

Radioactivity in the Risø District July-December 2022



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Preface

A specific monitoring programme in the vicinity of the nuclear installations at the Risø site is carried out by DTU Environment on behalf of and as a contractor to Danish Decommissioning (DD). This report presents the analytical results of the monitoring and sampling carried out in the period July-December 2022. The materials and methods used in connection with the monitoring programme are described in pages 27-28.

Risø, October 2023

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Summary

The environmental surveillance of the Risø environment was continued in July-December 2022. The mean concentrations in air were: $0.17 \pm 0.11 \mu\text{Bq m}^{-3}$ of ^{137}Cs , $2.46 \pm 0.98 \text{ mBq m}^{-3}$ of ^7Be and $0.22 \pm 0.11 \text{ mBq m}^{-3}$ of ^{210}Pb (± 1 standard uncertainty). The depositions by precipitation at Risø in the second half of 2022 were: $0.027 \pm 0.004 \text{ Bq m}^{-2}$ of ^{137}Cs , $384 \pm 46 \text{ Bq m}^{-2}$ of ^7Be , $37.5 \pm 4.5 \text{ Bq m}^{-2}$ of ^{210}Pb and $<0.5 \text{ kBq m}^{-2}$ of ^3H . The average background dose rate (TLD) at Risø (Zone I) was measured as $0.09 \mu\text{Sv h}^{-1}$ compared with $0.09 \mu\text{Sv h}^{-1}$ in the four zones around Risø.

Table 1. Radionuclides in ground level air collected at Risø (cf. Figs. 1, 1.1 and 1.2), July-December 2022 (Unit: $\mu\text{Bq m}^{-3}$). Figures in brackets are relative standard uncertainties.

Date	^7Be	^{137}Cs	^{210}Pb
01-07-2022 – 08-07-2022	2447(11%)	0.043(13%)	95(11%)
08-07-2022 – 15-07-2022	1746(11%)	0.036(13%)	65(11%)
15-07-2022 – 22-07-2022	4120(11%)	0.171(12%)	224(11%)
22-07-2022 – 29-07-2022	1956(11%)	0.056(12%)	92(11%)
29-07-2022 – 05-08-2022	3271(11%)	0.121(12%)	172(11%)
05-08-2022 – 12-08-2022	2490(11%)	0.078(12%)	130(11%)
12-08-2022 – 19-08-2022	5148(11%)	0.431(11%)	537(11%)
19-08-2022 – 26-08-2022	4272(11%)	0.228(11%)	275(11%)
26-08-2022 – 02-09-2022	2478(11%)	0.340(12%)	232(11%)
02-09-2022 – 09-09-2022	3573(11%)	0.172(12%)	204(11%)
09-09-2022 – 16-09-2022	1678(11%)	0.368(12%)	163(11%)
16-09-2022 – 23-09-2022	789(11%)	0.090(11%)	119(11%)
23-09-2022 – 30-09-2022	3037(11%)	0.154(12%)	354(11%)
30-09-2022 – 07-10-2022	2010(11%)	0.078(11%)	147(11%)
07-10-2022 – 14-10-2022	2025(11%)	0.084(12%)	139(11%)
14-10-2022 – 21-10-2022	2408(11%)	0.127(11%)	231(11%)
21-10-2022 – 28-10-2022	2451(11%)	0.124(12%)	258(11%)
28-10-2022 – 04-11-2022	2877(11%)	0.119(12%)	368(11%)
04-11-2022 – 11-11-2022	2253(11%)	0.086(12%)	160(11%)
11-11-2022 – 18-11-2022	1985(11%)	0.100(12%)	217(11%)
18-11-2022 – 25-11-2022	1488(11%)	0.199(12%)	212(11%)
25-11-2022 – 02-12-2022	1546(11%)	0.224(12%)	282(11%)
02-12-2022 – 09-12-2022	2273(11%)	0.262(11%)	333(11%)
09-12-2022 – 16-12-2022	1457(11%)	0.287(11%)	278(11%)
16-12-2022 – 23-12-2022	2476(11%)	0.362(11%)	285(11%)
23-12-2022 – 28-12-2022	1759(11%)	0.144(12%)	79(11%)
Mean	2462	0.172	217
SD	976	0.109	107

Table 2.1. Radionuclides in precipitation in the 10 m² rain collector at Risø (cf. Fig. 8.1), July - December 2022. (Unit: Bq m⁻³)

Month	⁷ Be	¹³⁷ Cs	²¹⁰ Pb
July	2880(11%)*	0.180(13%)	234(11%)
August	2224(11%)	0.239(12%)	305(11%)
September	981(11%)	0.065(12%)	70(11%)
October	1576(11%)	0.062(14%)	111(11%)
November	2192(11%)	0.121(15%)	266(11%)
December	1375(11%)	0.058(13%)	108(11%)

*Figures in brackets are relative standard uncertainties

Table 2.2. Radionuclides in precipitation in the 10 m² rain collector at Risø (cf. Fig. 8.1), July - December 2022. (Unit: Bq m⁻²)

Month	Precipitation (m)	⁷ Be	¹³⁷ Cs	²¹⁰ Pb
July	0.017(10%)*	50(17%)	0.0030(17%)	4.0(17%)
August	0.054(10%)	121(17%)	0.0130(16%)	16.6(17%)
September	0.070(10%)	68(17%)	0.0045(16%)	4.9(17%)
October	0.039(10%)	62(17%)	0.0024(17%)	4.4(17%)
November	0.012(10%)	27(17%)	0.0015(18%)	3.2(17%)
December	0.041(10%)	56(17%)	0.0024(16%)	4.4(17%)
Sum	0.233(5%)	384(12%)	0.0268(15%)	37.5(12%)

*Figures in brackets are relative standard uncertainties

Table 2.3. Tritium in precipitation collected at Risø (cf. Figs. 1, 8.1, 2.3.1 and 2.3.2). July - December 2022. (Unit: kBq m⁻³)

Month	10 m ² rain collector*
July	3.1(19%) ^a
August	3.5(16%)
September	1.5(27%)
October	<1.3
November	<1.3
December	<1.3

* Double determinations.

