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

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Results in 2010

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Colophon

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NV. Electriciteit-Productiemaatschappij Zuid-Nederland EPZ

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Abstract

Environmental radioactivity in the Netherlands
Results in 2010

In 2010 the Netherlands fulfilled the European obligation to annually measure radioactivity in the environment and in food. According to the Euratom Treaty of 1957, all Member States of the European Union are obliged to perform these measurements each year. In addition the Netherlands complies with the guidelines established in 2000 for performing the measurements uniformly.

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

Radioactivity in air, food and milk
The measurements in the air and environment showed normal levels, which are within the range of previous years. The deposition of polonium-210 showed the highest level since 1993 but approximately the same level as in 2009. These levels do not pose a threat to public health. As in 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). However, these levels do not pose a threat to public health. Target values should preferably not be exceeded, but they are not limits as such.

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

Rapport in het kort

Radioactiviteit in het Nederlandse milieu
Resultaten in 2010

In 2010 voldeed Nederland aan de Europese verplichting om jaarlijks de hoeveelheid radioactiviteit in het milieu en in voeding te meten. Volgens het Euratom-verdrag uit 1957 zijn alle lidstaten van de Europese Unie verplicht deze metingen jaarlijks te verrichten. 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 radioactiviteits-niveaus 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
De metingen in lucht en omgeving lieten een normaal beeld zien, dat niet verschilde van voorgaande jaren. De depositie van polonium-210 is het hoogst sinds 1993 maar ongeveer even hoog als in 2009. De aangetroffen radioactiviteitsniveaus zijn echter niet schadelijk voor de volksgezondheid. 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 overschrijdingen zijn echter zodanig dat ze niet schadelijk zijn voor de volksgezondheid. Voor oppervlaktewater bestaan er geen limieten voor radioactieve stoffen, waarop wordt toegezien en gehandhaafd. Wel zijn er streefwaarden, die bij voorkeur niet overschreden mogen worden.

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

Preface

The following institutes 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/LSO), ir. J.F.M. Versteegh (RIVM/IMG).

RWS WD Centre for Water Management
Rijkswaterstaat Waterdienst (RWS WD)
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 foodstuff.
drs. K. Zwaagstra, ing. G. Visser.

RIKILT Wageningen UR
Data on milk and foodstuff.
dr. G. C. Krijger, J.M. Weseman, ing. A. Vos van Avezathe, J. Verbunt.

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

Contents

Summary

The Dutch government is obliged to measure radioactivity in air, water and soil under the terms of the Euratom Treaty of 1957. In 2000, the European 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 published yearly. This report presents the results of radioactivity measurements made in the Dutch environment in 2010. The measurements were carried out by RIVM, Centre for Water Management, RIKILT, NVWA, and (tasked by N.V. EPZ) NRG.

The yearly averaged activity concentration in air dust was determined for gross α, gross β, ^{7}Be, ^{137}Cs and ^{210}Pb. The yearly total activity in deposition was determined for gross α, gross β, ^{3}H, ^{7}Be, ^{137}Cs, ^{210}Pb and ^{210}Po. Gross α and gross β is the total activity of nuclides emitting α- and β-radiation, respectively. The results are presented in Table S1 and are within the range of those in previous years, except for the yearly total activity in deposition from ^{210}Po (33.2 Bq·m^{-2}), which was the highest since 1993 and approximately the same level as in 2009.

The National Radioactivity Monitoring Network (NMR) was used to determine the activity concentrations of gross α and artificial β (β-radiation emitted by man-made nuclides) in air dust. The difference between the NMR data and those mentioned above is due to the contribution of short-lived natural radionuclides (radon daughters). The yearly averaged gross α-activity concentration in air dust was 3.1 Bq·m^{-3}. The yearly average of the artificial β-activity concentration did not deviate significantly from zero. The NMR was also used to determine the ambient dose equivalent rate, the yearly averaged measured value was 73.3 nSv·h^{-1}.

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 in surface water. 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, Rhine, Scheldt and Meuse exceeded the target value (100 mBq·L^{-1}) in 9 out of 13, 2 out of 13, 1 out of 13, 12 out of 13 and 1 out of 13 samples taken, respectively. In 2010, the yearly averaged gross α-activity concentrations in the Noordzeekanaal and Scheldt (180 and 300 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 2 out of 13 samples taken. The yearly averaged residual β-activity concentrations were below the target value.

The ^{90}Sr-activity concentrations (of both individual samples and yearly average) in surface water were below the target value (10 mBq·L^{-1}).

The ^{3}H-activity concentration in the Rhine, Scheldt and Meuse exceeded the target value (10 Bq·L^{-1}) in 1 out of 13, 4 out of 6 and 10 out of 13 samples taken, respectively. The yearly averaged ^{3}H-activity concentration in the Scheldt and

Meuse (11.7 and 20.0 $Bq \cdot L^{-1}$, respectively) were above the target value, but within the range of those in previous years.

The ^{226}Ra-activity concentration in the Rhine and Scheldt exceeded the target value (5 $mBq \cdot L^{-1}$) in 1 out of 6 and 6 out of 6 samples taken, respectively. The yearly averaged ^{226}Ra-activity concentration in the Scheldt (15 $mBq \cdot L^{-1}$) 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 1 out of 46 samples taken, but the yearly averaged ^{60}Co-activity concentration was below the target value.

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 7 and 17 out of 46 samples taken, respectively. The yearly averaged ^{131}I-activity concentration in the Meuse was below the target value. The yearly averaged ^{131}I-activity concentration in the Noordzeekanaal (32 $Bq \cdot kg^{-1}$) was higher than those in previous years and exceeded the target value.

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

The ^{210}Pb-activity concentration in suspended solids in the Nieuwe Waterweg, Rhine and Meuse exceeded the target value (100 $Bq \cdot kg^{-1}$) in 3 out of 6, 7 out of 7 and 6 out of 7 samples taken, respectively. The yearly averaged ^{210}Pb-activity concentrations in the Nieuwe Waterweg, Rhine and Meuse (104, 126 and 151 $Bq \cdot kg^{-1}$, respectively) were above the target value, but within the range of those in previous years.

The yearly averaged gross α- and residual β-activity concentrations in seawater were within the range of those in previous years.

The yearly averaged ^{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. In 2010, the gross α-activity concentration averaged per production station exceeded 0.1 $Bq \cdot L^{-1}$ at 2 of the 196 production stations (in 3 of the 374 analyses).

The results of the monitoring program for milk and mixed diet are presented in Table S1. Radioactivity levels were well below the export and consumption limits set by the European Union.

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

In 2010, 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 2010. De metingen zijn verricht door RIVM, RWS Waterdienst, 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 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 uitzondering van de depositie van ^{210}Po (33,2 Bq·m^{-2}) die het hoogst sinds 1993 is en ongeveer even hoog als in 2009.

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). Het verschil tussen de NMR-metingen en bovenstaande metingen wordt veroorzaakt door de bijdrage van kortlevende natuurlijke radionucliden (radondochters). Het jaargemiddelde voor de totaal-α-activiteitsconcentratie in luchtstof was 3,1 Bq·m^{-3}. Het jaargemiddelde voor de kunstmatige β-activiteitsconcentratie in luchtstof week niet significant af van nul. Met het NMR werd daarnaast het omgevingsdosisequivalenttempo bepaald, de jaargemiddelde meetwaarde was 73,3 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, de Rijn, de Schelde en de Maas overschrijdt de streefwaarde (100 mBq·L^{-1}) in respectievelijk 9 van de 13, 2 van de 13, 1 van de 13, 12 van de 13 en 1 van de 13 genomen monsters. De jaargemiddelde totaal α-activiteitsconcentraties in het Noordzeekanaal en de Schelde (respectievelijk 180 en 300 mBq·L^{-1}) zijn boven de streefwaarde, maar vallen binnen het bereik van voorgaande jaren.

De rest β-activiteitsconcentratie in de Schelde overschrijdt de streefwaarde (200 mBq·L^{-1}) in respectievelijk 2 van de 13 genomen monsters. De jaargemiddelde rest β-activiteitsconcentraties zijn beneden de streefwaarde. De ^{90}Sr-activiteitsconcentraties (van zowel de individuele monsters als het jaargemiddelde) in oppervlaktewater zijn beneden de streefwaarde (10 mBq·L^{-1}).

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, 4 van de 6 en 10 van de 13 genomen monsters. De jaargemiddelde ^{3}H-activiteitsconcentraties in de Schelde en de Maas (respectievelijk 11,7 en 20,0 Bq·L^{-1}) zijn boven de streefwaarde, maar vallen binnen het bereik van voorgaande jaren.

De ^{226}Ra-activiteitsconcentratie in de Rijn en de Schelde overschrijdt de streefwaarde (5 mBq·L^{-1}) in respectievelijk 1 van de 6 en 6 van de 6 genomen monsters. De jaargemiddelde ^{226}Ra-activiteitsconcentratie in de Schelde (15 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 1 van de 46 genomen monsters. De jaargemiddelde ^{60}Co-activiteitsconcentratie is echter beneden de streefwaarde.

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 17 van de 46 genomen monsters. De jaargemiddelde ^{131}I-activiteitsconcentratie in de Maas is echter beneden de streefwaarde. De jaargemiddelde ^{131}I-activiteitsconcentratie in het Noordzeekanaal (32 Bq·kg^{-1}) is hoger dan in voorgaande jaren en overschrijdt de streefwaarde.

De ^{137}Cs-activiteitsconcentraties (van zowel de individuele monsters als het jaargemiddelde) 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 en de Maas overschrijdt de streefwaarde (100 Bq·kg^{-1}) in respectievelijk 3 van de 6, 7 van de 7 en 6 van de 7 genomen monsters.
De jaargemiddelde ^{210}Pb-activiteitsconcentraties in de Nieuwe Waterweg, de Rijn en de Maas (respectievelijk 104, 126 en 151 Bq·kg^{-1}) zijn boven de streefwaarde, maar vallen binnen het bereik van voorgaande jaren.

De jaargemiddelde totaal α- en rest β-activiteitsconcentraties in zeewater vallen binnen het bereik van voorgaande jaren.

De jaargemiddelde ^{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 2010 overschrijdt de totaal α-activiteitsconcentratie per productiestation de grenswaarde van 0,1 Bq·L^{-1} bij 2 van de 196 productiestations (in 3 van de 374 uitgevoerde analyses).

De resultaten van het meetprogramma voor melk en voedsel zijn weergegeven in Tabel S1. De radioactiviteitsniveaus zijn duidelijk beneden de Europese limieten voor consumptie en export.

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

Nederland voldeed in 2010 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 2010.
Tabel S1: Overzicht van de resultaten van het Nederlandse monitoringsprogramma in 2010.

Matrix	Parameter	Locations	Values	Frequency (per year)
Air dust (1)	Gross α	1	0.029 mBq·m^{-3}	52
	Gross β	1	0.445 mBq·m^{-3}	52
	^{7}Be	1	3.550 mBq·m^{-3}	52
	^{137}Cs	1	0.00064 mBq·m^{-3}	52
	^{210}Pb	1	0.411 mBq·m^{-3}	52
Deposition (2)	Gross α	1	36.7 Bq·m^{-2}	12
	Gross β	1	90 Bq·m^{-2}	12
	^{3}H	1	180 - 1400 Bq·m^{-2} (3)	12
	^{7}Be	1	1240 Bq·m^{-2}	52
	^{137}Cs	1	0 - 1.2 Bq·m^{-2} (3)	52
	^{210}Pb	1	93 Bq·m^{-2}	52
	^{210}Po	1	33.2 Bq·m^{-2}	12
Surface water (1)	Gross α	6	35 - 300 mBq·L^{-1}	10 or 13 (4)
	Residual β	6	22 - 140 mBq·L^{-1}	10 or 13 (4)
	^{3}H	6	2700 - 20000 mBq·L^{-1}	5, 6 or 13 (4)
	^{90}Sr	3	2.4 – 2.7 mBq·L^{-1}	6 or 7 (4)
	^{226}Ra	4	2.9 - 15 mBq·L^{-1}	6 or 7 (4)
Suspended solids in surface water (1)	^{60}Co	6	< 1 - 5 Bq·kg^{-1}	7, 10, 13 or 46 (4)
	^{131}I	6	< 1 - 32 Bq·kg^{-1}	7, 10, 13 or 46 (4)
	^{137}Cs	6	2.6 - 13.8 Bq·kg^{-1}	7, 10, 13 or 46 (4)
	^{210}Pb	4	88.6 - 151 Bq·kg^{-1}	6, 7 or 8 (4)
Seawater (1)	Gross α	8	220 - 440 mBq·L^{-1}	4, 11 or 13 (4)
	Residual β	8	51 - 150 mBq·L^{-1}	4, 11 or 13 (4)
	^{3}H	8	180 - 4600 mBq·L^{-1}	4, 11 or 13 (4)
	^{90}Sr	4	< 1 - < 3 mBq·L^{-1}	4 or 13 (4)
Suspended solids in seawater (1)	^{137}Cs	4	4 - 7 Bq·kg^{-1}	4 (4)
	^{210}Pb	4	61 - 103 Bq·kg^{-1}	4 (4)
Drinking water (1)	Gross α	196	< 0.1 Bq·L^{-1}	374 (5)
	Gross β	201	< 0.2 Bq·L^{-1}	431 (5)
	Residual β	183	< 0.2 Bq·L^{-1}	393 (5)
	^{3}H	193	< 4.1 Bq·L^{-1}	386 (5)
Milk (1)	^{40}K	26	59.3 Bq·L^{-1}	876 (5)
	^{60}Co	26	< 1.4 Bq·L^{-1}	876 (5)
	^{90}Sr	26	< 5 Bq·L^{-1}	52 (5)
	^{131}I	26	< 0.6 Bq·L^{-1}	876 (5)
	^{134}Cs	26	< 0.6 Bq·L^{-1}	876 (5)
	^{137}Cs	26	< 0.5 Bq·L^{-1}	876 (5)

Table S1: Continued.
Tabel S1: Vervolg.

Matrix	Parameter	Locations	Values	Frequency (per year)
Food [6, 7, 8]				
Grain and grain products	^{137}Cs	-	< 3.0 Bq·kg^{-1}	27 (0) [9]
Vegetables	^{137}Cs	-	< 3.0 Bq·kg^{-1}	57 (0) [9]
Fruit and fruit products	^{137}Cs	-	< 3.0 Bq·kg^{-1}	5 (0) [9]
Milk and dairy products	^{137}Cs	-	< 3.0 Bq·kg^{-1}	44 (0) [9]
Meat and meat products	^{137}Cs	-	< 3.0 Bq·kg^{-1}	26 (0) [9]
Game and poultry	^{137}Cs	-	< 3.0 Bq·kg^{-1}	18 (0) [9]
Salads	^{137}Cs	-	< 3.0 Bq·kg^{-1}	25 (0) [9]
Oil and butter	^{137}Cs	-	< 3.0 Bq·kg^{-1}	33 (0) [9]
Honey	^{137}Cs	-	15 - 209 Bq·kg^{-1}	60 (8) [9]
Food [6, 7, 10]				
Vegetables	^{137}Cs	-	16.4 - 136 Bq·kg^{-1}	64 (7) [9]
Meat and meat products	^{137}Cs	-	< 0.5 Bq·kg^{-1}	511 (0) [9]
Game and poultry	^{137}Cs	-	18.0 - 300 Bq·kg^{-1}	197 (21) [9]
Eggs	^{137}Cs	-	< 0.5 Bq·kg^{-1}	115 (0) [9]
Fish and seafood products	^{137}Cs	-	< 0.5 Bq·kg^{-1}	244 (0) [9]
Mixed diet	^{90}Sr	-	< 10.0 Bq·kg^{-1}	12 (0) [9]

[1] Yearly average is shown.

[2] Yearly total is shown.

[3] A 68% confidence range is shown.

[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] Samples were analysed for ^{134}Cs as well, but it was below the detection limit.

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

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

[10] As measured by RIKILT Wageningen UR.

Table S2: Summary of the results of the monitoring program in the vicinity of the nuclear power plant at Borssele in 2010.
Tabel S2: Overzicht van de resultaten van het monitoringsprogramma in de nabijheid van Kerncentrale Borssele in 2010.

