National Institute for Public Health
and the Environment
Ministry of Health, Welfare and Sport

Environmental radioactivity
in the Netherlands

Results in 2013

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Colophon

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RIKILT
WAGENINGEN UR

EPZ   NV. Electriciteit-Productiemaatschappij Zuid-Nederland EPZ

Synopsis

Environmental radioactivity in the Netherlands
Results in 2013

In 2013 the Netherlands fulfilled the European obligation to annually measure radioactivity in the environment and in food. All Member States of the European Union are required to perform these measurements each year under the terms of the Euratom Treaty of 1957. Moreover, the Netherlands complied with the guidelines (as established in 2000) for Member States to perform these measurements in a uniform manner.

The measurements provide background values of radioactivity, which are present under normal circumstances. These can be used as reference values, for instance, during a nuclear emergency. The National Institute for Public Health and the Environment (RIVM) reports to the European Commission on radioactivity in the environment on behalf of the competent authorities in the Netherlands.

Radioactivity in air, food, milk, grass and feed
Radioactivity levels in the air were normal and within the range of previous years. Radioactivity levels in food and milk were well below the export and consumption limits set by the European legislation, except for one out of almost 1,600 samples. This was a sample of boar in which the radioactivity level exceeded the consumption limit by a factor of almost two. In a risk assessment based on a single consumption of boar, it was found that this radioactivity level does not pose a threat to public health. Data on radioactivity levels in grass and feed are permanently added to this report as an additional chapter. Radioactivity levels in both were normal.

Radioactivity in surface water, seawater and drinking water
Radioactivity levels in surface water and seawater were within the range of previous years. Radioactivity levels in raw input water for drinking water were well below the screening levels, except for 31 samples (8% of the total number), which were slightly elevated. An investigation into these kinds of slightly elevated levels is ongoing. The measured radioactivity levels do not pose a threat to public health.

Keywords: radioactivity, environment, airborne particles, water, food, milk

Publiekssamenvatting

Radioactiviteit in het Nederlandse milieu
Resultaten in 2013

In 2013 voldeed Nederland aan de Europese verplichting om jaarlijks de hoeveelheid radioactiviteit in het milieu en in voeding te meten. Alle lidstaten van de Europese Unie zijn verplicht deze metingen jaarlijks te verrichten volgens het Euratom-verdrag uit 1957. Nederland voert daarbij de aanbevelingen uit die in 2000 zijn opgesteld om de metingen volgens een bepaald stramien uit te voeren. De metingen leveren achtergrondwaarden op, ofwel radioactiviteitsniveaus die onder normale omstandigheden aanwezig zijn. Deze waarden kunnen bij bijvoorbeeld calamiteiten of rampen als referentie dienen. Het RIVM rapporteert namens Nederland aan de Europese Unie over radioactiviteit in het milieu.

Radioactiviteit in lucht, voedsel, melk, gras en veevoer
De radioactiviteitsniveaus in lucht laten een normaal beeld zien dat niet verschilt van voorgaande jaren. De radioactiviteitsniveaus in voedsel en melk liggen net als in voorgaande jaren duidelijk onder de Europese limieten die zijn opgesteld voor consumptie en export, met uitzondering van een van de bijna 1.600 monsters. Dit was een wild zwijn-monster waarin het radioactiviteitsniveau de consumptielimiet met bijna een factor twee overschreed. Uitgaande van eenmalige consumptie is het risico voor de volksgezondheid verwaarloosbaar. Sinds 2013 zijn meetgegevens van gras en veevoer structureel toegevoegd aan deze rapportage. In beide laten de radioactiviteitsniveaus een normaal beeld zien.

Radioactiviteit in oppervlaktewater, zeewater en drinkwater
De radioactiviteitsniveaus in oppervlaktewater en zeewater verschillen niet van voorgaande jaren. De meeste radioactiviteitsniveaus in ongezuiverd water voor de drinkwaterproductie liggen duidelijk onder de screeningswaarden. Een uitzondering daarop zijn 31 monsters (8 procent van het totale aantal) waarbij licht verhoogde niveaus zijn gemeten. Een onderzoek naar de oorzaak van dit soort licht verhoogde niveaus is gaande. De overschrijdingen zijn in ieder geval zodanig dat ze niet schadelijk zijn voor de volksgezondheid.

Kernwoorden: radioactiviteit, milieu, luchtstof, water, voedsel, melk

Preface

The following institutions contributed to the report:

**The National Institute for Public Health and the Environment
Rijksinstituut voor Volksgezondheid en Milieu (RIVM)**
Data on air dust, deposition, ambient dose rates and drinking water.
ing. G.J. Knetsch (editor), ing. R.B. Tax, ing. M. Boshuis, ir. J.F.M.
Versteegh

Rijkswaterstaat (RWS)
Data on seawater and surface water from the main inland waters.
C. Engeler, ing. M. van der Weijden

**The Netherlands Food and Consumer Product Safety Authority
Nederlandse Voedsel en Waren Autoriteit (NVWA)**
Data on foodstuffs.
drs. K. Zwaagstra

RIKILT Wageningen UR
Data on milk and foodstuffs.
dr. M. van Bourgondiën, ir. P.N. Brandhoff, ing. C. Onstenk, ing. A. Vos
van Avezathe

N.V. Elektriciteits-Produktiemaatschappij Zuid-Nederland (EPZ)
Data on environmental samples near the nuclear power plant at
Borssele, measured by the Nuclear Research & Consultancy Group
(NRG). G.J.L. Goulooze

Contents

Summary

The Dutch government is obliged to measure radioactivity in air, water and soil under the terms of the Euratom Treaty of 1957. In 2000, the European Commission specified this treaty by means of recommendations describing the matrices to be measured (air dust, ambient dose, surface water, drinking water, milk and food) and the frequency of the measurements. The results should be reported to the European Commission annually.

This report presents the results of radioactivity measurements performed in the Dutch environment in 2013. The measurements were carried out by the RIVM, RWS, RIKILT, NVWA and (commissioned by N.V. EPZ) NRG. In 2013, the Netherlands complied with the Euratom recommendations on annually measuring radioactivity in the environment and in food.

Yearly averaged activity concentrations in air dust were determined for gross α, gross β, ^{7}Be, ^{137}Cs and ^{210}Pb. The yearly total activity in deposition was determined for gross α, gross β, ^{3}H, ^{7}Be, ^{137}Cs, ^{210}Pb and ^{210}Po. Gross α and gross β is the total activity of nuclides emitting α and β radiation, respectively. The results are presented in Table S1 and are within the range of those in previous years.

The National Radioactivity Monitoring Network (NMR) was also used to determine the activity concentrations of gross α and artificial β (β radiation emitted by man-made nuclides) in air dust. There is a difference between the NMR data and the gross α and gross β data mentioned above, due to the contribution of short-lived natural radionuclides (radon daughters) to the NMR data. The yearly averaged gross α activity concentration in air dust was 3.0 Bq·m^{-3}. The yearly average of the artificial β activity concentration did not deviate significantly from zero. The NMR was also used to determine the ambient dose equivalent rate: the yearly averaged measured value was 73.1 nSv·h^{-1}.

In surface water, the yearly averaged activity concentrations of gross α, residual β (gross β minus naturally occurring ^{40}K), ^{3}H, ^{90}Sr and ^{226}Ra were determined. The yearly averaged activity concentrations of ^{60}Co, ^{131}I, ^{137}Cs and ^{210}Pb in suspended solids in surface water were also determined. In seawater, the yearly averaged activity concentrations were determined for gross α, residual β, ^{3}H and ^{90}Sr. The yearly averaged activity concentrations of ^{137}Cs and ^{210}Pb in suspended solids in seawater were also determined. The results are presented in Table S1.

The yearly averaged gross α, residual β, ^{3}H, ^{90}Sr and ^{226}Ra activity concentrations in surface water were within the range of those in previous years. The yearly averaged ^{60}Co, ^{131}I, ^{137}Cs and ^{210}Pb activity concentrations in suspended solids in surface water were within the range of those in previous years.

The yearly averaged gross α, residual β, ^{3}H and ^{90}Sr activity concentrations in seawater were within the range of those in previous years. The yearly averaged ^{137}Cs and ^{210}Pb activity concentrations in

suspended solids in seawater were within the range of those in previous years.

Typical activities found in raw input water for drinking water production are presented in Table S1. There is little potassium (and thus ^{40}K) present in this water. The gross α activity concentration in raw input water for drinking water averaged per production station exceeded the screening level (0.1 Bq·L^{-1}) at 6 of the 182 production stations (in 31 of the 396 analyses). An investigation into these kinds of slightly elevated levels is ongoing. The gross β activity concentrations were below the screening level (1.0 Bq·L^{-1}) and the ^{3}H activity concentrations were below the parametric value of 100 Bq·L^{-1}.

The results of the monitoring programme for milk and food are presented in Table S1. Radioactivity was measured in over 700 milk samples and approximately 1,600 food products, of which 19 samples contained ^{137}Cs. Two samples of honey and 17 samples of game and poultry contained ^{137}Cs. Only one sample was above the set limit of 600 Bq·kg^{-1} (or 370 Bq·kg^{-1} for milk and dairy products) for the activity of radiocesium (sum of ^{134}Cs and ^{137}Cs). A sample of boar (originating from the Veluwe area) contained 1,100 Bq·kg^{-1} ^{137}Cs. In a risk assessment based on a single consumption of boar, it was found that this radioactivity level does not pose a threat to public health.

Starting in 2013, the measured concentrations of ^{90}Sr, ^{134}Cs and ^{137}Cs (Bq·kg^{-1}) in food are converted to an average daily intake value per person per day
(Bq·day^{-1}) using food consumption patterns. The average daily intake per person of ^{134}Cs, ^{137}Cs and ^{90}Sr is < 2.4, < 2.6 and < 3.6 Bq·day^{-1}, respectively.

Since 2013 data on grass and feed are permanently added as an additional chapter. None of the grass and feed samples analysed contained measurable levels of artificial radionuclides (^{60}Co, ^{131}I, ^{132}Te, ^{134}Cs and ^{137}Cs).

Data on environmental samples taken near the nuclear power plant at Borssele are presented in Table S2.

Samenvatting

In het kader van het Euratom Verdrag uit 1957 is de Nederlandse overheid verplicht om radioactiviteitsgehalten te meten in de compartimenten lucht, water en bodem. In 2000 heeft de Europese Commissie dit nader gespecificeerd middels aanbevelingen. Hierin is in detail beschreven wat moet worden gemeten (luchtstof, de omgevingsdosis, oppervlaktewater, drinkwater, melk en voedsel) en met welke frequentie. De resultaten dienen jaarlijks te worden gerapporteerd aan de Europese Commissie.

Dit rapport bevat de resultaten van radioactiviteitsmetingen in het Nederlandse milieu in 2013. De metingen zijn verricht door RIVM, RWS, RIKILT, NVWA en (in opdracht van N.V. EPZ) NRG. Nederland voldeed in 2013 aan de Europese aanbevelingen ten aanzien van de jaarlijkse radioactiviteitsmetingen in het milieu en in voedsel.

In luchtstof werd de jaargemiddelde activiteitsconcentratie bepaald van totaal-α, totaal-β, ^{7}Be, ^{137}Cs en ^{210}Pb. In depositie werd de totale jaarlijkse activiteit bepaald van totaal-α, totaal-β, ^{3}H, ^{7}Be, ^{137}Cs, ^{210}Pb en ^{210}Po. Totaal-α respectievelijk totaal-β is de totale activiteit aan α- dan wel β-straling uitzendende nucliden. De resultaten zijn weergegeven in Tabel S1 en vallen binnen het bereik van voorgaande jaren.

Met het Nationaal Meetnet Radioactiviteit (NMR) werden activiteitsconcentraties bepaald in luchtstof voor totaal-α en kunstmatige β (β-straling uitgezonden door nucliden ontstaan door menselijk handelen). Er is een verschil tussen de NMR-metingen en bovenstaande totaal-α- en totaal-β-metingen, wat wordt veroorzaakt door de bijdrage van kortlevende natuurlijke radionucliden (radondochters). Het jaargemiddelde voor de totaal-α-activiteitsconcentratie in luchtstof was 3,0 Bq·m^{-3}. Het jaargemiddelde voor de kunstmatige β-activiteitsconcentratie in luchtstof week niet significant af van nul. Met het NMR werd daarnaast het omgevingsdosisequivalenttempo bepaald, de jaargemiddelde meetwaarde was 73,1 nSv·h^{-1}.

In oppervlaktewater werd de jaargemiddelde activiteitsconcentratie bepaald van totaal-α, rest-β (totaal-β minus het van nature aanwezige ^{40}K), ^{3}H, ^{90}Sr en ^{226}Ra en de jaargemiddelde activiteitsconcentratie van ^{60}Co, ^{131}I, ^{137}Cs en ^{210}Pb in zwevend stof.
In zeewater werd de jaargemiddelde activiteitsconcentratie bepaald van totaal-α, rest-β, ^{3}H en ^{90}Sr. In zwevend stof in zeewater werd de jaargemiddelde activiteitsconcentratie bepaald van ^{137}Cs en ^{210}Pb. De resultaten zijn weergegeven in Tabel S1.

De jaargemiddelde activiteitsconcentraties van totaal-α, rest-β (totaal-β minus het van nature aanwezige ^{40}K), ^{3}H, ^{90}Sr en ^{226}Ra in oppervlaktewater vallen binnen het bereik van voorgaande jaren. De jaargemiddelde activiteitsconcentraties van ^{60}Co, ^{131}I, ^{137}Cs en ^{210}Pb in zwevend stof in oppervlaktewater vallen binnen het bereik van voorgaande jaren.

De jaargemiddelde totaal α-, rest β-, ^{3}H- en ^{90}Sr-activiteitsconcentraties in zeewater vallen binnen het bereik van voorgaande jaren. De jaargemiddelde ^{137}Cs- en ^{210}Pb-activiteitsconcentraties in zwevend stof in zeewater vallen binnen het bereik van voorgaande jaren.

Gangbare activiteitsconcentraties die in ongezuiverd water voor de drinkwaterproductie gevonden worden, zijn weergegeven in Tabel S1. In dit water is weinig kalium, en dus ^{40}K, aanwezig. In 2013 overschrijdt de totaal α-activiteitsconcentratie in ruw water voor drinkwaterbereiding per productiestation de screeningswaarde van 0,1 Bq·L^{-1} bij 6 van de 182 productiestations (in 31 van de 396 uitgevoerde analyses). De totaal β-activiteitsconcentraties waren lager dan 1,0 Bq·L^{-1} en de ^{3}H-activiteitsconcentraties waren lager dan 100 Bq·L^{-1}.

De resultaten van het meetprogramma voor melk en voedsel zijn weergegeven in Tabel S1. Radioactiviteit werd geanalyseerd in ruim 700 melkmonsters en bijna 1600 voedselprodukten, waarvan 19 monsters ^{137}Cs bevatten. Twee monsters honing en 17 monsters wild en gevogelte bevatte ^{137}Cs. Slechts één van de monsters kwam boven de limiet van 600 Bq·kg^{-1} (respectievelijk 370 Bq·kg^{-1} voor melk en melkprodukten) van radiocesium (som van ^{134}Cs en ^{137}Cs) uit. Een monster wild zwijn (afkomstig uit de Veluwe) bevatte 1100 Bq·kg^{-1} ^{137}Cs. Uitgaande van een eenmalige consumptie wild zwijn is het risico voor de volksgezondheid verwaarloosbaar.

Sinds 2013 worden de gemeten concentraties ^{90}Sr, ^{134}Cs en ^{137}Cs (Bq·kg^{-1}) in voedsel omgerekend naar een gemiddelde dagelijkse opname per persoon per dag (Bq·dag^{-1}) door gebruik te maken van voedselconsumptiepatronen. De gemiddelde dagelijkse opname per persoon is < 2,4, < 2,6 en < 3,6 Bq·dag^{-1} voor respectievelijk ^{134}Cs, ^{137}Cs en ^{90}Sr.

Sinds 2013 zijn meetgegevens van gras en veevoer permanent toegevoegd aan dit rapport als een extra hoofdstuk. Geen van de geanalyseerde monsters gras en veevoer bevatten meetbare hoeveelheden van kunstmatige radionucliden (^{60}Co, ^{131}I, ^{132}Te, ^{134}Cs en ^{137}Cs).

Gegevens betreffende milieumonsters genomen rondom de kerncentrale Borssele zijn weergegeven in Tabel S2.

Table S1: Summary of the results of the Dutch monitoring programme in 2013

Matrix	Parameter	Locations	Values	Frequency (per year)
Air dust [1]	Gross α	1	0.023 mBq·m^{-3}	52
	Gross β	1	0.384 mBq·m^{-3}	52
	^{7}Be	1	3.280 mBq·m^{-3}	52
	^{137}Cs	1	0.000317 mBq·m^{-3}	52
	^{210}Pb	1	0.366 mBq·m^{-3}	52
Deposition [2]	Gross α	1	48.1 Bq·m^{-2}	12
	Gross β	1	95 Bq·m^{-2}	12
	^{3}H	1	0–1,580 Bq·m^{-2} [3]	12
	^{7}Be	1	1,030 Bq·m^{-2}	52
	^{137}Cs	1	0–1.1 Bq·m^{-2} [3]	52
	^{210}Pb	1	82.9 Bq·m^{-2}	52
	^{210}Po	1	21.2 Bq·m^{-2} [4]	12
Surface water [1]	Gross α	6	35–310 mBq·L^{-1}	13–14 [5]
	Residual β	6	25–120 mBq·L^{-1}	13–14 [5]
	^{3}H	6	2,370–16,000 mBq·L^{-1}	7–13 [5]
	^{90}Sr	3	1.4–2.9 mBq·L^{-1}	6–7 [5]
	^{226}Ra	4	2.2–7.5 mBq·L^{-1}	6–7 [5]
Suspended solids in surface water [1]	^{60}Co	6	< 1–5.7 Bq·kg^{-1}	6–53 [5]
	^{131}I	6	< 1–29 Bq·kg^{-1}	6–53 [5]
	^{137}Cs	6	3.8–11.8 Bq·kg^{-1}	6–53 [5]
	^{210}Pb	4	85–125 Bq·kg^{-1}	6–7 [5]
Seawater [1]	Gross α	8	410–860 mBq·L^{-1}	4–14 [5]
	Residual β	8	29–160 mBq·L^{-1}	4–14 [5]
	^{3}H	8	340–4,540 mBq·L^{-1}	4–14 [5]
	^{90}Sr	4	1.8–3.0 mBq·L^{-1}	4–14 [5]
Suspended solids in seawater [1]	^{137}Cs	4	4.3–5.7 Bq·kg^{-1}	4 [5]
	^{210}Pb	4	68–101 Bq·kg^{-1}	4 [5]
Drinking water [1]	Gross α	182	< 0.1 Bq·L^{-1}	396 [6]
	Gross β	186	< 0.1 Bq·L^{-1}	443 [6]
	Residual β	168	< 0.1 Bq·L^{-1}	378 [6]
	^{3}H	183	< 4.1 Bq·L^{-1}	401 [6]
Milk [1]	^{40}K	24	52.8 Bq·L^{-1} [7]	707 [6, 7]
			80.5 Bq·L^{-1} [8]	19 [8]
	^{60}Co	24	< 1.4 Bq·L^{-1} [9]	726 [6, 9]
	^{90}Sr	24	< 0.2 Bq·L^{-1} [9]	51 [6, 9]
	^{131}I	24	< 0.6 Bq·L^{-1} [9]	726 [6, 9]
	^{134}Cs	24	< 0.6 Bq·L^{-1} [9]	726 [6, 9]
	^{137}Cs	24	< 0.5 Bq·L^{-1} [9]	726 [6, 9]

Continued on next page

Table S1: Continued

Matrix	Parameter	Locations	Values	Frequency (per year)
Food [10, 11]				
Grain and grain products	^{137}Cs [12]	-	< 5 Bq·kg^{-1}	85 (0) [13]
Vegetables	^{137}Cs [12]	-	< 5 Bq·kg^{-1}	86 (0) [13]
Fruit and fruit products	^{137}Cs [12]	-	< 5 Bq·kg^{-1}	46 (1) [13]
Milk and dairy products	^{137}Cs [12]	-	5 Bq·kg^{-1}	53 (1) [13]
Meat and meat products	^{137}Cs [12]	-	< 5 Bq·kg^{-1}	26 (0) [13]
Game and poultry	^{137}Cs [12]	-	7 Bq·kg^{-1}	15 (1) [13]
Salads	^{137}Cs [12]	-	< 5 Bq·kg^{-1}	18 (0) [13]
Oil and butter	^{137}Cs [12]	-	< 5 Bq·kg^{-1}	35 (0) [13]
Honey	^{137}Cs [12]	-	216–226 Bq·kg^{-1}	52 (2) [13]
Tea	^{137}Cs [12]	-	< 5 Bq·kg^{-1}	18 (0) [13]
Mineral water	^{137}Cs [12]	-	< 5 Bq·kg^{-1}	23 (0) [13]
Fish	^{137}Cs [12]	-	< 5 Bq·kg^{-1}	19 (0) [13]
Food [10, 14]				
Vegetables and fruits	^{137}Cs [15]	-	< 2 Bq·kg^{-1}	153 (0) [13]
	^{90}Sr	-	< 5 Bq·kg^{-1}	19 (0) [13]
Meat and meat products	^{137}Cs [15]	-	< 2 Bq·kg^{-1}	488 (0) [13]
	^{90}Sr	-	< 5 Bq·kg^{-1}	21 (0) [13]
Bone	^{90}Sr	-	< 25 Bq·kg^{-1}	8 (0) [13]
Game and poultry	^{137}Cs [15]	-	3.4–1,100 Bq·kg^{-1}	79 (17) [13]
	^{90}Sr	-	< 5 Bq·kg^{-1}	10 (0) [13]
Eggs	^{137}Cs [15]	-	< 2 Bq·kg^{-1}	120 (0) [13]
Fish and seafood products	^{137}Cs [15]	-	< 2 Bq·kg^{-1}	110 (0) [13]
	^{90}Sr	-	< 5 Bq·kg^{-1}	27 (0) [13]
Ready meals	^{137}Cs [16]	-	< 10 Bq·kg^{-1}	40 (0) [13]
	^{90}Sr	-	< 5 Bq·kg^{-1}	40 (0) [13]

[1] Yearly average.

[2] Yearly total.

[3] A 68% confidence interval.

[4] The yearly total deposition is based on ten monthly results.

[5] Frequency depends on location.

[6] Total number of samples taken combined over all locations.

[7] Yearly average in cow's milk.

[8] Yearly average in goat's milk.

[9] Yearly average for cow's and goat's milk combined.

[10] Given range represents values of individual (positive) samples.

[11] As measured by the Netherlands Food and Consumer Product Safety Authority.

[12] Samples were analysed for ^{134}Cs as well, but it was below the detection limit of 5 Bq·kg^{-1}.

[13] Total number of samples taken. Number of positive samples in brackets.

[14] As measured by RIKILT Wageningen UR.

[15] Samples were analysed for ^{134}Cs as well, but it was below the detection limit of 2 Bq·kg^{-1}.

[16] Samples were analysed for ^{134}Cs as well, but it was below the detection limit of 10 Bq·kg^{-1}.

Table S2: Summary of the results of the monitoring programme in the vicinity of the nuclear power plant at Borssele in 2013

Matrix	Parameter	Locations	Values [1]	Frequency (per year)
Air dust	Gross α	5	0.003–0.054 mBq·m^{-3}	12
	Gross β	5	0.01–0.61 mBq·m^{-3}	12
	^{60}Co	5 [2]	< 0.03–< 0.07 mBq·m^{-3}	12
	^{131}I$_{el}$ [3]	5 [2]	< 0.08–< 0.2 mBq·m^{-3}	12
	^{131}I$_{or}$ [4]	5 [2]	< 0.3–< 1 mBq·m^{-3}	12
	^{137}Cs	5 [2]	< 0.02–< 0.05 mBq·m^{-3}	12
	Nat. [5]	5 [2]	1.18–< 2 mBq·m^{-3}	12
Grass	^{60}Co	5 [2]	< 1–< 3 Bq·kg^{-1}	12
	^{131}I	5 [2]	< 1–< 3 Bq·kg^{-1}	12
	^{137}Cs	5 [2]	< 1–< 2 Bq·kg^{-1}	12
Soil	^{54}Mn	4	< 0.3–< 0.4 Bq·kg^{-1}	1
	^{60}Co	4	< 0.2–< 0.3 Bq·kg^{-1}	1
	^{134}Cs	4	< 0.2 Bq·kg^{-1}	1
	^{137}Cs	4	0.87–1.73 Bq·kg^{-1}	1
Water	Residual β	4	0.003–0.102 Bq·L^{-1}	12
	^{3}H	4	0.4–8.5 Bq·L^{-1}	12
Suspended solids	Gross β	4	0.53–2.6 kBq·kg^{-1}	12
Seaweed	^{60}Co	4 [2]	< 1–< 2 Bq·kg^{-1}	12
	^{131}I	4 [2]	< 1–< 2 Bq·kg^{-1}	12
	^{137}Cs	4 [2]	< 1–< 2 Bq·kg^{-1}	12
Sediment	^{60}Co	4 [2]	< 0.2–< 0.3 Bq·kg^{-1}	12
	^{131}I	4 [2]	< 0.2–< 0.5 Bq·kg^{-1}	12
	^{137}Cs	4 [2]	0.31–1.17 Bq·kg^{-1}	12

[1] Given range represents values of individual samples.

[2] Analysis was performed on a combined sample of the monthly samples in all four or five locations.

[3] Elemental bound ^{131}I.

[4] Organically bound ^{131}I.

[5] Naturally occurring γ-emitters.

1   Introduction

Radioactivity of natural and artificial origin can be found in low concentration levels all around the globe. So-called naturally occurring radionuclides can be found in soil, water and air, and have existed since the creation of the universe, or are continually generated as a result of cosmic radiation.

Concentration levels of naturally occurring radionuclides, such as ^{40}K and daughters from the uranium and thorium series, may be enhanced as a result of human activities within or outside national borders (e.g. discharges from the ore-processing industry). Man-made radionuclides are found in the environment as a result of, for example, nuclear weapons tests and discharges from nuclear installations and medical facilities.

The intake of radioactivity and exposure to ionising radiation can result in health problems. Therefore, it is important to monitor radioactivity levels in the environment. Monitoring radioactivity levels in the environment provides knowledge about radioactivity levels under normal circumstances, and enables detection and confirmation of abnormal levels. This report presents the results of radioactivity measurements performed in the environment in the Netherlands.

The aims of this report are threefold:
i) to present a survey of radioactivity measurements performed in the Dutch environment, providing information on the exposure of the population to ionising radiation; ii) to provide information on typical environmental radioactivity levels, which can be used as a reference in the event of a radiological or nuclear incident or emergency; iii) to show the compliance of monitoring programmes in the Netherlands with the corresponding European obligations and recommendations and to report possible omissions.

In the following chapters, the results of the measurements will be presented in graphs and tables. More detailed information is presented in Appendix A. Chapters 2 to 8 are subdivided according to the structure of the Commission Recommendation on the Application of Article 36 of the Euratom Treaty [1] and present the results of measurements for various environmental compartments. Chapter 9 contains data on radioactivity levels in grass and feed. Chapter 10 contains data on environmental samples taken near the nuclear power plant at Borssele. General conclusions are presented in Chapter 11.

Appendix B describes the methods used for the presentation of data. A glossary of frequently occurring terms is given in Appendix C.

2   Airborne particles

Table 2.1 describes the monitoring programme for determining radioactive nuclides in air dust. The sampling was done on the RIVM premises in Bilthoven, the Netherlands. Air dust samples for the measurement of gross α, gross β and γ-emitters were collected weekly with a high volume sampler. The high volume sampler described in [2] was replaced by a Snow White high volume sampler from Senya Ltd [3] in 2011.

The change in equipment coincided with a change in the filter type (polypropylene G-3 instead of glass fibre GF10), the volume sampled (125,000 m^3 instead of 50,000 m^3) and the sampling height (on top of a three-storey building instead of 1.8 m above ground level). Samples were collected weekly according to a standard procedure [4].

The collection efficiency of the filter type G-3 was determined to be 96 ± 1% with a flow rate of approximately 760 $Nm^3 \cdot h^{-1}$ based on ^{7}Be and ^{210}Pb results [3]. The results presented in this chapter take into account this collection efficiency.

After sampling, the G-3 filters were dried and weighed to determine the dust load. Then, a sub-sample was taken from the filter for the determination of gross α and gross β according to a standard procedure [5]. The remainder of the filter was folded into a 250 ml container and measured on a coaxial detector (3 days delay time, 100,000 seconds counting time) to determine volatile γ-emitters according to standard procedures [5, 6].

Following this measurement, the filter was dry-ashed at 450 ºC for 16 h. Calcium sulphate was added to the resulting residue to achieve a sample of 4 g, which was homogenised and transferred into a polyethylene vial. Measurements were carried out on a coaxial well-type detector (10 days delay time, 178,200 seconds counting time) according to standard procedures [5, 6].

The period between sampling and the gross α and gross β analysis was five to ten days, which is long compared with the decay time of the short-lived decay products ^{222}Rn and ^{220}Rn. This is done to ensure that these naturally occurring short-lived decay products do not contribute to the measured α and β activity concentrations.

The data from 1991 to 2004 were re-analysed to determine the yearly averages following the method described in Appendix B [7]. This might have led to small differences between the data presented in this report and the data reported prior to 2005.

Table 2.1: Monitoring programme for the determination of radioactive nuclides in air dust

Matrix	Location	Parameter	Sample period	Sample volume	Analysis frequency
Air dust	Bilthoven	gross α, gross β	week	925 m^3 [2]	weekly
Air dust	Bilthoven	γ-emitters [1]	week	125,000 m^3	weekly

[1] γ-spectroscopic analysis of specific γ-emitting nuclides.

[2] A sub-sample of 0.74% from the filter, through which approximately 125,000 m^3 of air was sampled.

2.1 Long-lived α and β activity

The weekly results of gross α and β activity concentrations in air dust are given in Figure 2.1 and Table A1 (see Appendix A). Due to large uncertainties caused by variations in the amount of dust on the filters, gross α activity concentrations in air dust should be regarded as indicative values [5]. The frequency distributions of gross α activity and gross β activity concentrations in air dust are given in Figures 2.2 and 2.3, respectively.

The yearly averages of the gross α and β activity concentrations of long-lived nuclides in 2013 were within the range of the results from the period 1992–2012, as illustrated in Figure 2.4. Since 2007, a new (more realistic) calibration for gross α has been applied to the measurements. The new calibration factor is 1.4 times higher than that used in previous years, which results in lower reported gross α activities.

Since 2011, a change in equipment, with a coinciding change in filter type, has resulted in changes in the reported gross α (-24%) and gross β (-15%) results, for which no correction is applied [3]. A possible explanation for these changes is a deeper permeation of the air dust in the present filter type G-3 than in the previous filter type GF10. This results in a difference in self-absorption of the α and β particles measured, i.e. lower gross α and gross β results in the present G-3 filter than the previous GF10 filter.
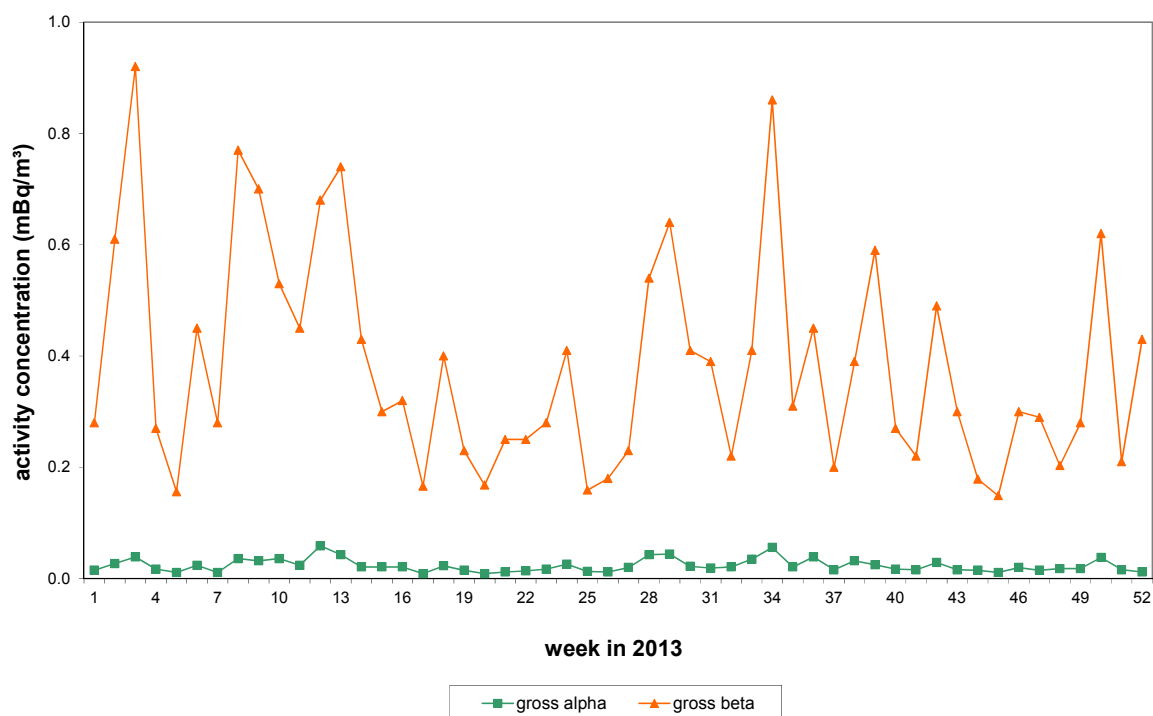
Figure 2.1: Weekly averaged gross α and β activity concentrations of long-lived nuclides in air dust sampled at RIVM

Figure 2.2: Frequency distribution of gross α activity concentration of long-lived nuclides in air dust collected weekly in 2013
The yearly average was 0.023 (SD=0.012) mBq·m^{-3}. SD is the standard deviation and illustrates the variation in weekly averages during the year.

Figure 2.3: Frequency distribution of gross β activity concentration of long-lived nuclides in air dust collected weekly in 2013
The yearly average was 0.384 ± 0.007 (SD=0.19) mBq·m^{-3}.

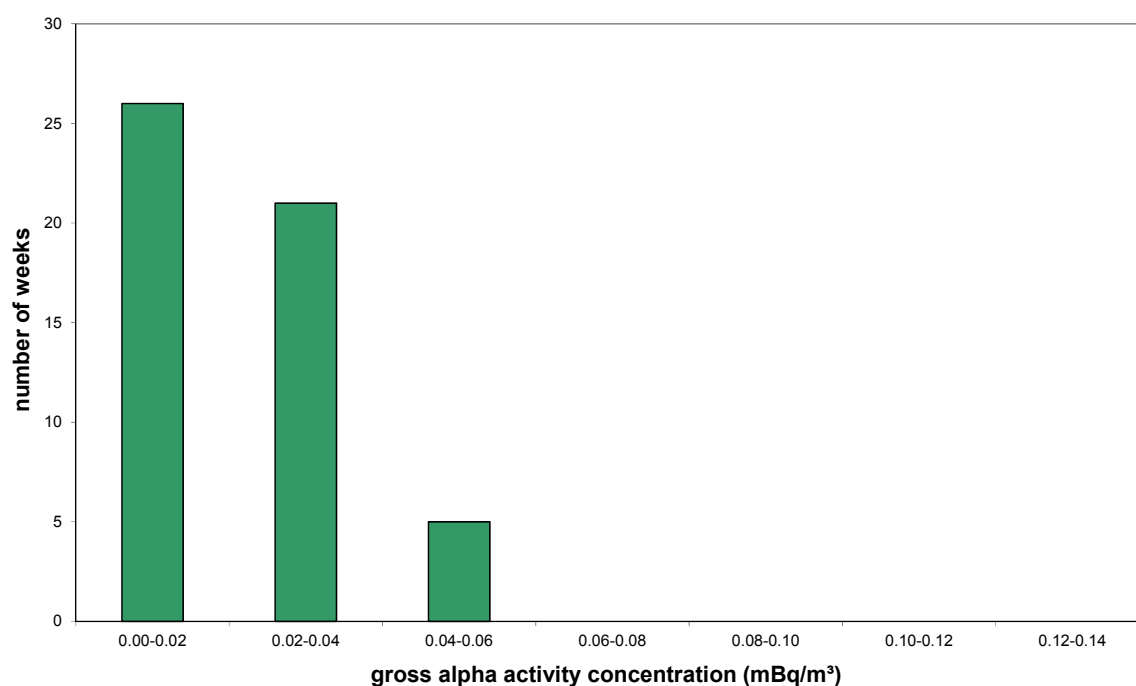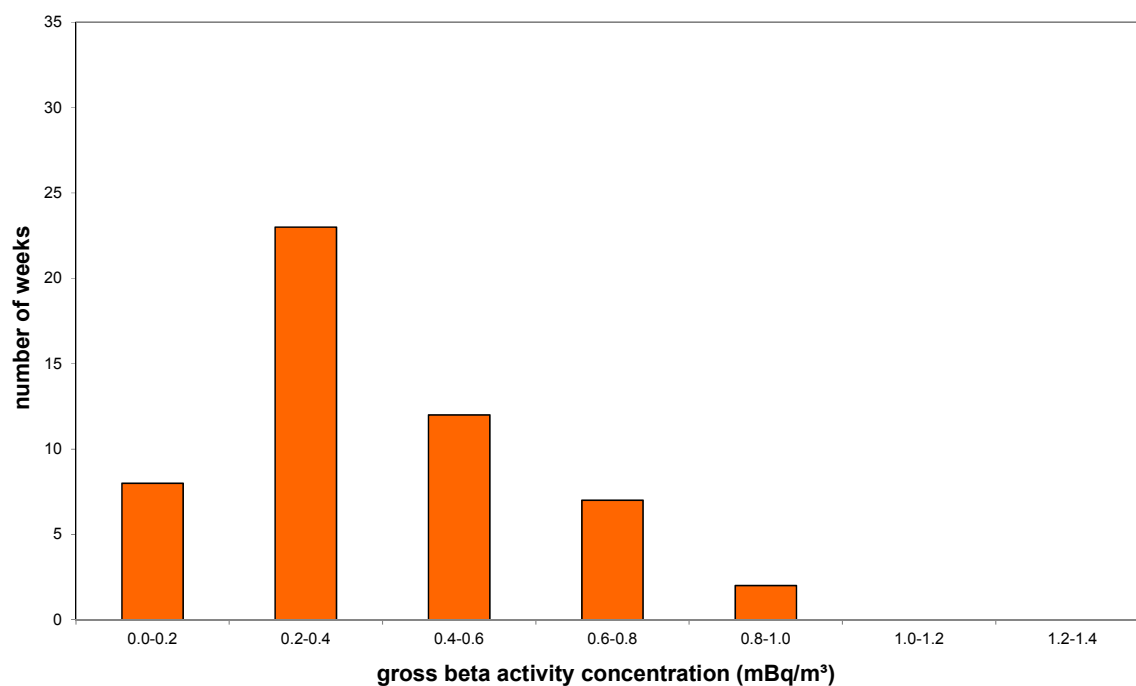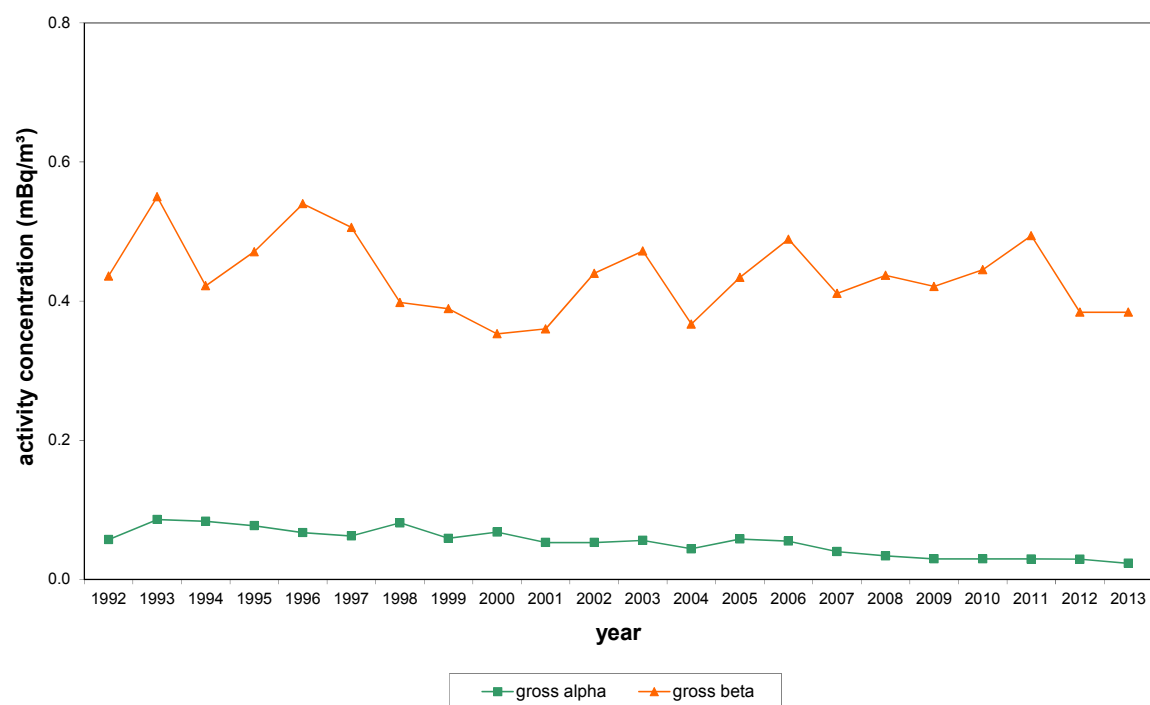

Figure 2.4: Yearly averaged gross α and gross β activity concentrations of long-lived nuclides in air dust at RIVM since 1992

2.2 γ-emitting nuclides

Several γ-emitting nuclides were detected frequently in air dust: [7]Be (52 times), [210]Pb (52 times) and [137]Cs (45 times). The results are presented in Table A3 and Figures 2.5, 2.6 and 2.7. The detection limits for nuclides considered in the gammaspectroscopic analysis of the HVS samples are given in Table A2.

