-	10	3.810
137-CS	-	-	6	8.977
7-BE	1986 NOV 06-1986 NOV 10	-	1	2183.197
40-K	-	-	2	0.013
103-RU	-	-	33	1.067
134-CS	-	-	7	4.953
137-CS	-	-	5	10.579
7-BE	1986 NOV 10-1986 NOV 13	-	1	3007.491
134-CS	-	-	3	24.227
137-CS	-	-	2	53.365
7-BE	1986 NOV 13-1986 NOV 17	-	0	3957.638
103-RU	-	-	23	2.138
134-CS	-	-	6	6.868
137-CS	-	-	4	15.153
7-BE	1986 NOV 17-1986 NOV 20	-	1	2025.399
134-CS	-	-	8	5.215
137-CS	-	-	5	11.662
7-BE	1986 NOV 20-1986 NOV 24	-	0	2276.174
134-CS	-	-	15	1.434
137-CS	-	-	9	3.543
7-BE	1986 NOV 24-1986 NOV 27	-	1	1166.273
134-CS	-	-	10	3.689
137-CS	-	-	7	7.734
7-BE	1986 NOV 27-1986 DEC 01	-	1	2388.669
103-RU	-	-	21	33.576
134-CS	-	-	27	1.036
137-CS	-	-	13	2.798
7-BE	1986 DEC 01-1986 DEC 04	-	1	3089.000
134-CS	-	-	6	7.170
137-CS	-	-	4	15.230
7-BE	1986 DEC 04-1986 DEC 08	-	1	3060.000
103-RU	-	-	21	29.400
134-CS	-	-	4	6.880
137-CS	-	-	3	17.290
7-BE	1986 DEC 08-1986 DEC 11	-	1	2822.000
103-RU	-	-	38	1.980
134-CS	-	-	2	39.100
137-CS	-	-	-	87.600
7-BE	1986 DEC 11-1986 DEC 15	-	1	2138.630
134-CS	-	-	8	4.637
137-CS	-	-	6	8.482
7-BE	1986 DEC 15-1986 DEC 18	-	1	1168.093
134-CS	-	-	3	9.392
137-CS	-	-	2	23.829
7-BE	1986 DEC 18-1986 DEC 22	-	0	2065.135
103-RU	-	-	16	1.033
106-RU	-	-	22	8.527
134-CS	-	-	5	3.054
137-CS	-	-	3	6.926
7-BE	1986 DEC 22-1986 DEC 26	-	1	1254.307
137-CS	-	-	3	17.659
7-BE	1986 DEC 26-1986 DEC 29	-	1	1478.296
134-CS	-	-	26	1.359
137-CS	-	-	14	3.268

7-BE	1986 DEC 29-1987 JAN 02	-	1	2175.665
103-RU	-	-	40	1.587
106-RU	-	-	33	17.329
134-CS	-	-	2	26.941
137-CS	-	-	2	59.317

SPECIES : NEW SAMPLER 6 FILTERS
LOCATION : BORNHOLM
UNIT : MICRO BQ/M3

ISOTOP	DATE	SD %	RESULTS		
95-ZR	1986 MAY 02-1986 MAY 05	12	1183.251		
103-RU	-	3	5205.698		
106-RU	-	29	3808.689		
131-I	-	0	192651.325		
132-I	-	1	11254.748		
134-CS	-	2	5011.187		
136-Cs	-	8	1345.474		
137-CS	-	2	8121.691		
140-BA	-	15	3261.525		
140-LA	-	4	3880.042		
141-CE	-	14	1545.055		
95-ZR	1986 MAY 05-1986 MAY 07	3	2801.164		
103-RU	-	1	16032.798		
106-RU	-	15	6200.000		
131-I	-	0	227771.067		
132-I	-	0	14821.007		
133-I	-	15	68516.597		
134-CS	-	1	5137.085		
136-Cs	-	10	1339.422		
137-CS	-	1	8882.184		
140-LA	-	1	5424.666		
141-CE	-	3	3335.389		
95-ZR	1986 MAY 07-1986 MAY 09	8	3239.239		
103-RU	-	0	959775.437		
106-RU	-	1	287693.571		
131-I	-	0	604494.510		
134-CS	-	0	100152.987		
136-Cs	-	8	244307.825		
137-CS	-	0	180162.815		
140-BA	-	22	76752.980		
140-LA	-	3	70583.876		
141-CE	-	14	4987.464		
144-CE	-	22	4718.322		
238-PU	-	8	0.281	0.733	
239,240-PU	-	5	0.753	1.722	
241-AM	-	11	0.368	0.315	0.034
242-CM	-	3	5.169	4.429	9.426
244-CM	-	21	0.227	0.093	0.109
7-BE	1986 MAY 09-1986 MAY 12	7	1866.466		
95-ZR	-	32	43.519		
103-RU	-	2	1146.979		
106-RU	-	22	495.114		
131-I	-	1	4977.351		
132-I	-	5	479.930		
134-CS	-	3	391.580		
136-Cs	-	12	80.801		
137-CS	-	3	700.557		
140-LA	-	9	172.897		
131-I	1986 MAY 12-1986 MAY 14	1	6995.655		
134-CS	-	3	899.848		
137-CS	-	2	1532.602		
7-BE	1986 MAY 14-1986 MAY 16	10	2640.000		
103-RU	-	2	767.714		

