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

Environmental radioactivity in the Netherlands

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Results in 2012

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Colophon

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Abstract

Environmental radioactivity in the Netherlands
Results in 2012

In 2012 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 performing the measurements on a uniform basis for every Member State.

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 Union about radioactivity in the environment on behalf of the Netherlands.

Radioactivity in air, food, and milk
In 2012 a radiological incident occurred, the consequences of which could be detected in the Netherlands. A radionuclide originating from an accidental release at a facility in Budapest (Hungary) was detected in air dust from 27 January until 2 February. The level of the radionuclide measured in the Netherlands as a result of this incident was very low and did not pose a threat to public health.
Except for measurements performed during this radiological incident, 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 Union.

Radioactivity in surface water
In some locations, the radioactivity levels in surface water were above the target values set by the Vierde Nota Waterhuishouding (1998). Target values should preferably not be exceeded, but they are not set limits as such. The measured levels do not, however, pose a threat to public health.

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

Publiekssamenvatting

Radioactiviteit in het Nederlandse milieu
Resultaten in 2012

In 2012 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, oftewel radioactiviteitsniveaus die onder normale omstandigheden aanwezig zijn. Deze waarden kunnen bijvoorbeeld bij calamiteiten of rampen als referentie dienen. Het RIVM rapporteert namens Nederland over radioactiviteit in het milieu aan de Europese Unie.

Radioactiviteit in lucht, voedsel en melk
In 2012 vond in een niet nader gespecificeerd gebouw in Budapest (Hongarije) een radiologisch incident plaats waarna in Nederland het vrijgekomen radionuclide te meten was. Dit radionuclide werd hier van 27 januari tot 2 februari in luchtstof aangetoond. Het niveau was zeer laag en vormde geen risico voor de volksgezondheid.
Op bovenstaand incident na lieten metingen in lucht en omgeving een normaal beeld zien, dat niet verschilde 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.

Radioactiviteit in oppervlaktewater
In het oppervlaktewater liggen de radioactiviteitsniveaus op een aantal locaties boven de streefwaarden die in de Vierde Nota waterhuishouding (1998) zijn bepaald. De streefwaarden mogen bij voorkeur niet overschreden worden, maar de overschrijdingen zijn zodanig dat ze niet schadelijk zijn voor de volksgezondheid. De mate van radioactiviteit in oppervlaktewater wordt beoordeeld op basis van streefwaarden; er bestaan voor oppervlaktewater geen limieten voor toezicht en handhaving op radioactieve stoffen.

Trefwoorden:
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 (RIVM/VLH), ir. J.F.M. Versteegh (RIVM/DMG)

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, ing. C. Onstenk, ing. A. Vos van Avezathe

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

Contents

Summary

The Dutch government is required to measure radioactivity in air, water, and soil under the terms of the Euratom Treaty of 1957. In 2000, the European Union 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 annually. This report presents the results of radioactivity measurements performed in the Dutch environment in 2012. The measurements were carried out by RIVM, RWS, RIKILT, NVWA, and (tasked by N.V. EPZ) NRG.

Yearly averaged activity concentrations in air dust were determined for gross α, gross β, ^{7}Be, ^{137}Cs and ^{210}Pb. A trace amount of ^{131}I was detected in the air sample from week 5 (27 January to 2 February), with an activity concentration of 2.7 ± 0.8 μBq·m^{-3}. This concentration does not pose a threat to public health. During the same period, and the previous week, ^{131}I was detected by several other institutes in countries across Europe in the same order of magnitude. The source of the ^{131}I detected across Europe was a release into the atmosphere from a facility in Budapest, Hungary.

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 72.6 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 were determined in suspended solids in surface water. 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 were determined in suspended solids in seawater. The results are presented in Table S1.

The gross α activity concentration in the Noordzeekanaal, Nieuwe Waterweg, and Scheldt exceeded the target value (100 mBq·L^{-1}) in 10 out of the 13, 6 out of the 13, and 13 out of the 13 samples taken, respectively. The yearly averaged gross α activity concentrations in the Noordzeekanaal and Scheldt (180 and 250 mBq·L^{-1}, respectively) were above the target value, but within the range of those in previous years.

The residual β activity concentration in the Scheldt exceeded the target value (200 mBq·L^{-1}) in 1 out of the 13 samples taken. The yearly averaged residual β activity concentrations were below the target value.

The ^{3}H activity concentration in the Rhine, Scheldt and Meuse exceeded the target value (10 $Bq \cdot L^{-1}$) in 1 out of the 13, 1 out of the 6, and 6 out of the 13 samples taken, respectively. The yearly averaged ^{3}H activity concentration in the Meuse (14.0 $Bq \cdot L^{-1}$) was above the target value, but within the range of those in previous years.

The yearly averaged and individual ^{90}Sr activity concentrations in surface water were below the target value (10 $mBq \cdot L^{-1}$).

The ^{226}Ra activity concentration in the Nieuwe Waterweg, Rhine and Scheldt exceeded the target value (5 $mBq \cdot L^{-1}$) in 1 out of the 6, 1 out of 7, and 6 out of the 6 samples taken, respectively. The yearly averaged ^{226}Ra activity concentration in the Scheldt (7.4 $mBq \cdot L^{-1}$) was above the target value, but within the range of those in previous years.

The ^{60}Co activity concentration in suspended solids in the Meuse exceeded the target value (10 $Bq \cdot kg^{-1}$) in 33 out of the 52 samples taken. The yearly averaged ^{60}Co activity concentration in the Meuse (14.7 $Bq \cdot kg^{-1}$) was above the target value, but within the range of those in previous years.

The ^{131}I activity concentration in suspended solids in the Noordzeekanaal and Meuse exceeded the target value (20 $Bq \cdot kg^{-1}$) in 5 out of the 7, and 9 out of the 52 samples taken, respectively. The yearly averaged ^{131}I activity concentration in the Noordzeekanaal (23 $Bq \cdot kg^{-1}$) was above the target value, but within the range of those in previous years.

The yearly averaged and individual ^{137}Cs activity concentrations in suspended solids in surface water were below the target value (40 $Bq \cdot kg^{-1}$).

The ^{210}Pb activity concentrations in suspended solids in the Nieuwe Waterweg, Rhine, Scheldt, and Meuse exceeded the target value (100 $Bq \cdot kg^{-1}$) in 6 out of the 6, 7 out of the 7, 1 out of the 6, and 7 out of the 7 samples taken, respectively. The yearly averaged ^{210}Pb activity concentrations in the Nieuwe Waterweg, Rhine and Meuse (111, 126 and 147 $Bq \cdot kg^{-1}$, respectively) were above the target value, but 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 concentrations were below 0.1 $Bq \cdot L^{-1}$. The gross β activity concentrations were below 1.0 $Bq \cdot L^{-1}$ and the ^{3}H activity concentrations were below 100 $Bq \cdot L^{-1}$.

The results of the monitoring program for milk and food (including mixed diet) are presented in Table S1. Radioactivity was measured in approximately 900 milk samples and 1,300 food products, of which 13 samples contained ^{137}Cs. One sample of honey, one sample of fruit, and nine samples of game contained ^{137}Cs. None of the samples exceeded the set limit of 600 $Bq \cdot kg^{-1}$ (or 370 $Bq \cdot kg^{-1}$ for milk and dairy products) for the activity of radiocesium (sum of ^{134}Cs and ^{137}Cs).

Data on environmental samples taken around the nuclear power plant at Borssele are presented in Table S2. The ^{3}H activity concentrations in surface water are 3 to 4 times lower than those in previous years. The gross β activity concentrations in suspended solids are 1.5 times higher than those in previous years. The changes in trend of these ^{3}H and gross β activity concentrations coincide with a change in the analysis procedures, and are currently under investigation.

In 2012, the Netherlands complied with the Euratom recommendations on annually measuring radioactivity in the environment and in food.

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 Unie dit nauwkeuriger gespecificeerd middels aanbevelingen. Hierin wordt 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. In dit rapport worden de resultaten gegeven van radioactiviteitsmetingen in het Nederlandse milieu in 2012. De metingen zijn verricht door RIVM, RWS, RIKILT, NVWA en (in opdracht van N.V. EPZ) NRG.

In luchtstof werd de jaargemiddelde activiteitsconcentratie bepaald van totaal-α, totaal-β, ^{7}Be, ^{137}Cs en ^{210}Pb. In week 5 (27 januari tot 2 februari) werd een spoor ^{131}I aangetroffen in luchtstof met een activiteitsconcentratie van 2,7 ± 0,8 µBq·m^{-3}, dit vormt geen risico voor de volksgezondheid. Gedurende dezelfde periode en de week ervoor werd ^{131}I in dezelfde ordegrootte gedetecteerd door verschillende instituten in landen verspreid over Europa. Het ^{131}I was afkomstig van een lozing in de atmosfeer door een faciliteit in Budapest, Hongarije.

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, dit 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 72,6 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 totaal α-activiteitsconcentratie in het Noordzeekanaal, de Nieuwe Waterweg en de Schelde overschrijdt de streefwaarde (100 mBq·L^{-1}) in respectievelijk 10 van de 13, 6 van de 13 en 13 van de 13 genomen monsters. De jaargemiddelde totaal α-activiteitsconcentraties in het Noordzeekanaal en de Schelde (respectievelijk 180 en 250 mBq·L^{-1}) zijn boven de streefwaarde, maar vallen binnen het bereik van voorgaande jaren.

De rest β-activiteitsconcentratie de Schelde overschrijdt de streefwaarde (200 mBq·L^{-1}) in 1 van de 13 genomen monsters. De jaargemiddelde rest β-activiteitsconcentraties zijn beneden de streefwaarde.

De ^{3}H-activiteitsconcentratie in de Rijn, de Schelde en de Maas overschrijdt de streefwaarde (10 Bq·L^{-1}) in respectievelijk 1 van de 13, 1 van de 6 en 6 van de 13 genomen monsters. De jaargemiddelde ^{3}H-activiteitsconcentratie in de Maas (14,0 Bq·L^{-1}) is boven de streefwaarde, maar valt binnen het bereik van voorgaande jaren.

De jaargemiddelde en individuele ^{90}Sr-activiteitsconcentraties in oppervlaktewater zijn beneden de streefwaarde (10 mBq·L^{-1}).

De ^{226}Ra-activiteitsconcentratie in de Nieuwe Waterweg, de Rijn en de Schelde overschrijdt de streefwaarde (5 mBq·L^{-1}) in respectievelijk 1 van de 6, 1 van de 7 en 6 van de 6 genomen monsters. De jaargemiddelde ^{226}Ra-activiteitsconcentratie in de Schelde (7,4 mBq·L^{-1}) is boven de streefwaarde, maar valt binnen het bereik van voorgaande jaren.

De ^{60}Co-activiteitsconcentratie in zwevend stof in de Maas overschrijdt de streefwaarde (10 Bq·kg^{-1}) in 33 van de 52 genomen monsters. De jaargemiddelde ^{60}Co-activiteitsconcentratie in de Maas (14.7 Bq·kg^{-1}) is boven de streefwaarde, maar valt binnen het bereik van voorgaande jaren.

De ^{131}I-activiteitsconcentratie in zwevend stof in het Noordzeekanaal en de Maas overschrijdt de streefwaarde (20 Bq·kg^{-1}) in respectievelijk 5 van de 7 en 9 van de 52 genomen monsters. De jaargemiddelde ^{131}I-activiteitsconcentratie in de Maas is echter beneden de streefwaarde. De jaargemiddelde ^{131}I-activiteitsconcentratie in het Noordzeekanaal (23 Bq·kg^{-1}) is boven de streefwaarde, maar valt binnen het bereik van voorgaande jaren.

De jaargemiddelde en individuele ^{137}Cs-activiteitsconcentraties in zwevend stof in oppervlaktewater zijn beneden de streefwaarde (40 Bq·kg^{-1}).

De ^{210}Pb-activiteitsconcentratie in zwevend stof in de Nieuwe Waterweg, de Rijn, de Schelde en de Maas overschrijdt de streefwaarde (100 Bq·kg^{-1}) in respectievelijk 6 van de 7, 7 van de 7, 1 van de 6 en 7 van de 7 genomen monsters.
De jaargemiddelde ^{210}Pb-activiteitsconcentraties in de Nieuwe Waterweg, de Rijn en de Maas (respectievelijk 111, 126 en 147 Bq·kg^{-1}) zijn boven de streefwaarde, maar 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 ruw water voor de drinkwaterproductie gevonden worden, zijn weergegeven in Tabel S1. In dit water is weinig kalium, en dus ^{40}K, aanwezig. In 2012 waren de totaal α-activiteitsconcentraties lager dan 0,1 Bq·L^{-1}. 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 ongeveer 900 melkmonsters en 1300 voedselprodukten waarvan 13 monsters ^{137}Cs bevatte. Eén monster honing,

één monster fruit en 9 monsters wild bevatte ^{137}Cs. Geen 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).

Gegevens betreffende milieumonsters genomen rondom de kerncentrale Borssele zijn weergegeven in Tabel S2. De ^{3}H-activiteitsconcentratie in oppervlaktewater was 3 à 4 keer lager dan in voorgaande jaren. De totaal β-activiteitsconcentratie in zwevend stof was 1,5 keer hoger dan in voorgaande jaren. Deze veranderingen in trend voor ^{3}H- en totaal β-activiteitsconcentraties overlappen met veranderingen in de analyseprocedures en een nader onderzoek hiernaar loopt nog.

Nederland voldeed in 2012 aan alle Europese aanbevelingen ten aanzien van de jaarlijkse radioactiviteitsmetingen in het milieu en in voedsel.

Table S1: Summary of the results of the Dutch monitoring program in 2012

Matrix	Parameter	Locations	Values	Frequency (per year)
Air dust [1]	Gross α	1	0.029 mBq·m^{-3}	53
	Gross β	1	0.384 mBq·m^{-3}	53
	^{7}Be	1	3.540 mBq·m^{-3}	53
	^{137}Cs	1	0.000272 mBq·m^{-3}	53
	^{210}Pb	1	0.365 mBq·m^{-3}	53
Deposition [2]	Gross α	1	32.7 Bq·m^{-2}	12
	Gross β	1	88 Bq·m^{-2}	12
	^{3}H	1	316–1,650 Bq·m^{-2} [3]	12
	^{7}Be	1	1,330 Bq·m^{-2}	53
	^{137}Cs	1	0–1.2 Bq·m^{-2} [3]	53
	^{210}Pb	1	98 Bq·m^{-2}	53
	^{210}Po	1	33.8 Bq·m^{-2}	12
Surface water [1]	Gross α	6	29–250 mBq·L^{-1}	12–13 [4]
	Residual β	6	26–110 mBq·L^{-1}	12–13 [4]
	^{3}H	6	2,580–14,000 mBq·L^{-1}	6–13 [4]
	^{90}Sr	3	2.2–4.0 mBq·L^{-1}	6–7 [4]
	^{226}Ra	4	2.2-7.4 mBq·L^{-1}	6–7 [4]
Suspended solids in surface water [1]	^{60}Co	6	< 1–14.7 Bq·kg^{-1}	7–52 [4]
	^{131}I	6	< 1–23 Bq·kg^{-1}	7–52 [4]
	^{137}Cs	6	4.0–12.7 Bq·kg^{-1}	7–52 [4]
	^{210}Pb	4	93–147 Bq·kg^{-1}	6–7 [4]
Seawater [1]	Gross α	8	310–460 mBq·L^{-1}	4–13 [4]
	Residual β	8	37–168 mBq·L^{-1}	4–13 [4]
	^{3}H	8	120–4,930 mBq·L^{-1}	4–13 [4]
	^{90}Sr	4	< 1–2.6 mBq·L^{-1}	4–13 [4]
Suspended solids in seawater [1]	^{137}Cs	4	4.2–7.1 Bq·kg^{-1}	4 [4]
	^{210}Pb	4	66–105 Bq·kg^{-1}	4 [4]
Drinking water [1]	Gross α	184	< 0.1 Bq·L^{-1}	370 [5]
	Gross β	185	< 0.1 Bq·L^{-1}	399 [5]
	Residual β	170	< 0.2 Bq·L^{-1}	369 [5]
	^{3}H	188	< 4.2 Bq·L^{-1}	435 [5]
Milk [1]	^{40}K	24	55.8 Bq·L^{-1}	891 [5]
	^{60}Co	24	< 1.4 Bq·L^{-1}	891 [5]
	^{90}Sr	24	< 0.2 Bq·L^{-1}	51 [5]
	^{131}I	24	< 0.6 Bq·L^{-1}	891 [5]
	^{134}Cs	24	< 0.6 Bq·L^{-1}	891 [5]
	^{137}Cs	24	< 0.5 Bq·L^{-1}	891 [5]

Continued on the next page

Table S1: Continued

Matrix	Parameter	Locations	Values	Frequency (per year)
Food [6, 7]				
Grain and grain products	^{137}Cs [8]	-	< 5 Bq·kg^{-1}	42 (0) [9]
Vegetables	^{137}Cs [8]	-	< 5 Bq·kg^{-1}	73 (0) [9]
Fruit and fruit products	^{137}Cs [8]	-	10 Bq·kg^{-1}	43 (1) [9]
Milk and dairy products	^{137}Cs [8]	-	< 5 Bq·kg^{-1}	32 (0) [9]
Meat and meat products	^{137}Cs [8]	-	< 5 Bq·kg^{-1}	18 (0) [9]
Game and poultry	^{137}Cs [8]	-	7 Bq·kg^{-1}	41 (1) [9]
Salads	^{137}Cs [8]	-	< 5 Bq·kg^{-1}	33 (0) [9]
Oil and butter	^{137}Cs [8]	-	< 5 Bq·kg^{-1}	36 (0) [9]
Honey	^{137}Cs [8]	-	50 Bq·kg^{-1}	46 (1) [9]
Tea	^{137}Cs [8]	-	< 5 Bq·kg^{-1}	50 (0) [9]
Food [6, 10]				
Vegetables	^{137}Cs [11]	-	< 2 Bq·kg^{-1}	50 (0) [9]
	^{90}Sr	-	< 0.5 Bq·kg^{-1}	2 (0) [9]
Meat and meat products	^{137}Cs [11]	-	< 2 Bq·kg^{-1}	539 (0) [9]
	^{90}Sr	-	< 5 Bq·kg^{-1}	21 (0) [9]
Bone	^{90}Sr	-	< 10 Bq·kg^{-1}	40 (0) [9]
Game and poultry	^{137}Cs [11]	-	6.9–44 Bq·kg^{-1}	44 (8) [9]
	^{90}Sr	-	< 5 Bq·kg^{-1}	5 (0) [9]
Eggs	^{137}Cs [11]	-	< 2 Bq·kg^{-1}	81 (0) [9]
	^{90}Sr	-	< 5 Bq·kg^{-1}	2 (0) [9]
Fish and seafood products	^{137}Cs [11]	-	< 2 Bq·kg^{-1}	155 (0) [9]
	^{90}Sr	-	< 10 Bq·kg^{-1}	24 (0) [9]
Mixed diet	^{137}Cs [8]	-	< 5 Bq·kg^{-1}	40 (0) [9]
	^{90}Sr	-	< 5 Bq·kg^{-1}	40 (0) [9]

[1] Yearly average.

[2] Yearly total.

[3] A 68% confidence range.

[4] Frequency depends on location.

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

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

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

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

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

[10] As measured by RIKILT Wageningen UR.

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

Table S2: Summary of the results of the monitoring program in the vicinity of the nuclear power plant at Borssele in 2012

Matrix	Parameter	Locations	Values [1]	Frequency (per year)
Air dust	Gross α	5	0.003–0.43 mBq·m^{-3}	12
	Gross β	5	0.024–0.717 mBq·m^{-3}	12
	^{60}Co	5 [2]	< 0.024–< 0.08 mBq·m^{-3}	12
	$^{131}I_{el}$ [3]	5 [2]	< 0.1–0.6 mBq·m^{-3}	12
	$^{131}I_{or}$ [3]	5 [2]	< 0.2–1 mBq·m^{-3}	12
	^{137}Cs	5 [2]	< 0.020–< 0.07 mBq·m^{-3}	12
	Nat. [4]	5 [2]	0.96–2.5 mBq·m^{-3}	12
Grass	^{60}Co	5 [2]	< 2–< 6 Bq·kg^{-1}	12
	^{131}I	5 [2]	< 2–< 5 Bq·kg^{-1}	12
	^{137}Cs	5 [2]	< 1–< 5 Bq·kg^{-1}	12
Soil	^{54}Mn	4	< 0.1–< 0.2 Bq·kg^{-1}	1
	^{60}Co	4	< 0.2 Bq·kg^{-1}	1
	^{134}Cs	4	< 0.1–< 0.2 Bq·kg^{-1}	1
	^{137}Cs	4	0.39–0.78 Bq·kg^{-1}	1
Water	Residual β	4	0.017–0.169 Bq·L^{-1}	12
	^{3}H	4	0.44–7.9 Bq·L^{-1}	12
Suspended solids	Gross β	4	0.755–3.1 kBq·kg^{-1}	12
Seaweed	^{60}Co	4 [2]	< 1–< 4 Bq·kg^{-1}	12
	^{131}I	4 [2]	< 1–< 4 Bq·kg^{-1}	12
	^{137}Cs	4 [2]	< 1–< 3 Bq·kg^{-1}	12
Sediment	^{60}Co	4 [2]	< 0.2–< 1 Bq·kg^{-1}	12
	^{131}I	4 [2]	< 0.2–< 0.4 Bq·kg^{-1}	12
	^{137}Cs	4 [2]	0.34–1.62 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 respectively organically bound ^{131}I.

[4] Naturally occurring γ-emitters.

1 Introduction

Levels of radioactive nuclides of natural origin, such as ^{40}K and daughters from the uranium and thorium series, may be enhanced as a result of human activities (e.g. emissions from factories processing ores). Man-made radionuclides are found in the environment as a result of, for example, nuclear weapons tests or discharges from nuclear installations. Monitoring radiation in the environment provides knowledge about radiation levels under normal circumstances, and enables detection and confirmation of abnormal levels. This report presents the results of radioactivity measurements made in the environment in the Netherlands. The aims of this report are threefold: 1) to present a survey of radioactivity measurements made in the Dutch environment under normal circumstances; 2) to show the compliance of monitoring programs in the Netherlands with the EU recommendation and to report possible omissions; 3) to be transmitted to the EU and to other Member States as the Dutch national report on radioactivity in the environment.

In the chapters, the results will be presented in graphs and tables. More detailed tables are presented in Appendix A. Chapters 2 to 8 are subdivided according to the structure of the 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 environmental samples taken around the nuclear power plant at Borssele. General conclusions from Chapters 1 to 9 are presented in Chapter 10.

A glossary of frequently occurring terms is given in Appendix C.

2 Airborne particles

Table 2.1 describes the monitoring program 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 (three 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 data from 1991 to 2004 were re-analysed to determine the yearly averages following the method described in Appendix B [7]. This can lead to small differences between the data presented in this report and the data reported prior to 2005.

Table 2.1: Monitoring program 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
	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 about 125,000 m^3 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 period between sampling and analysis was five to ten days, which is long compared with the decay time of the short-lived decay products of ^{222}Rn and ^{220}Rn. This is done to ensure that these naturally occurring decay products do not contribute to the measured α and β activity concentrations. 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 2012 were within the range of the results from the period 1992-2011, 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 a change in the reported gross α (-24%) and gross β (-15%) results for which no correction is applied [3]. A possible explanation for this change 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.

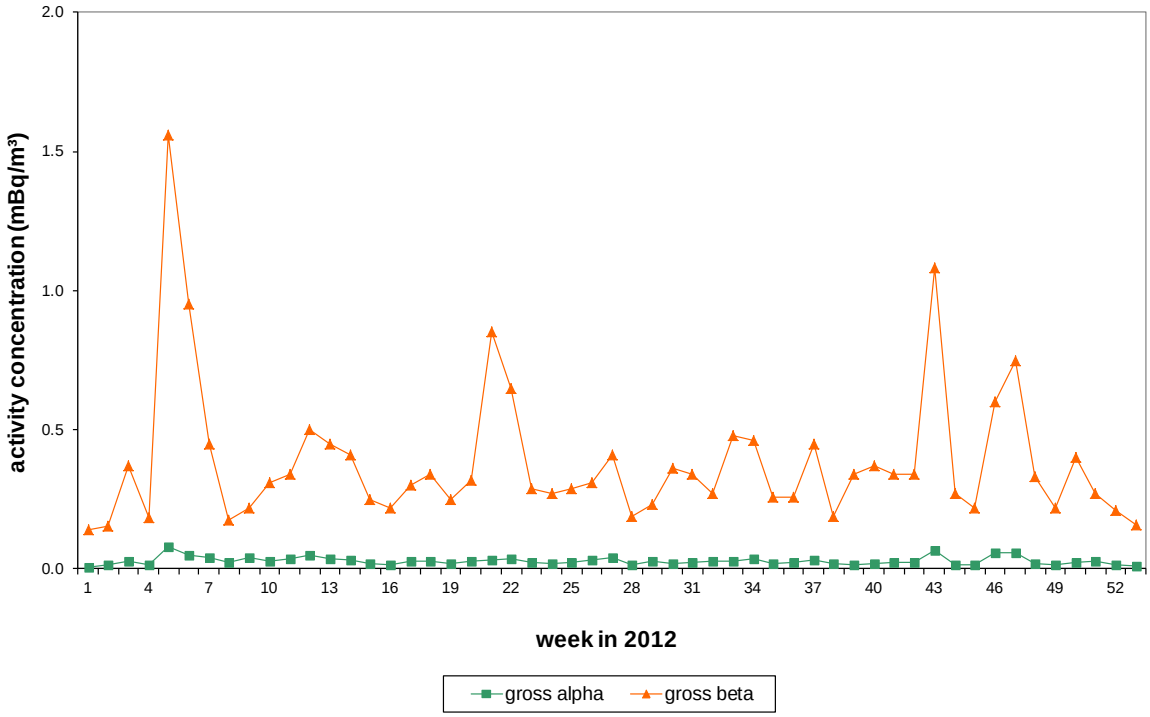

Figure 2.1: Weekly averaged gross α and β activity concentrations of long-lived nuclides in air dust sampled at RIVM

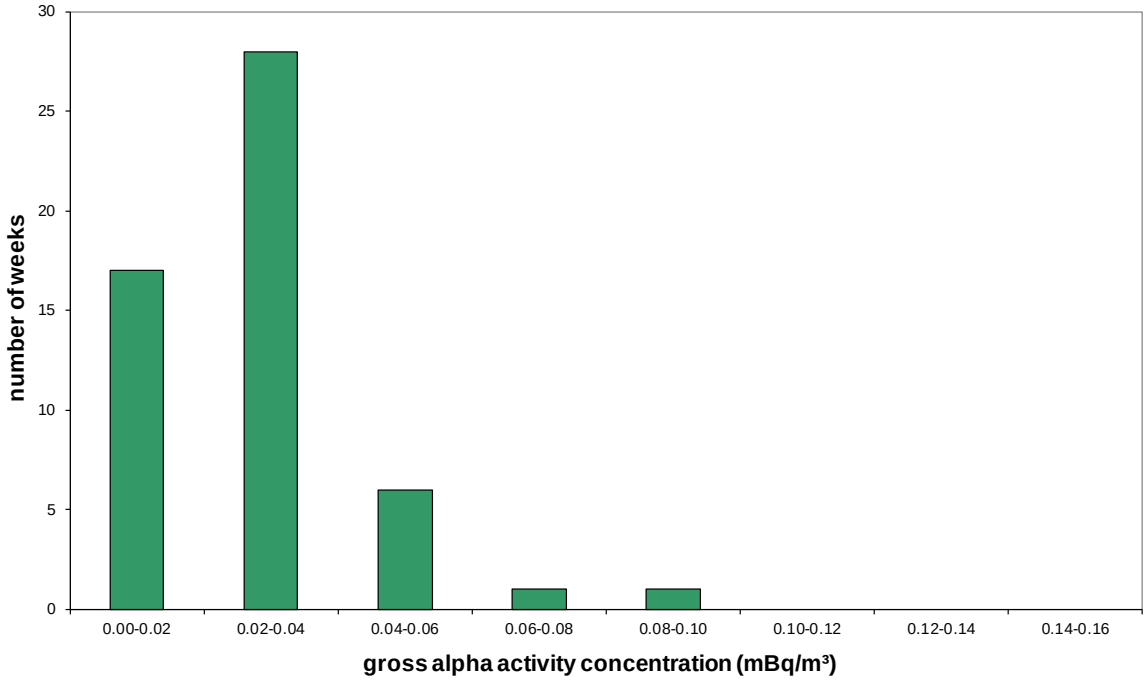

Figure 2.2: Frequency distribution of gross α activity concentration of long-lived nuclides in air dust collected weekly in 2012

The yearly average was 0.029 (SD=0.014) mBq·m^{-3}. SD is the standard deviation and illustrates the variation in weekly averages during the year.

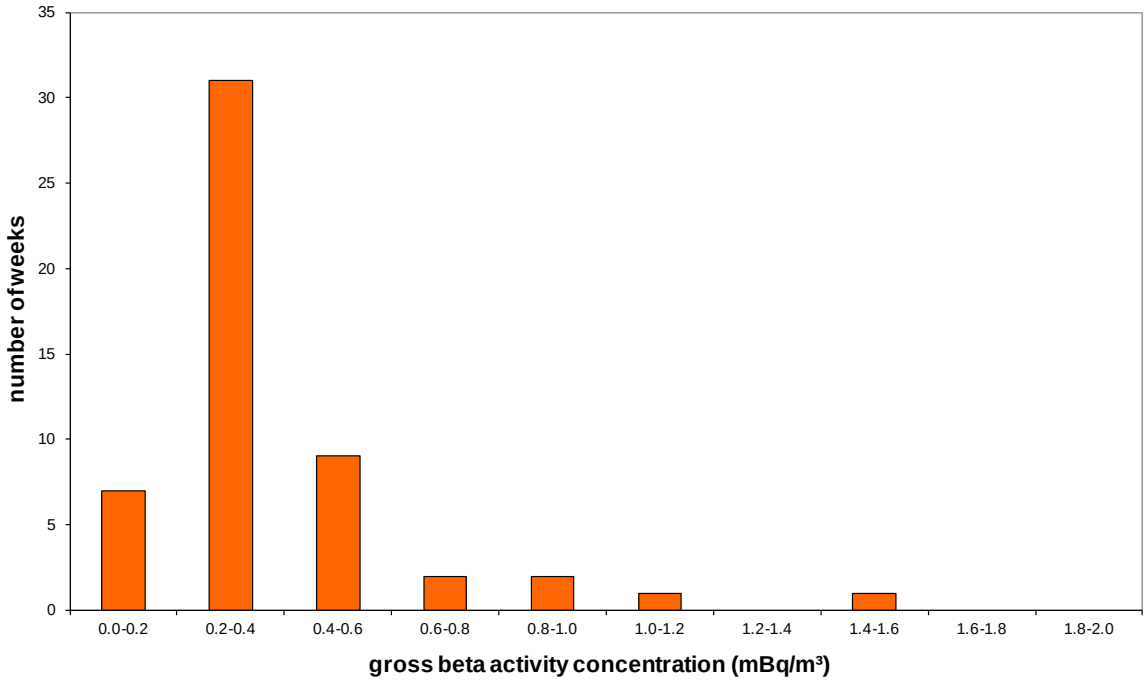

Figure 2.3: Frequency distribution of gross β activity concentration of long-lived nuclides in air dust collected weekly in 2012
The yearly average was 0.384 ± 0.007 *(SD=0.3) mBq·m^{-3}.*

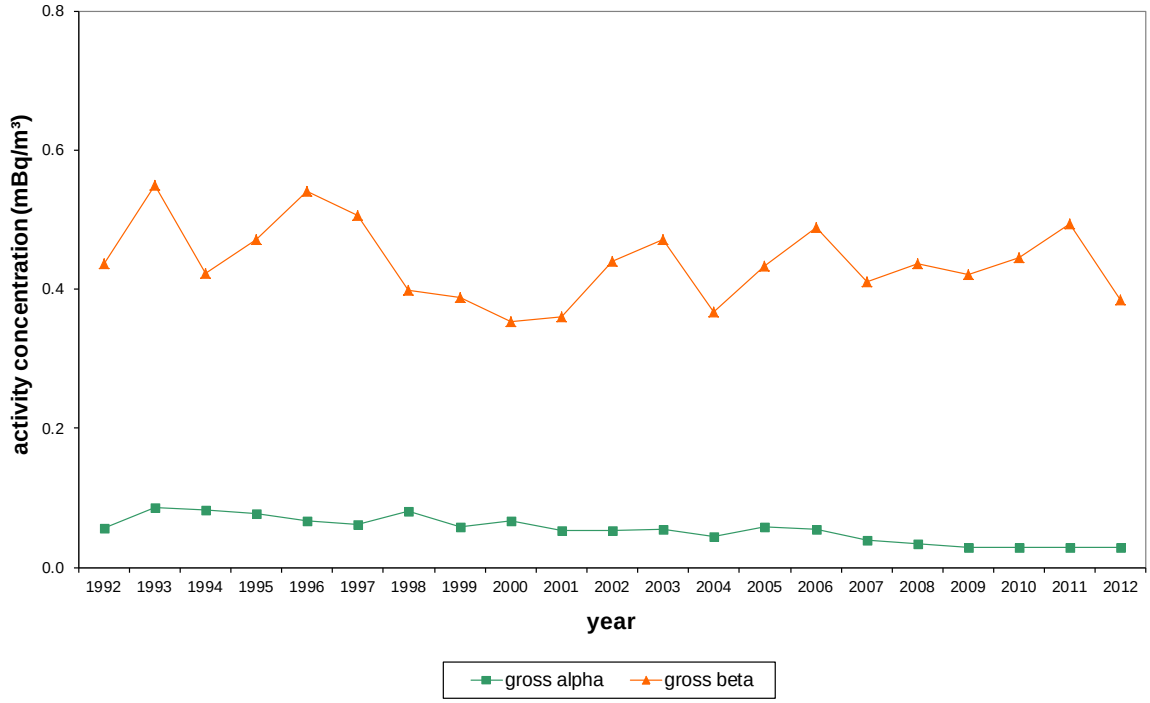

Figure 2.4: Yearly averaged gross α and gross β activity concentrations of long-lived nuclides in air dust at RIVM since 1992

2.2 γ-emitting nuclides

Several nuclides were detected regularly, ^{7}Be (52 times), ^{210}Pb (52 times), and ^{137}Cs (41 times). The results are presented in Table A3 and Figures 2.5, 2.6 and 2.7. The detection limits for the nuclides considered in the gammaspectroscopic analysis of the HVS samples are given in Table A2. Between 2000 and the middle of 2009, the detection limit of ^{137}Cs was higher than from 1991 to 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.