Matrix	Parameter	Locations	Values [1]	Frequency (per year)
Air dust	Gross α	5	0.008 - 0.231 mBq·m^{-3}	12
	Gross β	5	0.10 - 0.70 mBq·m^{-3}	12
	^{60}Co	5 [2]	< 0.05 - < 0.12 mBq·m^{-3}	12
	$^{131}I_{el}$ [3]	5 [2]	< 0.1 - < 0.8 mBq·m^{-3}	12
	$^{131}I_{or}$ [3]	5 [2]	< 0.1 - < 0.5 mBq·m^{-3}	12
	^{137}Cs	5 [2]	< 0.04 - < 0.08 mBq·m^{-3}	12
	Nat. [4]	5 [2]	1.49 – 3.0 mBq·m^{-3}	12
Grass	^{60}Co	5 [2]	< 1 - < 6 Bq·kg^{-1}	12
	^{131}I	5 [2]	< 0.9 - < 4 Bq·kg^{-1}	12
	^{137}Cs	5 [2]	< 1 - < 5 Bq·kg^{-1}	12
Soil	^{54}Mn	4	< 0.2 - < 0.3 Bq·kg^{-1}	1
	^{60}Co	4	< 0.2 - < 0.4 Bq·kg^{-1}	1
	^{134}Cs	4	< 0.2 - < 0.3 Bq·kg^{-1}	1
	^{137}Cs	4	0.40 - 1.27 Bq·kg^{-1}	1
Water	Residual β	4	0.032 - 0.101 Bq·L^{-1}	12
	^{3}H	4	7.2 - 10.3 Bq·L^{-1}	12
Suspended solids	Gross β	4	0.1 - 1.76 kBq·kg^{-1}	12
Seaweed	^{60}Co	4 [2]	< 2 - < 4 Bq·kg^{-1}	12
	^{131}I	4 [2]	< 1 - < 4 Bq·kg^{-1}	12
	^{137}Cs	4 [2]	0.8 - < 3 Bq·kg^{-1}	12
Sediment	^{60}Co	4 [2]	< 0.4 - < 0.5 Bq·kg^{-1}	12
	^{131}I	4 [2]	< 0.3 - < 0.4 Bq·kg^{-1}	12
	^{137}Cs	4 [2]	0.64 - 1.29 Bq·kg^{-1}	12

[1] Given range represents values of individual samples.

[2] Analysis was performed on a combined sample of the monthly samples of 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 due to, 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 the confirmation of abnormal levels. This report presents results of radioactivity measurements made in the environment in the Netherlands. The aim of this report is threefold. First, it presents a survey of radioactivity measurements made in the Dutch environment under normal circumstances in 2010. Second, it is aimed at determining the compliance of monitoring programs in the Netherlands with the EU recommendation and at reporting omissions. Third, it is the Dutch national report on radioactivity in the environment to the EU and to other Member States.

In the chapters, the results will be presented in graphs and tables. More detailed tables are presented in Appendix A. Chapters 2 through 8 are subdivided according to the structure of the Recommendation on the Application of Article 36 of the Euratom Treaty [1] and give 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 through 8 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 (HVS).

A detailed description of sampling, sample treatment and the analytical method was given in previous reports [2, 3, 4]. The data from 1991 to 2004 were reanalysed to determine the yearly averages by the method described in Appendix B [5]. This can lead to small differences between data presented in this report and 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	500 m^3 (1)	weekly
	Bilthoven	γ-emitters (2)	week	50000 m^3	weekly

(1) A sub sample of 1% from the filter through which about 50000 m^3 is sampled.

(2) γ-spectroscopic analysis of specific γ-emitting nuclides.

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 dust thickness on the filters, gross α-activity concentrations in air dust should be regarded as indicative values [6]. The period between sampling and analysis was five to ten days, which is long compared to 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 2010 were within the range of the results from the period of 1992-2009, as is illustrated in Figure 2.4. Since 2007, a new (more realistic) calibration for gross α has been implemented. The new calibration factor is 1.4 times higher than the one used in previous years, which results in lower reported gross α-activities.

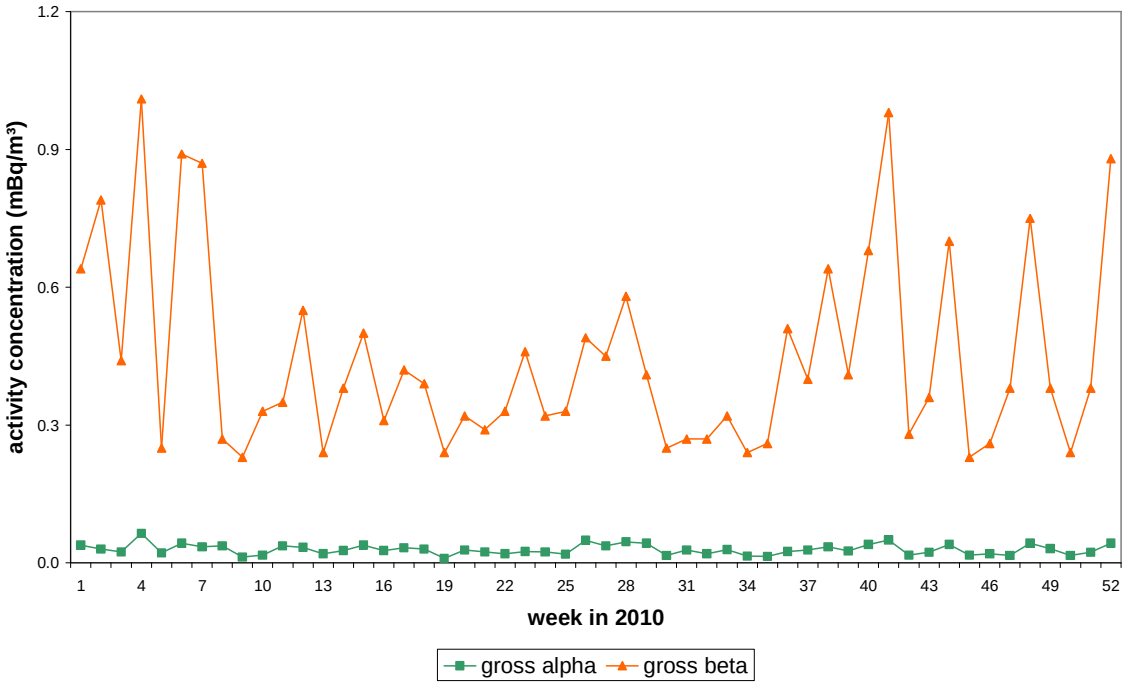


Figure 2.1: Weekly averaged gross α- and β-activity concentrations of long-lived nuclides in air dust sampled at RIVM.

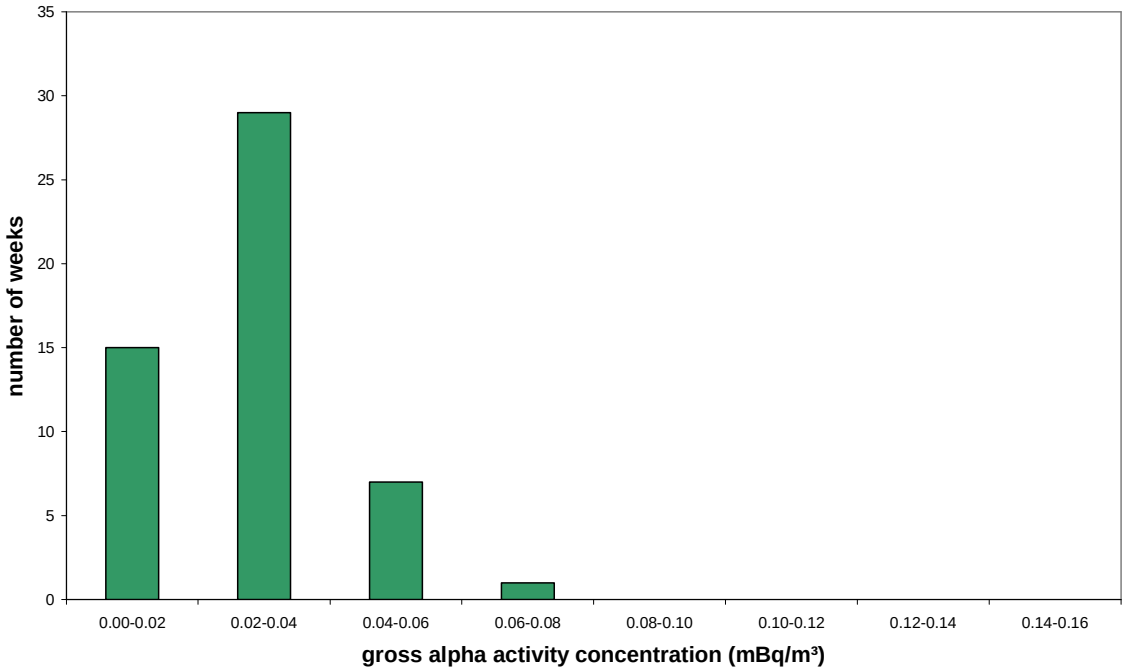


Figure 2.2: Frequency distribution of gross α-activity concentration of long-lived nuclides in air dust collected weekly in 2010. The yearly average was 0.029 (SD=0.011) mBq·m^{-3}. SD is the standard deviation and illustrates the variation in weekly averages during the year.

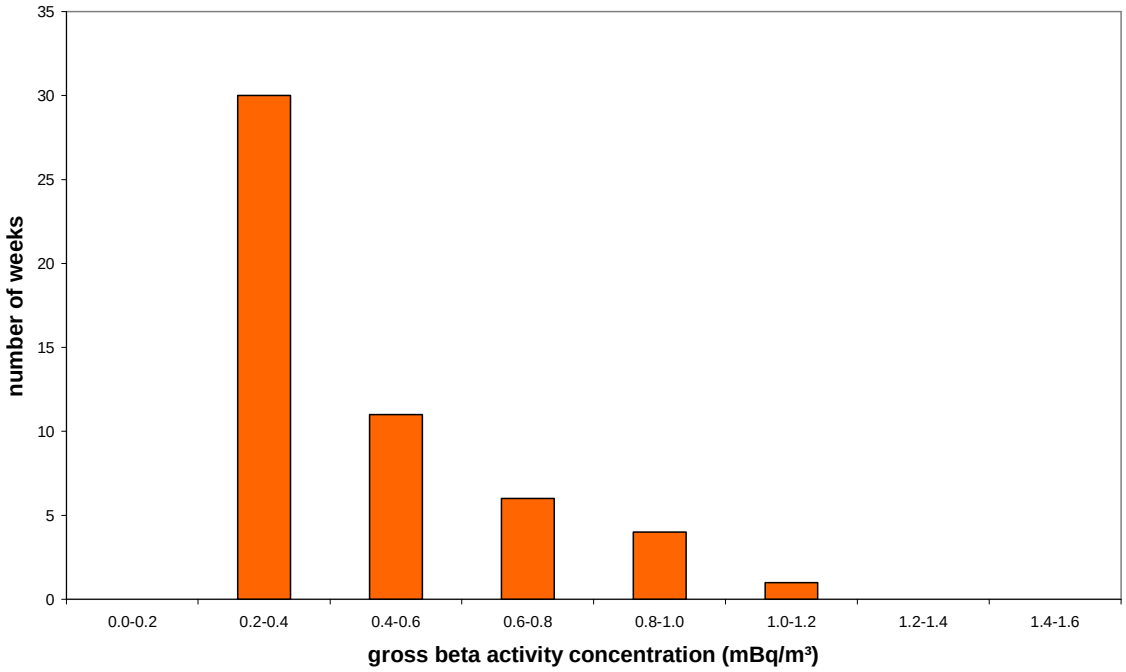


Figure 2.3: Frequency distribution of gross β-activity concentration of long-lived nuclides in air dust collected weekly in 2010. The yearly average was 0.445 ± 0.007 (SD=0.2) mBq·m^{-3}.

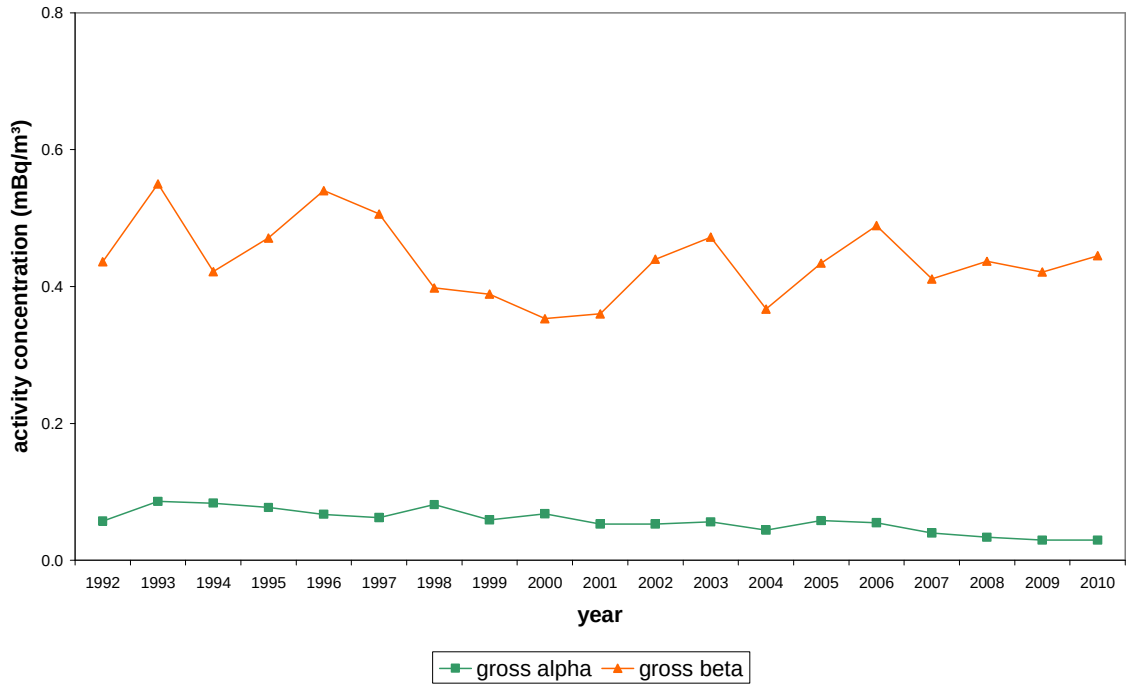


Figure 2.4: Yearly averaged gross α- and gross β-activity concentrations of long-lived nuclides in air dust at RIVM in 1992-2010.

2.2 γ-emitting nuclides

The only nuclides that could be detected were ^{7}Be (52 times), ^{210}Pb (52 times) and ^{137}Cs (20 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.

The behaviour of ^{7}Be in the atmosphere has been studied worldwide [7, 8, 9, 10, 11, 12, 13]. 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 midlatitudes 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 is 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 midlatitudes into 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 [14]. 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, unprecedented in at least the previous four decades [15]. 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 2010 fit into the pattern described above.

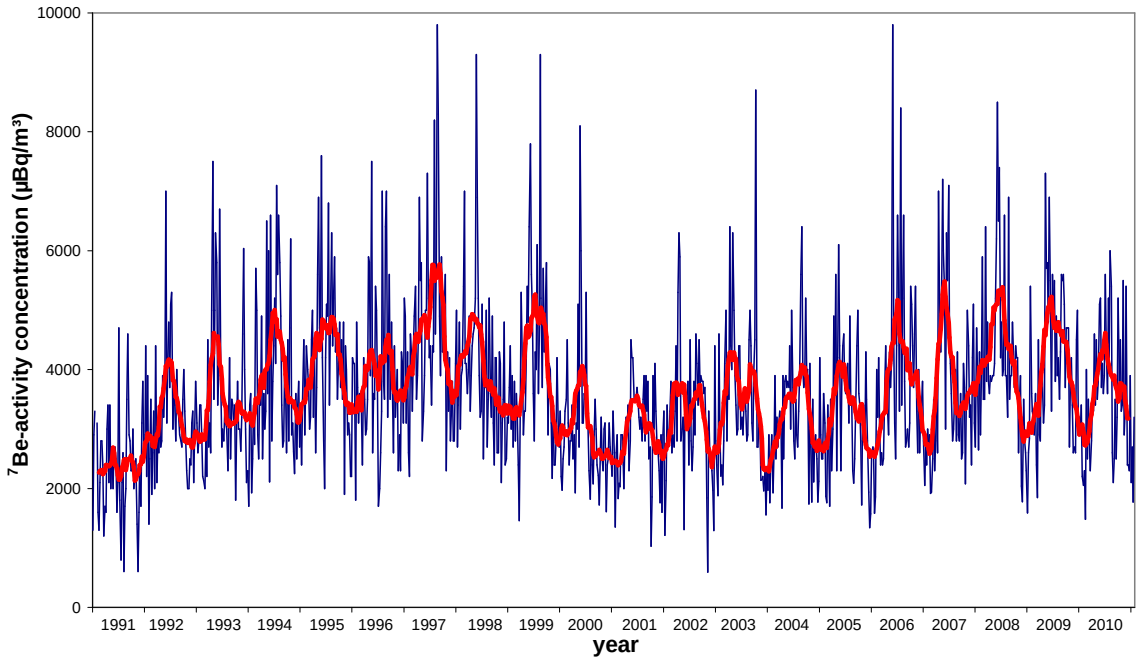


Figure 2.5: Weekly averaged ^{7}Be-activity concentrations (blue) in air dust at RIVM in 1991-2010. The red line is a moving average of 13 weeks. The yearly average for 2010 was 3550 ± 50 (SD=1100) µBq·m^{-3}.