106-RU	-	39	227.489
131-I	-	1	2787.888
132-I	-	11	178.499
134-CS	-	3	473.915
136-Cs	-	11	93.303
137-CS	-	2	805.018
140-LA	-	10	125.655
7-BE	1986 MAY 16-1986 MAY 20	5	2260.000
95-ZR	-	14	42.966
103-RU	-	1	1156.176
106-RU	-	11	452.523
131-I	-	1	1484.095
132-I	-	6	121.147
134-CS	-	1	670.454
136-Cs	-	4	104.756
137-CS	-	1	1160.655
140-BA	-	14	180.209
140-LA	-	3	195.447
141-CE	-	13	50.970
7-BE	1986 MAY 20-1986 MAY 23	5	4060.000
95-ZR	-	22	48.207
103-RU	-	1	2480.399
106-RU	-	11	930.197
131-I	-	1	2029.049
134-CS	-	1	1011.882
136-Cs	-	8	125.928
137-CS	-	1	1801.111
140-LA	-	4	277.182
141-CE	-	17	72.520
7-BE	1986 MAY 23-1986 MAY 26	5	4350.000
95-ZR	-	33	37.684
103-RU	-	1	3045.773
106-RU	-	10	1078.448
131-I	-	2	1217.083
134-CS	-	1	1035.889
136-Cs	-	25	164.875
137-CS	-	1	1810.297
140-BA	-	30	182.773
140-LA	-	6	221.495
141-CE	-	24	56.717
7-BE	1986 MAY 26-1986 MAY 28	5	2725.006
95-ZR	-	8	161.604
103-RU	-	2	1224.700
106-RU	-	27	410.568
131-I	-	5	454.070
134-CS	-	3	503.445
137-CS	-	2	866.157
140-BA	-	33	165.064
140-LA	-	8	155.478
141-CE	-	12	108.070
7-BE	1986 MAY 28-1986 MAY 30	7	1191.099
95-ZR	-	27	35.473
103-RU	-	2	599.735
106-RU	-	29	202.062
131-I	-	5	246.501
134-CS	-	4	177.977
137-CS	-	4	311.344
140-LA	-	20	38.306
141-CE	-	33	23.254
7-BE	1986 MAY 30-1986 JUN 02	2	2088.991
103-RU	-	1	659.359
106-RU	-	12	265.777
131-I	-	3	264.948
134-CS	-	2	256.467
137-CS	-	1	493.228
140-LA	-	7	53.216

7-BE	1986 JUN 02-1986 JUN 04	3	2637.765
103-RU	-	2	356.181
106-RU	-	23	219.522
131-I	-	5	227.830
134-CS	-	3	175.850
137-CS	-	3	319.004
140-LA	-	22	24.328
7-BE	1986 JUN 04-1986 JUN 09	5	1296.710
103-RU	-	2	615.127
106-RU	-	15	275.193
131-I	-	7	132.344
134-CS	-	6	67.394
137-CS	-	5	135.325
140-LA	-	26	15.771
141-CE	-	38	15.899
7-BE	1986 JUN 09-1986 JUN 11	4	4167.319
103-RU	-	4	346.866
106-RU	-	28	254.540
134-CS	-	8	111.313
137-CS	-	7	175.734
7-BE	1986 JUN 11-1986 JUN 13	3	4980.265
103-RU	-	5	254.056
131-I	-	15	71.366
134-CS	-	10	66.851
137-CS	-	8	119.810
141-CE	-	34	25.090
7-BE	1986 JUN 13-1986 JUN 16	3	3048.538
103-RU	-	3	304.273
131-I	-	21	39.145
134-CS	-	5	105.361
137-CS	-	5	193.019
7-BE	1986 JUN 16-1986 JUN 19	2	3292.591
95-ZR	-	35	11.875
103-RU	-	3	247.396
106-RU	-	27	109.672
131-I	-	15	44.856
134-CS	-	6	56.406
137-CS	-	5	111.795
7-BE	1986 JUN 19-1986 JUN 23	2	2450.162
95-ZR	-	22	10.480
103-RU	-	4	89.096
106-RU	-	37	54.499
134-CS	-	5	36.210
137-CS	-	5	60.667
7-BE	1986 JUN 23-1986 JUN 30	1	2972.612
103-RU	-	5	46.227
134-CS	-	5	29.577
137-CS	-	5	52.948
7-BE	1986 JUN 30-1986 JUL 07	1	3097.882
95-ZR	-	30	5.227
103-RU	-	4	41.193
134-CS	-	6	19.712
137-CS	-	4	41.623
7-BE	1986 JUL 07-1986 JUL 14	1	1734.630
95-ZR	-	26	1.757
103-RU	-	2	20.347
106-RU	-	15	18.734
134-CS	-	2	13.799
137-CS	-	2	25.083
141-CE	-	32	1.501
7-BE	1986 JUL 14-1986 JUL 21	0	3040.798
95-ZR	-	20	2.082
103-RU	-	3	13.881
106-RU	-	18	15.532
134-CS	-	3	11.153
137-CS	-	2	22.400

7-BE	1986 JUL 21-1986 JUL 28	0	2244.350
95-ZR	-	7	5.988
103-RU	-	3	15.586
106-RU	-	19	16.218
134-CS	-	3	11.108
137-CS	-	2	22.388
141-CE	-	28	1.945
144-CE	-	24	8.832
7-BE	1986 JUL 28-1986 AUG 04	0	2774.752
95-ZR	-	2	29.484
103-RU	-	2	23.576
106-RU	-	10	24.240
134-CS	-	2	12.334
137-CS	-	2	25.865
141-CE	-	5	10.606
144-CE	-	4	51.097
7-BE	1986 AUG 04-1986 AUG 11	0	3280.868
103-RU	-	7	4.047
106-RU	-	35	7.473
134-CS	-	5	5.393
137-CS	-	4	10.587
7-BE	1986 AUG 11-1986 AUG 18	0	2854.097
103-RU	-	3	12.671
106-RU	-	16	18.063
134-CS	-	3	8.854
137-CS	-	2	17.755
7-BE	1986 AUG 18-1986 AUG 26	0	2197.875
103-RU	-	7	4.294
106-RU	-	35	7.840
134-CS	-	4	5.786
137-CS	-	3	12.054
7-BE	1986 AUG 26-1986 SEP 01	0	2589.754
103-RU	-	9	3.891
106-RU	-	35	9.136
134-CS	-	3	9.829
137-CS	-	2	20.487
7-BE	1986 SEP 01-1986 SEP 08	0	2289.680
65-ZN	-	36	1.632
103-RU	-	13	2.091
134-CS	-	6	3.495
137-CS	-	5	7.173
7-BE	1986 SEP 08-1986 SEP 15	1	1853.749
103-RU	-	8	4.186
106-RU	-	22	11.392
134-CS	-	3	8.461
137-CS	-	2	16.748
7-BE	1986 SEP 15-1986 SEP 22	0	2347.673
103-RU	-	24	0.910
134-CS	-	6	3.065
137-CS	-	4	6.530
7-BE	1986 SEP 22-1986 SEP 29	0	2328.896
103-RU	-	14	1.523
134-CS	-	4	4.985
137-CS	-	2	11.970
7-BE	1986 SEP 29-1986 OCT 06	0	1996.896
60-CO	-	14	1.071
103-RU	-	14	..577
134-CS	-	4	4.201
137-CS	-	3	9.083
7-BE	1986 OCT 06-1986 OCT 13	0	2218.322
103-RU	-	6	5.604
106-RU	-	14	20.118
134-CS	-	2	16.192
137-CS	-	1	36.487
7-BE	1986 OCT 13-1986 OCT 20	0	3897.194
103-RU	-	15	3.630