The behaviour of [7]Be in the atmosphere has been studied worldwide [8, 9, 10, 11, 12, 13, 14]. Natural [7]Be (half-life of 53.3 days) is formed by spallation reactions of cosmogenic radiation with atmospheric nuclei such as carbon, nitrogen and oxygen, resulting in the formation of BeO or Be(OH)$_2$ molecules. Approximately 70% of [7]Be is produced in the stratosphere, and the remainder is produced in the troposphere. It has an estimated residence time of about one year in the stratosphere and about six weeks in the troposphere. Most of the [7]Be produced in the stratosphere does not reach the troposphere, except during spring, when seasonal thinning of the tropopause takes place at mid-latitudes, resulting in air exchange between the stratosphere and the troposphere.
In the troposphere, [7]Be rapidly associates mainly with submicron-sized aerosol particles. Gravitational settling and precipitation processes accomplish transfer to the earth's surface. Seasonal variations in the concentration of [7]Be in surface air are influenced by the following main atmospheric processes: wet and dry deposition, mass exchange between stratosphere and troposphere, vertical transport in the troposphere, and horizontal transport of air masses from the subtropics and mid-latitudes to the tropics and polar regions.
The red line in Figure 2.5 shows the seasonal variation of the [7]Be activity concentration, with peaks during the spring and summer periods, reflecting the seasonal variations in the transport rate of air from stratosphere to troposphere. Figure 2.5 further shows the influence of the solar cycle. The maxima at 1997 and 2007–2009, and the minimum at 2000–2002 are consistent with the solar minima (measured by radio flux and sunspot count) of 1996–1997 and 2008–2009, and the solar maximum of 2000–2002, respectively [15]. In the summer of 1991 two severe geomagnetic storms caused a significant worldwide disturbance of the earth's geomagnetic field. This resulted in a considerable decrease in cosmogenic radiation, which was unprecedented in at least the previous four decades [16]. The absence of a 1991 summer peak in the [7]Be activity concentration can be explained by the decrease in cosmogenic radiation. The concentrations found for [7]Be in 2013 fit into the pattern described above.
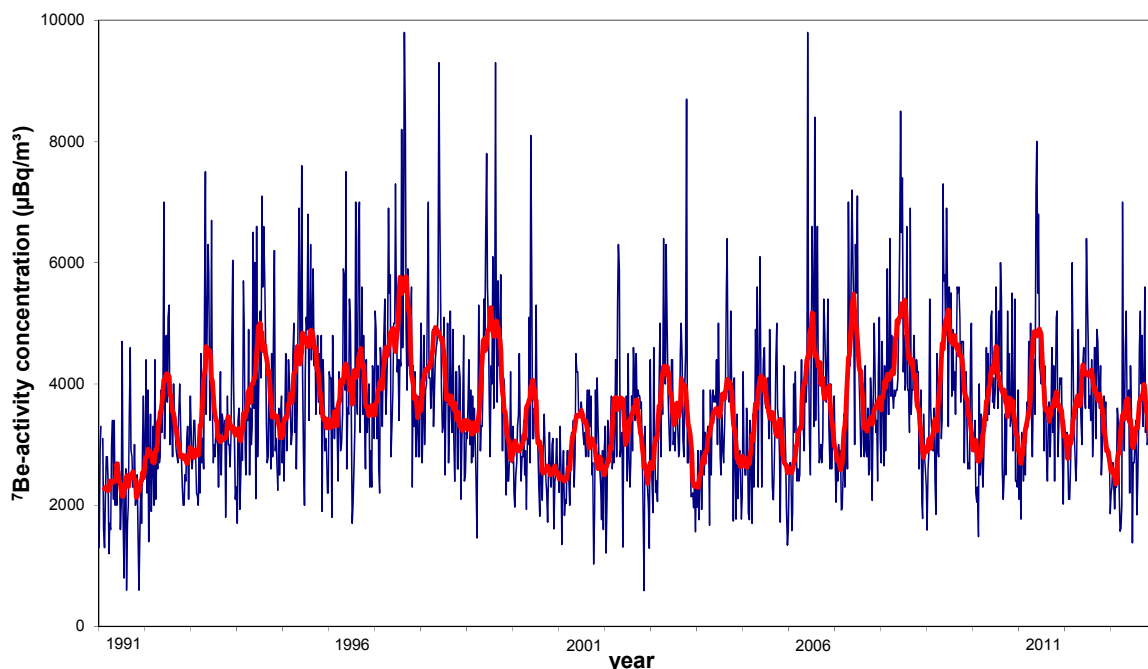
Figure 2.5: Weekly averaged [7]Be activity concentrations (blue) in air dust at RIVM since 1991

The red line is a moving average of 13 weeks. The yearly average for 2013 was 3280 ± 50 (SD=1100) µBq·m^{-3}.

The nuclide [137]Cs (half-life of 30.2 years) is of anthropogenic origin. Until 2011, when the nuclear accident at the Fukushima Nuclear Plant occurred, the two main sources of ^{137}Cs in the environment were nuclear weapons tests and the Chernobyl accident of 1986. Resuspension of previously deposited activity is the main source of airborne ^{137}Cs activity in the Netherlands from 1986 onwards.

Figure 2.6 shows a peak during May 1992. During the same month, several wildfires occurred near the Chernobyl area [17], and the level of airborne ^{137}Cs activity increased ten times in the 30 km exclusion zone around Chernobyl. It is possible that the airborne ^{137}Cs was transported to Western Europe by the weather conditions in the same period (dry with a strong easterly wind [18]). On 29 May 1998, an incident occurred at Algeciras (Spain): an iron foundry melted a ^{137}Cs source concealed in scrap metal [19]. As a result, elevated levels of airborne ^{137}Cs activity were measured in France, Germany, Italy and Switzerland during late May and early June. Figure 2.6 shows a slightly elevated level of ^{137}Cs activity (second peak) around the same period (29 May to 5 June 1998). Such slightly elevated levels are not uncommon, as can be seen in Figure 2.6. These elevations may be related to resuspension of previously deposited dust, especially during a period of strong winds from the continent [19]. From 18 March until 10 June 2011, elevated levels of ^{137}Cs activity were measured as a result of the incident at Fukushima (Japan). More detailed results on ^{137}Cs and other nuclides during that period are presented in [20].
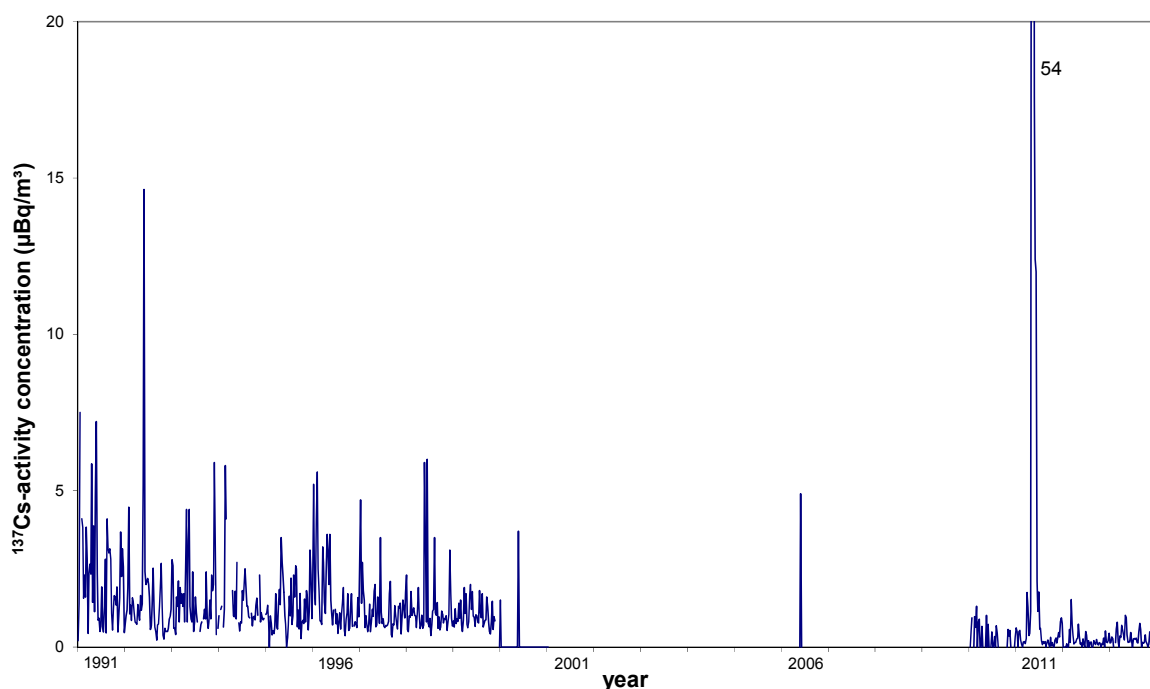
Figure 2.6: Weekly averaged ^{137}Cs activity concentrations in air dust at RIVM since 1991

Seven out of the 52 measurements were below the detection limit in 2013. The yearly average for 2013 was 0.317 ± 0.007 (SD=0.2) µBq·m^{-3}. Between 2000 and the middle of 2009, the detection limit was higher than during 1991–1999, due to a different detector set-up. Since July 2009, a new detector set-up has been used, which results in lower detection limits (similar to those before 2000).

The primary source of atmospheric ^{210}Pb (half-life of 22.3 years) is the decay of ^{222}Rn exhaled from continental surfaces. Therefore, the atmospheric concentration of ^{210}Pb over continental areas is generally higher than over oceanic areas (^{222}Rn exhalation from the ocean is 1,000 times less than that from the continents). The reported UNSCEAR reference level of ^{210}Pb in air dust is 500 µBq·m^{-3} [21]. In the atmosphere this radionuclide is predominantly associated with submicron-sized aerosol particles [22, 23]. The mean aerosol (carrying ^{210}Pb) residence time in the troposphere is approximately five days [24].

Other sources of ^{210}Pb in air dust are volcanic activity and industrial emissions [25, 26, 27, 28, 29, 30]. Examples of industrial emissions are discharges from power plants using fossil fuels, discharges from fertiliser and phosphorus industries, and exhaust gases from traffic. In the Netherlands, emissions by power plants are only of local importance regarding ^{210}Pb deposition. Emissions by the phosphorus industry contribute a negligible part of the yearly total ^{210}Pb deposition [30]. Volcanic eruptions bring uranium decay products into the atmosphere, such as ^{226}Ra, ^{222}Rn, ^{210}Pb and ^{210}Po. Beks et al. [27] estimate that volcanoes contribute 60 TBq·year^{-1} to the atmospheric ^{210}Pb stock. If the volcanic deposition were evenly distributed worldwide, the contribution to the yearly total ^{210}Pb deposition would be negligible.
Unusual ^{210}Pb values might be explained by natural phenomena such as an explosive volcanic eruption, Saharan dust [31, 32, 33] or resuspension

of (local) dust. Normally there is a good correlation between ^{210}Pb and gross β activity concentrations, as was the case in 2013 (Figure 2.8). The weekly averaged ^{210}Pb activity concentrations in 2013 were within the range of those found in previous years (Figure 2.7).
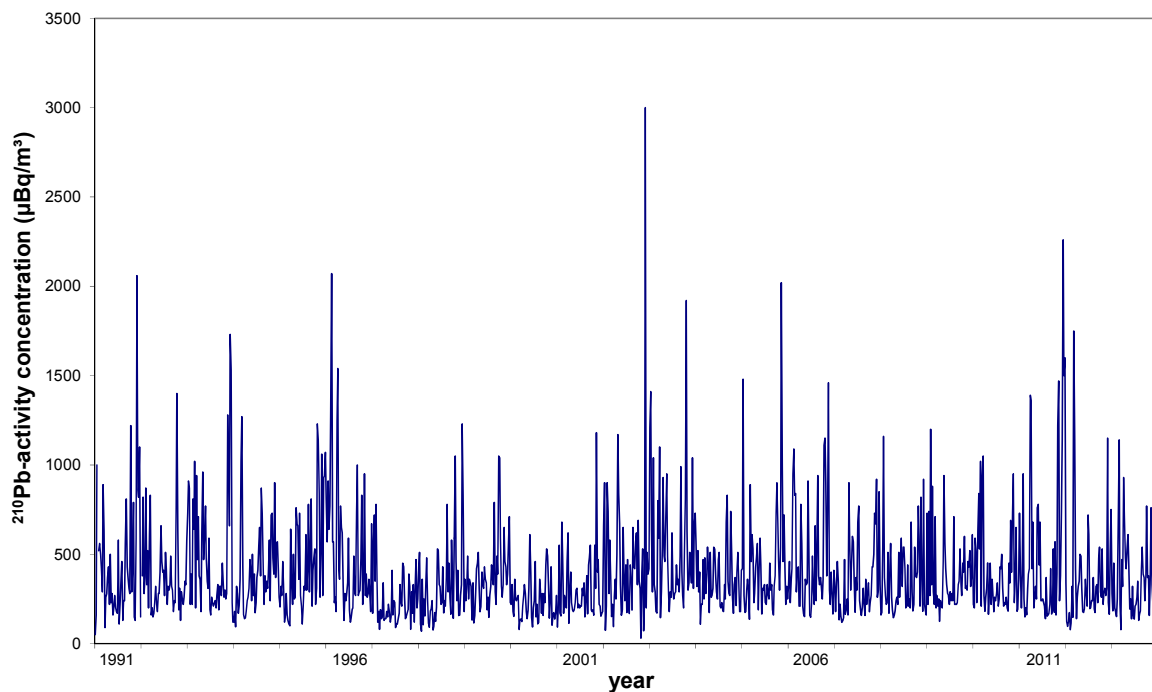

Figure 2.7: Weekly averaged ^{210}Pb activity concentrations in air dust at RIVM since 1991
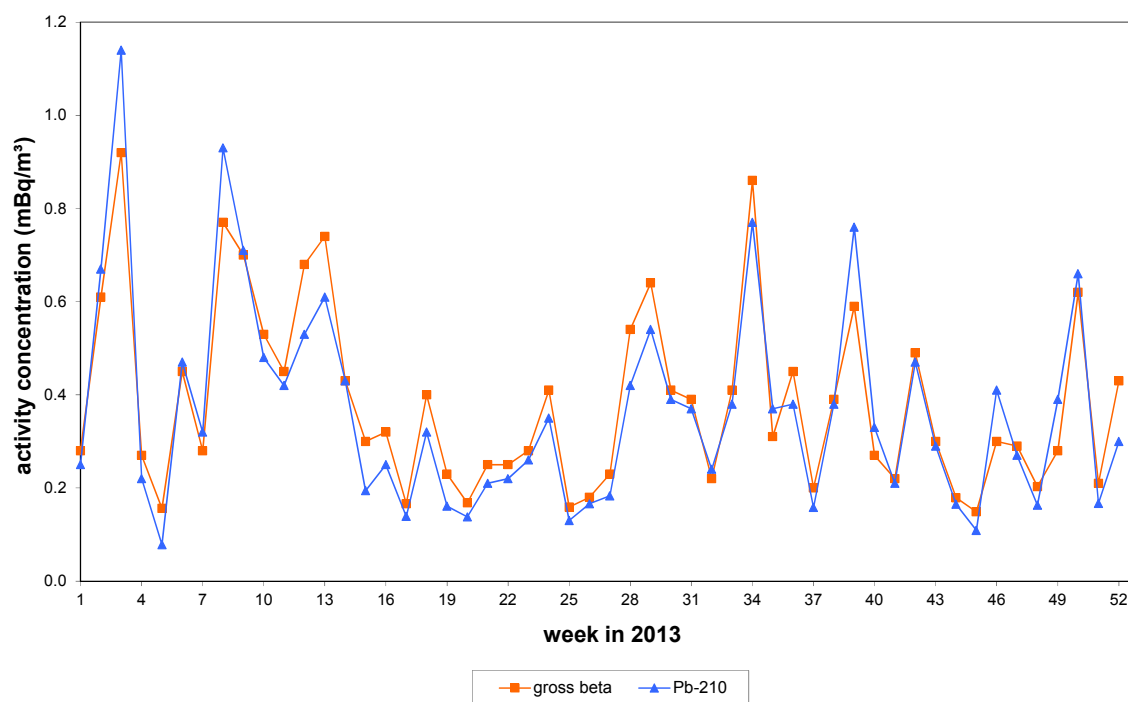The yearly average for 2013 was 366 ± 6 (SD=200) µBq·m^{-3}.

Figure 2.8: Figure illustrating the correlation between weekly averaged gross β and ²¹⁰Pb activity concentrations in air dust at RIVM

3 Deposition

Table 3.1 describes the monitoring programme for determining radioactive nuclides in deposition. Sampling was done on the RIVM premises in Bilthoven. Samples were collected weekly for γ-emitters and monthly for gross α, gross β, ^3H and ^{210}Po according to a standard procedure [34].

The weekly samples for γ-emitters and monthly samples for gross α and gross β were acidified with sulphuric acid and evaporated. The resulting sulphate residue was analysed according to standard procedures [6, 35, 36].

The monthly samples for ^3H were made alkaline by the addition of sodium carbonate and then distilled. A 10 ml aliquot of the distillate was mixed with an equal amount of scintillation solution (Ultima Gold LLT) in a plastic counting vial and then counted on an anti-coincidence liquid scintillation counter for 1,000 minutes per sample.

The monthly samples for ^{210}Po were reduced in volume by evaporation. The resulting solution was analysed according to a standard procedure [37], with a minor difference: the ingrowth of ^{210}Po from ^{210}Pb was derived from the ^{210}Pb results from the weekly samples for γ-emitters rather than by using the procedure described in [37].

The data from 1993 to 2004 were re-analysed to determine the yearly totals by the method described in Appendix B [7]. This can lead to small differences between data presented in this report and data reported prior to 2005.

Table 3.1: Monitoring programme for the determination of radioactive nuclides in deposition

Matrix	Location	Parameter	Sample period	Sample volume	Analysis frequency
Deposition	Bilthoven	γ-emitters [1]	week	variable	weekly
Deposition	Bilthoven	gross α, gross β and ^{210}Po	month	variable	monthly
Deposition	Bilthoven	^3H	month	variable	quarterly

[1] γ-spectroscopic analysis of specific γ-emitting nuclides.

3.1 Long-lived α and β activity

The monthly deposited gross α and gross β activities of long-lived nuclides are given in Figure 3.1, Figure 3.3 and Table A4. The yearly total deposition of gross α and gross β were 48.1 ± 1.6 and 95 ± 2 Bq·m^{-2}, respectively. These values are within the range of those from previous years, as illustrated in Figure 3.2, Figure 3.4 and Table A5.

The monthly deposition of ^3H is given in Table A4. In 2013, the yearly total deposition of ^3H ranged between 0 and 1,580 Bq·m^{-2} (68% confidence interval). The yearly total consisted of 12 samples, and all 12 measurements were below the detection limit. These detection limits

were used for the contribution to the yearly total, as described in Appendix B. The range in 2013 did not differ significantly from those measured since 1993, as illustrated in Figure 3.5 and Table A5. Until 1998, samples were electrolytically enriched before counting, which resulted in a much lower detection limit than after 1997.
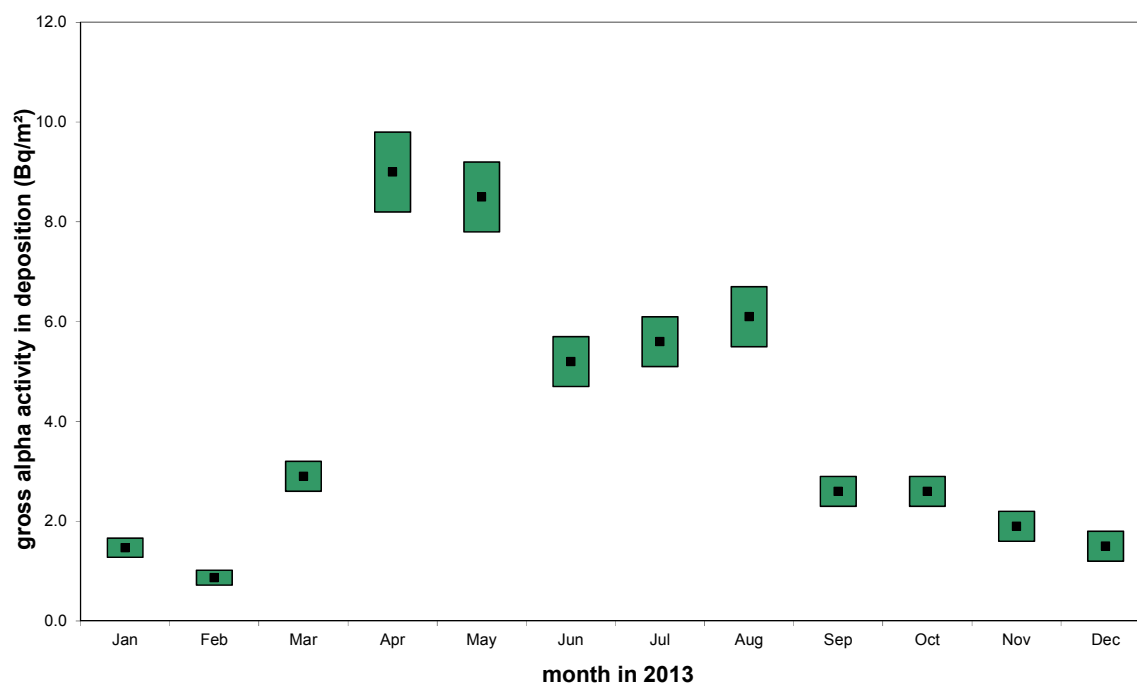
Figure 3.1: Monthly deposited gross a activity of long-lived nuclides at RIVM
Monthly totals (black dots) are shown with a 68% confidence interval (coloured bars).
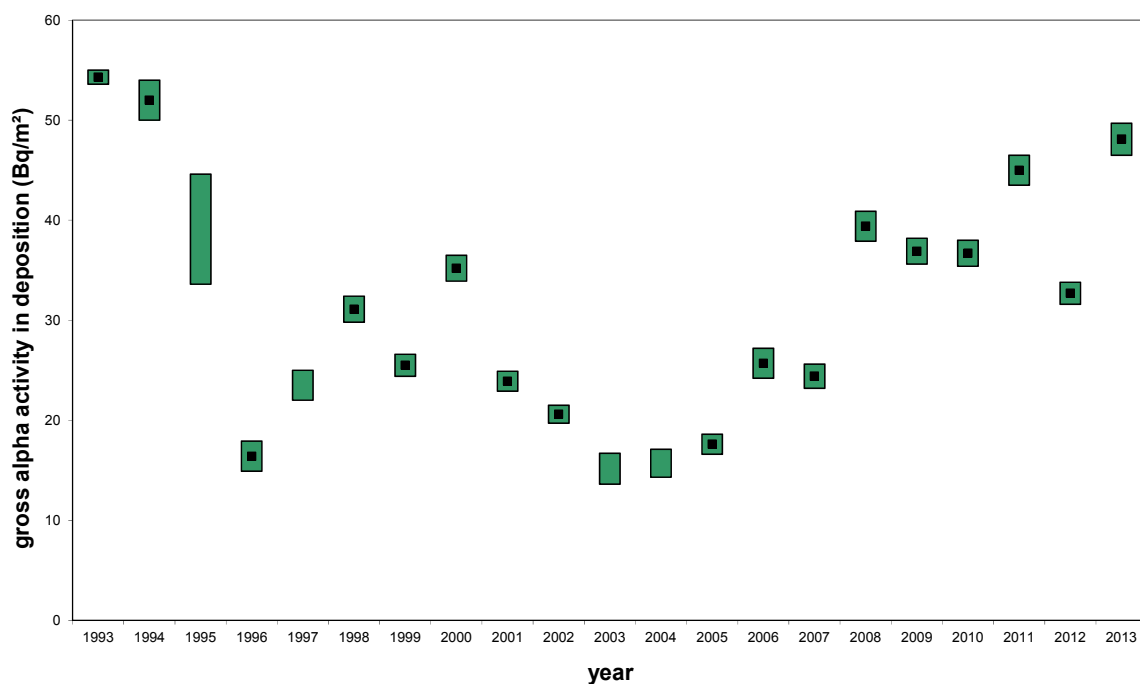
Figure 3.2: Yearly gross a activity of long-lived nuclides deposited at RIVM since 1993
Yearly totals (black dots) are shown with a 68% confidence interval (coloured bars). Only the 68% confidence interval is shown if the yearly result is made up of more than one detection limit.

Figure 3.3: Monthly deposited gross β activity of long-lived nuclides at RIVM
Monthly totals (black dots) are shown with a 68% confidence interval (coloured bars).
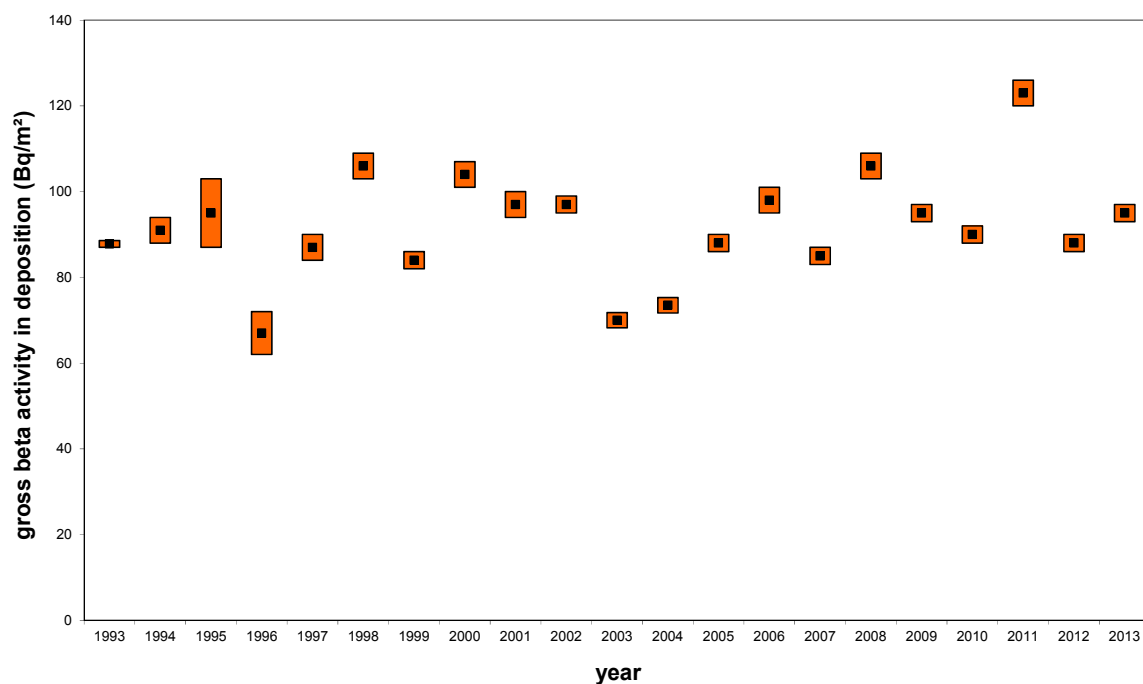
Figure 3.4: Yearly gross β activity of long-lived nuclides deposited at RIVM since 1993
Yearly totals (black dots) are shown with a 68% confidence interval (coloured bars).

Figure 3.5: Yearly deposition of ^{3}H at RIVM since 1993
Yearly totals (black dots) are shown with a 68% confidence interval (coloured bars). Only the 68% confidence interval is shown if the yearly result is made up of more than one detection limit.
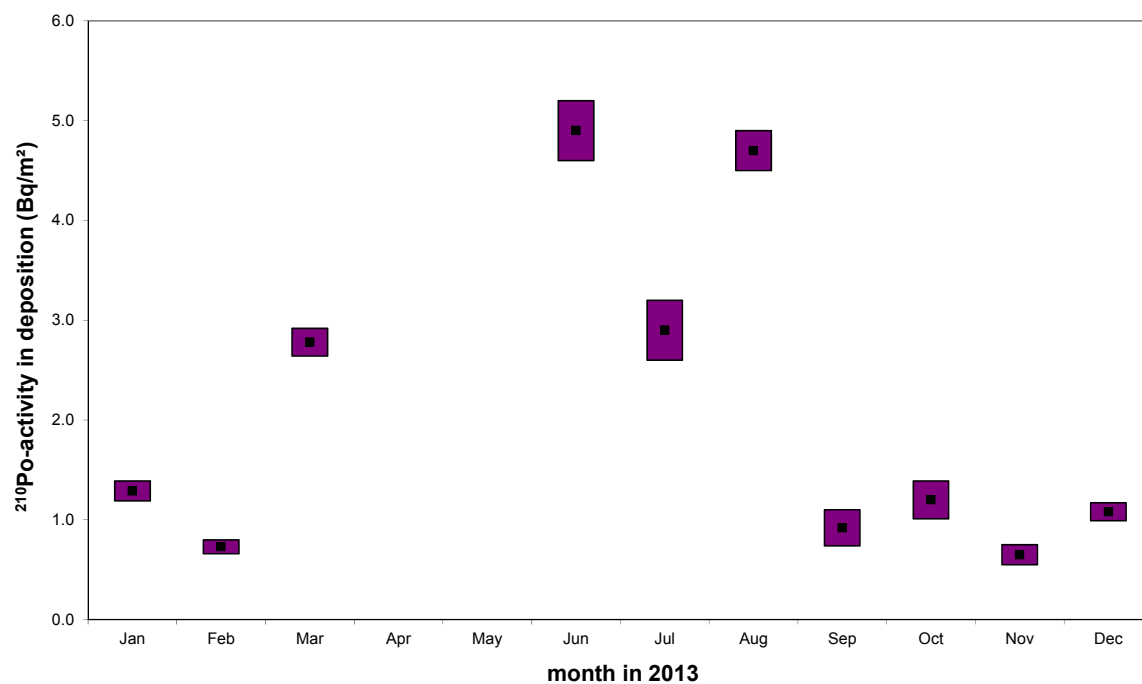
Figure 3.6: Monthly deposited ^{210}Po activity at RIVM
Monthly totals (black dots) are shown with a 68% confidence interval (coloured bars). The results for April and May were rejected.

Figure 3.7: Yearly ^{210}Po activity deposited at RIVM since 1993
Yearly totals (black dots) are shown with a 68% confidence interval (coloured bars). Only the 68% confidence interval is shown if the yearly result is made up of more than one detection limit. The yearly result of 2013 is based on 10 monthly results.
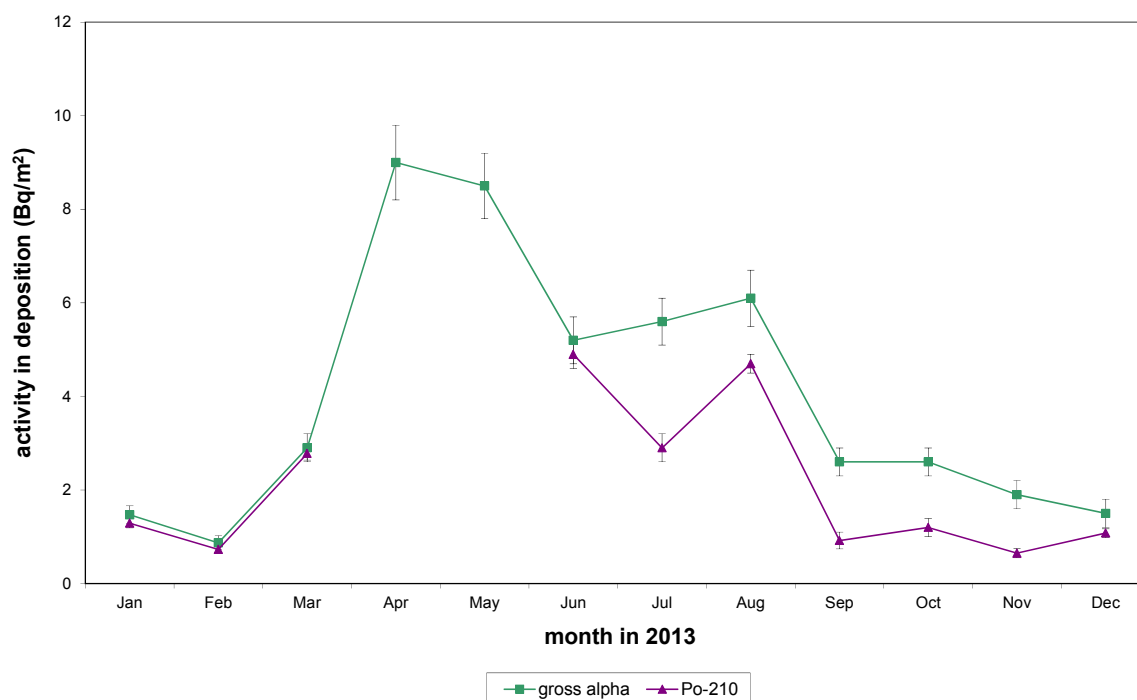
Figure 3.8: Correlation between monthly total gross α and ^{210}Po activity in deposition at RIVM
A 68% confidence interval is shown by means of an error bar. The ^{210}Po results for April and May were rejected.

The monthly α spectroscopy results for ^{210}Po are given in Figure 3.6 and Table A6. The results for previous years are given in Figure 3.7 and Table A7. The yearly total deposition of ^{210}Po in 2013 was 21.2 ± 0.6 Bq·m^{-2} (68% confidence interval) and is based on 10 monthly results. The results for April and May were rejected. This value is within the range of those from previous years, as illustrated in Figure 3.7 and Table A5. Contrary to expectation, the correlation between the level of ^{210}Po and the level of gross α, seen in Figure 3.8, is less evident than in previous years.