A trace amount of ^{131}I was detected in the sample from week 5 (27 January to 2 February) with an activity concentration of 2.7 ± 0.8 μBq·m^{-3}. This concentration did not pose a threat to public health. During the same period and the week before ^{131}I was detected by several other institutes in countries across Europe (Finland, Norway, Sweden, Germany, Austria, Poland, Czech republic, France, and Luxembourg) in the same order of magnitude [8, 9 10]. The source of the ^{131}I detected across Europe was a release into the atmosphere from a facility in Budapest, Hungary [11].

The behaviour of ^{7}Be in the atmosphere has been studied worldwide [12, 13, 14, 15, 16, 17, 18]. 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 remaining 30% 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 [19]. 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 [20]. 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 2012 fit into the pattern described above.

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.

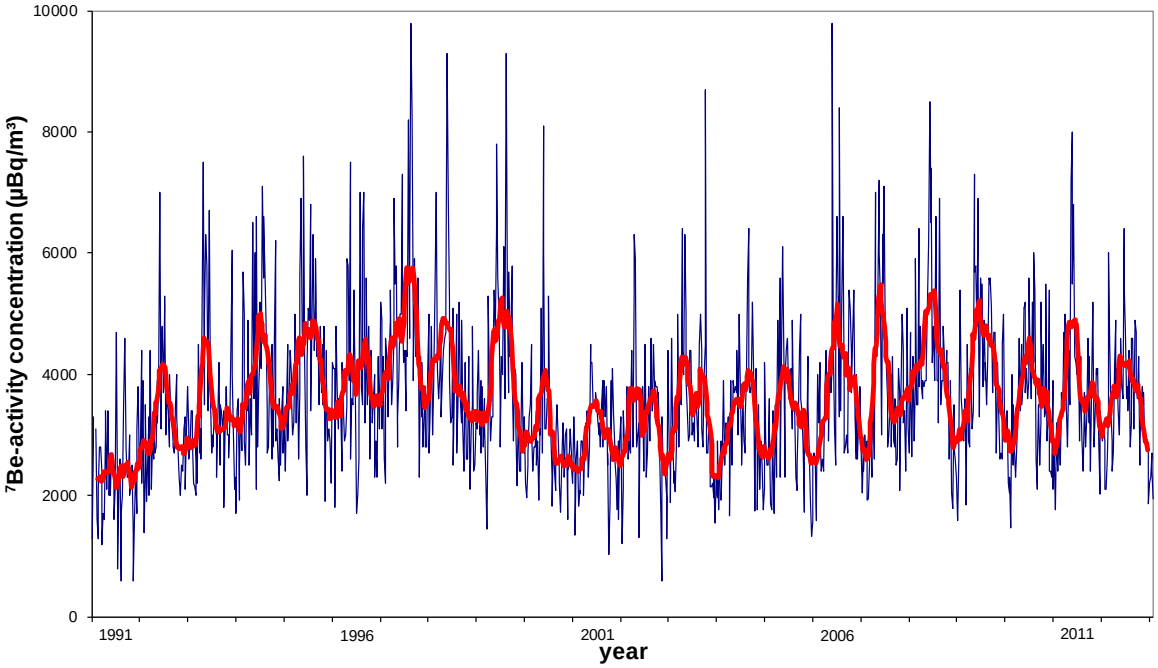

Figure 2.5: Weekly averaged ^{7}Be activity concentrations (blue) in air dust at RIVM since 1991

The red line is a moving average of 13 weeks. The yearly average for 2012 was 3540 ± 50 (SD=1000) µBq·m^{-3}.

Figure 2.6 shows a peak during May 1992. During the same period, several wildfires occurred near the Chernobyl area [21], and the level of airborne ^{137}Cs activity increased ten times in the 30 km exclusion zone around Chernobyl. It is plausible that the airborne ^{137}Cs was transported to Western Europe by the weather conditions in the same period (dry with a strong easterly wind [22]). On 29 May 1998, an incident occurred at Algeciras (Spain): an iron foundry melted a ^{137}Cs source concealed in scrap metal [23]. 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 until 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 strong wind from the continent [23]. 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 [24].

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 reference value of ^{210}Pb in air dust is 500 µBq·m^{-3} [25]. In the atmosphere this radionuclide is predominantly associated with submicron-sized aerosols [26,27]. The mean aerosol (carrying ^{210}Pb) residence time in the troposphere is approximately five days [28].

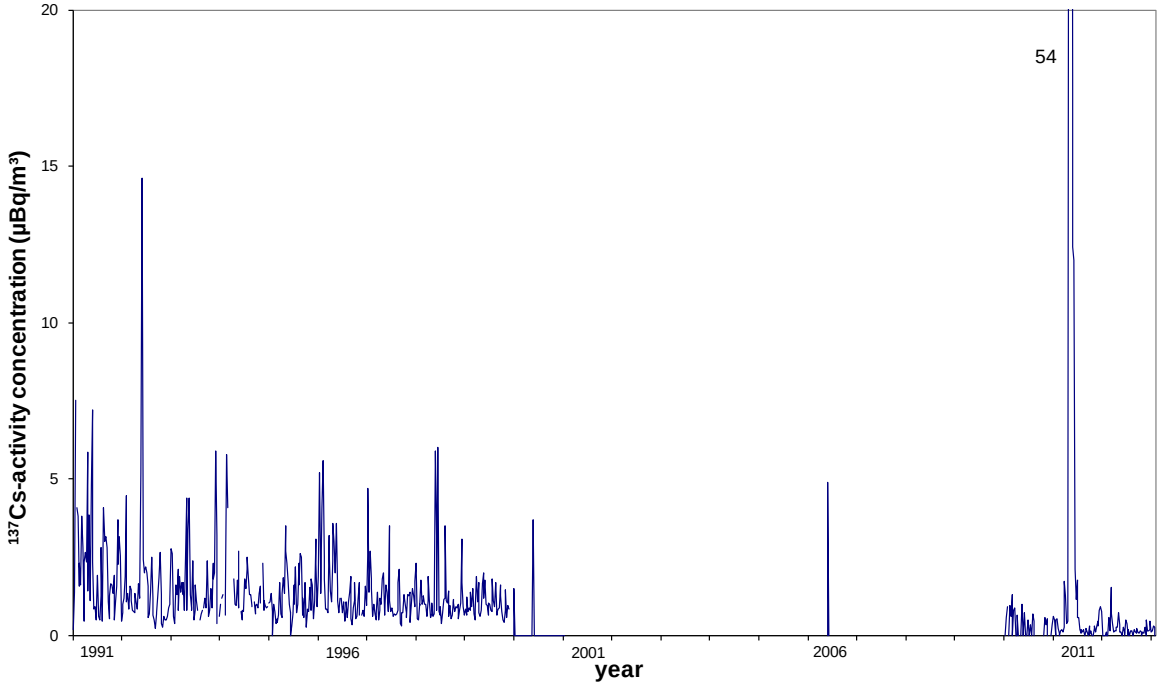

Figure 2.6: Weekly averaged ^{137}Cs activity concentrations in air dust at RIVM since 1991

Twelve out of the 53 measurements were below the detection limit in 2012. The yearly average for 2012 was 0.272 ± 0.007 (SD=0.3) 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 (see Table A2).

Other sources of ^{210}Pb in air dust are volcanic activity and industrial emissions [29,30,31,32,33,34]. 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 [34]. Volcanic eruptions bring uranium decay products into the atmosphere, such as ^{226}Ra, ^{222}Rn, ^{210}Pb, and ^{210}Po. Beks et al. [31] 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 [35, 36, 37], or resuspension of (local) dust. Normally there is a good correlation between ^{210}Pb and gross β activity concentrations, as was the case in 2012 (Figure 2.8). The weekly averaged ^{210}Pb activity concentrations in 2012 were within the range of those found in previous years (Figure 2.7).

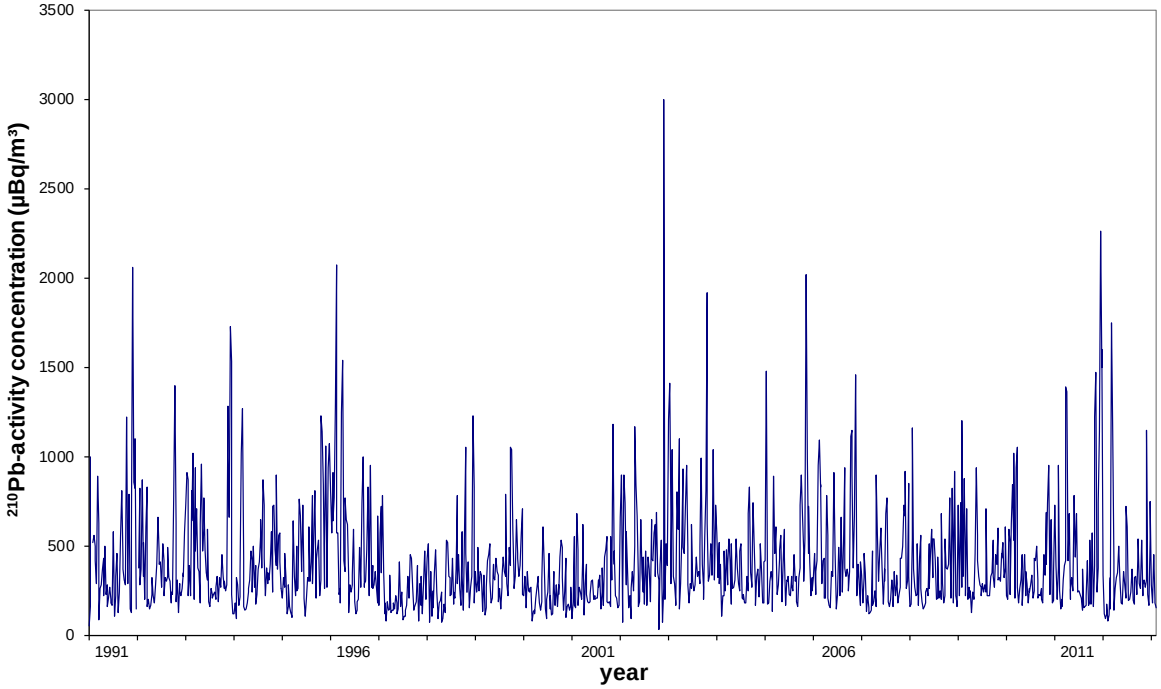

Figure 2.7: Weekly averaged ^{210}Pb activity concentrations in air dust at RIVM since 1991

The yearly average for 2012 was 365 ± 6 (SD=300) µBq·m^{-3}.

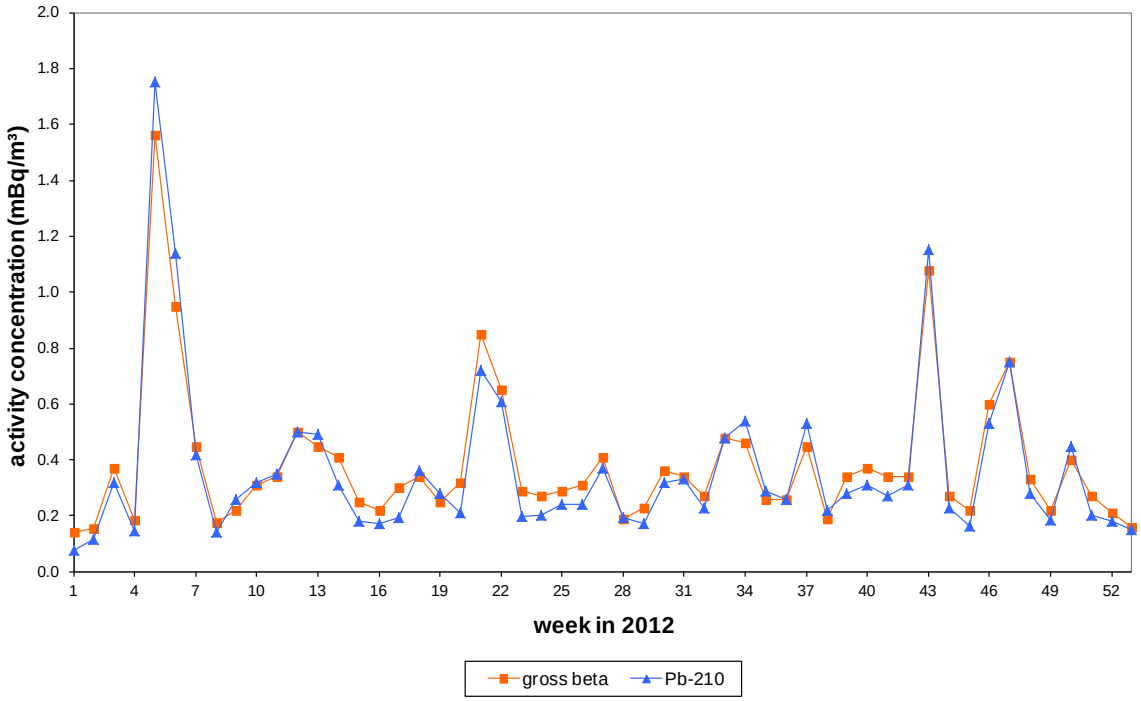

Figure 2.8: Figure illustrating the correlation between weekly averaged gross β and ^{210}Pb activity concentrations in air dust at RIVM

3 Deposition

Table 3.1 describes the monitoring program 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, ^{3}H and ^{210}Po according to a standard procedure [38].

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, 39, 40].

The monthly samples for ^{3}H 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 [41], 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 instead of the procedure described in [41].

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 program 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
	Bilthoven	gross α, gross β, and ^{210}Po	month	variable	monthly
	Bilthoven	^{3}H	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 32.7 ± 1.1 and 88 ± 2 $Bq \cdot m^{-2}$, 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 ^{3}H is given in Table A4. In 2012, the yearly total deposition of ^{3}H ranged between 316 and 1,650 $Bq \cdot m^{-2}$ (68% confidence level). The yearly total consisted of 12 samples, and 9 of the 12 measurements were below the detection limit. These detection limits were used for the contribution to the yearly total, following Appendix B. The range in 2012 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.

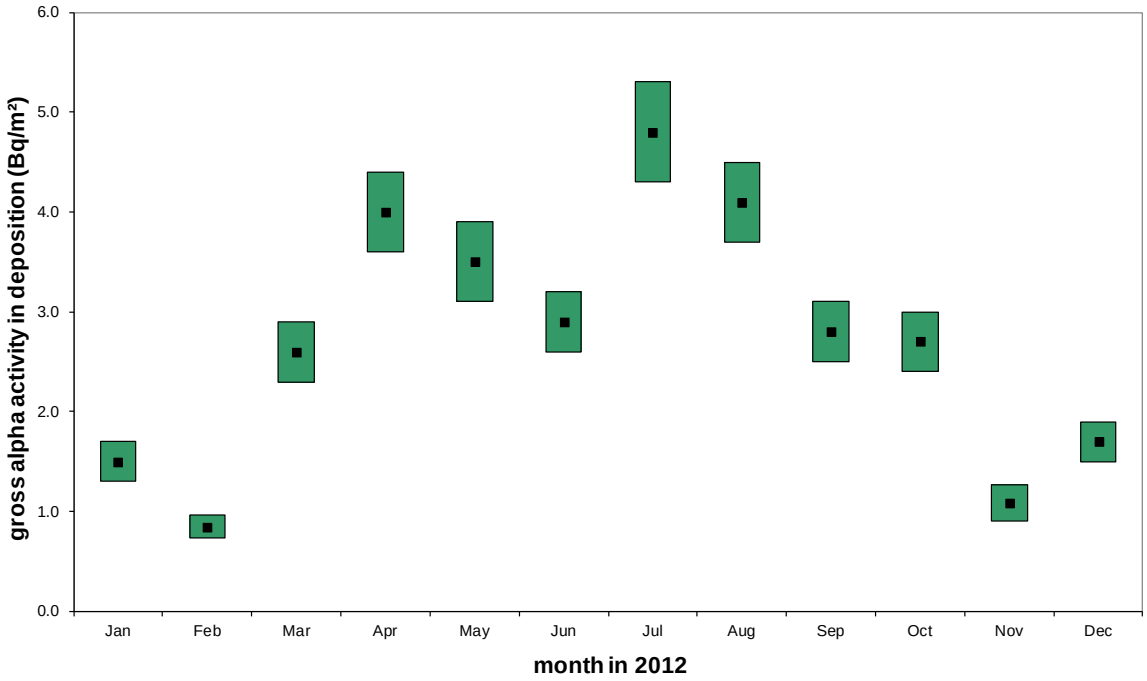

Figure 3.1: Monthly deposited gross α activity of long-lived nuclides at RIVM
Monthly totals (black dots) are shown with a 68% confidence range (coloured bars).

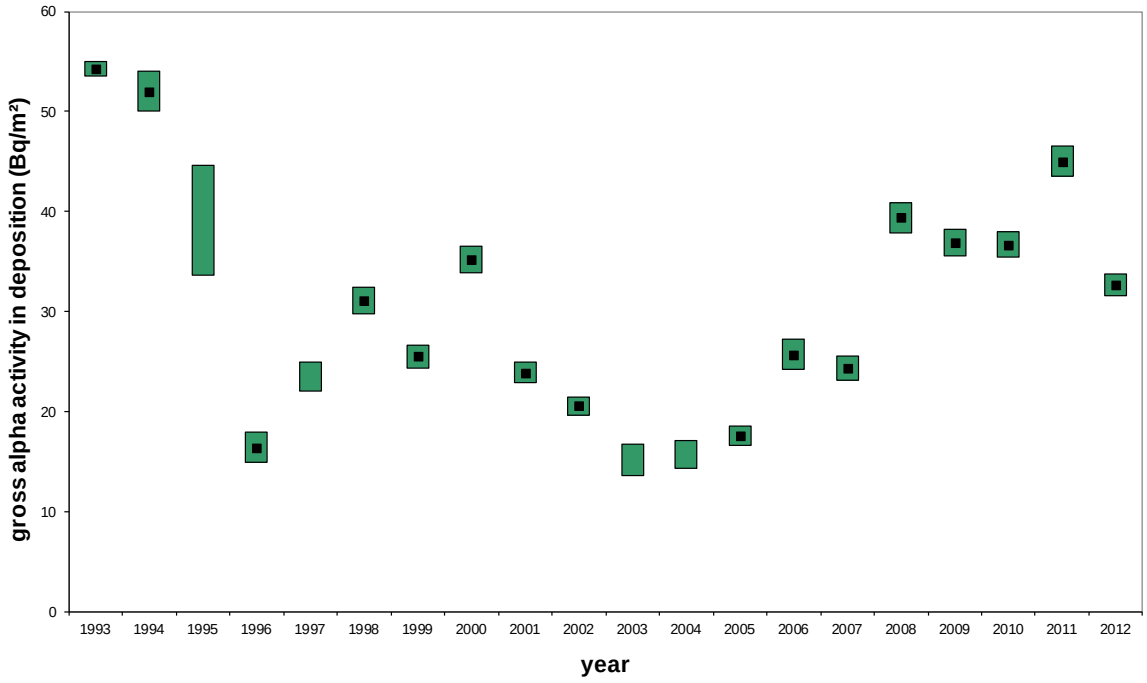

Figure 3.2: Yearly gross α activity of long-lived nuclides deposited at RIVM since 1993
Yearly totals (black dots) are shown with a 68% confidence range (coloured bars). Only the 68% confidence range is shown if the yearly result is made up of at least one detection limit.

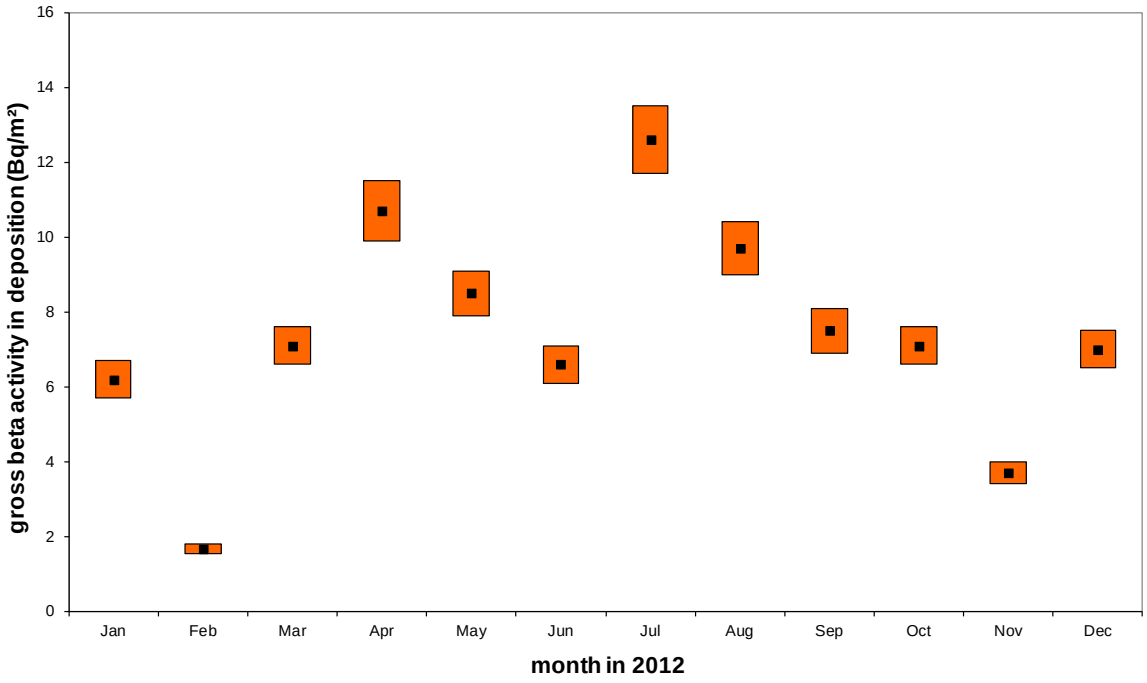

Figure 3.3: Monthly deposited gross β activity of long-lived nuclides at RIVM
Monthly totals (black dots) are shown with a 68% confidence range (coloured bars).

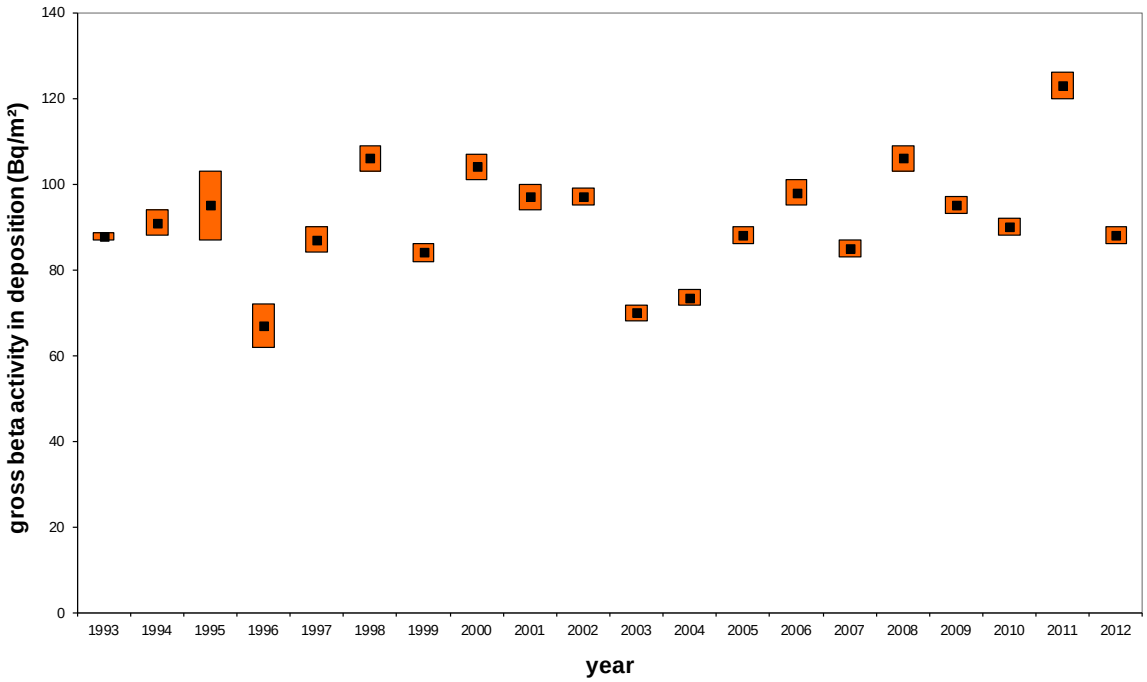

Figure 3.4: Yearly gross β activity of long-lived nuclides deposited at RIVM since 1993
Yearly totals (black dots) are shown with a 68% confidence range (coloured bars).

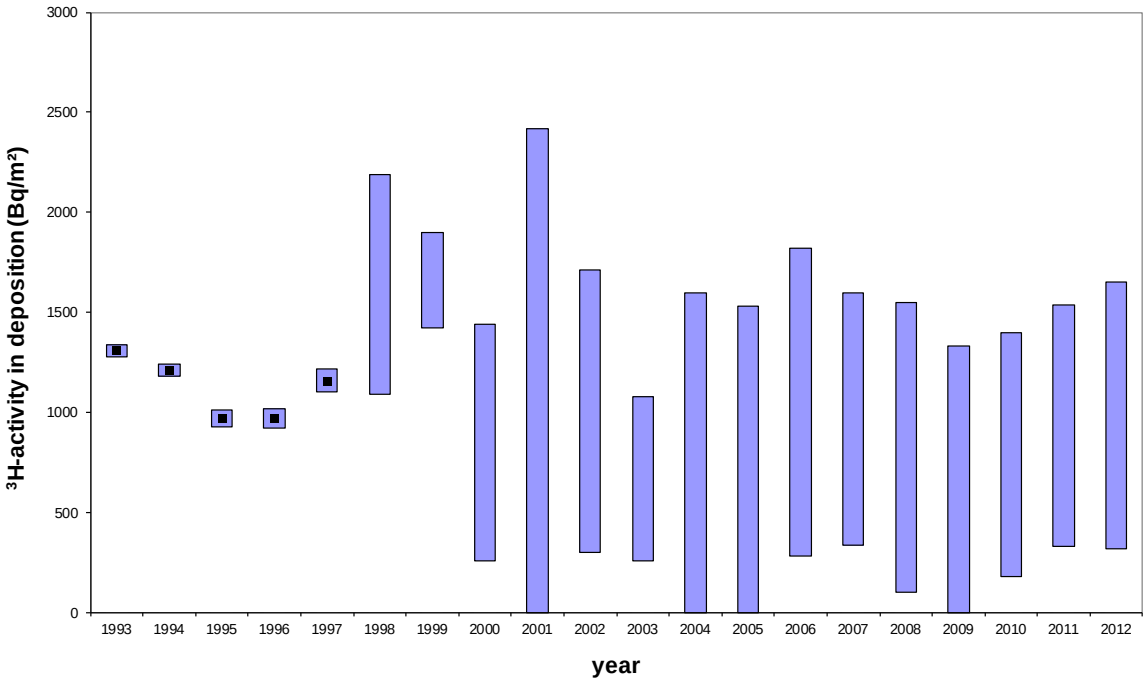

Figure 3.5: Yearly deposition of ^{3}H at RIVM since 1993
Yearly totals (black dots) are shown with a 68% confidence range (coloured bars). Only the 68% confidence range is shown if the yearly result is made up of at least one detection limit.

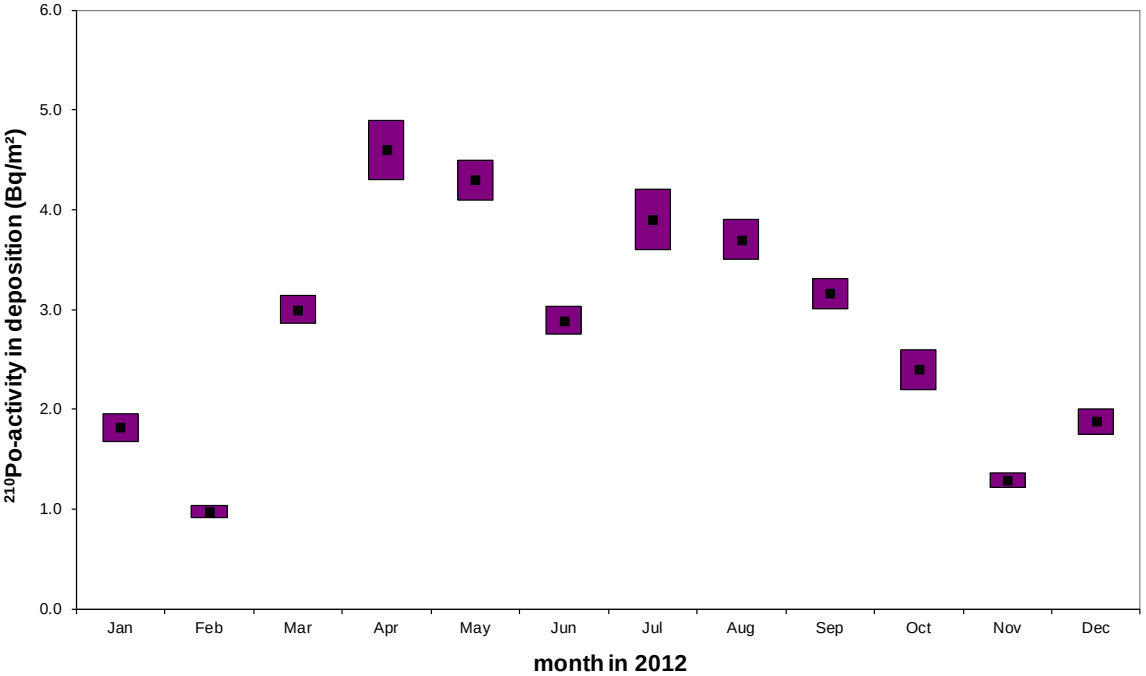

Figure 3.6: Monthly deposited ^{210}Po activity at RIVM
Monthly totals (black dots) are shown with a 68% confidence range (coloured bars).

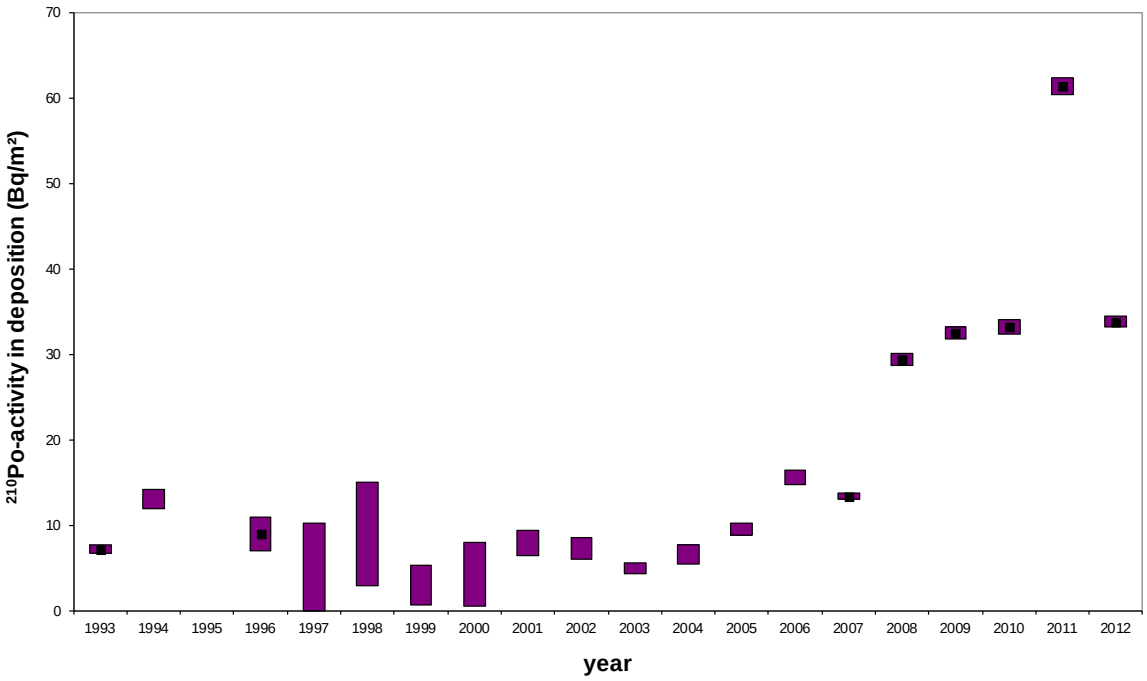

Figure 3.7: Yearly ^{210}Po activity deposited at RIVM since 1993
Yearly totals (black dots) are shown with a 68% confidence range (coloured bars). Only the 68% confidence range is shown if the yearly result is made up of at least one detection limit.