106-RU	-	33	14.915
134-CS	-	4	13.147
137-CS	-	2	28.733
7-BE	1986 OCT 20-1986 OCT 27	0	2162.880
103-RU	-	18	1.324
134-CS	-	5	4.662
137-CS	-	3	10.021
7-BE	1986 OCT 27-1986 NOV 03	0	2155.078
134-CS	-	8	2.428
137-CS	-	5	5.282
7-BE	1986 NOV 03-1986 NOV 10	0	2247.841
103-RU	-	30	0.805
106-RU	-	35	6.604
134-CS	-	6	3.851
137-CS	-	4	8.379
7-BE	1986 NOV 10-1986 NOV 17	0	4413.700
134-CS	-	4	5.297
137-CS	-	3	12.147
7-BE	1986 NOV 17-1986 NOV 24	0	2306.369
103-RU	-	31	0.977
134-CS	-	5	4.873
137-CS	-	3	10.997
7-BE	1986 NOV 24-1986 DEC 01	1	1931.618
103-RU	-	30	0.840
134-CS	-	9	2.468
137-CS	-	6	5.022
7-BE	1986 DEC 01-1986 DEC 08	1	3022.000
134-CS	-	3	8.210
137-CS	-	2	17.470
7-BE	1986 DEC 08-1986 DEC 15	0	2446.025
134-CS	-	6	4.005
137-CS	-	4	9.119
7-BE	1986 DEC 15-1986 DEC 22	1	1703.555
103-RU	-	22	1.367
106-RU	-	29	9.299
134-CS	-	4	7.357
137-CS	-	3	14.699
7-BE	1986 DEC 22-1986 DEC 29	1	1490.049
103-RU	-	28	1.202
106-RU	-	30	8.795
134-CS	-	5	5.683
137-CS	-	3	12.613
7-BE	1986 DEC 29-1987 JAN 01	0	2460.269
103-RU	-	27	1.247
106-RU	-	21	12.870
134-CS	-	3	7.879
137-CS	-	2	18.379

SPECIES : 10 M2 ION-EXCHANGER
LOCATION : RISOE
UNIT : BQ/M2

ISOTOP	DATE	SD %	RESULTS
7-BE	1986 APR 01-1986 APR 29	1	71.51
90-SR	-	1	0.48
95-ZR	-	1	14.85
103-RU	-	1	10.39
106-RU	-	12	1.68
134-CS	-	2	0.48
137-CS	-	2	0.88
140-LA	-	5	37.32
141-CE	-	1	17.54
144-CE	-	1	9.05
89-SR/90-SR	-	3	17.20
90-SR	1986 APR 29-1986 MAY 09	2	19.34
95-ZR	-	35	20.19
99-Mo	-	13	269.29
103-RU	-	1	2160.15
106-RU	-	5	566.69
131-I	-	2	3663.58
132-Te	-	29	412.45
132-I	-	2	785.45
134-CS	-	-	330.37
136-Cs	-	10	81.14
137-CS	-	2	624.92
140-BA	-	5	370.28
140-LA	-	2	401.19
141-CE	-	27	12.12
89-SR/90-SR	-	6	15.20
7-BE	1986 MAY 09-1986 JUN 01	1	121.13
90-SR	-	7	2.04
95-ZR	-	3	3.99
103-RU	-	0	104.60
106-RU	-	2	35.91
131-I	-	2	103.07
134-CS	-	0	63.30
136-Cs	-	12	7.64
137-CS	-	0	117.52
140-BA	-	5	50.66
140-LA	-	1	54.35
141-CE	-	2	10.51
144-CE	-	4	12.53
89-SR/90-SR	-	21	15.20
7-BE	1986 JUN 01-1986 JUN 30	2	31.93
90-SR	-	10	0.54
95-ZR	-	1	3.69
103-RU	-	0	34.81
106-RU	-	2	19.36
131-I	-	15	2.37
134-CS	-	0	14.92
137-CS	-	0	28.47
140-BA	-	21	2.98
140-LA	-	3	3.34
141-CE	-	2	3.96

144-CE	-	3	7.64
89-SR/90-SR	-	30	11.20
7-BE	1986 JUN 30-1986 AUG 01	1	120.11
95-ZR	-	7	0.79
103-RU	-	2	5.10
106-RU	-	9	4.17
110M-AG	-	12	0.22
134-CS	-	1	9.63
137-CS	-	0	18.66
141-CE	-	16	0.65
144-CE	-	11	2.09
7-BE	1986 AUG 01-1986 SEP 01	1	70.37
95-ZR	-	15	0.10
103-RU	-	3	0.79
106-RU	-	11	1.06
134-CS	-	1	2.20
137-CS	-	1	4.36
141-CE	-	30	0.09
144-CE	-	18	0.44
7-BE	1986 SEP 01-1986 OCT 01	1	46.35
95-ZR	-	17	0.09
103-RU	-	4	0.48
106-RU	-	11	1.18
110M-AG	-	15	0.07
134-CS	-	1	1.52
137-CS	-	1	3.19
141-CE	-	38	0.06
144-CE	-	14	0.58
7-BE	1986 OCT 01-1986 OCT 31	1	70.99
95-ZR	-	10	0.17
103-RU	-	11	0.16
106-RU	-	20	0.58
134-CS	-	1	1.14
137-CS	-	1	2.41
144-CE	-	14	0.53
7-BE	1986 OCT 31-1986 DEC 01	1	61.30
103-RU	-	16	0.09
106-RU	-	18	0.46
134-CS	-	1	0.85
137-CS	-	1	1.94
144-CE	-	30	0.20
7-BE	1986 DEC 01-1986 DEC 29	1	40.76
106-RU	-	33	0.35
134-CS	-	3	0.56
137-CS	-	2	1.25