3.2   γ-emitting nuclides

The naturally occurring nuclides ^{7}Be and ^{210}Pb were found in all 52 weekly deposition samples. The yearly total deposition of ^{7}Be was 1,030 ± 30 Bq·m^{-2} and the yearly total deposition of ^{210}Pb was 82.9 ± 1.8 Bq·m^{-2}. The nuclide ^{137}Cs was detected in none of the 52 weekly samples (the detection limit for ^{137}Cs is 0.02 Bq·m^{-2}). The yearly total deposition of ^{137}Cs ranged between 0 and 1.1 Bq·m^{-2} (68% confidence interval). The weekly results for deposition of ^{7}Be, ^{137}Cs and ^{210}Pb are given in Table A8 and Figures 3.9 and 3.12. The results for previous years are given in Table A7 and Figures 3.10, 3.11 and 3.13.
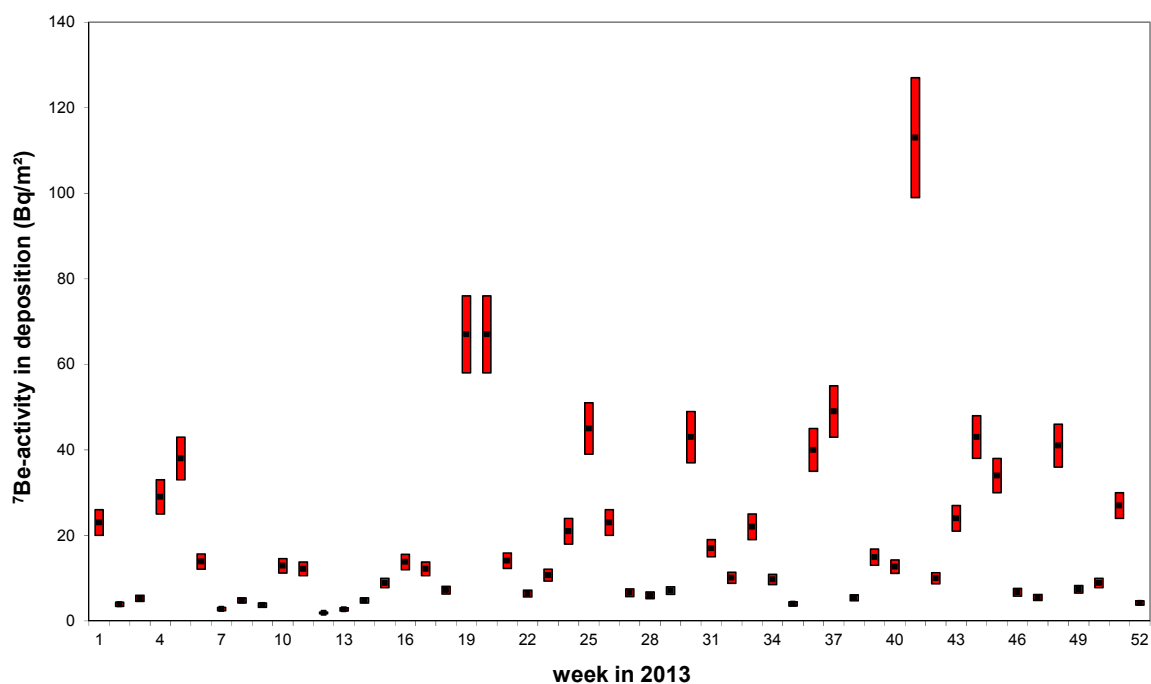
Figure 3.9: Weekly deposited ^{7}Be activity at RIVM
Weekly totals (black dots) are shown with a 68% confidence interval (coloured bars).
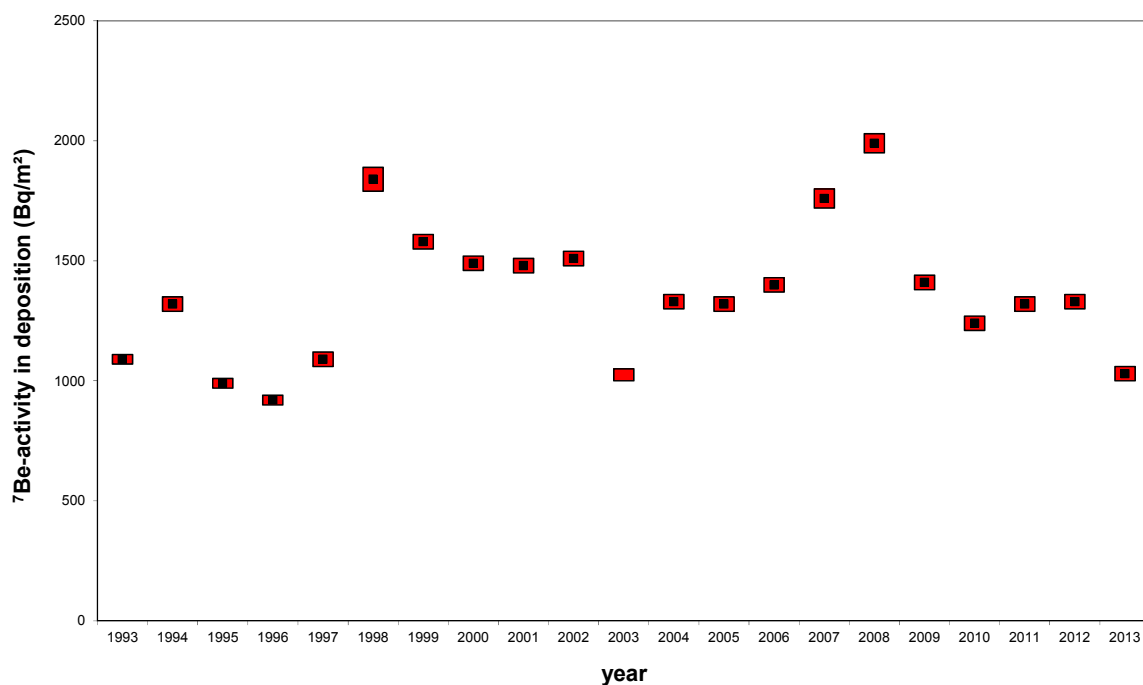
Figure 3.10: Yearly ^{7}Be activity deposited at RIVM since 1993
Yearly totals (black dots) are shown with a 68% confidence interval (coloured bars). Only the 68% confidence interval is shown if the yearly result is made up of more than one detection limit.
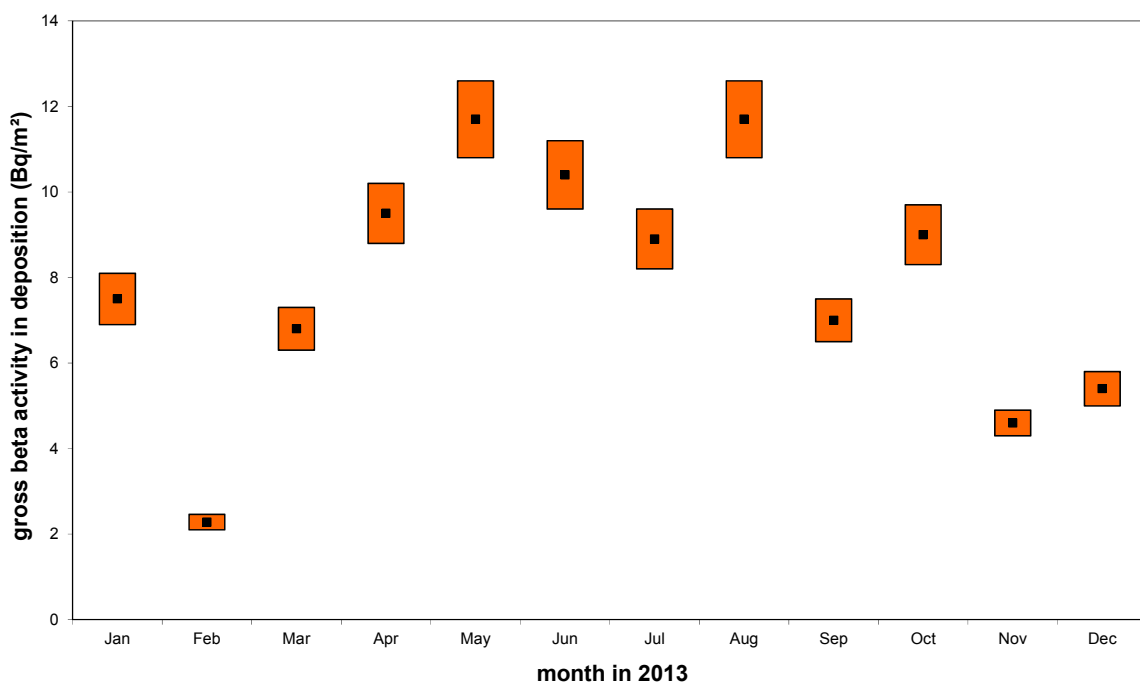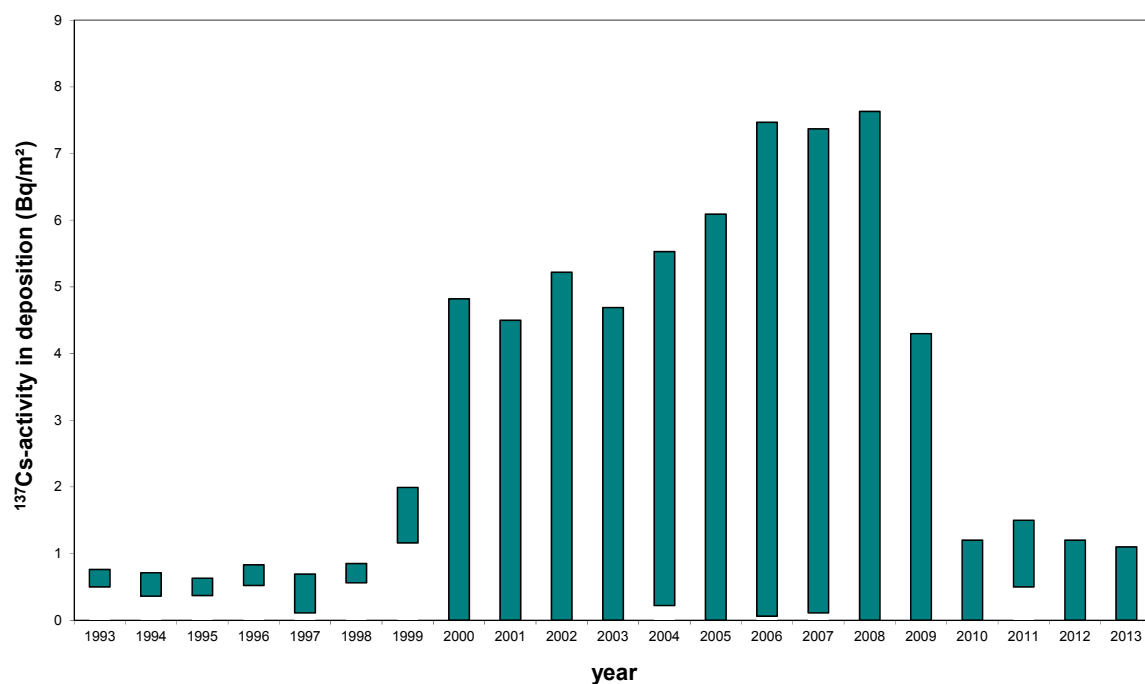
Figure 3.11: Yearly ¹³⁷Cs activity deposited at RIVM since 1993
Yearly averages are shown solely as a 68% confidence interval since the yearly result is
made up of more than one detection limit. From 2000 to June 2009, the detection limit
was higher than during 1993–1999, due to a different detector set-up. Since July 2009, a
new detector set-up has been used, which results in lower detection limits.
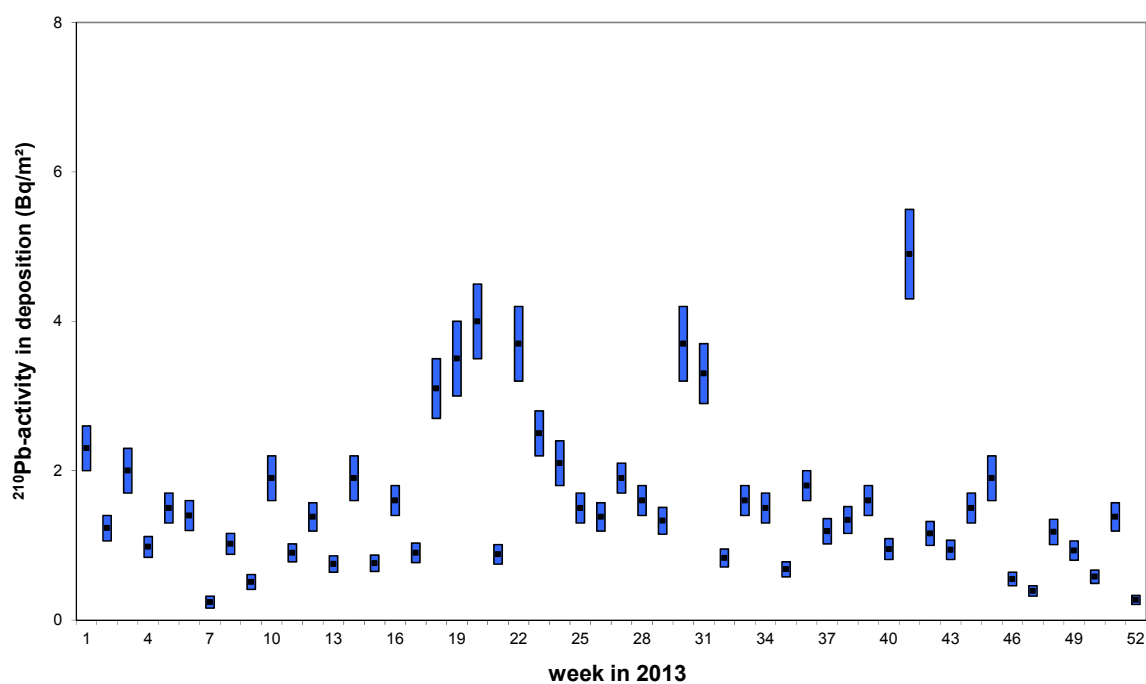
Figure 3.12: Weekly deposited ²¹⁰Pb activity at RIVM
Weekly averages (black dots) are shown with a 68% confidence interval (coloured bars).
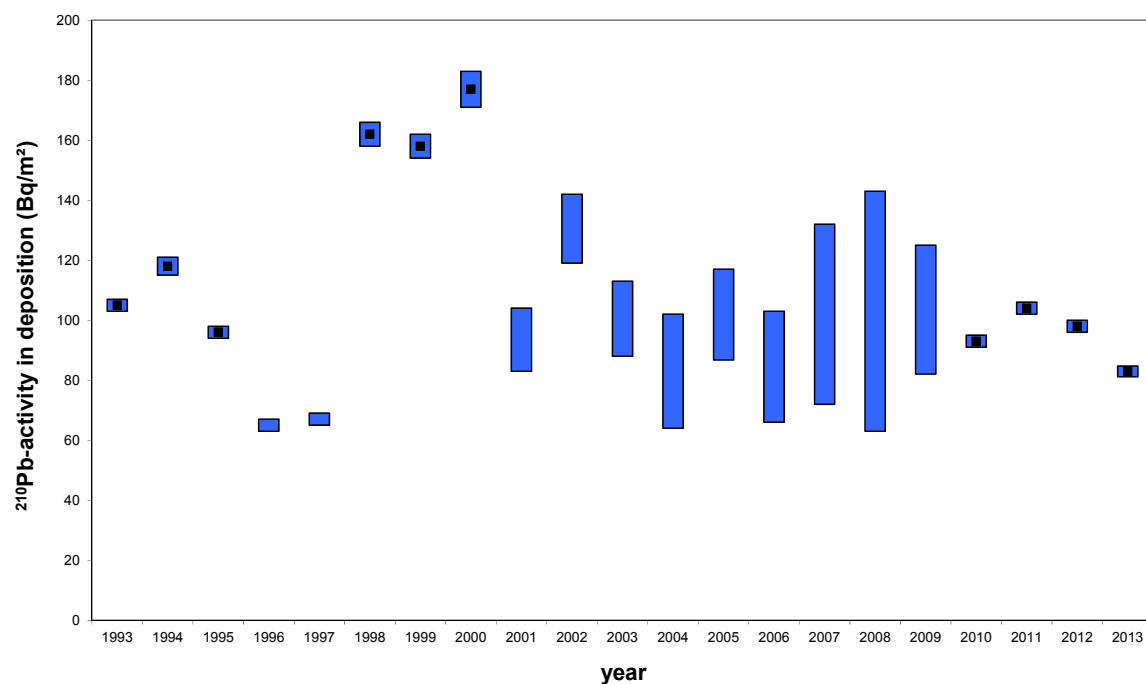
Figure 3.13: Yearly ^{210}Pb activity deposited at RIVM since 1993
Yearly averages (black dots) are shown with a 68% confidence interval (coloured bars).
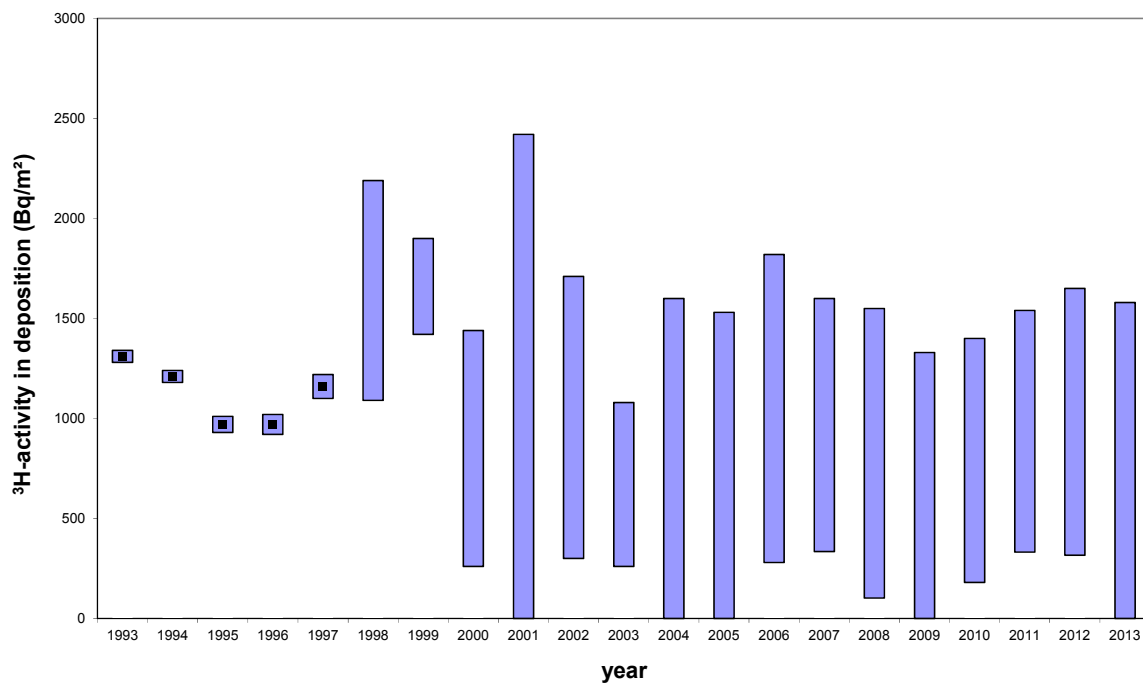Only the 68% confidence interval is shown if the yearly result is made up of more than one
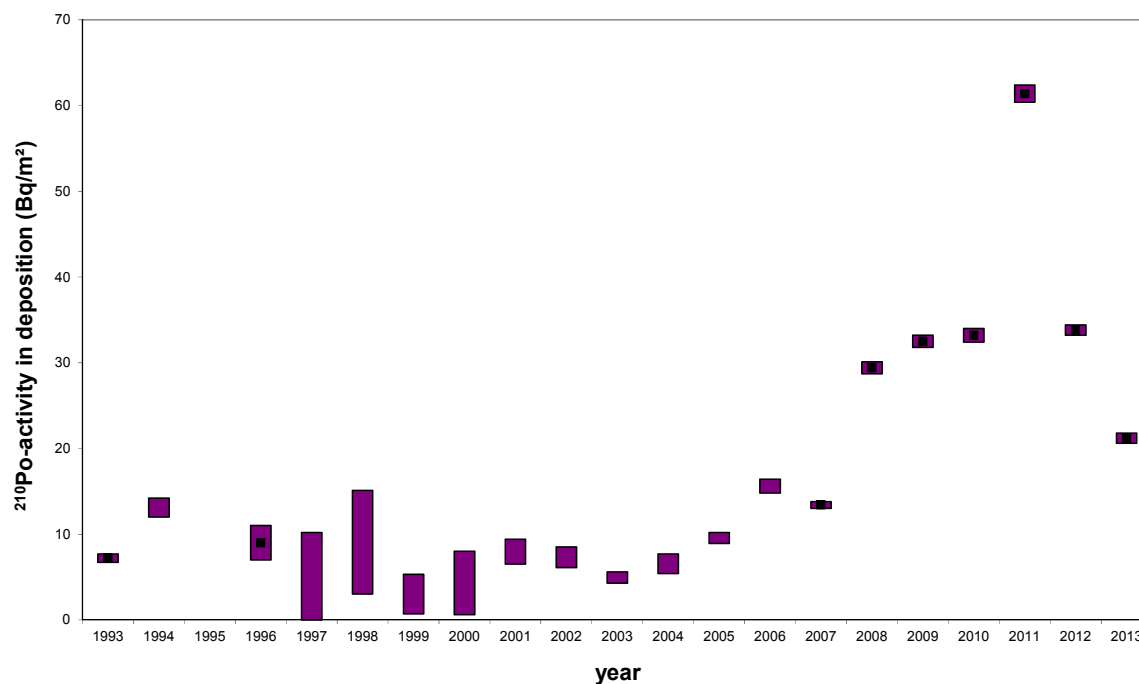detection limit.

4   National Radioactivity Monitoring Network

This chapter presents data on gross α and artificial β activity concentrations in air dust and ambient dose equivalent rates, as measured by the National Radioactivity Monitoring Network (Nationaal Meetnet Radioactiviteit, NMR). The data on gross α and artificial β differ in sample size, sampling frequency and analytical procedures from those given in the previous chapter. Furthermore, the difference between the NMR data and those mentioned in the previous chapter is due to the contribution of short-lived natural radionuclides (radon daughters).

The NMR consists of 167 sites, at which the ambient dose equivalent rate is determined. At 14 measuring sites gross α and artificial β activity concentrations are determined as well as the ambient dose equivalent rate (at a height of 3.5 m above ground level) [38]. At the other 153 measuring sites only the ambient dose equivalent rate is determined (at 1 m above ground level).

Since the dose equivalent rate monitors are placed differently at 14 of the 167 sites with regard to height and surface covering, results can differ between the two types of measuring site [39]. Hence, the 14 dose equivalent rate monitors are not taken into account when calculating the yearly averaged ambient dose equivalent. The reported artificial β activity concentrations are calculated from the difference between the measured gross β activity concentration and the natural gross β activity derived from the measured gross α activity concentration.

During the second half of 2002, the 14 aerosol FAG FHT59S monitors were gradually replaced by 14 new Berthold BAI 9128 monitors. Due to differences in detection method, filter transport, calibration nuclides and algorithms, the results for the activity concentrations are not exactly the same. By running both monitors simultaneously at the same location, the measured gross α activity concentration was compared. On average, the Berthold monitor systematically reported about 20% higher values than the FAG monitor [40]. The estimated random uncertainty for both types of monitor is about 20%. No correction was applied for the difference in the gross α activity concentration between the Berthold and FAG monitor.

The data presented in this chapter are based on ten-minute measurements. Averages over the year are calculated per location, using daily averages from the ten-minute measurements (Tables A9 and A10). The data on external radiation, expressed in ambient dose equivalents, contain a systematic uncertainty because of an overestimation of the cosmogenic dose rate. However, NMR data are not corrected for these response uncertainties.

An impression of the spatial variation in the yearly averages of the NMR data, constructed by using the RIVM's Geographical Information System (GIS), is shown in Figures 4.1 and 4.3. An inverse distance weight interpolation algorithm was applied to calculate values in between the NMR stations.

Figure 4.2 presents the yearly averages of gross α activity concentration since 1990, while Figure 4.4 presents the yearly averages of ambient dose equivalent rate since 1996.

In 2013 the yearly averaged gross α activity concentration in air dust was 3.0 Bq·m^{-3} (based on the yearly averages of the 14 measurement locations). To compare this value (yearly average of 3.0 Bq·m^{-3}) with data collected before 2002, it should be noted that the Berthold measurements are 20% higher than the FAG measurements and the value can be corrected to 2.5 Bq·m^{-3}. The yearly average of the artificial β activity concentration does not deviate significantly from zero.

Since 2004, the analysis of the ambient dose equivalent rate has been based on a set of 153 stations. The yearly averaged ambient dose equivalent rate in 2013 was calculated using 150 stations (3 stations were not operational).

In 2013, the yearly averaged measured value for the ambient dose equivalent rate was 73.1 nSv h^{-1}. Figure 4.5 shows the influence of the 11-year solar cycle on the cosmogenic contribution to the effective dose rate, which is related to the ambient dose equivalent rate. The decrease in the ambient dose equivalent rate (as given by the NMR) from 1996 to 2003 (Figure 4.4) might be related to the decrease in the cosmogenic contribution. However, the correlation between the increase in the cosmogenic contribution since 2004 and the measured ambient dose equivalent rate is less evident (Figure 4.4).
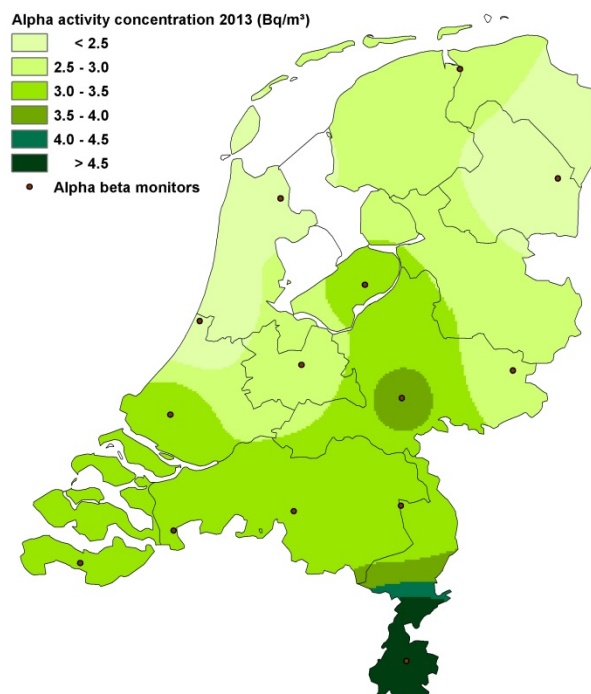
Figure 4.1: An impression of spatial variation in the average gross α activity concentration of (mainly) short-lived nuclides in air dust
The dots represent the locations of the aerosol monitors.
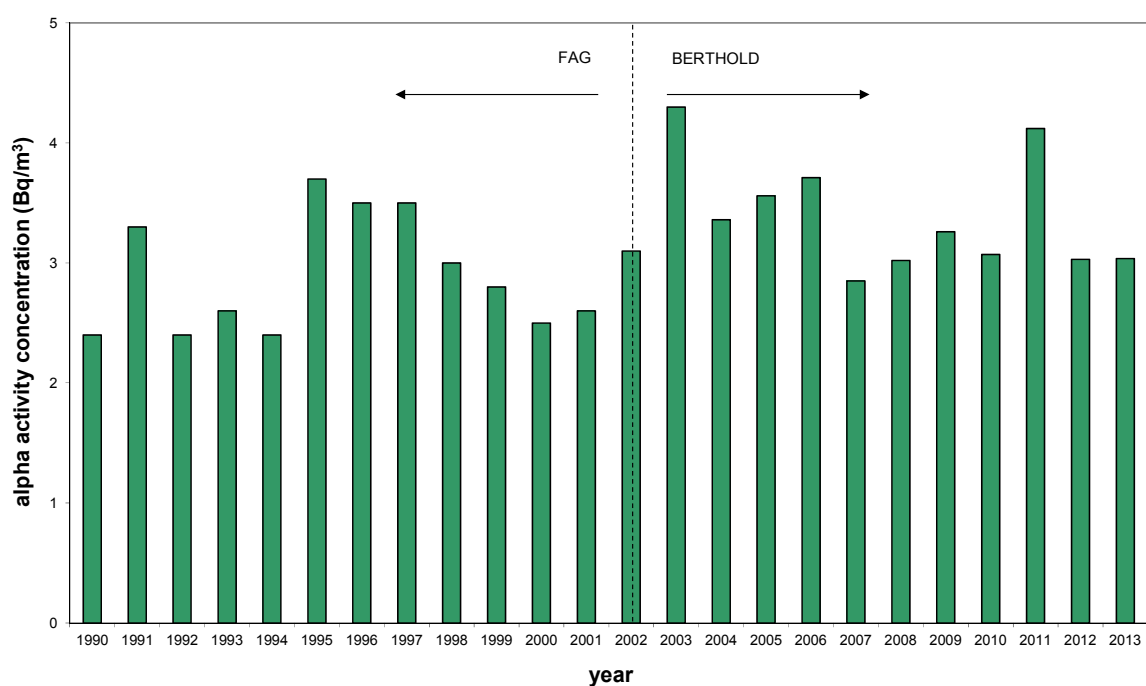
Figure 4.2: Yearly averaged gross α activity concentration of (mainly) short-lived nuclides in air dust
During the second half of 2002 the FAG monitors were replaced by Berthold monitors.
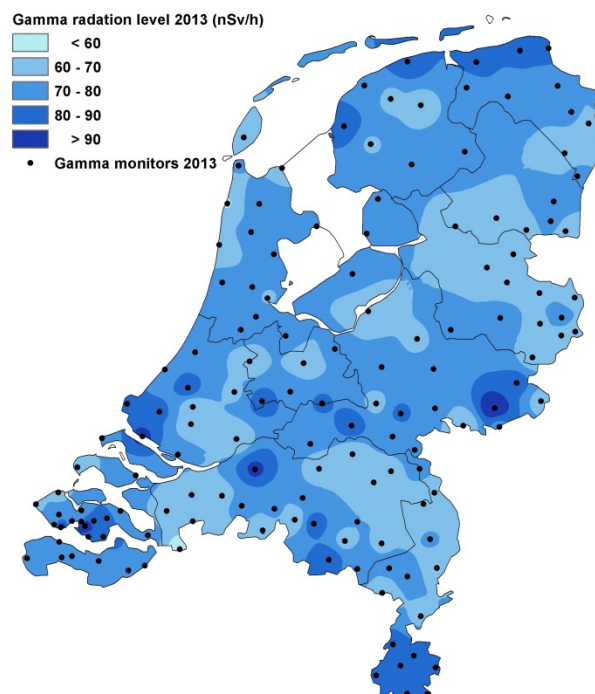
Figure 4.3: An impression of spatial variation in the average ambient dose equivalent rate
The dots represent the locations of the dose equivalent rate monitors.
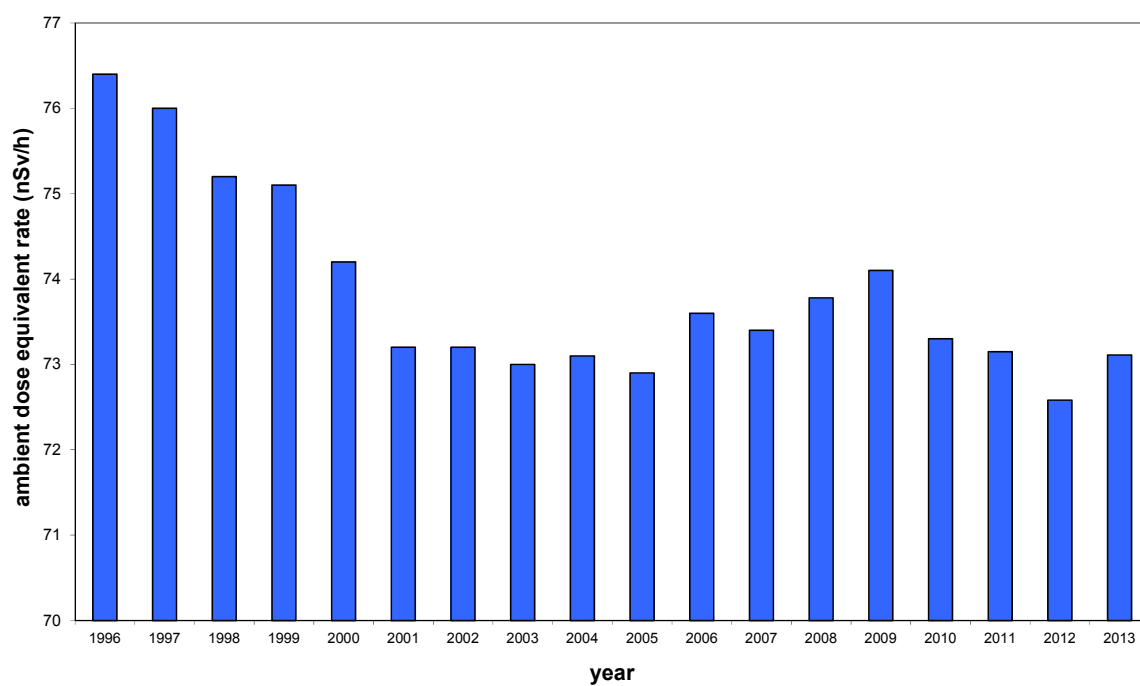
Figure 4.4: The yearly averaged ambient dose equivalent rate
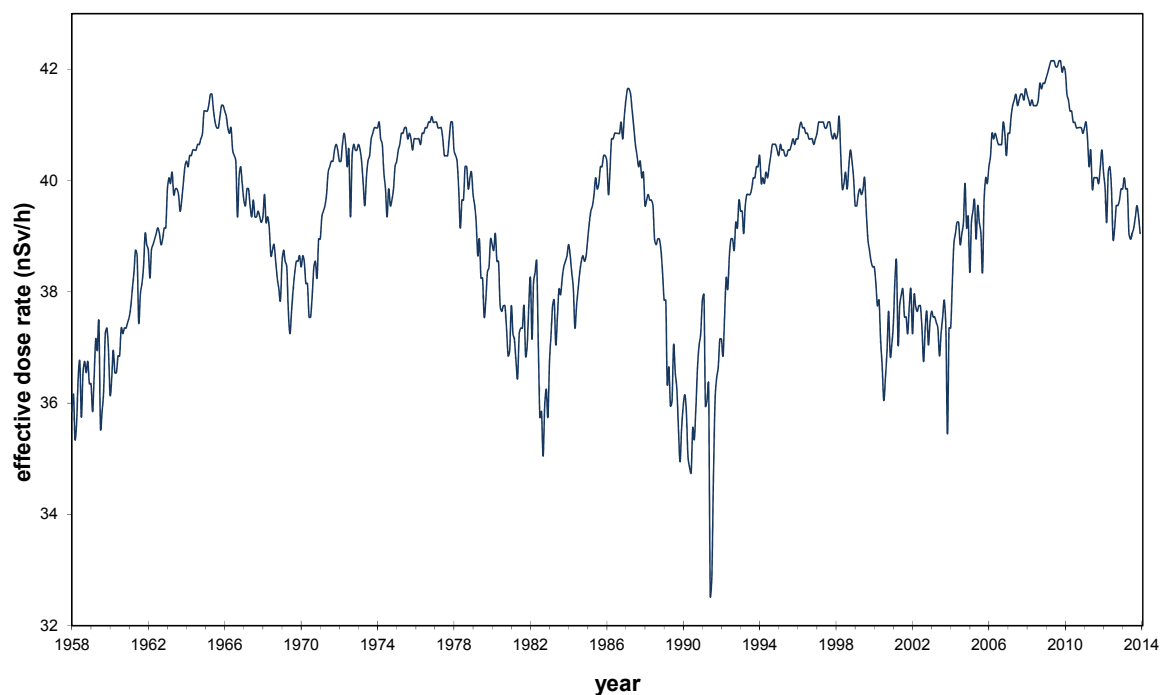
Figure 4.5: Cosmogenic contribution to the effective dose rate (at sea level), influenced by the solar cycle: location 51°26' north and 3°43' east (in the south-west of the Netherlands), air pressure 1019 hPa
Figure derived from data supplied by the Federal Aviation Administration [41].

5 Surface water and seawater

5.1 Introduction

Rijkswaterstaat (RWS) regularly monitors the concentration of a number of radioactive nuclides in surface water and seawater. Only part of the RWS's monitoring programme is presented here. A more detailed description of the monitoring programme, its underlying strategy and the results of radioactivity measurements in Dutch waters are reported elsewhere [42, 43, 44, 45].

The general monitoring strategy for surface water is to monitor the inland and border-crossing waters of the Netherlands. Therefore, the locations mentioned in Table 5.1 are used for monitoring as they represent the major inland, incoming and outgoing waters of the Netherlands. The locations for seawater presented in this report have been chosen to represent the major areas of seawater.
The monitoring programme for determining radioactive nuclides in surface water and seawater is shown in Tables 5.1 and 5.2 and Figure 5.1. Radioactive nuclides were measured in water and in suspended solids. The samples were collected at equidistant times.

Since 2010, measurements in sediment have been added to the RWS monitoring programme, but the results are not presented in this report. These results are presented elsewhere [45].

The radioactive nuclides were measured according to standard procedures [46, 47].

Table 5.1: Monitoring programme for the determination of radioactive nuclides in surface water

Location	Parameter	Matrix	Monitoring frequency (per year)
IJsselmeer (Vrouwezand)	Gross α	Water	14
	Residual β	Water	14
	^{3}H	Water	7
	^{60}Co	Suspended solids	14
	^{131}I	Suspended solids	14
	^{137}Cs	Suspended solids	14
Noordzeekanaal (IJmuiden)	Gross α	Water	13
	Residual β	Water	13
	^{3}H	Water	13
	^{60}Co	Suspended solids	6
	^{131}I	Suspended solids	6
	^{137}Cs	Suspended solids	6
Nieuwe Waterweg (Maassluis)	Gross α	Water	13
	Residual β	Water	13
	^{3}H	Water	7
	^{90}Sr	Water	7
	^{226}Ra	Water	7
	^{60}Co	Suspended solids	13
	^{131}I	Suspended solids	13
	^{137}Cs	Suspended solids	13
	^{210}Pb	Suspended solids	7
Rhine (Lobith)	Gross α	Water	13
	Residual β	Water	13
	^{3}H	Water	13
	^{90}Sr	Water	6
	^{226}Ra	Water	6
	^{60}Co	Suspended solids	26
	^{131}I	Suspended solids	26
	^{137}Cs	Suspended solids	26
	^{210}Pb	Suspended solids	6
Scheldt (Schaar van Ouden Doel)	Gross α	Water	13
	Residual β	Water	13
	^{3}H	Water	7
	^{226}Ra	Water	7
	^{60}Co	Suspended solids	13
	^{131}I	Suspended solids	13
	^{137}Cs	Suspended solids	13
	^{210}Pb	Suspended solids	7
Meuse (Eijsden)	Gross α	Water	13
	Residual β	Water	13
	^{3}H	Water	13
	^{90}Sr	Water	6
	^{226}Ra	Water	6
	^{60}Co	Suspended solids	53
	^{131}I	Suspended solids	53
	^{137}Cs	Suspended solids	53
	^{210}Pb	Suspended solids	6

Table 5.2: Monitoring programme for the determination of radioactive nuclides in seawater

Area	Location	Parameter	Matrix	Monitoring frequency (per year)
Coastal Area (KZ)	Noordwijk 2 [1]	Gross α	Water	4
		Residual β	Water	4
		^{3}H	Water	4
		^{137}Cs	Suspended solids	3
		^{210}Pb	Suspended solids	3
Southern North Sea (ZN)	Noordwijk 70 [1]	Gross α	Water	4
		Residual β	Water	4
		^{3}H	Water	4
		^{90}Sr	Water	4
Central North Sea (CN)	Terschelling 235 [1]	Gross α	Water	4
		Residual β	Water	4
		^{3}H	Water	4
		^{90}Sr	Water	4
Delta Coastal Waters (VD)	Schouwen 10 [1]	Gross α	Water	12
		Residual β	Water	12
		^{3}H	Water	12
		^{90}Sr	Water	4
Westerscheldt (WS)	Vlissingen Boei	Gross α	Water	14
		Residual β	Water	14
		^{3}H	Water	14
		^{90}Sr	Water	14
		^{137}Cs	Suspended solids	4
		^{210}Pb	Suspended solids	4
Eems-Dollard (ED)	Huibergat Oost	Gross α	Water	4
		Residual β	Water	4
		^{3}H	Water	4
	Bocht van Watum	^{137}Cs	Suspended solids	4
		^{210}Pb	Suspended solids	4
Wadden Sea West (WW)	Marsdiep Noord	Gross α	Water	4
		Residual β	Water	4
		^{3}H	Water	4
	Doove Balg West	^{137}Cs	Suspended solids	4
		^{210}Pb	Suspended solids	4
Wadden Sea East (WO)	Dantziggat	Gross α	Water	4
		Residual β	Water	4
		^{3}H	Water	4

[1] Number indicates distance from shore. For example, 'Noordwijk 2' means Noordwijk 2 km offshore.

Legend:

Seawater areas:
CN = Central North Sea
ED = Eems-Dollard
WO = Wadden Sea East
WW = Wadden Sea West
ZN = Southern North Sea
KZ = Coastal Area
VD = Delta Coastal Waters
WS = Westerscheldt

Surface water areas:
IJM = IJsselmeer
KM = Ketelmeer
NK = Noordzeekanaal
NW = Nieuwe waterweg
R = Rhine
M = Meuse
S = Scheldt

1 = Terschelling 235
2 = Terschelling 135
3 = Terschelling 100
4 = Huibergat Oost
5 = Bocht van Watum
6 = Dantziggat
7 = Doove Balg West
8 = Marsdiep Noord
9 = Vrouwezand
10 = Ketelmeer West
11 = IJmuiden
12 = Noordwijk 2
13 = Noordwijk 10
14 = Noordwijk 70
15 = Maassluis
16 = Schouwen 10
17 = Vlissingen Boei
18 = Schaar van Ouden Doel
19 = Lobith
20 = Eijsden

Figure 5.1: Overview of monitoring locations for the monitoring programme for surface water and seawater
Terschelling 135 km offshore and Terschelling 100 km offshore were the monitoring locations for the Central North Sea in 1989 and 1988–1994 (except 1989), respectively. Terschelling 235 km offshore has been the monitoring location for the Central North Sea since 1995. Noordwijk 10 km offshore was the monitoring location for the Coastal Area in the period 1988–1998. Noordwijk 2 km offshore has been the monitoring location for the Coastal Area since 1999 [42]. Ketelmeer West was a monitoring location until 2009.

