DTU SUSTAIN

Radioactivity in the Risø District January-June 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 January - June 2022. The materials and methods used in connection with the monitoring programme are described in pages 27-28.

Risø, December 2022

Contents

Summary

The environmental surveillance of the Risø environment was continued in January-June 2022. The mean concentrations in air were: 0.13±0.08 μBq m^{-3} of ^{137}Cs, 2.93±1.43 mBq m^{-3} of ^{7}Be and 0.13±0.08 mBq m^{-3} of ^{210}Pb (±1 standard uncertainty). The depositions by precipitation at Risø in the first half of 2021 were: 0.029±0.004 Bq m^{-2} of ^{137}Cs, 271±19 Bq m^{-2} of ^{7}Be, 21.6±2.4 Bq m^{-2} of ^{210}Pb and <0.5 kBq m^{-2} of ^{3}H. The average background dose rate (TLD) at Risø (Zone I) was measured as 0.10 μSv h^{-1} compared with 0.10 μSv 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), January-June 2022 (Unit: μBq m^{-3})**

Date			^{7}Be	^{137}Cs	^{210}Pb
31-dec-21	–	07-jan-22	2432(11%)	0.131(12%)	74(11%)
07-jan-22	–	14-jan-22	2217(11%)	0.212(11%)	95(11%)
14-jan-22	–	21-jan-22	2495(11%)	0.156(12%)	41(11%)
21-jan-22	–	28-jan-22	1586(11%)	0.137(12%)	58(11%)
28-jan-22	–	04-feb-22	1577(11%)	0.133(12%)	35(11%)
04-feb-22	–	11-feb-22	1937(11%)	0.085(12%)	15(11%)
11-feb-22	–	18-feb-22	2596(11%)	0.124(12%)	75(11%)
18-feb-22	–	25-feb-22	1971(11%)	0.063(12%)	37(11%)
25-feb-22	–	04-mar-22	1996(11%)	0.268(12%)	120(11%)
04-mar-22	–	11-mar-22	2206(11%)	0.379(11%)	164(11%)
11-mar-22	–	18-mar-22	3465(11%)	0.458(11%)	206(11%)
18-mar-22	–	25-mar-22	8529(11%)	1.332(11%)#	384(11%)
25-mar-22	–	01-apr-22	3510(11%)	0.454(11%)	240(11%)
01-apr-22	–	08-apr-22	1595(11%)	0.122(11%)	64(11%)
08-apr-22	–	15-apr-22	1884(11%)	0.213(11%)	91(11%)
15-apr-22	–	22-apr-22	2968(11%)	0.315(12%)	183(11%)
22-apr-22	–	29-apr-22	2684(11%)	0.221(12%)	137(11%)
29-apr-22	–	06-may-22	2791(11%)	0.134(12%)	122(11%)
06-may-22	–	12-may-22	3875(11%)	0.142(12%)	159(11%)
12-may-22	–	20-may-22	3562(11%)	0.140(12%)	171(11%)
20-may-22	–	25-may-22	4289(11%)	0.091(12%)	131(11%)
25-may-22	–	03-jun-22	2184(11%)	0.059(12%)	89(11%)
03-jun-22	–	10-jun-22	2578(11%)	0.063(12%)	185(11%)
10-jun-22	–	17-jun-22	3030(11%)	0.046(12%)	105(11%)
17-jun-22	–	24-jun-22	3235(11%)	0.062(12%)	110(11%)
24-jun-22	–	01-Jul-22	4980(11%)	0.169(11%)	246(11%)
Mean			2930	0.220	128
SD			1429	0.254	81

*Figures in brackets are relative standard uncertainties. # Elevated value: see text under Table 2.1.

Table 2.1. Radionuclides in precipitation in the 10 m^2 rain collector at Risø (cf. Fig. 8.1), January-June 2022. (Unit: Bq m^{-3})

Month	^{7}Be	^{137}Cs	^{210}Pb
January	1941(11%)*	0.070(27%)	109(11%)
February	889(11%)	0.020(18%)	32(11%)
March	2275(11%)	2.010(12%)#	637(11%)
April	841(11%)	0.266(13%)	102(11%)
May	4213(11%)	0.428(13%)	367(11%)
June	3117(11%)	0.204(12%)	248(11%)

* Figures in brackets are relative standard uncertainties

The caesium concentration in March was somewhat elevated, coinciding with a slight increase in air concentration (see Table 1) and very low precipitation rate (and thus little plume depletion). This small increase has no implications for health, but coincides in time with a reported forest fire very near to the Chernobyl NPP, where the flames were according to Ukrainian officials difficult to fight due to Russian control of the area.