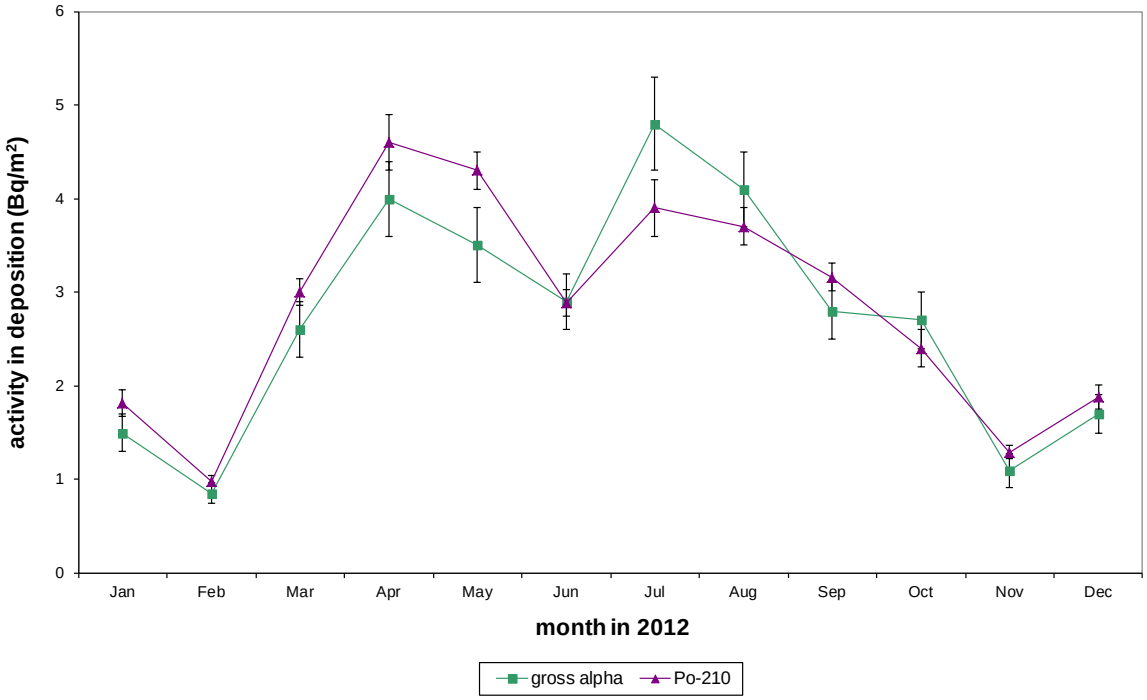

Figure 3.8: Figure illustrating the correlation between monthly total gross α and ^{210}Po activity in deposition at RIVM
A 68% confidence range is shown by means of an error bar.

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 2012 was 33.8 ± 0.6 Bq·m^{-2} (68% confidence level). 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 is less evident in May and July 2012, as can be seen in Figure 3.8.

3.2 γ-emitting nuclides

Detectable quantities of the naturally occurring nuclides ^{7}Be and ^{210}Pb were found in all 53 weekly samples. The yearly total deposition of ^{7}Be was 1,330 ± 30 Bq·m^{-2} and the yearly total deposition of ^{210}Pb was 98 ± 2 Bq·m^{-2}. The nuclide ^{137}Cs was detected in none of the 53 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 1.2 Bq·m^{-2} (68% confidence level). 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.

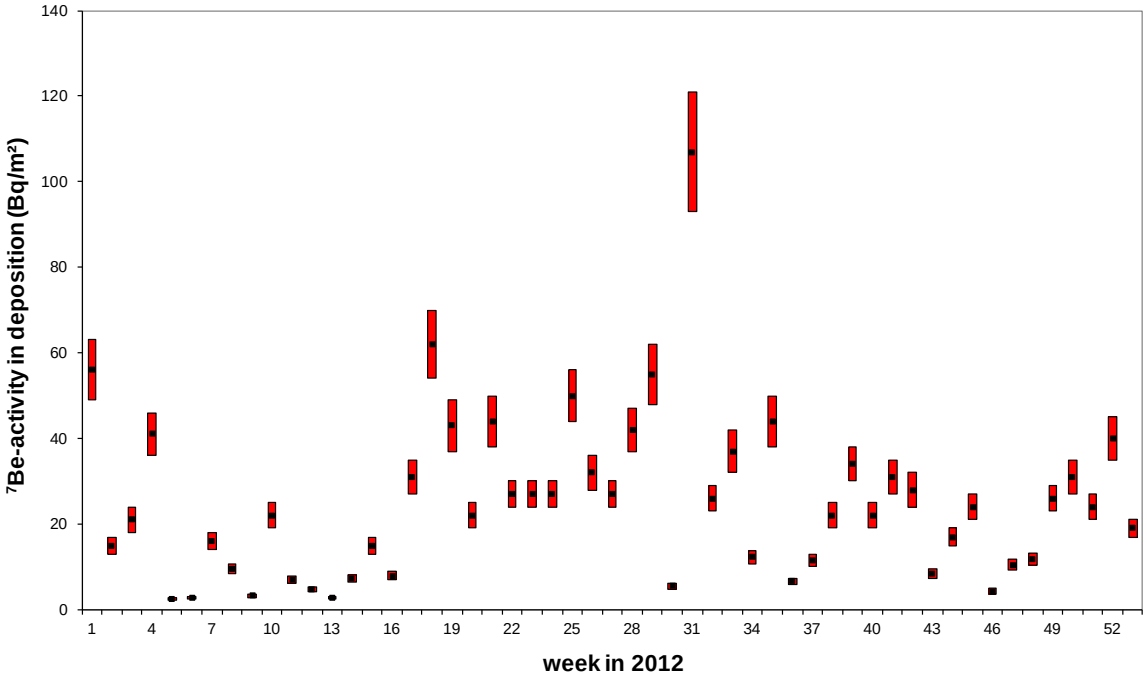

Figure 3.9: Weekly deposited ^{7}Be activity at RIVM
Weekly totals (black dots) are shown with a 68% confidence range (coloured bars).

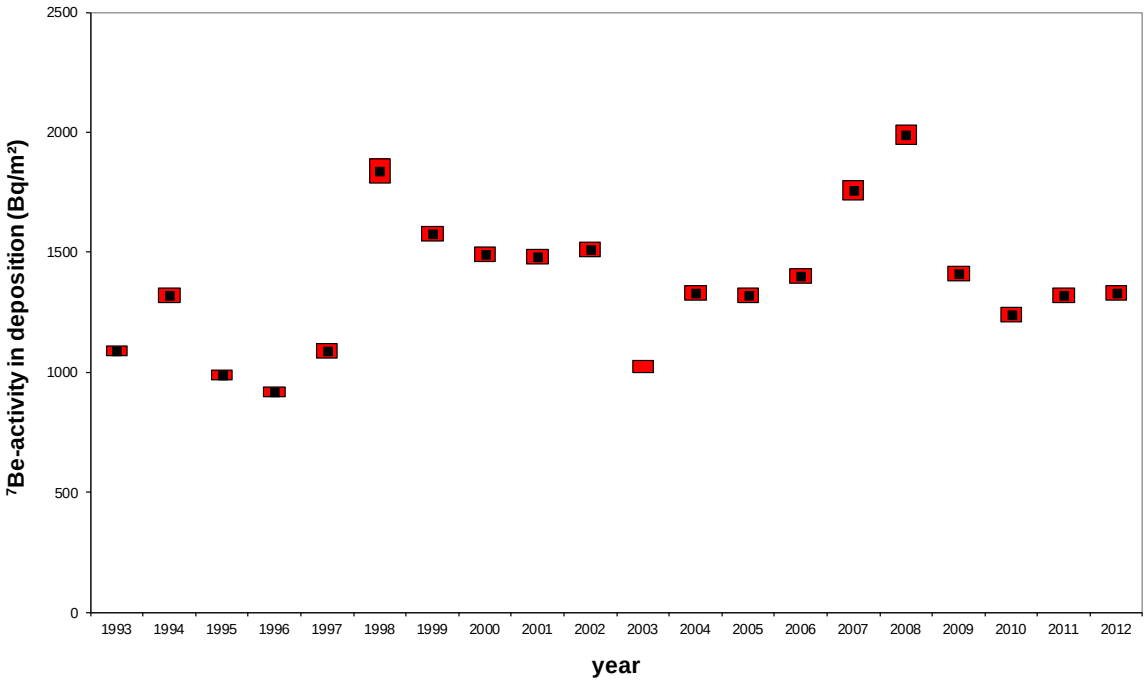

Figure 3.10: Yearly ^{7}Be activity deposited at RIVM since 1993
Yearly totals (black dots) are shown with a 68% confidence range (coloured bars). Only the 68% confidence range is shown if the yearly result is made up of at least one detection limit.

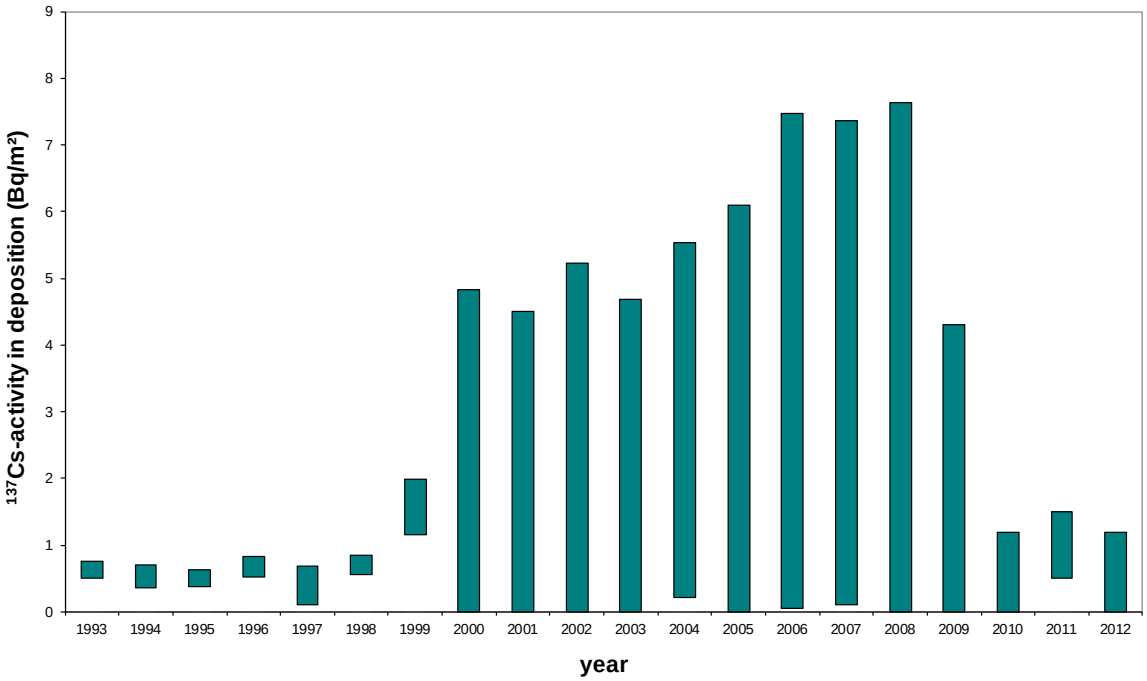

Figure 3.11: Yearly ^{137}Cs activity deposited at RIVM since 1993
Yearly averages are shown solely as a 68% confidence range since the yearly result is made up of at least one detection limit. From 2000 to June 2009, the detection limit was higher than during 1993–1999, due to a different detector set-up. Since July 2009, a new detector set-up has been used, which results in lower detection limits.

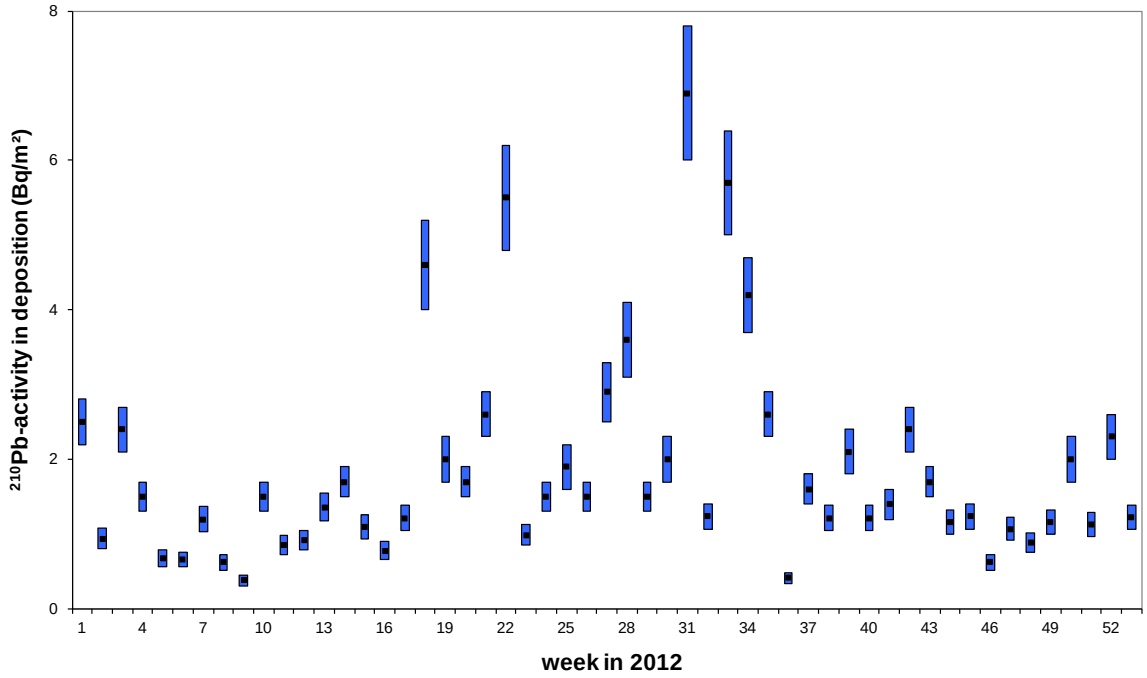

Figure 3.12: Weekly deposited ^{210}Pb activity at RIVM
Weekly averages (black dots) are shown with a 68% confidence range (coloured bars).

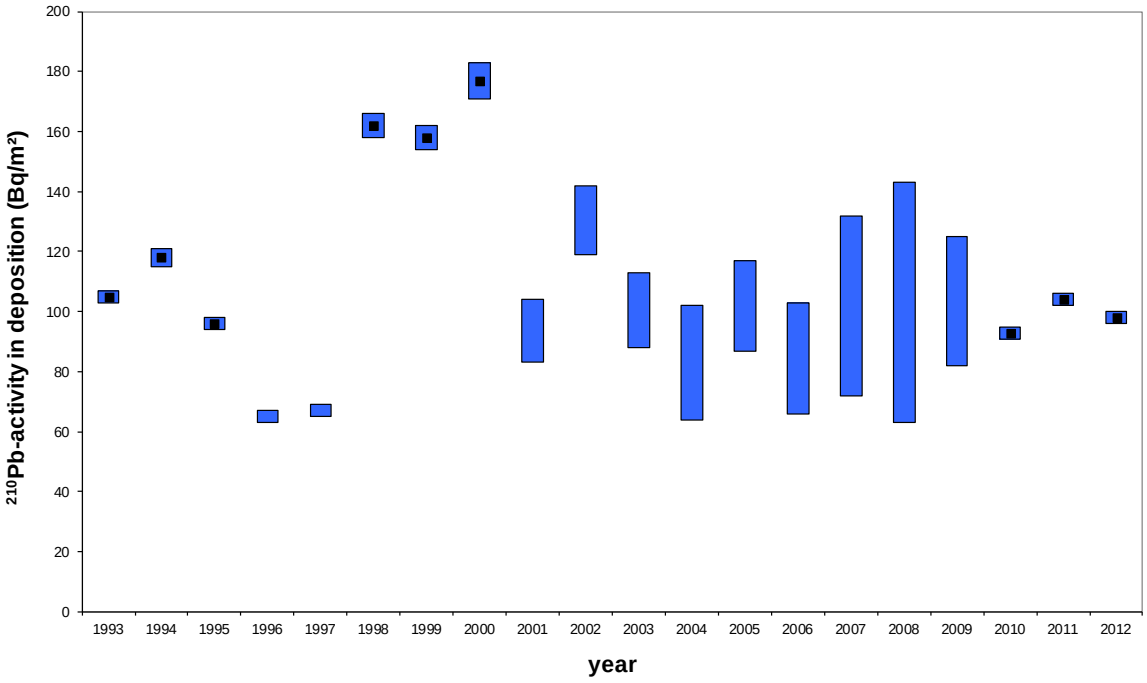

Figure 3.13: Yearly ^{210}Pb activity deposited at RIVM since 1993
Yearly averages (black dots) are shown with a 68% confidence range (coloured bars). Only the 68% confidence range is shown if the yearly result is made up of at least one detection limit.

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) [42]. At another 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 153 sites with regard to height and surface covering, results can differ between the two types of measuring sites [43]. 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 [44]. 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 10-minute measurements. Averages over the year are calculated per location, using daily averages from the 10-minute measurements (Tables A9 and A10). The data on external radiation, expressed in ambient dose equivalent, contain a systematic uncertainty because of an overestimation of the cosmogenic dose rate. However, NMR data are not corrected for these response uncertainties.

In Figures 4.1 and 4.3, an impression of the spatial variation in the yearly averages of the NMR data has been constructed using RIVM's Geographical Information System (GIS). 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 2012 the yearly averaged gross α activity concentration in air dust was 3.0 $Bq \cdot m^{-3}$ (based on the yearly averages of the 14 measurement locations). To compare this value (yearly average of 3.0 $Bq \cdot m^{-3}$) 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 $Bq \cdot m^{-3}$. The yearly average of the artificial β activity concentration does not deviate significantly from zero.

Between 1996 and 2003 the analysis of the ambient dose equivalent rate was based on a set of 163 stations. Since 2004, the analysis of the ambient dose equivalent rate has been based on a set of 153 stations (as 10 stations have been dismantled). The yearly averaged ambient dose equivalent rate in 2012 was calculated using 149 stations (4 stations were not operational).

In 2012, the yearly averaged measured value for the ambient dose equivalent rate was 72.6 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).

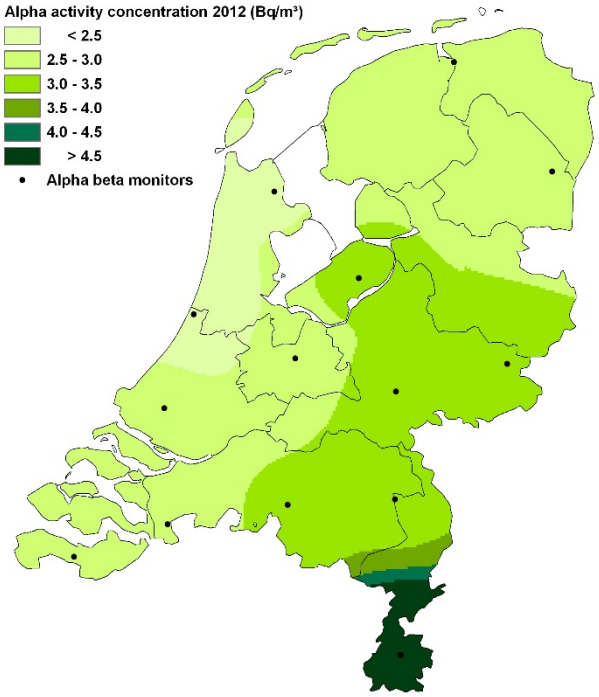

Figure 4.1: Spatial variation in the average gross α activity concentration of (mainly) short-lived nuclides in air dust
The dots represent the locations of the aerosol monitors.

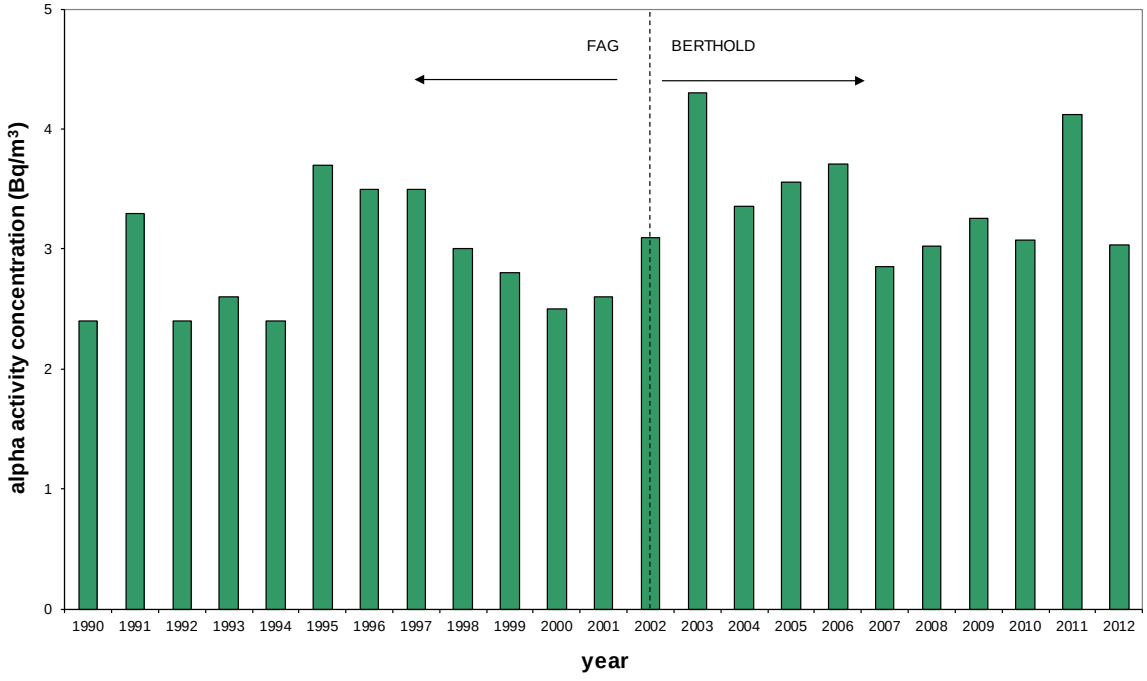

Figure 4.2: Yearly averaged gross α activity concentration of (mainly) short-lived nuclides in air dust
During the second half of 2002 the FAG monitors were replaced by Berthold monitors.

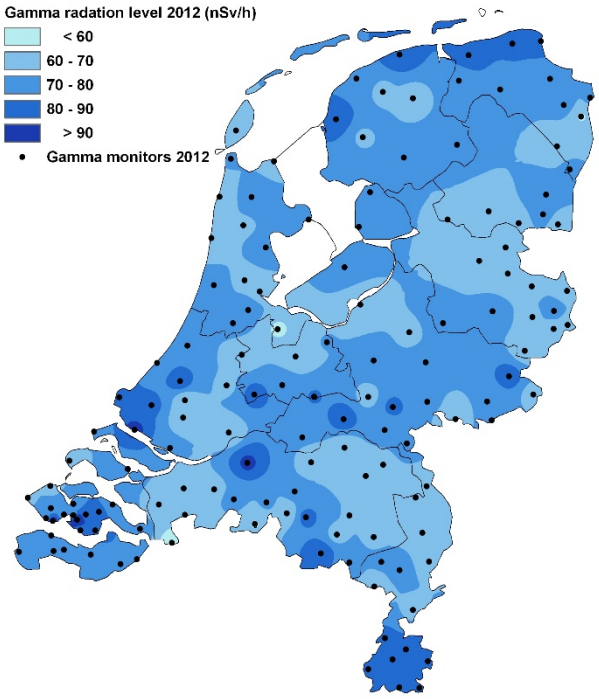

Figure 4.3: Spatial variation in the average ambient dose equivalent rate
The dots represent the locations of the dose equivalent rate monitors.

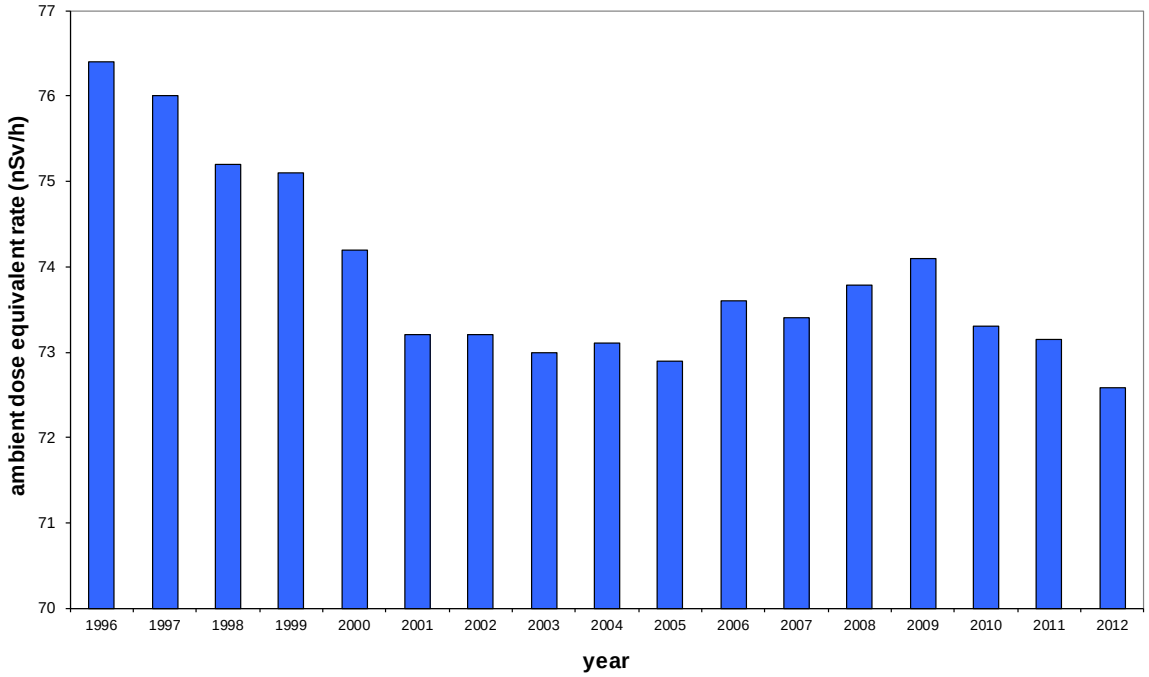

Figure 4.4: The yearly averaged ambient dose equivalent rate

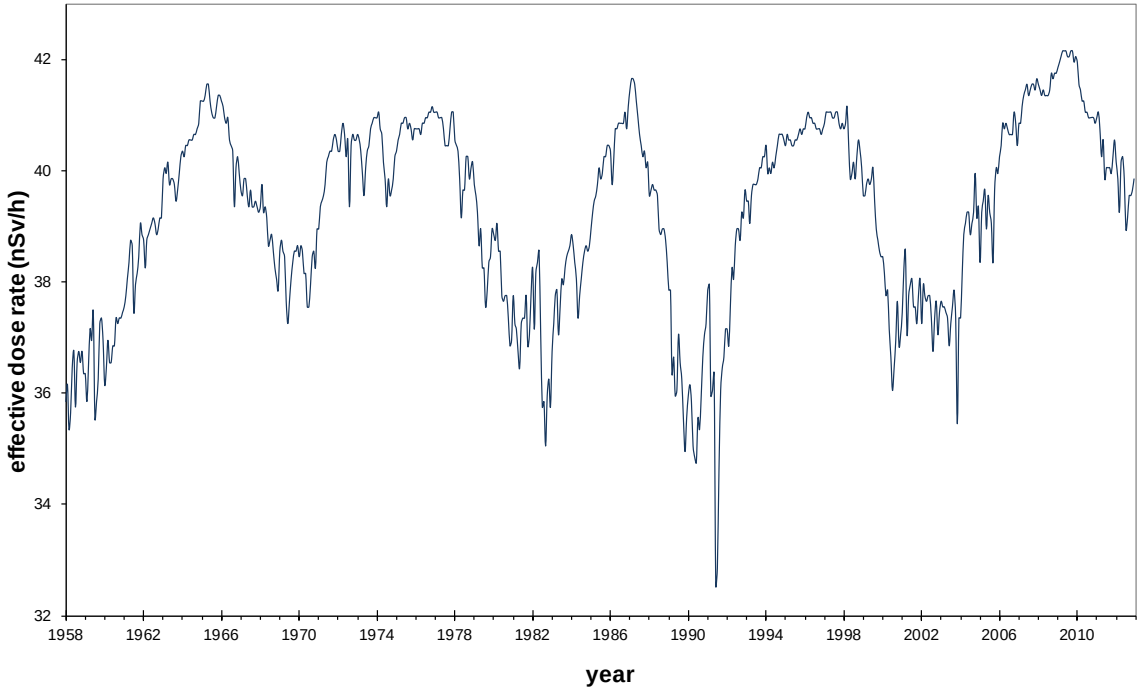

Figure 4.5: Cosmogenic contribution to the effective dose rate (at sea level), influenced by the solar cycle: location 51° 26' north and 3° 43' east (in the south-west of the Netherlands), air pressure 1019 hPa

Figure derived from data supplied by the Federal Aviation Administration [45].

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. The monitoring program presented here forms only part of its entire monitoring program. A more detailed description of the monitoring program, underlying strategy, and results of radioactivity measurements in Dutch waters are reported elsewhere [46, 47, 48, 49].

The locations presented in this report have been chosen to represent the major inland waters and seawater. The monitoring program is shown in Tables 5.1 and 5.2 and Figure 5.1. Radioactive nuclides were measured in water and suspended solids. The samples were collected at equidistant times.

Since 2010, measurements in sediment have been added to the entire monitoring program, but the results are not presented in this report. These results are presented elsewhere [49].

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

Location	Parameter	Matrix	Monitoring frequency (per year)
IJsselmeer	Gross α	Water	12
(Vrouwezand)	Residual β	Water	12
	^{3}H	Water	7
	^{60}Co	Suspended solids	12
	^{131}I	Suspended solids	12
	^{137}Cs	Suspended solids	12
Noordzeekanaal	Gross α	Water	13
(IJmuiden)	Residual β	Water	13
	^{3}H	Water	13
	^{60}Co	Suspended solids	7
	^{131}I	Suspended solids	7
	^{137}Cs	Suspended solids	7
Nieuwe Waterweg	Gross α	Water	13
(Maassluis)	Residual β	Water	13
	^{3}H	Water	6
	^{90}Sr	Water	6
	^{226}Ra	Water	6
	^{60}Co	Suspended solids	13
	^{131}I	Suspended solids	13
	^{137}Cs	Suspended solids	13
	^{210}Pb	Suspended solids	6

Continued on the next page

Table 5.1: Continued

Location	Parameter	Matrix	Monitoring frequency (per year)
Rhine	Gross α	Water	13
(Lobith)	Residual β	Water	13
	^{3}H	Water	13
	^{90}Sr	Water	7
	^{226}Ra	Water	7
	^{60}Co	Suspended solids	25
	^{131}I	Suspended solids	25
	^{137}Cs	Suspended solids	25
	^{210}Pb	Suspended solids	7
Scheldt	Gross α	Water	13
(Schaar van Ouden Doel)	Residual β	Water	13
	^{3}H	Water	6
	^{226}Ra	Water	6
	^{60}Co	Suspended solids	13
	^{131}I	Suspended solids	13
	^{137}Cs	Suspended solids	13
	^{210}Pb	Suspended solids	6
Meuse	Gross α	Water	13
(Eijsden)	Residual β	Water	13
	^{3}H	Water	13
	^{90}Sr	Water	7
	^{226}Ra	Water	7
	^{60}Co	Suspended solids	52
	^{131}I	Suspended solids	52
	^{137}Cs	Suspended solids	52
	^{210}Pb	Suspended solids	7

The radioactive nuclides were measured according to standard procedures [50, 51]. In the Netherlands, target values are used for radioactive materials in surface water, which are given in the Fourth Memorandum on Water Management (Vierde Nota waterhuishouding) [52]. The yearly averages are compared with those target values.

Table 5.2: Monitoring program 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	4
		^{210}Pb	Suspended solids	4
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	13
		Residual β	Water	13
		^{3}H	Water	13
		^{90}Sr	Water	13
		^{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.