SPECIES : RAINSAMPLER 1M2 DAILY
LOCATION : RISOE
UNIT : BQ/M2

ISOTOP	DATE	SD %	RESULTS
103-RU	1986 MAY 01-1986 MAY 31	4	297.6
106-RU	-	31	111.6
134-CS	-	2	158.4
137-CS	-	2	287.3
103-RU	1986 MAY 07-1986 MAY 08	1	1897.9
106-RU	-	12	965.6
131-I	-	1	2567.4
132-Te	-	25	1100.4
132-I	-	1	1346.0
134-CS	-	3	264.3
136-Cs	-	26	81.3
137-CS	-	3	486.2
140-LA	-	4	252.2
141-CE	-	26	45.8
103-RU	1986 MAY 08	2	251.8
106-RU	-	24	113.3
131-I	-	1	643.5
132-I	-	1	247.0
134-CS	-	5	48.4
136-Cs	-	38	15.2
137-CS	-	4	86.1
140-BA	-	12	97.1
140-LA	-	7	35.1
103-RU	1986 MAY 09	5	60.6
131-I	-	2	210.0
132-I	-	5	32.2
134-CS	-	11	13.9
137-CS	-	11	22.8
140-LA	-	17	10.6
103-RU	1986 MAY 10	11	49.1
131-I	-	6	97.8
132-I	-	8	42.6
134-CS	-	11	35.5
137-CS	-	9	73.4
140-LA	-	29	9.0
131-I	1986 MAY 14	12	12.5
134-CS	-	16	7.1
137-CS	-	19	8.8
131-I	1986 MAY 16	9	26.8
134-CS	-	13	11.2
137-CS	-	12	21.5
131-I	1986 MAY 19	23	2.9
134-CS	-	23	2.2
137-CS	-	19	3.5
131-I	1986 MAY 21	15	10.2
134-CS	-	15	7.2
137-CS	-	12	15.0

131-I	1986 MAY 23-1986 MAY 26	14	38.0
134-CS	-	21	17.4
137-CS	-	25	20.7
134-CS	1986 JUN 04	17	4.6
137-CS	-	13	9.4
103-RU	1986 JUN 06	4	7.1
131-I	-	14	1.8
134-CS	-	7	2.9
137-CS	-	6	5.3
103-RU	1986 JUN 09	14	14.3
137-CS	-	15	10.3
103-RU	1986 JUN 19	8	4.8
134-CS	-	11	2.4
137-CS	-	8	4.6
103-RU	1986 JUL 07	36	9.1
134-CS	-	15	7.2
137-CS	-	13	10.8
137-CS	1986 JUL 08	29	1.0
137-CS	1986 JUL 30	36	1.6

SPECIES : GRASS
LOCATION : RISOE
UNIT : BQ/KG FRESH

ISOTOP	DATE	SD %	RESULTS
Sr-90	1986 APR 28	2	4.19
Zr-95	1986 APR 28 KL.08	7	58.00
Nb-95	-	4	59.00
Mo-99	-	20	82.00
Tc-99m	-	10	67.00
Ru-103	-	8	35.00
I-131	-	4	870.00
Te-132	-	-	67.00
I-133	-	30	226.00
Cs-134	-	8	26.00
Cs-137	-	7	44.70
Ba-140	-	11	89.00
La-140	-	4	83.00
Ce-141	-	7	63.00
Ce-144	-	35	66.00
Zr-95	1986 APR 28 KL.11	2	117.80
Nb-95	-	1	190.00
Mo-99	-	20	59.00
Tc-99m	-	10	77.00
Ru-103	-	3	59.90
I-131	-	5	860.00
Te-132	-	10	71.00
I-133	-	-	115.00
Cs-134	-	-	10.20
Cs-137	-	7	21.90
Ba-140	-	6	128.00
La-140	-	2	124.00
Ce-141	-	-	114.00
Ce-144	-	11	95.00
Zr-95	1986 APR 29	5	62.40
Nb-95	-	3	65.60
Mo-99	-	16	55.40
Tc-99m	-	10	35.50
Ru-103	-	4	42.60
I-131	-	5	419.00
Te-132	-	10	33.80
I-133	-	-	56.10
Cs-134	-	13	7.70
Cs-137	-	14	10.80
Ba-140	-	9	65.40
La-140	-	3	68.00
Ce-141	-	4	63.40
Ce-144	-	20	59.70

Zr-95	1986 APR 30	4	200.00
Nb-95	-	-	106.00
Tc-99m	-	13	23.00
Ru-103	-	8	48.60
I-131	-	12	361.00
Te-132	-	20	26.00
I-133	-	-	27.80
Cs-134	-	32	7.45
Cs-137	-	-	10.80
Ba-140	-	13	118.00
La-140	-	4	144.60
Ce-141	-	3	198.00
Ce-144	-	11	233.00
Zr-95	1986 MAY 01	5	55.40
Nb-95	-	3	57.60
Mo-99	-	27	32.00
Tc-99m	-	6	25.70
Ru-103	-	2	182.00
I-131	-	5	532.00
Te-132	-	10	58.00
I-133	-	15	20.00
Cs-134	-	16	7.50
Cs-137	-	13	12.60
Ba-140	-	11	65.00
La-140	-	4	62.50
Ce-141	-	6	49.00
Ce-144	-	21	67.00
Zr-95	1986 MAY 02	6	117.00
Nb-95	-	4	117.00
Ru-103	-	6	68.80
I-131	-	2	474.00
Te-132	-	20	48.00
I-133	-	35	23.00
Cs-137	-	30	11.80
Ba-140	-	13	116.00
La-140	-	5	110.00
Ce-141	-	6	106.00
Ce-144	-	35	72.00
Sr-90	1986 MAY 04	3	1.59
Zr-95	-	10	42.00
Nb-95	-	7	40.00
Ru-103	-	9	27.00
I-131	-	1	820.00
Cs-134	-	17	9.50
Cs-137	-	15	15.80
Ba-140	-	19	50.00
La-140	-	7	48.00
Ce-141	-	12	40.00
Zr-95	1986 MAY 05	10	59.00
Nb-95	-	9	34.00
Ru-103	-	12	29.00
I-131	-	1	910.00
Te-132	-	15	28.00