5.2 The results for surface water

The results of measurements of radioactivity in surface water are presented in Tables A11 and A12 and in Figures 5.2 to 5.19.

Gross α and residual β are indicative parameters. The yearly averaged activity concentrations of gross α and residual β in 2013 were within the range of those in previous years.

Residual β in the Noordzeekanaal, Nieuwe Waterweg and Scheldt has shown a change in trend since 1994, which was caused by a change in measuring technique that applies only to salt and brackish water [42]. Therefore, this change in trend was not seen for residual β in the IJsselmeer, Rhine or Meuse.

Elevated levels of ^{3}H in the Rhine could have originated from several nuclear power plants or research reactors in Germany, France or Switzerland. Elevated levels of ^{3}H in the Meuse could have originated from the nuclear power plants at Tihange (Belgium) or Chooz (France). Elevated levels of ^{3}H in the Scheldt could have originated from the nuclear power plant at Doel (Belgium). The yearly averaged ^{3}H activity concentrations in 2013 were within the range of those in previous years.

The nuclide ^{90}Sr is released into the environment by nuclear power plants and nuclear reprocessing plants. The yearly averaged ^{90}Sr activity concentrations in 2013 were within the range of those in previous years.

The nuclide ^{226}Ra is released into the environment by the ore-processing industry. The yearly averaged ^{226}Ra activity concentrations in 2013 were within the range of those in previous years.
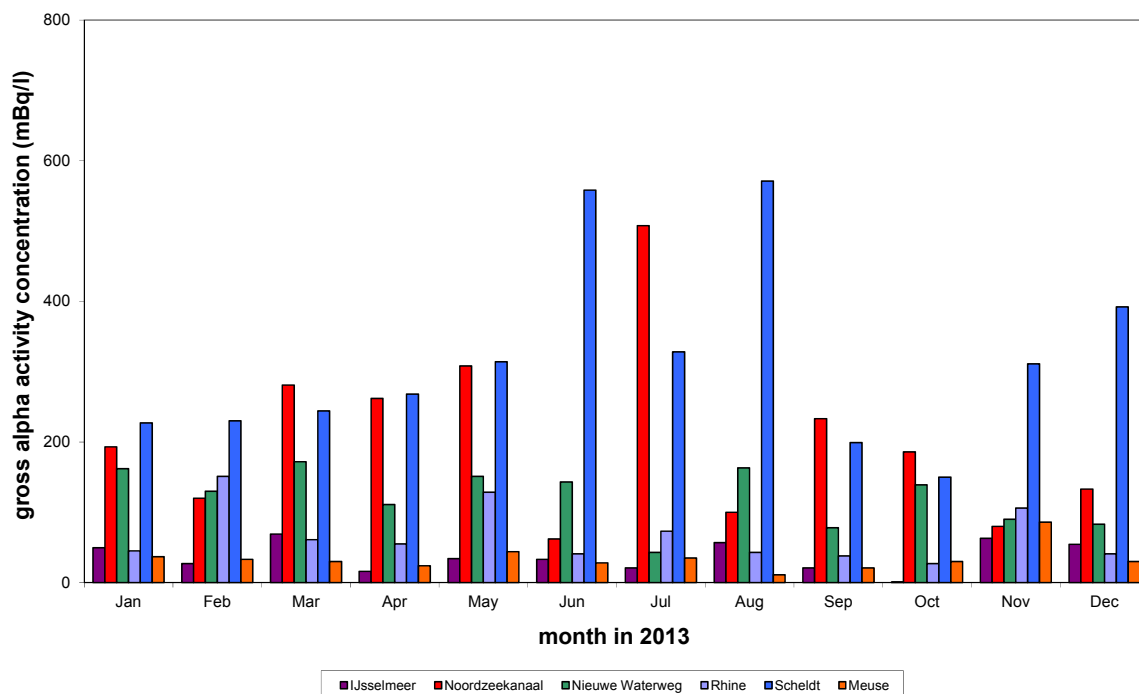
Figure 5.2: Gross a activity concentrations for the IJsselmeer, Noordzeekanaal, Nieuwe Waterweg, Rhine, Scheldt and Meuse, with yearly averages of 39, 230, 125, 72, 310 and 35 mBq·L⁻¹, respectively

Averaged values are shown in the case of multiple measurements per month.

Figure 5.3: Yearly averaged gross a activity concentrations

Figure 5.4: Residual β activity concentrations for the IJsselmeer, Noordzeekanaal, Nieuwe Waterweg, Rhine, Scheldt and Meuse, with yearly averages of 33, 27, 49, 50, 120 and 25 mBq·L⁻¹, respectively
Averaged values are shown in the case of multiple measurements per month.

Figure 5.5: Yearly averaged residual β activity concentrations

Figure 5.6: *³H activity concentrations for the IJsselmeer, Noordzeekanaal, Nieuwe Waterweg, Rhine, Scheldt and Meuse, with yearly averages of 2.6, 2.4, 4.1, 3.3, 6.8 and 16.0 Bq·L⁻¹, respectively*
Averaged values are shown in the case of multiple measurements per month.
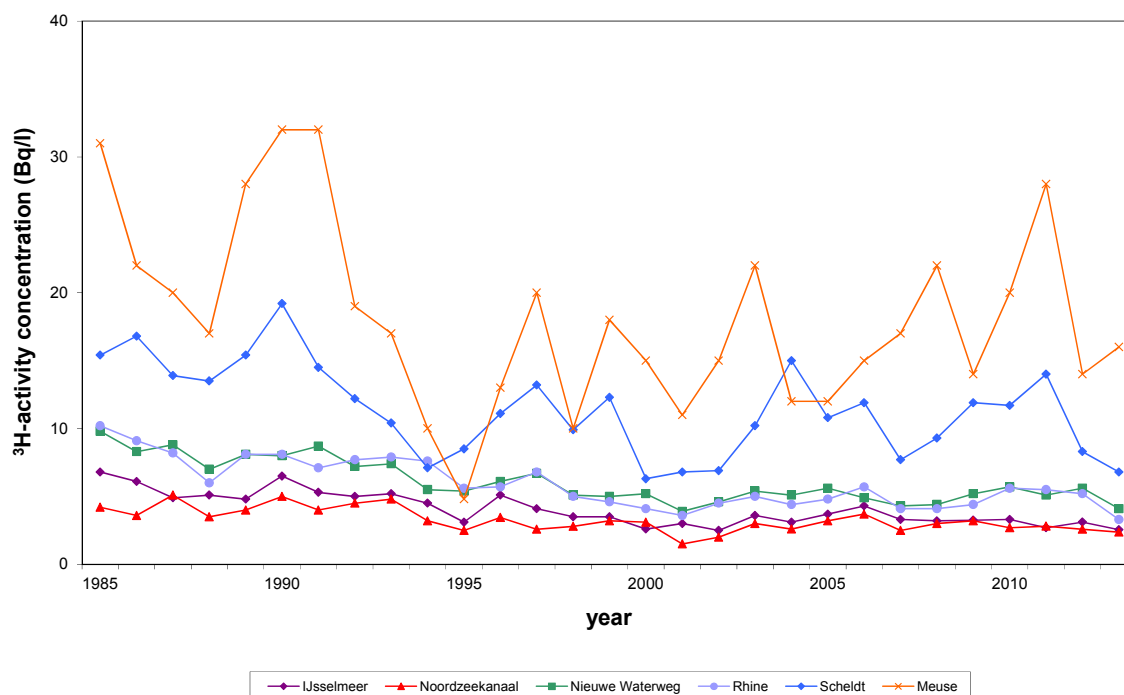
Figure 5.7: *Yearly averaged ³H activity concentrations*

Figure 5.8: *^{90}Sr activity concentrations for the Nieuwe Waterweg, Rhine and Meuse, with yearly averages of 1.4, 2.9 and 2.5 mBq·L^{-1}, respectively*
Averaged values are shown in the case of multiple measurements per month.
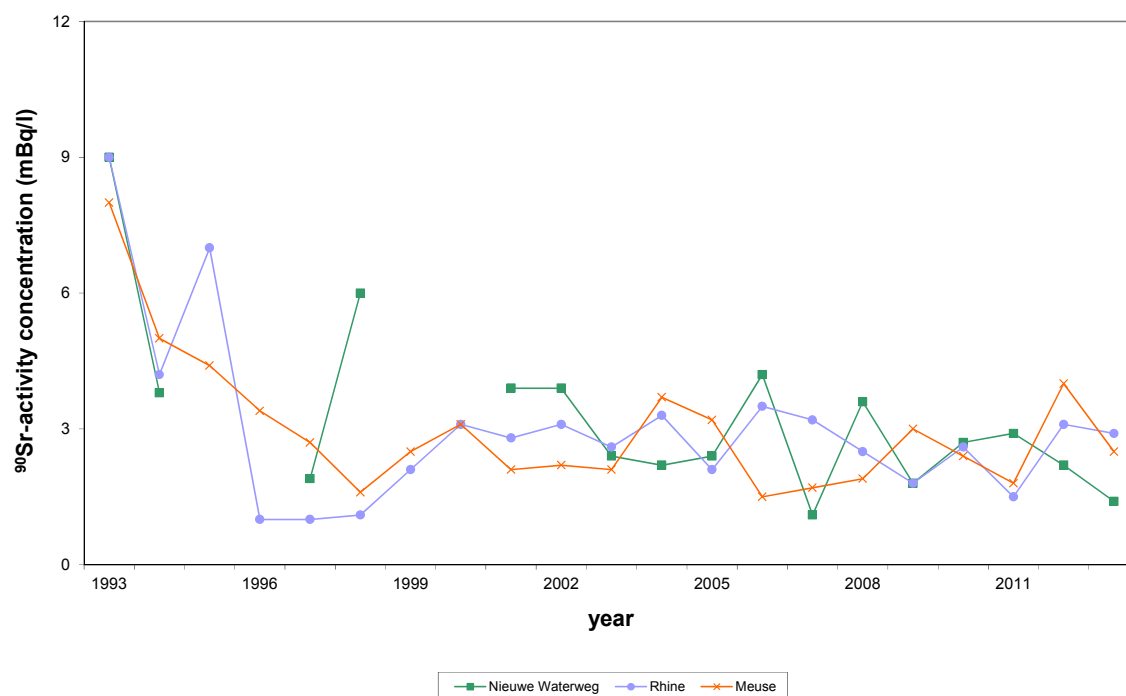
Figure 5.9: *Yearly averaged ^{90}Sr activity concentrations*
Data are not available for the Nieuwe Waterweg in 1995, 1996, 1999 and 2000.
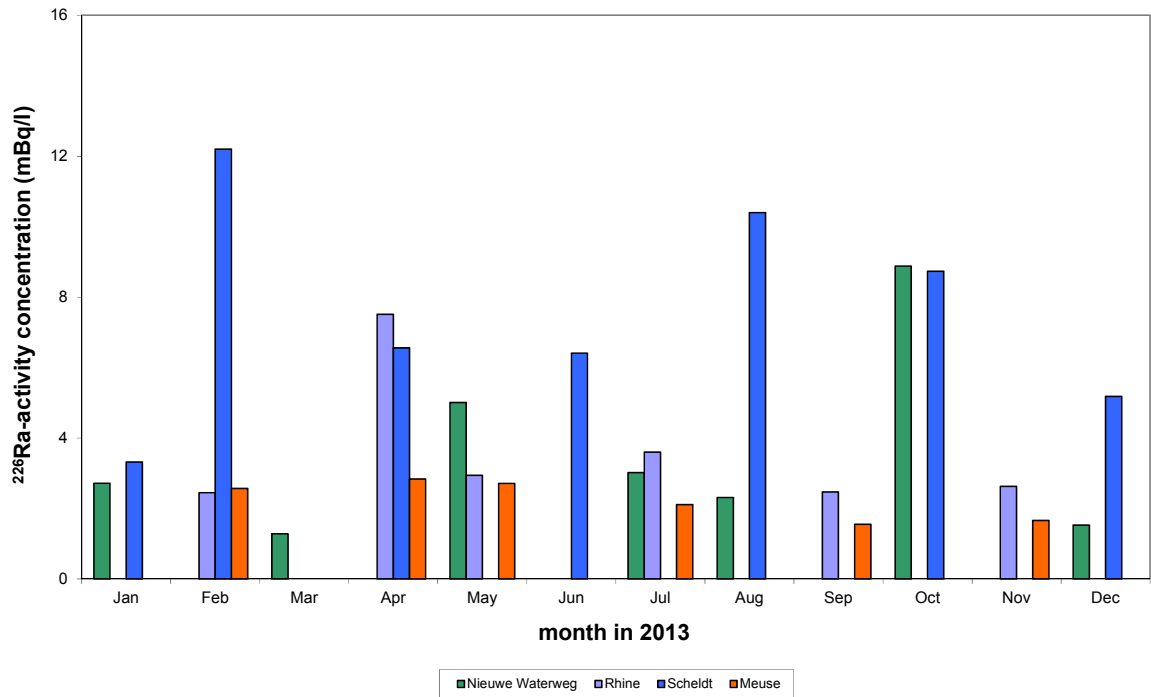
Figure 5.10: *226Ra activity concentrations for the Nieuwe Waterweg, Rhine, Scheldt and Meuse, with yearly averages of 3.5, 3.6, 7.5 and 2.2 mBq·L⁻¹, respectively*

Averaged values are shown in the case of multiple measurements per month.
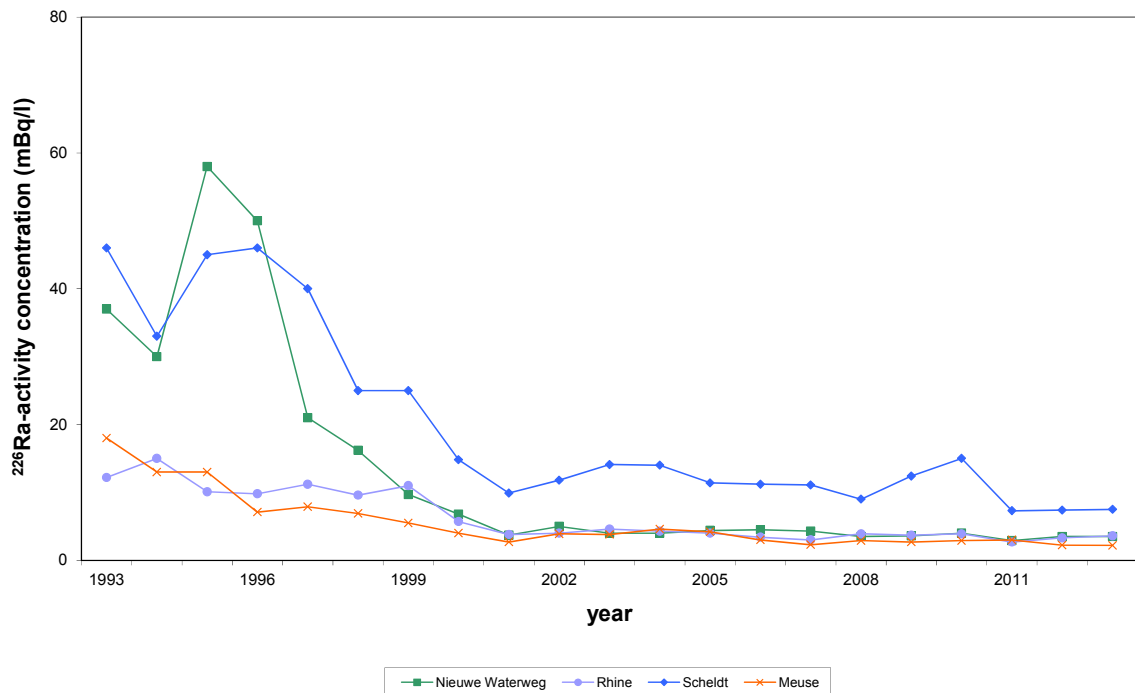
Figure 5.11: *Yearly averaged 226Ra activity concentrations*

Nuclear power plants discharge, among others the nuclides, ^{60}Co and ^{137}Cs. In 2013, the yearly averaged ^{60}Co and ^{137}Cs activity concentrations in suspended solids were within the range of those in previous years.

The nuclide ^{131}I is released into the environment by medical facilities. In 2013, the yearly averaged ^{131}I activity concentrations in suspended solids were within the range of those in previous years.

Since ^{210}Po is regularly in equilibrium with ^{210}Pb in suspended solids, RWS reports only ^{210}Pb. The nuclides ^{210}Po and ^{210}Pb originate from the uranium decay chain and are released by the ore-processing industry [42]. In 2013, the yearly averaged ^{210}Pb activity concentrations in suspended solids were within the range of those in previous years.
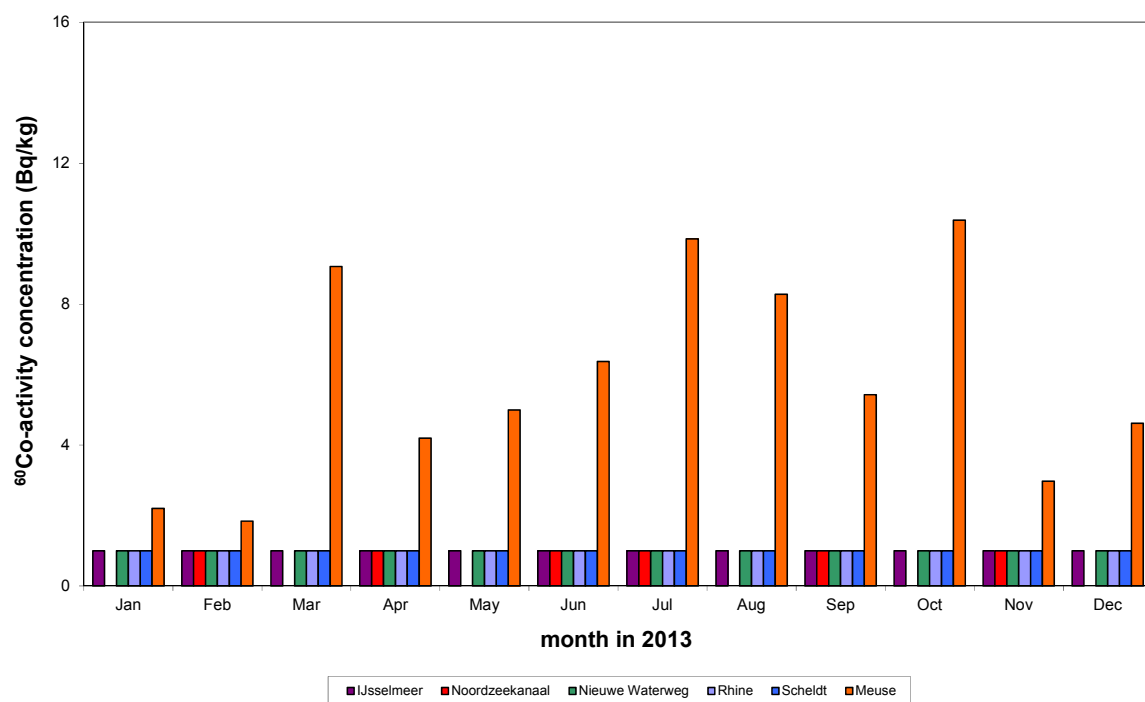
Figure 5.12: *60Co activity concentrations in suspended solids for the IJsselmeer, Noordzeekanaal, Nieuwe Waterweg, Rhine, Scheldt and Meuse, the yearly averages of all except for the Meuse (5.7 Bq·kg^-1) being < 1 Bq·kg^-1*
Averaged values are shown in the case of multiple measurements per month.
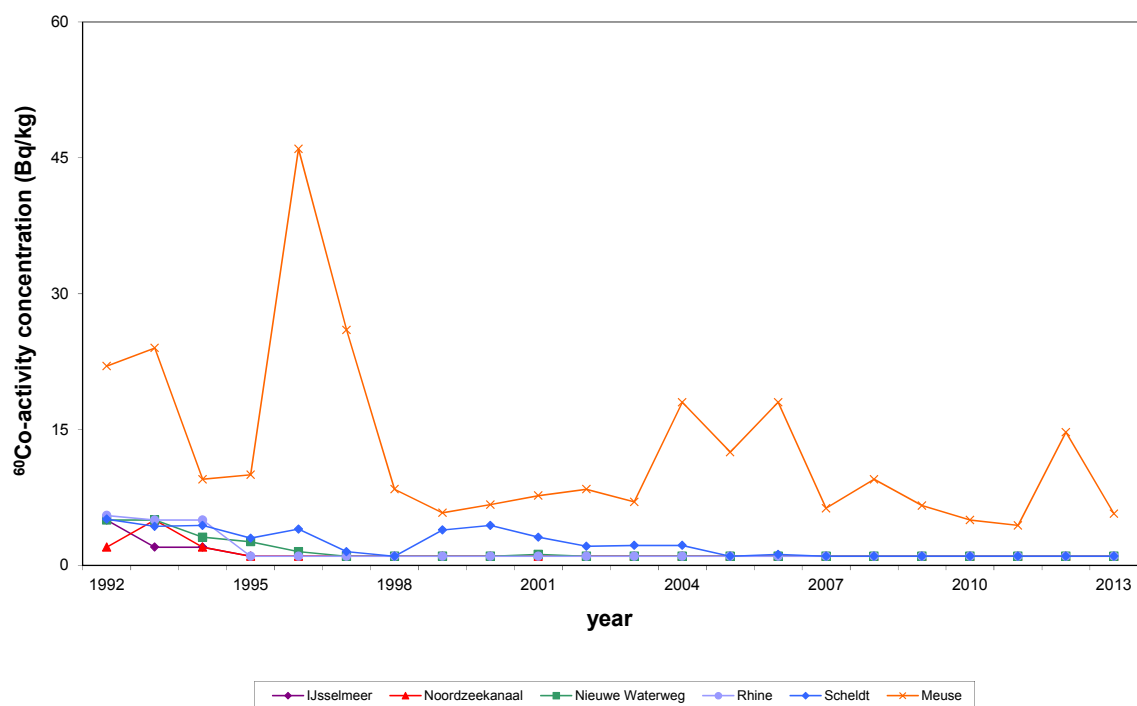
Figure 5.13: *Yearly averaged 60Co activity concentrations in suspended solids*
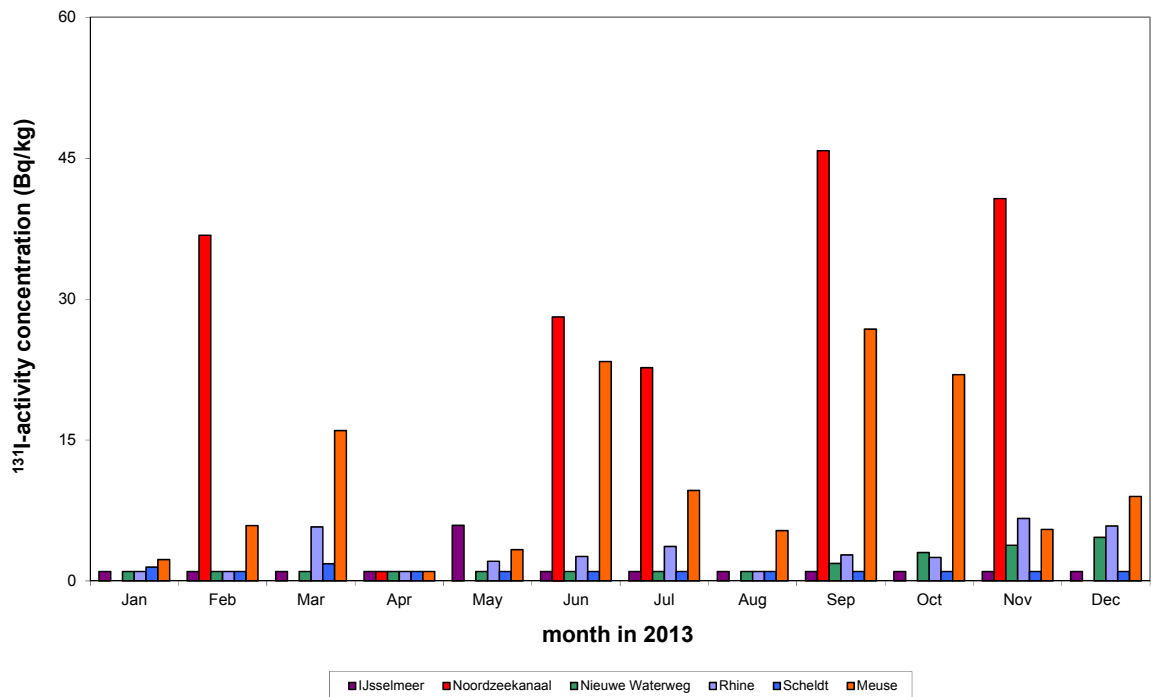
Figure 5.14: ^{131}I activity concentrations in suspended solids for the IJsselmeer, Noordzeekanaal, Nieuwe Waterweg, Rhine, Scheldt and Meuse, with yearly averages of < 1, 29, < 1.4, < 2.6, < 1 and 10.6 Bq·kg^{-1}, respectively
Averaged values are shown in the case of multiple measurements per month.
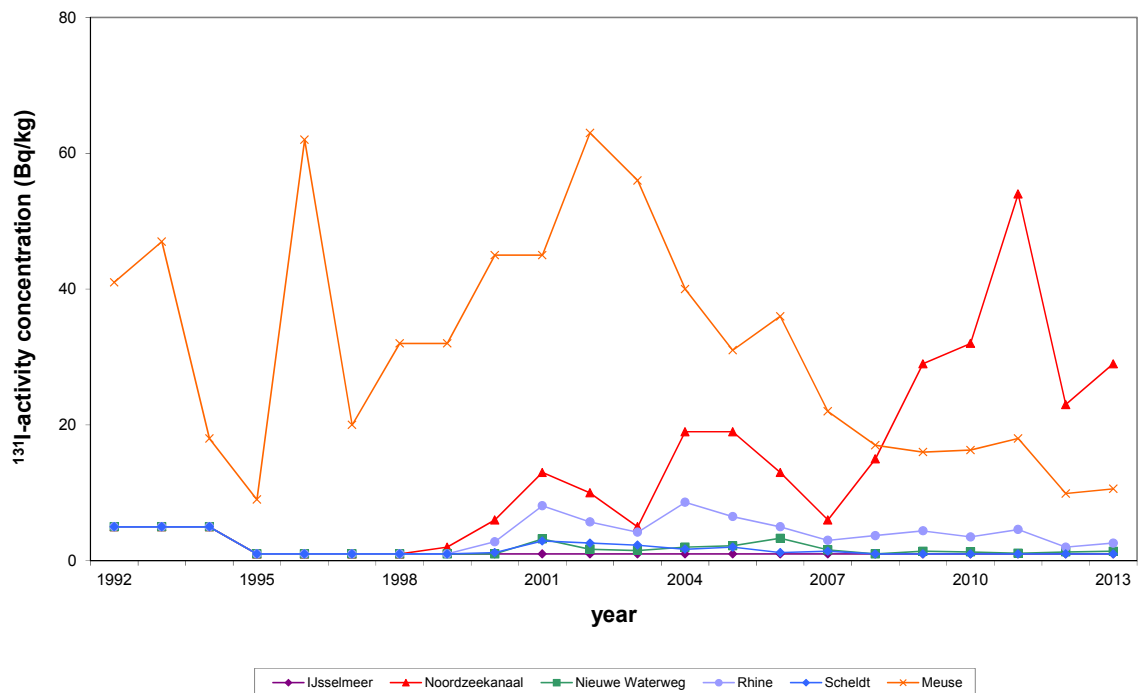
Figure 5.15: Yearly averaged ^{131}I activity concentrations in suspended solids
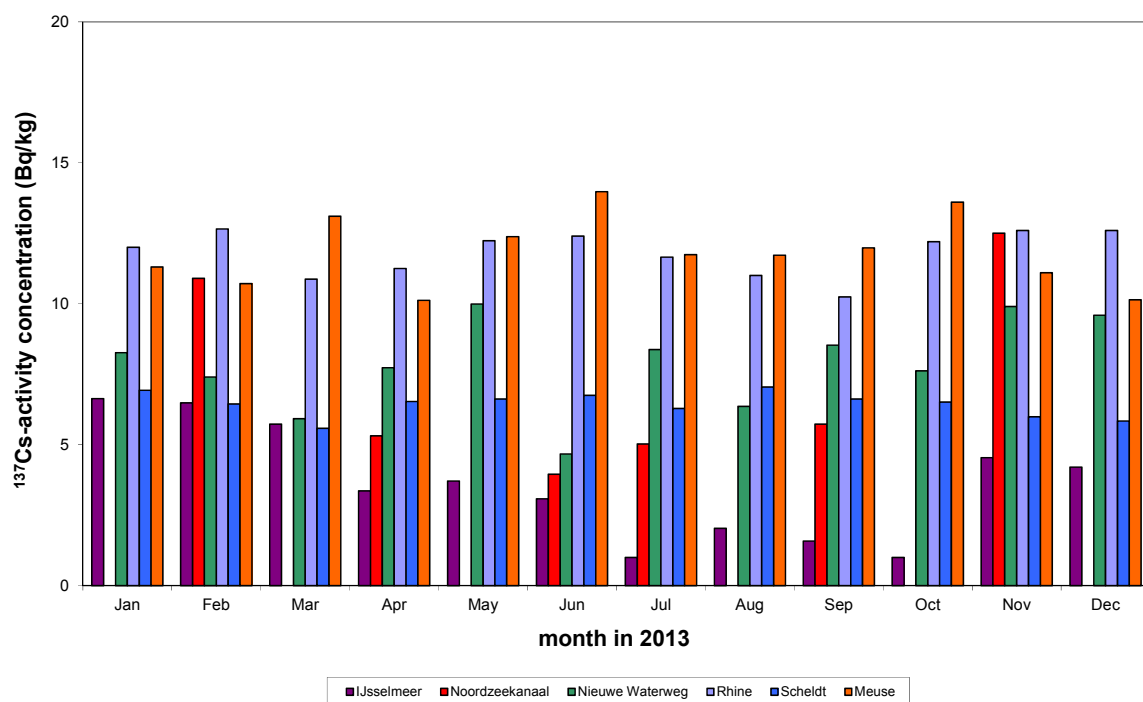
Figure 5.16: *^{137}Cs activity concentrations in suspended solids for the IJsselmeer, Noordzeekanaal, Nieuwe Waterweg, Rhine, Scheldt and Meuse, with yearly averages of 3.8, 7.2, 7.7, 11.8, 6.5 and 11.8 Bq·kg^{-1}, respectively*
Averaged values are shown in the case of multiple measurements per month.
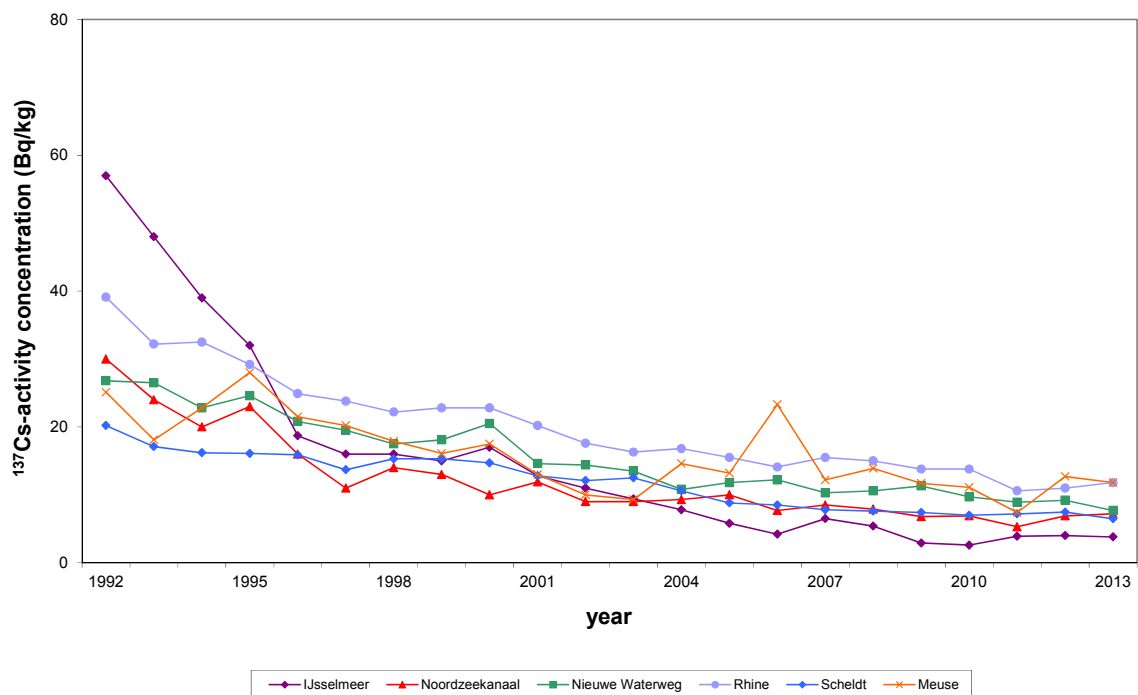
Figure 5.17: *Yearly averaged ^{137}Cs activity concentrations in suspended solids*
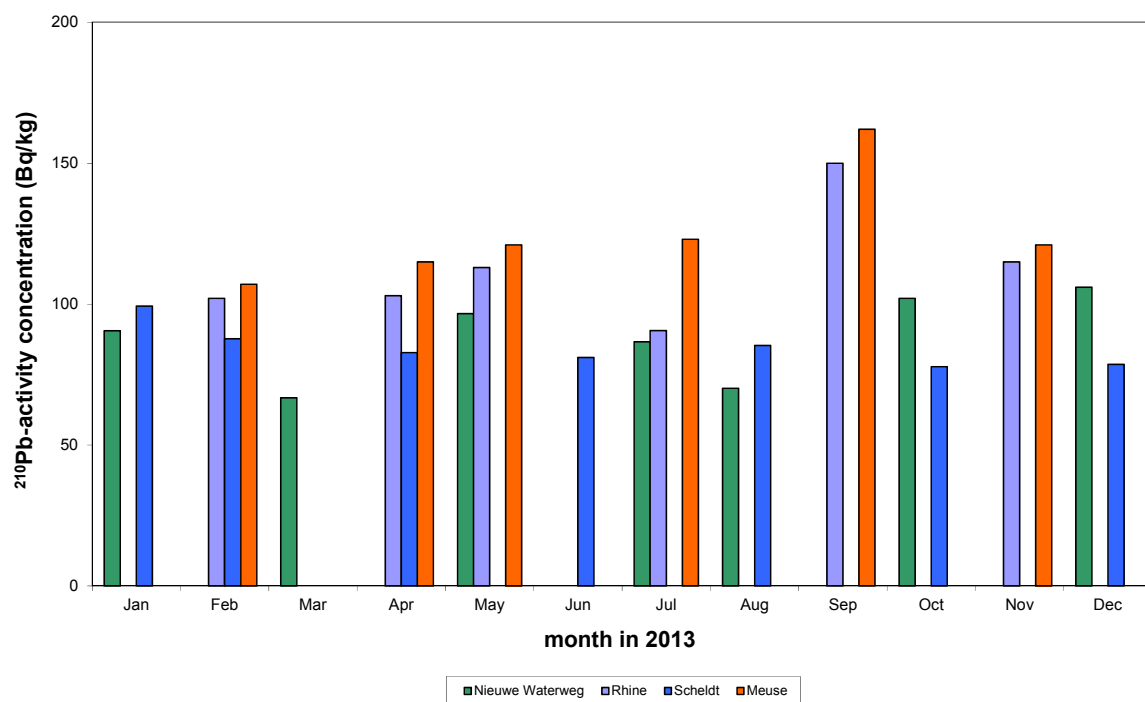
Figure 5.18: ^{210}Pb activity concentrations in suspended solids for the Nieuwe Waterweg, Rhine, Scheldt and Meuse, with yearly averages of 88, 112, 85 and 125 Bq·kg^{-1}, respectively
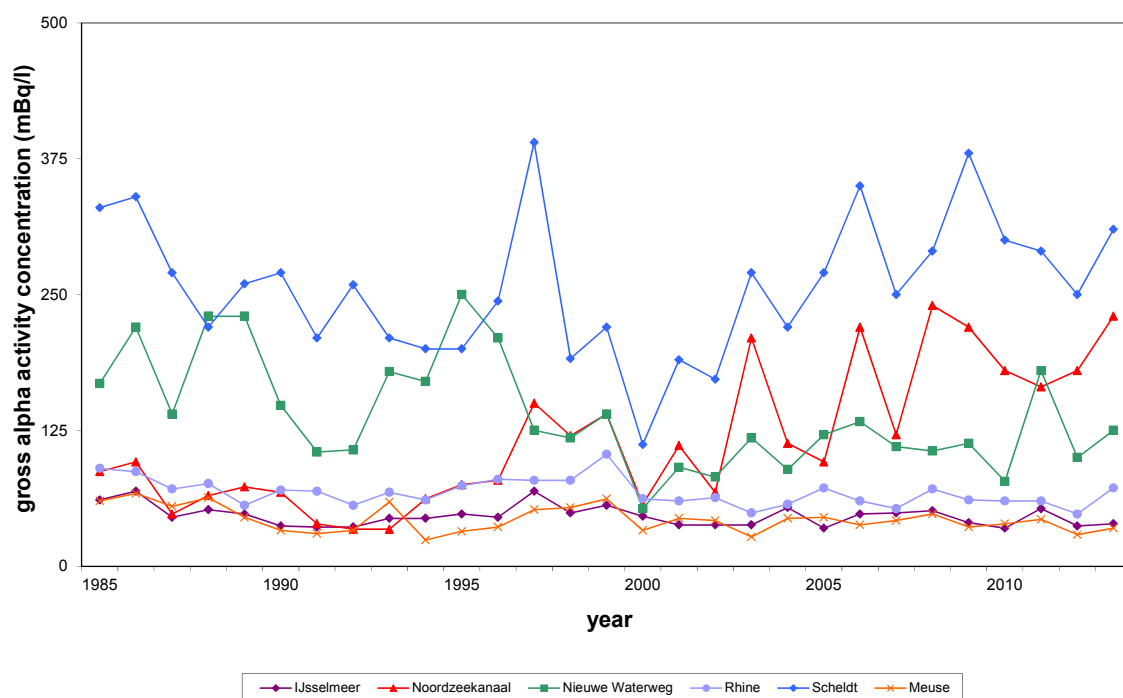Averaged values are shown in the case of multiple measurements per month.