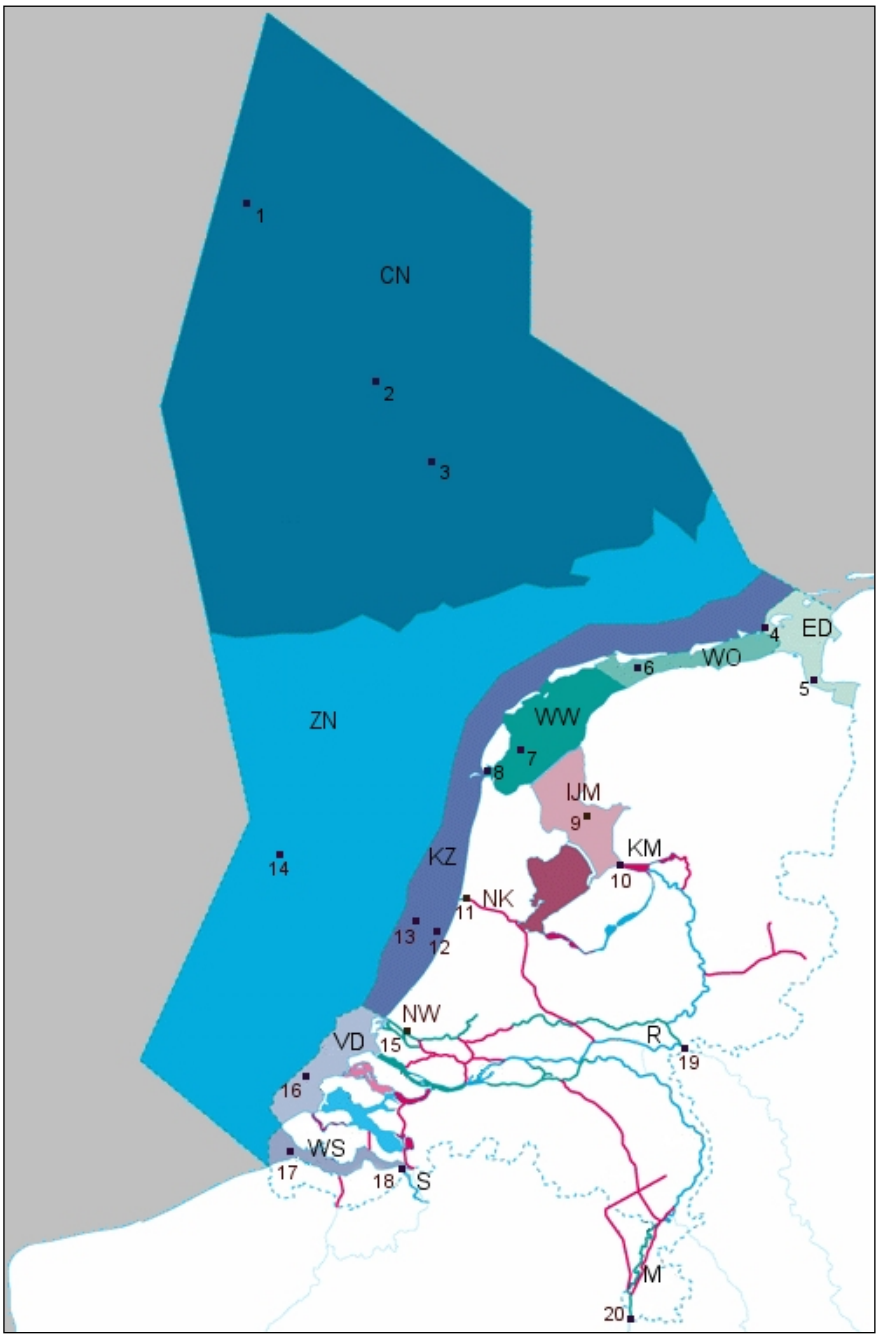

Figure 5.1: Overview of monitoring locations for the monitoring program in surface water and in seawater

Terschelling 135 km offshore and Terschelling 100 km offshore were the old monitoring locations for the Central North Sea in 1989 (135 km offshore) and 1988–1994 (100 km offshore). Terschelling 235 km offshore has been the monitoring location for the Central North Sea from 1995 and onwards. Noordwijk 10 km offshore was the old 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 [46]. Ketelmeer West has not been a monitoring location since 2009.

5.2 The results for surface water

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 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 2012 were within the range of those in previous years. The gross α activity concentration in the Noordzeekanaal, Nieuwe Waterweg and Scheldt exceeded the target value (100 $mBq \cdot L^{-1}$) in 10 out of the 13, 6 out of the 13 and 13 out of the 13 samples taken, respectively. In 2012, the yearly averaged gross α activity concentrations in the Noordzeekanaal and Scheldt (180 and 250 $mBq \cdot L^{-1}$, respectively) were above the target value of 100 $mBq \cdot L^{-1}$.

The residual β activity concentration in the Scheldt exceeded the target value (200 $mBq \cdot L^{-1}$) in 1 out of the 13 samples taken. The yearly averaged residual β activity concentrations were below the target value of 200 $mBq \cdot L^{-1}$. 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 only applies to salt and brackish water [46]. Therefore, this change in trend was not seen for residual β in the IJsselmeer, Rhine, or Meuse.

The ^{3}H activity concentration in the Rhine, Scheldt, and Meuse exceeded the target value (10 $Bq \cdot L^{-1}$) in 1 out of the 13, 1 out of the 6 and 6 out of the 13 samples taken, respectively. The elevated level of ^{3}H in the Rhine could have originated from several nuclear power plants or research reactors in Germany, France, or Switzerland. The elevated levels of ^{3}H in the Meuse could have originated from the nuclear power plants at Tihange (Belgium) or Chooz (France). The 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 2012 were within the range of those in previous years. In 2012, the yearly averaged ^{3}H activity concentration in the Meuse (14.0 $Bq \cdot L^{-1}$) was above the target value of 10 $Bq \cdot L^{-1}$.

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 2012 were within the range of those in previous years. The yearly averaged and individual ^{90}Sr activity concentrations were below the target value of 10 $mBq \cdot L^{-1}$.

The nuclide ^{226}Ra is released into the environment by the ore processing industry. The ^{226}Ra activity concentration in the Nieuwe Waterweg, Rhine and Scheldt exceeded the target value (5 $mBq \cdot L^{-1}$) in 1 out of the 6, 1 out of the 7 and 6 out of the 6 samples taken, respectively. The yearly averaged ^{226}Ra activity concentrations in 2012 were within the range of those in previous years. In 2012, the yearly averaged ^{226}Ra activity concentration in the Scheldt (7.4 $mBq \cdot L^{-1}$) was above the target value of 5 $mBq \cdot L^{-1}$.

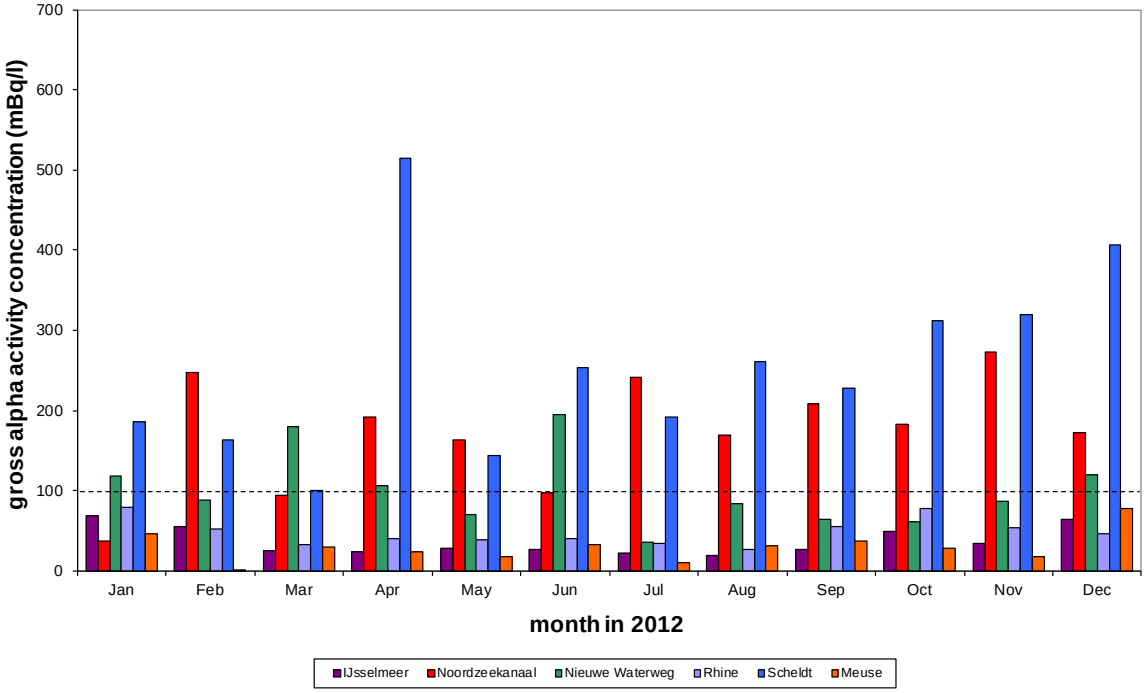

Figure 5.2: Gross α activity concentrations for the IJsselmeer, Noordzeekanaal, Nieuwe Waterweg, Rhine, Scheldt and Meuse, with yearly averages of 37, 180, 100, 48, 250 and 29 mBq·L^{-1}, respectively

Averaged values are shown in the case of multiple measurements per month. The dotted line represents the target value of 100 mBq·L^{-1} [52].

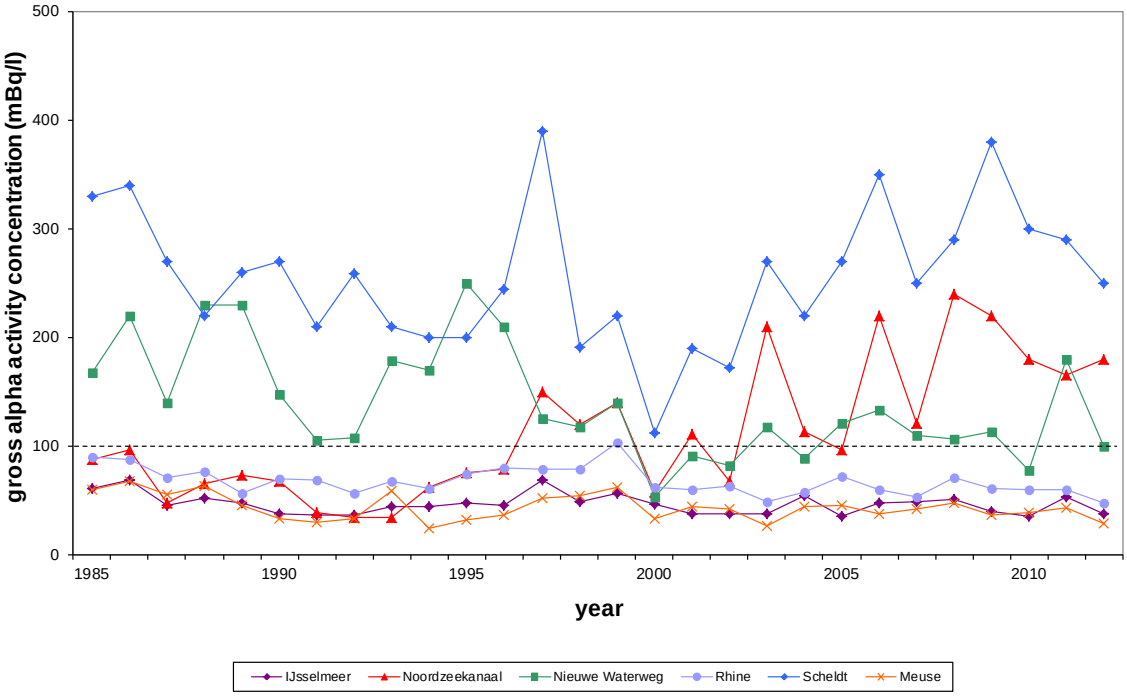

Figure 5.3: Yearly averaged gross α activity concentrations

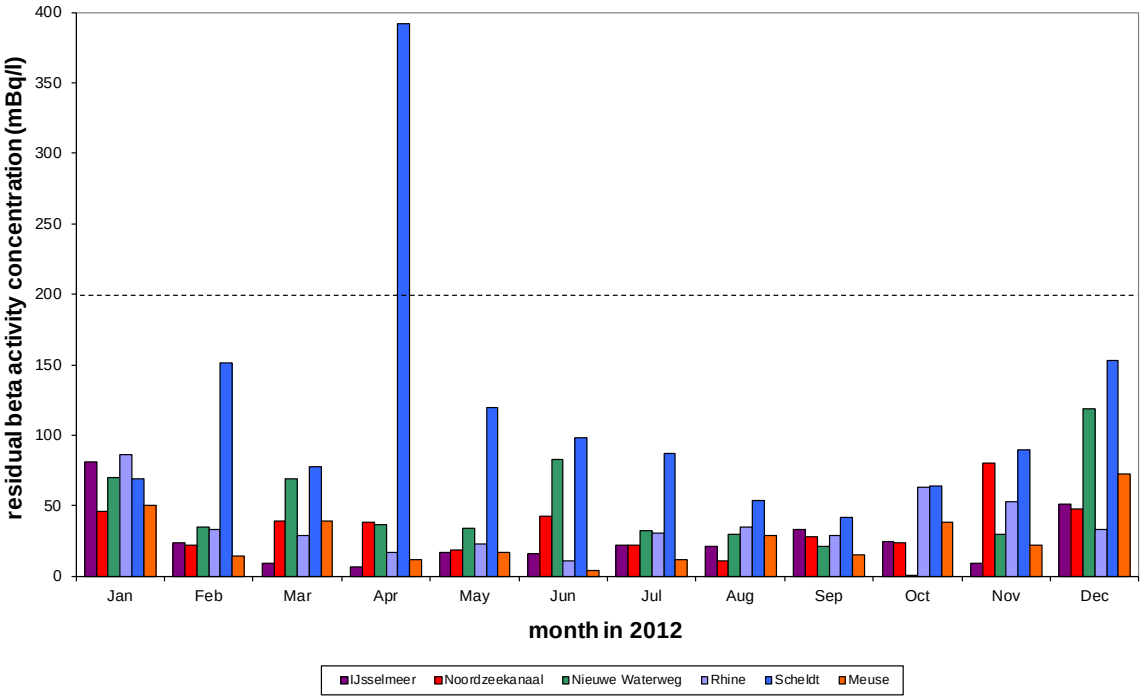

Figure 5.4: Residual β activity concentrations for the IJsselmeer, Noordzeekanaal, Nieuwe Waterweg, Rhine, Scheldt and Meuse, with yearly averages of 26, 34, 45, 36, 110 and 26 mBq·L^{-1}, respectively

Averaged values are shown in the case of multiple measurements per month. The dotted line represents the target value of 200 mBq·L^{-1} [52].

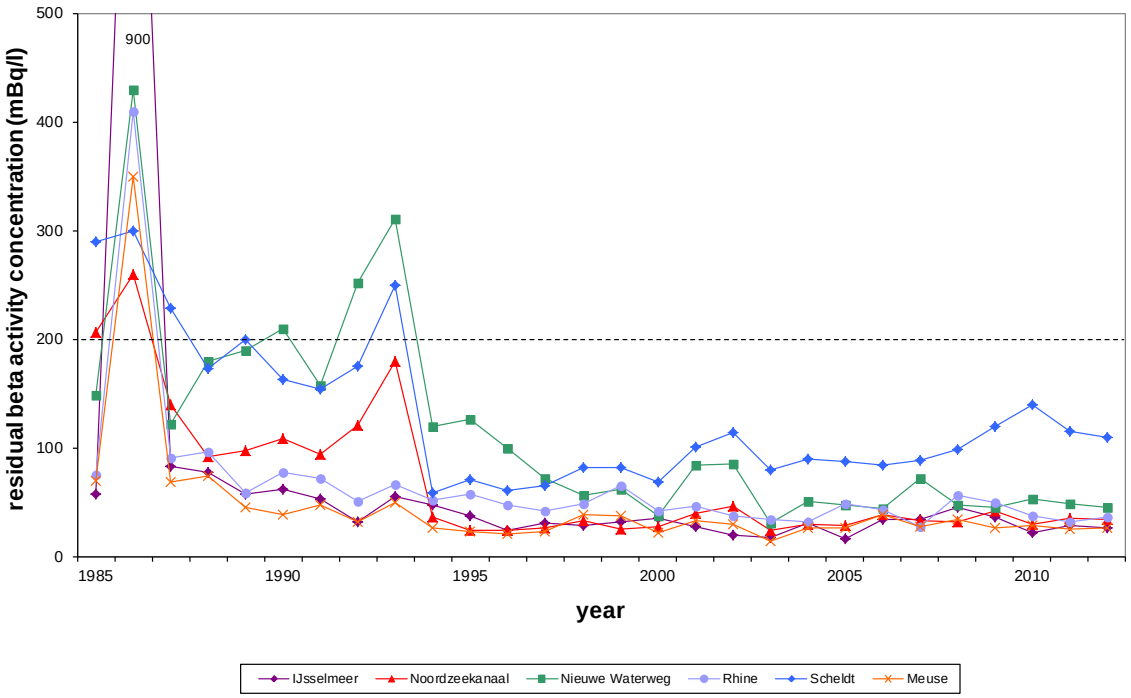

Figure 5.5: Yearly averaged residual β activity concentrations

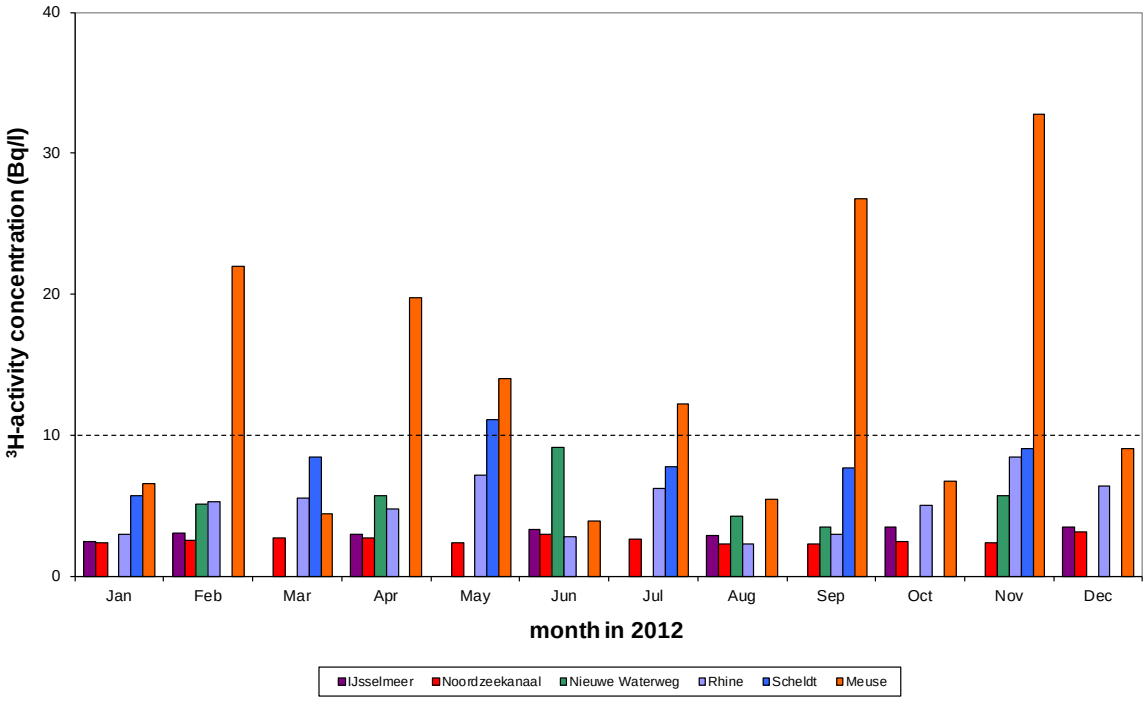

Figure 5.6: ^{3}H activity concentrations for the IJsselmeer, Noordzeekanaal, Nieuwe Waterweg, Rhine, Scheldt, and Meuse, with yearly averages of 3.1, 2.6, 5.6, 5.2, 8.3, and 14.0 Bq·L^{-1}, respectively

Averaged values are shown in the case of multiple measurements per month. The dotted line represents the target value of 10 Bq·L^{-1} [52].

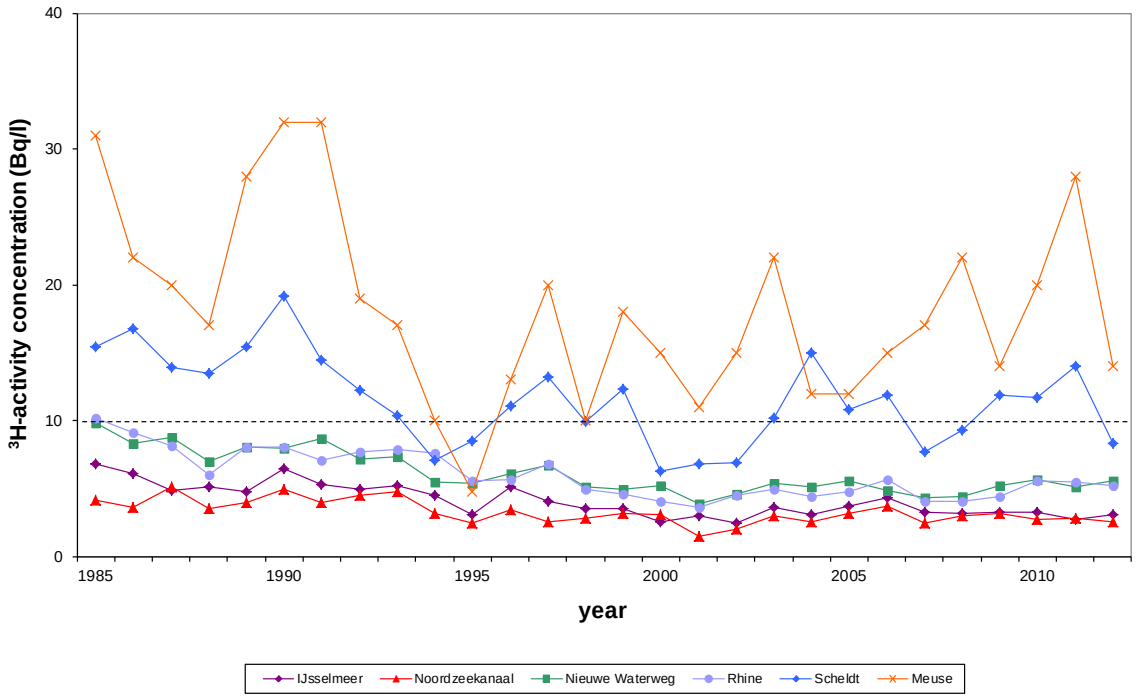

Figure 5.7: Yearly averaged ^{3}H activity concentrations

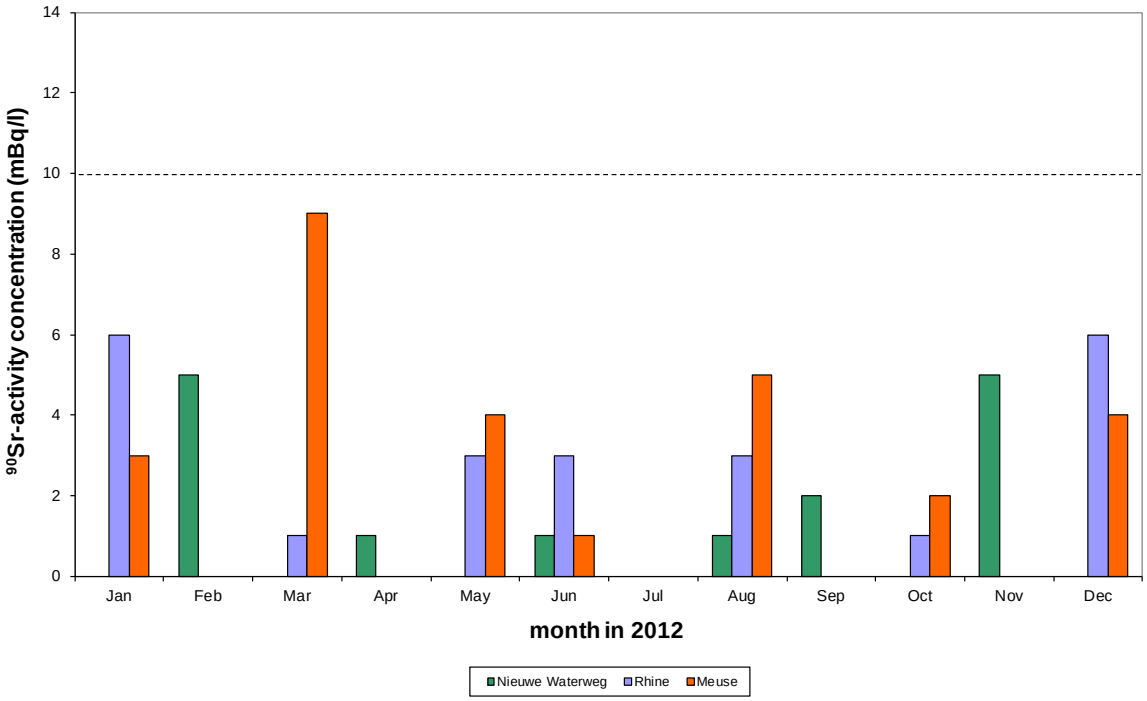

Figure 5.8: ^{90}Sr activity concentrations for the Nieuwe Waterweg, Rhine, and Meuse, with yearly averages of 2.2, 3.1, and 4.0 mBq·L^{-1}, respectively

Averaged values are shown in the case of multiple measurements per month. The dotted line represents the target value of 10 mBq·L^{-1} [52].

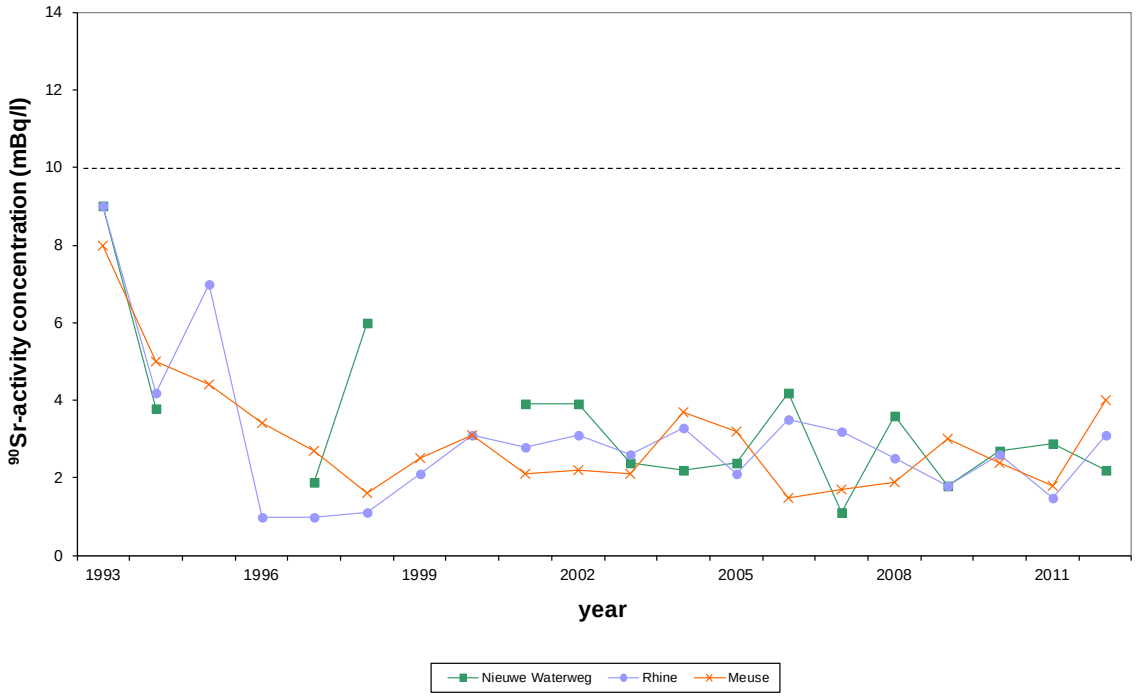

Figure 5.9: Yearly averaged ^{90}Sr activity concentrations

Data are not available for the Nieuwe Waterweg in 1995, 1996, 1999 and 2000.

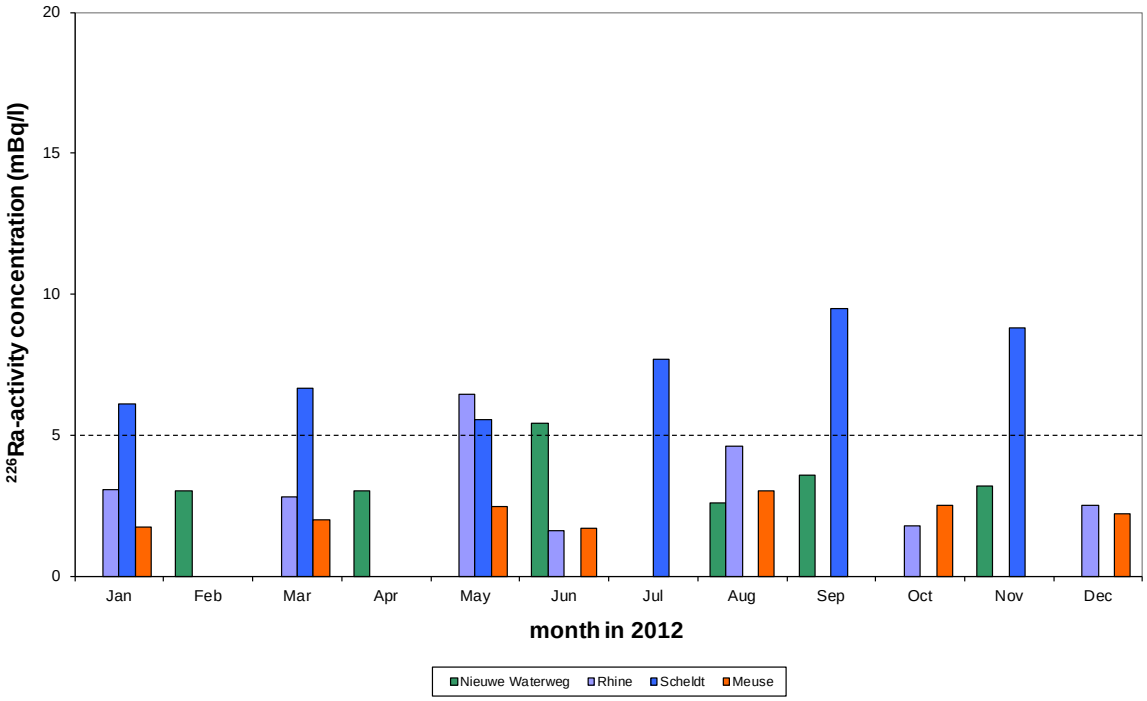

Figure 5.10: ^{226}Ra activity concentrations for the Nieuwe Waterweg, Rhine, Scheldt, and Meuse, with yearly averages of 3.5, 3.3, 7.4,, and 2.2 mBq·L^{-1}, respectively

Averaged values are shown in the case of multiple measurements per month. The dotted line represents the target value of 5 mBq·L^{-1} [52].

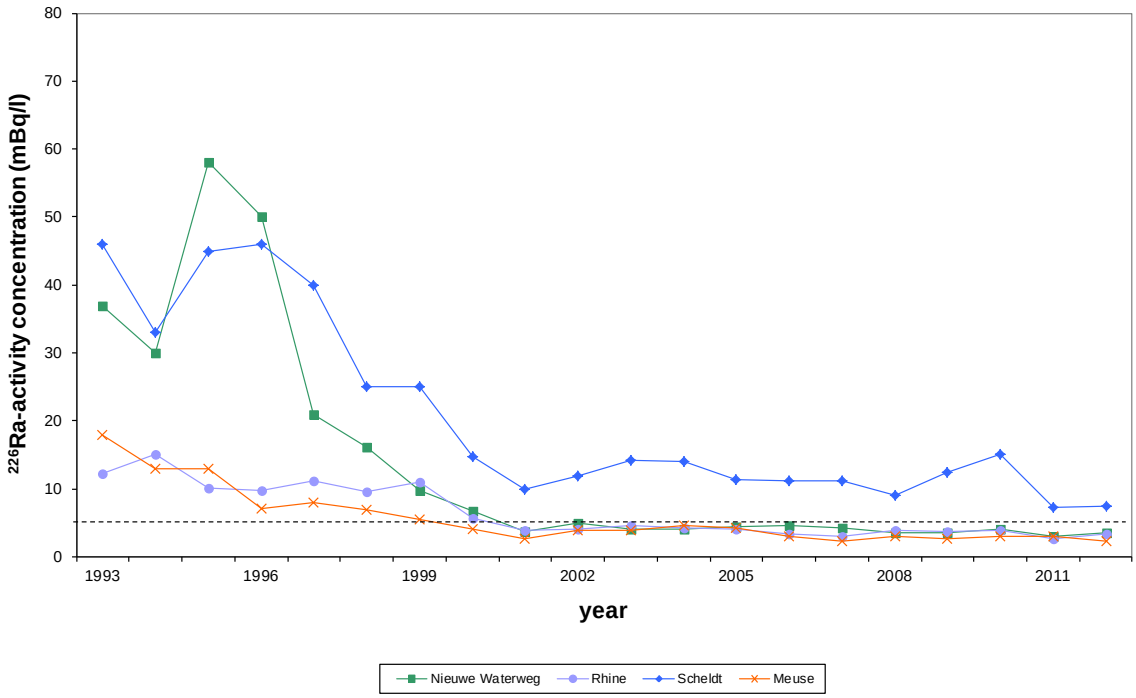

Figure 5.11: Yearly averaged ^{226}Ra activity concentrations

The nuclide ^{60}Co is a known corrosion product of nuclear power plants. The ^{60}Co activity concentration in suspended solids in the Meuse exceeded the target

value (10 Bq·kg^{-1}) in 33 out of the 52 samples taken. In 2012, the yearly averaged ^{60}Co activity concentration in the Meuse (14.7 Bq·kg^{-1}) was above the target value of 10 Bq·kg^{-1}, but within the range of those in previous years.

The nuclide ^{131}I is released into the environment by medical facilities. The ^{131}I activity concentration in suspended solids in the Noordzeekanaal and Meuse exceeded the target value (20 Bq·kg^{-1}) in 5 out of the 7 and 9 out of the 52 samples taken, respectively. In 2012, the yearly averaged ^{131}I activity concentration in the Noordzeekanaal (23 Bq·kg^{-1}) was above the target value of 20 Bq·kg^{-1}, but within the range of those in previous years.

The yearly averaged and individual ^{137}Cs concentrations in suspended solids in surface water were below the target value of 40 Bq·kg^{-1}. The yearly averaged concentrations of ^{137}Cs in suspended solids in 2012 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 [46]. The ^{210}Pb activity concentration in the Nieuwe Waterweg, Rhine, Scheldt and Meuse exceeded the target value (100 Bq·kg^{-1}) in 6 out of the 6, 7 out of the 7, 1 out of the 6, and 7 out of the 7 samples taken, respectively. In 2012 the yearly averaged ^{210}Pb activity concentrations in the Nieuwe Waterweg, Rhine, and Meuse (111, 126 and 147 Bq·kg^{-1}, respectively) were above the target value of 100 Bq·kg^{-1}, but within the range of those in previous years.