The nuclide ^{137}Cs (half-life of 30.2 years) is of anthropogenic origin. The two main sources of ^{137}Cs in the environment are nuclear weapons tests and the Chernobyl accident. Nowadays resuspension of previously deposited activity is the main source of airborne ^{137}Cs-activity.

Figure 2.6 shows a peak during May 1992. During the same period several wildfires occurred near the Chernobyl area [16] 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 due to the weather conditions in the same period (dry with a strong eastern wind [17]). On the 29 May 1998, an incident occurred at Algeciras (Spain), an iron foundry melted a ^{137}Cs-source concealed in scrap metal [18]. 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 [18].

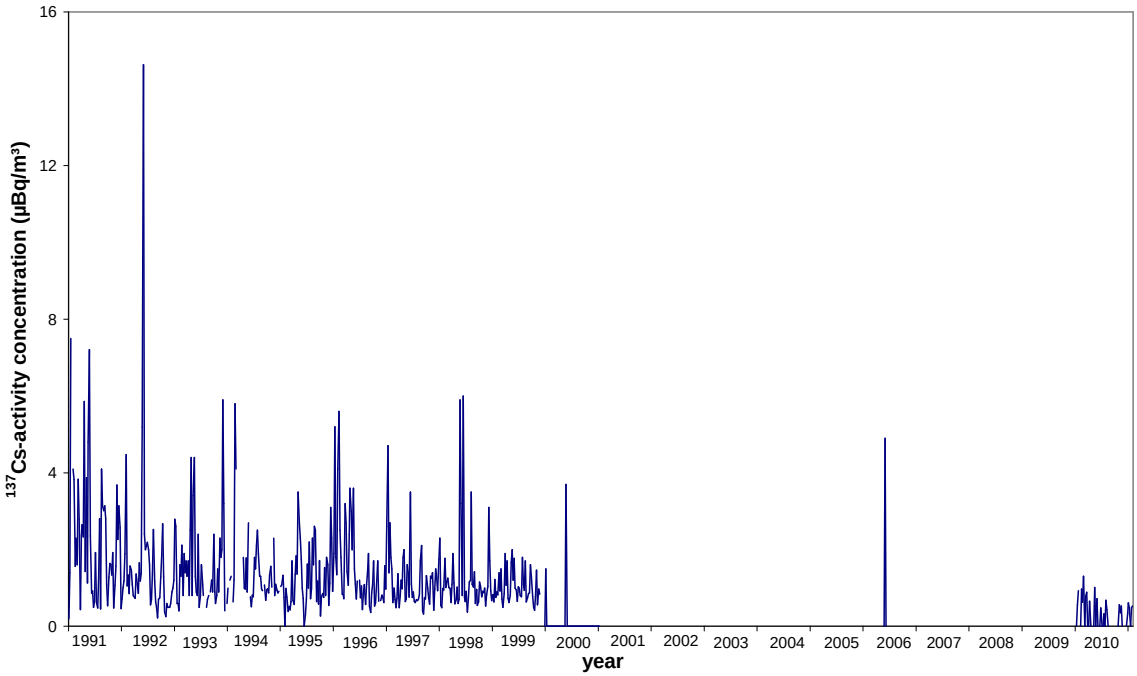


Figure 2.6: Weekly averaged ^{137}Cs-activity concentrations in air dust at RIVM in 1991-2010. 32 out of 52 measurements were below the detection limit in 2010. The yearly average for 2010 was 0.64 ± 0.03 (SD=0.2) µBq·m^{-3}. Between 2000 and the middle of 2009, the detection limit was higher than during 1991-1999, due to a different detector set-up. Since July 2009, a new detector set-up has been used, which results in lower detection limits (see Table A2).

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 that 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} [19]. In the atmosphere this radionuclide is predominantly associated with submicron-sized aerosols [20, 21]. The mean aerosol (carrying ^{210}Pb) residence time in the troposphere is approximately five days [22].

Other sources of ^{210}Pb in air dust are volcanic activity and industrial emissions [23, 24, 25, 26, 27, 28]. Examples of industrial emissions are discharges of power plants using fossil fuels, fertiliser and phosphorus industries, and exhaust gases from traffic. In the Netherlands, the emissions by power plants are only of local importance regarding ^{210}Pb deposition. In the Netherlands, the emission by the phosphorus industry contributes a negligible part to the yearly total ^{210}Pb deposition [28]. Volcanic eruptions bring uranium decay products into the atmosphere, such as ^{226}Ra, ^{222}Rn, ^{210}Pb and ^{210}Po. Beks et al. [25] estimate that volcanoes contribute 60 TBq·year^{-1} to the atmospheric ^{210}Pb stock. If the volcanic deposition is 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 [29, 30, 31] or resuspension of (local) dust. Normally there is a good correlation between ^{210}Pb- and gross β-activity concentrations, as was the case in 2010 (Figure 2.8). The weekly averaged

^{210}Pb-activity concentrations in 2010 were within range of those found in previous years (Figure 2.7).

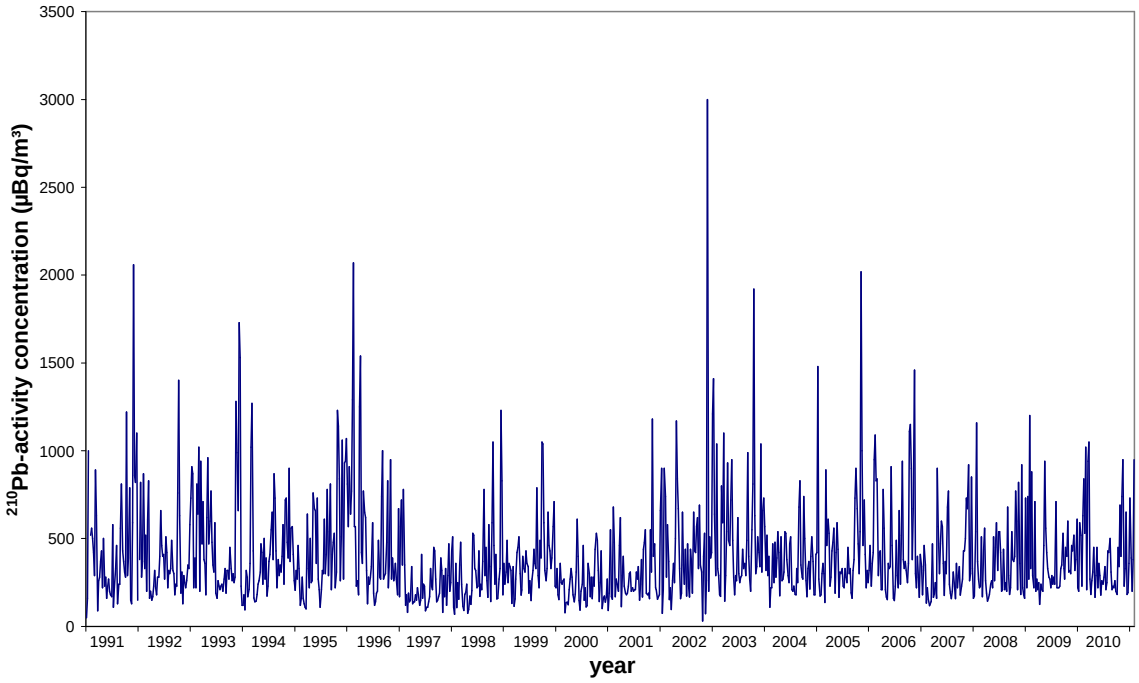


Figure 2.7: Weekly averaged ^{210}Pb-activity concentrations in air dust at RIVM in 1991-2010. The yearly average for 2010 was 411 ± 6 (SD=200) µBq·m^{-3}.

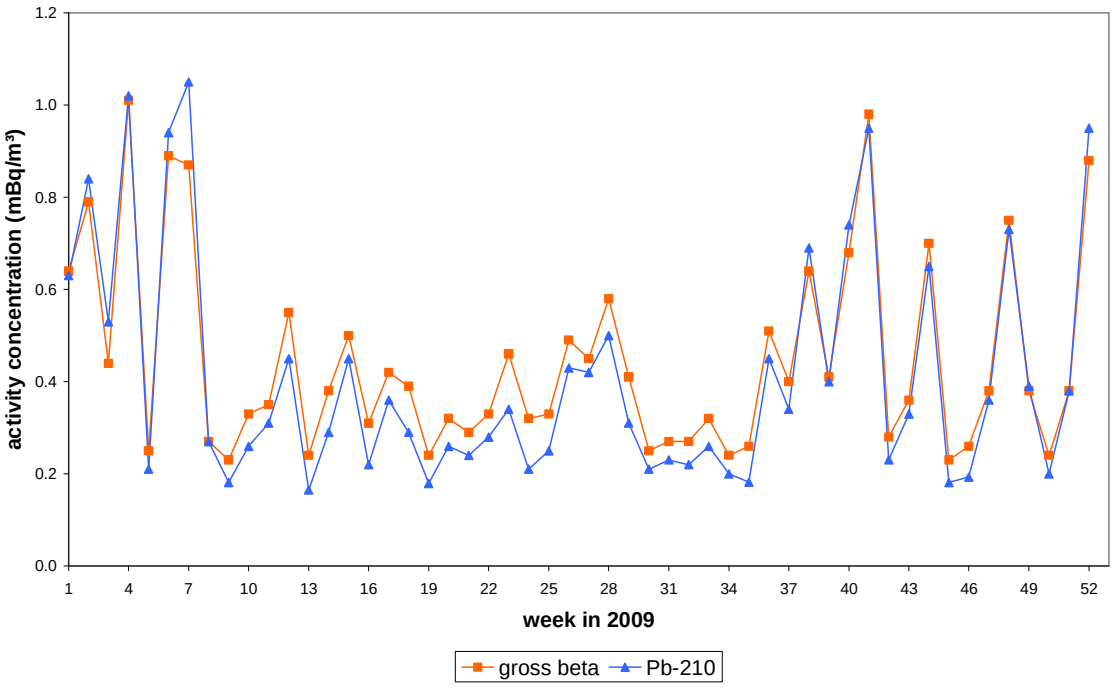


Figure 2.8: Figure illustrating the correlation between weekly averaged gross β- and ^{210}Pb-activity concentrations in air dust at RIVM.

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. The data from 1993 to 2004 were reanalysed to determine the yearly totals by the method described in Appendix B [5]. This can lead to small differences between data presented in this report and data reported prior to 2005.

Table 3.1: The 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 36.7 ± 1.3 and 90 ± 2 $Bq \cdot m^{-2}$, respectively. These values are within 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 2010, the yearly total deposition of ^{3}H ranged between 180 and 1400 $Bq \cdot m^{-2}$ (68% confidence level). The yearly total consists of 12 samples, 9 out of 12 measurements were below the detection limit. Therefore, detection limits were used for the contribution to the yearly total. The range in 2010 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.

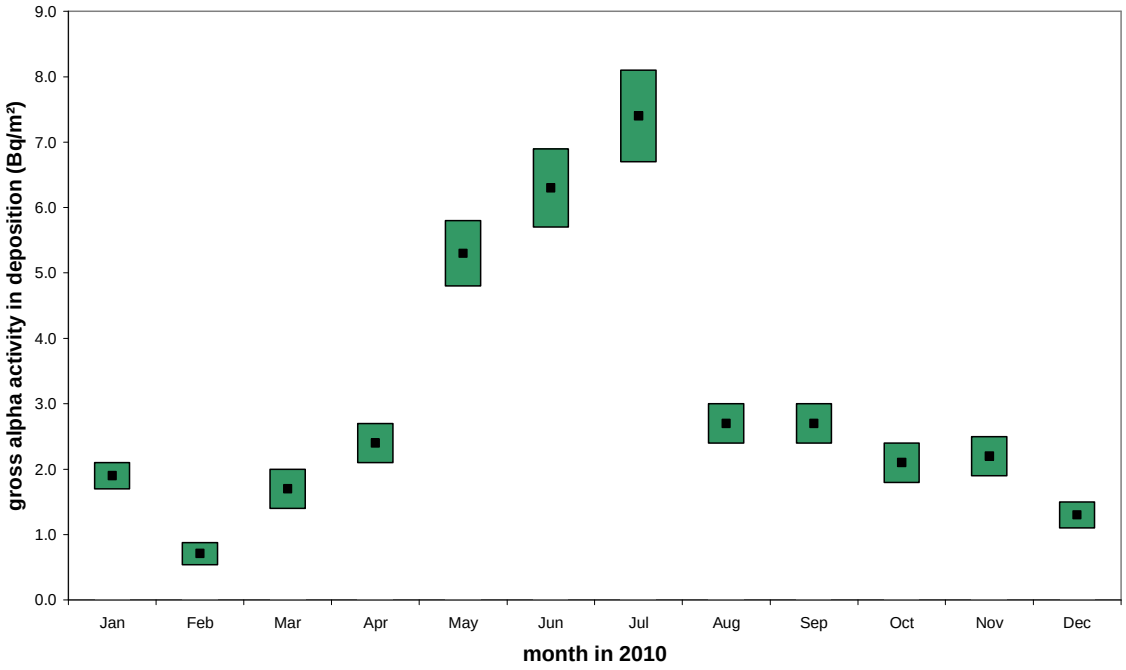


Figure 3.1: Monthly deposited gross α-activity of long-lived nuclides at RIVM. Monthly totals (black dots) are shown with a 68% confidence range (coloured bars).

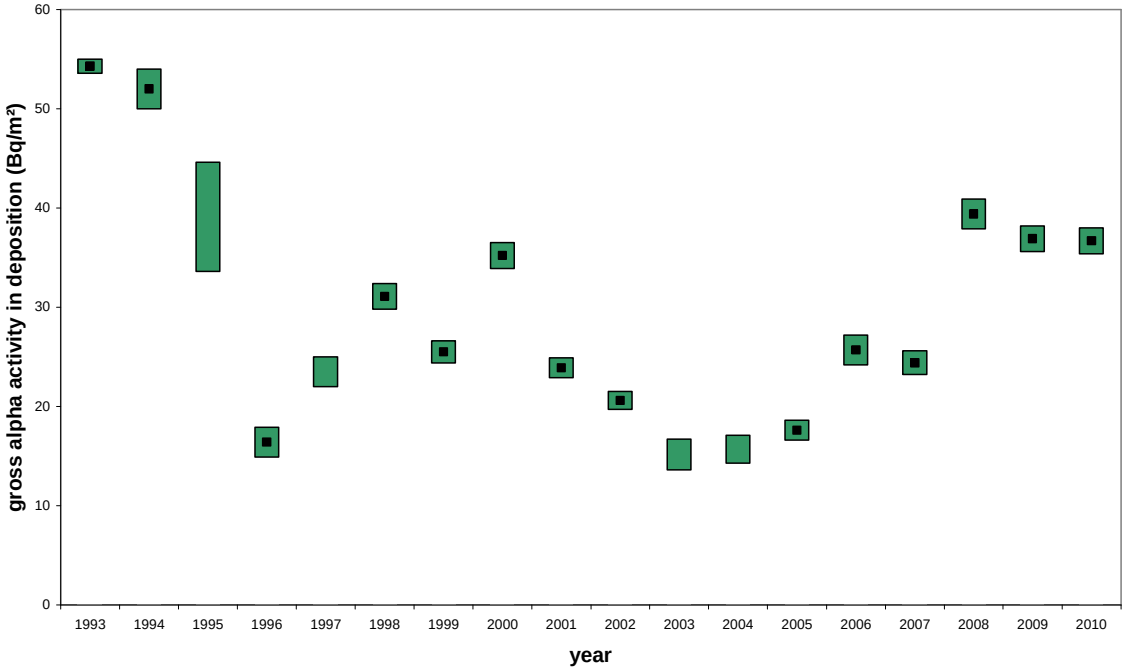


Figure 3.2: Yearly gross α-activity of long-lived nuclides deposited at RIVM from 1993 to 2010. Yearly totals (black dots) are shown with a 68% confidence range (coloured bars). Solely a 68% confidence range is shown if the yearly result is made up of at least one detection limit.