^a Figures in brackets are relative standard uncertainties. '<' means detection limit.

Table 2.4. Tritium in precipitation collected at Risø (cf. Fig. 1). July - December 2022 (Unit: kBq m⁻²)

Month	Precipitation (m)	10 m ² rain collector
July	0.017(10%)*	0.053(21%) ^a
August	0.054(10%)	0.189(19%)
September	0.070(10%)	0.105(29%)
October	0.039(10%)	< 0.051
November	0.012(10%)	< 0.016
December	0.041(10%)	< 0.053
Sum	0.233(5%)	< 0.467

^a Figures in brackets are relative standard uncertainties. '<' means detection limit.

Table 3.1. Radionuclides in sediment samples collected at Bolund in Roskilde Fjord.(cf. Fig. 3.1) July - December 2022. (Unit: Bq kg⁻¹ dry)

No samples in this period. Samples are only taken/measured once per year.

Table 4.1. Radionuclides in seawater collected in Roskilde Fjord (cf. Fig. 4.1) July - December 2022. (Unit: Bq m⁻³)

No samples in this period. Samples are only taken/measured once per year.

Table 4.2. Tritium in seawater collected in Roskilde Fjord (Risø pier) (cf. Fig. 4.2) July - December 2022^a.

Month	kBq m ⁻³
September	1.5(23.4%)
December	<1.3

* Double determinations

^a Figures in brackets are relative standard uncertainties. '<' means detection limit.

Table 5.1. Radionuclides in grass collected at Risø near the Waste Treatment Station, location I P3, Fig. 1, July - December 2022. (**Measured on bulked ash samples)

Week no. or month	Date	K (g kg ⁻¹ fresh)	¹³⁷ Cs (Bq kg ⁻¹ fresh)	¹³⁷ Cs (Bq m ⁻²)
28	15 July	6.1(11%) ^a	<0.3	
30	29 July	7.0(11%)	<0.6	
32	12 August	9.8(11%)	<0.3	
34	26 August	9.3(11%)	<0.4	
36	09 September	5.4(11%)	<0.2	
38	23 September	5.0(11%)	<0.3	
40	07 October	7.2(11%)	<0.3	
42	21 October	4.6(11%)	<0.3	
44	04 November	7.9(11%)	<0.3	
46	18 November	5.3(11%)	<0.2	
48	02 December	5.4(11%)	<0.2	
50	16 December	5.3(11%)	<0.2	
52	28 December	5.2(11%)	<0.2	
** July		5.5(11%)	0.037(13%)	0.013(13%)
** August		8.3(11%)	<0.031	<0.007
** September		4.8(11%)	<0.024	<0.008
** October		5.7(11%)	<0.039	<0.013
** November		5.7(11%)	0.030(24%)	0.010(24%)
** December		5.1(11%)	0.037(12%)	0.014(12%)

^a Figures in brackets are relative standard uncertainties. '<' means detection limit.

Table 5.2. Radionuclides in Fucus vesiculosus collected at Bolund in Roskilde Fjord. July - December 2022. (Unit: Bq kg⁻¹ dry)

No samples in this period. Samples are only taken/measured once per year.

Table 7.1. Waste water collected at Risø (cf. Fig. 1), July - December 2022.

Week Number	Total beta (eqv. mg KCl l ⁻¹)	¹³⁷ Cs (Bq m ⁻³)	¹³¹ I (Bq m ⁻³)	²²⁶ Ra (Bq m ⁻³)
27	143(11%) ^a	<41	<57	<90
28	145(11%)	<54	<66	<109
29	141(10%)	<44	<41	<190
30	148(10%)	<77	<96	<157
31	166(10%)	<71	<83	<154
32	148(11%)	<59	<77	<125
33	192(10%)	<69	<82	<144
34	184(10%)	<53	<65	<119
35	120(11%)	<79	<82	<159
36	121(10%)	<55	<67	<129
37	127(10%)	<77	<82	<162
38	119(10%)	<79	<88	<162
39	108(11%)	<51	<59	<112
40	116(10%)	<50	<61	<122
41	129(10%)	<54	<63	<105
42	131(10%)	<75	<86	<157
43	117(10%)	<78	<90	<169
44	132(10%)	<53	<60	<113
45	144(11%)	<68	<64	<130
46	130(11%)	<56	<71	<119
47	135(10%)	<50	<58	<107
48	138(11%)	<78	<95	<162
49	133(11%)	<83	<105	<170
50	150(10%)	<89	<98	<177
51	148(10%)	<87	<176	<186
52	125(10%)	<75	<105	<150
Mean	136.8	<66	<80	<142
SD	21.4			

^a Figures in brackets are relative standard uncertainties. '<' means detection limit.