Table 2.2. Radionuclides in precipitation in the 10 m^2 rain collector at Risø (cf. Fig. 8.1), January-June 2022. (Unit: Bq m^{-2})

Month	Precipitation (m)	^{7}Be	^{137}Cs	^{210}Pb
January	0.020(10%)*	27(12%)	0.0013(29%)	2.2(12%)
February	0.073(10%)	59(12%)	0.0015(20%)	2.3(12%)
March	0.004(10%)	10(12%)	0.0077(16%)	2.5(12%)
April	0.025(10%)	19(12%)	0.0066(16%)	2.5(12%)
May	0.016(10%)	78(12%)	0.0068(17%)	5.8(12%)
June	0.026(10%)	78(12%)	0.0054(16%)	6.3(12%)
Sum	0.164(5%)	271(7%)	0.0293(14%)	21.6(9%)

* Figures in brackets are relative standard uncertainties

Table 2.3. Tritium in precipitation collected at Risø (cf. Figs. 1, 2.3.1 and 2.3.2). January – June 2022. (Unit: kBq m^{-3})

Month	10 m^2 rain collector*
January	<2.5
February	2.8(60%)[a]
March	<2.5
April	<2.5
May	<2.5
June	<2.5
Double determinations*.	

[a] Figures in brackets are relative standard uncertainties

Table 2.4. Tritium in precipitation collected at Risø (cf. Fig. 1). January – June 2022 (Unit: kBq m^{-2})

Month	Precipitation (m)	10 m^2 rain collector
January	0.020(10%)[a]	<0.050
February	0.073(10%)	0.204(61%)[a]
March	0.004(10%)	<0.010
April	0.025(10%)	<0.063
May	0.016(10%)	<0.040
June	0.026(10%)	< 0.065
Sum	0.139(5%)	< 0.432

[a] Figures in brackets are relative standard uncertainties

Table 3.1. Radionuclides in sediment samples collected at Bolund in Roskilde Fjord.(cf. Fig. 3.1) January - June 2022. (Unit: Bq kg^{-1} dry)

Date	^{137}Cs	K*
8 June	<0.12	13.7(11%)[a]

*Unit: g kg^{-1} dry

[a] Figures in brackets are relative standard uncertainties

Table 4.1. Radionuclides in seawater collected in Roskilde Fjord (cf. Fig. 4.1) January - June 2022. (Unit: Bq m–3)

Date	^{137}Cs
3 June	5.2(12%)[a]

[a] Figures in brackets are relative standard uncertainties

Table 4.2. Tritium in seawater collected in Roskilde Fjord (Risø pier) (cf. Fig. 4.2) January – June 2022 [a].*

Month	kBq m^{-3}
March	<2.5
June	<2.5

* Double determinations

[a] Figures in brackets are relative standard uncertainties

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

Week no. or month	Date	K ($g\ kg^{-1}$ fresh)	^{137}Cs ($Bq\ kg^{-1}$ fresh)	^{137}Cs ($Bq\ m^{-2}$)
2	14 January	5.9(12%) [a]	<0.3	
4	28 January	3.2(12%)	<0.2	
6	11 February	3.9(12%)	<0.4	
8	25 February	2.6(13%)	<0.2	
10	11 March	4.6(12%)	<0.2	
12	25 March	5.6(12%)	<0.2	
14	08 April	4.3(12%)	<0.2	
16	22 April	6.3(12%)	<0.2	
18	06 May	7.0(12%)	<0.2	
20	20 May	5.3(12%)	<0.2	
22	03 June	4.2(12%)	<0.2	
24	17 June	5.4(12%)	<0.2	
26	01 July	6.1(12%)	<0.3	
**January		4.3(11%)	0.074(13%)	0.023(16%)
**February		3.4(11%)	0.072(16%)	0.021(20%)
**March		6.3(11%)	0.171(15%)	0.044(18%)
**April		6.2(11%)	0.050(21%)	0.019(24%)
**May		6.7(11%)	0.067(19%)	0.016(21%)
**June		5.7(11%)	<0.036	<0.010