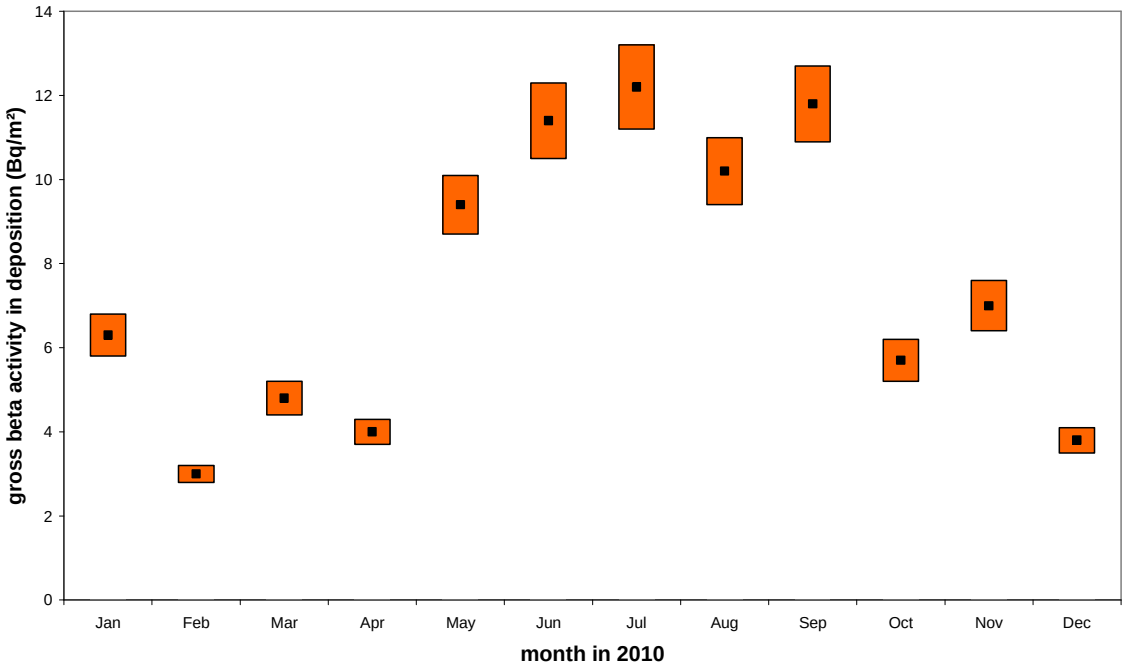


Figure 3.3: Monthly deposited gross β-activity of long-lived nuclides at RIVM. Monthly totals (black dots) are shown with a 68% confidence range (coloured bars).

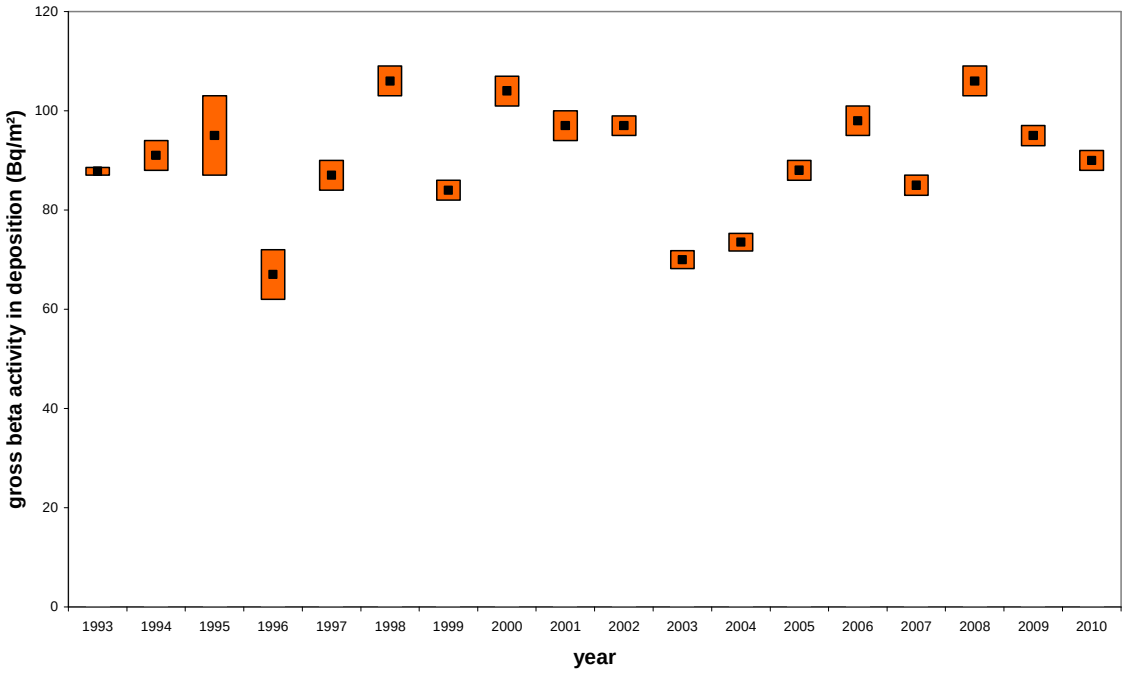


Figure 3.4: Yearly gross β-activity of long-lived nuclides deposited at RIVM from 1993 to 2010. Yearly totals (black dots) are shown with a 68% confidence range (coloured bars).

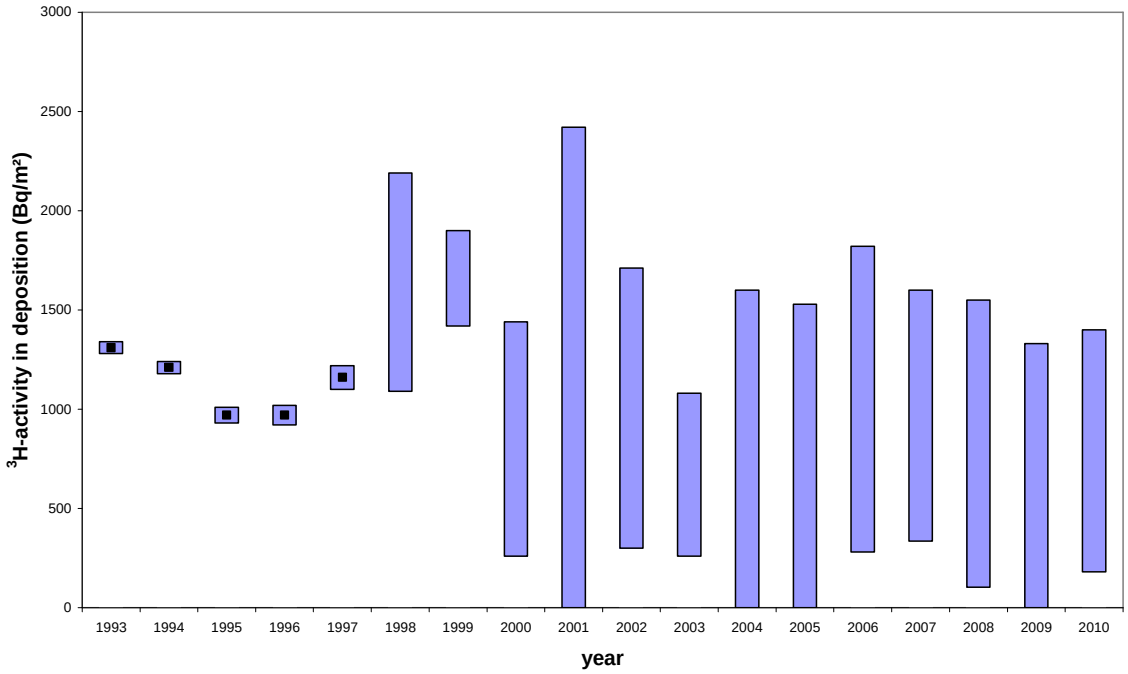


Figure 3.5: Yearly deposition of ^{3}H at RIVM from 1993 to 2010. Yearly totals (black dots) are shown with a 68% confidence range (coloured bars). Solely a 68% confidence range is shown if the yearly result is made up of at least one detection limit.

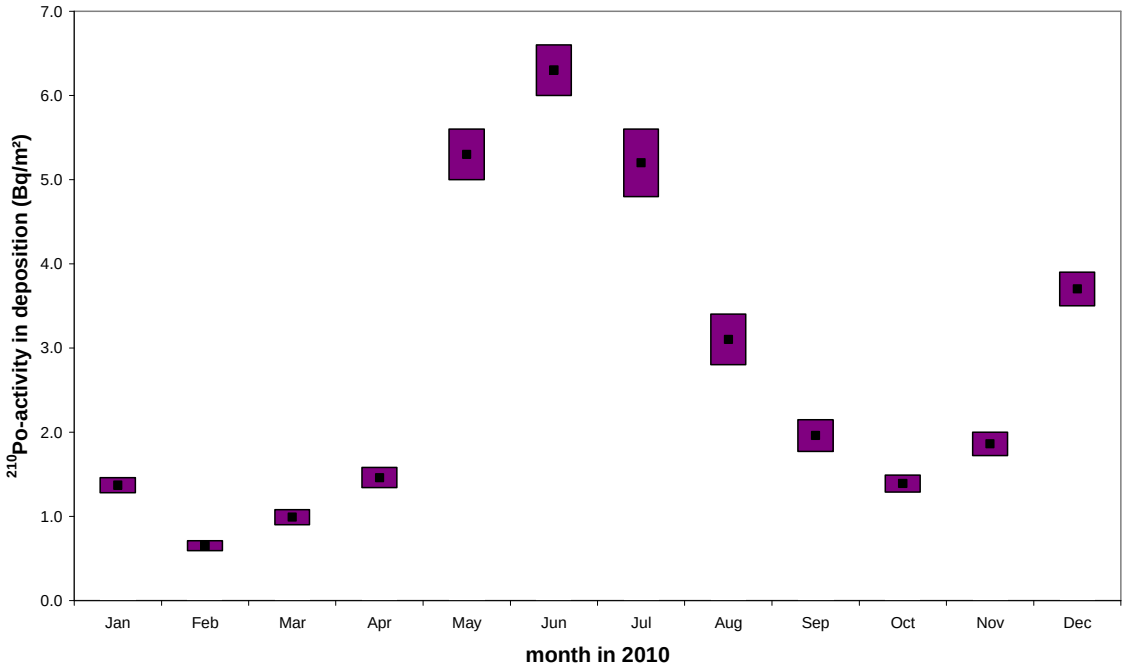


Figure 3.6: Monthly deposited ^{210}Po-activity at RIVM. Monthly totals (black dots) are shown with a 68% confidence range (coloured bars).

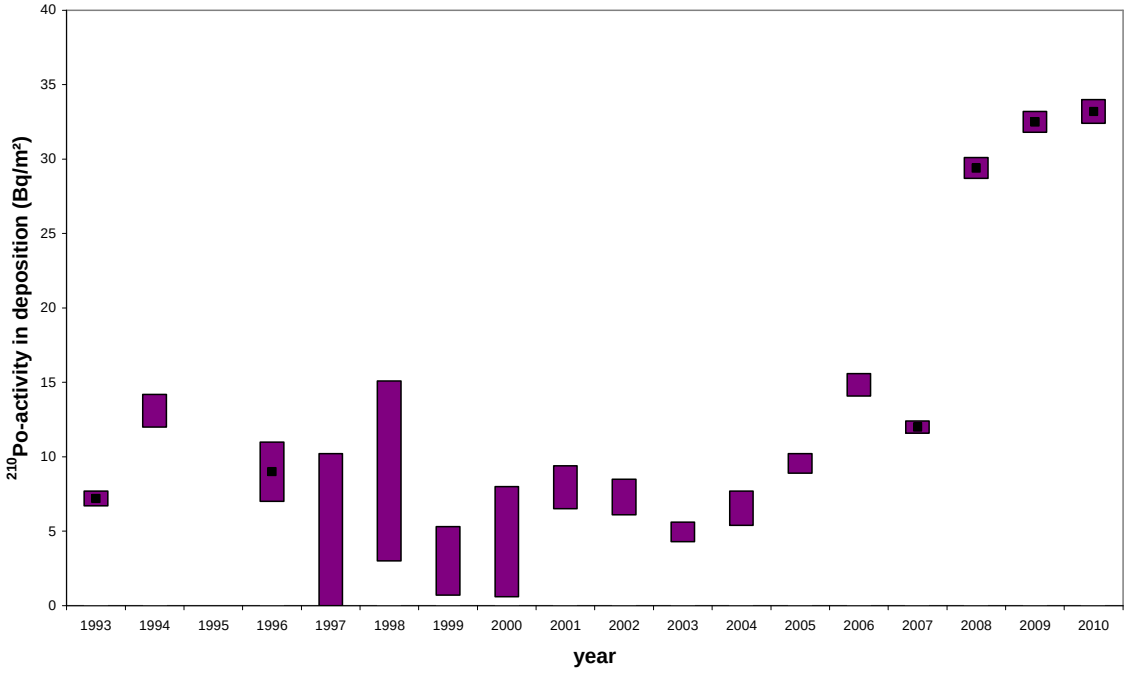


Figure 3.7: Yearly ^{210}Po-activity deposited at RIVM from 1993 to 2010. Yearly totals (black dots) are shown with a 68% confidence range (coloured bars). Solely a 68% confidence range is shown if the yearly result is made up of at least one detection limit.

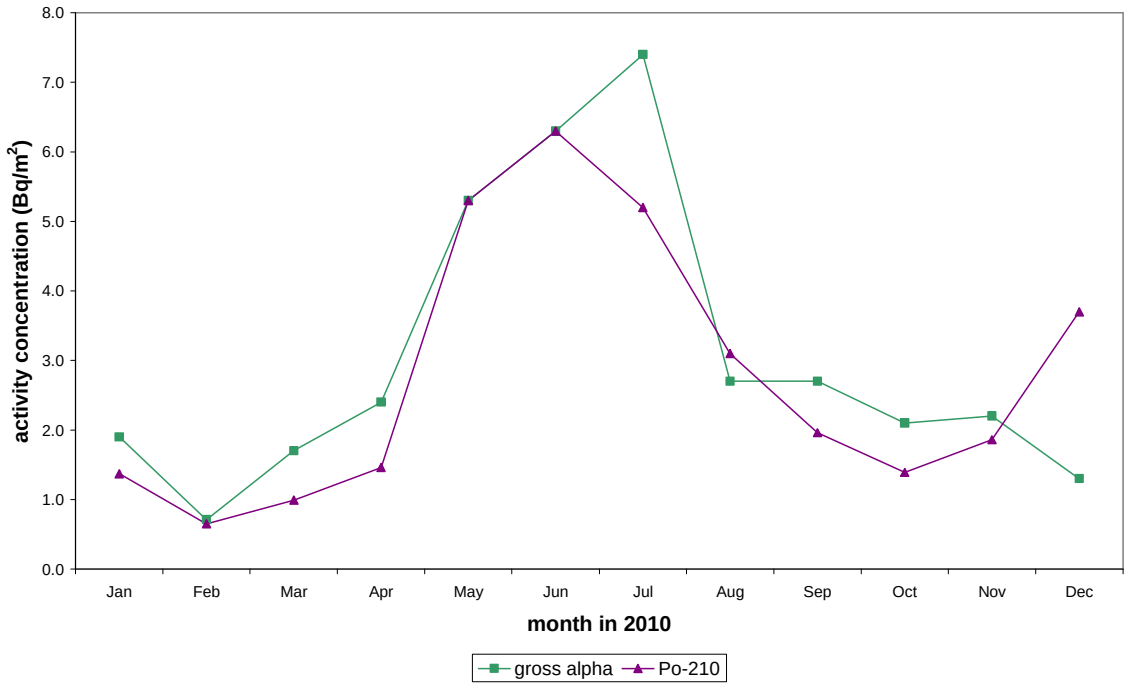


Figure 3.8: Figure illustrating the correlation between monthly total gross α- and ^{210}Po-activity in deposition at RIVM.

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 deposited in 2010 was 33.2 ± 0.8 Bq·m^{-2} (68% confidence level). This is the highest yearly total since 1993 and approximately the same level as in 2009. The correlation between the level of ^{210}Po and the level of gross α was less evident in July and December 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 52 samples. The yearly total deposition of ^{7}Be was 1240 ± 30 Bq·m^{-2} and the yearly total deposition of ^{210}Pb was 93 ± 2 Bq·m^{-2}. The nuclide ^{137}Cs was detected in none of the 52 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 Figure 3.10, 3.11 and 3.13.