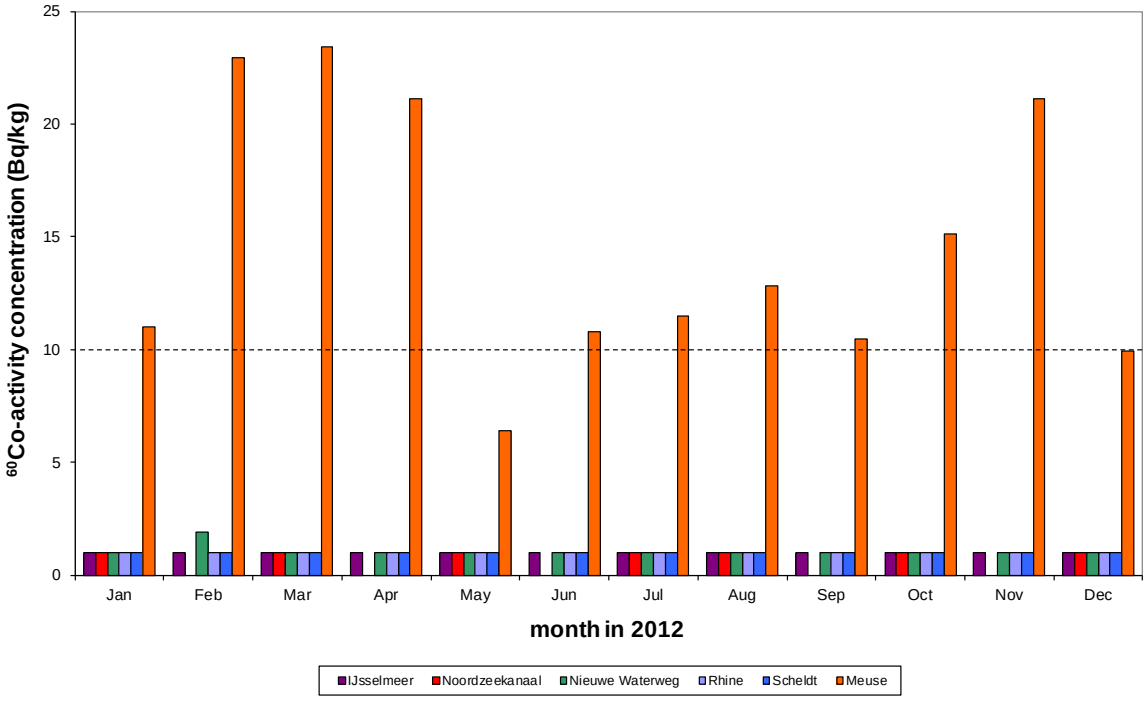

Figure 5.12: ^{60}Co activity concentrations in suspended solids for the IJsselmeer, Noordzeekanaal, Nieuwe Waterweg, Rhine, Scheldt, and Meuse, the yearly averages of all except for the Meuse (14.7 Bq·kg^{-1}) being < 1 Bq·kg^{-1}

Averaged values are shown in the case of multiple measurements per month. The dotted line represents the target value of 10 Bq·kg^{-1} [52].

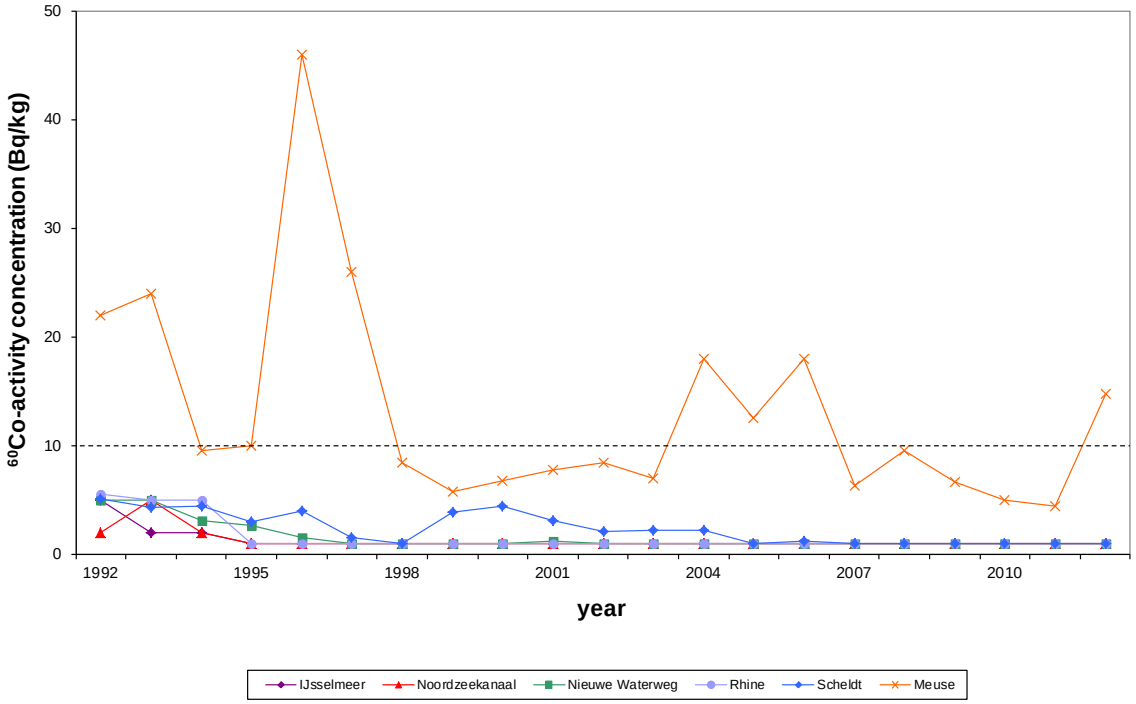

Figure 5.13: Yearly averaged ^{60}Co activity concentrations in suspended solids

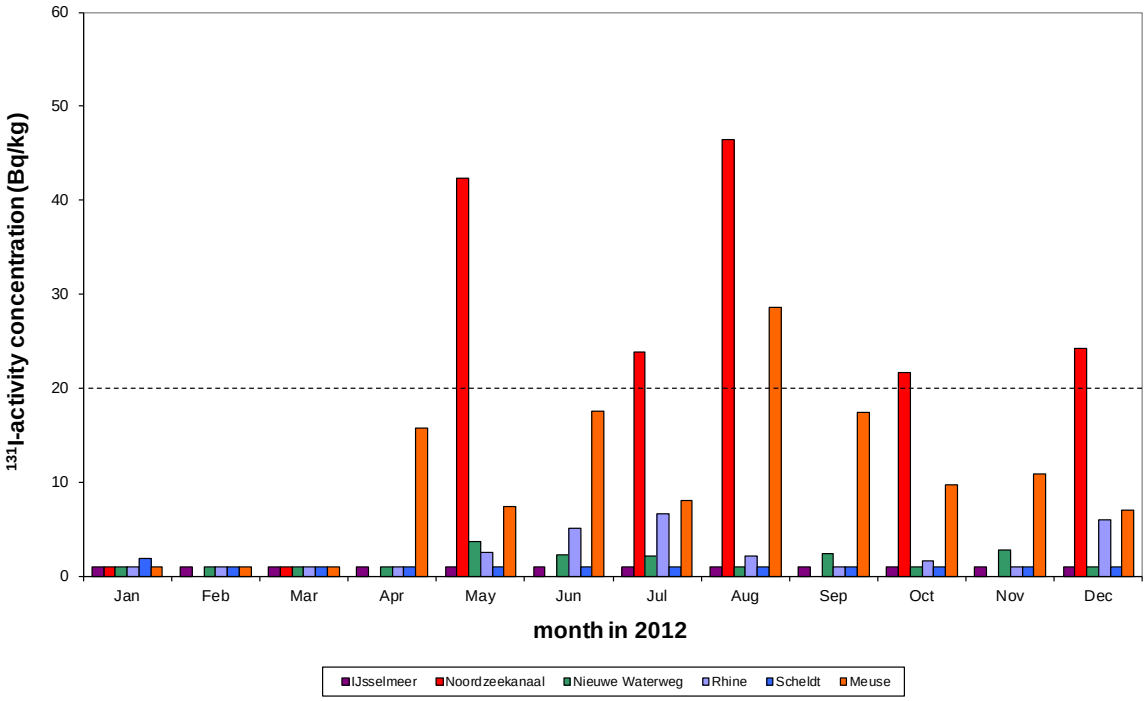

Figure 5.14: ^{131}I activity concentrations in suspended solids for the IJsselmeer, Noordzeekanaal, Nieuwe Waterweg, Rhine, Scheldt, and Meuse, with yearly averages of < 1, 23, < 1.3, < 2, < 1, and 9.9 Bq·kg^{-1}, respectively

Averaged values are shown in the case of multiple measurements per month. The dotted line represents the target value of 20 Bq·kg^{-1} [52].

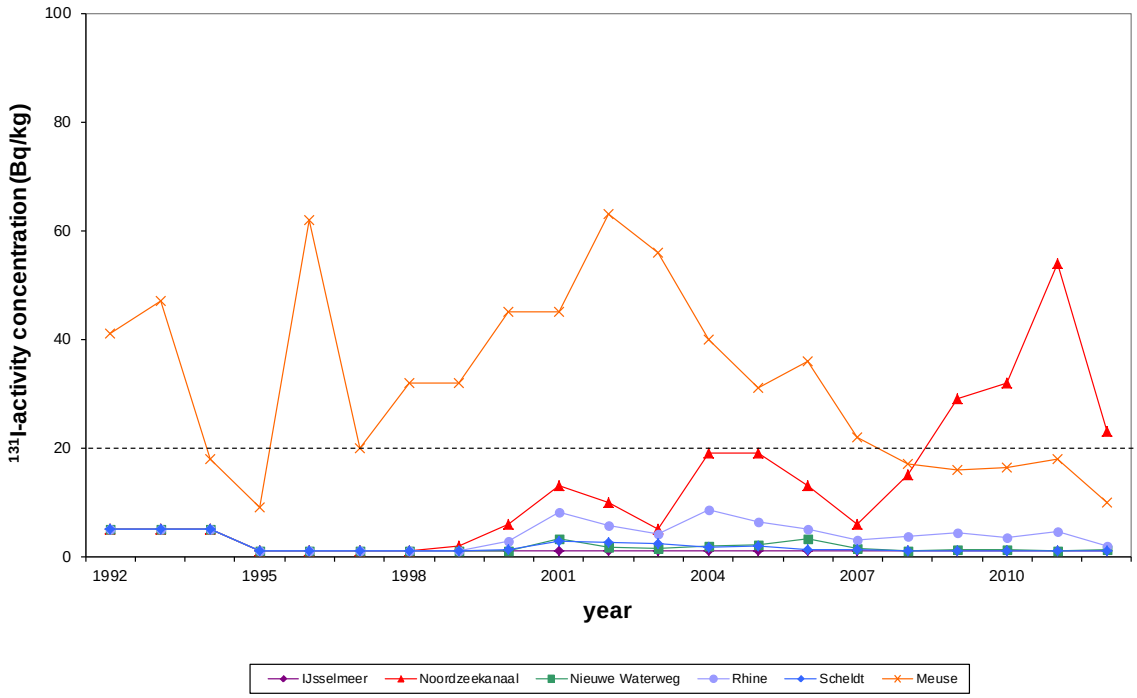

Figure 5.15: Yearly averaged ^{131}I activity concentrations in suspended solids

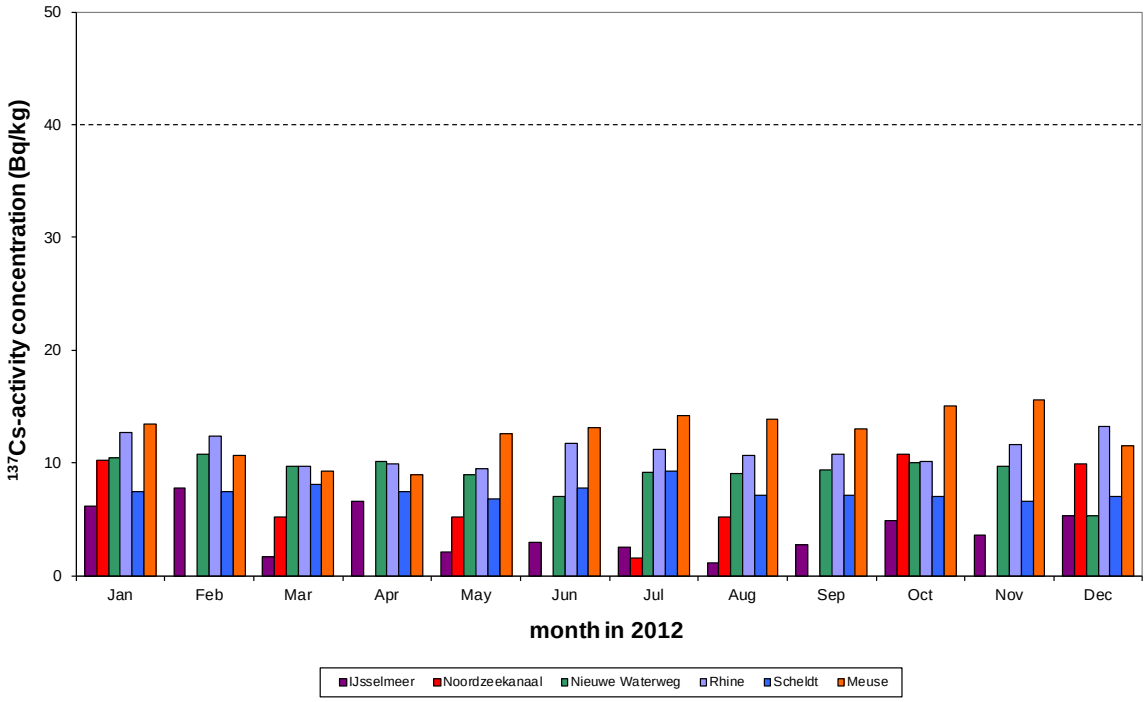

Figure 5.16: ^{137}Cs activity concentrations in suspended solids for the IJsselmeer, Noordzeekanaal, Nieuwe Waterweg, Rhine, Scheldt, and Meuse, with yearly averages of 4.0, 6.9, 9.2, 11, 7.5, and 12.7 Bq·kg^{-1}, respectively

Averaged values are shown in the case of multiple measurements per month. The dotted line represents the target value of 40 Bq·kg^{-1} [52].

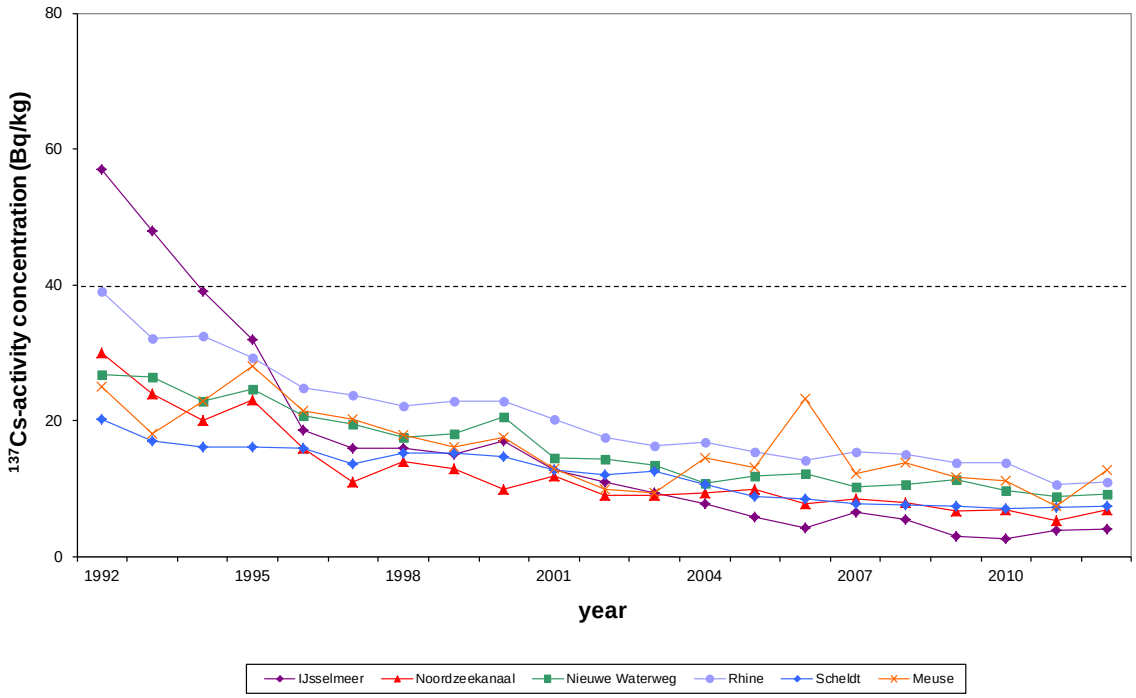

Figure 5.17: Yearly averaged ^{137}Cs activity concentrations in suspended solids

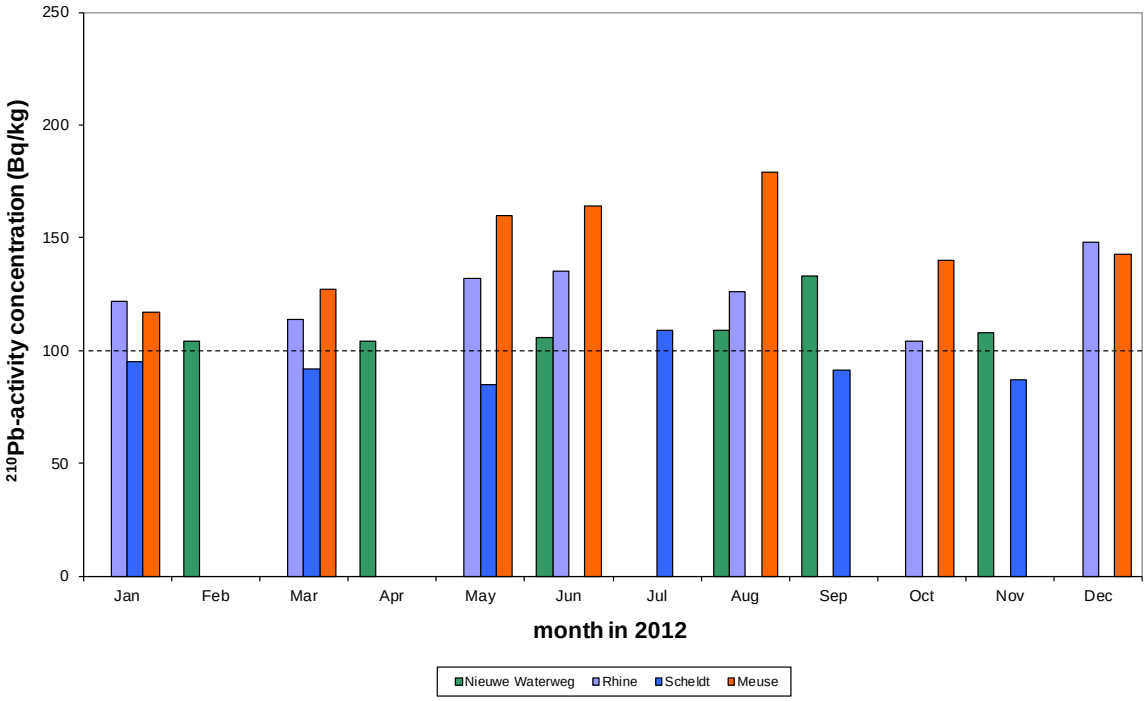

Figure 5.18: ^{210}Pb activity concentrations in suspended solids for the Nieuwe Waterweg, Rhine, Scheldt, and Meuse, with yearly averages of 111, 126, 93, and 147 Bq·kg^{-1}, respectively

Averaged values are shown in the case of multiple measurements per month. The dotted line represents the target value of 100 Bq·kg^{-1} [52].

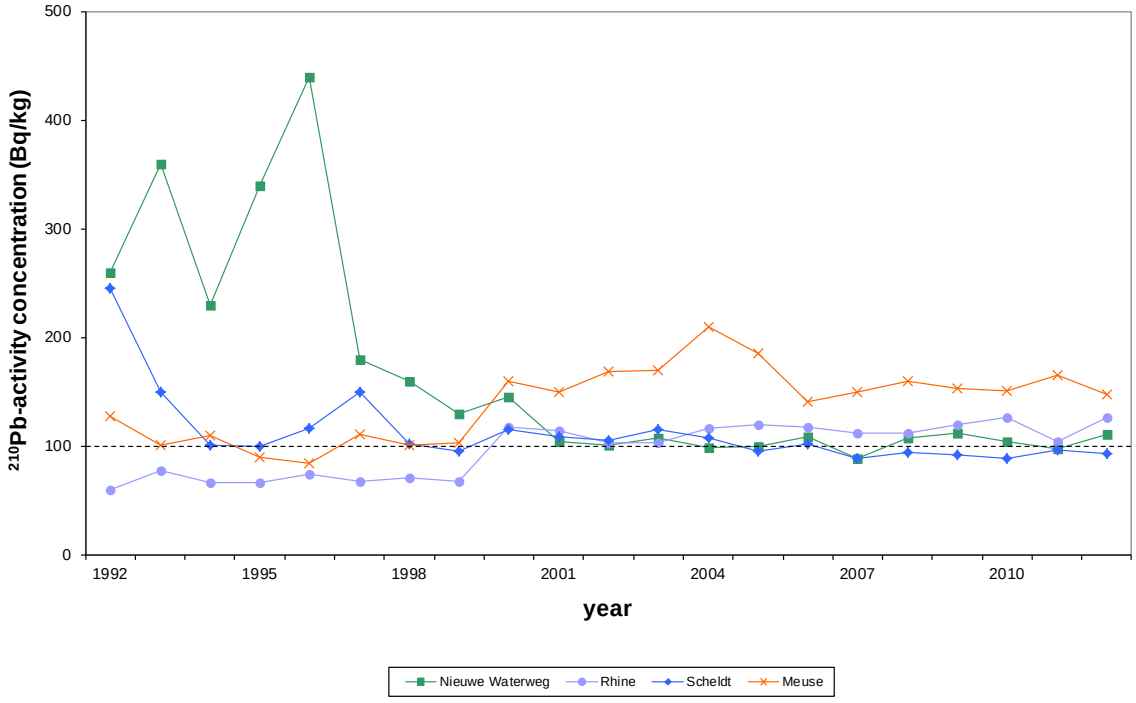

Figure 5.19: Yearly averaged ^{210}Pb activity concentrations in suspended solids

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 [46]. 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 [46]. The yearly averaged gross α activity concentrations in 2012 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, which only applies to salt and brackish water [46]. The yearly averaged residual β activity concentrations in 2012 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). 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), respectively [46]. The impact of both sources (nuclear power and reprocessing plants) is monitored indirectly in the Delta Coastal Waters (VD).

The yearly averaged ^{3}H concentrations in 2012 were within the range of those in previous years (Figure 5.25). The yearly averaged ^{90}Sr concentrations in 2012 were within the range of those in previous years (Figure 5.27).

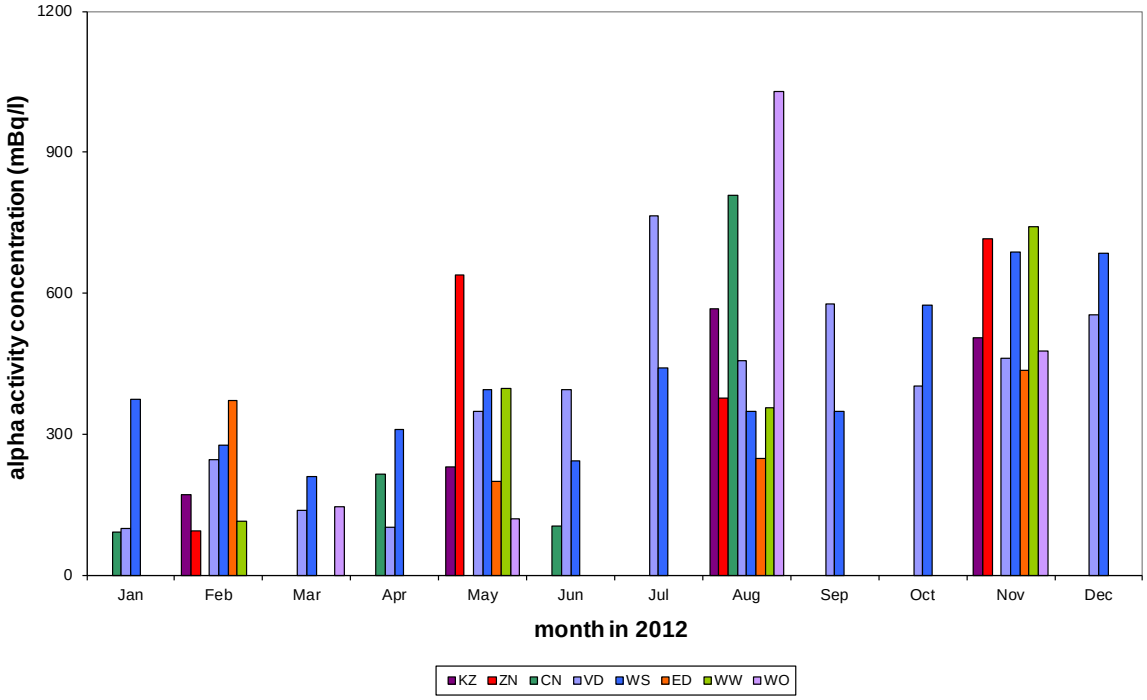

Figure 5.20: Gross α activity concentrations in seawater for the Coastal Area (KZ), Southern North Sea (ZN), Central North Sea (CN), Delta Coastal Waters (VD), Westerscheldt (WS), Eems-Dollard (ED), Wadden Sea West (WW), and Wadden Sea East (WO), with yearly averages of 370, 460, 310, 380, 400, 310, 400, and 400 mBq·L^{-1}, respectively.

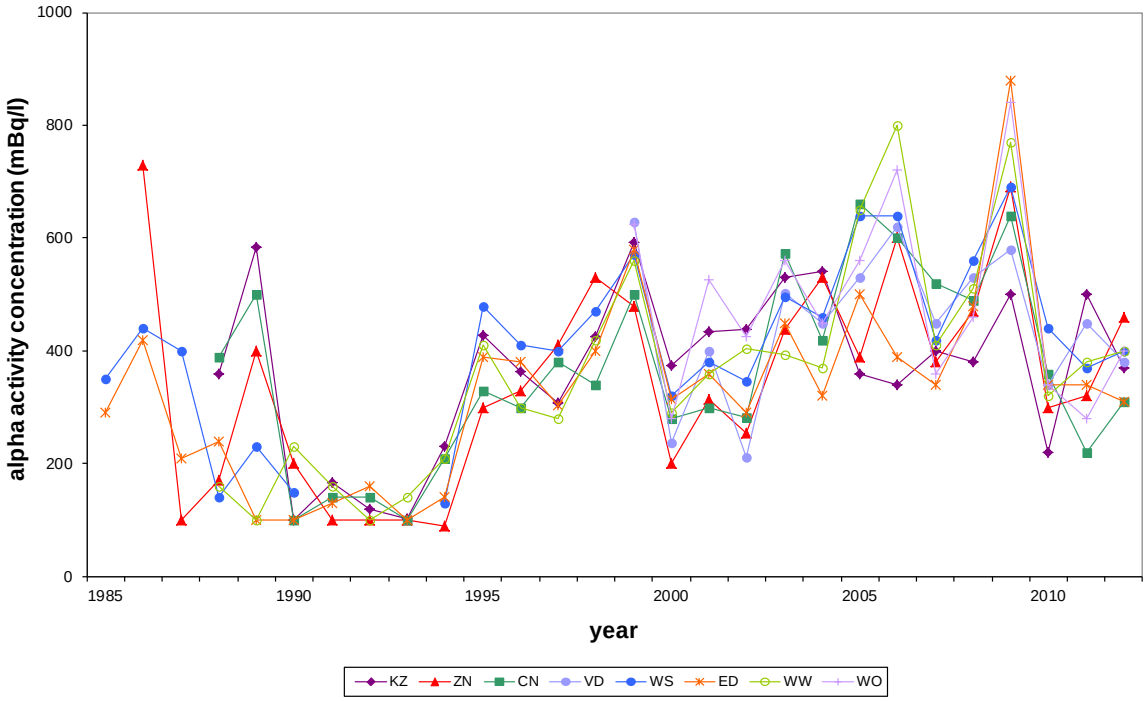

Figure 5.21: Yearly averaged gross α activity concentrations

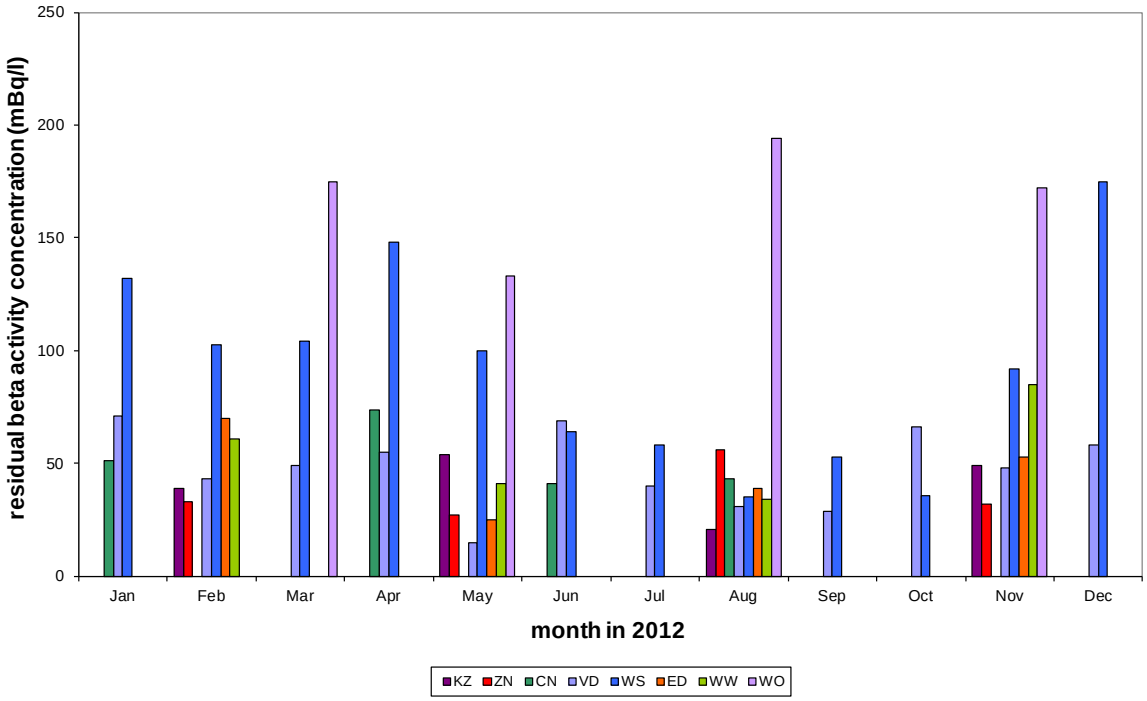

Figure 5.22: Residual β activity concentrations in seawater for the Coastal Area, Southern North Sea, Central North Sea, Delta Coastal Waters, Westerscheldt, Eems-Dollard, Wadden Sea West, and Wadden Sea East, with yearly averages of 41, 37, 52, 48, 92, 47, 55, and 168 mBq·L^{-1}, respectively