[a] Figures in brackets are relative standard uncertainties

Table 5.2. Radionuclides in Fucus vesiculosus collected at Bolund in Roskilde Fjord. January – June 2022. (Unit: Bq kg^{-1} dry)

Date	^{137}Cs	K*	% dry matter
08 June	2.0(12%)[a]	29(11%)	15(10%)
*Unit: g kg^{-1} dry			

[a] Figures in brackets are relative standard uncertainties

Table 7.1. Waste water collected at Risø (cf. Fig. 1), January – June 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})
1	29(11%)[a]	<70	<70	<138
2	36(12%)	<80	<70	<168
3	56(13%)	<79	<99	<165
4	115(11%)	<59	<73	<131
5	61(12%)	<67	<65	<154
6	63(10%)	<70	<86	<158
7	56(11%)	<41	<46	<83
8	37(13%)	<74	<89	<163
9	36(14%)	<56	<58	<124
10	52(12%)	<47	<50	<100
11	85(10%)	<74	<81	<160
12	95(12%)	<76	<92	<178
13	101(11%)	<75	<83	<155
14	92(11%)	<73	<85	<160
15	88(11%)	<47	<66	<113
16	82(10%)	<46	<54	<108
17	80(11%)	<55	<58	<121
18	91(12%)	<69	<84	<151
19	93(11%)	<50	<61	<100
20	66(11%)	<76	<180	<170
21	105(11%)	<70	<116	<156
22	119(10%)	<73	<91	<159
23	134(10%)	<70	<84	<153
24	138(11%)	<68	<84	<136
25	158(11%)	<50	<52	<105
26	157(10%)	<75	<84	<157
Mean	85.6	<65	<79	<141
SD	36.4			

[a] Figures in brackets are relative standard uncertainties

Table 8.1. Background dose rates around the border of Risø (cf. Fig. 8.1) measured with thermoluminescence dosimeters (TLD) in the period October 2021 – May 2022. (Results are normalized to μSv h^{-1}).

Location	μSv 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 October 2021 – May 2022. (Results are normalized to μSv h–1).

Risø zone	Location	μSv h–1 ¤
I	1	0.09[a]
I	2	0.11
I	3	0.11
I	4	0.09
I	5	0.11
Mean		0.10
II	P1	0.09
II	P2	0.09
II	P3	0.09
II	P4	0.11
Mean		0.09
III	P1	0.11
III	P2	0.09
III	P3	0.11
Mean		0.10
IV	P1	0.09
IV	P2	0.09
IV	P3	0.09
IV	P4	0.09
IV	P5	0.09
IV	P6	0.11
IV	P7	0.11
Mean		0.10
V	P1	0.09
V	P2	0.11
V	P3	0.11
V	P4	0.09
V	P5	0.09
V	P6	0.11
V	P7	0.09
V	P8	0.11
V	P9	0.09
V	P10	0.11
Mean		0.10

Table 8.3. Terrestrial dose rates at the Risø zones (cf. Fig. 8.2 and Fig. 1) October 2021 – May 2022. Measured with a NaI(Tl) detector. (Unit: µSv h–1)

Risø zone	Location	May
I	P1	0.039(10%)
I	P2	0.055(10%)
I	P3	0.325(10%)
I	P4	0.045(10%)
I	P5	0.044(10%)
Mean		0.102(5%)
II	P1	0.043(10%)
II	P2	0.044(10%)
II	P3	0.040(10%)
II	P4	0.041(10%)
Mean		0.042(4%)
III	P1	0.047(10%)
III	P2	0.047(10%)
III	P3	0.046(10%)
Mean		0.047(6%)
IV	P1	0.038(10%)
IV	P2	0.049(10%)
IV	P3	0.043(10%)
IV	P4	0.041(10%)
IV	P5	0.041(10%)
IV	P6	0.039(10%)
IV	P7	0.045(10%)
Mean		0.042(4%)
V	P1	0.043(10%)
V	P2	0.046(10%)
V	P3	0.055(10%)
V	P4	0.052(10%)
V	P5	0.047(10%)
V	P6	0.050(10%)
V	P7	0.045(10%)
V	P7a	0.040(10%)
V	P8	0.042(10%)
V	P9	0.038(10%)
V	P10	0.037(10%)
Mean		0.045(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)