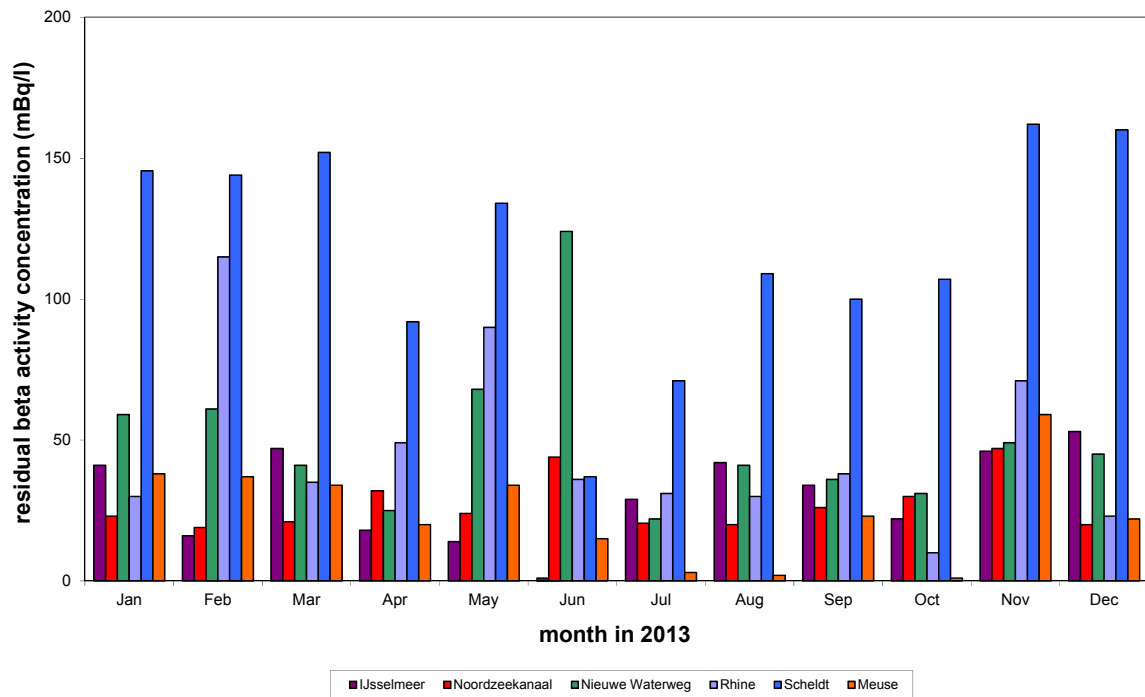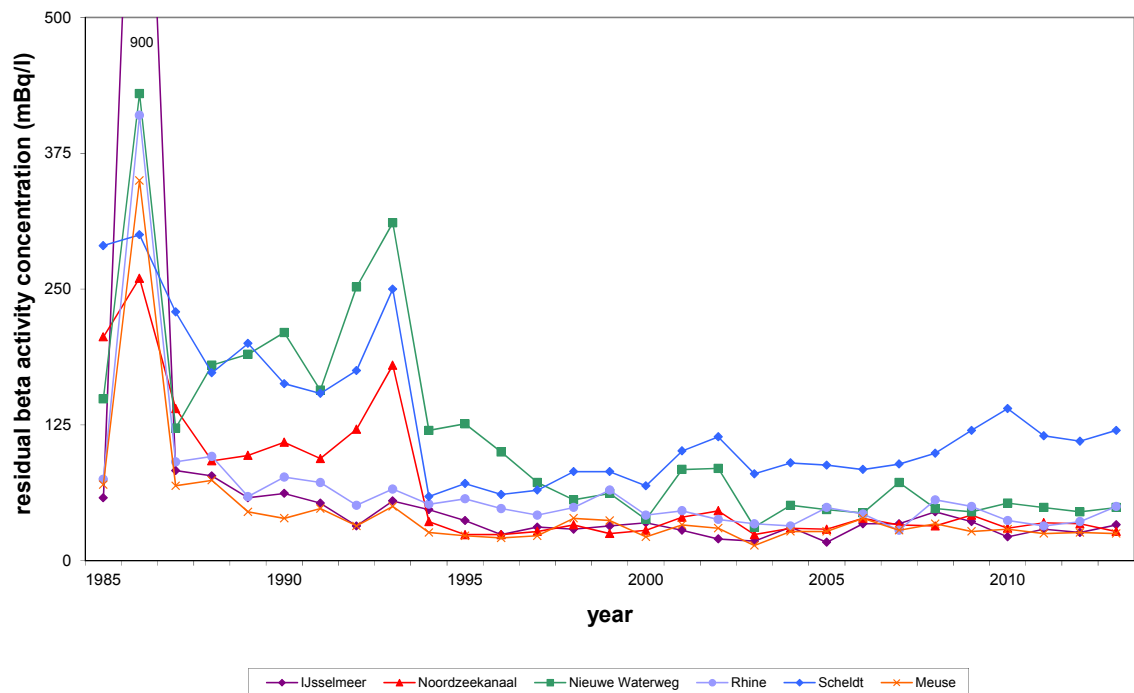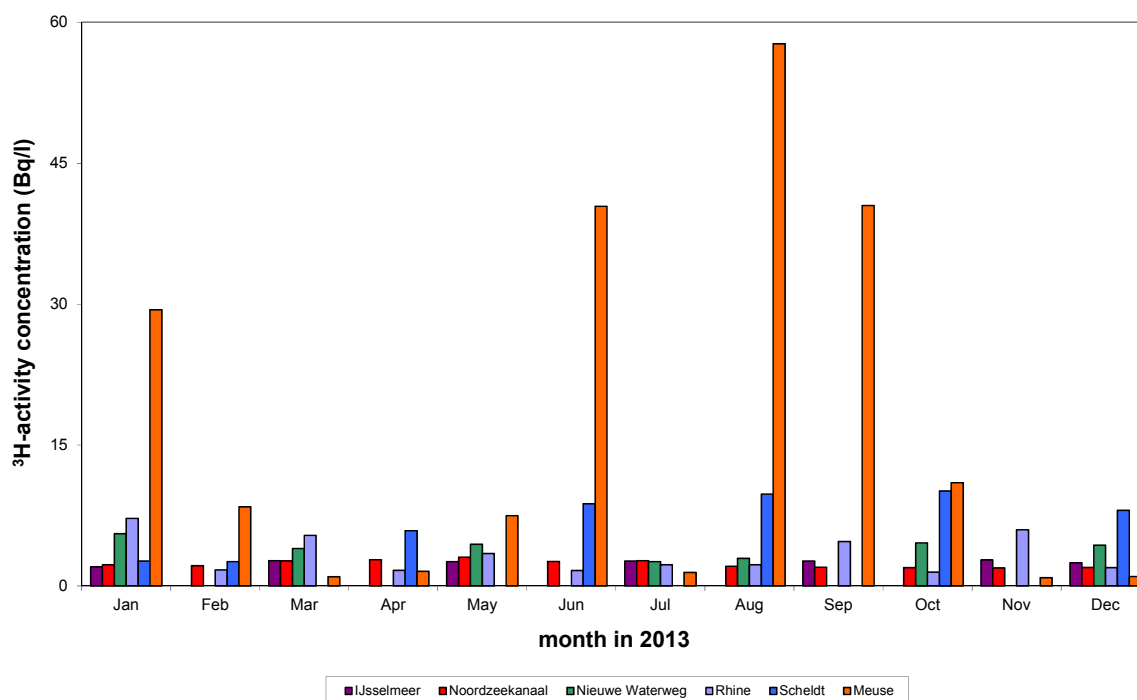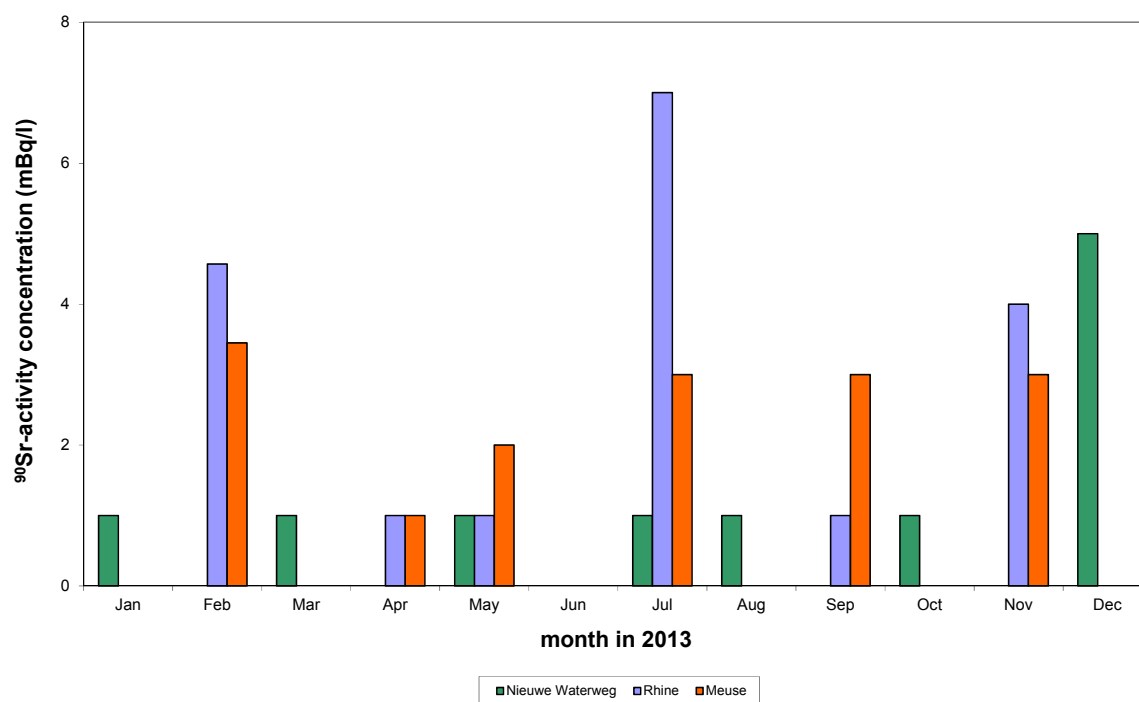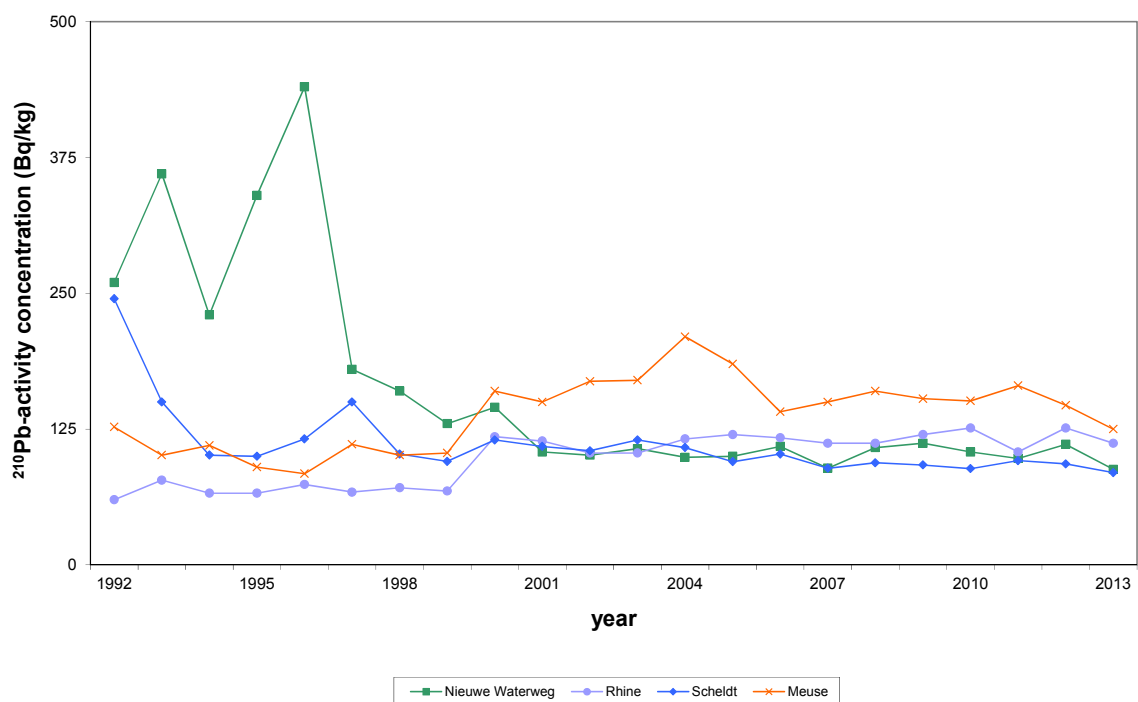Figure 5.19: Yearly averaged ^{210}Pb activity concentrations in suspended solids

5.3   The results for seawater

The results of measurements of radioactivity in seawater are presented in Tables A13 and A14 and in Figures 5.20 to 5.31.

Gross α and residual β are indicative parameters [42]. In the first half of 2000, the background of the measuring equipment was unstable and higher than usual, which resulted in lower results. Therefore, yearly averaged concentrations of gross α in 2000 were based on data starting from the end of July 2000. Changes in the trend of gross α in the period from 1985 to 1997 are explained elsewhere [42]. The yearly averaged gross α activity concentrations in 2013 were within the range of those in previous years (Figure 5.21).

Residual β shows an apparent change in trend since 1994 (Figure 5.23). This was caused by a change in measuring technique that applies only to salt and brackish water [42]. The yearly averaged residual β activity concentrations in 2013 were within the range of those in previous years (Figure 5.23).

Nuclear power plants discharge, among others the nuclides, ^{3}H and ^{137}Cs. Nuclear fuel reprocessing plants discharge, among others the nuclides, ^{3}H and ^{90}Sr. Discharges from the nuclear power plants at Doel (Belgium) and Borssele (Netherlands) are monitored in the Westerscheldt (WS) area. The impact of reprocessing plants at Sellafield (England) and Le Havre (France) is monitored in the Central North Sea (CN) and Southern North Sea (ZN) areas, respectively [42]. The impact of both sources (nuclear power and reprocessing plants) is monitored indirectly in the Delta Coastal Waters (VD) area.

The yearly averaged ^{3}H concentrations in 2013 were within the range of those in previous years (Figure 5.25). The yearly averaged ^{90}Sr concentrations in 2013 were within the range of those in previous years (Figure 5.27).
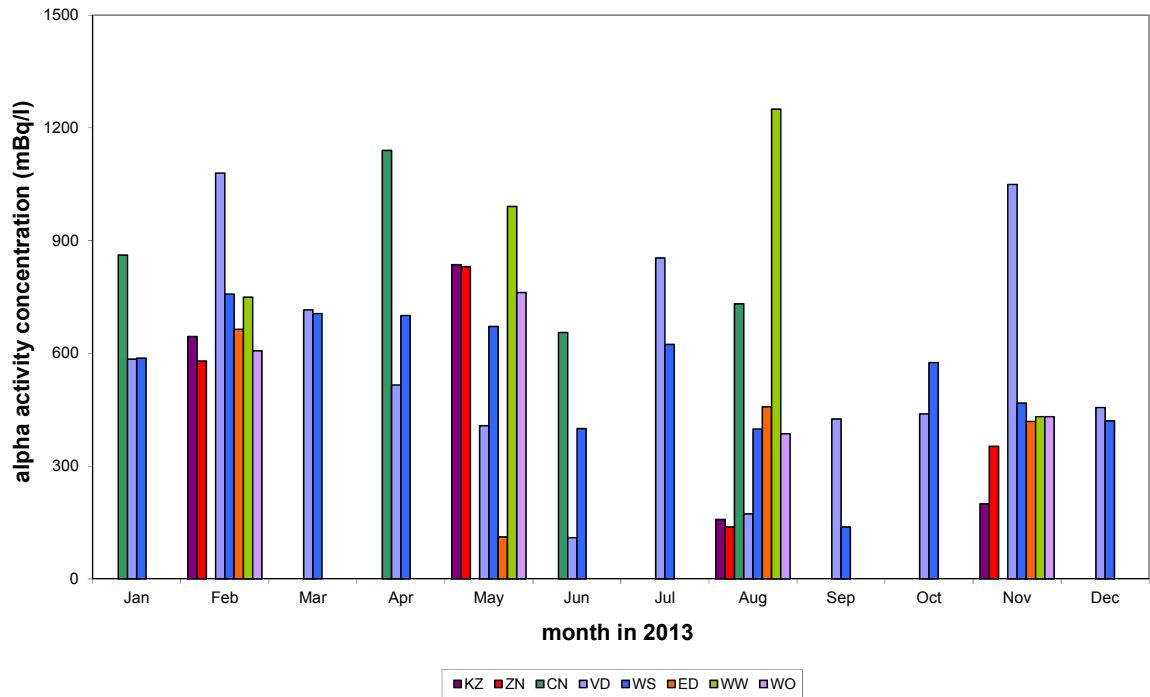
Figure 5.20: Gross a activity concentrations in seawater for the Coastal Area (KZ), Southern North Sea (ZN), Central North Sea (CN), Delta Coastal Waters (VD), Westerscheldt (WS), Eems-Dollard (ED), Wadden Sea West (WW) and Wadden Sea East (WO), with yearly averages of 460, 480, 850, 570, 530, 410, 860 and 550 mBq·L⁻¹, respectively
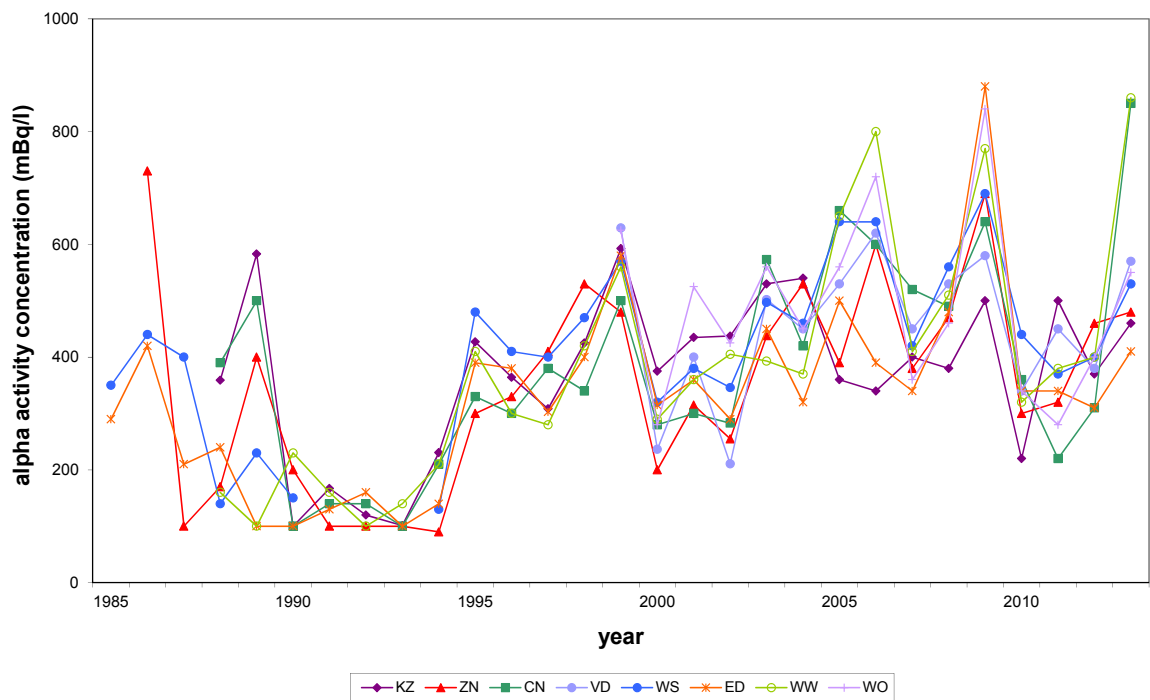
Figure 5.21: Yearly averaged gross a activity concentrations
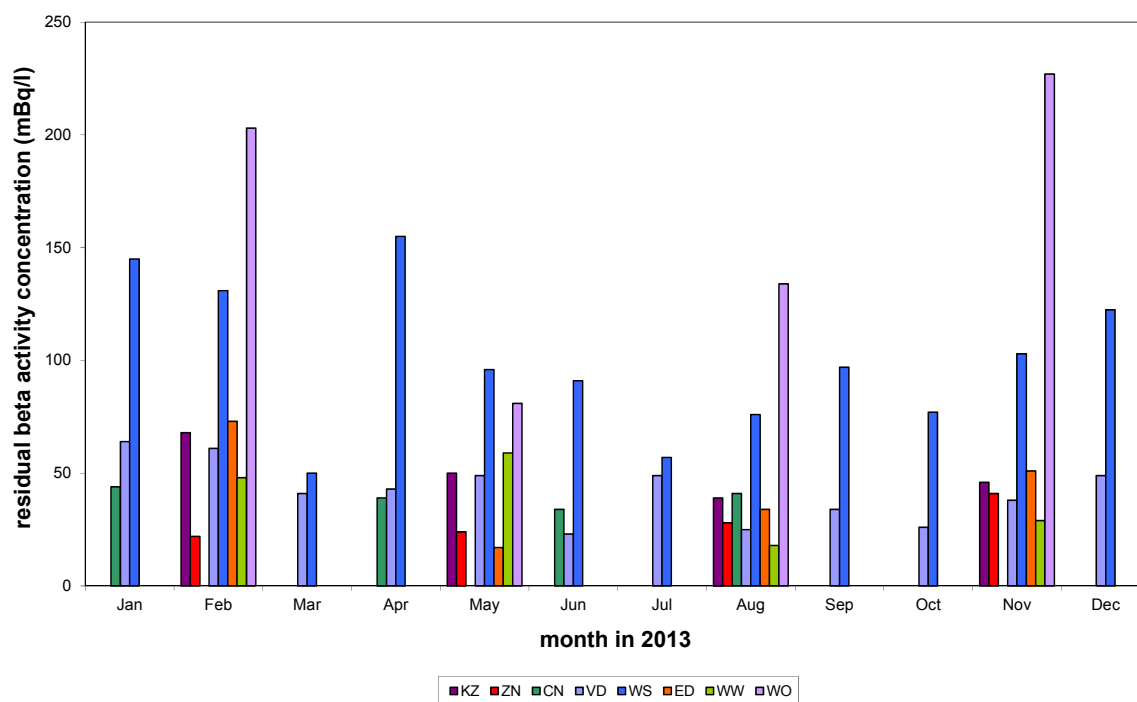
Figure 5.22: Residual β activity concentrations in seawater for the Coastal Area, Southern North Sea, Central North Sea, Delta Coastal Waters, Westerscheldt, Eems-Dollard, Wadden Sea West and Wadden Sea East, with yearly averages of 51, 29, 40, 42, 105, 44, 38 and 160 mBq·L^{-1}, respectively
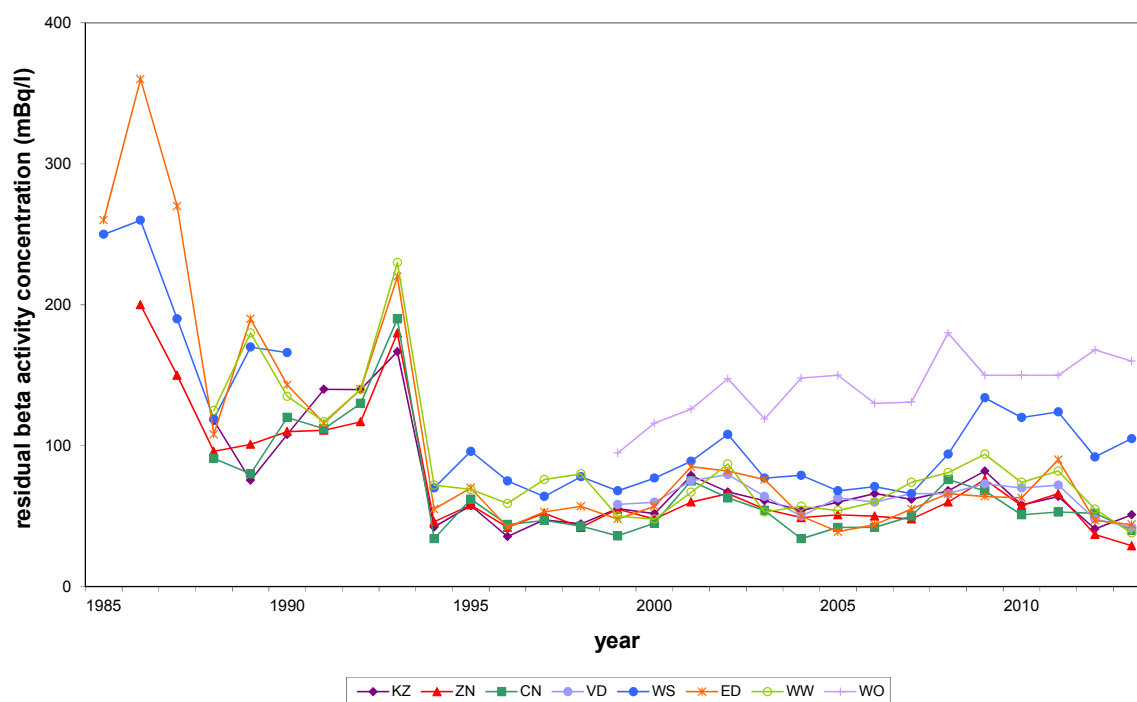
Figure 5.23: Yearly averaged residual β activity concentrations
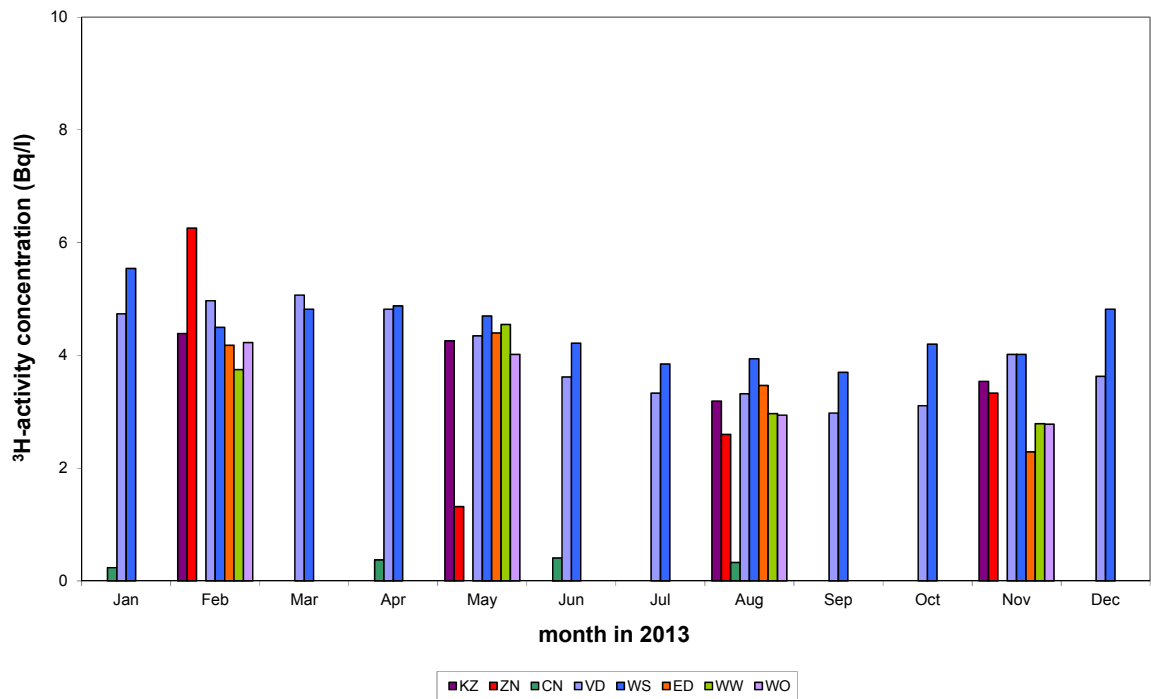
Figure 5.24: ³H activity concentrations in seawater for the Coastal Area, Southern North Sea, Central North Sea, Delta Coastal Waters, Westerscheldt, Eems-Dollard, Wadden Sea West and Wadden Sea East, with yearly averages of 3.8, 3.4, 0.34, 4.0, 4.5, 3.6, 3.5 and 3.5 Bq·L⁻¹, respectively
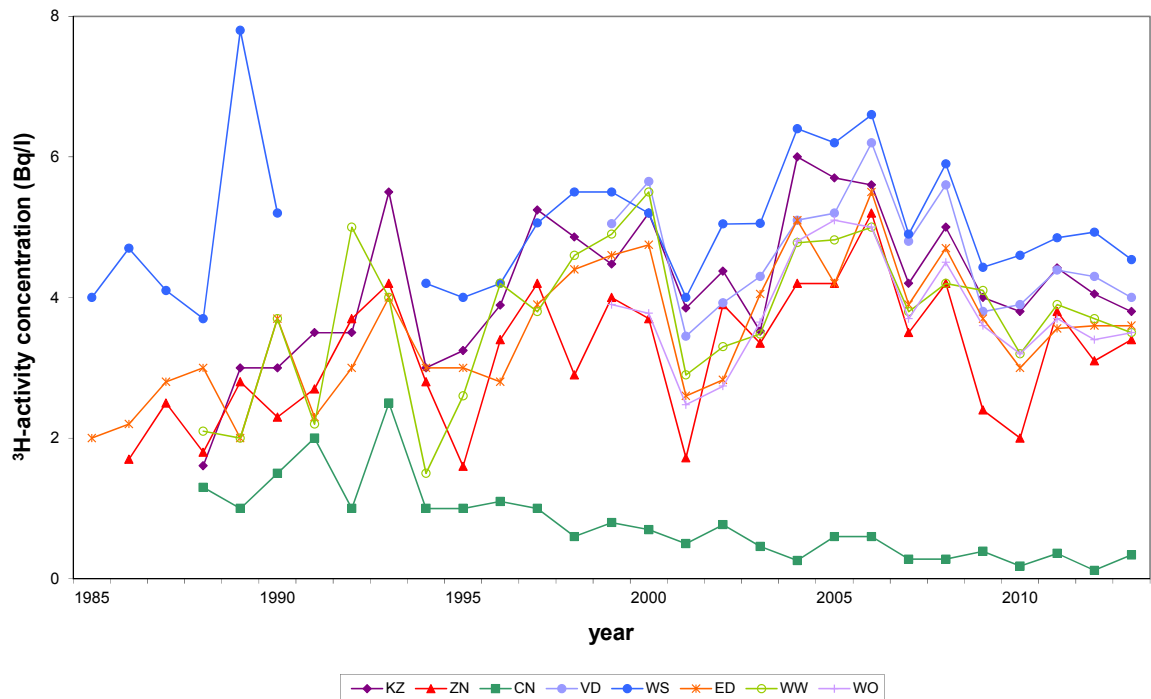
Figure 5.25: Yearly averaged ³H activity concentrations
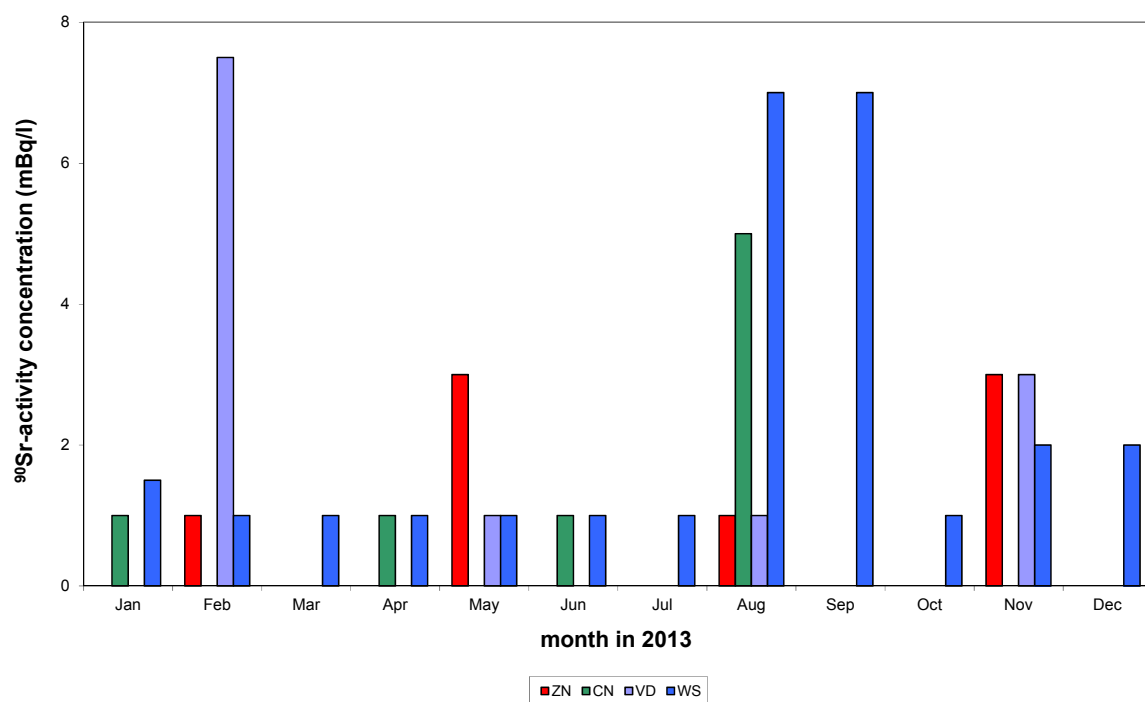
Figure 5.26: ^{90}Sr activity concentrations in seawater for the Southern North Sea, Central North Sea, Delta Coastal Waters and Westerscheldt, with yearly averages of 1.8, 1.8, 3.0 and 1.9 mBq·L^{-1}, respectively
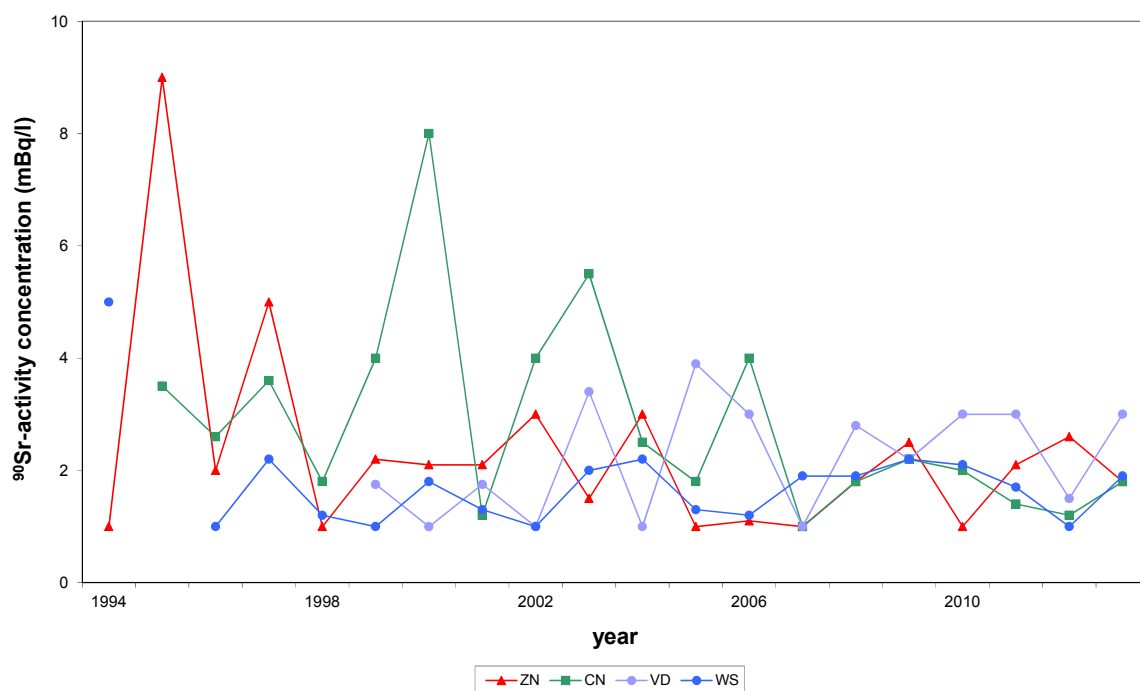
Figure 5.27: Yearly averaged ^{90}Sr activity concentrations

Since ^{210}Po is regularly in equilibrium with ^{210}Pb in suspended solids, RWS reports only ^{210}Pb (as in surface water). In cases where a strong increase in the gross α value is noticed, however, ^{210}Po is determined as well. The nuclides ^{210}Pb and ^{210}Po originate from the uranium decay chain and are released, for example, by the phosphate-processing industry and production platforms for oil and gas [42]. Discharges via the main rivers are monitored in the Coastal Area (KZ). Discharges from the ore- and phosphate-processing industries in Belgium and the Netherlands are monitored in the Westerscheldt (WS) area. Discharges from Delfzijl, Eemshaven and plants in Germany are monitored in the Eems-Dollard (ED) area. The impact of these discharges, together with activity originating from the North Sea, is monitored indirectly in the Wadden Sea (WW and WO) area.