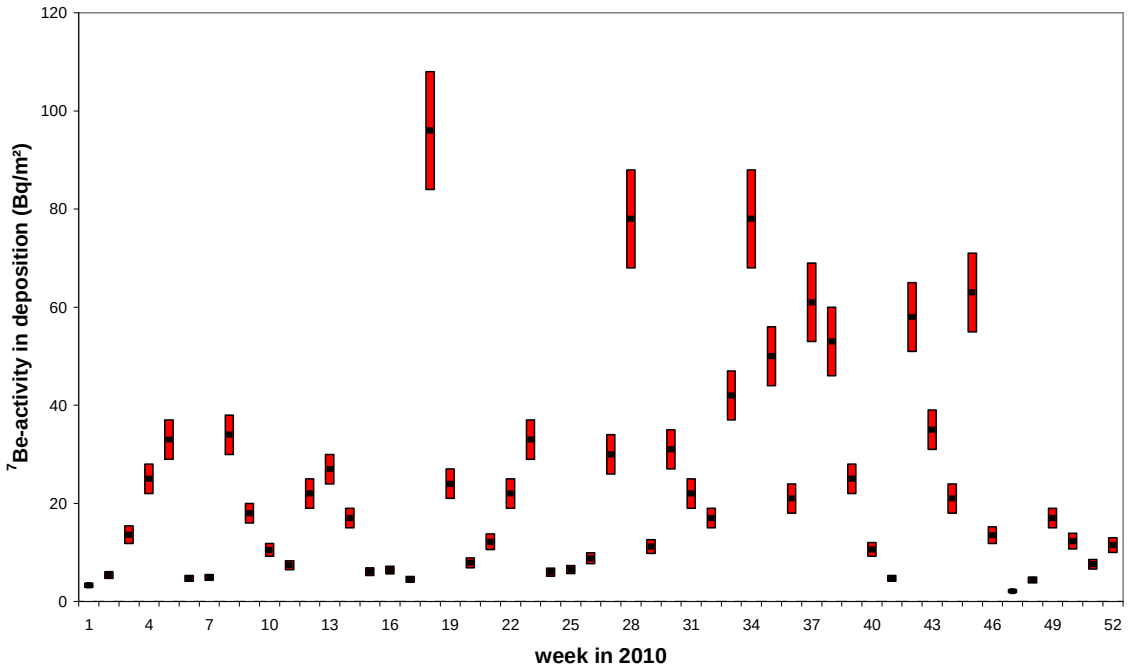


Figure 3.9: Weekly deposited ^{7}Be-activity at RIVM. Weekly totals (black dots) are shown with a 68% confidence range (coloured bars).

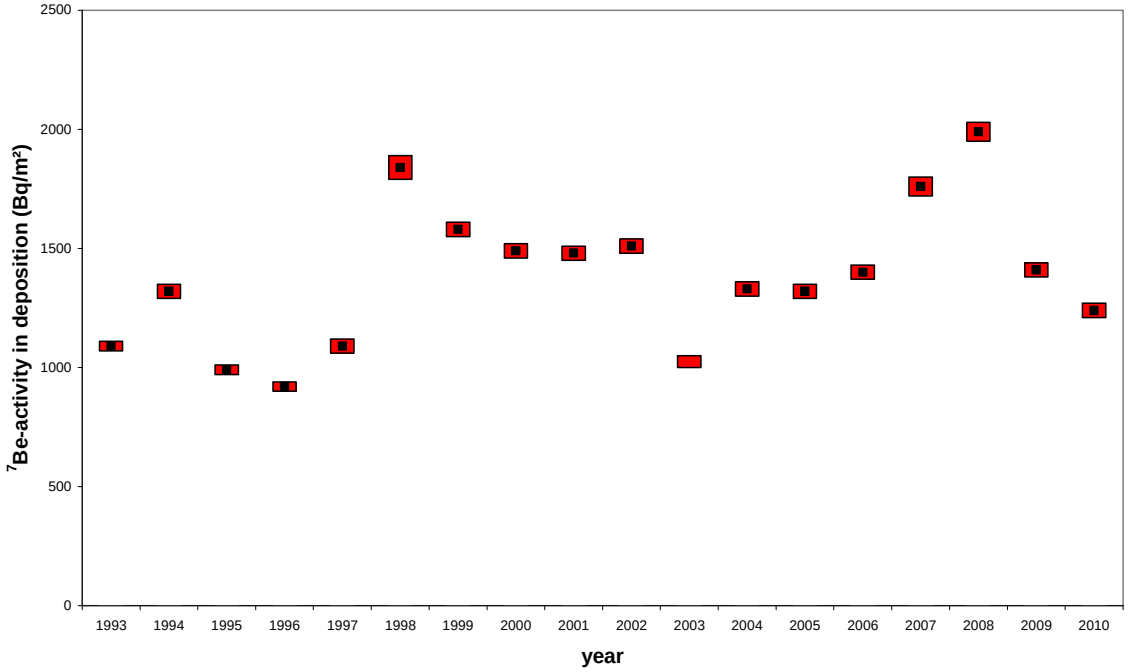


Figure 3.10: Yearly ^{7}Be-activity deposited at RIVM from 1993 to 2010. Yearly totals (black dots) are shown with a 68% confidence range (coloured bars). Solely a 68% confidence range is shown if the yearly result is made up of at least one detection limit.

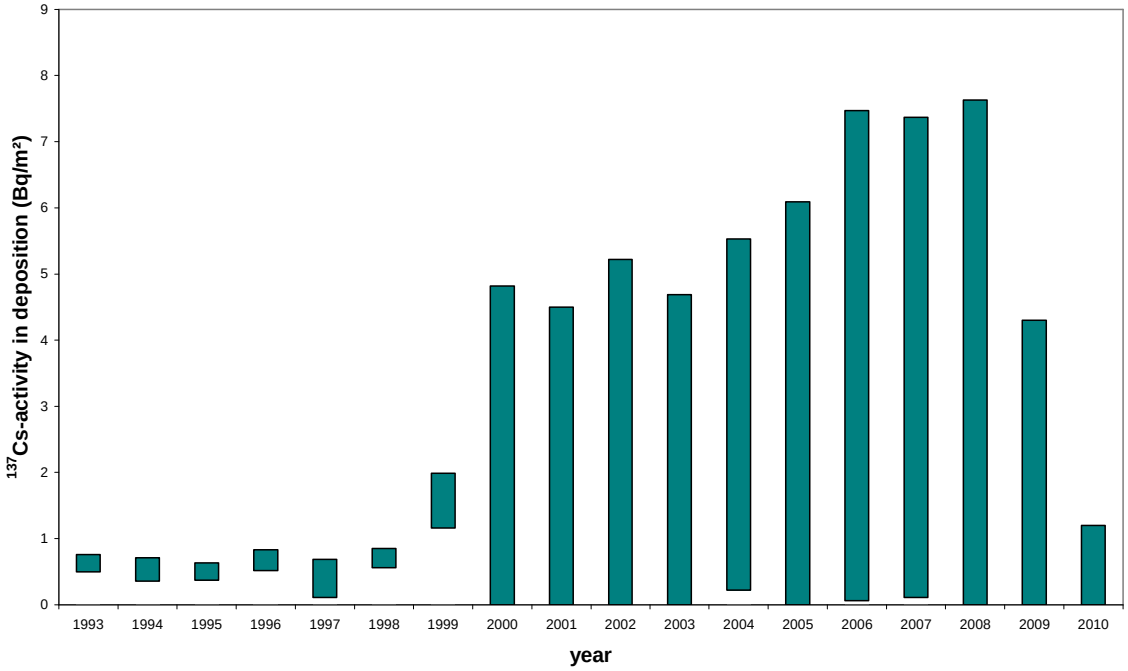


Figure 3.11: Yearly ^{137}Cs-activity deposited at RIVM from 1993 to 2010. Yearly averages are shown solely as a 68% confidence range since the yearly result is made up of at least one detection limit. Since 2000, the detection limit is higher than during 1993-1999, due to a different detector set-up. Since July 2009, a new detector set-up has been used, which results in lower detection limits.

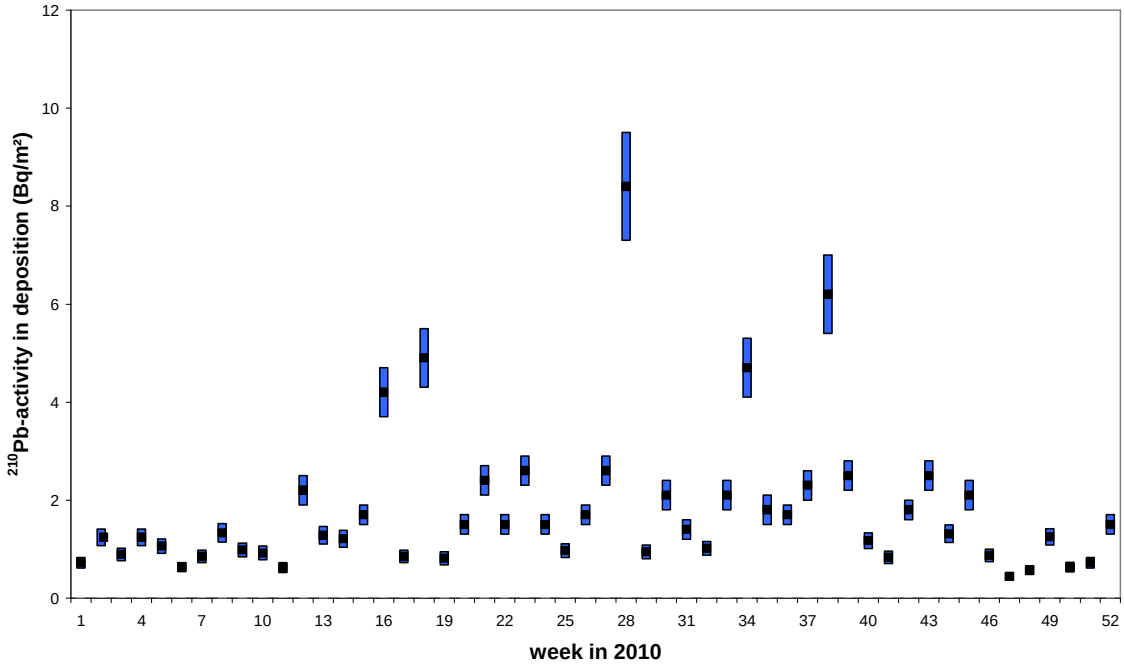


Figure 3.12: Weekly deposited ^{210}Pb-activity at RIVM. Weekly averages (black dots) are shown with a 68% confidence range (coloured bars). Solely a black dot is shown if the result is a detection limit.

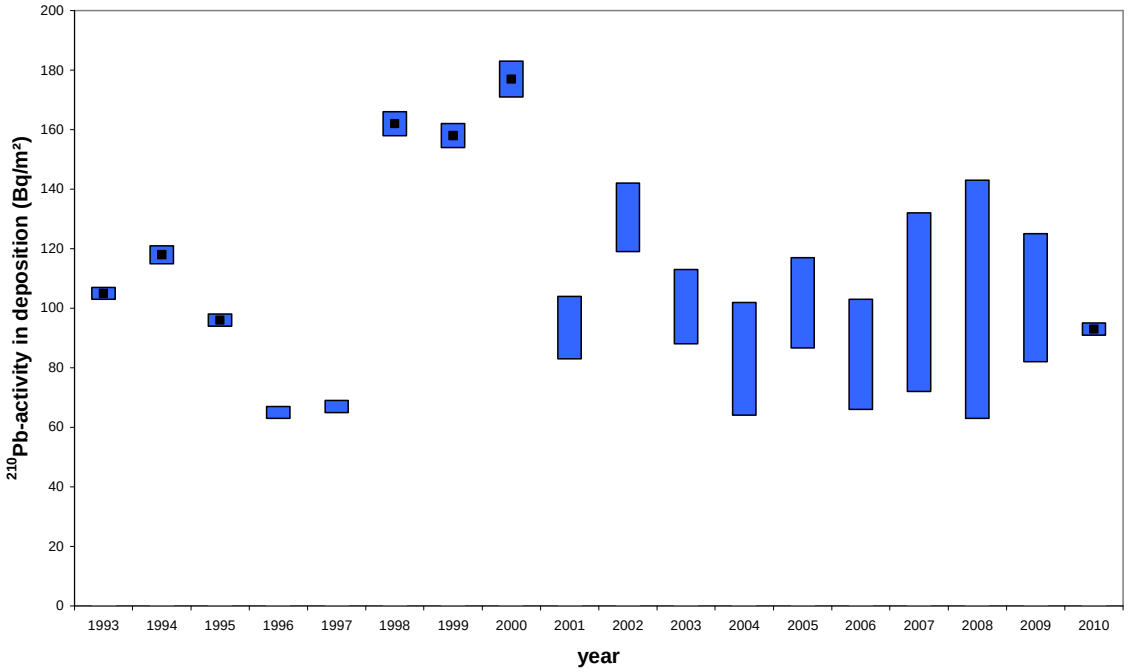


Figure 3.13: Yearly ^{210}Pb-activity deposited at RIVM from 1993 to 2010. Yearly averages (black dots) are shown with a 68% confidence range (coloured bars). Solely a 68% confidence range is shown if the yearly result is made up of at least one detection limit.

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. 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 the ambient dose equivalent rate is determined (at a height of 3.5 meter above ground level) as well as gross α- and artificial β-activity concentrations [32]. 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 the 14 sites compared to the 153 sites with regard to height and surface covering, results can differ between the two types of measuring sites [33]. 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 [34]. 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 from 1990 to 2010, while Figure 4.4 presents the yearly averages of ambient dose equivalent rate from 1996 to 2010.

In 2010 the yearly averaged gross α-activity concentration in air dust was 3.1 $Bq \cdot m^{-3}$ (based on the yearly averages of the 14 measurement locations). To compare this value (yearly average of 3.1 $Bq \cdot m^{-3}$) with data collected before 2002, it should be noted that the Berthold measurements are 20% higher than FAG measurements and the value can be corrected to 2.6 $Bq \cdot m^{-3}$. This value is within the range of those in previous years. 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. From 2004 onwards, the analysis of the ambient dose equivalent rate has been based on a set of 153 stations (10 stations have been dismantled). The yearly averaged ambient dose equivalent rate in 2010 was calculated using 148 stations (the remaining 5 stations were not operational).

In 2010, the yearly averaged measured value for the ambient dose equivalent rate was 73.3 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).

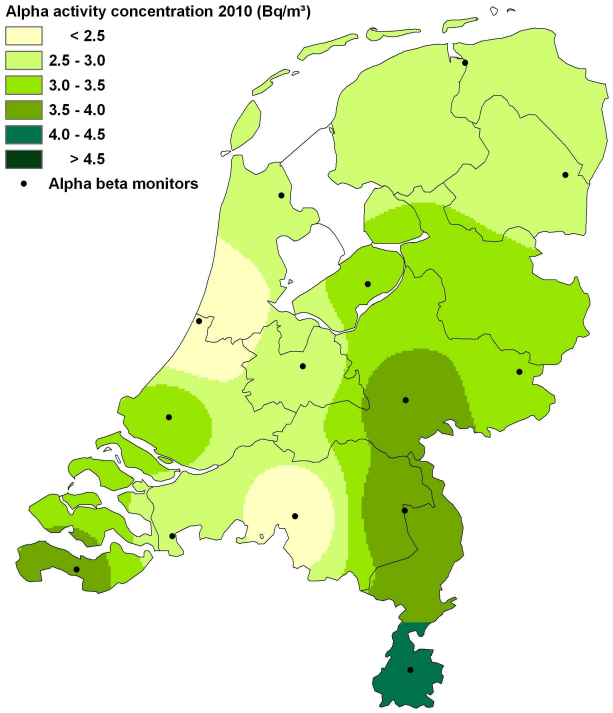


Figure 4.1: Spatial variation in the average gross α-activity concentration of (mainly) short-lived nuclides in air dust. The dots represent the locations of the aerosol monitors.