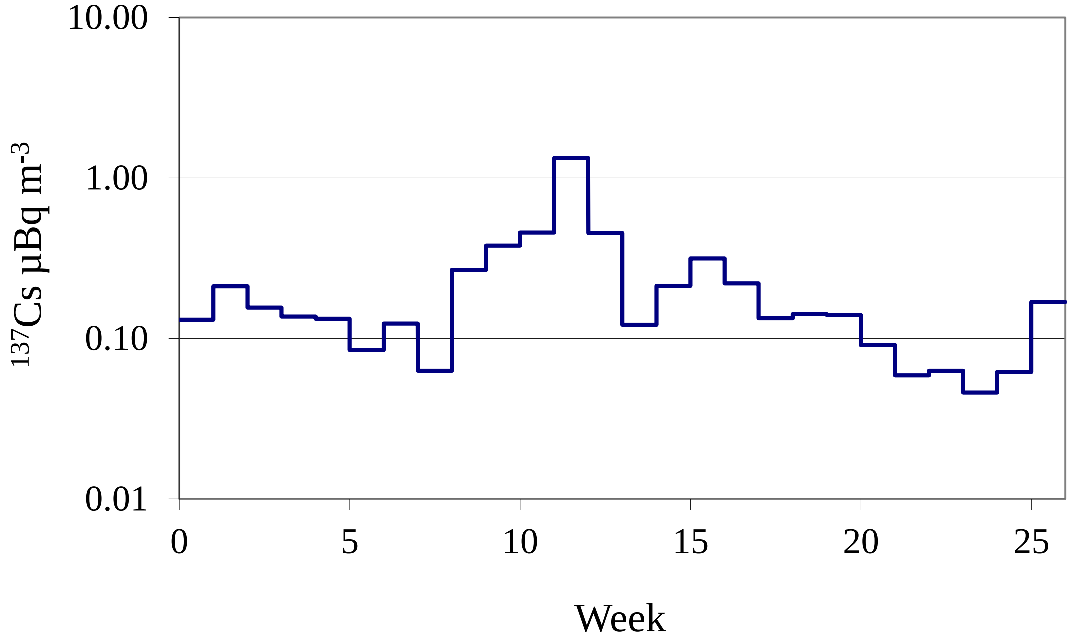

Fig. 1.1. Caesium-137 in ground level air collected at Risø in January-June 2022. (Unit: µBq m^{-3})

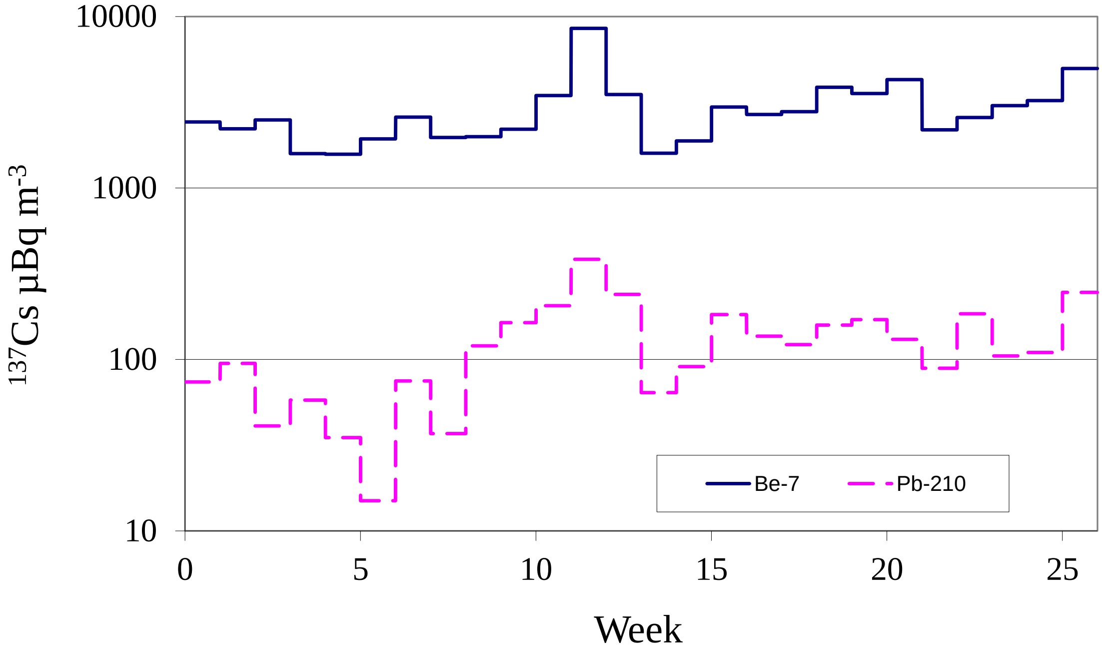

Fig. 1.2. Beryllium-7 and Lead-210 in ground level air collected at Risø in January-June 2022. (Unit: µBq m^{-3})