Since 2009, ^{137}Cs and ^{210}Pb have been determined at Wadden Sea West instead of Wadden Sea East. The yearly averaged concentrations of ^{137}Cs in 2013 were within the range of those in previous years (Figure 5.29). The yearly averaged concentrations of ^{210}Pb in 2013 were within the range of those in previous years (Figure 5.31).
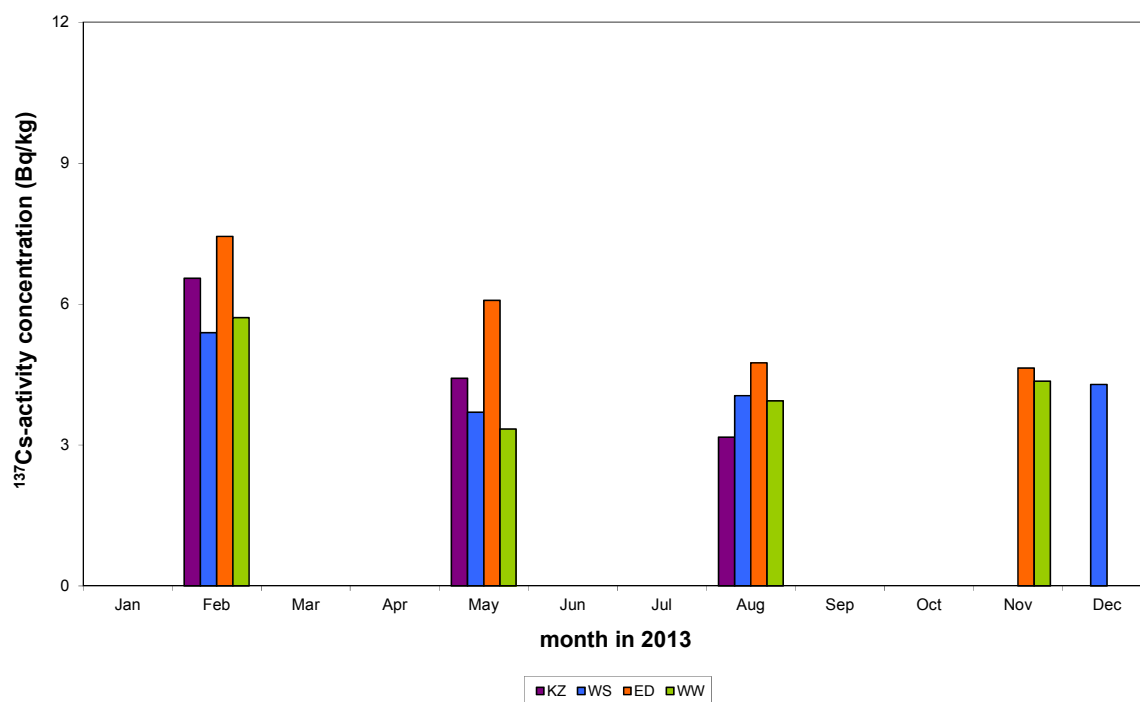
Figure 5.28: ¹³⁷Cs activity concentrations in suspended solids in seawater for the Coastal Area, Westerscheldt, Eems-Dollard and Wadden Sea West, with yearly averages of 4.7, 4.4, 5.7 and 4.3 Bq·kg⁻¹, respectively
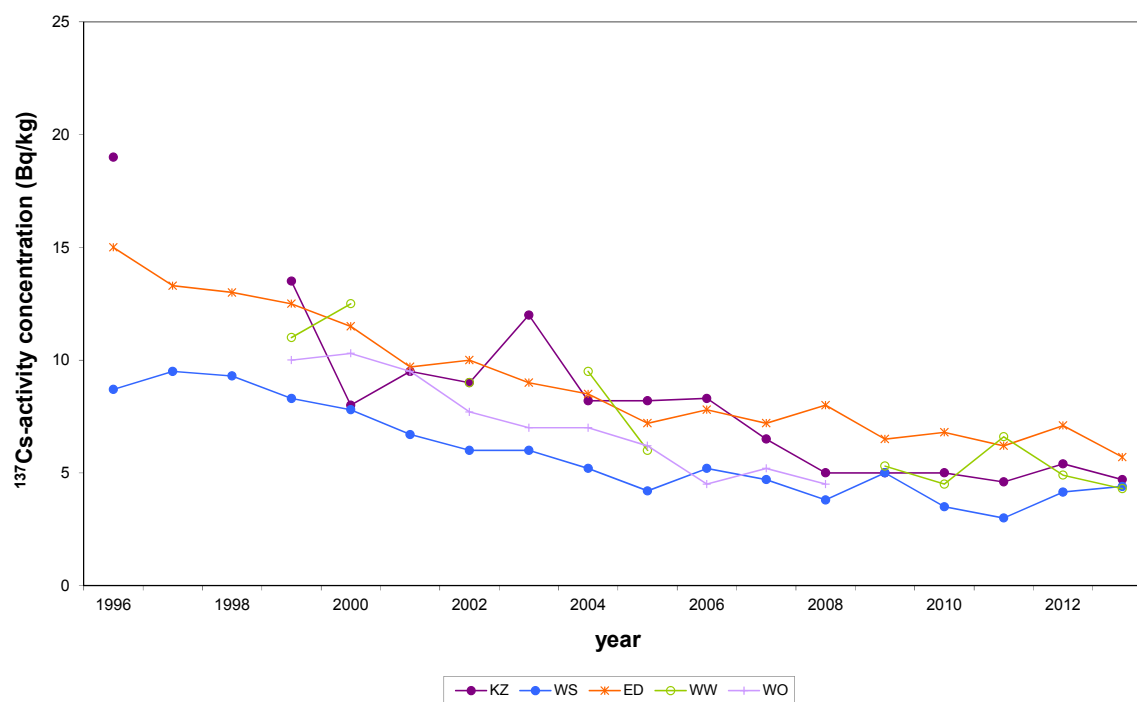
Figure 5.29: Yearly averaged ¹³⁷Cs activity concentrations in suspended solids
Since 2009, ¹³⁷Cs has been determined at Wadden Sea West instead of Wadden Sea East.
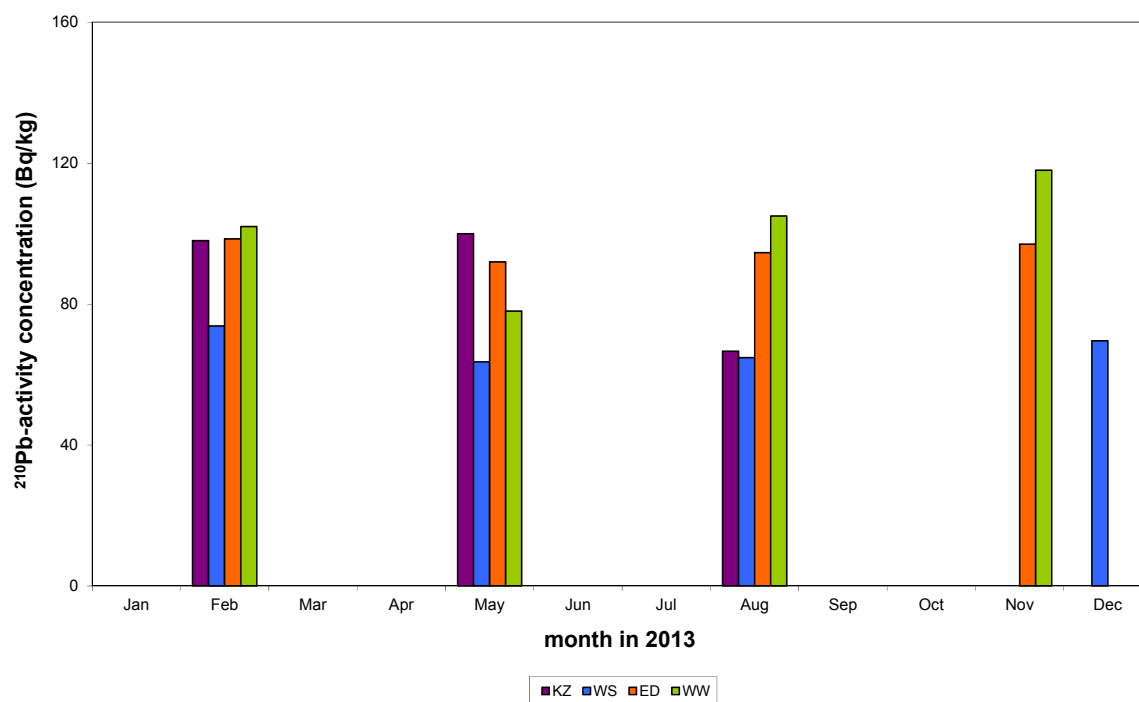
Figure 5.30: ^{210}Pb activity concentrations in suspended solids in seawater for the Coastal Area, Westerscheldt, Eems-Dollard and Wadden Sea West, with yearly averages of 88, 68, 96 and 101 Bq·kg^{-1}, respectively
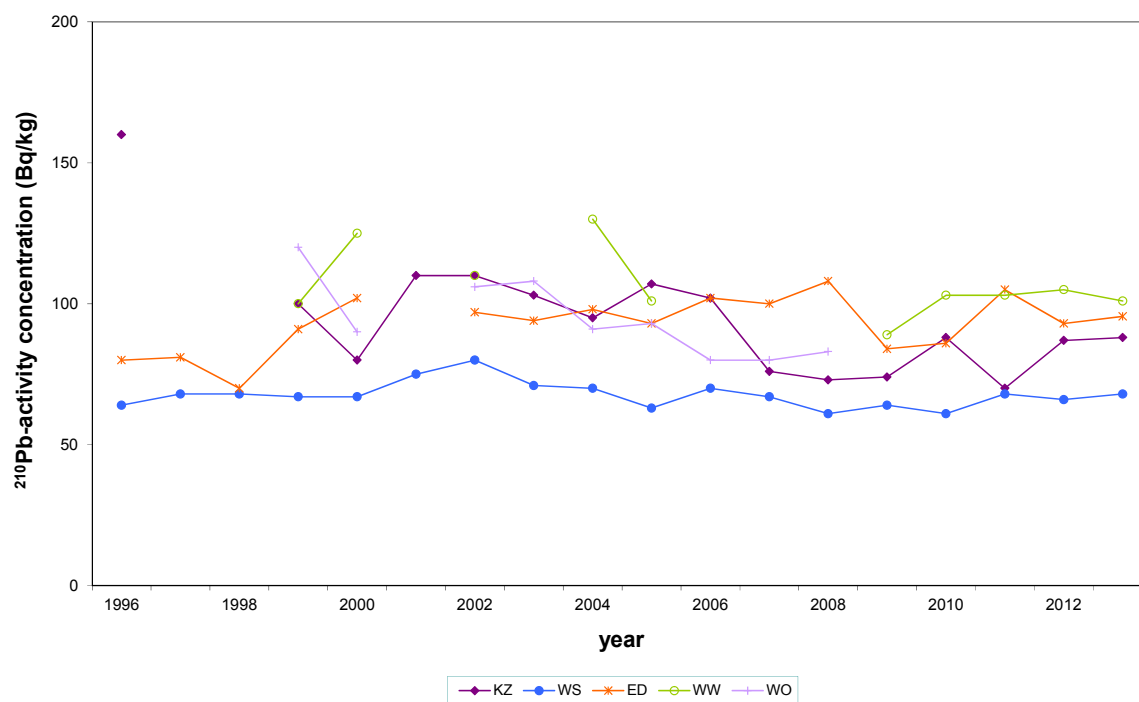
Figure 5.31: Yearly averaged ^{210}Pb activity concentrations in suspended solids
Since 2009, ^{210}Pb has been determined at Wadden Sea West instead of Wadden Sea East.

6 Water for human consumption

In addition to the Recommendation on the Application of Article 36 of the Euratom Treaty [1], regulations for the monitoring of drinking water are given in Council Directive 98/83/EC [48]. According to this directive, the parameters ^{3}H and the total indicative dose should be monitored. Screening methods for gross α and gross β activity concentrations may be used to monitor the total indicative dose. If the gross α and gross β activity concentrations are less than the screening levels of 0.1 and 1.0 Bq·L^{-1}, respectively, it can be assumed that the total indicative dose is less than the parametric value of 0.1 mSv·year^{-1} [49, 50, 51].

In the Netherlands, drinking water production stations monitor raw input water for ^{3}H, gross α, gross β and residual β activity concentrations. The monitoring frequency per location ranges from 1 to 26 times per year, depending on the volume of water produced. The activity concentrations are averaged over a year for each production station.

The results for 2013 are presented in Table 6.1. For gross α, ^{3}H, gross β and residual β, several hundred analyses were performed at 168 to 186 production stations.

Table 6.1: Drinking water analyses in 2013

Parameter	Gross α	^{3}H	Residual β	Gross β
Average value [1]	< 0.1 Bq·L^{-1}	< 4.1 Bq·L^{-1}	< 0.1 Bq·L^{-1}	< 0.1 Bq·L^{-1}
No. of all production stations	182	183	168	186
No. of all analyses	396	401	378	443
Maximum value [2]	0.29 Bq·L^{-1}	11.8 Bq·L^{-1}	< 0.5 Bq·L^{-1}	0.5 Bq·L^{-1}
No. of production stations [3]	2	1	11	1
No. of analyses [4]	1	1	102	1

[1] Activity concentration averaged over all production stations.

[2] Maximum value of activity concentration averaged per production station.

[3] Number of production stations with maximum value.

[4] Number of analyses per production station that led to maximum value.

In 2013, the gross α activity concentration in raw input water for drinking water averaged per production station exceeded the screening level of 0.1 Bq·L^{-1} at 6 of the 182 production stations (in 31 of the 396 analyses). An investigation into these kinds of slightly elevated levels is ongoing.

For ^{3}H, gross β and residual β, the results were within the range of those in previous years [7, 20, 52, 53, 54, 55, 56, 57, 58, 59, 60]. Since there was almost no ^{40}K present, there was no significant difference between average gross β and residual β activity concentrations. The gross β activity concentrations were below the screening level of 1.0 Bq·L^{-1} and the ^{3}H activity concentrations were below the parametric value of 100 Bq·L^{-1} [48, 50, 51].

The activity of natural nuclides, such as ^{226}Ra and ^{222}Rn, in Dutch drinking water is very low. In 1994, a survey was carried out to determine radon activity in Dutch water [61]. The average concentration found was 2.2 Bq·L^{-1} for drinking water produced from groundwater. The difference between this value and the values mentioned in Table 6.1 is due to the contribution of short-lived and volatile natural radionuclides (radon daughters), which are not included in the gross α, gross β and residual β activity concentrations.

7 Milk

RIKILT Wageningen UR monitors radioactivity in milk on a weekly basis, mainly via the National Monitoring Network Radioactivity in Food (Landelijk Meetnet Radioactiviteit in Voedsel, LMRV). The LMRV has been set up as an emergency network for monitoring relatively high contamination levels. The LMRV consists of 50 NaI food monitors in active service, of which 24 are stationed at dairy factories.

The results of the weekly samples of cow's milk from all locations are combined into a monthly average for the whole country. The monthly averages for 2013 are presented in Table 7.1. Figure 7.1 shows an impression of the spatial variation yearly averaged ^{40}K concentrations per region and the distribution of the sampling locations across the Netherlands. None of the samples exceeded the limit of 370 Bq·kg^{-1} for radiocesium activity (sum of ^{134}Cs and ^{137}Cs) set by the European Union [62, 63]. The activity concentration of the natural radionuclide ^{40}K is measured as a qualitative check of the method used.

Table 7.1: Monthly averaged activity concentrations in cow's milk in 2013 [1]

Month	Number of samples	^{40}K Bq·L^{-1}	^{60}Co Bq·L^{-1}	^{131}I Bq·L^{-1}	^{134}Cs Bq·L^{-1}	^{137}Cs Bq·L^{-1}
January	64	54.3 ± 12.4	< 1.4	< 0.6	< 0.6	< 0.5
February	55	52.5 ± 10.6	< 1.4	< 0.6	< 0.6	< 0.5
March	54	54.5 ± 9.7	< 1.4	< 0.6	< 0.6	< 0.5
April	60	52.3 ± 11.2	< 1.4	< 0.6	< 0.6	< 0.5
May	61	53.0 ± 10.9	< 1.4	< 0.6	< 0.6	< 0.5
June	51	51.6 ± 13.0	< 1.4	< 0.6	< 0.6	< 0.5
July	60	53.4 ± 12.5	< 1.4	< 0.6	< 0.6	< 0.5
August	61	52.1 ± 10.0	< 1.4	< 0.6	< 0.6	< 0.5
September	52	51.3 ± 13.8	< 1.4	< 0.6	< 0.6	< 0.5
October	60	51.8 ± 13.3	< 1.4	< 0.6	< 0.6	< 0.5
November	58	53.1 ± 13.0	< 1.4	< 0.6	< 0.6	< 0.5
December	71	54.0 ± 14.5	< 1.4	< 0.6	< 0.6	< 0.5
Average	707 [2]	52.8 ± 12.1	< 1.4	< 0.6	< 0.6	< 0.5

[1] Uncertainty is given as 1σ.

[2] Yearly total.

Additionally, 19 goat's milk samples were analysed. As in cow's milk, no artificial radionuclides were found above detection limits. The average ^{40}K concentration in these samples was 80.5 ± 13.6 Bq·L^{-1}.

In addition to the LMRV samples, RIKILT Wageningen UR analysed 51 milk samples (49 cow's milk and 2 goat's milk samples) for a wide spectrum of γ-emitters and ^{90}Sr. The samples were collected across the Netherlands and were analysed for γ-emitters on an HPGe detector. None of the samples showed any γ-activity above the detection limits (2 Bq·L^{-1} for ^{137}Cs) except for the natural radionuclide ^{40}K (55.3 ± 12.4 Bq·L^{-1}).

The ^{90}Sr activity concentration was below the detection limit (0.2 Bq·L^{-1}) in all samples taken, so none of the samples exceeded the set limit of 125 Bq·kg^{-1} [64].
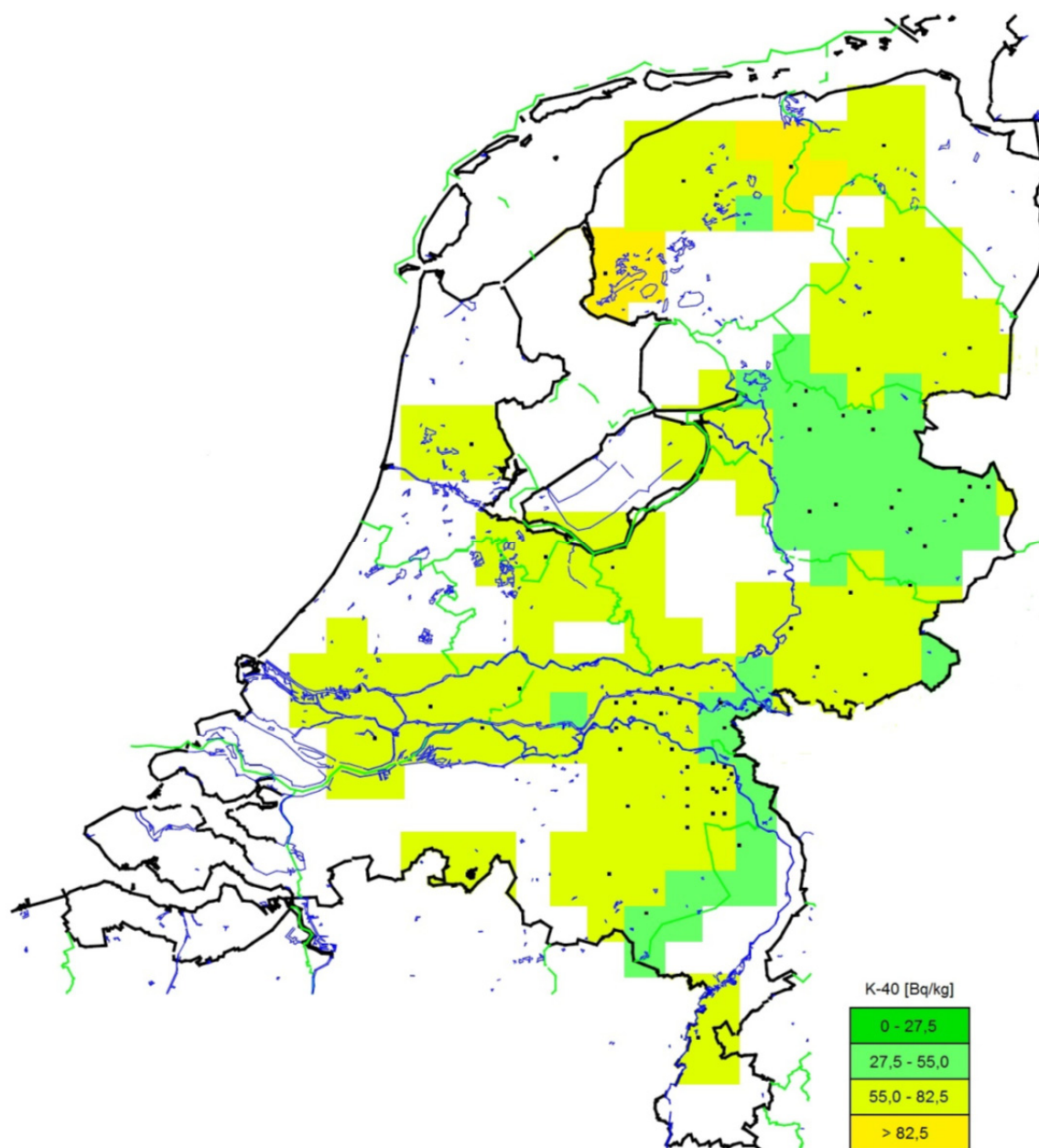
Figure 7.1: Impression of spatial variation of ^{40}K activity concentrations (Bq/kg) in cow's milk
Based on data provided by dairy factories.

8 Food

The Netherlands Food and Consumer Product Safety Authority (NVWA) performs measurements on finished products from retail shops, wholesale produce auctions and distribution centres, while RIKILT Wageningen UR performs measurements on samples from earlier stages in the food production chain.

The measurements on food performed by the NVWA were carried out according to standard procedures [65, 66]. Since 2005, the NVWA has monitored activity concentrations in a 'mixed diet' every year by sampling and measuring separate ingredients. Over a period of four weeks in 2013, 478 samples were taken from retail shops, wholesale produce auctions and distribution centres, including 52 samples of honey [67]. Though honey is not considered to be part of the mixed diet, samples are taken each year because it regularly contains higher levels of radioactivity (mainly ^{137}Cs).

The separate ingredients were divided into the following product groups: grain and grain products, vegetables, fruit and fruit products, milk and dairy products, meat and meat products, game and poultry, salads, oil and butter, honey, tea, mineral water, and fish. The 2013 results are presented in Table 8.1. None of the samples exceeded the set limit of 600 Bq·kg^{-1} (or 370 Bq·kg^{-1} for milk and dairy products) [62, 63].

In 2013, RIKILT Wageningen UR analysed radioactivity in food products as part of the government monitoring programme. Samples were taken throughout the year and measurements were carried out according to standard procedures. A total of 990 samples were analysed, of which 199 were part of a certification programme for the export of Dutch meat products to Russia. The 2013 results are presented in Table 8.2. One of the samples, a game sample, exceeded the set limit of 600 Bq·kg^{-1}. With respect to milk and dairy products, none of the samples exceeded the set limit of 370 Bq·kg^{-1}.

In addition, RIKILT Wageningen UR analysed 125 samples for ^{90}Sr content. The results are presented in Table 8.3. No limits for existing exposure situations are set, but these results are well below the EU limit for new emergency exposure situations of 750 Bq·kg^{-1} for major food products [64]. In addition, 33 samples were measured for gross α and gross β content. No elevated levels were found in these samples.

8.1 Milk and dairy products

In the product group 'Milk and dairy products' analysed by the NVWA, only one sample of milk contained ^{137}Cs (5 Bq·kg^{-1}). This radiocesium activity (sum of ^{134}Cs and ^{137}Cs) was below the set limit of 370 Bq·kg^{-1} [62, 63].

8.2 Honey

In total, 52 samples of honey were analysed by the NVWA [67]. Only two samples of honey contained ^{137}Cs (216 and 226 Bq·kg^{-1}). This radiocesium activity was below the set limit of 600 Bq·kg^{-1} [62, 63].

8.3 Game and poultry

In the product group 'Game and poultry' analysed by RIKILT Wageningen UR, 17 samples of game contained ^{137}Cs. The activity varied from 3.4 up to 1,100 Bq·kg^{-1}. In 16 samples the radiocesium activity was below the set limit of 600 Bq·kg^{-1} [62, 63]. The sample of game contaminated with 1,100 Bq·kg^{-1} ^{137}Cs was a sample of wild boar from the Veluwe area. This measurement result was reported to the NVWA. The NVWA took and analysed samples from additional boars from the same area, but those were all far below the set limit of 600 Bq·kg^{-1} [62,63]. In addition, the NVWA made a risk assessment: assuming a single consumption of 300 grams of boar, the radioactivity level of 1,100 Bq·kg^{-1} results in an effective dose of 4.3 µSv. This does not pose a threat to public health.

8.4 Mixed diet

The measured concentrations of ^{90}Sr, ^{134}Cs and ^{137}Cs in food in Bq·kg^{-1} were converted to an average daily intake value per person per day (Bq·day^{-1}) using food consumption patterns, according to the method described in Appendix B. This was done for all the results of food monitoring carried out by both RIKILT and the NVWA.

The average daily intake per person of ^{134}Cs, ^{137}Cs and ^{90}Sr is < 2.4, < 2.6 and < 3.6 Bq·day^{-1}, respectively. These values are solely based on the detection limits mentioned in the Tables 8.1 to 8.3 since consumption data of the specific food categories with sample results above the detection limit (game and honey) are not known. It is expected that these categories represent only a small part of yearly consumption patterns, resulting in an insignificant contribution to the average yearly dose.

Table 8.1: Results of 2013 analysis of food for ^{134}*Cs and* ^{137}*Cs as measured by the Netherlands Food and Consumer Product Safety Authority*

Product	Number of samples	^{134}Cs [1, 2] Bq·kg^{-1}	^{137}Cs [1, 2] Bq·kg^{-1}
Grain and grain products	85	< 5 (0)	< 5 (0)
Vegetables	86	< 5 (0)	< 5 (0)
Fruit and fruit products	46	< 5 (0)	< 5 (0)
Milk and dairy products	53	< 5 (0)	5 (1)
Meat and meat products	26	< 5 (0)	< 5 (0)
Game and poultry	15	< 5 (0)	< 5 (0)
Salads	18	< 5 (0)	< 5 (0)
Oil and butter	35	< 5 (0)	< 5 (0)
Honey	52	< 5 (0)	216–226 (2)
Tea	18	< 5 (0)	< 5 (0)
Mineral water	23	< 5 (0)	< 5 (0)
Fish	19	< 5 (0)	< 5 (0)

[1] Number of samples above the given reporting limit is given in brackets.

[2] The detection limit was lower than previous years (10 Bq·kg^{-1}), due to an increase in measuring time.

Table 8.2: Results of 2013 analysis of food for ^{134}*Cs and* ^{137}*Cs as measured by RIKILT Wageningen UR*

Product	Number of samples	^{134}Cs [1] Bq·kg^{-1}	^{137}Cs [1] Bq·kg^{-1}
Vegetables	75	< 2 (0)	< 2 (0)
Fruits	78	< 2 (0)	< 2 (0)
Meat and meat products	488	< 2 (0)	< 2 (0)
Game and poultry	79	< 2 (0)	3.4–1,100 (17)
Eggs	120	< 2 (0)	< 2 (0)
Fish and seafood products	110	< 2 (0)	< 2 (0)
Ready meals	40	< 10 (0)	< 10 (0)

[1] Number of samples above the given detection limit is given in brackets.

Table 8.3: Results of 2013 analysis of food for ^{90}*Sr as measured by RIKILT Wageningen UR*

Product	Number of samples	^{90}Sr [1] Bq·kg^{-1}
Vegetables and fruits	19	< 5 (0)
Meat and meat products	21	< 5 (0)
Bone	8	< 25 (0)
Game and poultry	10	< 5 (0)
Fish and seafood products	27	< 5 (0)
Ready meals	40	< 5 (0)

[1] Number of samples above the given detection limit is given in brackets.

9   Grass & feed

The National Monitoring Network Radioactivity in Food (Landelijk Meetnet Radioactiviteit in Voedsel, LMRV), referred to in Chapter 7, is an important monitoring network used in case of a nuclear or radiological emergency, as described in the National Crisis Management Plan Radiation Incidents (Nationaal Crisisbeheersplan Stralingsongevallen, NCS). In addition to measuring radioactivity levels in milk and food samples, the network is used to measure radioactivity levels in grass samples. For this purpose, reference pastures and fields have been designated across the Netherlands in proximity to the companies and organisations which participate in the LMRV. In this way the extent of radioactive deposition can be assessed rapidly by the LMRV in the event of a nuclear or radiological incident.

It is important to have accurate and recent information on the natural background levels of radioactivity in grass to compare with samples analysed during a nuclear or radiological incident. For this reason, every year all LMRV locations are requested to take a grass sample from their reference pasture or field, according to a standardised protocol, and measure this sample using the food monitor.

Grass samples were taken at 42 locations and measured on 17 and 18 September. None of the grass samples taken contained artificial radionuclides above the detection limits. Detection limits were approximately 5 Bq·m^{-2} for the artificial radionuclides ^{60}Co, ^{131}I, ^{132}Te, ^{134}Cs and ^{137}Cs. Natural ^{40}K was found in all samples.

The results of the grass deposition measurements are plotted on a map of the Netherlands, resulting in a deposition map, for use in the event of contamination in an emergency situation. An impression of the spatial variation of the ^{40}K activity in grass is shown in Figure 9.1. The variation in the ^{40}K activity can be attributed to factors such as fertilisation, grass species, length of stalk and soil type.

In addition, 503 feed samples were analysed for gamma content as part of the monitoring programme of RIKILT Wageningen UR. No artificial radioactivity was found in these samples; the results for ^{134}Cs and ^{137}Cs were all lower than the reporting limit of 2 Bq·kg^{-1}.
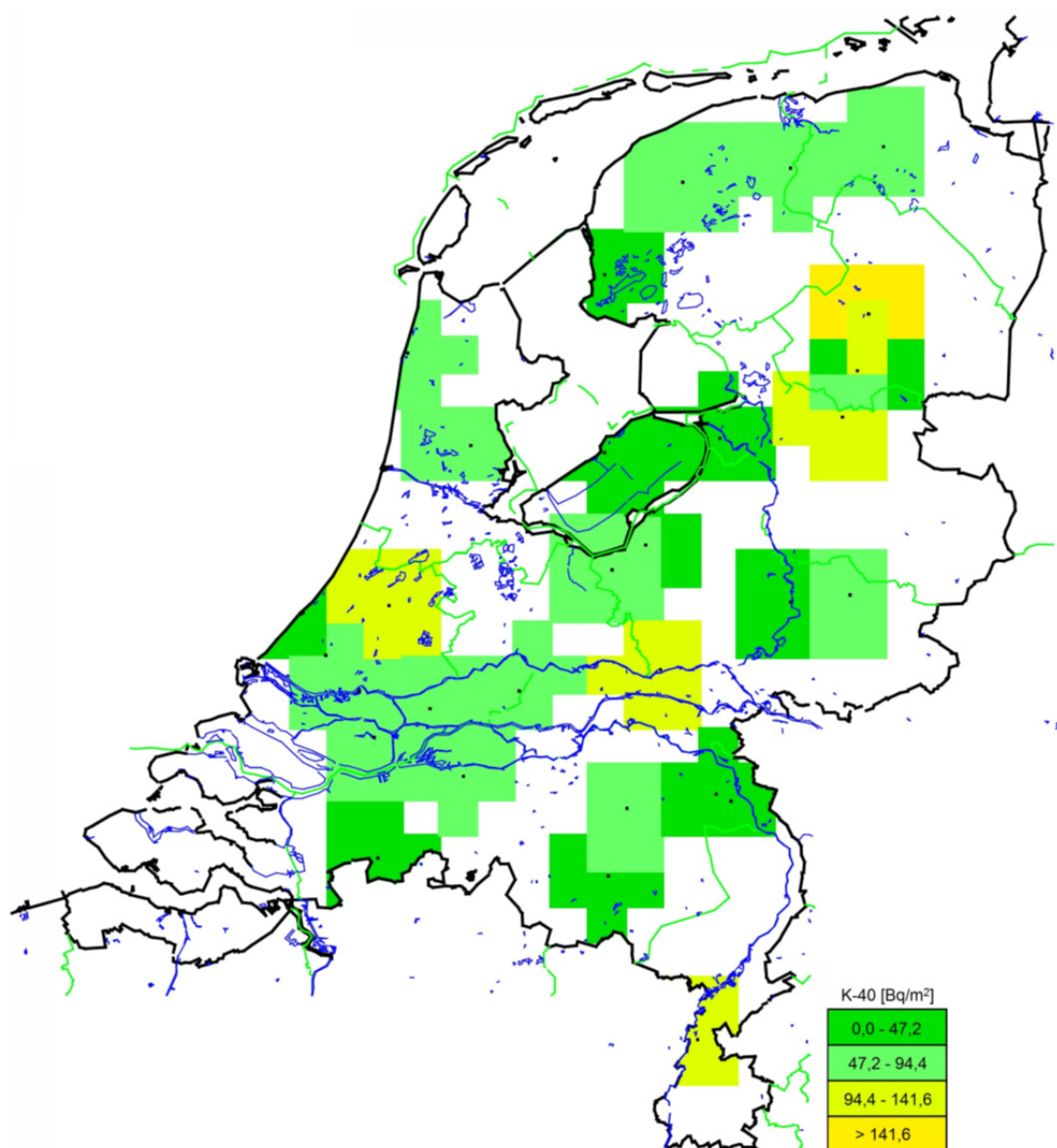
Figure 9.1: Spatial variation of ^{40}K activity in grass, as measured on 17 and 18 September 2013

10   Nuclear power plant at Borssele

The Nuclear Research & Consultancy Group (NRG) is commissioned by Elektriciteits-Productiemaatschappij Zuid-Nederland (N.V. EPZ) to perform monthly measurements on environmental samples taken in the vicinity of the nuclear power plant at Borssele (owned by N.V. EPZ). Samples are taken to monitor the compartments air, water and soil. Only part of the total monitoring programme carried out near the nuclear power plant is presented here [68]. A more detailed description of the monitoring programme and underlying strategy can be found elsewhere [69]. The 2013 monitoring programme for environmental samples is outlined in Table 10.1 and Figure 10.1. Radioactive nuclides were determined in air dust, grass, soil, water, suspended solids, seaweed and sediment.

Table 10.1: Monitoring programme for environmental samples near the nuclear power plant at Borssele in 2013
The location numbers correspond to the location numbers given in Figure 10.1.

Matrix	Location	Parameter	Monitoring frequency (per year)
Air dust	21, 22, 23, 27 and 29	gross α, gross β γ-emitters [1]	12 12 [2]
Grass	21, 22, 23, 27 and 29	γ-emitters [3]	12 [2]
Soil	O1, O2, O3 and O4 [4]	γ-emitters [5]	1
Water	1, 2, 3 and 4	residual β, ^{3}H	12
Suspended solids	1, 2, 3 and 4	gross β	12
Seaweed	1, 2, 3 and 4	γ-emitters [3]	12 [2]
Sediment	1, 2, 3 and 4	γ-emitters [3]	12 [2]

[1] γ-spectroscopic analysis of specific γ-emitting nuclides: ^{60}Co, ^{137}Cs, naturally occurring radionuclides and elemental and organically bound ^{131}I.

[2] Analysis was performed on a combined sample of monthly samples from all four respectively five locations.

[3] γ-spectroscopic analysis of specific γ-emitting nuclides: ^{60}Co, ^{131}I and ^{137}Cs.

[4] The f four locations where samples were taken near the outlet are not shown in Figure 10.1.

[5] γ-spectroscopic analysis of specific γ-emitting nuclides: ^{54}Mn, ^{60}Co, ^{134}Cs and ^{137}Cs.
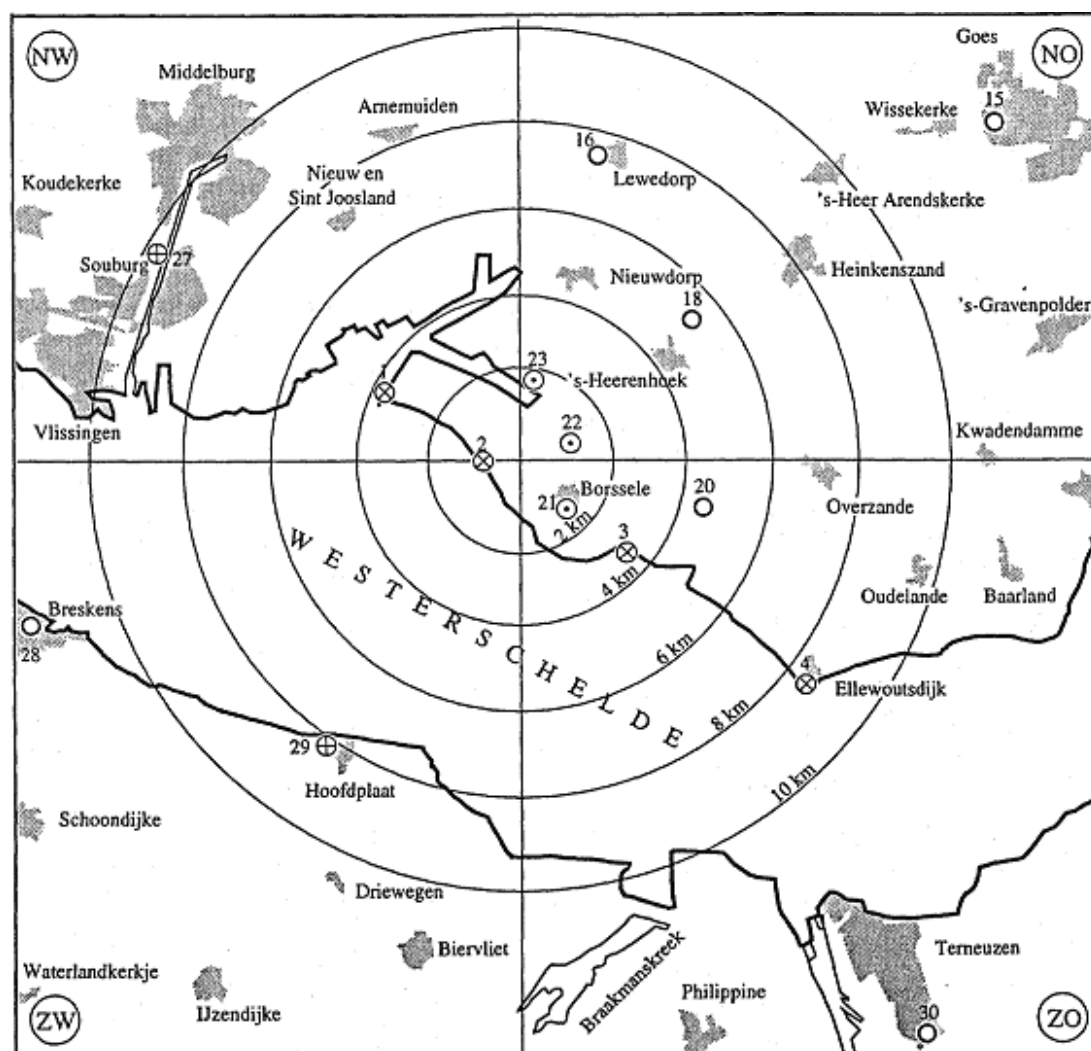
Figure 10.1: Overview of monitoring locations for the monitoring programme conducted by NRG near the nuclear power plant at Borssele
The numbers given in Table 10.1 correspond with the locations on the map.

10.1 Air

The results for gross α and β activity concentrations in air dust are presented in Tables A15 and A16. Due to large uncertainties caused by variations in the amount of dust on the filters, gross α activity concentrations in air dust should be regarded as indicative values [5]. The period between sampling and analysis was at least five days, which is long compared with the decay time of the short-lived decay products of ^{222}Rn and ^{220}Rn. This is to ensure that these naturally occurring decay products do not contribute to the measured α and β activity concentrations.

The 2013 yearly averages of the gross α and β activity concentrations of long-lived nuclides were within the range of the results from previous years, as illustrated in Figures 10.2 and 10.3.