Table 8.1. Background dose rates around the border of Risø (cf. Fig. 8.1) measured with thermoluminescence dosimeters (TLD) in the period May 2022 – October 2022. (Results are normalized to $\mu\text{Sv h}^{-1}$)

Location	$\mu\text{Sv h}^{-1}$
1	0.09 ^a
2	0.09
3	0.09
4	0.09
5	0.09
6	0.09
Mean	0.09

^a In relation to the uncertainty on dose rate values reported in Tables 8.1 and 8.2 the Danish Health Authority, Radiation Protection that carries out the dose determination state that for a dose of 0.1 mSv the uncertainty will for a measurement period of 1 month or 3 months be respectively ca. 50 % and 100 % (95 % confidence). At doses higher than 1 mSv the uncertainty is a bit less than 25 % (95 % confidence) regardless of the length of the measurement period. The values in these tables are a bit in the high end compared with those typically reported in previous years when the dose determination was made at DTU, and with the NaI(Tl) detector measurements in Table 8.3, but considered to agree reasonably taking the clearly high uncertainty into account. Anyway all dose rates reported are very low and close to the TLD detection limit.

Table 8.2. Background dose rates around Risø (cf. Fig. 8.2 and Fig. 1) measured with thermoluminescence dosimeters (TLD) in the period May 2022– October 2022. (Results are normalized to $\mu\text{Sv h}^{-1}$)

Risø zone	Location	$\mu\text{Sv h}^{-1}$ ^a
I	1	0.09 ^a
I	2	0.09
I	3	0.11
I	4	0.09
I	5	0.09
Mean		0.09
II	P1	0.09
II	P2	0.11
II	P3	0.09
II	P4	0.09
Mean		0.10
III	P1	0.09
III	P2	0.09
III	P3	0.09
Mean		0.09
IV	P1	0.09
IV	P2	0.09
IV	P3	0.09
IV	P4	0.09
IV	P5	0.09
IV	P6	0.09
IV	P7	0.11
Mean		0.09
V	P1	0.11
V	P2	0.09
V	P3	0.09
V	P4	0.11
V	P5	0.09
V	P6	0.09
V	P7	0.11
V	P8	0.09
V	P9	0.09
V	P10	0.09
Mean		0.10

Table 8.3. Terrestrial dose rates at the Risø zones (cf. Fig. 8.2 and Fig. 1) May 2022– October 2022. Measured with a NaI(Tl) detector. (Unit: $\mu\text{Sv h}^{-1}$)

Risø zone	Location	May
I	P1	0.040(10%)
I	P2	0.057(10%)
I	P3	0.330(10%)
I	P4	0.048(10%)
I	P5	0.046(10%)
Mean		0.104(5%)
II	P1	0.047(10%)
II	P2	0.045(10%)
II	P3	0.042(10%)
II	P4	0.043(10%)
Mean		0.044(4%)
III	P1	0.047(10%)
III	P2	0.049(10%)
III	P3	0.046(10%)
Mean		0.048(6%)
IV	P1	0.041(10%)
IV	P2	0.050(10%)
IV	P3	0.043(10%)
IV	P4	0.040(10%)
IV	P5	0.042(10%)
IV	P6	0.040(10%)
IV	P7	0.045(10%)
Mean		0.043(4%)
V	P1	0.044(10%)
V	P2	0.048(10%)
V	P3	0.056(10%)
V	P4	0.053(10%)
V	P5	0.053(10%)
V	P6	0.050(10%)
V	P7	0.044(10%)
V	P7a	0.041(10%)
V	P8	0.047(10%)
V	P9	0.041(10%)
V	P10	0.038(10%)
Mean		0.047(4%)