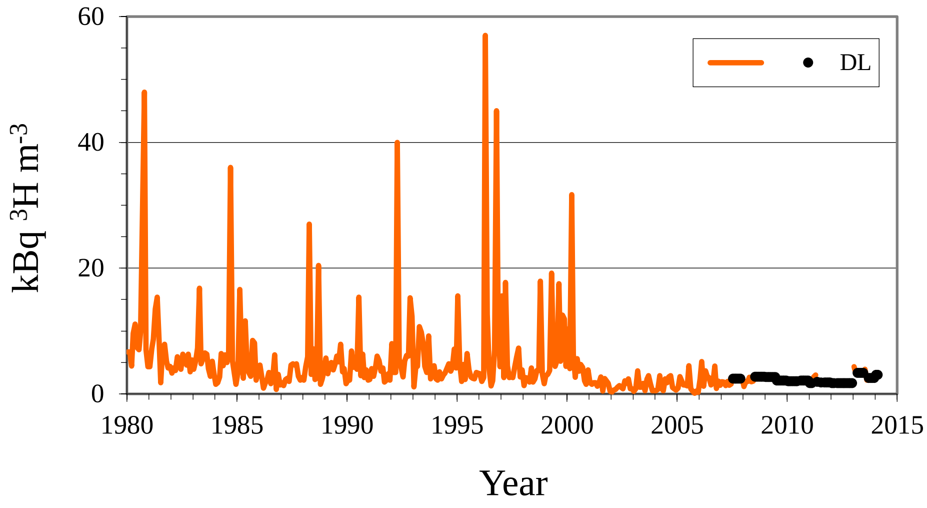

Fig. 2.3.1. Tritium in precipitation collected at Risø (1 m² rain collector) 1980 - 2013. (Unit: kBq m⁻³; DL = detection limit). This rain collector was taken out of operation in 2013.

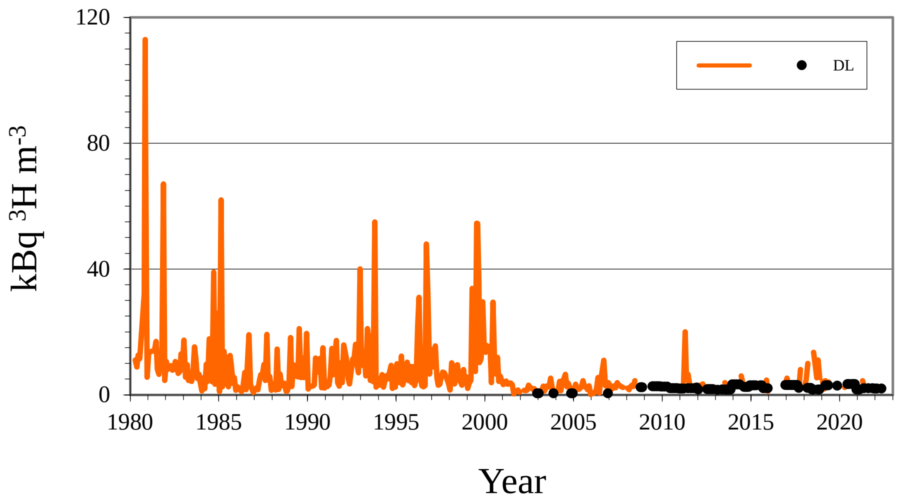

Fig. 2.3.2. Tritium in precipitation collected at Risø (10 m² rain collector) 1980 - 2022. (Unit: kBq m⁻³; DL = detection limit)