I-133	1986 MAY 05	35	11.00
Cs-134	-	33	9.40
Cs-137	-	24	13.30
Ba-140	-	10	121.00
La-140	-	5	119.00
Ce-141	-	7	90.00
Zr-95	1986 MAY 06	14	35.00
Nb-95	-	11	29.00
Ru-103	-	9	45.00
I-131	-	1	900.00
Cs-137	-	14	21.90
La-140	-	-	27.00
Zr-95	1986 MAY 07	18	25.00
Nb-95	-	9	35.00
Ru-103	-	10	32.00
I-131	-	2	467.00
Cs-134	-	19	9.50
Cs-137	-	18	14.40
Ba-140	-	40	27.00
La-140	-	14	31.00
Ce-141	-	19	28.00
Zr-95	1986 MAY 08	25	24.00
Nb-95	-	14	23.00
Ru-103	-	1	532.00
I-131	-	-	814.00
Cs-134	-	3	143.00
Cs-137	-	2	258.00
Ba-140	-	8	196.00
La-140	-	3	187.00
Ce-141	-	23	27.00
Zr-95	1986 MAY 09	17	20.80
Nb-95	-	9	24.50
Ru-103	-	2	342.00
I-131	-	1	403.00
Cs-134	-	2	118.00
Cs-137	-	-	198.00
Ba-140	-	8	159.00
La-140	-	3	154.00
Zr-95	1986 MAY 10	25	26.40
Nb-95	-	13	27.80
Ru-103	-	3	282.00
I-131	-	-	245.00
Cs-134	-	6	61.00
Cs-137	-	5	108.00
Ba-140	-	21	74.00
La-140	-	6	117.00
Ce-141	-	22	28.00
Zr-95	1986 MAY 11	13	37.00
Nb-95	-	9	31.00
Ru-103	-	7	286.00
I-131	-	3	219.00
Cs-134	-	5	60.00
Cs-137	-	4	106.00
Ba-140	-	16	83.00
La-140	-	5	107.00
Ce-141	-	14	34.00
Ce-144	-	26	85.00

Zr-95	1986 MAY 12	37	8.30
Nb-95	-	17	10.80
Ru-103	-	2	219.00
I-131	-	-	148.00
Cs-134	-	4	54.00
Cs-137	-	-	90.00
Ba-140	-	11	74.00
La-140	-	4	89.00
Ce-141	-	40	7.00
Zr-95	1986 MAY 13	15	26.40
Nb-95	-	10	32.90
Ru-103	-	3	276.00
I-131	-	2	209.81
Cs-134	-	3	86.17
Cs-137	-	2	154.20
Ba-140	-	15	103.70
La-140	-	8	107.10
Ce-141	-	10	32.00
Ce-144	-	25	42.00
Zr-95	1986 MAY 14	37	6.60
Nb-95	-	13	10.40
Ru-103	-	2	192.00
I-131	-	2	160.77
Cs-134	-	2	75.12
Cs-137	-	2	128.10
Ba-140	-	9	71.00
La-140	-	3	81.00
Ce-141	-	21	11.70
Zr-95	1986 MAY 15	10	24.80
Nb-95	-	6	28.80
Ru-103	-	2	155.00
I-131	-	2	107.24
Cs-134	-	3	49.72
Cs-137	-	3	87.02
Ba-140	-	10	67.00
La-140	-	4	62.00
Ce-141	-	9	26.00
Ce-144	-	32	34.00
Zr-95	1986 MAY 16	17	25.00
Nb-95	-	8	34.00
Ru-103	-	2	285.00
I-131	-	3	172.09
Cs-134	-	5	63.08
Cs-137	-	4	135.30
Ba-140	-	15	78.00
La-140	-	6	78.00
Zr-95	1986 MAY 17	37	8.00
Nb-95	-	27	6.30
Ru-103	-	3	149.00
I-131	-	5	88.91
Cs-134	-	5	50.36
Cs-137	-	5	83.45
Ba-140	-	17	52.00
La-140	-	8	51.00
Ce-141	-	26	12.00

Zr-95	1986 MAY 18	27	15.60
Nb-95	-	12	21.00
Ru-103	-	4	125.00
I-131	-	6	68.57
Cs-134	-	7	32.92
Cs-137	-	7	56.14
La-140	-	11	35.90
Ce-141	-	36	10.30
Nb-95	1986 MAY 19	23	6.10
Ru-103	-	3	112.00
I-131	-	5	61.72
Cs-134	-	6	29.75
Cs-137	-	5	60.27
Ba-140	-	24	30.00
La-140	-	11	23.00
Zr-95	1986 MAY 20	29	7.70
Nb-95	-	14	10.40
Ru-103	-	3	87.00
I-131	-	5	42.99
Cs-134	-	6	24.43
Cs-137	-	5	42.17
Ba-140	-	28	19.80
La-140	-	7	32.00
Ce-141	-	18	11.40
Ru-103	1986 MAY 21	5	58.00
I-131	-	7	34.77
Cs-134	-	9	18.92
Cs-137	-	8	34.87
La-140	-	13	16.70
Zr-95	1986 MAY 22	5	93.01
Nb-95	-	4	97.60
Ru-103	-	5	90.13
I-131	-	8	38.94
Cs-134	-	10	26.70
Cs-137	-	7	51.02
Ba-140	-	23	47.36
La-140	-	8	45.25
Ce-141	-	5	94.53
Ce-144	-	15	122.79
Nb-95	1986 MAY 23	28	3.50
Ru-103	-	4	51.00
I-131	-	8	23.07
Cs-134	-	8	17.64
Cs-137	-	7	30.77
La-140	-	15	11.10
Zr-95	1986 MAY 26	36	5.00
Nb-95	-	14	8.10
Ru-103	-	3	64.00
I-131	-	7	22.46
Cs-134	-	6	20.32
Cs-137	-	5	39.97
Ba-140	-	33	13.10
La-140	-	10	14.40
Ce-141	-	34	5.00