^a Figures in brackets are relative standard uncertainties

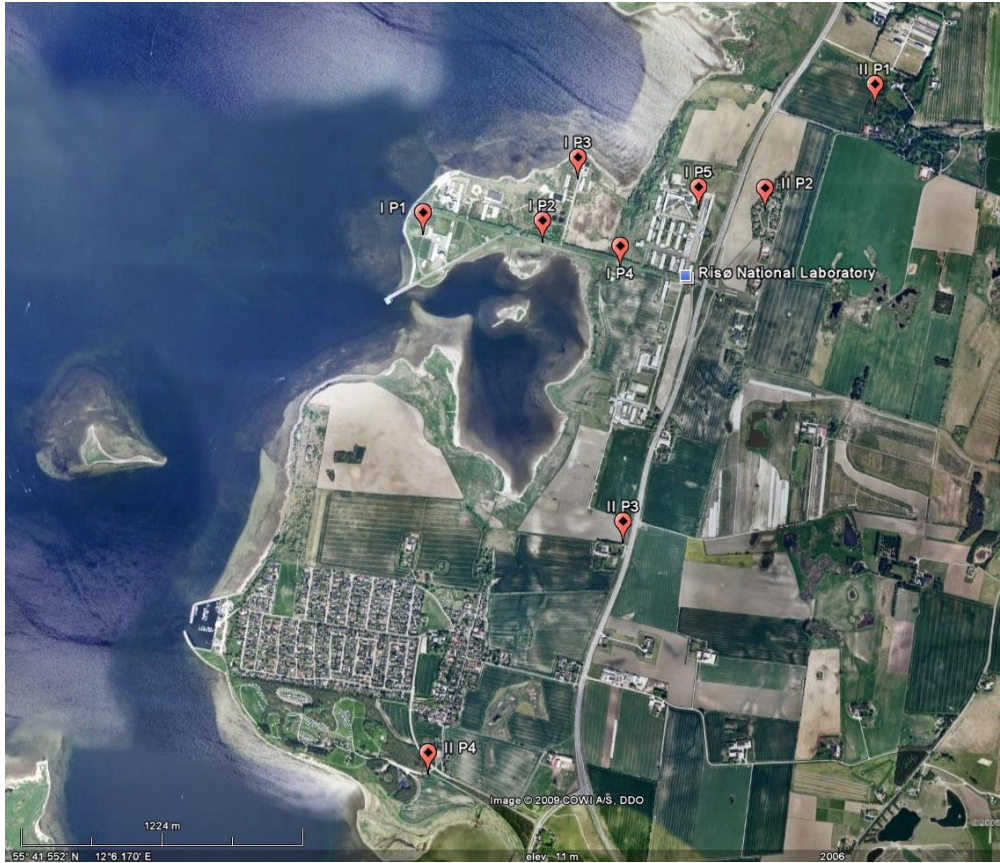


Fig. 1. Locations for measurements of gamma-background radiation Zone I and II (cf. Tables 8.2 and 8.3)

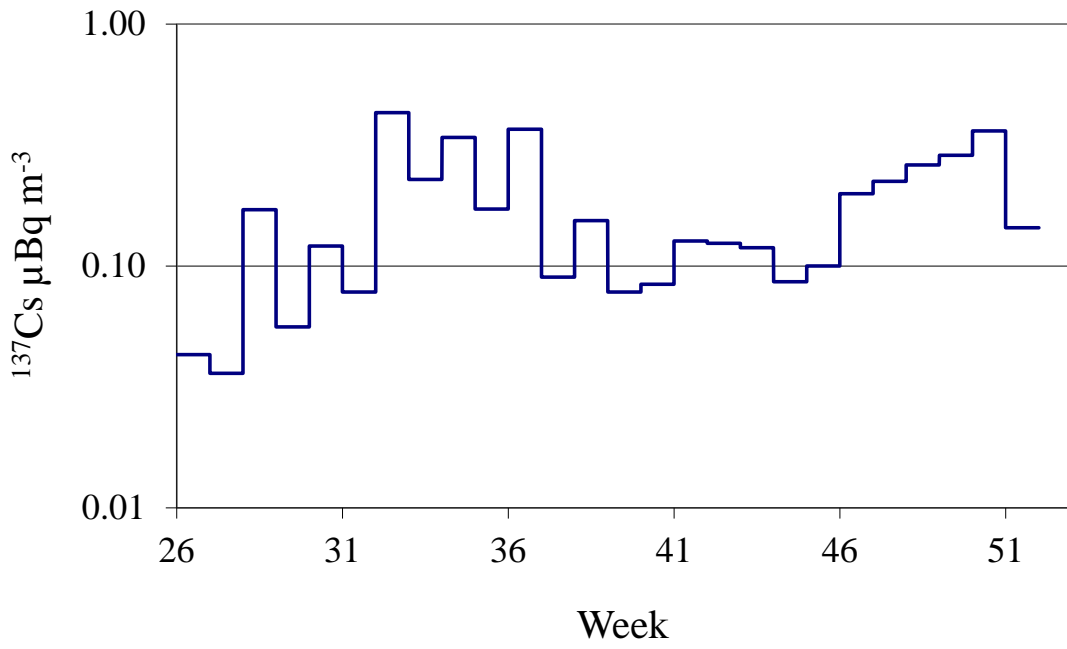


Fig. 1.1. Caesium-137 in ground level air collected at Risø in July-December 2022. (Unit: $\mu\text{Bq m}^{-3}$)