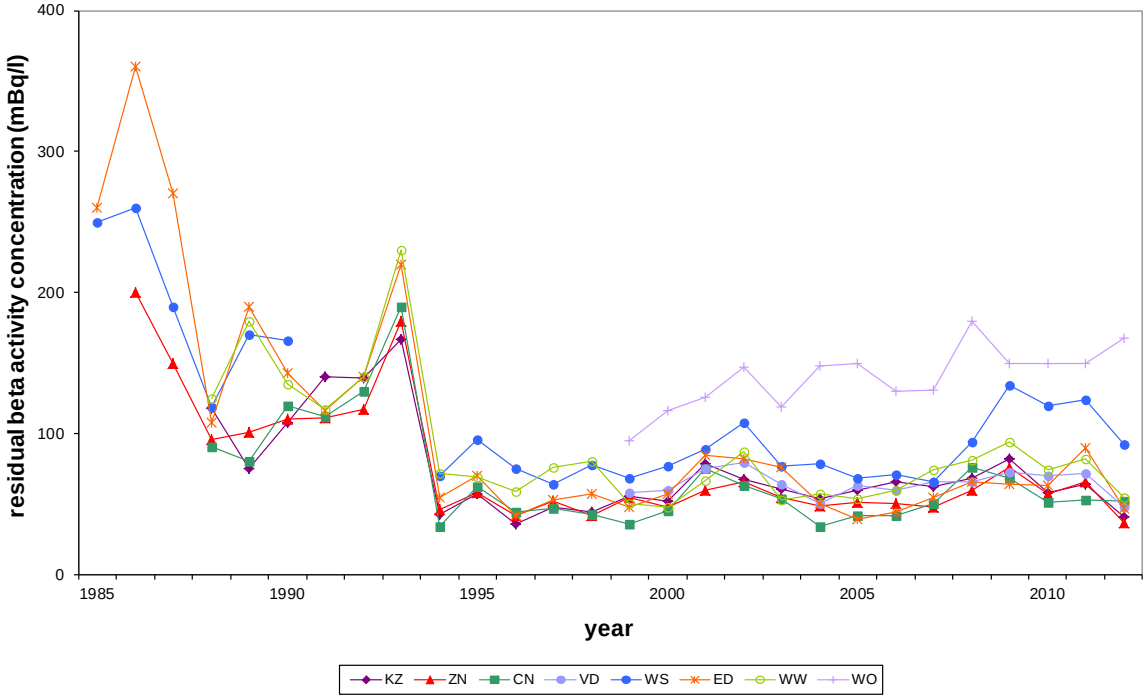

Figure 5.23: Yearly averaged residual β activity concentrations

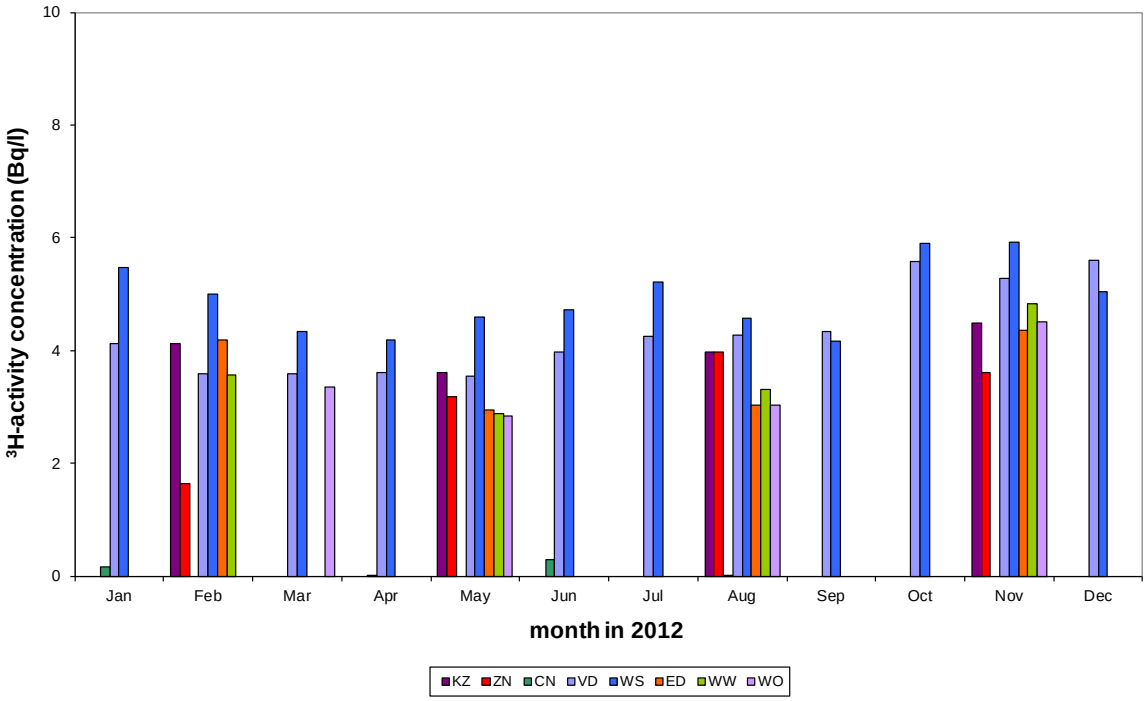

Figure 5.24: ^{3}H activity concentrations in seawater for the Coastal Area, Southern North Sea, Central North Sea, Delta Coastal Waters, Westerscheldt, Eems-Dollard, Wadden Sea West, and Wadden Sea East, with yearly averages of 4.0, 3.1, 0.12, 4.3, 4.9, 3.6, 3.7, and 3.4 Bq·L^{-1}, respectively

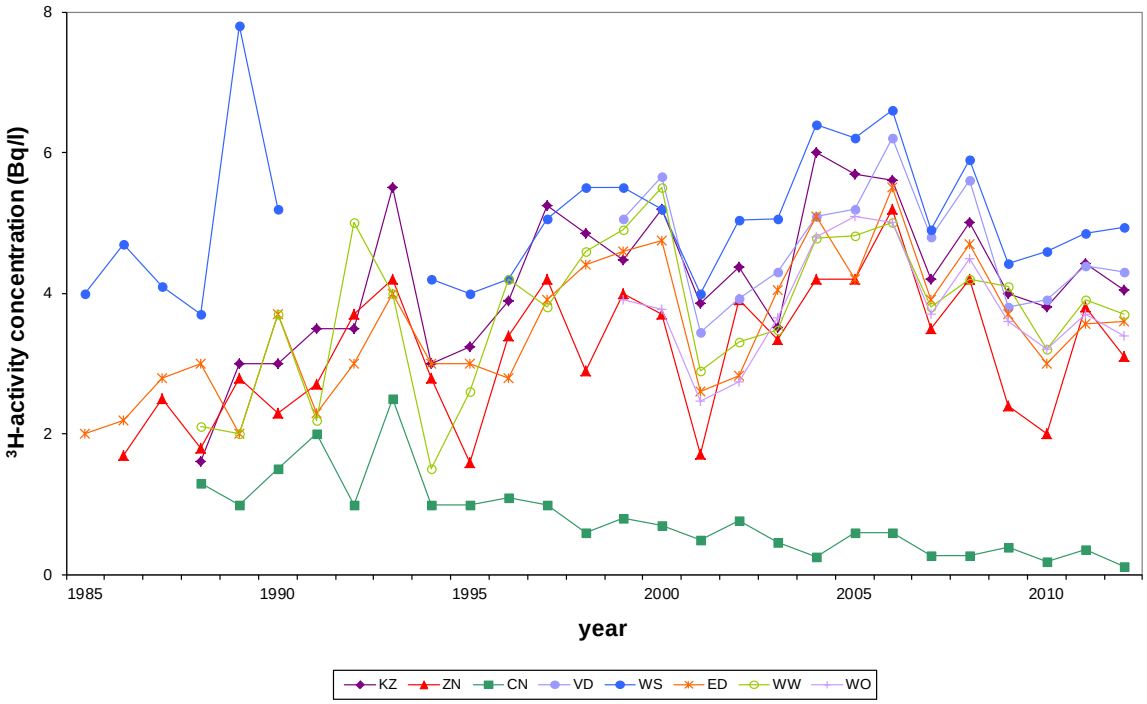

Figure 5.25: Yearly averaged ^{3}H activity concentrations

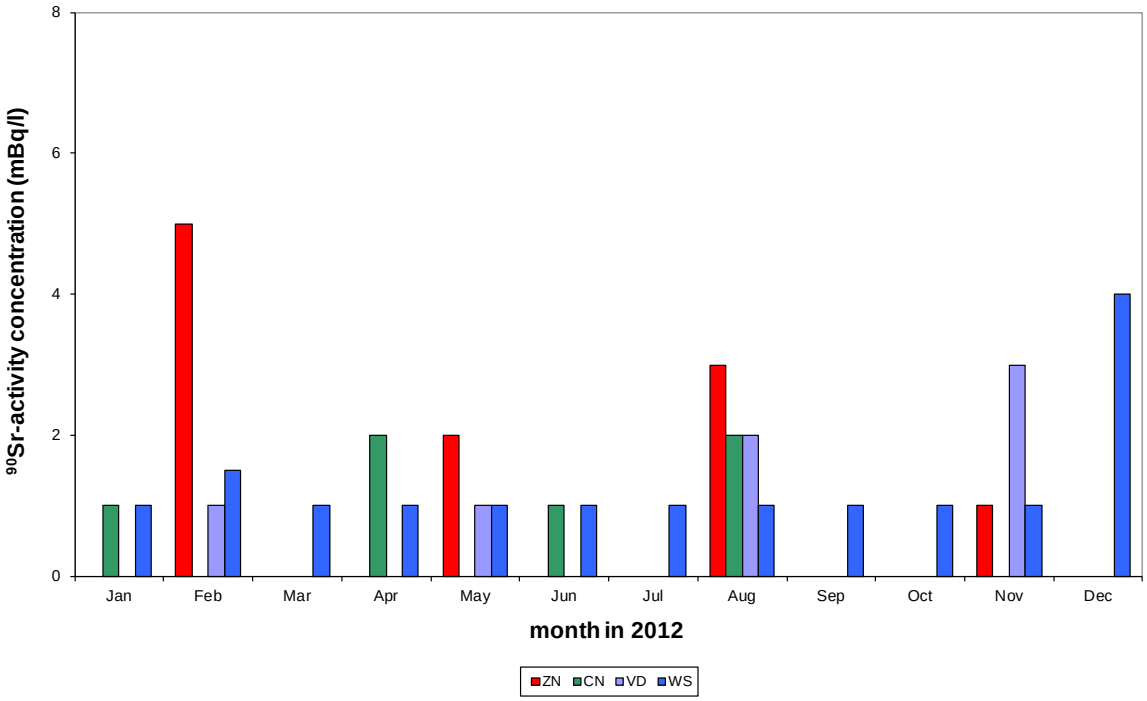

Figure 5.26: ^{90}Sr activity concentrations in seawater for Southern North Sea, Central North Sea, Delta Coastal Waters, and Westerscheldt, with yearly averages of 2.6, 1.2, 1.5, and < 1 mBq·L^{-1}, respectively

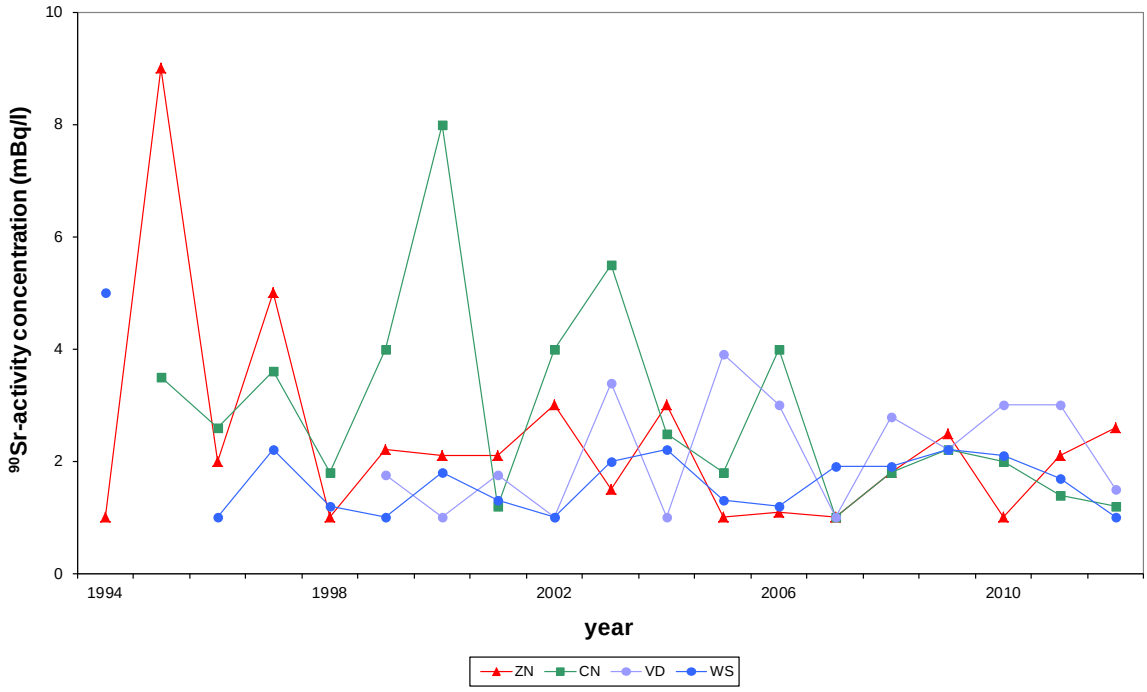

Figure 5.27: Yearly averaged ^{90}Sr activity concentrations

Since ^{210}Po is regularly in equilibrium with ^{210}Pb in suspended solids, RWS reports only ^{210}Pb (analogous to surface water). In cases where a strong increase of the gross α value is noticed, ^{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 [46]. Discharges via the main rivers are monitored in the Coastal Area (KZ). Discharges by the ore and phosphate processing industries in Belgium and the Netherlands are monitored in the Westerscheldt (WS). Discharges by Germany, Delfzijl and Eemshaven are monitored in the Eems-Dollard (ED). The impact of these discharges is monitored indirectly in the Wadden Sea (WW and WO), together with activity originating from the North Sea.

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 2012 were within the range of those in previous years (Figure 5.29). The yearly averaged concentrations of ^{210}Pb in 2012 were within the range of those in previous years (Figure 5.31).

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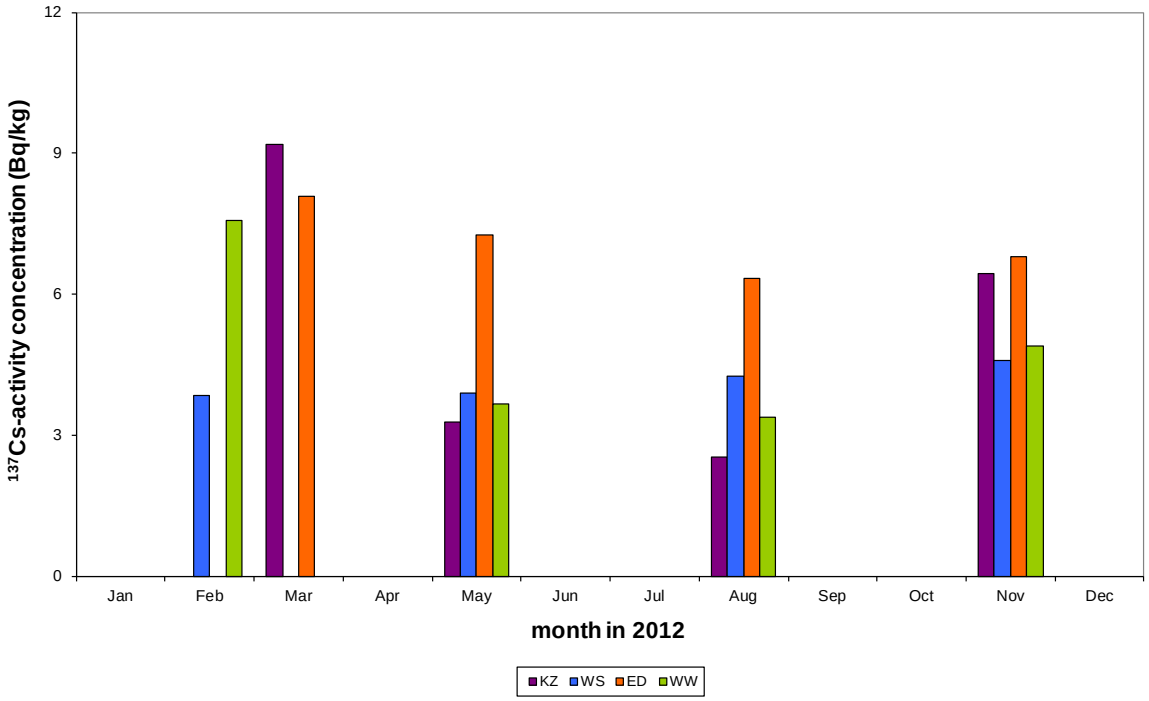

Figure 5.28: ^{137}Cs activity concentrations in suspended solids in seawater for the Coastal Area, Westerscheldt, Eems-Dollard, and Wadden Sea West, with yearly averages of 5.4, 4.2, 7.1, and 4.9 Bq·kg^{-1}, respectively

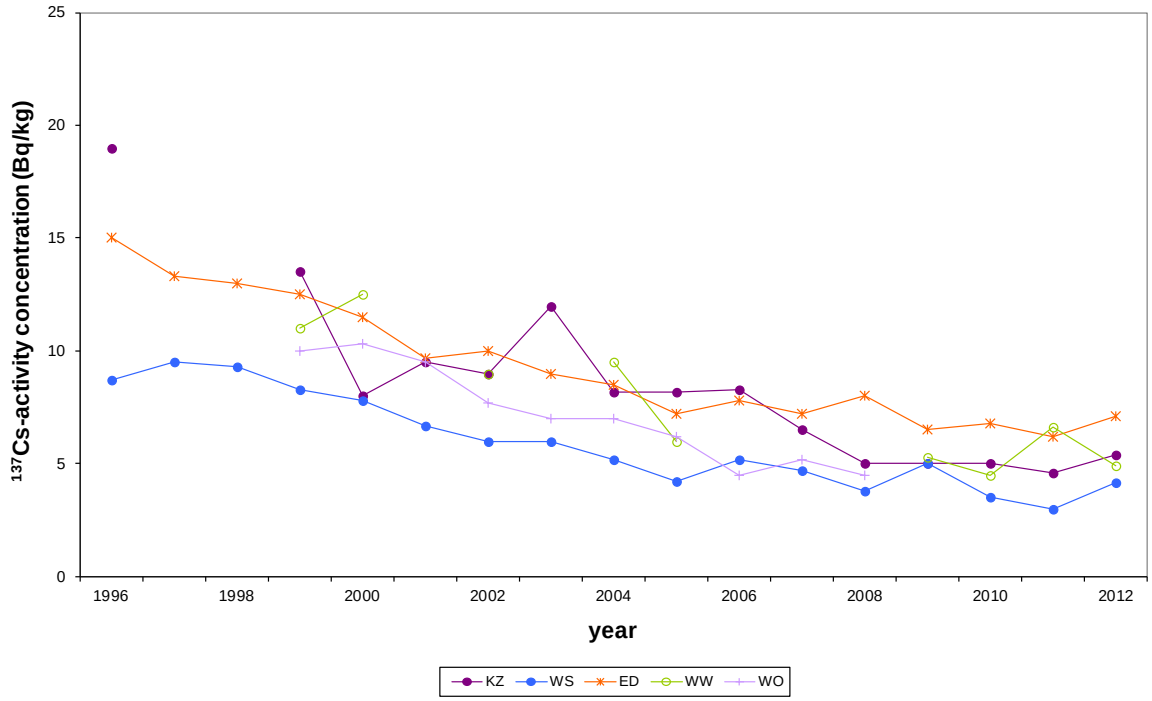

Figure 5.29: Yearly averaged ^{137}Cs activity concentrations in suspended solids
Since 2009, ^{137}Cs has been determined at Wadden Sea West instead of Wadden Sea East.

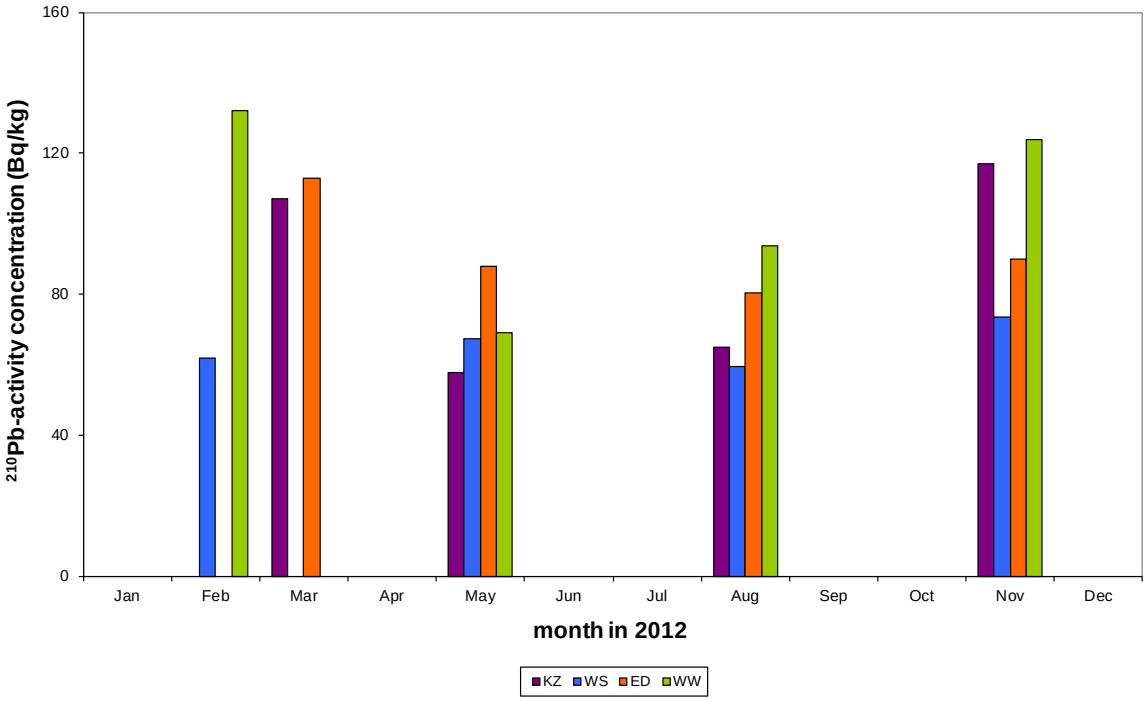

Figure 5.30: ^{210}Pb activity concentrations in suspended solids in seawater for the Coastal Area, Westerscheldt, Eems-Dollard, and Wadden Sea West, with yearly averages of 87, 66, 93, and 105 Bq·kg^{-1}, respectively

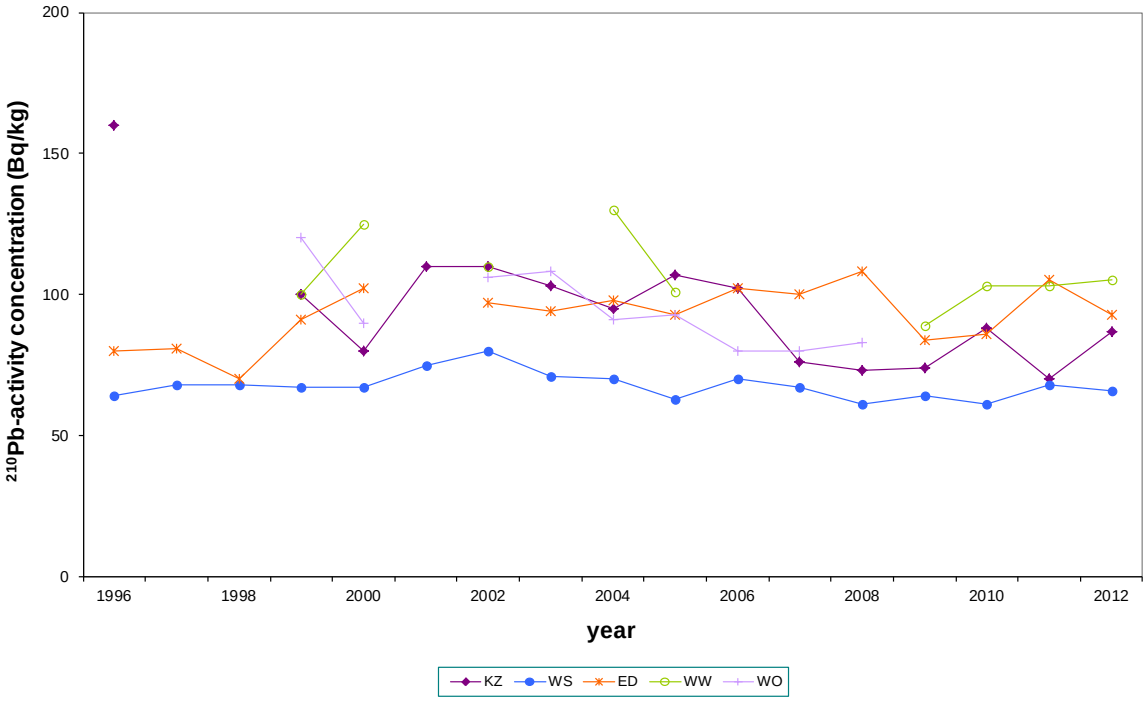

Figure 5.31: Yearly averaged ^{210}Pb activity concentrations in suspended solids
Since 2009, ^{210}Pb has been determined at Wadden Sea West instead of Wadden Sea East.

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 [53]. 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 0.1 and 1.0 $Bq \cdot L^{-1}$, respectively, it can be assumed that the total indicative dose is less than the parametric value of 0.1 $mSv \cdot year^{-1}$ [54, 55, 56].

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 for each production station.

The results for 2012 are presented in Table 6.1. For gross α, ^{3}H, gross β and residual β, several hundred analyses were performed at 170 to 188 production stations.

Table 6.1: Drinking water analyses in 2012

Parameter	Gross α	^{3}H	Residual β	Gross β
Average value [1]	< 0.1 $Bq \cdot L^{-1}$	< 4.2 $Bq \cdot L^{-1}$	< 0.2 $Bq \cdot L^{-1}$	< 0.1 $Bq \cdot L^{-1}$
No. of all production stations	184	185	170	188
No. of all analyses	370	399	369	435
Maximum value [2]	< 0.1 $Bq \cdot L^{-1}$	12.5 $Bq \cdot L^{-1}$	< 0.5 $Bq \cdot L^{-1}$	0.5 $Bq \cdot L^{-1}$
No. of production stations [3]	55	1	11	1
No. of analyses [4]	105	1	100	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, which lead to maximum value.

For gross α, ^{3}H, gross β and residual β, the results were within the range of those in previous years [7, 24, 57, 58, 59, 60, 61, 62, 63, 64, ^{65}]. Since there was almost no ^{40}K present, there was no significant difference between average gross β and residual β activity concentrations. The gross α activity concentrations were below 0.1 $Bq \cdot L^{-1}$. The gross β activity concentrations were below 1.0 $Bq \cdot L^{-1}$ and the ^{3}H activity concentrations were below the parametric value of 100 $Bq \cdot L^{-1}$ [53, 55, 56].

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 the radon activity of Dutch water [66]. The average concentration found was 2.2 $Bq \cdot L^{-1}$ 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 is a monitoring network that has been set up as an emergency network for monitoring relatively high contamination levels. The LMRV consists of 50 NaI-monitors in active service, of which 24 are stationed at dairy factories. The results of the weekly samples from all locations are combined into a monthly average for the whole country. The monthly averages for 2012 are presented in Table 7.1. None of the samples exceeded the limit of 370 Bq·kg^{-1} for the radiocesium activity (sum of ^{134}Cs and ^{137}Cs) set by the European Union [67]. The activity concentration of the natural radionuclide ^{40}K is measured as a reference value.

Table 7.1: Monthly averaged activity concentrations in milk in 2012 [(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	61.6 ± 14.2	< 1.4	< 0.6	< 0.6	< 0.5
February	49	59.8 ± 14.9	< 1.4	< 0.6	< 0.6	< 0.5
March	67	59.8 ± 17.8	< 1.4	< 0.6	< 0.6	< 0.5
April	57	56.3 ± 16.7	< 1.4	< 0.6	< 0.6	< 0.5
May	64	53.9 ± 10.4	< 1.4	< 0.6	< 0.6	< 0.5
June	58	53.1 ± 13.7	< 1.4	< 0.6	< 0.6	< 0.5
July	61	52.6 ± 11.7	< 1.4	< 0.6	< 0.6	< 0.5
August	60	54.9 ± 13.2	< 1.4	< 0.6	< 0.6	< 0.5
September	60	52.8 ± 10.7	< 1.4	< 0.6	< 0.6	< 0.5
October	79	58.0 ± 14.1	< 1.4	< 0.6	< 0.6	< 0.5
November	61	52.2 ± 12.3	< 1.4	< 0.6	< 0.6	< 0.5
December	60	54.9 ± 15.2	< 1.4	< 0.6	< 0.6	< 0.5
Average	891 [(2)]	55.8 ± 13.8	< 1.4	< 0.6	< 0.6	< 0.5

[(1)] Uncertainty is given as 1σ.

[(2)] Yearly total.

In addition to the LMRV samples, RIKILT Wageningen UR analysed 51 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 reporting limit of 2 Bq·L^{-1} except for the natural radionuclide ^{40}K (61.3 ± 4.1 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} [68]. The detection limit was lower than previous year (0.5 Bq·L^{-1}), due to an improvement in the sample preparation procedure.

8 Food

The Netherlands Food and Consumer Product Safety Authority 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 Netherlands Food and Consumer Product Safety Authority were carried out according to standard procedures [69, 70]. Since 2005, the Netherlands Food and Consumer Product Safety Authority has monitored activity concentrations in a mixed diet every year. Over a period of four weeks in 2012, 406 samples were taken from retail shops, wholesale produce auctions and distribution centres, including 46 samples of honey and 50 samples of tea [71]. Though honey is not considered to be part of the mixed diet, samples are taken each year because it is a product that is sometimes known to contain higher levels of radioactivity. In 2012 special attention was given to imported tea, with respect to possible contamination from the 2011 Fukushima (Japan) incident.

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, and tea. The 2012 results are presented in Table 8.1. None of the samples exceeded the set limit of 600 $Bq \cdot kg^{-1}$ (or 370 $Bq \cdot kg^{-1}$ for milk and dairy products) [67].

In 2012, RIKILT Wageningen UR measured radioactivity in food products as part of the governmental monitoring programme. Samples were taken throughout the year and measurements were carried out according to standard procedures. A total of 869 samples were analysed of which 162 samples were part of a certification programme for the export of Dutch meat products to Russia. The 2012 results are presented in Table 8.2. None of the samples exceeded the set limit of 600 $Bq \cdot kg^{-1}$ (or 370 $Bq \cdot kg^{-1}$ for milk and dairy products).

In addition, RIKILT Wageningen UR analysed 135 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 $Bq \cdot kg^{-1}$ for major food products [68].

8.1 Fruit and fruit products

In the product group ‘Fruit and fruit products’, which was analysed by the Netherlands Food and Consumer Product Safety Authority, only one sample of jam contained ^{137}Cs (10 $Bq \cdot kg^{-1}$). This radiocesium activity (sum of ^{134}Cs and ^{137}Cs) was below the set limit of 600 $Bq \cdot kg^{-1}$ [67].

8.2 Honey

In total, 46 samples of honey were analysed by the Netherlands Food and Consumer Product Safety Authority [71]. Only one sample of honey contained ^{137}Cs (50 $Bq \cdot kg^{-1}$). This radiocesium activity was below the set limit of 600 $Bq \cdot kg^{-1}$ [67].

8.3 Game and poultry

In the product group 'Game and poultry', which was analysed by the Netherlands Food and Consumer Product Safety Authority, only one sample of deer contained ^{137}Cs (7 Bq·kg^{-1}). This radiocesium activity was below the set limit of 600 Bq·kg^{-1} [67].

In the product group 'Game and poultry', which was analysed by RIKILT Wageningen UR, only eight samples of game contained ^{137}Cs. The activity varied from 6.9 up to 44 Bq·kg^{-1}. In all eight samples the radiocesium activity was below the set limit of 600 Bq·kg^{-1} [67].

Table 8.1: Results of 2012 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	42	< 5 (0)	< 5 (0)
Vegetables	73	< 5 (0)	< 5 (0)
Fruit and fruit products	43	< 5 (0)	10 (1)
Milk and dairy products	32	< 5 (0)	< 5 (0)
Meat and meat products	18	< 5 (0)	< 5 (0)
Game and poultry	41	< 5 (0)	7 (1)
Salads	33	< 5 (0)	< 5 (0)
Oil and butter	36	< 5 (0)	< 5 (0)
Honey	46	< 5 (0)	50 (1)
Tea	50	< 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 2012 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	50	< 2 (0)	< 2 (0)
Meat and meat products	539	< 2 (0)	< 2 (0)
Game and poultry	44	< 2 (0)	6.9 - 44 (8)
Eggs	81	< 2 (0)	< 2 (0)
Fish and seafood products	155	< 2 (0)	< 2 (0)
Mixed diet	40	< 5 (0)	< 5 (0)

(1) Number of samples above the given detection limit is given in brackets.

Table 8.3: Results of 2012 analysis of food for ^{90}Sr as measured by RIKILT Wageningen UR

Product	Number of samples	^{90}Sr (1) Bq·kg^{-1}
Vegetables	2	< 0.5 (0)
Meat and meat products	21	< 5 (0)
Bone	40	< 10 (0)
Game and poultry	5	< 5 (0)
Eggs	2	< 5 (0)
Fish and seafood products	24	< 10 (0)
Mixed diet	40	< 5 (0)

(1) Number of samples above the given detection limit is given in brackets.

9 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. The monitoring program [72] presented here, forms only part of the total monitoring program performed near the nuclear power plant. A more detailed description of the monitoring program and underlying strategy can be found elsewhere [73]. The 2012 monitoring program is outlined in Table 9.1 and Figure 9.1. Radioactive nuclides were determined in air dust, grass, soil, water, suspended solids, seaweed, and sediment.

Table 9.1: Monitoring program for environmental samples near the nuclear power plant at Borssele in 2012

The location numbers correspond with the location numbers given in Figure 9.1.

Matrix	Location	Parameter	Monitoring frequency (per year)
Air dust	21, 22, 23, 27 and 29	gross α, gross β	12
		γ-emitters [1]	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 or five locations.

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

[4] The four samples taken near the outlet are not shown in Figure 9.1.

[5] γ-spectroscopic analysis of specific γ-emitting nuclides: ^{54}Mn, ^{60}Co, ^{134}Cs and ^{137}Cs.