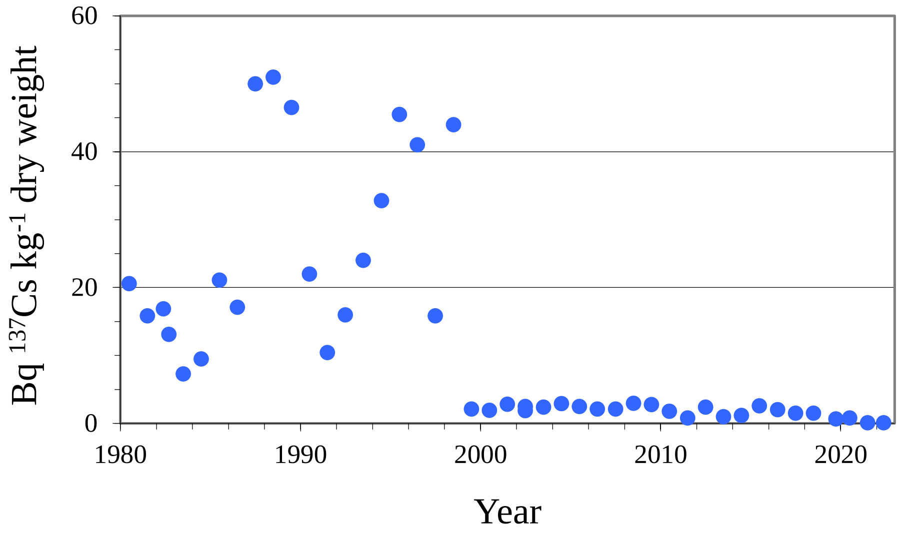

Fig. 3.1. Caesium–137 in sediment samples collected at Bolund in Roskilde Fjord. 1980 – 2022. (Unit: Bq kg^{-1} dry matter)

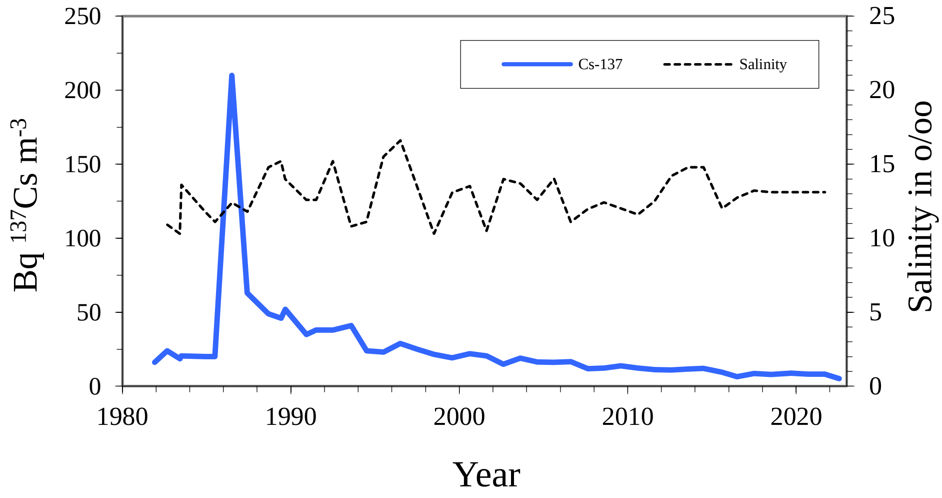

Fig. 4.1. Caesium–137 in seawater collected in Roskilde Fjord 1980 – 2022. (Unit: Bq m⁻³)