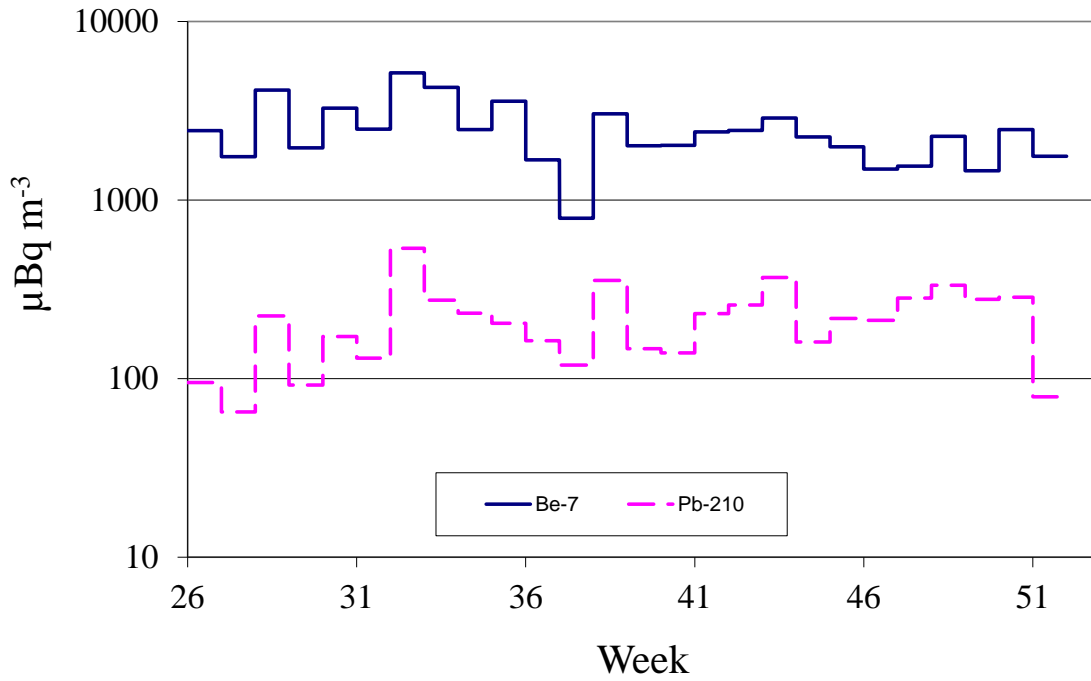


Fig. 1.2. Beryllium-7 and Lead-210 in ground level air collected at Risø in July-December 2022. (Unit: $\mu\text{Bq m}^{-3}$)

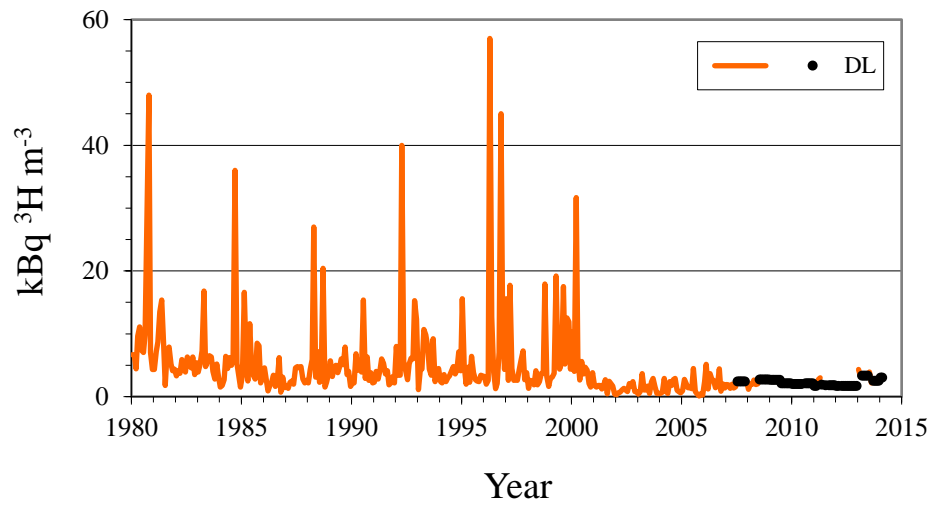


Fig. 2.3.1. Tritium in precipitation collected at Risø (1 m² rain collector) 1980 - 2013. (Unit: kBq m⁻³; DL = detection limit). This rain collector was taken out of operation in 2013.

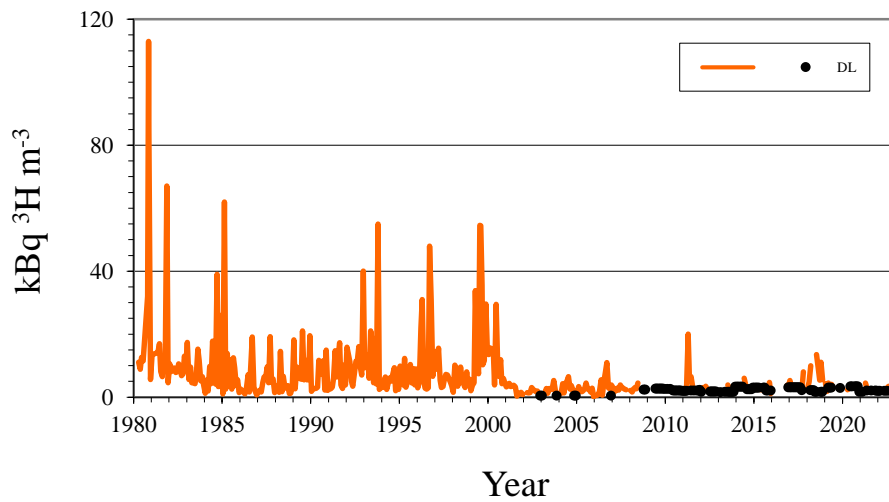


Fig. 2.3.2. Tritium in precipitation collected at Risø (10 m² rain collector) 1980 - 2022. (Unit: kBq m⁻³; DL = detection limit)