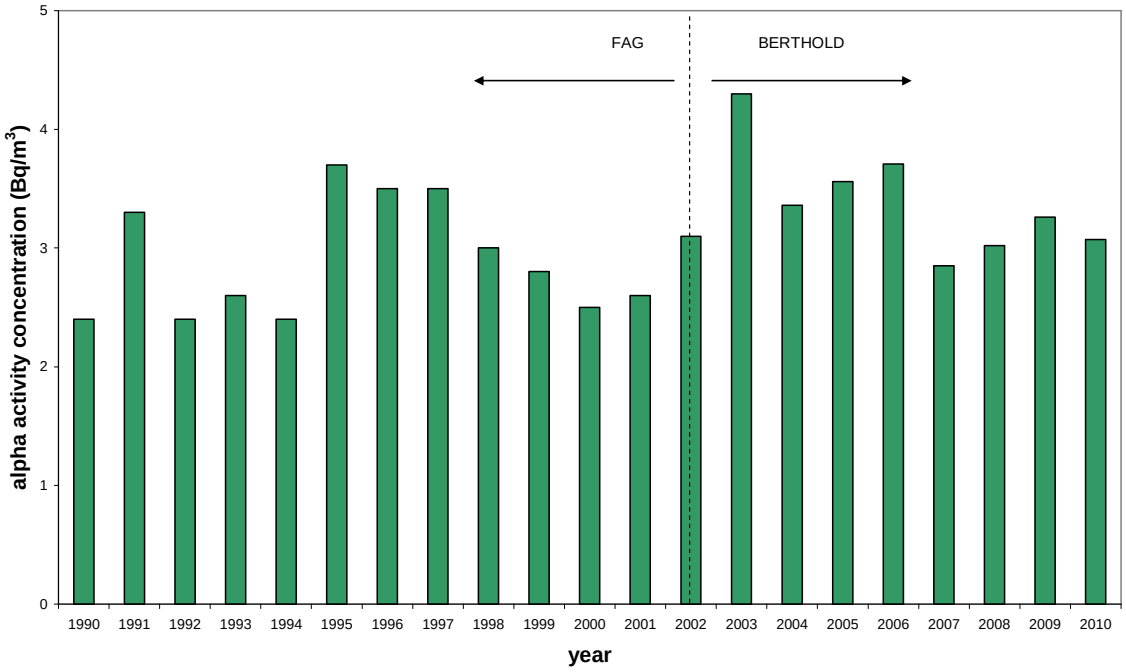


Figure 4.2: Yearly averaged gross α-activity concentration of (mainly) short-lived nuclides in air dust. During the second half of 2002 the FAG monitors were gradually replaced by the Berthold monitors.

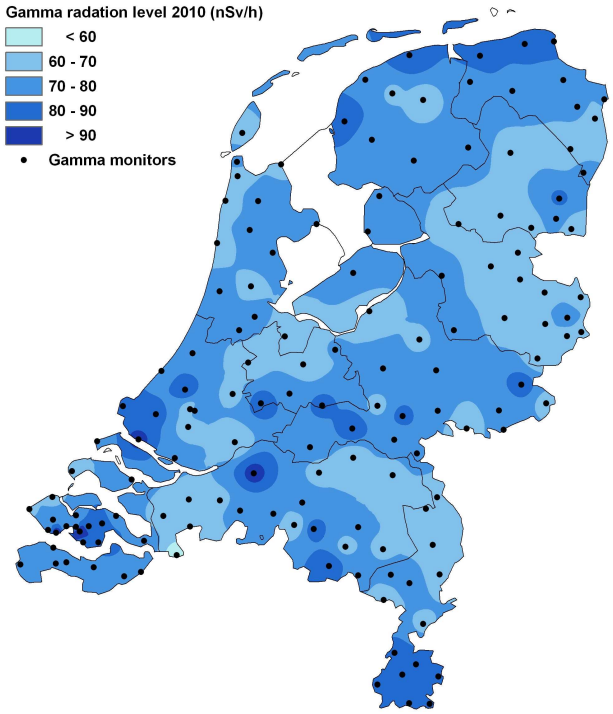


Figure 4.3: Spatial variation in the average ambient dose equivalent rate. The dots represent the locations of the dose equivalent rate monitors.

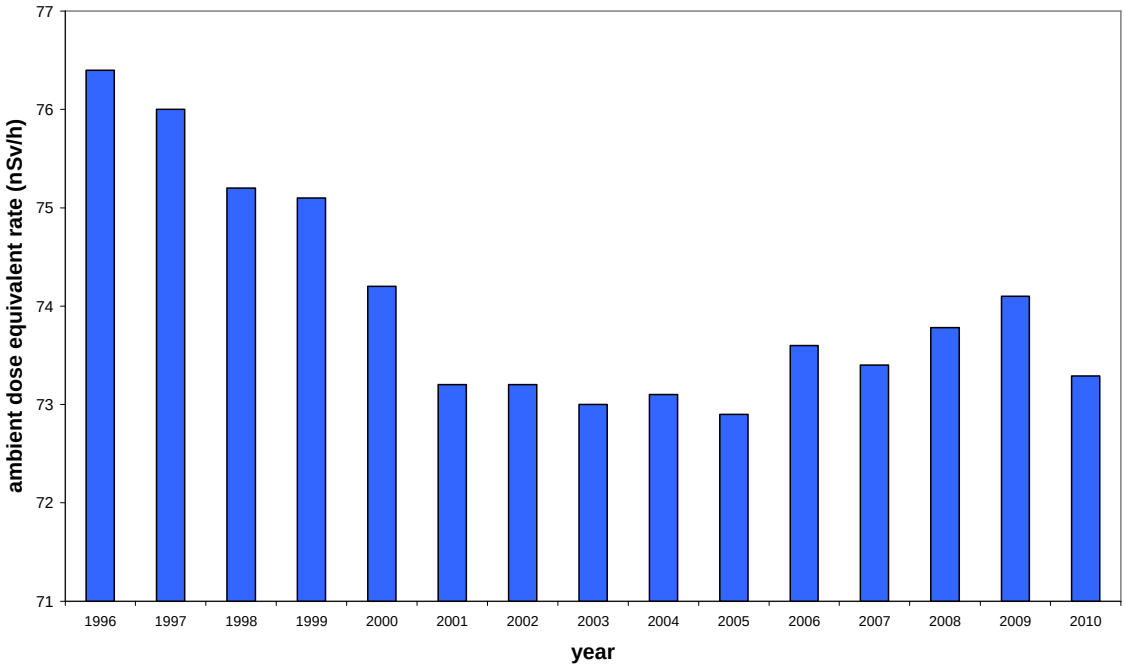


Figure 4.4: The yearly averaged ambient dose equivalent rate.

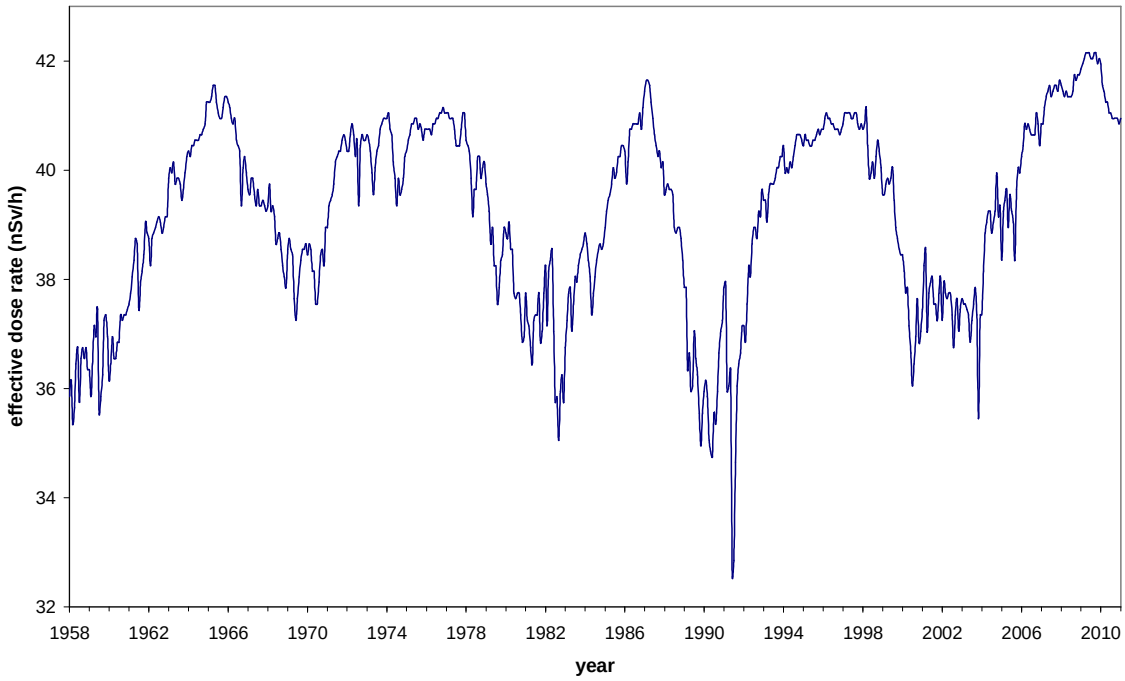


Figure 4.5: Cosmogenic contribution to the effective dose rate (at sea level), influenced by the solar cycle. Location 51°26′ north latitude and 3°43′ eastern longitude (in the southwest of the Netherlands), air pressure 1019 hPa. Figure derived from data supplied by the Federal Aviation Administration [35].

5 Surface water and seawater

5.1 Introduction

The RWS WD Centre for Water Management regularly monitors the concentration of a number of radioactive nuclides in surface water and seawater. The monitoring program presented here forms only part of their total monitoring program. A more detailed description of the monitoring program, underlying strategy and results of radioactivity measurements in Dutch waters are reported elsewhere [36, 37, 38].

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.

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

Location	Parameter	Matrix	Monitoring frequency (per year)
IJsselmeer (Vrouwezand)	Gross α	Water	10 (1)
	Residual β	Water	10 (1)
	^{3}H	Water	5 (2)
	^{60}Co	Suspended solids	10 (1)
	^{131}I	Suspended solids	10 (1)
	^{137}Cs	Suspended solids	10 (1)
Noordzeekanaal (IJmuiden)	Gross α	Water	13
	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 (Maassluis)	Gross α	Water	13
	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	13
	^{131}I	Suspended solids	13
	^{137}Cs	Suspended solids	13
	^{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	8
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	46 [3]
	^{131}I	Suspended solids	46 [3]
	^{137}Cs	Suspended solids	46 [3]
	^{210}Pb	Suspended solids	7

[1] Normally 13 times per year. Sampling did not occur on three occasions.

[2] Normally 7 times per year. Sampling did not occur on two occasions.

[2] Normally 52 times per year. Sampling did not occur on six occasions.

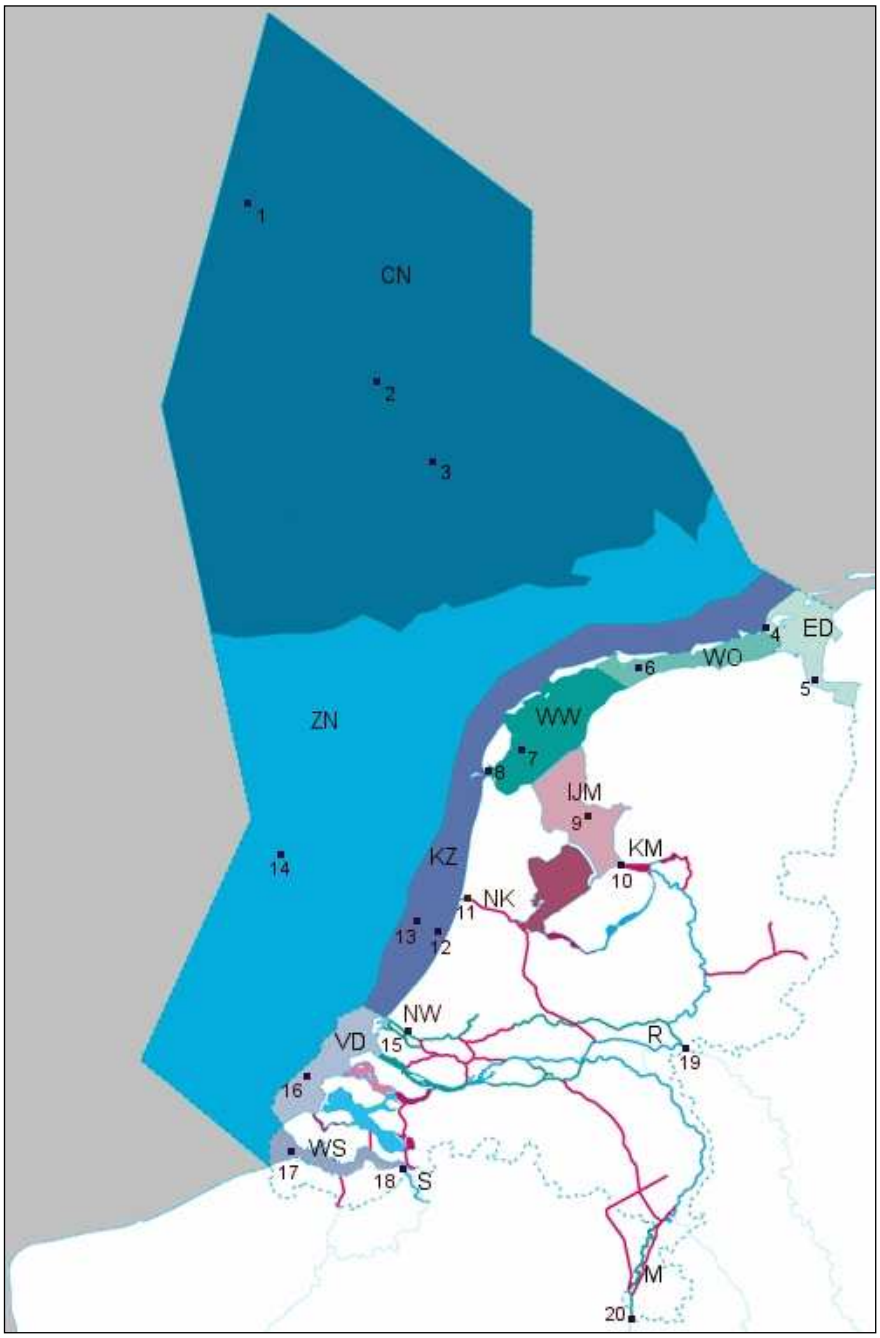
The radioactive nuclides were measured according to standard procedures [36, 39]. In the Netherlands, target values are used for radioactive materials in surface water, which are given in the Fourth memorandum on water management (Vierde Nota waterhuishouding) [40]. The yearly averages are compared with 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	11 [2]
		Residual β	Water	11 [2]
		^{3}H	Water	11 [2]
		^{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.

[2] Normally 12 times per year. Sampling did not occur on one occasion.



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

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

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

Figure 5.1: Overview of monitoring locations for the monitoring 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 during 1989 (135 km offshore) and 1988-1994 (100 km off shore). 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 during 1988-1998. Noordwijk 2 km offshore has been the monitoring location for the Coastal area since 1999 [36]. 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 for surface water are presented in Tables A11 and A12 and in Figures 5.2 through 5.19.

Gross α and residual β are indicative parameters. The yearly averaged activity concentrations of gross α and residual β in 2010 were within the range of those in previous years. The gross α-activity concentration in the Noordzeekanaal, Nieuwe Waterweg, Rhine, Scheldt and Meuse exceeded the target value (100 $mBq \cdot L^{-1}$) in 9 out of 13, 2 out of 13, 1 out of 13, 12 out of 13 and 1 out of 13 samples taken, respectively. In 2010, the yearly averaged gross α-activity concentrations in the Noordzeekanaal and Scheldt (180 and 300 $mBq \cdot L^{-1}$, 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 2 out of 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 the trend since 1994, which was caused by a change in measuring technique that only applies to salt and brackish water [36]. 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 13, 4 out of 6 and 10 out of 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 2010 were within the range of those in previous years. In 2010, the yearly averaged ^{3}H-activity concentration in the Scheldt and Meuse (11.7 and 20.0 $Bq \cdot L^{-1}$, respectively) were 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 2010 were within the range of those in previous years. The yearly averaged ^{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 Rhine and Scheldt exceeded the target value (5 $mBq \cdot L^{-1}$) in 1 out of 6 and 6 out of 6 samples taken, respectively. The yearly averaged ^{226}Ra-activity concentrations in 2010 were within the range of those in previous years. In 2010 the yearly averaged ^{226}Ra-activity concentration in the Scheldt (15 $mBq \cdot L^{-1}$) was above the target value of 5 $mBq \cdot L^{-1}$.