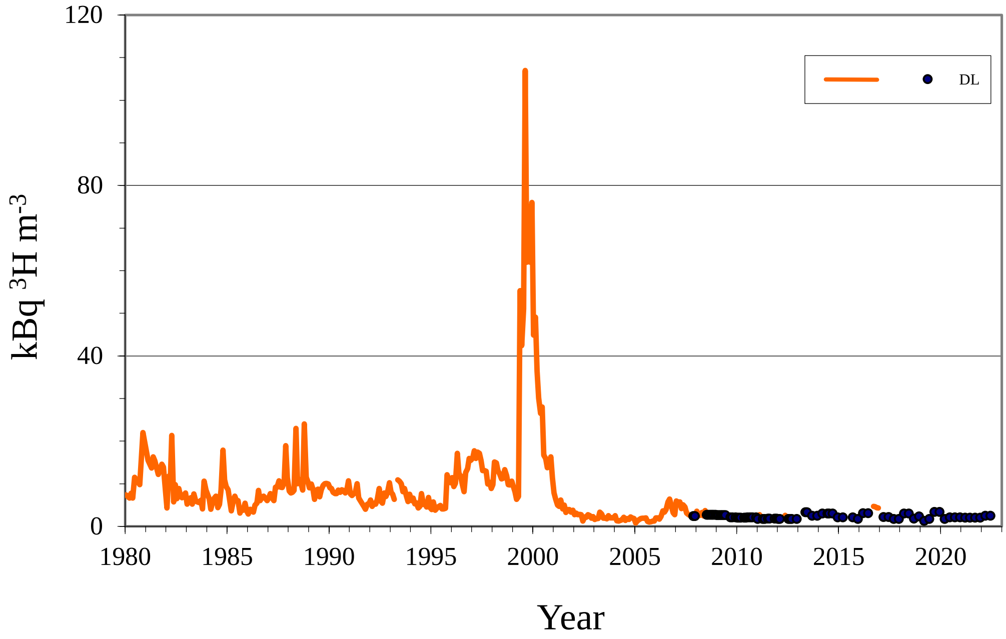

Fig. 4.2. Tritium in seawater collected in Roskilde Fjord 1980 - 2022. (Unit: kBq m⁻³; DL = detection limit)

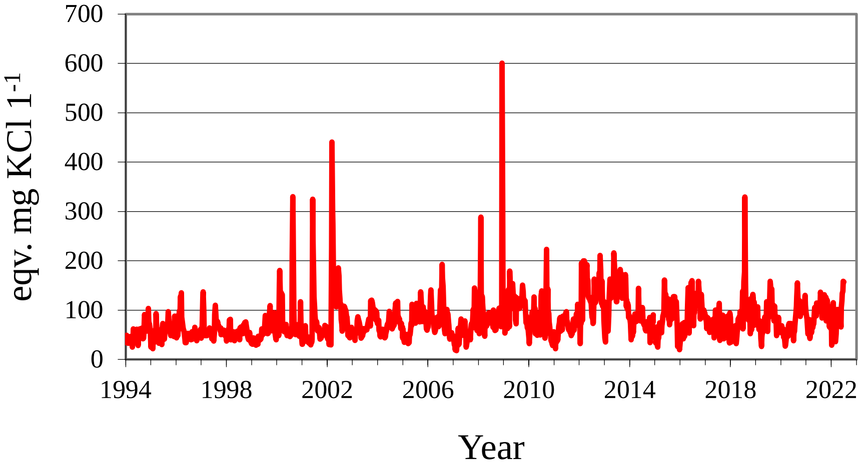

Fig. 7.1. Total-beta radioactivity in waste water collected at Risø 1994 - 2022. (Unit: eqv. mg KCl l^{-1})