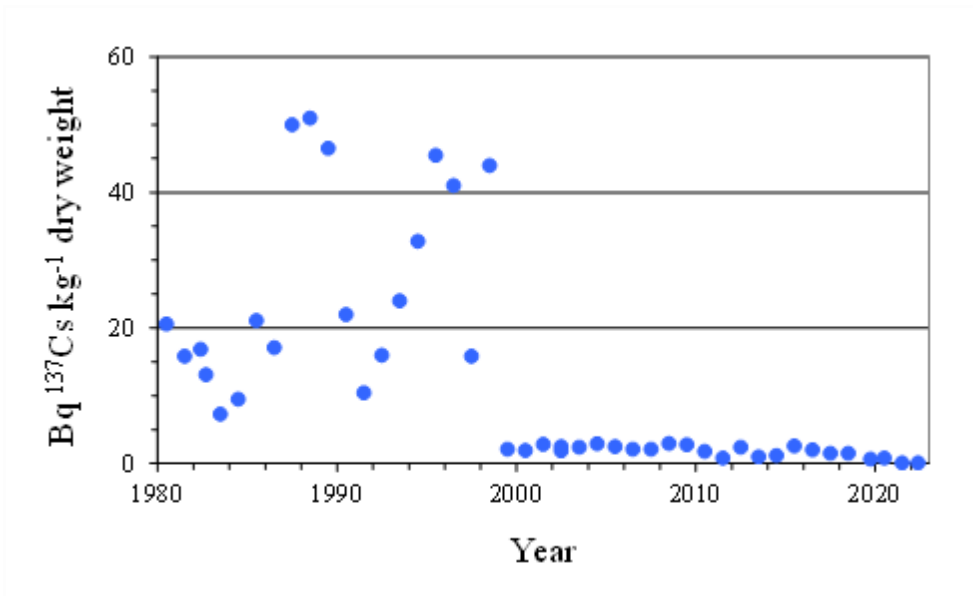


Fig. 3.1. Caesium-137 in sediment samples collected at Bolund in Roskilde Fjord. 1980 – 2022. (Unit: Bq kg⁻¹ dry matter)

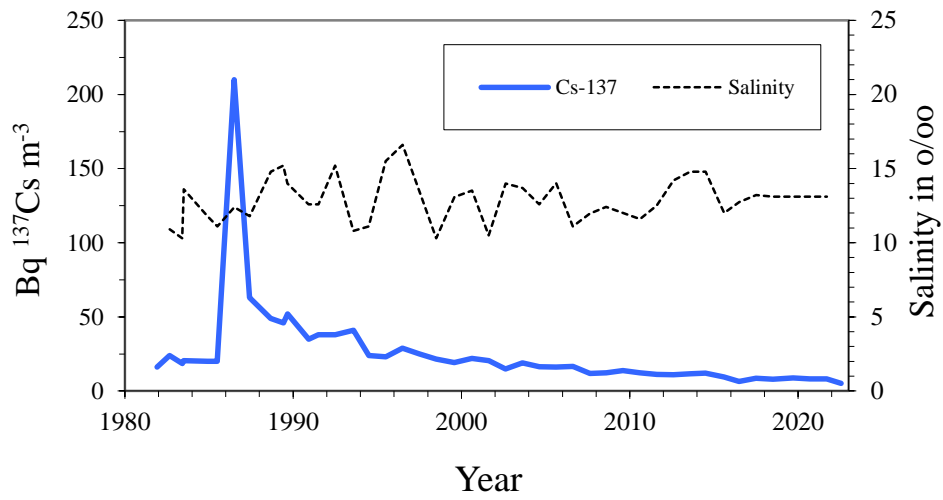


Fig. 4.1. Caesium-137 in seawater collected in Roskilde Fjord 1980 – 2022. (Unit: Bq m^{-3})

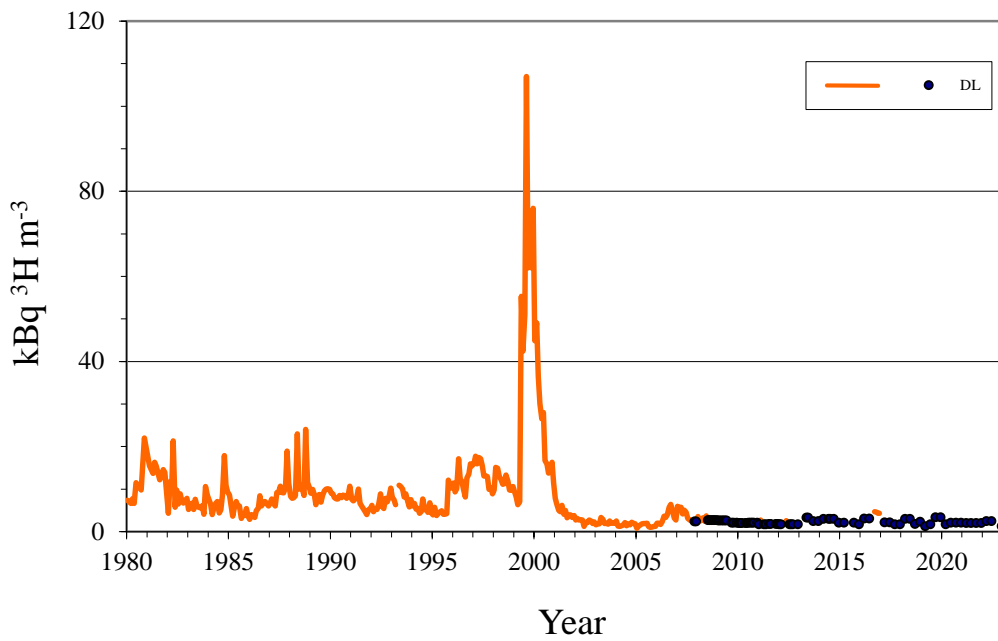
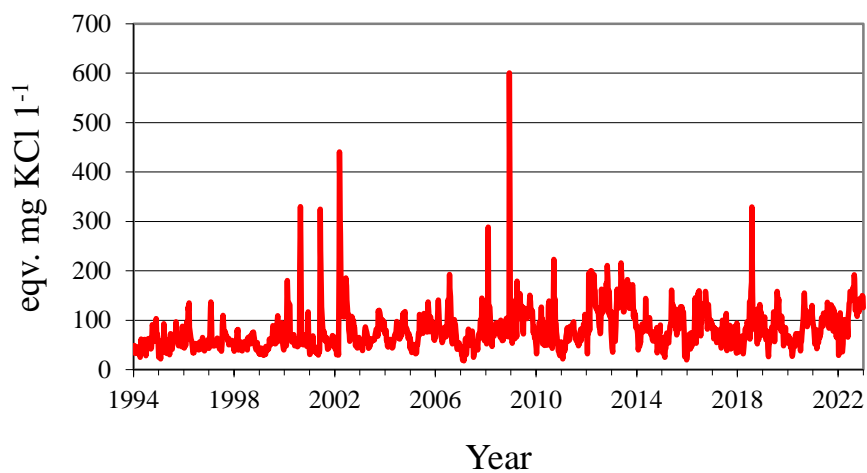