Nb-95	1986 MAY 27	23	5.00
Ru-103	-	4	68.00
I-131	-	5	39.27
Cs-134	-	7	22.67
Cs-137	-	6	41.75
Ba-140	-	33	14.60
La-140	-	12	16.10
Ce-141	-	34	5.60
Ru-103	1986 MAY 28	5	63.00
I-131	-	7	33.09
Cs-134	-	9	25.07
Cs-137	-	8	40.62
Nb-95	1986 MAY 29	36	2.50
Ru-103	-	5	61.00
La-140	-	17	10.20
Zr-95	1986 MAY 30	29	4.40
Nb-95	-	11	6.90
Ru-103	-	3	42.00
I-131	-	7	14.97
Cs-134	-	6	15.06
Cs-137	-	5	26.11
Ba-140	-	28	10.30
La-140	-	13	7.50
Ce-141	-	22	5.10

SPECIES : GRASS
LOCATION : RISOE
UNIT : BQ/M2

ISOTOP	DATE	SD %	RESULTS
Zr-95	1986 APR 28 KL.08	7	12.10
Nb-95	-	4	12.20
Mo-99	-	20	17.00
Tc-99m	-	10	13.80
Ru-103	-	8	7.30
I-131	-	4	180.00
Te-132	-	-	14.00
I-133	-	30	47.00
Cs-134	-	8	5.30
Cs-137	-	7	9.26
Ba-140	-	11	18.60
La-140	-	4	17.10
Ce-141	-	7	13.10
Ce-144	-	35	13.60
Zr-95	1986 APR 28 KL.11	2	20.75
Nb-95	-	1	33.40
Mo-99	-	20	10.40
Tc-99m	-	10	13.50
Ru-103	-	3	10.60
I-131	-	5	152.00
Te-132	-	10	12.40
I-133	-	-	20.30
Cs-134	-	-	1.80
Cs-137	-	7	3.85
Ba-140	-	6	22.40
La-140	-	2	22.00
Ce-141	-	-	20.10
Ce-144	-	11	16.70
Zr-95	1986 APR 29	5	42.50
Nb-95	-	3	44.70
Mo-99	-	16	37.70
Tc-99m	-	10	24.20
Ru-103	-	4	29.00
I-131	-	5	285.00
Te-132	-	10	23.10
I-133	-	-	38.20
Cs-134	-	13	5.20
Cs-137	-	14	7.40
Ba-140	-	9	44.60
La-140	-	3	46.30
Ce-141	-	4	43.20
Ce-144	-	20	40.60

Zr-95	1986 APR 30	4	162.00
Nb-95	-	-	85.60
Tc-99m	-	13	18.70
Ru-103	-	8	39.40
I-131	-	12	293.00
Te-132	-	20	21.00
I-133	-	-	22.60
Cs-134	-	32	6.00
Cs-137	-	-	8.70
Ba-140	-	13	95.70
La-140	-	4	117.00
Ce-141	-	3	160.00
Ce-144	-	11	189.00
Zr-95	1986 MAY 01	5	27.40
Nb-95	-	3	28.50
Mo-99	-	27	16.00
Tc-99m	-	6	12.70
Ru-103	-	2	89.90
I-131	-	5	264.00
Te-132	-	10	29.00
I-133	-	15	10.00
Cs-134	-	16	3.70
Cs-137	-	13	6.21
Ba-140	-	11	32.00
La-140	-	4	31.00
Ce-141	-	6	24.00
Ce-144	-	21	33.00
Zr-95	1986 MAY 02	6	58.00
Nb-95	-	4	58.00
Ru-103	-	6	34.30
I-131	-	2	236.00
Te-132	-	20	24.00
I-133	-	35	11.00
Cs-137	-	30	5.90
Ba-140	-	13	58.00
La-140	-	5	55.00
Ce-141	-	6	53.00
Ce-144	-	35	36.00
Zr-95	1986 MAY 04	10	16.70
Nb-95	-	7	15.90
Ru-103	-	9	10.70
I-131	-	1	330.00
Cs-134	-	17	2.00
Cs-137	-	15	3.40
Ba-140	-	19	10.70
La-140	-	7	10.20
Ce-141	-	12	8.50
Zr-95	1986 MAY 05	10	14.20
Nb-95	-	9	8.10
Ru-103	-	12	7.00
I-131	-	1	218.00