The results for the nuclides considered in the gammaspectroscopic analysis are given in Table A17.
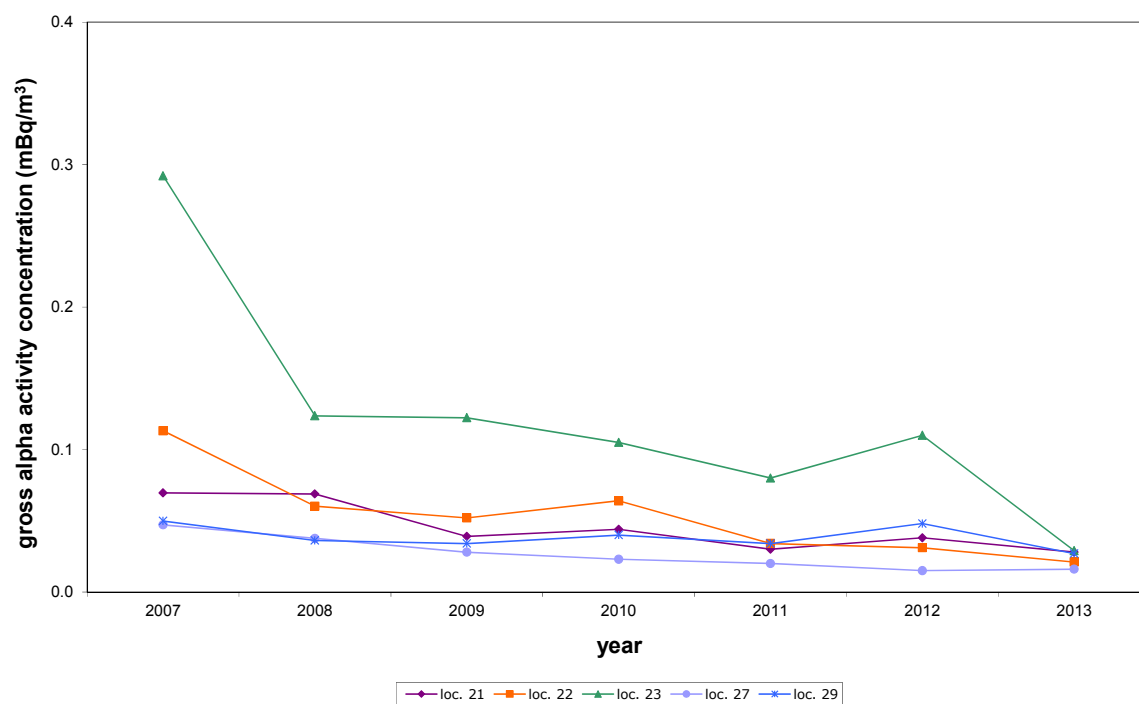
Figure 10.2: Yearly averaged gross a activity concentrations in air dust at five locations near Borssele (see Figure 10.1)
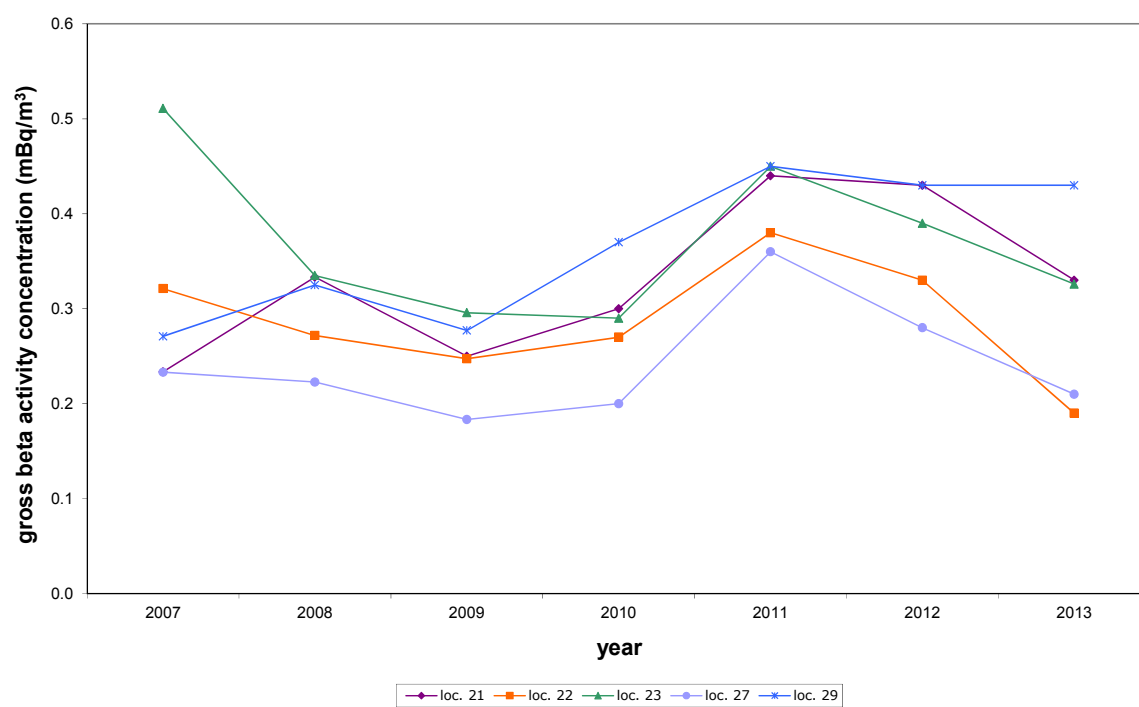
Figure 10.3: Yearly averaged gross β activity concentrations in air dust at five locations near Borssele (see Figure 10.1)

10.2 Soil and grass

The results for the nuclides considered in the gammaspectroscopic analysis of grass and soil are given in Tables A18 and A19. The four soil samples were taken near the outlet of the nuclear power plant. In 2013, the yearly averaged concentrations of [54]Mn, ^{60}Co, [134]Cs and ^{137}Cs in soil were within the range of those in previous years [20, 56, 57, 58, 59, 60].

10.3 Water

The results for residual β and ^{3}H activity concentrations in surface water and gross β activity concentrations in suspended solids in the Westerscheldt area are presented in Tables A20, A21 and A22.

In 2013, the yearly averages of the residual β concentrations in surface water were within the range of the results from previous years, as illustrated in Figure 10.4. Since 2012, the ^{3}H activity concentrations in water were three to four times lower than those in previous years, as illustrated in Figure 10.5. Since 2012, the gross β activity concentrations in suspended solids were somewhat higher than those in previous years, as illustrated in Figure 10.6. The changes in trends of ^{3}H and gross β activity concentrations coincided with a change in the analysis procedures, and are currently under investigation.

The results for the nuclides considered in the gammaspectroscopic analysis of seaweed and sediment are given in Tables A23 and A24.
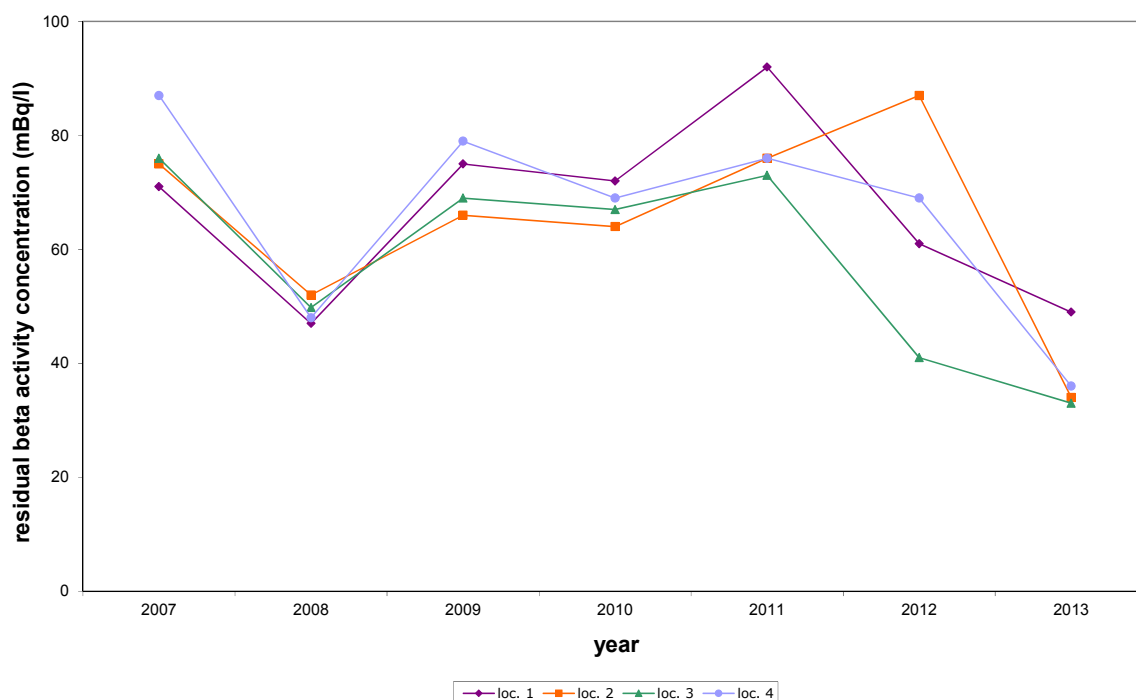
Figure 10.4: Yearly averaged residual β activity concentrations in surface water in the Westerscheldt area at four locations near Borssele (see Figure 10.1)
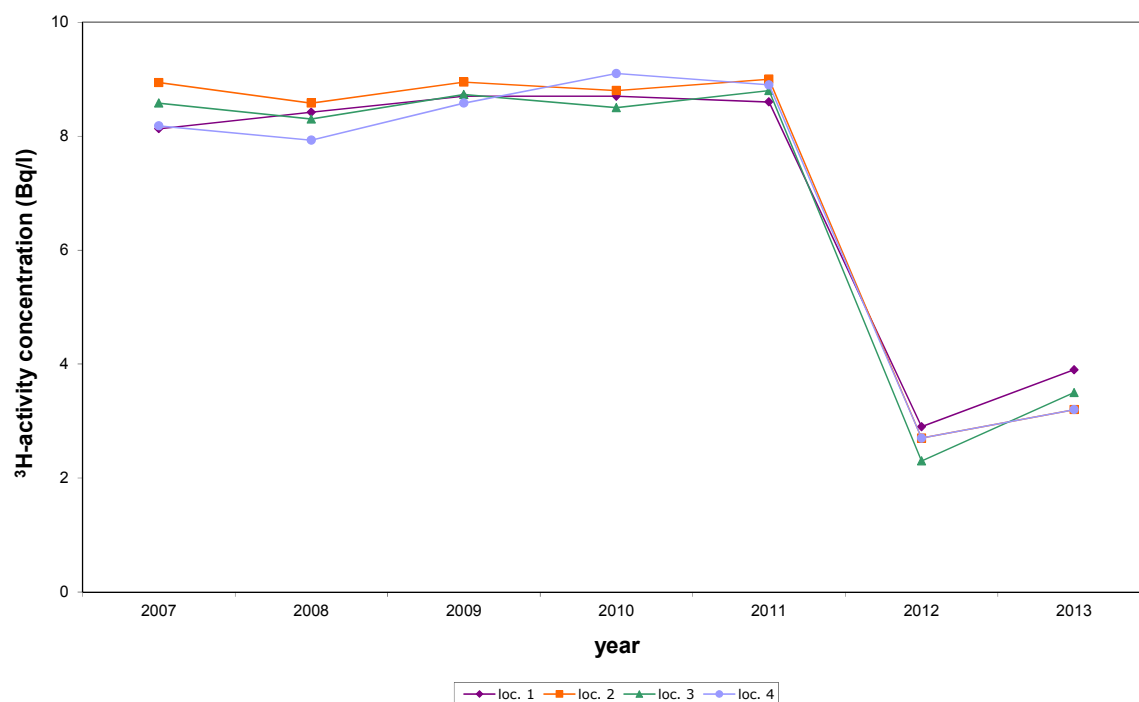
Figure 10.5: Yearly averaged ^3H activity concentrations in surface water in the Westerscheldt area at four locations near Borssele (see Figure 10.1)
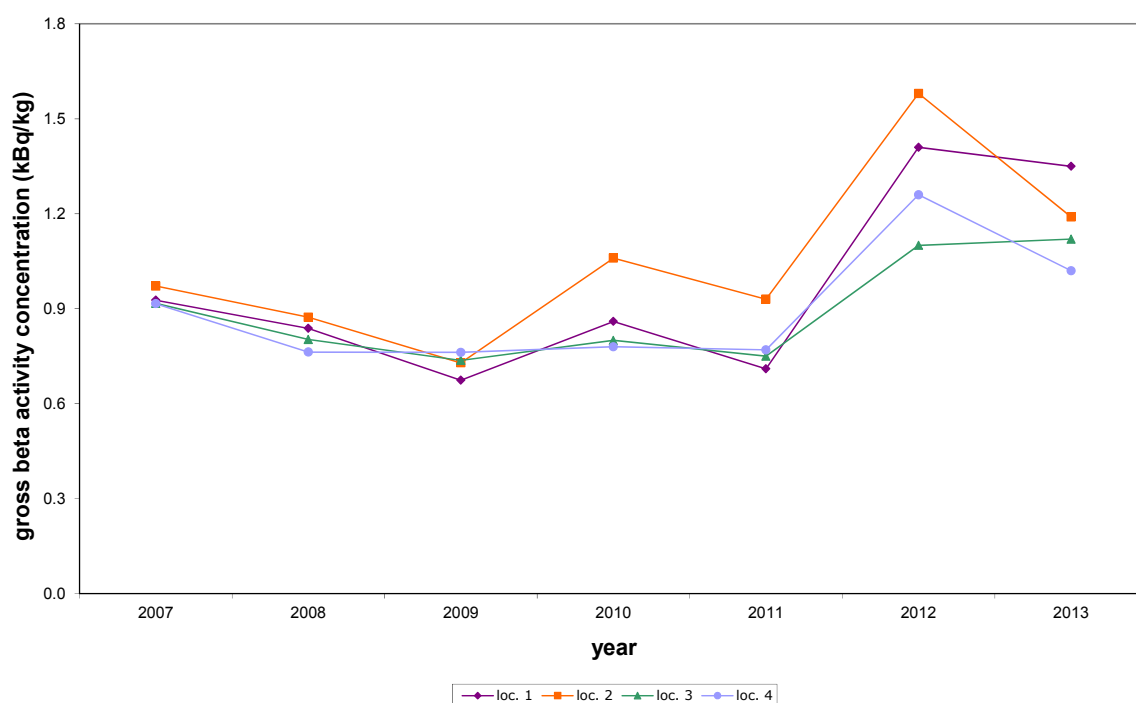
Figure 10.6: Yearly averaged gross β activity concentrations in suspended solids in the Westerscheldt area at four locations near Borssele (see Figure 10.1)

11   Conclusions

In 2013, the Netherlands complied with the Euratom recommendations on annually measuring radioactivity in the environment and in food.

The gross α activity concentration in raw input water for drinking water averaged per production station exceeded the screening level (0.1 Bq·L^{-1}) at 6 of the 182 production stations (in 31 of the 396 analyses). An investigation into these kinds of slightly elevated levels is ongoing.

Radioactivity was measured in almost 1,600 food products, of which 19 samples contained ^{137}Cs. Two samples of honey contained ^{137}Cs (216 and 226 Bq·kg^{-1}). Seventeen samples of game and poultry contained ^{137}Cs and the activity varied from 3.4 to 1,100 Bq·kg^{-1}. Only one sample was above the set limit of 600 Bq·kg^{-1}. A sample of boar (originating from the Veluwe area) contained 1,100 Bq·kg^{-1} ^{137}Cs. In a risk assessment based on a single consumption of boar, this radioactivity level was found not to pose a threat to public health.

As of 2013, the measured concentrations of ^{90}Sr, ^{134}Cs and ^{137}Cs in food in Bq·kg^{-1} are converted to an average daily intake value per person per day (Bq·day^{-1}) using food consumption patterns. The average daily intake per person of ^{134}Cs, ^{137}Cs and ^{90}Sr is < 2.4, < 2.6 and < 3.6 Bq·day^{-1}, respectively.

Since 2013, data on grass and feed are permanently added as an additional chapter to this report. None of the grass and feed samples taken contained artificial radionuclides.

All other radioactivity measurements were within the range of those in previous years.

Appendix A – Tables of results

Table A1: Weekly averaged gross α and gross β activity concentrations in air dust sampled with the Snow White high volume sampler at RIVM in 2013

Week [1] number	Gross α [2] mBq.m⁻³	Gross β mBq.m⁻³	Week [1] number	Gross α [2] mBq.m⁻³	Gross β mBq.m⁻³
1	0.015	0.28 ± 0.03	27	0.020	0.23 ± 0.03
2	0.027	0.61 ± 0.06	28	0.043	0.54 ± 0.06
3	0.039	0.92 ± 0.10	29	0.044	0.64 ± 0.08
4	0.017	0.27 ± 0.03	30	0.022	0.41 ± 0.05
5	0.011	0.156 ± 0.016	31	0.019	0.39 ± 0.05
6	0.024	0.45 ± 0.05	32	0.021	0.22 ± 0.03
7	0.011	0.28 ± 0.03	33	0.035	0.41 ± 0.05
8	0.036	0.77 ± 0.08	34	0.056	0.86 ± 0.10
9	0.032	0.70 ± 0.07	35	0.021	0.31 ± 0.04
10	0.036	0.53 ± 0.06	36	0.039	0.45 ± 0.05
11	0.024	0.45 ± 0.05	37	0.016	0.20 ± 0.02
12	0.059	0.68 ± 0.07	38	0.032	0.39 ± 0.05
13	0.043	0.74 ± 0.08	39	0.025	0.59 ± 0.07
14	0.021	0.43 ± 0.04	40	0.017	0.27 ± 0.03
15	0.021	0.30 ± 0.03	41	0.016	0.22 ± 0.02
16	0.021	0.32 ± 0.03	42	0.029	0.49 ± 0.05
17	0.009	0.166 ± 0.018	43	0.016	0.30 ± 0.03
18 [3]	0.023	0.40 ± 0.04	44	0.015	0.179 ± 0.019
19 [3]	0.015	0.23 ± 0.02	45	0.011	0.149 ± 0.016
20	0.009	0.168 ± 0.018	46	0.020	0.30 ± 0.03
21	0.012	0.25 ± 0.03	47	0.015	0.29 ± 0.03
22	0.014	0.25 ± 0.03	48	0.018	0.203 ± 0.017
23	0.017	0.28 ± 0.03	49	0.018	0.28 ± 0.02
24	0.026	0.41 ± 0.05	50	0.038	0.62 ± 0.06
25	0.013	0.159 ± 0.019	51 [3]	0.016	0.21 ± 0.02
26	0.012	0.18 ± 0.02	52 [3]	0.012	0.43 ± 0.04
Average				0.023	0.384 ± 0.007 [4]
SD [5]				0.012	0.19

[1] The precise sampling period is given in Table A3.

[2] Values are indicative due to large uncertainties caused by variations in the amount of dust on the filters [5].

[3] Sampling period deviated from the regular seven-day sampling period.

[4] The uncertainty in the yearly average is equal to the square root of the sum of the squared weekly uncertainties divided by the number of weeks. Uncertainties are given as 1σ.

[5] SD is the standard deviation of the weekly results.

Table A2: Detection limits (µBq/m^3) in the residue measurement of air dust sampled during a seven-day sampling period with the Snow White high volume sampler at RIVM in 2013

Measurements were carried out on the ash residue in the filter on a well-type detector, with a ten-day delay between sampling and the start of measurement, and a sample volume of about 125,000 m^3. Between 2000 and July 2009, the detection limits were higher than before 2000 [70], due to a different detector set-up. The detector set-up changed again in the second half of 2009, including a change in counting time from 100,000 seconds to 178,200 seconds. Therefore, detection limits were lower from July 2009. A change in high volume sampler (and consequently the sample volume) in 2011 resulted in a further reduction of the detection limits.

Nuclide	Detection limit µBq·m^{-3}
^{7}Be	2.0
^{22}Na	0.2
^{60}Co	0.1
^{131}I	2.1 [1]
^{137}Cs	0.1
^{210}Pb	3.7

[1] The detection limit is given for the filter measurement on the coaxial detector (3 days delay time, 100,000 seconds counting time). Due to the sample preparation procedure, the volatile nuclide ^{131}I cannot be determined in the residue measurement on the well-type detector.

Table A3: Weekly averaged ^{7}Be, ^{137}Cs and ^{210}Pb activity concentrations in air dust sampled with the Snow White high volume sampler at RIVM in 2013

Week number	Period	^{7}Be µBq·m^{-3}	^{137}Cs µBq·m^{-3}	^{210}Pb µBq·m^{-3}
1	04/01–11/01	2,400 ± 200	0.14 ± 0.04	250 ± 20
2	11/01–18/01	2,300 ± 200	0.58 ± 0.06	670 ± 70
3	18/01–25/01	3,600 ± 400	0.79 ± 0.08	1,140 ± 110
4	25/01–01/02	3,400 ± 300	0.17 ± 0.03	220 ± 20
5	01/02–08/02	2,300 ± 200	< 0.12	78 ± 8
6	08/02–15/02	1,570 ± 150	0.35 ± 0.04	470 ± 50
7	15/02–22/02	1,610 ± 160	0.31 ± 0.05	320 ± 30
8	22/02–01/03	2,000 ± 200	0.69 ± 0.07	930 ± 90
9	01/03–08/03	7,000 ± 700	0.54 ± 0.06	710 ± 70
10	08/03–15/03	3,800 ± 400	0.37 ± 0.05	480 ± 50
11	15/03–22/03	2,900 ± 300	0.23 ± 0.04	420 ± 40
12	22/03–29/03	4,600 ± 500	1.01 ± 0.10	530 ± 50
13	29/03–05/04	5,200 ± 500	0.94 ± 0.10	610 ± 60
14	05/04–12/04	3,700 ± 400	0.39 ± 0.05	430 ± 40
15	12/04–19/04	3,700 ± 400	0.15 ± 0.03	194 ± 19
16	19/04–26/04	3,900 ± 400	0.17 ± 0.03	250 ± 20
17	26/04–03/05	2,200 ± 200	0.16 ± 0.03	139 ± 14
18 [1]	03/05–08/05	4,300 ± 400	0.46 ± 0.06	320 ± 30
19 [1]	08/05–17/05	3,500 ± 300	0.19 ± 0.03	161 ± 16
20	17/05–24/05	1,380 ± 140	< 0.14	138 ± 14
21	24/05–31/05	2,700 ± 300	0.26 ± 0.04	210 ± 20
22	31/05–07/06	2,700 ± 300	0.27 ± 0.04	220 ± 20
23	07/06–14/06	3,000 ± 300	0.25 ± 0.04	260 ± 30
24	14/06–21/06	3,400 ± 300	0.28 ± 0.04	350 ± 30
25	21/06–28/06	1,840 ± 180	0.15 ± 0.03	130 ± 13
26	28/06–05/07	2,400 ± 200	0.13 ± 0.03	166 ± 16

Continued on next page

Table A3: Continued

Week number	Period	^{7}Be µBq·m^{-3}	^{137}Cs µBq·m^{-3}	^{210}Pb µBq·m^{-3}
27	05/07–12/07	3,300 ± 300	0.49 ± 0.06	183 ± 18
28	12/07–19/07	4,600 ± 500	0.75 ± 0.08	420 ± 40
29	19/07–26/07	5,200 ± 500	0.56 ± 0.06	540 ± 50
30	26/07–02/08	4,000 ± 400	< 0.15	390 ± 40
31	02/08–09/08	4,800 ± 500	0.15 ± 0.03	370 ± 40
32	09/08–16/08	3,300 ± 300	0.12 ± 0.03	240 ± 20
33	16/08–23/08	4,000 ± 400	0.14 ± 0.03	380 ± 40
34	23/08–30/08	5,600 ± 600	0.39 ± 0.05	770 ± 80
35	30/08–06/09	3,200 ± 300	0.17 ± 0.03	370 ± 40
36	06/09–13/09	3,600 ± 400	0.11 ± 0.03	380 ± 40
37	13/09–20/09	3,000 ± 300	< 0.10	158 ± 16
38	20/09–27/09	3,100 ± 300	0.08 ± 0.03	380 ± 40
39	27/09–04/10	4,200 ± 400	0.48 ± 0.06	760 ± 70
40	04/10–11/10	2,300 ± 200	0.08 ± 0.03	330 ± 30
41	11/10–18/10	1,640 ± 160	0.16 ± 0.03	210 ± 20
42	18/10–25/10	3,400 ± 300	0.14 ± 0.03	470 ± 50
43	25/10–01/11	3,300 ± 300	0.09 ± 0.03	290 ± 30
44	01/11–08/11	2,100 ± 200	< 0.12	165 ± 16
45	08/11–15/11	2,100 ± 200	< 0.16	109 ± 11
46	15/11–22/11	2,300 ± 200	0.38 ± 0.05	410 ± 40
47	22/11–29/11	3,200 ± 300	0.10 ± 0.02	270 ± 30
48	29/11–06/12	2,500 ± 180	0.30 ± 0.04	163 ± 12
49	06/12–13/12	2,550 ± 190	0.25 ± 0.05	390 ± 30
50	13/12–20/12	5,000 ± 500	0.21 ± 0.04	660 ± 60
51 [1]	20/12–30/12	3,000 ± 300	0.12 ± 0.03	167 ± 16
52 [1]	30/12–02/01	4,000 ± 400	< 0.3	300 ± 30
Average		3,280 ± 50 [2]	0.317 ± 0.007 [2, 3]	366 ± 6 [2]
SD [4]		1,100	0.2	200

[1] Sampling period deviated from the regular seven-day sampling period.

[2] The uncertainty in the yearly average is equal to the square root of the sum of the squared weekly uncertainties divided by the number of weeks. Uncertainties are given as 1σ.

[3] The detection limits are omitted in the calculation of the averages.

[4] SD is the standard deviation of the weekly results.

Table A4: Precipitation per month and monthly deposited ^{3}H, long-lived gross a and gross β activity sampled at RIVM in 2013

Month	Precipitation mm	^{3}H [1] Bq·m^{-2}	Gross α Bq·m^{-2}	Gross β Bq·m^{-2}
January	46.6	< 90	1.47 ± 0.19	7.5 ± 0.6
February	54.5	< 100	0.87 ± 0.15	2.28 ± 0.18
March	40.3	< 70	2.9 ± 0.3	6.8 ± 0.5
April	22.2	< 40	9.0 ± 0.8	9.5 ± 0.7
May	78.0	< 150	8.5 ± 0.7	11.7 ± 0.9
June	36.5	< 70	5.2 ± 0.5	10.4 ± 0.8
July	47.6	< 90	5.6 ± 0.5	8.9 ± 0.7
August	29.1	< 50	6.1 ± 0.6	11.7 ± 0.9
September	118.6	< 220	2.6 ± 0.3	7.0 ± 0.5
October	165.9	< 310	2.6 ± 0.3	9.0 ± 0.7
November	133.3	< 250	1.9 ± 0.3	4.6 ± 0.3
December	79.1	< 150	1.5 ± 0.3	5.4 ± 0.4
Total	851.4	-	48.1 ± 1.6 [2]	95 ± 2 [2]
Lower limit [3]	-	0		
Upper limit [3]	-	1,580		

[1] The detection limit in Bq·m^{-2} is mainly dependent on the amount of precipitation as the detection limit of the counting sample itself is more or less constant (1.8–1.9 Bq·L^{-1}).

[2] The uncertainty in the sum is equal to the square root of the sum of the squared monthly uncertainties. Uncertainties are given as 1σ.

[3] The lower and upper limits are defined in Appendix B.

Table A5: Yearly totals for long-lived gross α, gross β and ^{3}H activity in deposition since 1993
Either the yearly total with uncertainty [1] or the lower and upper limits [2] of the 68% confidence interval are given.

Year	Precipitation mm	^{3}H Bq·m^{-2}	Gross α Bq·m^{-2}	Gross β Bq·m^{-2}
1993	886	1,310 ± 30	54.3 ± 0.7	87.8 ± 0.8
1994	1,039	1,210 ± 30	52 ± 2	91 ± 3
1995	724	970 ± 40	33.6–44.6	95 ± 8
1996	626	970 ± 50	16.4 ± 1.5	67 ± 5
1997	760	1,160 ± 60	22.0–25.0	87 ± 3
1998	1,238	1,090–2,190	31.1 ± 1.3	106 ± 3
1999	916	1,420–1,900	25.5 ± 1.1	84 ± 2
2000	935	260–1,440	35.2 ± 1.3	104 ± 3
2001	1,053	0–2,420	23.9 ± 1	97 ± 3
2002	965	300–1,710	20.6 ± 0.9	97 ± 2
2003	605	260–1,080	13.6–16.7	70.0 ± 1.8
2004	875	0–1,600	14.3–17.1	73.5 ± 1.8
2005	856	0–1,530	17.6 ± 1.0	88 ± 2
2006	854	280–1,820	25.7 ± 1.5	98 ± 3
2007	984	335–1,600	24.4 ± 1.2	85 ± 2
2008	908	102–1,550	39.4 ± 1.5	106 ± 3
2009	794	0–1,330	36.9 ± 1.3	95 ± 2
2010	868	180–1,400	36.7 ± 1.3	90 ± 2
2011	895	332–1,540	45.0 ± 1.5	123 ± 3
2012	922	316–1,650	32.7 ± 1.1	88 ± 2
2013	851	0–1,580	48.1 ± 1.6	95 ± 2

[1] Uncertainties are given as 1σ.

[2] Lower and upper limits are given as defined in Appendix B.

Table A6: Monthly deposited ^{210}*Po activity* [1] *sampled at RIVM in 2013*

Month	^{210}Po Bq·m^{-2}
January	1.29 ± 0.10
February	0.73 ± 0.07
March	2.78 ± 0.14
April [2]	
May [2]	
June	4.9 ± 0.3
July	2.9 ± 0.3
August	4.7 ± 0.2
September	0.92 ± 0.18
October	1.20 ± 0.19
November	0.65 ± 0.10
December	1.08 ± 0.09
Total	21.2 [2] ± 0.6 [3]
Lower limit [4]	-
Upper limit [4]	-

[1] Measurements were carried out using α-spectroscopy. Uncertainties are given as 1σ.

[2] The results of April and May were rejected. The yearly total deposition is based on ten monthly results.

[3] The uncertainty in the sum is equal to the square root of the sum of the squared monthly uncertainties. Uncertainties are given as 1σ.

[4] The lower and upper limits are defined in Appendix B.

Table A7: Yearly totals for ^{7}Be, ^{137}Cs, ^{210}Pb and ^{210}Po activity in deposition since 1993
Either the yearly total with uncertainty [1] or the lower and upper limits [2] of the 68% confidence range are given.

Year	^{7}Be [3] Bq·m^{-2}	^{137}Cs [3] Bq·m^{-2}	^{210}Pb [3] Bq·m^{-2}	^{210}Pb [4] Bq·m^{-2}	^{210}Po [4] Bq·m^{-2}
1993	1,090 ± 20	0.50–0.76	105 ± 2	78 ± 3	7.2 ± 0.5
1994	1,320 ± 30	0.36–0.71	118 ± 3	82 ± 3	12.0–14.2
1995	990 ± 20	0.37–0.63	96 ± 2	n/a [5]	n/a [5]
1996	920 ± 20	0.52–0.83	63–67	57 ± 3	9 ± 2
1997	1,090 ± 30	0.11–0.69	65–69	80 ± 4	0–10.2
1998	1,840 ± 50	0.56–0.85	162 ± 4	91 ± 4	3.0–15.1
1999	1,580 ± 30	1.16–1.99	158 ± 4	- [6]	0.7–5.3
2000	1,490 ± 30	0–4.82	177 ± 6	-	0.6–8.0
2001	1,480 ± 30	0–4.50	83–104	-	6.5–9.4
2002	1,510 ± 30	0–5.22	119–142	-	6.1–8.5
2003	1,000–1,050	0–4.69	88–113	-	4.3–5.6
2004	1,330 ± 30	0.22–5.53	64–102	-	5.4–7.7
2005	1,320 ± 30	0–6.09	87–117	-	8.9–10.2
2006	1,400 ± 30	0.06–7.47	66–103	-	14.8–16.4 [7]
2007	1,760 ± 40	0.11–7.37	72–132	-	13.4 ± 0.4 [7]
2008	1,990 ± 40	0–7.63	63–143	-	29.4 ± 0.7
2009	1,410 ± 30	0–4.3	82–125	-	32.5 ± 0.7
2010	1,240 ± 30	0–1.2	93 ± 2	-	33.2 ± 0.8
2011	1,320 ± 30	0.5–1.5	104 ± 2	-	61.4 ± 1.0
2012	1,330 ± 30	0–1.2	98 ± 2	-	33.8 ± 0.6
2013	1,030 ± 30	0–1.1	82.9 ± 1.8	-	21.2 ± 0.6 [8]

[1] Uncertainties are given as 1σ.

[2] Lower and upper limits are given as defined in Appendix B.

[3] Data from γ-spectroscopy.

[4] Data from α-spectroscopy.

[5] Not available. Result rejected [71].

[6] α-spectroscopy analysis of ^{210}Pb stopped in 1999.

[7] Results revised in RIVM Report 610791003.

[8] The yearly total deposition is based on ten monthly results.

Table A8: Weekly deposited [7]Be, ^{137}Cs and ^{210}Pb activity [(1)] sampled at RIVM in 2013

Week number	Period	Precipitation mm	[7]Be Bq·m^{-2}	[137]Cs Bq·m^{-2}	[210]Pb Bq·m^{-2}
1	04/01–11/01	10.1	23 ± 3	< 0.02	2.3 ± 0.3
2	11/01–18/01	5.1	3.9 ± 0.5	< 0.02	1.23 ± 0.17
3	18/01–25/01	3.9	5.3 ± 0.7	< 0.02	2.0 ± 0.3
4	25/01–01/02	27.5	29 ± 4	< 0.02	0.98 ± 0.14
5	01/02–08/02	37.0	38 ± 5	< 0.02	1.5 ± 0.2
6	08/02–15/02	10.5	13.9 ± 1.8	< 0.03	1.4 ± 0.2
7	15/02–22/02	2.2	2.8 ± 0.4	< 0.03	0.24 ± 0.08
8	22/02–01/03	4.8	4.8 ± 0.6	< 0.02	1.02 ± 0.14
9	01/03–08/03	1.3	3.7 ± 0.5	< 0.03	0.51 ± 0.10
10	08/03–15/03	31.0	12.9 ± 1.7	< 0.02	1.9 ± 0.3
11	15/03–22/03	8.0	12.2 ± 1.6	< 0.019	0.90 ± 0.12
12	22/03–29/03	0.0	1.9 ± 0.2	< 0.02	1.38 ± 0.19
13	29/03–05/04	0.0	2.7 ± 0.4	0.02	0.75 ± 0.11
14	05/04–12/04	5.5	4.8 ± 0.6	0.02	1.9 ± 0.3
15	12/04–19/04	7.3	8.9 ± 1.1	0.02	0.76 ± 0.11
16	19/04–26/04	4.5	13.8 ± 1.8	0.02	1.6 ± 0.2
17	26/04–03/05	4.9	12.2 ± 1.6	0.02	0.90 ± 0.13
18	03/05–08/05	0.0	7.2 ± 0.9	0.02	3.1 ± 0.4
19	08/05–17/05	41.0	67 ± 9	0.017	3.5 ± 0.5
20	17/05–24/05	28.5	67 ± 9	< 0.02	4.0 ± 0.5
21	24/05–31/05	8.5	14.1 ± 1.8	0.02	0.88 ± 0.13
22	31/05–07/06	0.0	6.4 ± 0.8	< 0.02	3.7 ± 0.5
23	07/06–14/06	5.5	10.7 ± 1.4	< 0.02	2.5 ± 0.3
24	14/06–21/06	8.5	21 ± 3	< 0.02	2.1 ± 0.3
25	21/06–28/06	22.5	45 ± 6	< 0.03	1.5 ± 0.2
26	28/06–05/07	17.5	23 ± 3	< 0.02	1.38 ± 0.19

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Table A8: Continued

Week number	Period	Precipitation mm	^{7}Be Bq·m^{-2}	^{137}Cs Bq·m^{-2}	^{210}Pb Bq·m^{-2}
27	05/07–12/07	0.0	6.6 ± 0.9	< 0.02	1.9 ± 0.2
28	12/07–19/07	0.0	6.0 ± 0.8	< 0.02	1.6 ± 0.2
29	19/07–26/07	0.6	7.1 ± 0.9	< 0.02	1.33 ± 0.18
30	26/07–02/08	29.5	43 ± 6	< 0.02	3.7 ± 0.5
31	02/08–09/08	10.5	17 ± 2	< 0.019	3.3 ± 0.4
32	09/08–16/08	7.3	10.1 ± 1.3	< 0.019	0.83 ± 0.12
33	16/08–23/08	10.8	22 ± 3	< 0.02	1.6 ± 0.2
34	23/08–30/08	0.6	9.7 ± 1.2	< 0.02	1.5 ± 0.2
35	30/08–06/09	0.3	4.0 ± 0.5	< 0.02	0.68 ± 0.10
36	06/09–13/09	69.3	40 ± 5	< 0.019	1.8 ± 0.2
37	13/09–20/09	40.0	49 ± 6	< 0.02	1.19 ± 0.17
38	20/09–27/09	0.0	5.4 ± 0.7	< 0.02	1.34 ± 0.18
39	27/09–04/10	9.0	14.9 ± 1.9	< 0.019	1.6 ± 0.2
40	04/10–11/10	2.7	12.7 ± 1.6	< 0.02	0.95 ± 0.14
41	11/10–18/10	124.8	113 ± 14	< 0.04	4.9 ± 0.6
42	18/10–25/10	9.9	10.0 ± 1.3	< 0.02	1.16 ± 0.16
43	25/10–01/11	28.5	24 ± 3	< 0.019	0.94 ± 0.13
44	01/11–08/11	82.0	43 ± 5	< 0.02	1.5 ± 0.2
45	08/11–15/11	45.0	34 ± 4	< 0.02	1.9 ± 0.3
46	15/11–22/11	4.5	6.7 ± 0.9	< 0.02	0.55 ± 0.09
47	22/11–29/11	1.8	5.5 ± 0.7	< 0.02	0.39 ± 0.07
48	29/11–06/12	20.3	41 ± 5	< 0.02	1.18 ± 0.17
49	06/12–13/12	2.5	7.4 ± 0.9	< 0.019	0.93 ± 0.13
50	13/12–20/12	13.7	8.9 ± 1.1	< 0.02	0.58 ± 0.09
51	20/12–30/12	38.6	27 ± 3	< 0.019	1.38 ± 0.19
52	30/12–02/01	4.1	4.2 ± 0.5	< 0.019	0.27 ± 0.06
Total [2]		922.5	1,030 ± 30	-	82.9 ± 1.8
Lower limit [3]		-	-	0	-
Upper limit [3]		-	-	1.1	-

[1] Measurements were carried out using γ-spectroscopy.

[2] The uncertainty in the sum is equal to the square root of the sum of the squared weekly uncertainties. Uncertainties are given as 1σ.

[3] The lower and upper limits are defined in Appendix B.

Table A9: Yearly averaged α activity concentration in air and ambient dose equivalent rate in 2013 as measured by the NMR stations equipped with aerosol monitors

Station	No.	α activity concentration Bq.m^{-3}	Ambient dose equivalent rate [1] nSv.h^{-1}
Arnhem [2]	970	3.6	67
Kollumerwaard	972	2.6	71
Valthermond [3]	974	2.2	58
Vlaardingen	976	3.1	71
Braakman	978	3.4	66
Huijbergen	980	3.0	57
Houtakker	982	3.1	66
Wijnandsrade	984	5.2	70
Eibergen	986	2.8	60
De Zilk	988	2.0	65
Wieringerwerf	990	2.4	69
Vredepeel	992	3.3	66
Biddinghuizen	994	3.1	74
Bilthoven	998	2.8	61

[1] These dose equivalent rate monitors are placed differently from the dose equivalent rate monitors mentioned in Table A10 with regard to height and surface covering.

[2] The Wageningen station was replaced by the Arnhem station in December 2006.

[3] This station was formerly known as Witteveen.