Fig. 4.2. Tritium in seawater collected in Roskilde Fjord 1980 - 2022. (Unit: kBq m^{-3} ; DL = detection limit)



*Fig. 7.1. Total-beta radioactivity in waste water collected at Risø 1994 - 2022.
(Unit: eqv. mg KCl l⁻¹)*

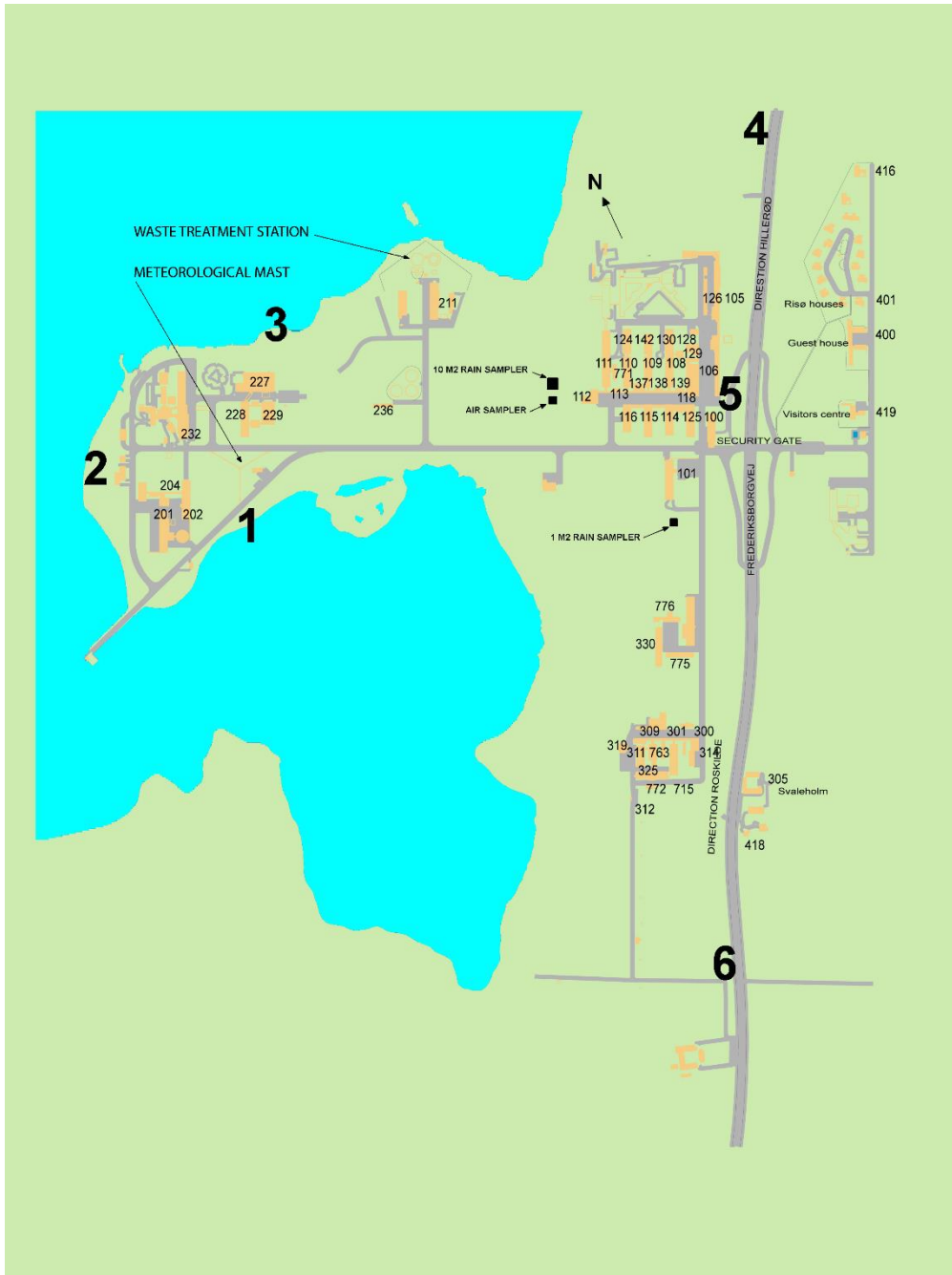


Fig. 8.1. Locations (1-6) for TLD measurements around the border of Risø (cf. Table 8.1).



Fig. 8.2. Locations for measurements of background radiation around Risø in Zones III, IV and V.