Te-132	1986 MAY 05	15	6.80
I-133	-	35	2.60
Cs-134	-	33	2.30
Cs-137	-	24	3.20
Ba-140	-	10	29.00
La-140	-	5	29.00
Ce-141	-	7	22.00
Zr-95	1986 MAY 06	14	8.70
Nb-95	-	11	7.20
Ru-103	-	9	11.20
I-131	-	1	220.00
Cs-137	-	14	5.40
La-140	-	-	6.70
Zr-95	1986 MAY 07	18	10.50
Nb-95	-	9	14.90
Ru-103	-	10	13.40
I-131	-	2	198.00
Cs-134	-	19	4.00
Cs-137	-	18	6.10
Ba-140	-	40	11.40
La-140	-	14	13.20
Ce-141	-	19	11.80
Zr-95	1986 MAY 08	25	12.50
Nb-95	-	14	12.00
Ru-103	-	1	277.00
I-131	-	-	424.00
Cs-134	-	3	74.00
Cs-137	-	2	134.00
Ba-140	-	8	102.00
La-140	-	3	97.00
Ce-141	-	23	13.80
Zr-95	1986 MAY 09	17	13.80
Nb-95	-	9	16.20
Ru-103	-	2	227.00
I-131	-	1	267.00
Cs-134	-	2	78.00
Cs-137	-	-	131.00
Ba-140	-	8	106.00
La-140	-	3	102.00
Zr-95	1986 MAY 10	25	10.00
Nb-95	-	13	10.60
Ru-103	-	3	107.00
I-131	-	-	93.00
Cs-134	-	6	23.00
Cs-137	-	5	41.00
Ba-140	-	21	28.00
La-140	-	6	44.60
Ce-141	-	22	10.60
Zr-95	1986 MAY 11	13	14.10
Nb-95	-	9	11.90
Ru-103	-	2	108.00
I-131	-	3	83.00
Cs-134	-	5	23.00
Cs-137	-	4	40.20
Ba-140	-	16	31.50
La-140	-	5	40.40
Ce-141	-	14	12.90
Ce-144	-	26	32.10

Zr-95	1986 MAY 12	37	4.80
Nb-95	-	17	6.30
Ru-103	-	2	127.00
I-131	-	-	86.00
Cs-134	-	4	31.00
Cs-137	-	-	53.00
Ba-140	-	11	43.00
La-140	-	4	52.00
Ce-141	-	40	4.10
Zr-95	1986 MAY 13	15	9.00
Nb-95	-	10	11.20
Ru-103	-	3	94.20
I-131	-	2	71.55
Cs-134	-	3	29.38
Cs-137	-	2	52.58
Ba-140	-	15	35.40
La-140	-	8	36.50
Ce-141	-	10	11.10
Ce-144	-	25	14.40
Zr-95	1986 MAY 14	37	3.70
Nb-95	-	13	5.90
Ru-103	-	2	109.00
I-131	-	2	91.27
Cs-134	-	2	42.65
Cs-137	-	2	72.72
Ba-140	-	9	40.00
La-140	-	3	46.00
Ce-141	-	21	6.60
Zr-95	1986 MAY 15	10	9.30
Nb-95	-	6	10.80
Ru-103	-	2	58.00
I-131	-	2	40.11
Cs-134	-	3	18.60
Cs-137	-	3	32.55
Ba-140	-	10	25.00
La-140	-	4	23.30
Ce-141	-	9	9.80
Ce-144	-	32	12.70
Zr-95	1986 MAY 16	17	7.70
Nb-95	-	8	10.50
Ru-103	-	2	88.10
I-131	-	3	53.18
Cs-134	-	5	19.49
Cs-137	-	4	41.81
Ba-140	-	15	24.00
La-140	-	6	24.00
Zr-95	1986 MAY 17	37	3.30
Nb-95	-	27	2.60
Ru-103	-	3	61.00
I-131	-	5	36.54
Cs-134	-	5	20.70
Cs-137	-	5	34.30
Ba-140	-	17	21.00
La-140	-	8	21.00
Ce-141	-	26	4.90

Zr-95	1986 MAY 18	27	6.80
Nb-95	-	12	9.20
Ru-103	-	4	35.00
I-131	-	6	29.96
Cs-134	-	7	14.39
Cs-137	-	7	24.53
La-140	-	11	15.70
Ce-141	-	36	4.50
Nb-95	1986 MAY 19	23	3.10
Ru-103	-	3	57.00
I-131	-	5	31.55
Cs-134	-	6	15.21
Cs-137	-	5	30.81
Ba-140	-	24	15.20
La-140	-	11	11.70
Zr-95	1986 MAY 20	29	4.10
Nb-95	-	14	5.50
Ru-103	-	3	46.00
I-131	-	5	22.83
Cs-134	-	6	12.97
Cs-137	-	5	22.39
Ba-140	-	28	10.50
La-140	-	7	16.80
Ce-141	-	18	6.10
Ru-103	1986 MAY 21	5	30.00
I-131	-	7	17.74
Cs-134	-	9	9.66
Cs-137	-	8	17.79
La-140	-	13	8.50
Zr-95	1986 MAY 22	5	37.48
Nb-95	-	4	39.33
Ru-103	-	5	36.32
I-131	-	8	15.69
Cs-134	-	10	10.76
Cs-137	-	7	20.56
Ba-140	-	23	19.09
La-140	-	8	18.23
Ce-141	-	5	38.10
Ce-144	-	15	49.48
Nb-95	1986 MAY 23	28	2.00
Ru-103	-	4	29.00
I-131	-	8	13.21
Cs-134	-	8	10.10
Cs-137	-	7	17.63
La-140	-	15	6.30
Zr-95	1986 MAY 26	36	3.20
Nb-95	-	14	5.20
Ru-103	-	3	41.00
I-131	-	7	14.37
Cs-134	-	6	13.00
Cs-137	-	5	25.57
Ba-140	-	33	8.40
La-140	-	10	9.20
Ce-141	-	34	3.20

Nb-95	1986 MAY 27	23	1.70
Ru-103	-	4	23.00
I-131	-	5	13.51
Cs-134	-	7	7.80
Cs-137	-	6	14.36
Ba-140	-	33	5.00
La-140	-	12	5.50
Ce-141	-	34	1.90
Ru-103	1986 MAY 28	5	13.80
I-131	-	7	7.28
Cs-134	-	9	5.52
Cs-137	-	8	8.94
Nb-95	1986 MAY 29	36	1.40
Ru-103	-	5	35.00
La-140	-	17	5.80
Zr-95	1986 MAY 30	29	2.10
Nb-95	-	11	3.30
Ru-103	-	3	20.50
I-131	-	7	7.26
Cs-134	-	6	7.30
Cs-137	-	5	12.66
Ba-140	-	28	5.00
La-140	-	13	3.60
Ce-141	-	22	2.50