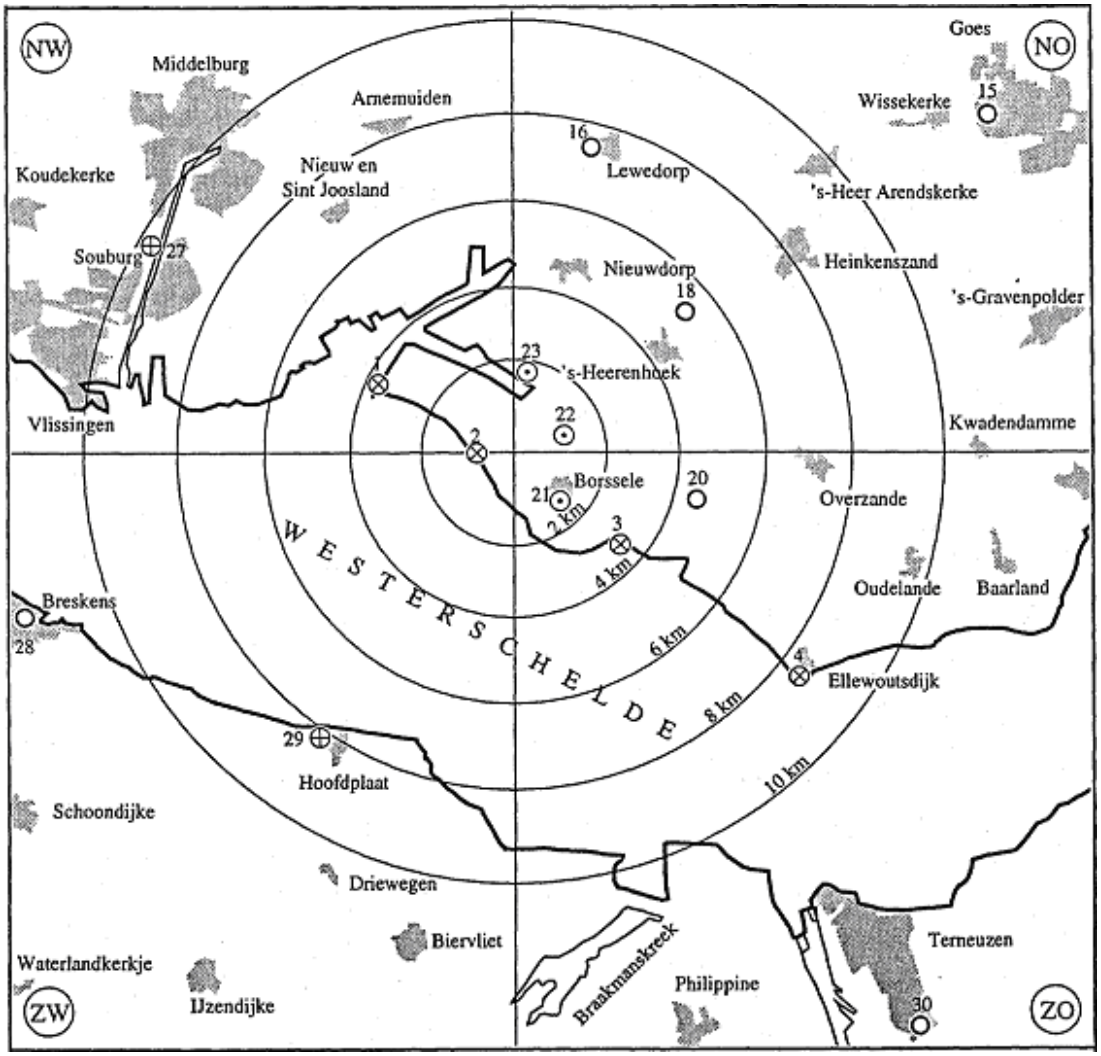

Figure 9.1: Overview of monitoring locations for the monitoring program conducted by NRG near the nuclear power plant at Borssele

The numbers given in Table 9.1 correspond with the locations on the map.

9.1 Air

The results of 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 2012 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 9.2 and 9.3.

The results for the nuclides considered in the gammaspectroscopic analysis are given in Table A17.

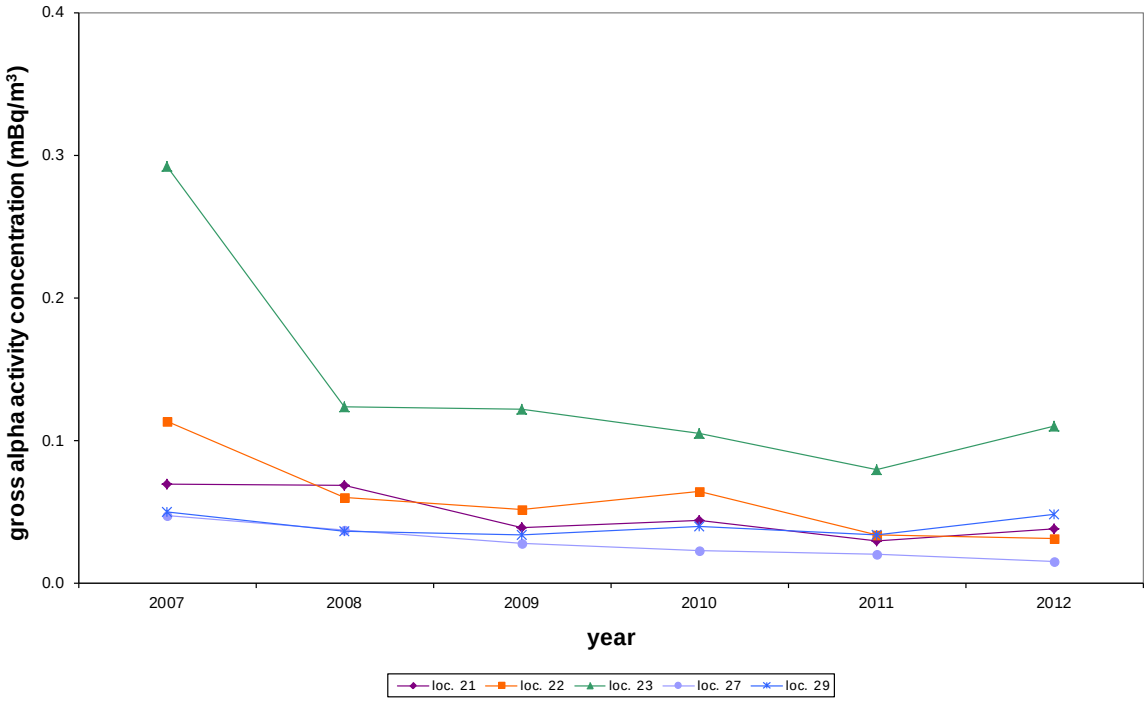

Figure 9.2: Yearly averaged gross α activity concentrations in air dust at five locations near Borssele (see Figure 9.1)

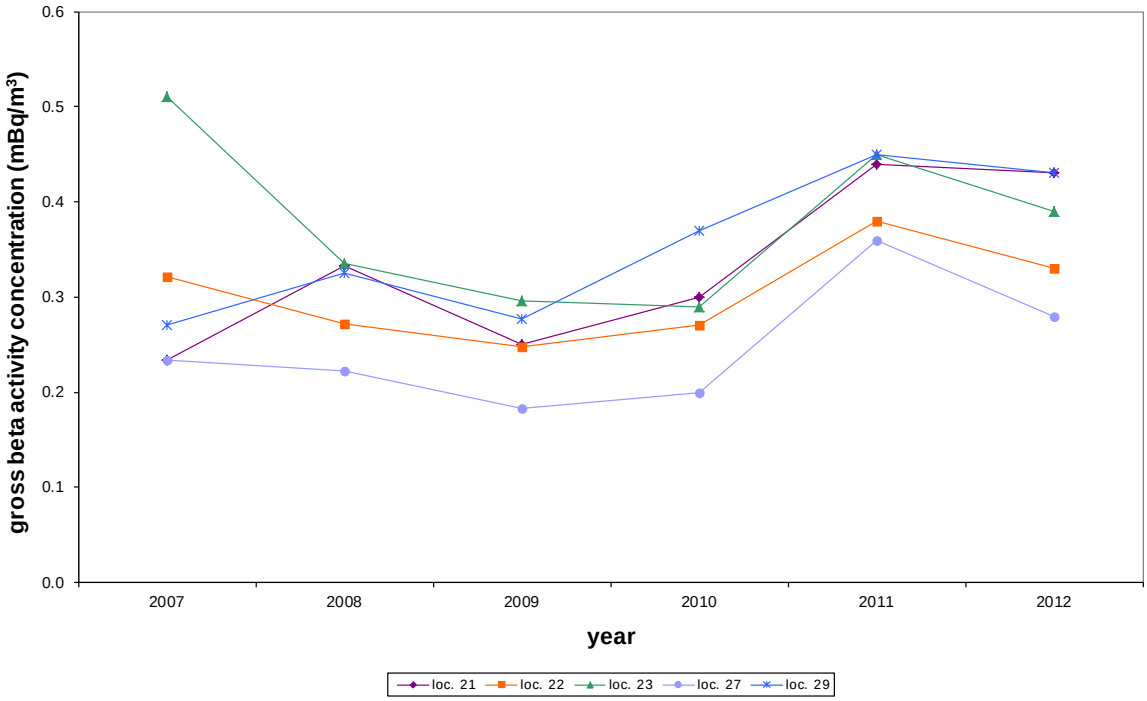

Figure 9.3: Yearly averaged gross β activity concentrations in air dust at five locations near Borssele (see Figure 9.1)

9.2 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 2012, 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 [61, 62, 63, 64, 65].

9.3 Water

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

In 2012, 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 9.4. The ^{3}H activity concentrations in water are 3 to 4 times lower than those in previous years, as illustrated in Figure 9.5. The gross β activity concentrations in suspended solids are 1.5 times higher than those in previous years, as illustrated in Figure 9.6. The changes in trend of ^{3}H and gross β activity concentrations coincide 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.

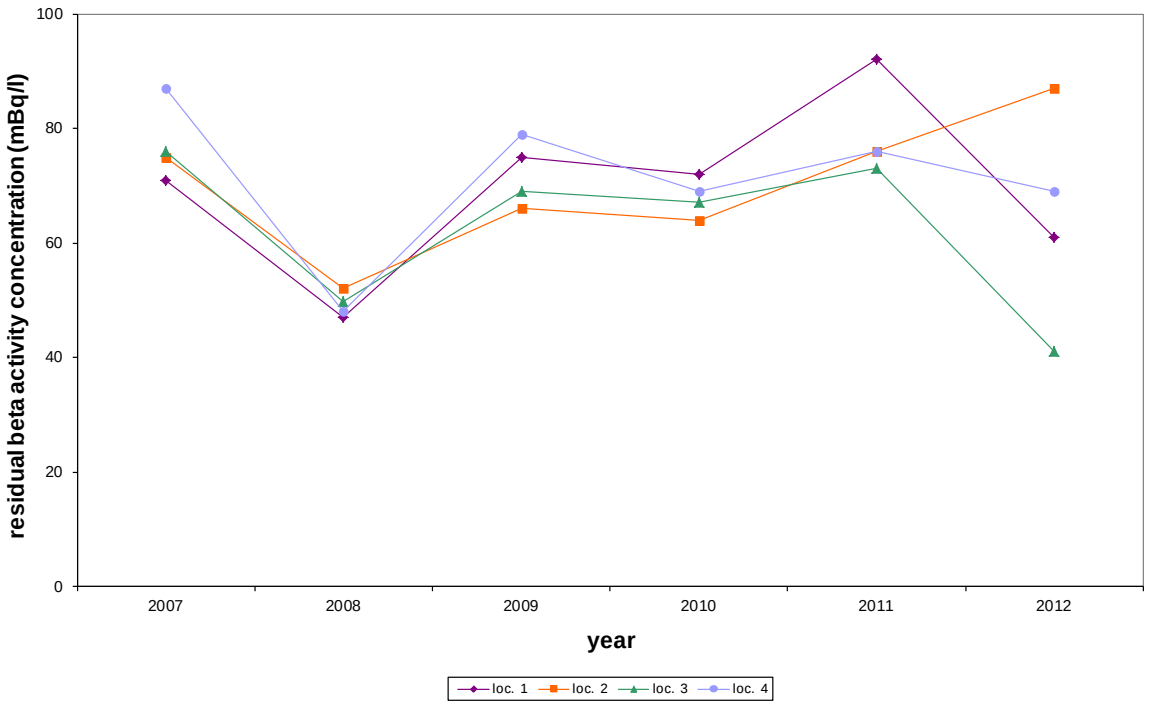

Figure 9.4: Yearly averaged residual β activity concentrations in surface water from the Westerscheldt at four locations near Borssele (see Figure 9.1)

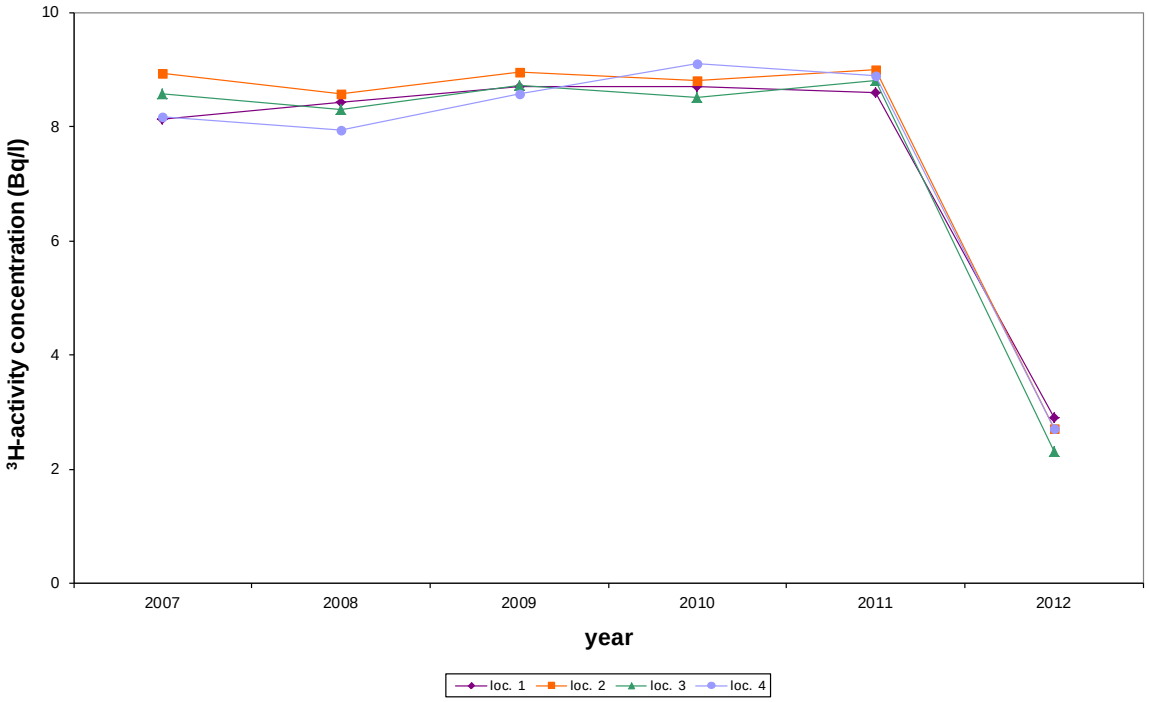

Figure 9.5: Yearly averaged ^{3}H activity concentrations in surface water from the Westerscheldt at four locations near Borssele (see Figure 9.1)

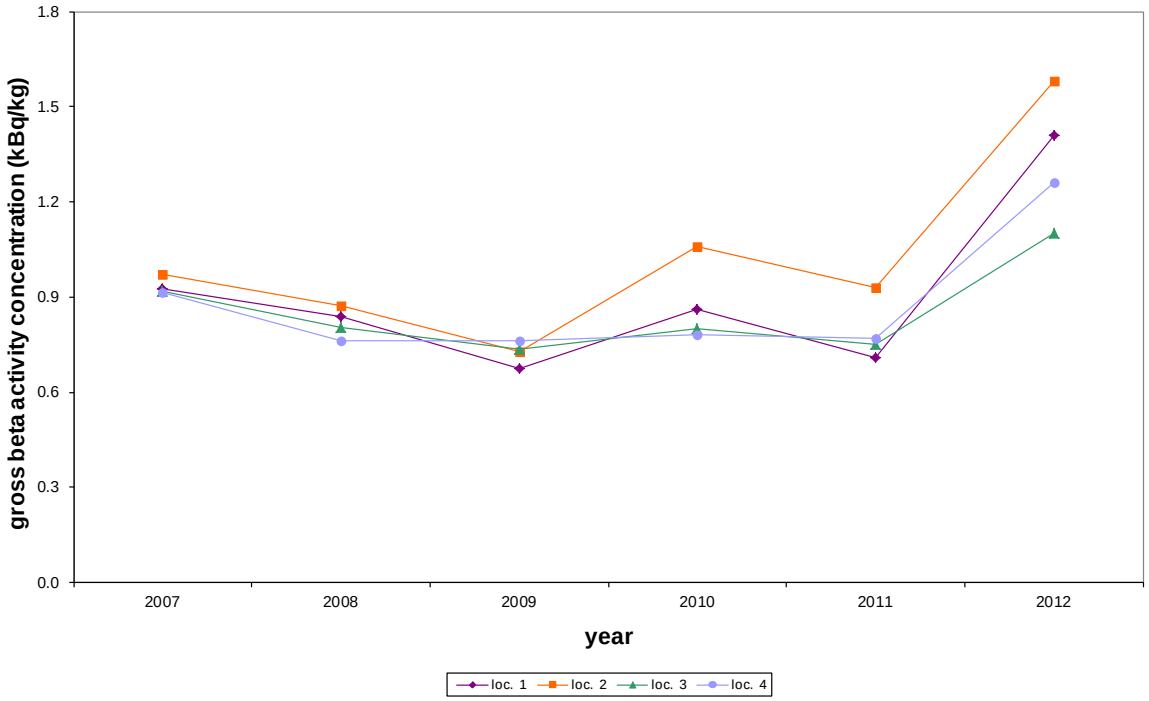

Figure 9.6: Yearly averaged gross β activity concentrations in suspended solids from the Westerscheldt at four locations near Borssele (see Figure 9.1)

10 Conclusions

A trace amount of ^{131}I was detected in the air sample from week 5 (27 January to 2 February) with an activity concentration of 2.7 ± 0.8 µBq·m^{-3}, which did not pose a threat to public health. During the same period, and the week before, ^{131}I was detected by several other institutes in countries across Europe in the same order of magnitude. The source of the ^{131}I detected across Europe was a release into the atmosphere from a facility in Budapest, Hungary.

In surface waters, all yearly averaged activity concentrations were within the range of those in previous years. The yearly averaged gross α activity concentration exceeded the target value of 100 mBq·L^{-1} in the Noordzeekanaal (180 mBq·L^{-1}) and Scheldt (250 mBq·L^{-1}). The yearly averaged ^{3}H activity concentration exceeded the target value of 10 Bq·L^{-1} in the Meuse (14.0 Bq·L^{-1}). The yearly averaged ^{226}Ra activity concentration exceeded the target value of 5 mBq·L^{-1} in the Scheldt (7.4 mBq·L^{-1}).

The yearly averaged activity concentrations in suspended solids were also within the range of those in previous years. The yearly averaged ^{60}Co activity concentration in suspended solids exceeded the target value of 10 Bq·kg^{-1} in the Meuse (14.7 Bq·kg^{-1}). The yearly averaged ^{131}I activity concentration in suspended solids exceeded the target value of 20 Bq·kg^{-1} in the Noordzeekanaal (23 Bq·kg^{-1}). The early averaged ^{210}Pb activity concentration in suspended solids exceeded the target value of 100 Bq·kg^{-1} in the Nieuwe Waterweg (111 Bq·kg^{-1}), the Rhine (126 Bq·kg^{-1}), and the Meuse (147 Bq·kg^{-1}).

With respect to data on environmental samples taken around the nuclear power plant at Borssele, a change in the analysis procedures of ^{3}H and gross β activity concentrations, respectively in water and suspended solids, coincides with a change in trend for those parameters. The ^{3}H activity concentrations in water are 3 to 4 times lower than those in previous years. The gross β activity concentrations in suspended solids are 1.5 times higher than those in previous years. The changes in trend are currently under investigation.

The results of all other radioactivity measurements were within the range of those in previous years. In 2012, the Netherlands complied with the Euratom recommendations on annually measuring radioactivity in the environment and in food.

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 2012

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	0.0075	0.140 ± 0.015	27	0.039	0.41 ± 0.04
2	0.014	0.156 ± 0.016	28	0.014	0.19 ± 0.02
3	0.029	0.37 ± 0.04	29	0.030	0.23 ± 0.02
4	0.015	0.183 ± 0.019	30	0.019	0.36 ± 0.04
5	0.081	1.56 ± 0.16	31	0.023	0.34 ± 0.04
6	0.049	0.95 ± 0.10	32	0.027	0.27 ± 0.03
7	0.041	0.45 ± 0.05	33	0.028	0.48 ± 0.05
8	0.023	0.175 ± 0.018	34	0.038	0.46 ± 0.05
9	0.042	0.22 ± 0.02	35	0.021	0.26 ± 0.03
10	0.027	0.31 ± 0.03	36	0.025	0.26 ± 0.03
11	0.038	0.34 ± 0.04	37	0.034	0.45 ± 0.05
12	0.050	0.50 ± 0.05	38	0.018	0.19 ± 0.02
13	0.036	0.45 ± 0.05	39	0.017	0.34 ± 0.04
14	0.033	0.41 ± 0.04	40	0.021	0.37 ± 0.04
15	0.019	0.25 ± 0.03	41	0.022	0.34 ± 0.04
16	0.013	0.22 ± 0.02	42	0.023	0.34 ± 0.04
17	0.029	0.30 ± 0.03	43	0.067	1.08 ± 0.11
18	0.027	0.34 ± 0.04	44	0.017	0.27 ± 0.03
19	0.019	0.25 ± 0.03	45	0.016	0.22 ± 0.02
20	0.028	0.32 ± 0.03	46	0.058	0.60 ± 0.06
21	0.033	0.85 ± 0.09	47	0.060	0.75 ± 0.08
22	0.035	0.65 ± 0.07	48	0.018	0.33 ± 0.03
23	0.022	0.29 ± 0.03	49	0.015	0.22 ± 0.02
24	0.020	0.27 ± 0.03	50	0.023	0.40 ± 0.04
25	0.024	0.29 ± 0.03	51	0.028	0.27 ± 0.03
26	0.034	0.31 ± 0.03	52	0.017	0.21 ± 0.02
			53	0.011	0.157 ± 0.017
Average				0.029	0.384 ± 0.007 [3]
SD [4]				0.014	0.3

[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] 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.

[4] 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 2012

Measurements were carried out on the ash residue of the filter on a well-type detector, with a 10-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 [74], 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 since 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 2012

Week number	Period	^{7}Be µBq·m^{-3}	^{137}Cs µBq·m^{-3}	^{210}Pb µBq·m^{-3}
1	30/12-06/01	2,100 ± 200	< 0.12	78 ± 8
2	06/01-13/01	2,100 ± 200	< 0.12	115 ± 11
3	13/01-19/01	2,600 ± 300	0.56 ± 0.07	320 ± 30
4	19/01-27/01	3,400 ± 300	0.15 ± 0.03	147 ± 15
5 (1)	27/01-02/02	6,000 ± 600	1.52 ± 0.15	1,750 ± 170
6	02/02-09/02	4,500 ± 400	0.71 ± 0.07	1,140 ± 110
7	09/02-17/02	3,400 ± 300	0.37 ± 0.06	420 ± 40
8	17/02-24/02	2,900 ± 300	0.10 ± 0.03	140 ± 14
9	24/02-02/03	2,400 ± 200	0.14 ± 0.03	260 ± 30
10	02/03-09/03	2,700 ± 300	0.15 ± 0.04	320 ± 30
11	09/03-16/03	4,100 ± 400	0.25 ± 0.04	350 ± 30
12	16/03-23/03	4,900 ± 500	0.28 ± 0.03	500 ± 50
13	23/03-30/03	3,700 ± 400	0.73 ± 0.08	490 ± 50
14	30/03-06/04	4,100 ± 400	0.33 ± 0.05	310 ± 30
15	06/04-13/04	3,400 ± 300	0.10 ± 0.03	179 ± 18
16	13/04-20/04	3,000 ± 300	0.13 ± 0.04	174 ± 17
17	20/04-27/04	4,300 ± 400	< 0.12	194 ± 19
18	27/04-04/05	4,600 ± 500	0.26 ± 0.04	360 ± 40
19	04/05-11/05	3,800 ± 400	0.10 ± 0.03	280 ± 30
20	11/05-16/05	3,600 ± 400	< 0.16	210 ± 20
21	16/05-25/05	6,400 ± 600	0.49 ± 0.05	720 ± 70
22	25/05-01/06	5,500 ± 500	0.38 ± 0.05	610 ± 60
23	01/06-08/06	4,700 ± 500	< 0.15	196 ± 19
24	08/06-15/06	3,600 ± 400	0.20 ± 0.04	200 ± 20
25	15/06-22/06	3,800 ± 400	< 0.16	240 ± 20
26	22/06-29/06	3,400 ± 300	0.14 ± 0.03	240 ± 20

Continued on the next page

Table A3: Continued

Week number	Period	^{7}Be µBq·m^{-3}	^{137}Cs µBq·m^{-3}	^{210}Pb µBq·m^{-3}
27	29/06-06/07	4,400 ± 400	0.16 ± 0.04	370 ± 40
28	06/07-13/07	2,800 ± 300	< 0.12	195 ± 19
29	13/07-20/07	3,200 ± 300	< 0.10	174 ± 17
30	20/07-27/07	4,600 ± 500	0.20 ± 0.03	320 ± 30
31	27/07-03/08	4,600 ± 400	0.13 ± 0.03	330 ± 30
32	03/08-10/08	3,100 ± 300	0.079 ± 0.016	230 ± 20
33	10/08-17/08	4,900 ± 500	0.24 ± 0.04	480 ± 50
34	17/08-24/08	4,700 ± 500	0.13 ± 0.04	540 ± 50
35	24/08-31/08	3,800 ± 400	0.066 ± 0.016	290 ± 30
36	31/08-07/09	3,600 ± 400	0.14 ± 0.04	260 ± 30
37	07/09-14/09	4,300 ± 400	0.12 ± 0.03	530 ± 50
38	14/09-21/09	2,500 ± 200	< 0.17	220 ± 20
39	21/09-28/09	2,900 ± 300	0.11 ± 0.02	280 ± 30
40	28/09-05/10	3,500 ± 300	0.08 ± 0.03	310 ± 30
41	05/10-12/10	3,800 ± 400	0.28 ± 0.04	270 ± 30
42	12/10-19/10	3,500 ± 300	< 0.15	310 ± 30
43	19/10-26/10	3,700 ± 400	0.51 ± 0.06	1,150 ± 110
44	26/10-02/11	2,900 ± 300	0.16 ± 0.04	230 ± 20
45	02/11-09/11	2,800 ± 300	0.14 ± 0.04	165 ± 16
46	09/11-16/11	2,900 ± 300	0.20 ± 0.03	530 ± 50
47	16/11-23/11	2,800 ± 300	0.44 ± 0.06	750 ± 70
48	23/11-30/11	1,860 ± 180	0.13 ± 0.04	280 ± 30
49	30/11-07/12	2,200 ± 200	0.14 ± 0.03	184 ± 18
50	07/12-14/12	2,300 ± 200	0.32 ± 0.05	450 ± 40
51	14/12-21/12	2,700 ± 300	0.27 ± 0.04	200 ± 20
52	21/12-28/12	2,400 ± 200	< 0.14	181 ± 18
53	28/12-04/01	1,940 ± 190	< 0.16	152 ± 15
Average		3,540 ± 50 [2]	0.272 ± 0.007 [2, 3]	365 ± 6 [2]
SD [4]		1,000	0.3	300

[1] During this week a trace amount of ^{131}I was detected with an activity concentration of 2.7 ± 0.8 µ Bq·m^{-3}.

[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 α and gross β activity sampled at RIVM in 2012

Month	Precipitation mm	^{3}H (1) Bq·m^{-2}	Gross α Bq·m^{-2}	Gross β Bq·m^{-2}
January	95.3	< 140	1.5 ± 0.2	6.2 ± 0.5
February	23.5	35 ± 11	0.85 ± 0.11	1.67 ± 0.14
March	21.8	< 30	2.6 ± 0.3	7.1 ± 0.5
April	50.6	< 90	4.0 ± 0.4	10.7 ± 0.8
May	54.0	< 90	3.5 ± 0.4	8.5 ± 0.6
June	88.5	< 150	2.9 ± 0.3	6.6 ± 0.5
July	129.3	< 200	4.8 ± 0.5	12.6 ± 0.9
August	84.3	< 150	4.1 ± 0.4	9.7 ± 0.7
September	60.3	< 100	2.8 ± 0.3	7.5 ± 0.6
October	108.5	< 190	2.7 ± 0.3	7.1 ± 0.5
November	41.9	90 ± 20	1.09 ± 0.18	3.7 ± 0.3
December	164.8	280 ± 90	1.7 ± 0.2	7.0 ± 0.5
Total	922.5	-	32.7 ± 1.1 (2)	88 ± 2 (2)
Lower limit (3)	-	316		
Upper limit (3)	-	1,650		

(1) The detection limit (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 (1.4-1.7 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 range 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

(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 2012

Month	**^{210}Po** **Bq·m^{-2}**
January	1.82 ± 0.14
February	0.98 ± 0.06
March	3.00 ± 0.14
April	4.6 ± 0.3
May	4.3 ± 0.2
June	2.89 ± 0.14
July	3.9 ± 0.3
August	3.7 ± 0.2
September	3.16 ± 0.15
October	2.4 ± 0.2
November	1.29 ± 0.07
December	1.88 ± 0.13
Total	33.8 ± 0.6 [(2)]
Lower limit [(3)]	-
Upper limit [(3)]	-

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

[(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 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]	^{137}Cs [3]	^{210}Pb [3]	^{210}Pb [4]	^{210}Po [4]
	$Bq \cdot m^{-2}$	$Bq \cdot m^{-2}$	$Bq \cdot m^{-2}$	$Bq \cdot m^{-2}$	$Bq \cdot m^{-2}$
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

[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 [75].

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

[7] Results revised in RIVM Report 610791003.