Table A10: Yearly averaged ambient dose equivalent rate for the NMR stations in 2013

Station	No.	Ambient dose equivalent rate nSv.h^{-1}	Station	No.	Ambient dose equivalent rate nSv.h^{-1}
Den Burg	1001	66	Lelystad	1103	73
Den Helder [1]	1002	70	Urk	1105	75
Den Oever	1003	68	Eemshaven	1106	83
Petten	1006	60	Uithuizen	1107	82
Kolhorn	1007	77	Wagenborgen	1109	75
Egmond aan Zee	1009	66	Winschoten	1110	74
Heerhugowaard	1011	72	Ter Apel	1111	71
Nederhorst Den Berg	1015	76	Stadskanaal	1112	62
Velsen [2]	1016	71	Nieuweschans	1113	71
Enkhuizen	1018	71	Bellingwolde	1114	60
Oosthuizen	1019	72	Groningen	1116	73
Zaandam [3]	1021	71	Leens	1117	86
Gouda	1024	69	Grijpskerk	1118	72
Dordrecht	1027	64	Meppel	1125	68
Zuid Beijerland	1028	73	Hoogeveen	1126	61
Rotterdam-Schiebroek[4]	1031	64	Steenwijksmoer	1129	64
Pijnacker	1032	85	Nieuw Amsterdam	1130	78
Maasvlakte	1035	83	Nw. Schoonebeek/	1131	61
Rotterdam-Waalhaven	1036	65	Weiteveen		
Maassluis	1037	81	Emmen	1132	80
Hellevoetsluis	1038	91	Hengelo (Ov)	1135	69
Ouddorp	1039	72	Hengelo (Gld) [7]	1136	-
Wekerom	1041	74	Vroomshoop [8]	1138	64
Wageningen	1043	68	Enschede	1139	64
Amersfoort	1046	72	Losser	1140	62
Harderwijk	1050	64	Oldenzaal	1141	77
Wijk bij Duurstede	1056	81	Rijssen	1143	74
Nieuwegein	1062	79	's Heerenberg	1144	61
Zegveld [5]	1063	64	Dinxperlo	1145	79
Lopik (Cabauw) [6]	1064	84	Varsseveld	1146	98
Apeldoorn	1066	69	Groenlo	1147	83
Heerenveen	1071	70	Deventer	1148	77
Oosterwolde	1072	80	Etten-Leur	1154	68
Bergum	1074	67	Den Bosch	1157	68
Witmarsum	1076	86	Raamsdonkveer	1159	91
Sneek	1077	70	Ulvenhout	1160	72
St Jacobiparochie	1081	77	Baarle Nassau	1161	67
Holwerd	1082	87	Uden	1163	66
Leeuwarden	1085	69	Mill	1164	61
Zwolle-Zuid [7]	1087	-	Oss	1167	64
Ommen	1093	64	Nuenen	1172	70
Hardenberg	1095	64	Bergeijk	1174	87
Assen [7]	1097	-	Waalre	1175	68
Rutten	1099	74	Someren (Dorp)	1176	69

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Table A10: Continued

Station	No.	Ambient dose equivalent rate nSv.h^{-1}	Station	No.	Ambient dose equivalent rate nSv.h^{-1}
Oisterwijk	1178	71	Hoensbroek	1225	82
Riel	1179	71	Gennep	1228	73
Oostelbeers	1180	84	Elst (Gld)	1229	81
Hilvarenbeek	1181	65	Zevenaar	1230	72
Venray	1183	62	Nijmegen	1231	74
Nieuw-Bergen	1184	62	Amstelveen	1233	75
Sevenum	1185	70	Amsterdam Oost	1234	70
Reuver	1188	67	Aalsmeer	1236	74
Nederweert	1189	71	Nispen	1237	61
Heythuysen	1190	73	Groesbeek	1240	77
Mariahoop	1191	68	Tubbergen	1243	69
Stramproy	1192	64	Haaksbergen	1244	66
Eerbeek	1193	72	Scheveningen	1247	76
Leiden	1196	75	Zaltbommel	1251	70
Hulst	1197	77	IJzendijke	1252	76
Terneuzen	1199	70	Ritthem	1253	96
Sluis	1201	73	Vlissingen Haven	1254	73
Vlissingen	1202	76	Nieuwdorp	1255	74
Halsteren	1204	65	's Heerenhoek [9]	1256	114
Oud Gastel	1206	65	Driewegen	1257	81
Goes	1207	81	Arnemuiden	1258	72
Bruinisse	1209	74	Heinkenszand	1259	80
Burgh-Haamstede	1211	62	Baarland	1260	86
Vrouwenpolder	1212	63	Biervliet	1261	75
Wemeldinge	1214	75	Nummer Een	1262	75
Middelburg	1215	76	Rilland	1263	73
Westkapelle	1216	67	Putte	1264	56
Stein	1219	82	Nieuw Namen	1265	78
Maastricht	1220	88	Beneden Leeuwen	1272	85
Ravensbos (Arensgehout)	1221	85	Denekamp	1278	64
			Winterswijk (Kotten)	1279	68
Vaals	1222	80	Bilthoven	1280	61
Gulpen	1223	82	Gastel (Maarheze)	1281	77
Kerkrade	1224	85			

[1] The Julianadorp station was dismantled in January 2010 and relocated to Den Helder in October 2010.

[2] The Haarlem-Noord station was dismantled in October 2012 and relocated to Velsen in April 2013.

[3] The Zaandam station was dismantled in March 2012.

[4] The Rotterdam-Crooswijk station was dismantled and relocated to Rotterdam-Schiebroek in October 2010.

[5] The Noordwijk-Binnen station was dismantled and relocated to Zegsveld in July 2009.

[6] The Rhenen station was dismantled and relocated to Lopik (Cabouw) in July 2009.

[7] Station not operational in 2012.

[8] The Westerhaar station was dismantled and relocated to Vroomshoop in June 2012.

[9] As in previous years, the 's Heerenhoek station showed a significantly higher value than the other stations. This is due to a higher background level of the ground surface at the site. Since September 2009, this background level has been reduced by covering the surrounding ground surface with a layer of shells.

Table A11: Gross α, residual β, 3H, 90Sr and 226Ra activity concentrations (mBq·L-1) in surface water in 2013 as measured by RWS

Date	Gross α mBq·L^{-1}	Residual β mBq·L^{-1}	^{3}H mBq·L^{-1}	^{90}Sr mBq·L^{-1}	^{226}Ra mBq·L^{-1}
Location	**IJsselmeer**				
02/01/13	52	28			
31/01/13	47	54	2,040		
26/02/13	27	16			
26/03/13	69	47	2,700		
23/04/13	16	18			
22/05/13	34	14	2,590		
18/06/13	33	1			
16/07/13	21	29	2,660		
13/08/13	57	42			
11/09/13	21	34	2,660		
08/10/13	< 1	22			
05/11/13	63	46	2,770		
03/12/13	44	40			
30/12/13	65	66	2,460		
Average	39	33	2,550		
Location	**Nieuwe Waterweg**				
17/01/13	162	59	5,570	1.0	2.7
14/02/13	130	61			
14/03/13	172	41	3,990	1.0	1.3
11/04/13	111	25			
07/05/13	151	68	4,440	1.0	5.0
06/06/13	143	124			
04/07/13	43	22	2,600	< 1	3.0
01/08/13	140	40			
29/08/13	186	42	2,940	< 1	2.3
26/09/13	78	36			
24/10/13	139	31	4,580	< 1	8.9
21/11/13	90	49			
19/12/13	83	45	4,340	5.0	1.5
Average	125	49	4,100	1.4	3.5
Location	**Noordzeekanaal**				
14/01/13	193	23	2,260		
11/02/13	120	19	2,150		
11/03/13	281	21	2,670		
08/04/13	262	32	2,790		
06/05/13	308	24	3,060		
03/06/13	62	44	2,620		
01/07/13	392	27	2,780		
29/07/13	623	14	2,590		
26/08/13	100	20	2,100		
23/09/13	233	26	1,990		
21/10/13	186	30	1,960		
18/11/13	80	47	1,910		
17/12/13	133	20	1,970		
Average	230	27	2,370		

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Table A11: Continued

Date	Gross α mBq·L^{-1}	Residual β mBq·L^{-1}	^{3}H mBq·L^{-1}	^{90}Sr mBq·L^{-1}	^{226}Ra mBq·L^{-1}
Location	**Rhine**				
09/01/13	45	30	7,190		
06/02/13	151	115	1,700	4.6	2.5
06/03/13	61	35	5,380		
03/04/13	55	49	1,670	< 1	7.5
01/05/13	189	133	5,080		
29/05/13	68	47	1,840	1.0	2.9
26/06/13	41	36	1,640		
24/07/13	73	31	2,270	7.0	3.6
21/08/13	43	30	2,270		
18/09/13	38	38	4,720	< 1	2.5
16/10/13	27	10	1,490		
13/11/13	106	71	5,980	4.0	2.6
11/12/13	41	23	1,960		
Average	72	50	3,300	2.9	3.6
Location	**Scheldt**				
03/01/13	150	118	2,660		3.3
30/01/13	304	173			
27/02/13	230	144	2,600		12.2
28/03/13	244	152			
25/04/13	268	92	5,880		6.6
21/05/13	314	134			
17/06/13	558	37	8,750		6.4
15/07/13	328	71			
13/08/13	571	109	9,770		10.4
09/09/13	199	100			
08/10/13	150	107	10,100		8.7
07/11/13	311	162			
05/12/13	392	160	8,050		5.2
Average	310	120	6,800		7.5
Location	**Meuse**				
08/01/13	37	38	29,400		
05/02/13	33	37	8,430	3.5	2.6
05/03/13	30	34	980		
02/04/13	24	20	1,570	< 1	2.8
01/05/13	45	36	14,000		
28/05/13	43	32	958	2.0	2.7
25/06/13	28	15	40,400		
23/07/13	35	3	1,430	3.0	2.1
20/08/13	11	2	57,700		
17/09/13	21	23	40,500	3.0	1.6
15/10/13	30	< 1	11,000		
12/11/13	86	59	886	3.0	1.7
10/12/13	30	22	1,000		
Average	35	25	16,000	2.5	2.2

Table A12: ^{60}Co, ^{131}I, ^{137}Cs and ^{210}Pb activity concentrations in suspended solids (Bq·kg^{-1}) in surface water in 2013 as measured by RWS

Date	^{60}Co Bq·kg^{-1}	^{131}I Bq·kg^{-1}	^{137}Cs Bq·kg^{-1}	^{210}Pb Bq·kg^{-1}
Location	**IJsselmeer**			
02/01/13	< 1	< 1	6.9	
31/01/13	< 1	< 1	6.4	
26/02/13	< 1	< 1	6.5	
26/03/13	< 1	< 1	5.7	
23/04/13	< 1	< 1	3.4	
22/05/13	< 1	5.9	3.7	
18/06/13	< 1	< 1	3.1	
16/07/13	< 1	< 1	< 1	
13/08/13	< 1	< 1	2.0	
11/09/13	< 1	< 1	1.6	
08/10/13	< 1	< 1	< 1	
05/11/13	< 1	< 1	4.5	
03/12/13	< 1	< 1	3.3	
30/12/13	< 1	< 1	5.1	
Average	< 1	< 1	3.8	
Location	**Nieuwe Waterweg**			
17/01/13	< 1	< 1	8.3	91
14/02/13	< 1	< 1	7.4	
14/03/13	< 1	< 1	5.9	67
11/04/13	< 1	< 1	7.7	
07/05/13	< 1	< 1	10.0	97
06/06/13	< 1	< 1	4.7	
04/07/13	< 1	< 1	8.4	87
01/08/13	< 1	< 1	6.1	
29/08/13	< 1	< 1	6.7	70
26/09/13	< 1	1.9	8.5	
24/10/13	< 1	3.0	7.6	102
21/11/13	< 1	3.8	9.9	
19/12/13	< 1	4.6	9.6	106
Average	< 1	< 1.4	7.7	88
Location	**Noordzeekanaal**			
11/02/13	< 1	36.8	10.9	
08/04/13	< 1	< 1	5.3	
03/06/13	< 1	28.1	4.0	
29/07/13	< 1	22.7	5.0	
23/09/13	< 1	45.8	5.7	
18/11/13	< 1	40.7	12.5	
Average	< 1	29	7.2	

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Table A12: Continued

Date	^{60}Co Bq·kg^{-1}	^{131}I Bq·kg^{-1}	^{137}Cs Bq·kg^{-1}	^{210}Pb Bq·kg^{-1}
Location	**Rhine**			
09/01/13	< 1	< 1	12.8	
23/01/13	< 1	< 1	11.2	
06/02/13	< 1	< 1	13.5	102
20/02/13	< 1	< 1	11.8	
06/03/13	< 1	< 1	12.1	
20/03/13	< 1	10.5	9.6	
03/04/13	< 1	< 1	10.8	103
17/04/13	< 1	< 1	11.7	
01/05/13	< 1	< 1	10.3	
15/05/13	< 1	< 1	12.6	
29/05/13	< 1	4.3	13.8	113
12/06/13	< 1	< 1	12.3	
26/06/13	< 1	4.2	12.5	
10/07/13	< 1	< 1	10.0	
23/07/13	< 1	6.4	13.3	91
07/08/13	< 1	< 1	11.1	
21/08/13	< 1	< 1	10.9	
04/09/13	< 1	< 1	9.2	
18/09/13	< 1	4.5	11.3	150
02/10/13	< 1	< 1	10.6	
16/10/13	< 1	< 1	12.1	
30/10/13	< 1	5.5	13.9	
13/11/13	< 1	< 1	11.8	115
27/11/13	< 1	12.3	13.4	
11/12/13	< 1	< 1	12.8	
23/12/13	< 1	10.7	12.4	
Average	< 1	< 2.6	11.8	112
Location	**Scheldt**			
03/01/13	< 1	< 1	6.8	99
30/01/13	< 1	2.0	7.1	
27/02/13	< 1	< 1	6.4	88
28/03/13	< 1	1.8	5.6	
25/04/13	< 1	< 1	6.5	83
21/05/13	< 1	< 1	6.6	
17/06/13	< 1	< 1	6.8	81
15/07/13	< 1	< 1	6.3	
13/08/13	< 1	< 1	7.0	85
09/09/13	< 1	< 1	6.6	
09/10/13	< 1	< 1	6.5	78
07/11/13	< 1	< 1	6.0	
05/12/13	< 1	< 1	5.8	79
Average	< 1	< 1	6.5	85
Location	**Meuse**			
02/01/13	1.3	< 1	10.6	
08/01/13	3.6	< 1	12.4	
16/01/13	2.7	< 1	11.9	
22/01/13	2.5	< 1	14.6	
29/01/13	< 1	7.5	7.0	
05/02/13	3.0	< 1	11.8	107

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Table A12: Continued

Date	^{60}Co Bq·kg^{-1}	^{131}I Bq·kg^{-1}	^{137}Cs Bq·kg^{-1}	^{210}Pb Bq·kg^{-1}
Location	**Meuse**			
12/02/13	< 1	< 1	10.4	
19/02/13	1.6	9.8	9.5	
26/02/13	1.8	11.8	11.2	
05/03/13	3.5	17.3	10.0	
12/03/13	19.9	26.9	15.4	
19/03/13	11.2	10.1	13.8	
26/03/13	1.7	9.7	13.2	
02/04/13	< 1	< 1	11.2	115
09/04/13	< 1	< 1	9.6	
16/04/13	4.2	< 1	10.0	
23/04/13	10.6	< 1	9.7	
03/05/13	5.1	< 1	11.7	
08/05/13	5.7	< 1	11.3	
13/05/13	6.4	< 1	12.9	
21/05/13	5.7	12.6	12.6	
28/05/13	2.1	< 1	13.4	121
04/06/13	7.0	< 1	14.1	
10/06/13	2.0	18.4	15.9	
18/06/13	3.3	51.0	12.0	
24/06/13	13.1	23.0	13.9	
01/07/13	17.1	< 1	15.9	
08/07/13	9.1	< 1	11.5	
15/07/13	7.3	< 1	11.3	
23/07/13	5.0	30.8	8.4	123
29/07/13	10.7	14.4	11.6	
05/08/13	18.3	10.0	10.6	
12/08/13	6.3	< 1	15.1	
19/08/13	< 1	7.4	9.3	
27/08/13	7.5	3.1	11.9	
02/09/13	4.0	9.6	11.4	
09/09/13	3.5	38.9	11.2	
16/09/13	5.2	20.3	12.2	162
23/09/13	7.6	30.0	12.5	
30/09/13	6.9	35.2	12.6	
07/10/13	7.9	32.4	13.1	
14/10/13	12.8	11.9	14.7	
21/10/13	9.2	35.1	13.8	
28/10/13	11.6	8.4	12.8	
04/11/13	5.7	4.0	12.7	
11/11/13	< 1	6.1	10.0	121
19/11/13	1.9	3.1	10.6	
25/11/13	3.3	8.7	11.1	
02/12/13	9.3	10.3	12.1	
09/12/13	< 1	12.4	10.9	
16/12/13	< 1	8.0	9.9	
23/12/13	10.8	13.3	9.3	
30/12/13	< 1	< 1	8.5	
Average	5.7	10.6	11.8	125

Table A13: Gross α, residual β, ^3H and ^{90}Sr activity concentrations (mBq·L^{-1}) in seawater in 2013 as measured by RWS

Date	Gross α mBq·L^{-1}	Residual β mBq·L^{-1}	^3H mBq·L^{-1}	^{90}Sr mBq·L^{-1}
Location	**Coastal Area**			
13/02/13	645	68	4,390	
22/05/13	836	50	4,260	
12/08/13	158	39	3,190	
11/11/13	200	46	3,540	
Average	460	51	3,800	
Location	**Southern North Sea**			
13/02/13	580	22	6,260	< 1
22/05/13	831	24	1,320	3
15/08/13	138	28	2,600	< 1
11/11/13	353	41	3,330	3
Average	480	29	3,400	1.8
Location	**Central North Sea**			
15/01/13	862	44	236	1
16/04/13	1,140	39	374	< 1
12/06/13	656	34	407	< 1
14/08/13	732	41	329	5
Average	850	40	340	1.8
Location	**Delta Coastal Waters**			
16/01/13	585	64	4,740	
13/02/13	1,080	61	4,970	7.5
13/03/13	716	41	5,070	
15/04/13	516	43	4,820	
23/05/13	408	49	4,350	< 1
05/06/13	110	23	3,620	
18/07/13	854	49	3,330	
15/08/13	173	25	3,320	1
19/09/13	426	34	2,980	
16/10/13	439	26	3,110	
14/11/13	1,050	38	4,020	3
18/12/13	456	49	3,630	
Average	570	42	4,000	3

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Table A13: Continued

Date	Gross α mBq·L⁻¹	Residual β mBq·L⁻¹	³H mBq·L⁻¹	⁹⁰Sr mBq·L⁻¹
Location	**Westerscheldt**			
02/01/13	604	137	6,050	< 1
28/01/13	571	153	5,040	2
25/02/13	758	131	4,500	1
25/03/13	706	50	4,820	< 1
22/04/13	701	155	4,880	1
21/05/13	672	96	4,700	< 1
19/06/13	400	91	4,220	< 1
17/07/13	624	57	3,850	< 1
15/08/13	399	76	3,940	7
12/09/13	138	97	3,700	7
07/10/13	576	77	4,200	< 1
04/11/13	468	103	4,020	2
03/12/13	559	160	4,680	3
30/12/13	282	85	4,960	< 1
Average	530	105	4,540	1.9
Location	**Eems-Dollard**			
20/02/13	664	73	4,180	
21/05/13	112	17	4,400	
14/08/13	458	34	3,470	
13/11/13	419	51	2,290	
Average	410	44	3,600	
Location	**Wadden Sea West**			
12/02/13	750	48	3,750	
07/05/13	991	59	4,550	
20/08/13	1,250	18	2,970	
20/11/13	432	29	2,790	
Average	860	38	3,500	
Location	**Wadden Sea East**			
15/02/13	607	203	4,230	
17/05/13	762	81	4,020	
09/08/13	386	134	2,940	
12/11/13	432	227	2,780	
Average	550	160	3,500	

Table A14: ^{137}Cs and ^{210}Pb activity concentrations in suspended solids (Bq·kg^{-1}) in seawater in 2013 as measured by RWS

Date	^{137}Cs Bq·kg^{-1}	^{210}Pb [1] Bq·kg^{-1}
Location	**Coastal area**	
25/02/13	6.6	98
21/05/13	4.4	100
12/08/13	3.2	67
Average	4.7	88
Location	**Westerscheldt**	
18/02/13	5.4	74
16/05/13	3.7	64
27/08/13	4.1	65
02/12/13	4.3	70
Average	4.4	68
Location	**Eems-Dollard**	
19/02/13	7.4	99
16/05/13	6.1	92
17/09/13	4.8	95
15/11/13	4.6	97
Average	5.7	96
Location	**Wadden Sea West [2]**	
13/02/13	5.7	102
08/05/13	3.3	78
18/09/13	3.9	105
19/11/13	4.4	118
Average	4.3	101

[1] Since 2009, ^{210}Pb has been reported instead of ^{210}Po.

[2] Since 2009, ^{137}Cs and ^{210}Pb have not been determined at Wadden Sea East, but at Wadden Sea West.

Table A15: Monthly averaged gross α activity concentrations in air dust near the nuclear power plant at Borssele in 2013

Date [1]	Gross α [2] mBq·m^{-3}				
Location	**21**	**22**	**23**	**27**	**29**
05/02/13	0.021	0.006	0.028	0.015	0.026
06/03/13	0.012	0.012	0.021	0.005	0.032
03/04/13	0.037	0.012	0.046	0.028	0.026
01/05/13	0.013	0.030	0.027	0.037	0.020
05/06/13	0.045	< 0.013	0.022	0.010	0.018
03/07/13	0.011	0.032	0.038	0.018	0.028
08/08/13	0.054	< 0.013	0.036	0.016	0.026
05/09/13	0.043	0.026	0.038	0.010	0.036
07/10/13	0.026	0.019	0.037	0.024	- [3]
05/11/13	0.038	0.043	0.027	0.003	- [3]
04/12/13	0.03	0.008	0.016	0.021	- [3]
02/01/14	0.01	0.019	0.007	0.005	- [3]

[1] End date of monthly sampling period.

[2] Gross α activity concentrations in air dust are given as indicative values.

[3] Results unavailable due to a defective pump.

Table A16: Monthly averaged gross β activity concentrations in air dust near the nuclear power plant at Borssele in 2013

Date [1]	Gross β mBq·m⁻³				
	21	22	23	27	29
05/02/13	0.47 ± 0.05	0.01 ± 0.02	0.34 ± 0.03	0.35 ± 0.04	0.431 ± 0.014
06/03/13	0.32 ± 0.05	0.29 ± 0.02	0.36 ± 0.04	0.27 ± 0.04	0.610 ± 0.018
03/04/13	0.49 ± 0.06	0.11 ± 0.02	0.46 ± 0.04	0.36 ± 0.05	0.421 ± 0.015
01/05/13	0.22 ± 0.05	0.28 ± 0.02	0.30 ± 0.04	0.16 ± 0.04	0.410 ± 0.016
05/06/13	0.35 ± 0.05	0.031 ± 0.018	0.26 ± 0.03	0.17 ± 0.04	0.256 ± 0.013
03/07/13	0.05 ± 0.02	0.33 ± 0.03	0.28 ± 0.04	0.19 ± 0.04	0.323 ± 0.017
08/08/13	0.35 ± 0.04	0.08 ± 0.02	0.29 ± 0.03	0.22 ± 0.04	0.45 ± 0.03
05/09/13	0.41 ± 0.05	0.29 ± 0.03	0.36 ± 0.04	0.31 ± 0.04	0.56 ± 0.07
07/10/13	0.31 ± 0.05	0.15 ± 0.03	0.37 ± 0.03	0.18 ± 0.04	- [2]
05/11/13	0.28 ± 0.07	0.29 ± 0.02	0.28 ± 0.04	0.17 ± 0.04	- [2]
04/12/13	0.31 ± 0.06	0.057 ± 0.015	0.31 ± 0.03	0.03 ± 0.03	- [2]
02/01/14	0.43 ± 0.11	0.32 ± 0.02	0.30 ± 0.04	0.15 ± 0.04	- [2]

[1] End date of monthly sampling period.

[2] Results unavailable due to a defective pump.

Table A17: Monthly averaged activity concentrations of γ-emitters in air dust near the nuclear power plant at Borssele in 2013

Analysis was performed on a combined sample of the monthly samples from all five locations (21, 22, 23, 27 and 29).

Date [1]	^{60}Co mBq·m⁻³	$^{131}I_{el}$ [2] mBq·m⁻³	$^{131}I_{or}$ [3] mBq·m⁻³	^{137}Cs mBq·m⁻³	Nat. [4] mBq·m⁻³
05/02/13	< 0.03	< 0.1	< 0.4	< 0.02	< 1.2
06/03/13	< 0.04	< 0.1	< 0.4	< 0.03	1.54 ± 0.06
03/04/13	< 0.04	< 0.1	< 0.6	< 0.02	1.18 ± 0.06
01/05/13	< 0.04	< 0.10	< 0.4	< 0.03	< 1.5
05/06/13	< 0.03	< 0.08	< 0.3	< 0.02	< 1.2
03/07/13	< 0.03	< 0.2	< 0.4	< 0.03	< 1.2
08/08/13	< 0.04	< 0.1	< 0.4	< 0.03	< 1.3
05/09/13	< 0.06	< 0.2	< 0.8	< 0.04	< 2
07/10/13	< 0.05	< 0.2	< 0.7	< 0.04	< 2
05/11/13	< 0.06	< 0.2	< 0.7	< 0.05	< 2
04/12/13	< 0.07	< 0.1	< 1	< 0.05	< 1.9
02/01/14	< 0.06	< 0.2	< 1	< 0.05	< 2

[1] End date of monthly sampling period.

[2] Elemental ^{131}I.

[3] Organically bound ^{131}I.

[4] Naturally occurring γ-emitters.

Table A18: Activity concentrations of γ-emitters in grass near the nuclear power plant at Borssele in 2013
Analysis was performed on a combined sample of the monthly samples from all five locations (21, 22, 23, 27 and 29).

Date	Mass kg·m^{-2}	^{60}Co Bq·kg^{-1} [1]	^{131}I Bq·kg^{-1} [1]	^{137}Cs Bq·kg^{-1} [1]
05/02/13	0.837	< 2	< 2	< 2
06/03/13	0.535	< 2	< 2	< 1
03/04/13	0.501	< 2	< 2	< 2
01/05/13	0.440	< 3	< 2	< 2
05/06/13	0.818	< 3	< 3	< 2
03/07/13	0.978	< 3	< 2	< 2
08/08/13	0.775	< 2	< 2	< 2
05/09/13	0.799	< 2	< 2	< 1
07/10/13	0.497	< 2	< 2	< 2
05/11/13	0.749	< 2	< 2	< 2
04/12/13	1.66	< 1	< 1	< 1
02/01/14	0.746	< 2	< 3	< 2

[1] Dry weight.

Table A19: Activity concentrations of γ-emitters in soil near the nuclear power plant at Borssele in 2013
Analysis was performed on four samples taken near the outlet of the plant on 22 May 2013.

Location	Mass kg·m^{-2}	^{54}Mn Bq·kg^{-1} [1]	^{60}Co Bq·kg^{-1} [1]	^{134}Cs Bq·kg^{-1} [1]	^{137}Cs Bq·kg^{-1} [1]
O1	62.0	< 0.3	< 0.3	< 0.2	0.87 ± 0.10
O2	66.0	< 0.4	< 0.2	< 0.2	1.50 ± 0.06
O3	68.1	< 0.4	< 0.3	< 0.2	1.49 ± 0.12
O4	65.8	< 0.3	< 0.2	< 0.2	1.73 ± 0.07

[1] Dry weight.

Table A20: Residual β activity concentrations in water from the Westerscheldt area in 2013

Date	Residual β Bq·L^{-1}			
Location	1	2	3	4
05/02/13	0.102 ± 0.010	0.044 ± 0.007	0.042 ± 0.009	0.050 ± 0.008
06/03/13	0.074 ± 0.009	0.036 ± 0.008	0.040 ± 0.008	0.021 ± 0.008
03/04/13	0.027 ± 0.008	0.018 ± 0.007	0.019 ± 0.008	0.024 ± 0.008
01/05/13	0.003 ± 0.008	0.028 ± 0.008	0.018 ± 0.007	0.028 ± 0.006
05/06/13	0.020 ± 0.008	0.029 ± 0.007	0.031 ± 0.007	0.020 ± 0.006
03/07/13	0.045 ± 0.008	0.026 ± 0.005	0.017 ± 0.007	0.045 ± 0.007
08/08/13	0.095 ± 0.011	0.024 ± 0.008	0.083 ± 0.008	0.053 ± 0.008
05/09/13	0.041 ± 0.009	0.031 ± 0.009	0.022 ± 0.009	0.067 ± 0.009
07/10/13	0.029 ± 0.010	0.047 ± 0.009	0.047 ± 0.009	0.037 ± 0.009
05/11/13	0.079 ± 0.009	0.060 ± 0.010	0.015 ± 0.007	0.035 ± 0.006
04/12/13	0.047 ± 0.007	0.046 ± 0.007	0.036 ± 0.008	0.037 ± 0.007
02/01/14	0.022 ± 0.009	0.023 ± 0.007	0.030 ± 0.008	0.017 ± 0.005

Table A21: ^3H activity concentrations in water from the Westerscheldt area in 2013

Date	^3H $Bq·L^{-1}$			
Location	1	2	3	4
05/02/13	1.8 ± 1.1	2.6 ± 1.2	0.7 ± 1.1	2.9 ± 1.3
06/03/13	3.5 ± 1.2	2.6 ± 1.2	4.3 ± 1.2	2.6 ± 1.2
03/04/13	5.0 ± 1.2	2.0 ± 1.3	4.9 ± 1.2	2.5 ± 1.3
01/05/13	7.7 ± 1.2	6.8 ± 1.2	8.5 ± 1.2	4.0 ± 1.2
05/06/13	5.2 ± 1.2	2.3 ± 1.2	3.2 ± 1.2	3.7 ± 1.2
03/07/13	2.6 ± 1.3	2.4 ± 1.7	1.9 ± 1.7	6.7 ± 1.3
08/08/13	4.0 ± 1.7	2.2 ± 1.2	1.8 ± 1.2	4.9 ± 1.7
05/09/13	2.8 ± 1.2	2.5 ± 1.2	5.0 ± 1.2	5.3 ± 1.2
07/10/13	<1	2.1 ± 1.2	0.4 ± 1.2	2.4 ± 1.3
05/11/13	5.0 ± 1.1	5.3 ± 1.2	5.0 ± 1.1	4.5 ± 1.2
04/12/13	3.3 ± 1.2	3.4 ± 1.2	3.4 ± 1.2	4.4 ± 1.3
02/01/14	2.3 ± 1.1	4.5 ± 1.2	3.1 ± 1.2	5.6 ± 1.2

Table A22: Gross β activity concentrations in suspended solids from the Westerscheldt in 2013

Date	Gross β $kBq·kg^{-1}$			
Location	1	2	3	4
05/02/13	1.31 ± 0.08	1.01 ± 0.06	1.16 ± 0.06	0.79 ± 0.02
06/03/13	1.53 ± 0.11	1.52 ± 0.09	1.01 ± 0.02	0.530 ± 0.007
03/04/13	0.769 ± 0.014	0.88 ± 0.03	1.22 ± 0.03	1.07 ± 0.02
01/05/13	1.24 ± 0.16	0.648 ± 0.011	0.84 ± 0.03	1.17 ± 0.19
05/06/13	1.32 ± 0.08	1.53 ± 0.12	1.7 ± 0.3	1.33 ± 0.09
03/07/13	1.65 ± 0.17	1.19 ± 0.12	1.17 ± 0.06	0.92 ± 0.03
08/08/13	0.83 ± 0.04	0.62 ± 0.09	0.69 ± 0.04	1.05 ± 0.05
05/09/13	1.46 ± 0.19	2.6 ± 0.5	1.7 ± 0.3	0.97 ± 0.03
07/10/13	2.2 ± 0.4	1.08 ± 0.12	0.832 ± 0.017	1.14 ± 0.05
05/11/13	1.56 ± 0.09	0.71 ± 0.06	1.10 ± 0.05	1.17 ± 0.05
04/12/13	1.12 ± 0.04	1.27 ± 0.09	1.03 ± 0.04	0.92 ± 0.04
02/01/14	1.21 ± 0.06	1.28 ± 0.08	1.01 ± 0.02	1.21 ± 0.04

Table A23: Activity concentrations of γ-emitters in seaweed from the Westerscheldt area in 2013
Analysis was performed on a combined sample of the monthly samples from all four locations (1, 2, 3 and 4).

Date	Mass kg	^{60}Co Bq·kg^{-1} [1]	^{131}I Bq·kg^{-1} [1]	^{137}Cs Bq·kg^{-1} [1]
05/02/13	0.086	< 2	< 2	< 2
06/03/13	0.096	< 2	< 2	< 2
03/04/13	0.099	< 1	< 1	< 1
01/05/13	0.08	< 2	< 2	< 2
05/06/13	0.057	< 2	< 1	< 2
03/07/13	0.081	< 2	< 2	< 2
08/08/13	0.083	< 2	< 2	< 2
05/09/13	0.095	< 1	< 2	< 1
07/10/13	0.099	< 2	< 2	< 2
05/11/13	0.094	< 2	< 2	< 2
04/12/13	0.095	< 2	< 2	< 2
02/01/14	0.1	< 1	< 2	< 1

[1] Dry weight.

Table A24: Activity concentrations of γ-emitters in sediment from the Westerscheldt area in 2013
Analysis was performed on a combined sample of the monthly samples from all four locations (1, 2, 3 and 4).

Location	Mass kg·m^{-2}	^{60}Co Bq·kg^{-1} [1]	^{131}I Bq·kg^{-1} [1]	^{137}Cs Bq·kg^{-1} [1]
05/02/13	74.7	< 0.3	< 0.3	0.73 ± 0.04
06/03/13	71.9	< 0.3	< 0.4	0.83 ± 0.06
03/04/13	77.2	< 0.3	< 0.3	0.46 ± 0.05
01/05/13	66.1	< 0.3	< 0.3	1.17 ± 0.06
05/06/13	65.1	< 0.2	< 0.3	0.50 ± 0.04
03/07/13	64.3	< 0.3	< 0.5	0.31 ± 0.04
08/08/13	68.6	< 0.2	< 0.2	0.44 ± 0.04
05/09/13	65.6	< 0.3	< 0.4	0.90 ± 0.11
07/10/13	76.7	< 0.3	< 0.3	0.72 ± 0.04
05/11/13	65.3	< 0.3	< 0.2	1.06 ± 0.05
04/12/13	69.8	< 0.3	< 0.3	0.40 ± 0.04
02/01/14	72.6	< 0.3	< 0.4	1.03 ± 0.05

[1] Dry weight.

Appendix B – Presentation of data

The methods described below were applied to the data provided by RIVM/VLH (e.g. air dust and deposition), unless otherwise stated. Data from the other institutions are reported as provided, unless otherwise stated.

B.1 Correction for radioactive decay
In general, the activities of specific nuclides are corrected for radioactive decay. The measured activities in the sample are multiplied by a decay factor combining the time from halfway through the sampling period to the time of analysis, the decay during the measurement and the half-life of the nuclide. If the nuclides are unknown, as with gross α and gross β, no correction for radioactive decay is made.

B.2 Calculation of sums and averages
In the calculation of weekly, monthly or yearly averages or sums, the original results before rounding are used. If a certain nuclide cannot be measured, the detection limit is used in the calculation of the sums. In that case, solely a range (lower and upper limit) is given instead of a total with an uncertainty. Both range and total with an uncertainty are presented with a 68% confidence interval.

The lower and upper limits are calculated as follows:

$$\text{Lower limit} = \sum x_i - \sqrt{\sum s_i^2}$$

$$\text{Upper limit} = \sum x_i + \sqrt{\sum s_i^2} + \sum MDA_i$$

where

x_i = weekly or monthly result that is not a detection limit;

$\sqrt{\sum s_i^2}$ = the uncertainty in the sum;

s_i = uncertainty in the weekly or monthly result (1σ);

MDA_i = weekly or monthly result that is a detection limit.

The detection limits are omitted in the calculation of the averages. If data are not reported (e.g. no sample is analysed), the sampling period is not taken into account for the calculation of the sum or average.

B.3 Calculation of uncertainties
The uncertainties given in Tables A1 to A8 are a combination of the statistical uncertainties and estimations of the experimental uncertainties. In the yearly total, the uncertainty is the square root of the sum of the squared weekly or monthly uncertainties. In the yearly average, the uncertainty is the square root of the sum of the squared weekly uncertainties divided by the number of weeks.

B.4 Mixed diets: conversion from Bq·kg⁻1 to intake in Bq·day⁻¹
With respect to the results presented for mixed diets (Chapter 8), RIKILT Wageningen UR converted the measured concentrations of ^{90}Sr,

^{134}Cs and ^{137}Cs in food (Bq·kg^{-1}) to an average daily intake value per person per day (Bq·day^{-1}) using food consumption patterns. For the Netherlands, the food consumption patterns were investigated by the RIVM and the results can be found in the report 'Dutch National Food Consumption Survey 2007–2010. Diet of children and adults aged 7 to 69 years' [72]. In this report the consumption patterns are presented per food category, sex and age group, in grams per consumption day, and the percentage of consumption days. These values were combined to an average consumption amount in g·day^{-1} for each food category, sex and age group.

For each sex and age group and specific nuclide, the daily intake ($DI_{a,s,n}$) is then calculated as follows:

$$DI_{a,s,n} = \sum_{i} \frac{DI_{a,s,i}}{1000} \times AC_{i,n}$$

where

$DI_{a,s,n}$ = daily intake per age group, sex and nuclide (Bq·day^{-1});

i = food category;

$DI_{a,s,i}$ = daily intake per age group, sex and food category (g·day^{-1});

$AC_{i,n}$ = activity concentration per food category and nuclide (Bq·kg^{-1}).

These daily intakes were then averaged over the different age groups and sexes to get the total daily intake per person for each nuclide. To include the monitoring results of ready meals in the final result, the assumption was made that these ready meals make up 10% of the consumption of the categories meat, fish and vegetables.

Appendix C – Glossary

Ambient dose equivalent	An operational quantity used when monitoring radiation in the environment. The unit of ambient dose equivalent is the Sievert (Sv).
Becquerel (Bq)	One radioactive transformation per second.
Decay product	A decay product (also known as a daughter product, daughter isotope, or daughter nuclide) is a nuclide resulting from the radioactive decay of a parent isotope or precursor nuclide. The decay product may be stable or it may decay to form a daughter product of its own.
Dose rate	The radiation dose delivered per unit of time.
Effective dose	The sum of the equivalent doses from internal and external radiation in all tissue and organs of the body, having been weighted by their tissue weighting factors. The unit of effective dose is the Sievert (Sv).
Gross alpha activity	Gross α (or total α) activity is the total activity of nuclides emitting α radiation.
Gross beta activity	Gross β (or total β) activity is the total activity of nuclides emitting β-radiation. Depending on the measurement methodology, it might exclude tritium and/or radon daughters.
Radioactivity	The emission of α particles, β particles, neutrons, and γ or X radiation from the disintegration of an atomic nucleus. The unit of radioactivity is the Becquerel (Bq).
Radiocesium activity	Sum of the activity of ^{134}Cs and ^{137}Cs.
Radionuclide	An unstable form of an element that undergoes radioactive decay.
Residual beta activity	The residual β activity is the gross β activity (total β activity) minus the β activity of naturally occurring 40K. For brackish and salt water, the RWS uses a direct method to determine the residual β activity [43].

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