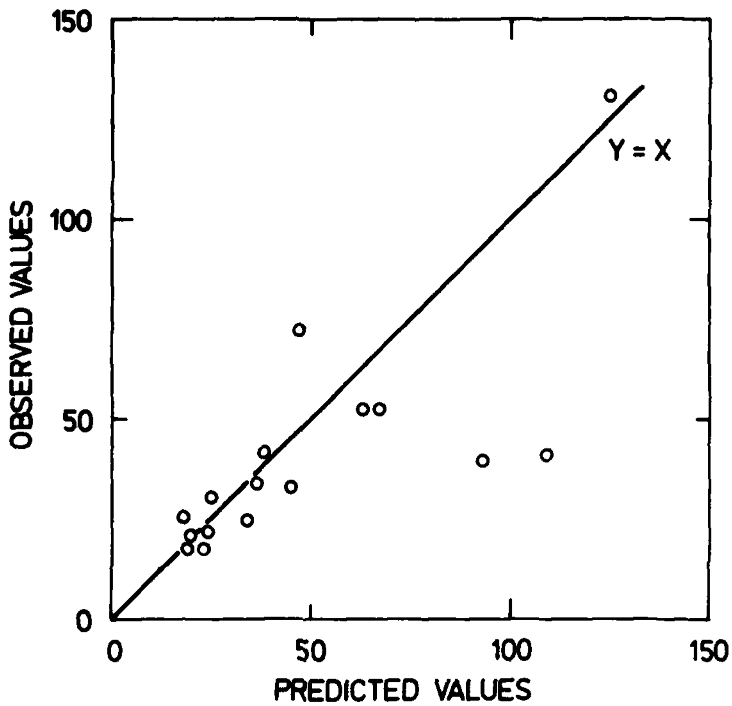

Fig. E.6. Comparison between model predictions and observations for Bq ^{137}Cs m^{-2} grass at Risø in May 1986.
The model assumes an initial uptake in grass of 28% of the deposition. Furthermore, it is assumed that the field loss during rain corresponds to a field half-life of 2 days. During dry weather the half-life is 14 days.

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Risø National Laboratory **Risø - R - 549**

Title and author(s)	
ENVIRONMENTAL RADIOACTIVITY IN DENMARK IN 1986 A. Aarkrog, L. Bøtter-Jensen, Chen Qing Jiang, H. Dahlgaard, Heinz Hansen, Elis Holm[+], Bente Lauridsen, S.P. Nielsen and J. Søgaard-Hansen [+]International Laboratory for Marine Radioactivity, Monaco	Date November 1988 Department or group Health Physics Groups own registration number(s) Project/contract no.
Pages 274 Tables 178 Illustrations 70 References 34	ISBN 87-550-1339-2

Abstract (Max. 2000 char.)

Strontium-90, radiocesium and other radionuclides were determined in samples from all over the country of air, precipitation, stream stream water, lake water, ground water, drinking 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 of the mean contents of radiostrontium and radiocesium in the human diet in Denmark during 1986 are given. Tritium was determined in precipitation, ground water, other fresh waters and sea water. The γ-background was measured regularly by TLD, ionization chamber and on site γ-spectroscopy at locations around Risø, at ten of the State experimental farms, along the coasts of the Great Belt and around Gylling Næs. The marine environments at Barsebäck and Ringhals were monitored for ^{137}Cs and corrosion products (^{58}Co, ^{60}Co, ^{65}Zn, ^{54}Mn).

The Chernobyl accident caused a substantial expansion of the environmental monitoring activities in Denmark. The programme was expanded to an extent similar to that in the sixties.

Descriptors - INIS

AIR; AMERICIUM 241; AQUATIC ECOSYSTEMS; ATMOSPHERIC PRECIPITATIONS; BACKGROUND RADIATION; BARIUM 140; BARSEBAECK-1 REACTOR; BARSEBAECK-2 REACTOR; BONE TISSUES; CERIUM ISOTOPES; CESIUM 134; CESIUM 137; CHERNOBYLSK-4 REACTOR; COBALT ISOTOPES; CURIUM ISOTOPES; DENMARK; DIET; ENVIRONMENT; FALLOUT DEPOSITS; FISHES; FOOD; FOOD CHAINS; GLOBAL FALLOUT; GROUND WATER; IODINE ISOTOPES; LANTHANUM 140; LOCAL FALLOUT; MAN; MANGANESE 54; MILK; NEPTUNIUM 239; NIOBIUM 95; NUMERICAL DATA; PLANTS; PLUTONIUM ISOTOPES; RADIOACTIVITY; REACTOR ACIDENTS; RINGHALS-1 REACTOR; RINGHALS-2 REACTOR; RINGHALS-3 REACTOR; RISOE NATIONAL LABORATORY; RUTHENIUM ISOTOPES; SEAWATER; SEAWEEDS; SEDIMENTS; SILVER 110; STRONTIUM 89; STRONTIUM 90; TECHNETIUM 99; TRITIUM; URANIUM 237; ZINC 65; ZIRCONIUM 95.

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INFORMATION

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Errata to Risø-R-549

Environmental Radioactivity in Denmark in 1986

p 9 second paragraf line 5: delete: and milk

p 61 second paragraf line 6: case: read core
" line 11: delete the rest of the paragraf from: If we consider the ratio: $^{239}Np/^{141}Ce$

p 156 - 158 Tables 5.7.4, 5.7.5, and 5.7.6:	Bq $(kg\ K)^{-1}$:	read Bq $^{137}Cs\ (kg\ K)^{-1}$
	Bq $day^{-1}\ cap^{-1}$:	read Bq $^{137}Cs\ day^{-1}\ cap^{-1}$
p 160 Table 5.8.1.2:	Bq kg^{-1}:	read Bq $^{137}Cs\ kg^{-1}$
	Bq $(kg\ K)^{-1}$:	read Bq $^{137}Cs\ (kg\ K)^{-1}$

p 168 5.9.9.: The ^{137}Cs mean concentration for 1986 may be a little lower because the increased radiocesium levels in fish due to Chernobyl first appeared in May. (cf. also p 164)

p 226 Appendix A1: $^{95}Sr/^{137}Cs$: read $^{90}Sr/^{137}Cs$