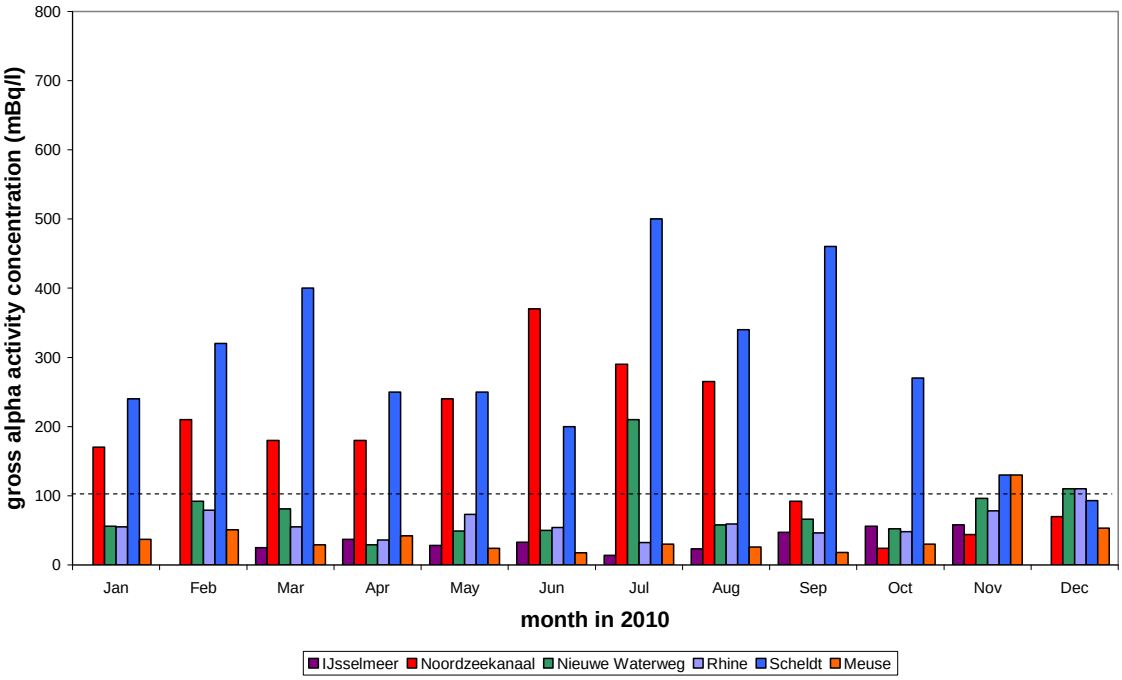


Figure 5.2: The gross α-activity concentration for the IJsselmeer, Noordzeekanaal, Nieuwe Waterweg, Rhine, Scheldt and Meuse, with yearly averages of 35, 180, 78, 60, 300 and 39 mBq·L^{-1}, respectively. Averaged values are shown in case of multiple measurements per month. The dotted line represents the target value of 100 mBq·L^{-1} [40].

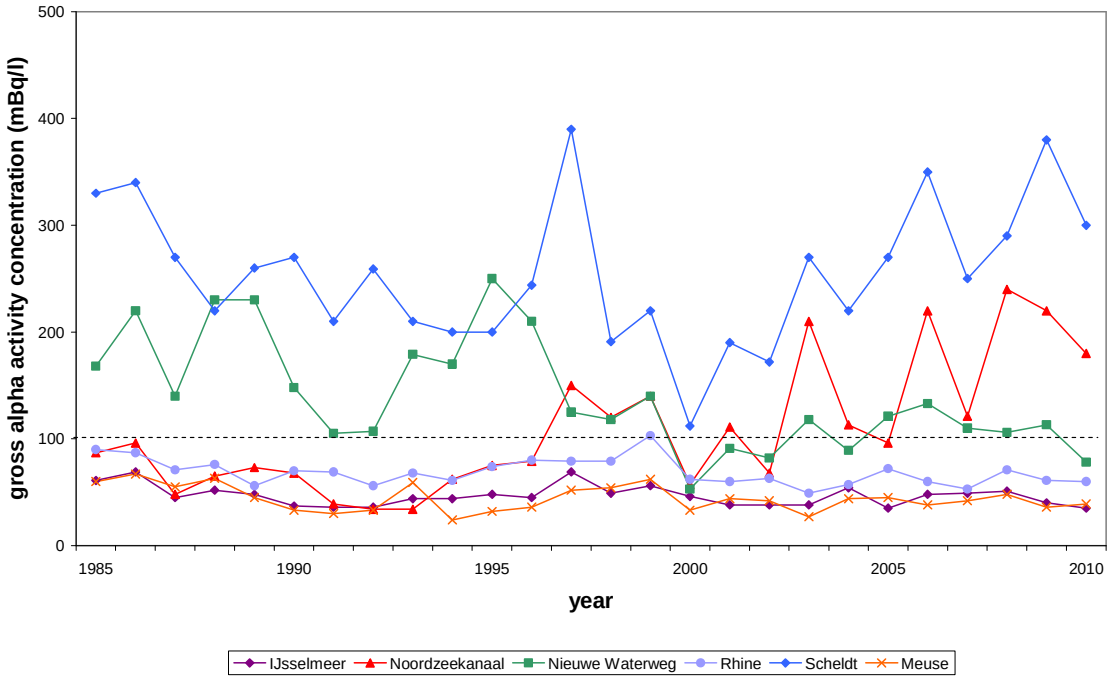


Figure 5.3: Yearly averaged gross α-activity concentrations.

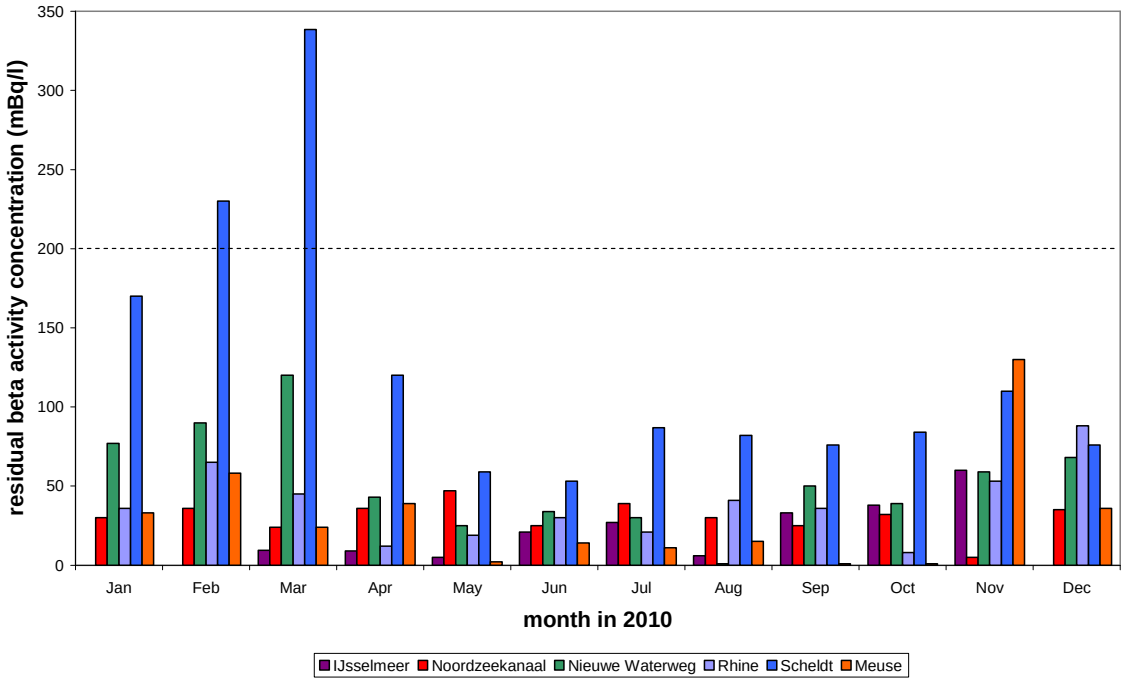


Figure 5.4: The residual β-activity concentration for the IJsselmeer, Noordzeekanaal, Nieuwe Waterweg, Rhine, Scheldt and Meuse, with yearly averages of 22, 30, 53, 37, 140 and 29 mBq·L^{-1}, respectively. Averaged values are shown in case of multiple measurements per month. The dotted line represents the target value of 200 mBq·L^{-1} [40].

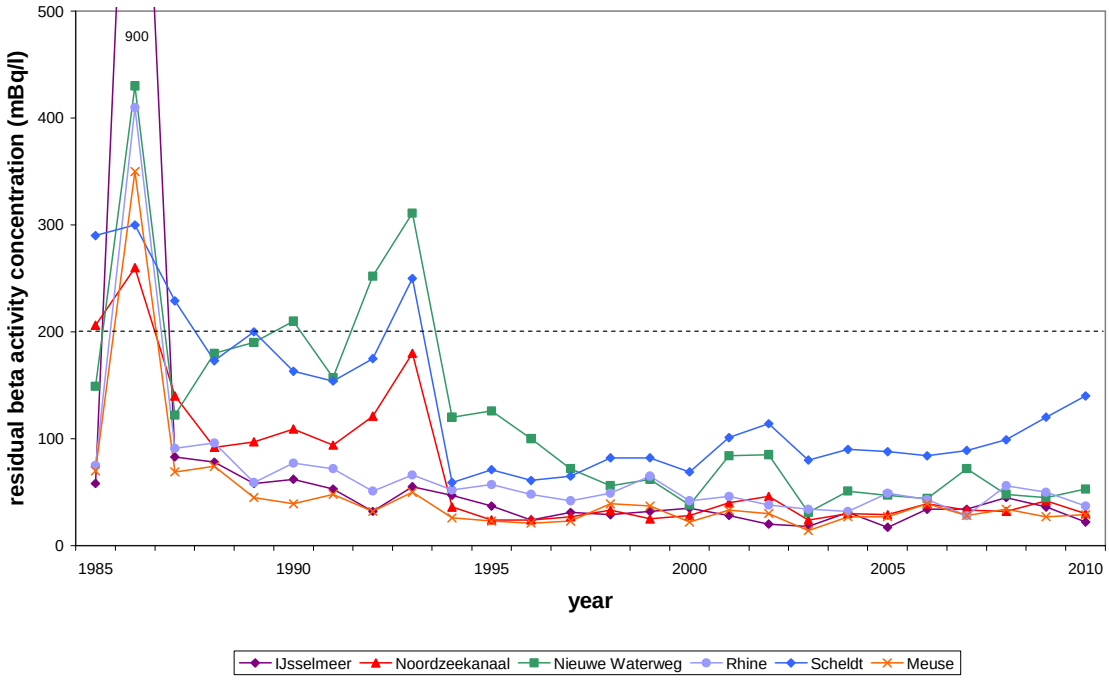


Figure 5.5: Yearly averaged residual β-activity concentrations.

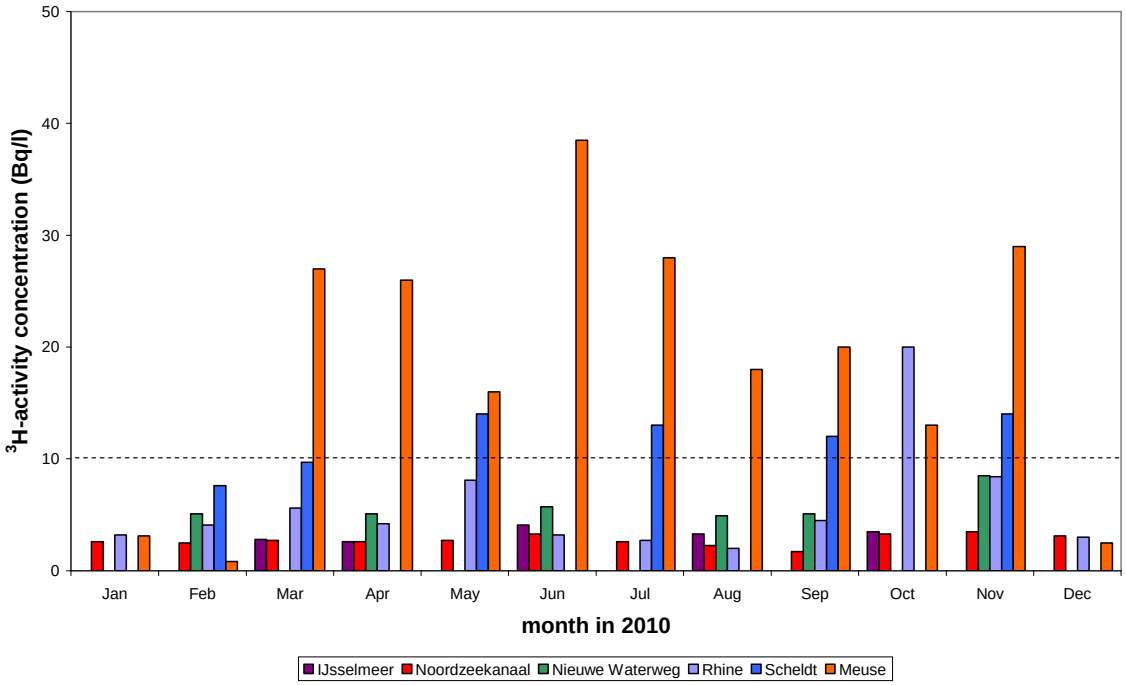


Figure 5.6: The ^{3}H-activity concentration for the IJsselmeer, Noordzeekanaal, Nieuwe Waterweg, Rhine, Scheldt and Meuse, with yearly averages of 3.3, 2.7, 5.7, 5.6, 11.7 and 20.0 Bq·L^{-1}, respectively. Averaged values are shown in case of multiple measurements per month. The dotted line represents the target value of 10 Bq·L^{-1} [40].

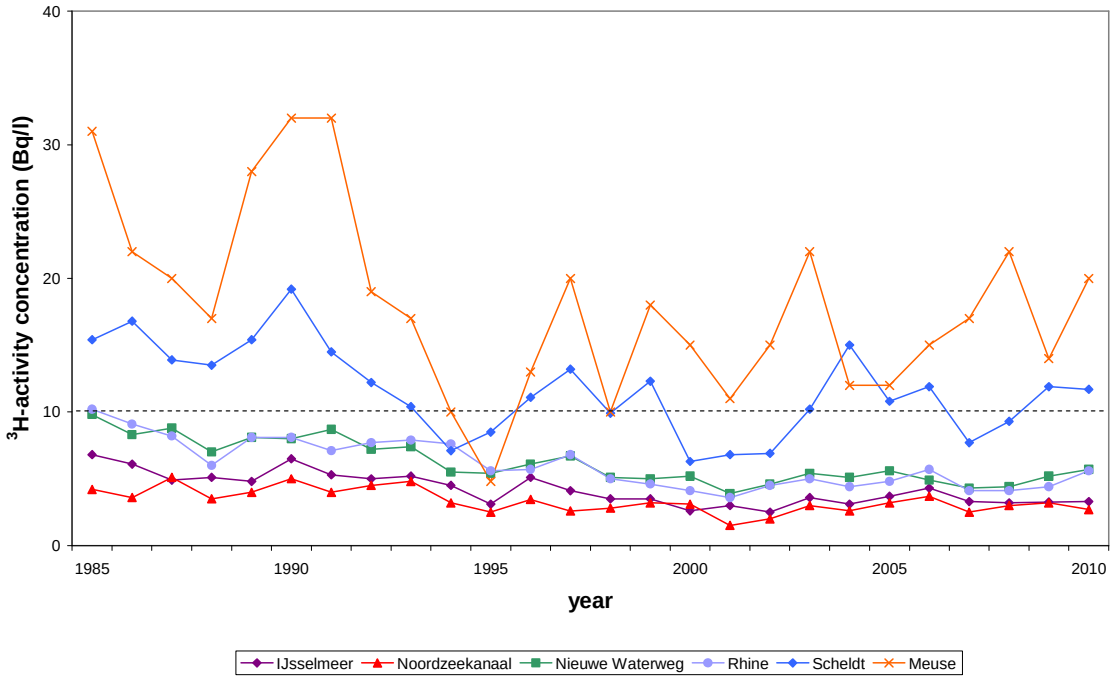


Figure 5.7: Yearly averaged ^{3}H-activity concentrations.