Table A8: Weekly deposited ^{7}Be, ^{137}Cs and ^{210}Pb activity (1) sampled at RIVM in 2012

Week number	Period	Precipitation mm	^{7}Be Bq·m^{-2}	^{137}Cs Bq·m^{-2}	^{210}Pb Bq·m^{-2}
1	30/12-06/01	54.0	56 ± 7	< 0.02	2.5 ± 0.3
2	06/01-13/01	6.9	15 ± 2	< 0.02	0.94 ± 0.14
3	13/01-20/01	14.5	21 ± 3	< 0.02	2.4 ± 0.3
4	20/01-27/01	19.3	41 ± 5	< 0.02	1.5 ± 0.2
5	27/01-03/02	0.7	2.4 ± 0.3	< 0.02	0.68 ± 0.11
6	03/02-10/02	3.3	2.7 ± 0.3	< 0.02	0.66 ± 0.10
7	10/02-17/02	7.8	16 ± 2	< 0.03	1.20 ± 0.17
8	17/02-24/02	11.5	9.5 ± 1.2	< 0.02	0.62 ± 0.10
9	24/02-02/03	1.0	3.3 ± 0.4	< 0.02	0.38 ± 0.07
10	02/03-09/03	20.5	22 ± 3	< 0.02	1.5 ± 0.2
11	09/03-16/03	0.6	7.0 ± 0.9	< 0.02	0.86 ± 0.13
12	16/03-23/03	0.6	4.8 ± 0.6	< 0.02	0.92 ± 0.13
13	23/03-30/03	0.0	2.8 ± 0.4	< 0.02	1.36 ± 0.19
14	30/03-06/04	0.8	7.3 ± 0.9	< 0.02	1.7 ± 0.2
15	06/04-13/04	15.4	15 ± 2	< 0.02	1.10 ± 0.16
16	13/04-20/04	6.6	7.9 ± 1.0	< 0.02	0.78 ± 0.12
17	20/04-27/04	15.9	31 ± 4	< 0.02	1.21 ± 0.17
18	27/04-04/05	12.0	62 ± 8	< 0.02	4.6 ± 0.6
19	04/05-11/05	31.5	43 ± 6	< 0.02	2.0 ± 0.3
20	11/05-16/05	5.3	22 ± 3	< 0.03	1.7 ± 0.2
21	16/05-25/05	8.7	44 ± 6	< 0.02	2.6 ± 0.3
22	25/05-01/06	8.5	27 ± 3	< 0.02	5.5 ± 0.7
23	01/06-08/06	27.5	27 ± 3	< 0.02	0.99 ± 0.14
24	08/06-15/06	10.3	27 ± 3	< 0.02	1.5 ± 0.2
25	15/06-22/06	34.8	50 ± 6	< 0.02	1.9 ± 0.3
26	22/06-29/06	16.0	32 ± 4	< 0.02	1.5 ± 0.2

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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	29/06-06/07	6.5	27 ± 3	< 0.02	2.9 ± 0.4
28	06/07-13/07	38.8	42 ± 5	< 0.02	3.6 ± 0.5
29	13/07-20/07	37.5	55 ± 7	< 0.03	1.5 ± 0.2
30	20/07-27/07	0.0	5.5 ± 0.7	< 0.02	2.0 ± 0.3
31	27/07-03/08	46.5	107 ± 14	< 0.019	6.9 ± 0.9
32	03/08-10/08	18.5	26 ± 3	< 0.02	1.24 ± 0.17
33	10/08-17/08	21.3	37 ± 5	< 0.02	5.7 ± 0.7
34	17/08-24/08	0.0	12.3 ± 1.6	< 0.02	4.2 ± 0.5
35	24/08-31/08	44.5	44 ± 6	< 0.02	2.6 ± 0.3
36	31/08-07/09	2.1	6.6 ± 0.8	< 0.02	0.41 ± 0.08
37	07/09-14/09	4.9	11.5 ± 1.5	< 0.02	1.6 ± 0.2
38	14/09-21/09	23.8	22 ± 3	< 0.02	1.21 ± 0.17
39	21/09-28/09	29.5	34 ± 4	< 0.02	2.1 ± 0.3
40	28/09-05/10	26.5	22 ± 3	< 0.02	1.21 ± 0.17
41	05/10-12/10	39.0	31 ± 4	< 0.03	1.4 ± 0.2
42	12/10-19/10	19.5	28 ± 4	< 0.02	2.4 ± 0.3
43	19/10-26/10	1.0	8.4 ± 1.1	< 0.02	1.7 ± 0.2
44	26/10-02/11	22.5	17 ± 2	< 0.02	1.16 ± 0.16
45	02/11-09/11	19.8	24 ± 3	< 0.018	1.24 ± 0.17
46	09/11-16/11	4.1	4.3 ± 0.6	< 0.02	0.62 ± 0.10
47	16/11-23/11	5.5	10.5 ± 1.3	< 0.02	1.07 ± 0.15
48	23/11-30/11	12.6	11.8 ± 1.5	< 0.02	0.88 ± 0.13
49	30/11-07/12	30.3	26 ± 3	< 0.02	1.16 ± 0.16
50	07/12-14/12	25.0	31 ± 4	< 0.02	2.0 ± 0.3
51	14/12-21/12	29.5	24 ± 3	< 0.02	1.13 ± 0.16
52	21/12-28/12	55.5	40 ± 5	< 0.02	2.3 ± 0.3
53	28/12-04/01	24.5	19 ± 2	< 0.02	1.22 ± 0.16
Total [2]		922.5	1,330 ± 30	-	98 ± 2
Lower limit [3]		-	-	0	-
Upper limit [3]		-	-	1.2	-

[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 2012 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	3.3	67
Kollumerwaard	972	2.6	70
Valthermond [3]	974	2.7	58
Vlaardingen	976	2.7	70
Braakman	978	2.7	65
Huijbergen	980	2.8	57
Houtakker	982	3.0	67
Wijnandsrade	984	6.0	70
Eibergen	986	3.1	60
De Zilk	988	2.0	64
Wieringerwerf	990	2.4	69
Vredepeel	992	3.3	66
Biddinghuizen	994	3.2	74
Bilthoven	998	2.6	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 2012

Station	No.	Ambient dose equivalent rate nSv.h^{-1}	Station	No.	Ambient dose equivalent rate nSv.h^{-1}
Den Burg	1001	66	Lelystad	1103	76
Den Helder [1]	1002	70	Urk	1105	74
Den Oever	1003	68	Eemshaven	1106	83
Petten	1006	60	Uithuizen	1107	81
Kolhorn	1007	76	Wagenborgen	1109	75
Egmond aan Zee	1009	66	Winschoten	1110	75
Heerhugowaard	1011	69	Ter Apel	1111	71
Haarlem-Noord	1014	72	Stadskanaal	1112	62
Nederhorst Den Berg	1015	60	Nieuweschans	1113	71
Enkhuizen	1018	71	Bellingwolde	1114	60
Oosthuizen	1019	73	Groningen	1116	75
Zaandam [2]	1021	69	Leens	1117	86
Gouda	1024	69	Grijpskerk	1118	72
Dordrecht	1027	64	Meppel	1125	70
Zuid Beijerland	1028	72	Hoogeveen	1126	60
Rotterdam-Schiebroek[3]	1031	65	Steenwijksmoer	1129	64
Pijnacker	1032	85	Nieuw Amsterdam	1130	78
Maasvlakte	1035	83	Nw. Schoonebeek/	1131	60
Rotterdam-Waalhaven	1036	65	Weiteveen		
Maassluis	1037	82	Emmen	1132	80
Hellevoetsluis	1038	91	Hengelo (Ov)	1135	69
Ouddorp	1039	72	Hengelo (Gld) [6]	1136	-
Wekerom	1041	74	Enschede	1139	64
Wageningen	1043	68	Losser	1140	62
Amersfoort	1046	70	Oldenzaal	1141	77
Harderwijk	1050	64	Westerhaar	1142	62
Wijk bij Duurstede	1056	80	Rijssen	1143	74
Nieuwegein	1062	79	's Heerenberg	1144	62
Zegveld [4]	1063	64	Dinxperlo	1145	79
Lopik (Cabauw) [5]	1064	82	Varsseveld	1146	71
Apeldoorn	1066	69	Groenlo	1147	84
Heerenveen	1071	70	Deventer	1148	76
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	76	Baarle Nassau	1161	60
Holwerd	1082	87	Uden	1163	65
Leeuwarden	1085	69	Mill	1164	61
Zwolle-Zuid [6]	1087	-	Oss	1167	64
Ommen	1093	64	Nuenen	1172	70
Hardenberg	1095	64	Bergeijk	1174	87
Assen [6]	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 [6]	1228	-
Oostelbeers	1180	82	Elst (Gld)	1229	81
Hilvarenbeek	1181	65	Zevenaar	1230	72
Venray	1183	62	Nijmegen	1231	73
Nieuw-Bergen	1184	62	Amstelveen	1233	74
Sevenum	1185	69	Amsterdam Oost	1234	67
Reuver	1188	67	Aalsmeer	1236	73
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	75
Leiden	1196	75	Zaltbommel	1251	70
Hulst	1197	77	IJzendijke	1252	76
Terneuzen	1199	70	Ritthem	1253	96
Sluis	1201	74	Vlissingen Haven	1254	73
Vlissingen	1202	76	Nieuwdorp	1255	74
Halsteren	1204	65	's Heerenhoek [7]	1256	114
Oud Gastel	1206	65	Driewegen	1257	81
Goes	1207	81	Arnemuiden	1258	72
Bruinisse	1209	73	Heinkenszand	1259	81
Burgh-Haamstede	1211	62	Baarland	1260	85
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	81	Nieuw Namen	1265	78
Maastricht	1220	88	Beneden Leeuwen	1272	84
Ravensbos (Arensgehout)	1221	84	Denekamp	1278	64
			Winterswijk (Kotten)	1279	68
Vaals	1222	80	Bilthoven	1280	61
Gulpen	1223	81	Gastel (Maarheze)	1281	74
Kerkrade	1224	85			

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

[2] The Zaandam station has been dismantled since March 2012.

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

[4] The Noordwijk-Binnen station was relocated to Zegsveld in July 2009.

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

[6] Station was not operational in 2012.

[7] As in previous years, then '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, ^{3}H, ^{90}Sr and ^{226}Ra activity concentrations ($mBq \cdot L^{-1}$) in surface water in 2012 as measured by RWS

Date	Gross α $mBq \cdot L^{-1}$	Residual β $mBq \cdot L^{-1}$	^{3}H $mBq \cdot L^{-1}$	^{90}Sr $mBq \cdot L^{-1}$	^{226}Ra $mBq \cdot L^{-1}$
Location	**IJsselmeer**				
04/01/12	69	81	2,490		
29/02/12	55	24	3,070		
28/03/12	26	9			
25/04/12	24	7	2,970		
23/05/12	28	17			
21/06/12	27	16	3,360		
18/07/12	22	22			
15/08/12	19	21	2,920		
12/09/12	27	33			
09/10/12	50	25	3,480		
07/11/12	34	9			
04/12/12	64	51	3,500		
Average	37	26	3,110		
Location	**Nieuwe Waterweg**				
18/01/12	118	70			
15/02/12	88	35	5,120	5.0	3.0
14/03/12	180	69			
11/04/12	106	37	5,730	< 1	3.0
09/05/12	71	34			
06/06/12	195	83	9,180	< 1	5.4
04/07/12	36	32			
01/08/12	119	35	4,230	< 1	2.6
29/08/12	49	24			
26/09/12	65	21	3,480	2.0	3.6
24/10/12	61	< 1			
21/11/12	87	30	5,710	5.0	3.2
19/12/12	120	119			
Average	100	45	5,600	2.2	3.5
Location	**Noordzeekanaal**				
16/01/12	38	46	2,360		
13/02/12	248	22	2,520		
12/03/12	94	39	2,690		
10/04/12	192	38	2,700		
07/05/12	163	19	2,410		
04/06/12	98	43	3,010		
02/07/12	140	14	2,720		
31/07/12	343	30	2,480		
27/08/12	170	11	2,330		
24/09/12	208	28	2,320		
22/10/12	183	24	2,500		
19/11/12	273	80	2,380		
17/12/12	172	48	3,110		
Average	180	34	2,580		

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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**				
11/01/12	79	86	3,020	6.0	3.1
08/02/12	52	33	5,310		
07/03/12	33	29	5,520	< 1	2.8
04/04/12	40	17	4,750		
02/05/12	37	17	2,720	3.0	6.5
30/05/12	40	29	11,600		
27/06/12	41	11	2,820	3.0	1.6
25/07/12	35	31	6,200		
22/08/12	27	35	2,310	3.0	4.6
19/09/12	56	29	2,960		
17/10/12	78	63	5,050	< 1	1.8
14/11/12	54	53	8,460		
12/12/12	47	33	6,380	6.0	2.5
Average	48	36	5,200	3.1	3.3
Location	**Scheldt**				
02/01/12	224	72			
30/01/12	147	66	5,720		6.1
29/02/12	164	151			
27/03/12	101	78	8,450		6.7
25/04/12	514	392			
24/05/12	144	120	11,100		5.6
20/06/12	253	98			
17/07/12	192	87	7,760		7.7
15/08/12	261	54			
10/09/12	228	42	7,720		9.5
08/10/12	312	64			
05/11/12	320	90	9,100		8.8
04/12/12	407	153			
Average	250	110	8,300		7.4
Location	**Meuse**				
10/01/12	47	50	6,560	3.0	1.8
07/02/12	< 1	14	22,000		
06/03/12	30	39	4,430	9.0	2.0
03/04/12	24	12	19,800		
01/05/12	21	20	1,180	4.0	2.5
29/05/12	15	14	26,900		
26/06/12	33	4	3,890	1.0	1.7
24/07/12	11	12	12,200		
21/08/12	31	29	5,480	5.0	3.0
18/09/12	37	15	26,800		
16/10/12	29	38	6,720	2.0	2.5
13/11/12	18	22	32,800		
11/12/12	78	73	9,060	4.0	2.2
Average	29	26	14,000	4.0	2.2

Table A12: ^{60}Co, ^{131}I, ^{137}Cs and ^{210}Pb activity concentrations in suspended solids ($Bq \cdot kg^{-1}$) in surface water in 2012 as measured by RWS

Date	^{60}Co $Bq \cdot kg^{-1}$	^{131}I $Bq \cdot kg^{-1}$	^{137}Cs $Bq \cdot kg^{-1}$	^{210}Pb $Bq \cdot kg^{-1}$
Location	**IJsselmeer**			
04/01/12	< 1	< 1	6.2	
29/02/12	< 1	< 1	7.8	
28/03/12	< 1	< 1	1.7	
25/04/12	< 1	< 1	6.6	
23/05/12	< 1	< 1	2.1	
21/06/12	< 1	< 1	3.0	
18/07/12	< 1	< 1	2.5	
15/08/12	< 1	< 1	1.1	
12/09/12	< 1	< 1	2.7	
09/10/12	< 1	< 1	4.9	
07/11/12	< 1	< 1	3.6	
04/12/12	< 1	< 1	5.4	
Average	< 1	< 1	4.0	
Location	**Nieuwe Waterweg**			
18/01/12	< 1	< 1	10.5	
15/02/12	1.9	< 1	10.8	104
14/03/12	< 1	< 1	9.7	
11/04/12	< 1	< 1	10.1	104
09/05/12	< 1	3.7	9.0	
06/06/12	< 1	2.3	7.1	106
04/07/12	< 1	2.1	9.1	
01/08/12	< 1	< 1	9.6	109
29/08/12	< 1	< 1	8.6	
26/09/12	< 1	2.4	9.4	133
24/10/12	< 1	< 1	10.0	
21/11/12	< 1	2.8	9.8	108
19/12/12	< 1	< 1	5.4	
Average	< 1	< 1.3	9.2	111
Location	**Noordzeekanaal**			
16/01/12	< 1	< 1	10.3	
12/03/12	< 1	< 1	5.3	
07/05/12	< 1	42.4	5.2	
02/07/12	< 1	23.9	1.6	
27/08/12	< 1	46.4	5.2	
22/10/12	< 1	21.7	10.8	
17/12/12	< 1	24.2	9.9	
Average	< 1	23	6.9	

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Table A12: Continued

Date	^{60}Co	^{131}I	^{137}Cs	^{210}Pb
	Bq·kg^{-1}	Bq·kg^{-1}	Bq·kg^{-1}	Bq·kg^{-1}
Location	**Rhine**			
11/01/12	< 1	< 1	12.7	122
25/01/12	< 1	< 1	12.8	
08/02/12	< 1	< 1	14.1	
22/02/12	< 1	< 1	10.6	
07/03/12	< 1	< 1	10.3	114
21/03/12	< 1	< 1	9.1	
04/04/12	< 1	< 1	10.7	
18/04/12	< 1	< 1	9.2	
02/05/12	< 1	< 1	8.6	132
14/05/12	< 1	< 1	9.4	
30/05/12	< 1	5.8	10.6	
13/06/12	< 1	5.9	12.1	
27/06/12	< 1	4.4	11.3	135
25/07/12	< 1	6.6	11.2	
08/08/12	< 1	< 1	11.4	
22/08/12	< 1	3.3	9.9	126
05/09/12	< 1	< 1	11.1	
19/09/12	< 1	< 1	10.5	
03/10/12	< 1	< 1	9.6	
17/10/12	< 1	3.1	10.8	104
31/10/12	< 1	< 1	10.0	
14/11/12	< 1	< 1	11.4	
28/11/12	< 1	< 1	11.8	
13/12/12	< 1	8.0	12.3	148
27/12/12	< 1	4.0	14.3	
Average	< 1	< 2	11.0	126
Location	**Scheldt**			
02/01/12	< 1	2.8	7.3	
30/01/12	< 1	< 1	7.7	95
29/02/12	< 1	< 1	7.5	
27/03/12	< 1	< 1	8.1	92
25/04/12	< 1	< 1	7.5	
24/05/12	< 1	< 1	6.8	85
20/06/12	< 1	< 1	7.8	
17/07/12	< 1	< 1	9.3	109
15/08/12	< 1	< 1	7.1	
10/09/12	< 1	< 1	7.2	91
08/10/12	< 1	< 1	7.0	
05/11/12	< 1	< 1	6.6	87
04/12/12	< 1	< 1	7.0	
Average	< 1	< 1	7.5	93
Location	**Meuse**			
03/01/12	2.5	< 1	12.2	
10/01/12	< 1	< 1	11.8	117
17/01/12	39.6	< 1	18.6	
24/01/12	< 1	< 1	11.4	
01/02/12	5.1	< 1	13.0	
07/02/12	4.3	< 1	13.3	
14/02/12	82.6	< 1	7.9	

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Table A12: Continued

Date	^{60}Co	^{131}I	^{137}Cs	^{210}Pb
	Bq·kg^{-1}	Bq·kg^{-1}	Bq·kg^{-1}	Bq·kg^{-1}
Location	**Meuse**			
21/02/12	13.4	< 1	9.9	
28/02/12	9.4	< 1	9.3	
06/03/12	24.4	< 1	11.7	127
13/03/12	6.4	< 1	9.2	
20/03/12	33.8	< 1	8.7	
27/03/12	29.0	< 1	7.4	
03/04/12	11.6	< 1	7.1	
10/04/12	40.4	49.6	9.8	
17/04/12	12.5	< 1	9.1	
24/04/12	20.0	11.3	9.8	
01/05/12	10.1	< 1	10.4	160
08/05/12	4.2	6.7	11.1	
15/05/12	8.7	9.4	10.9	
22/05/12	4.7	12.9	11.3	
29/05/12	4.5	7.1	19.2	
05/06/12	6.6	7.0	11.4	
12/06/12	8.5	11.9	13.2	
19/06/12	14.6	41.2	14.1	
26/06/12	13.5	10.1	13.7	164
03/07/12	15.6	< 1	15.7	
10/07/12	11.0	< 1	13.1	
17/07/12	7.1	4.2	13.7	
24/07/12	15.5	6.9	13.6	
31/07/12	8.4	27.1	14.8	
07/08/12	12.8	21.5	15.2	
14/08/12	15.2	28.6	13.5	
21/08/12	9.9	25.3	12.8	179
28/08/12	13.4	38.8	14.0	
06/09/12	10.2	< 1	12.6	
13/09/12	10.6	11.9	13.2	
19/09/12	10.4	< 1	12.1	
26/09/12	10.8	55.7	14.3	
02/10/12	11.7	< 1	13.1	
09/10/12	14.9	18.9	15.7	
16/10/12	17.9	10.1	17.8	140
23/10/12	22.4	7.9	15.9	
30/10/12	8.7	10.5	13.1	
06/11/12	12.7	11.6	14.7	
13/11/12	13.9	< 1	14.3	
20/11/12	19.9	< 1	17.8	
27/11/12	38.0	29.9	15.5	
05/12/12	13.9	10.0	10.9	
11/12/12	19.0	8.2	13.3	143
18/12/12	3.8	7.1	11.5	
27/12/12	3.1	2.6	10.4	
Average	14.7	9.9	12.7	147

Table A13: Gross α, residual β, ^{3}H and ^{90}Sr activity concentrations ($mBq \cdot L^{-1}$) in seawater in 2012 as measured by RWS

Date	Gross α $mBq \cdot L^{-1}$	Residual β $mBq \cdot L^{-1}$	^{3}H $mBq \cdot L^{-1}$	^{90}Sr $mBq \cdot L^{-1}$
Location	**Coastal Area**			
13/02/12	172	39	4,130	
14/05/12	230	54	3,610	
13/08/12	566	21	3,970	
15/11/12	505	49	4,490	
Average	370	41	4,050	
Location	**Southern North Sea**			
13/02/12	95	33	1,650	5
14/05/12	638	27	3,190	2
13/08/12	376	56	3,980	3
15/11/12	716	32	3,620	< 1
Average	460	37	3,100	2.6
Location	**Central North Sea**			
17/01/12	92	51	162	< 1
24/04/12	215	74	14	2
20/06/12	105	41	299	< 1
15/08/12	809	43	< 10	2
Average	310	52	120	1.2
Location	**Delta Coastal Waters**			
19/01/12	100	71	4,120	
14/02/12	246	43	3,590	< 1
19/03/12	137	49	3,590	
18/04/12	101	55	3,620	
15/05/12	349	15	3,550	< 1
14/06/12	394	69	3,980	
26/07/12	766	40	4,250	
16/08/12	456	31	4,280	2
13/09/12	578	29	4,350	
15/10/12	402	66	5,590	
19/11/12	462	48	5,280	3
13/12/12	554	58	5,600	
Average	380	48	4,300	1.5

Continued on the next page

Table A13: Continued

Date	Gross α $mBq \cdot L^{-1}$	Residual β $mBq \cdot L^{-1}$	^{3}H $mBq \cdot L^{-1}$	^{90}Sr $mBq \cdot L^{-1}$
Location	**Westerscheldt**			
04/01/12	375	132	5,470	< 1
02/02/12	210	58	5,880	2
28/02/12	344	147	4,120	< 1
26/03/12	210	104	4,340	< 1
23/04/12	310	148	4,180	< 1
23/05/12	395	100	4,600	< 1
19/06/12	244	64	4,720	1
16/07/12	442	58	5,220	1
14/08/12	349	35	4,580	< 1
13/09/12	349	53	4,160	< 1
11/10/12	574	36	5,910	< 1
08/11/12	688	92	5,930	1
03/12/12	686	175	5,040	4
Average	400	92	4,930	< 1
Location	**Eems-Dollard**			
17/02/12	373	70	4,180	
14/05/12	200	25	2,960	
10/08/12	249	39	3,040	
09/11/12	435	53	4,360	
Average	310	47	3,600	
Location	**Wadden Sea West**			
22/02/12	115	61	3,580	
16/05/12	398	41	2,880	
15/08/12	356	34	3,320	
15/11/12	741	85	4,840	
Average	400	55	3,700	
Location	**Wadden Sea East**			
01/03/12	147	175	3,350	
22/05/12	120	133	2,850	
08/08/12	1030	194	3,040	
20/11/12	478	172	4,510	
Average	400	168	3,400	

Table A14: ^{137}Cs and ^{210}Pb activity concentrations in suspended solids ($Bq \cdot kg^{-1}$) in seawater in 2012 as measured by RWS

Date	**^{137}Cs**	**^{210}Pb (1)**
	$Bq \cdot kg^{-1}$	**$Bq \cdot kg^{-1}$**
Location	**Coastal area**	
06/03/12	9.2	107
29/05/12	3.3	58
13/08/12	2.5	65
12/11/12	6.4	117
Average	5.4	87
Location	**Westerscheldt**	
27/02/12	3.9	62
22/05/12	3.9	68
13/08/12	4.3	59
07/11/12	4.6	74
Average	4.2	66
Location	**Eems-Dollard**	
08/03/12	8.1	113
10/05/12	7.3	88
09/08/12	6.3	81
08/11/12	6.8	90
Average	7.1	93
Location	**Wadden Sea West (2)**	
21/02/12	7.6	132
08/05/12	3.7	69
16/08/12	3.4	94
14/11/12	4.9	124
Average	4.9	105

(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 2012

Date (1)			**Gross α (2)**		
			$mBq \cdot m^{-3}$		
Location	**21**	**22**	**23**	**27**	**29**
08/02/12	0.030	0.067	0.164	0.003	0.017
08/03/12	0.06	0.094	0.050	<0.09	0.04
03/04/12	0.05	0.009	0.17	0.01	0.08
03/05/12	0.033	0.029	0.035	0.03	0.014
11/06/12	0.051	0.019	0.089	0.02	0.116
03/07/12	0.03	0.01	0.04	0.01	0.035
08/08/12	0.035	0.039	0.040	0.022	0.076
04/09/12	< 0.035	0.042	0.43	0.016	0.055
03/10/12	0.034	0.025	0.064	0.02	0.035
07/11/12	0.037	0.023	0.156	0.013	0.047
05/12/12	0.039	0.008	0.007	0.006	0.040
02/01/13	0.024	0.010	0.019	0.014	0.020

(1) End date of monthly sampling period.

(2) Gross α activity concentrations in air dust are given as indicative values.

Table A16: Monthly averaged gross β activity concentrations in air dust near the nuclear power plant at Borssele in 2012

Date [1]	Gross β mBq·m^{-3}				
Location	**21**	**22**	**23**	**27**	**29**
08/02/12	0.40 ± 0.03	0.329 ± 0.019	0.46 ± 0.02	0.22 ± 0.02	0.56 ± 0.03
08/03/12	0.33 ± 0.03	0.31 ± 0.02	0.28 ± 0.03	0.17 ± 0.03	0.49 ± 0.04
03/04/12	0.46 ± 0.04	0.108 ± 0.019	0.45 ± 0.03	0.14 ± 0.03	0.37 ± 0.05
03/05/12	0.13 ± 0.03	0.123 ± 0.015	0.13 ± 0.04	0.10 ± 0.03	0.024 ± 0.014
11/06/12	0.34 ± 0.03	< 0.043	0.40 ± 0.02	0.27 ± 0.02	0.717 ± 0.018
03/07/12	0.33 ± 0.04	0.21 ± 0.03	0.18 ± 0.03	0.13 ± 0.03	0.285 ± 0.013
08/08/12	0.63 ± 0.03	0.50 ± 0.02	0.39 ± 0.02	0.35 ± 0.02	0.447 ± 0.011
04/09/12	0.46 ± 0.03	0.61 ± 0.03	0.66 ± 0.03	0.37 ± 0.03	0.470 ± 0.012
03/10/12	0.71 ± 0.03	0.64 ± 0.03	0.45 ± 0.03	0.54 ± 0.08	0.480 ± 0.012
07/11/12	0.65 ± 0.03	0.54 ± 0.02	0.58 ± 0.02	0.41 ± 0.02	0.563 ± 0.012
05/12/12	0.58 ± 0.06	0.10 ± 0.04	0.43 ± 0.04	0.55 ± 0.05	0.496 ± 0.019
02/01/13	0.16 ± 0.06	0.14 ± 0.04	0.25 ± 0.04	0.08 ± 0.05	0.281 ± 0.018

[1] End date of monthly sampling period.

Table A17: Monthly averaged activity concentrations of γ-emitters in air dust near the nuclear power plant at Borssele in 2012

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}	$^{131}I_{or}$ [2] mBq·m^{-3}	^{137}Cs mBq·m^{-3}	Nat. [3] mBq·m^{-3}
08/02/12	< 0.08	< 0.1	< 0.3	< 0.07	2.5 ± 0.2
08/03/12	< 0.07	< 0.5	< 0.8	< 0.042	< 1.6
03/04/12	< 0.053	< 0.6	< 0.3	< 0.042	1.95 ± 0.06
03/05/12	< 0.042	< 0.3	< 0.4	< 0.031	< 1.4
11/06/12	< 0.033	< 0.6	< 0.2	< 0.025	1.12 ± 0.06
03/07/12	< 0.042	< 0.3	< 0.3	< 0.035	< 1.4
08/08/12	< 0.024	< 0.5	< 0.2	< 0.020	0.96 ± 0.06
04/09/12	< 0.034	< 0.4	< 0.7	< 0.027	< 1.4
03/10/12	< 0.032	< 0.2	< 0.3	< 0.029	< 1.3
07/11/12	< 0.031	< 0.2	< 0.2	< 0.026	1.11 ± 0.06
05/12/12	< 0.038	< 0.4	< 0.3	< 0.029	< 1.4
02/01/13	< 0.036	< 0.2	< 1	< 0.031	< 1.4

[1] End date of monthly sampling period.

[2] Elemental respectively organically bound ^{131}I.

[3] Naturally occurring γ-emitters.

Table A18: Activity concentrations of γ-emitters in grass near the nuclear power plant at Borssele in 2012

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

Date	Mass	^{60}Co	^{131}I	^{137}Cs
	kg·m^{-2}	Bq·kg^{-1} (1)	Bq·kg^{-1} (1)	Bq·kg^{-1} (1)
08/02/12	0,0971	< 6	< 5	< 5
08/03/12	0,209	< 2	< 2	1,5 ± 0,4
03/04/12	0,209	< 3	< 3	< 2
03/05/12	0,117	< 4	< 4	< 3
11/06/12	0,145	< 4	< 3	< 4
03/07/12	0,172	< 4	< 5	< 4
08/08/12	0,390	< 2	< 2	< 2
04/09/12	0,470	< 2	< 2	< 2
03/10/12	0,462	< 3	< 3	< 2
07/11/12	0,402	< 2	< 3	< 2
05/12/12	0,621	< 3	< 2	< 3
02/01/13	0,629	< 2	< 3	< 1

(1) Dry weight.

Table A19: Activity concentrations of γ-emitters in soil near the nuclear power plant at Borssele in 2012

Analysis was performed on four samples taken near the outlet of the plant on 21 May 2012.

Location	Mass	^{54}Mn	^{60}Co	^{134}Cs	^{137}Cs
	kg·m^{-2}	Bq·kg^{-1} (1)	Bq·kg^{-1} (1)	Bq·kg^{-1} (1)	Bq·kg^{-1} (1)
O1	74.0	< 0.2	< 0.2	< 0.1	0.78 ± 0.06
O2	67.6	< 0.2	< 0.2	< 0.2	0.42 ± 0.03
O3	71.6	< 0.1	< 0.2	< 0.1	0.39 ± 0.03
O4	74.2	< 0.2	< 0.2	< 0.1	0.51 ± 0.03

(1) Dry weight.

Table A20: Residual β activity concentrations in water from the Westerscheldt in 2012

Date	Residual β Bq·L^{-1}			
Location	1	2	3	4
08/02/12	0.045 ± 0.006	0.058 ± 0.006	0.065 ± 0.005	0.072 ± 0.005
08/03/12	0.049 ± 0.016	0.147 ± 0.016	0.024 ± 0.016	0.064 ± 0.015
03/04/12	0.043 ± 0.015	0.108 ± 0.015	0.026 ± 0.015	0.102 ± 0.015
03/05/12	0.169 ± 0.017	0.161 ± 0.017	0.052 ± 0.015	0.060 ± 0.010
11/06/12	0.045 ± 0.019	0.060 ± 0.019	0.034 ± 0.018	0.064 ± 0.016
03/07/12	0.047 ± 0.018	0.065 ± 0.017	0.023 ± 0.016	0.065 ± 0.017
08/08/12	0.064 ± 0.017	0.120 ± 0.016	0.072 ± 0.015	0.087 ± 0.015
04/09/12	0.07 ± 0.02	0.056 ± 0.015	0.035 ± 0.018	0.036 ± 0.020
03/10/12	0.065 ± 0.019	0.076 ± 0.018	0.060 ± 0.015	0.107 ± 0.016
07/11/12	0.061 ± 0.016	0.076 ± 0.018	0.047 ± 0.014	0.070 ± 0.015
05/12/12	0.034 ± 0.012	0.046 ± 0.016	0.017 ± 0.015	0.054 ± 0.014
02/01/13	0.045 ± 0.013	0.068 ± 0.012	0.042 ± 0.013	0.042 ± 0.011

Table A21: ^{3}H activity concentrations in water from the Westerscheldt in 2012

Date		**^{3}H Bq·L^{-1}**		
Location	**1**	**2**	**3**	**4**
08/02/12	3.5 ± 0.3	2.8 ± 0.3	3.0 ± 0.3	3.2 ± 0.3
08/03/12	3.5 ± 0.3	3.4 ± 0.3	3.3 ± 0.3	5.0 ± 0.4
03/04/12	1.6 ± 0.2	2.6 ± 0.3	1.5 ± 0.2	1.2 ± 0.3
03/05/12	0.80 ± 0.15	3.0 ± 0.3	4.6 ± 0.5	< 1
11/06/12	3.9 ± 0.3	4.8 ± 0.4	3.1 ± 0.3	7.9 ± 0.5
03/07/12	1.07 ± 0.18	2.2 ± 0.3	0.53 ± 0.13	2.8 ± 0.4
08/08/12	2.5 ± 0.3	2.9 ± 0.4	2.8 ± 0.3	1.8 ± 0.2
04/09/12	4.9 ± 0.4	3.8 ± 0.4	2.5 ± 0.3	3.9 ± 0.4
03/10/12	3.1 ± 0.4	0.68 ± 0.14	1.4 ± 0.3	1.3 ± 0.3
07/11/12	2.3 ± 0.4	0.91 ± 0.17	0.62 ± 0.20	0.44 ± 0.12
05/12/12	2.9 ± 0.3	2.4 ± 0.3	1.0 ± 0.3	1.6 ± 0.2
02/01/13	4.7 ± 0.4	2.9 ± 0.3	3.3 ± 0.3	2.6 ± 0.3

Table A22: Gross β activity concentrations in suspended solids from the Westerscheldt in 2012

Date		**Gross β kBq·kg^{-1}**		
Location	**1**	**2**	**3**	**4**
08/02/12	0.78 ± 0.07	0.91 ± 0.06	0.87 ± 0.09	1.12 ± 0.06
08/03/12	1.27 ± 0.13	2.10 ± 0.09	1.32 ± 0.08	2.39 ± 0.10
03/04/12	1.98 ± 0.12	2.8 ± 0.3	1.14 ± 0.04	2.1 ± 0.2
03/05/12	1.1 ± 0.3	1.8 ± 0.3	1.20 ± 0.12	1.15 ± 0.09
11/06/12	1.41 ± 0.08	1.54 ± 0.19	0.755 ± 0.014	1.14 ± 0.10
03/07/12	1.6 ± 0.4	1.24 ± 0.12	1.38 ± 0.11	1.11 ± 0.05
08/08/12	1.49 ± 0.11	2.2 ± 0.5	0.78 ± 0.02	0.93 ± 0.05
04/09/12	0.87 ± 0.02	1.2 ± 0.3	0.828 ± 0.018	0.97 ± 0.05
03/10/12	3.1 ± 1.4	1.20 ± 0.06	1.30 ± 0.14	1.18 ± 0.08
07/11/12	1.10 ± 0.03	1.27 ± 0.06	1.5 ± 0.2	0.84 ± 0.05
05/12/12	0.98 ± 0.03	1.24 ± 0.06	0.876 ± 0.019	0.93 ± 0.07
02/01/13	1.28 ± 0.10	1.5 ± 0.2	1.24 ± 0.06	1.28 ± 0.10

Table A23: Activity concentrations of γ-emitters in seaweed from the Westerscheldt in 2012

Analysis was performed on a combined sample of the monthly samples from all four locations (1, 2, 3 and 4).

Date	Mass	^{60}Co	^{131}I	^{137}Cs
	kg	Bq·kg^{-1} (1)	Bq·kg^{-1} (1)	Bq·kg^{-1} (1)
08/02/12	0.095	< 4	< 3	< 3
08/03/12	0.103	< 2	< 1	< 1
03/04/12	0.089	< 2	< 2	< 2
03/05/12	0.075	< 3	< 4	< 2
11/06/12	0.086	< 2	< 2	< 2
03/07/12	0.093	< 2	< 2	< 2
08/08/12	0.076	< 2	< 2	< 2
04/09/12	0.125	< 2	< 2	< 1
03/10/12	0.097	< 2	< 3	< 2
07/11/12	0.125	< 1	< 2	< 1
05/12/12	0.097	< 1	< 1	< 1
02/01/13	0.088	< 2	< 3	< 2

(1) Dry weight.

Table A24: Activity concentrations of γ-emitters in sediment from the Westerscheldt in 2012

Analysis was performed on a combined sample of the monthly samples from all four locations (1, 2, 3, and 4).

Location	Mass	^{60}Co	^{131}I	^{137}Cs
	kg·m^{-2}	Bq·kg^{-1} (1)	Bq·kg^{-1} (1)	Bq·kg^{-1} (1)
08/02/12	54.5	< 0.4	< 0.3	1.62 ± 0.09
08/03/12	79.6	< 0.3	< 0.2	0.54 ± 0.04
03/04/12	87.8	< 0.2	< 0.2	0.34 ± 0.03
03/05/12	74.4	< 0.3	< 0.4	0.65 ± 0.04
11/06/12	71.5	< 0.2	< 0.2	0.34 ± 0.04
03/07/12	63.4	< 0.3	< 0.3	0.72 ± 0.05
08/08/12	79.8	< 0.3	< 0.2	0.47 ± 0.10
04/09/12	72.7	< 1	< 0.2	0.35 ± 0.03
03/10/12	73.6	< 0.2	< 0.3	< 0.5
07/11/12	69.9	< 0.3	< 0.3	0.56 ± 0.04
05/12/12	68.5	< 0.3	< 0.2	0.39 ± 0.04
02/01/13	60.1	< 0.3	< 0.4	1.21 ± 0.06

(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). Data from the other institutions are reported as provided.

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 containing 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 level.

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.

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 daughter 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, RWS uses a direct method to determine the residual β activity [47].

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