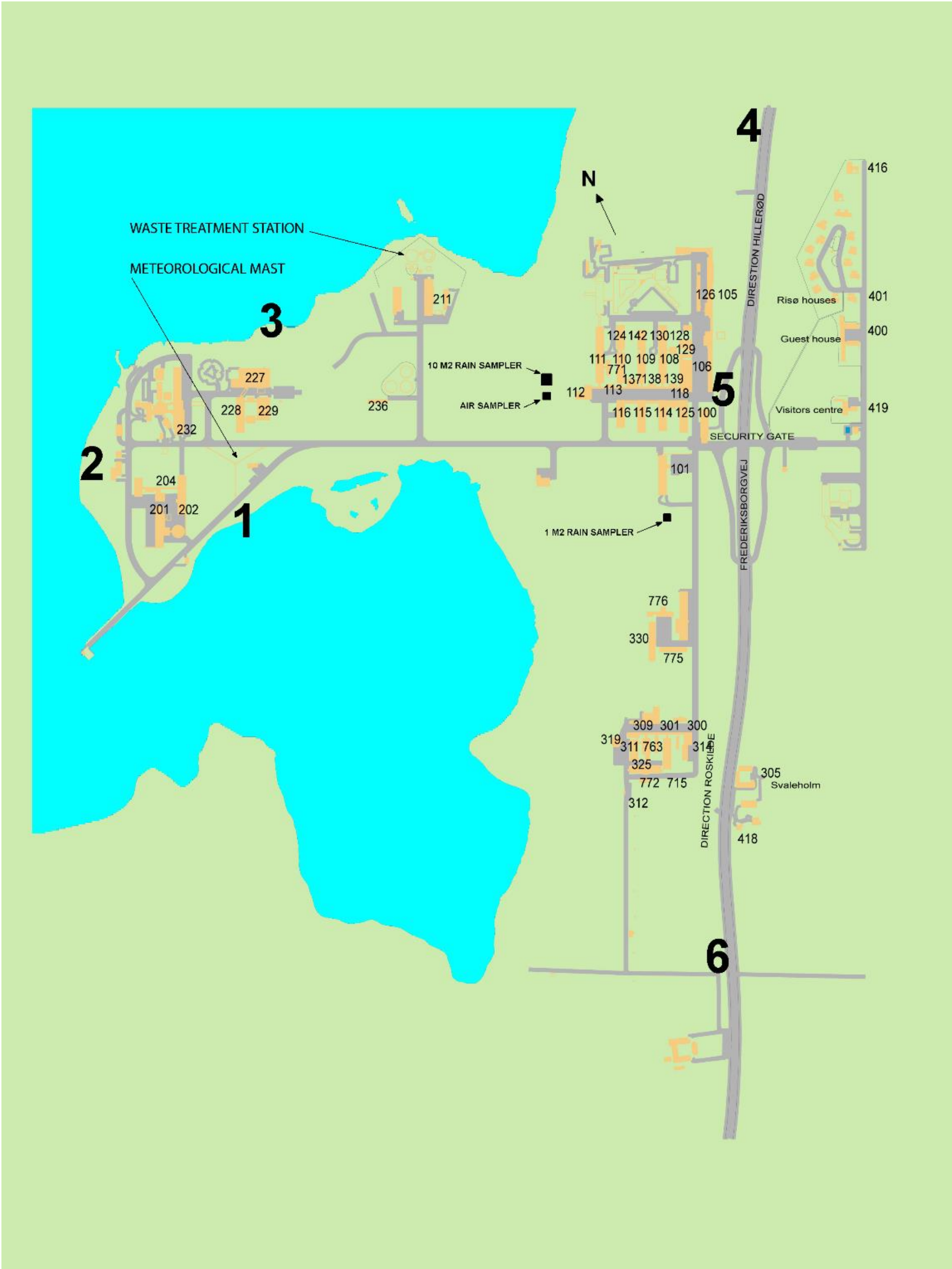

Fig. 8.1. Locations (1-6) for TLD measurements around the border of Risø (cf. Table 8.1).

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

- Thermolumiscence 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 m^3/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 ^{137}Cs, ^{7}Be and ^{210}Pb and other gamma emitters.

Deposition collector

The Risø site operates a large rain collector of 10 m^2. The collector is heated and water is passed through an ion exchange column to a large tank. The 10 m^2 collector provides monthly samples of rain water analysed for tritium and ion exchange resin which is analysed by gamma spectrometry for ^{7}Be, ^{137}Cs and ^{210}Pb 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 ^{131}I, ^{137}Cs and ^{226}Ra. Water samples from Roskilde Fjord are collected each quarter and analysed for tritium, annually for ^{137}Cs. A sediment sample is collected annually from Roskilde Fjord and analysed for ^{137}Cs.

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

The environmental surveillance of the Risø environment was continued in January-June 2022. The mean concentrations in air were: 0.13±0.08 μBq m^{-3} of ^{137}Cs, 2.93±1.43 mBq m^{-3} of ^{7}Be and 0.13±0.08 mBq m^{-3} of ^{210}Pb (±1 standard uncertainty). The depositions by precipitation at Risø in the first half of 2021 were: 0.029±0.004 Bq m^{-2} of ^{137}Cs, 271±19 Bq m^{-2} of ^{7}Be, 21.6±2.4 Bq m^{-2} of ^{210}Pb and <0.5 kBq m^{-2} of ^{3}H. The average background dose rate (TLD) at Risø (Zone I) was measured as 0.10 µSv h^{-1} compared with 0.10 µSv h^{-1} in the four zones around Risø. None of the recorded levels of radioactivity and radiation have given rise to concern, although an increase in ^{137}Cs air concentration was measured in March, at which time a forest fire was reported in the Chernobyl area.

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 Group under the Climate and Monitoring Section in DTU SUSTAIN is responsible for caring out the environmental radioactivity monitoring program in Denmark.

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