Materials and methods

External gamma dose rate monitoring

Monitoring of external gamma dose rate is carried out with the following devices

- Thermoluminescence dosimeters TLD: LiF, TLD equipment manufacturer: Harshaw
- NaI detector: 3x3 inch, SAM 935 Surveillance and Measurement System, Berkeley Nucleonics Cooperation, USA, visual read-out

Calibration of TLD is carried out at the Danish Health Authority, Radiation Protection.

Traceability of delivered doses is ensured through calibration of the dose rate of the calibration irradiator by the Danish Health Authority, Radiation Protection. Further information on, e.g., the reported dosis, associated uncertainty and the lower detection limit is given by the Danish Health Authority, Radiation Protection at https://www.sst.dk/-/media/Opgaver/Strålebeskyttelse/Selvbetjening/Helkropsdosimeter_Infoseddel.ashx?la=da&hash=B6E03F283B84F87BF76CB1138912716608854948. The NaI detector is calibrated periodically vs. a Reuter Stokes high-pressure ionisation chamber.

Air sampler

The sampler at Risø is manufactured by DTU. Air is drawn through a polypropylene filter at a rate of about 2000 m³/h. The filter is normally changed weekly. The flow rate is monitored by a gas meter connected to a shunt. The gas meter reading is compared to that of a reference gas meter intermittently.

DTU analyse the filters by gamma spectrometry shortly after filter change to check for the presence of short-lived man-made radionuclides. The air filters are subsequently stored for a minimum of one week to allow for decay of short-lived naturally occurring radionuclides before repeated gamma analysis. Filters are analysed for ¹³⁷Cs, ⁷Be and ²¹⁰Pb and other gamma emitters.

Deposition collector

The Risø site operates a large rain collector of 10 m². The collector is heated and water is passed through an ion exchange column to a large tank. The 10 m² collector provides monthly samples of rain water analysed for tritium and ion exchange resin which is analysed by gamma spectrometry for ⁷Be, ¹³⁷Cs and ²¹⁰Pb and other gamma emitters.

Water and sediment

A waste water sample from the Waste Treatment Station is collected weekly and analysed for total beta radioactivity and the radionuclides ¹³¹I, ¹³⁷Cs and ²²⁶Ra. Water samples from Roskilde Fjord are collected each quarter and analysed for tritium, annually for ¹³⁷Cs. A sediment sample is collected annually from Roskilde Fjord and analysed for ¹³⁷Cs.

Terrestrial and aquatic biota and flora

Grass samples are collected weekly at the Risø site and analysed by gamma spectrometry. Samples are bulked to monthly samples which are analysed for ^{137}Cs .

Seaweed samples are collected annually from Roskilde Fjord at Risø and analysed for ^{137}Cs .

Sample reception and preparation

Sample identification numbers are entered in log books. Sample preparation methods include drying, freeze drying, ashing, sorting and sieving. Selected samples are archived.

Sample measurements

Radioactivity in samples is measured by total beta counting and gamma spectrometry.

Measurement devices

- Ge detectors for gamma spectrometry. Calibration of detectors is based on mixed-nuclide standards used occasionally. Monthly checks are made of detector efficiency and energy resolution. Background measurements of gamma systems are made a few times per year.
- Low-level Geiger-Müller counters for total beta counting, manufactured by DTU. Calibration based on standards of KCl. Counting efficiency and background are checked monthly.
- Liquid scintillation spectrometer for analysis of tritium in water. Samples are analysed with a calibration standard.

Analytical results, data handling and reporting tools

Analytical results are printed on paper, recorded in log books and stored in a data base on intranet. Results below detection limits recorded as such. Spreadsheets are used for calculating results from raw data.

Quality assurance, laboratory accreditation and intercomparison exercises

Analytical results are checked by experienced staff and discussed with senior scientists if questions arise.

DTU is accredited to testing for radioactivity by DANAK according to the international standard ISO 17025. The accreditation covers testing for certain non-gamma emitting radionuclides but not for radionuclides occurring in the environment and food in general.

DTU participate regularly in international intercomparisons on laboratory analyses of radionuclides.

Conclusions

This report shows the results of the environmental surveillance monitoring programme carried out at and around the Risø site in July-December 2022. The mean concentrations in air were: $0.17 \pm 0.11 \mu\text{Bq m}^{-3}$ of ^{137}Cs , $2.46 \pm 0.98 \text{ mBq m}^{-3}$ of ^7Be and $0.22 \pm 0.11 \text{ mBq m}^{-3}$ of ^{210}Pb (± 1 standard uncertainty). The depositions by precipitation at Risø in the second half of 2022 were: $0.027 \pm 0.004 \text{ Bq m}^{-2}$ of ^{137}Cs , $384 \pm 46 \text{ Bq m}^{-2}$ of ^7Be , $37.5 \pm 4.5 \text{ Bq m}^{-2}$ of ^{210}Pb and $< 0.5 \text{ kBq m}^{-2}$ of ^3H . The average background dose rate (TLD) at Risø (Zone I) was measured as $0.09 \mu\text{Sv h}^{-1}$ compared with $0.09 \mu\text{Sv h}^{-1}$ in the four zones around Risø.

None of the recorded levels of radioactivity and radiation have given rise to concern.

DTU Sustain is working to develop new environmentally friendly and sustainable technologies and disseminate this knowledge to society and new generations of engineers. Research in Radioecology & Tracer Studies (RTS) aims at developing methods and instruments for analysing manmade and naturally recurring radionuclides in the environment and samples from nuclear facilities. The RTS Section is responsible for carrying out the environmental radioactivity monitoring program in Denmark.

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