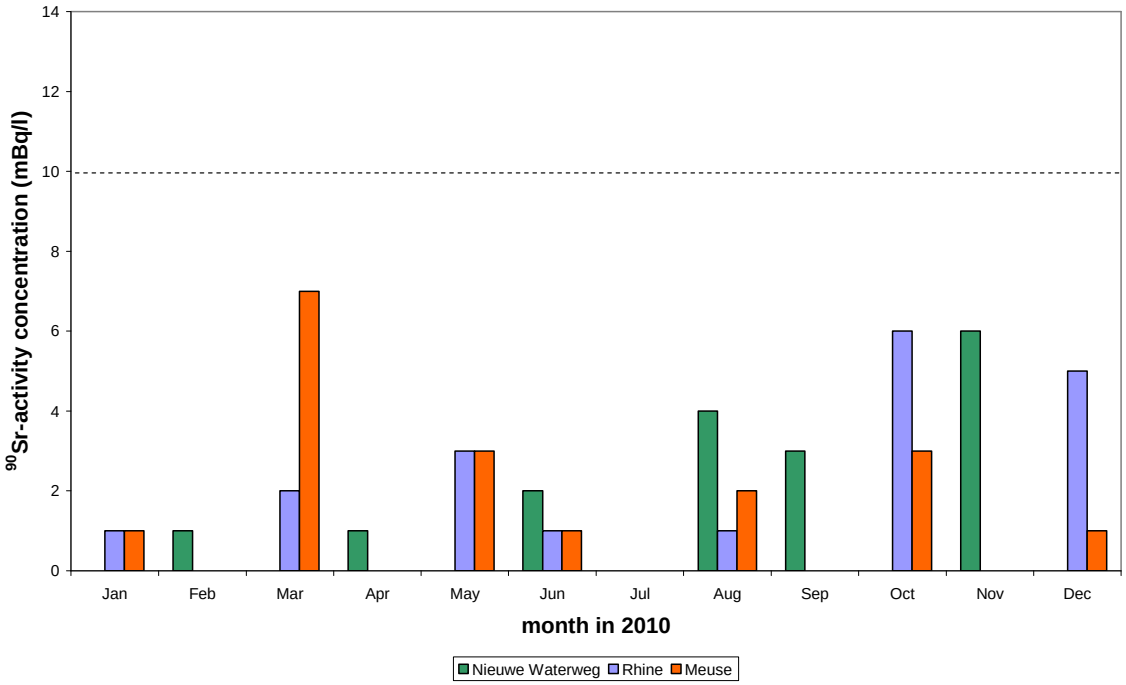


Figure 5.8: The ^{90}Sr-activity concentration for the Nieuwe Waterweg, Rhine and Meuse, with yearly averages of 2.7, 2.6 and 2.4 mBq·L^{-1}, respectively. Averaged values are shown in case of multiple measurements per month. The dotted line represents the target value of 10 mBq·L^{-1} [40].

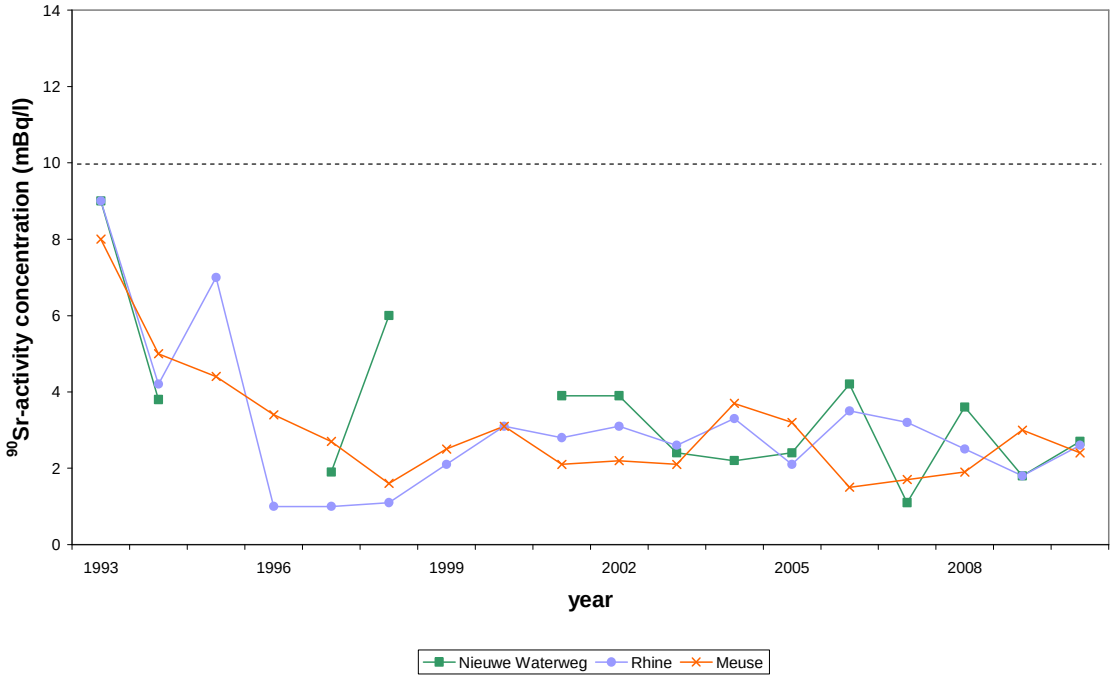


Figure 5.9: Yearly averaged ^{90}Sr-activity concentrations. Data are not available for the Nieuwe Waterweg in 1995, 1996, 1999 and 2000.

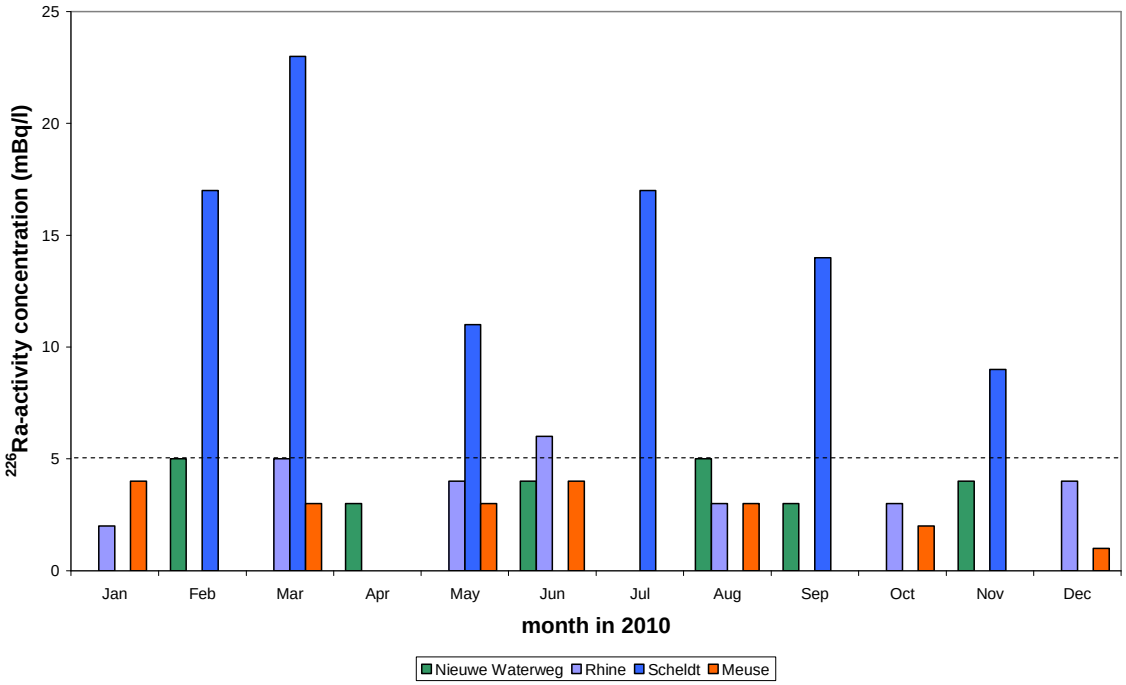


Figure 5.10: The ^{226}Ra-activity concentration for the Nieuwe Waterweg, Rhine, Scheldt and Meuse, with yearly averages of 4.0, 3.9, 15 and 2.9 mBq·L^{-1}, respectively. Averaged values are shown in case of multiple measurements per month. The dotted line represents the target value of 5 mBq·L^{-1} [40].

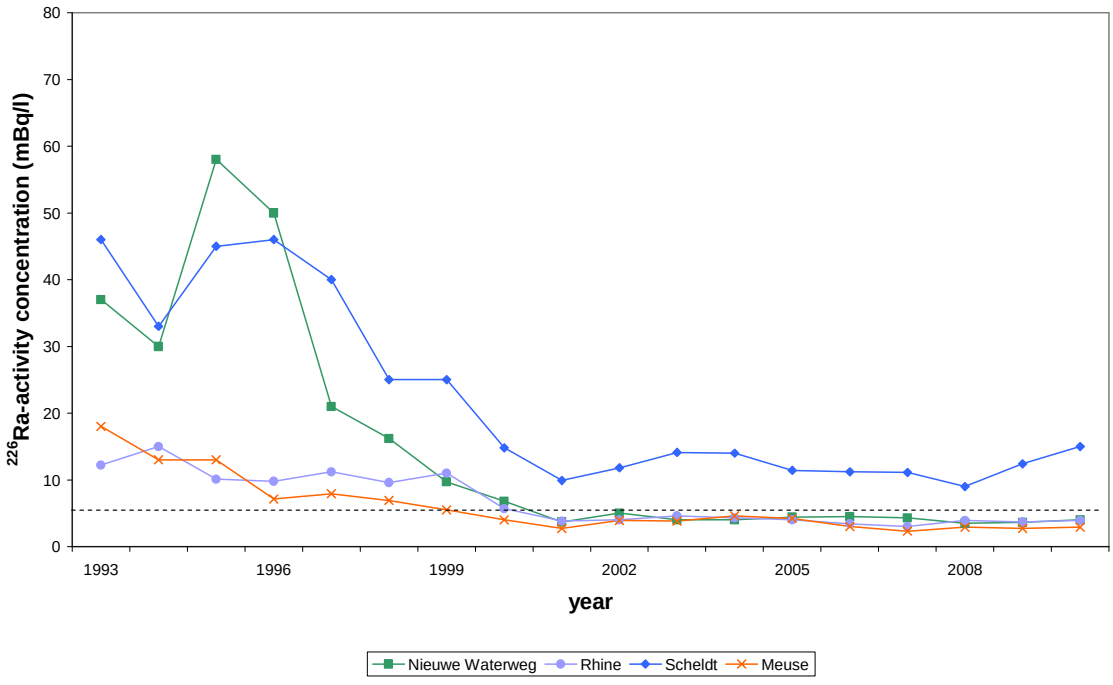


Figure 5.11: Yearly averaged ^{226}Ra-activity concentrations.

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 $Bq \cdot kg^{-1}$) in 1 out of 46 samples taken. In 2010, the yearly averaged ^{60}Co-activity concentrations were below the target value of 10 $Bq \cdot kg^{-1}$.

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 $Bq \cdot kg^{-1}$) in 5 out of 7 and 17 out of 46 samples taken, respectively. In 2010, the yearly averaged ^{131}I-activity concentration in the Noordzeekanaal (32 $Bq \cdot kg^{-1}$) was higher than those in previous years, and exceeded the target value of 20 $Bq \cdot kg^{-1}$.

The yearly averaged concentrations of ^{137}Cs in suspended solids in 2010 were within the range of those in previous years. The yearly averaged ^{137}Cs-concentrations were below the target value of 40 $Bq \cdot kg^{-1}$.

Since ^{210}Po is regularly in equilibrium with ^{210}Pb in suspended solids, the Centre for Water Management only reports ^{210}Pb. The nuclides ^{210}Po and ^{210}Pb originate from the uranium decay chain and are released by the phosphate processing industry [36]. The ^{210}Pb-activity concentration in the Nieuwe Waterweg, Rhine and Meuse exceeded the target value (100 $Bq \cdot kg^{-1}$) in 3 out of 6, 7 out of 7 and 6 out of 7 samples taken, respectively. In 2010 the yearly averaged ^{210}Pb-activity concentrations in the Nieuwe Waterweg, Rhine and Meuse (104, 126 and 151 $Bq \cdot kg^{-1}$, respectively) were above the target value of 100 $Bq \cdot kg^{-1}$, but within range of those in previous years.

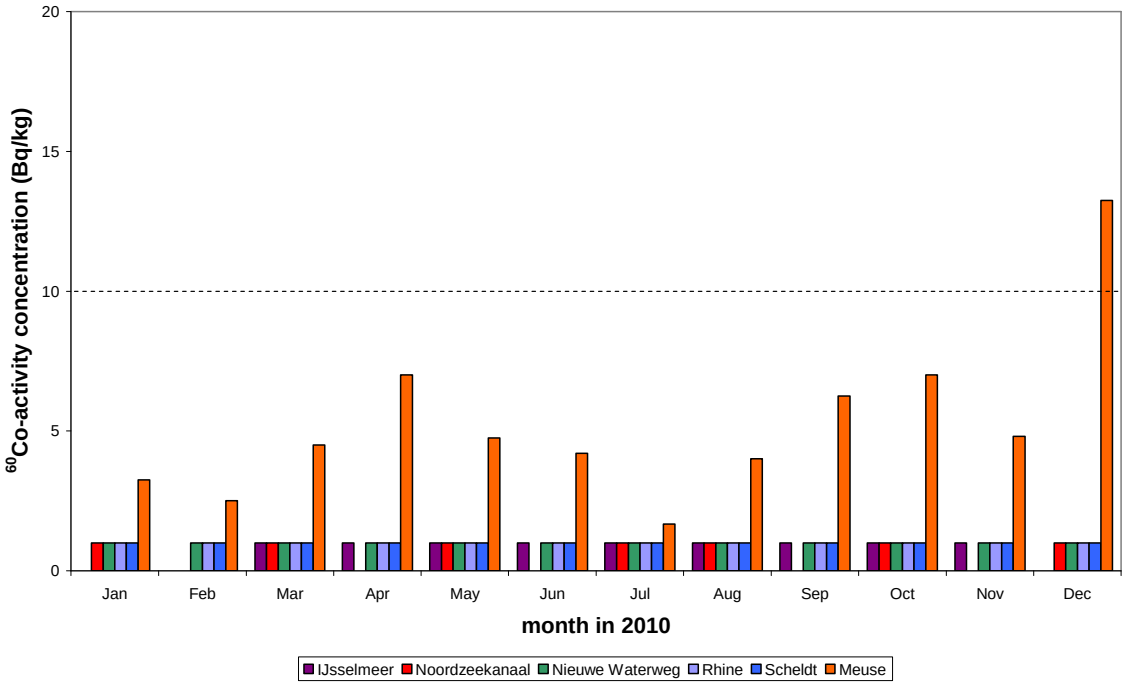


Figure 5.12: The ^{60}Co-activity concentration in suspended solids for the IJsselmeer, Noordzeekanaal, Nieuwe Waterweg, Rhine, Scheldt and Meuse. The yearly averages of all except for the Meuse (5 Bq·kg^{-1}) are < 1 Bq·kg^{-1}. Averaged values are shown in case of multiple measurements per month. The dotted line represents the target value of 10 Bq·kg^{-1} [40].

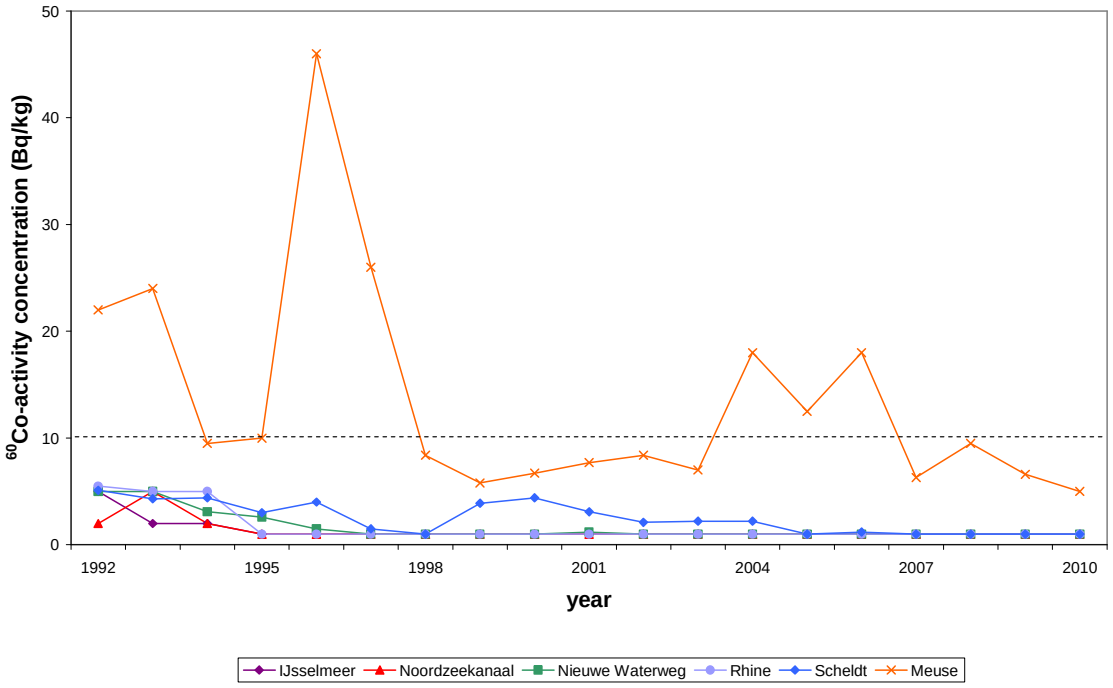


Figure 5.13: Yearly averaged ^{60}Co-activity concentrations in suspended solids.

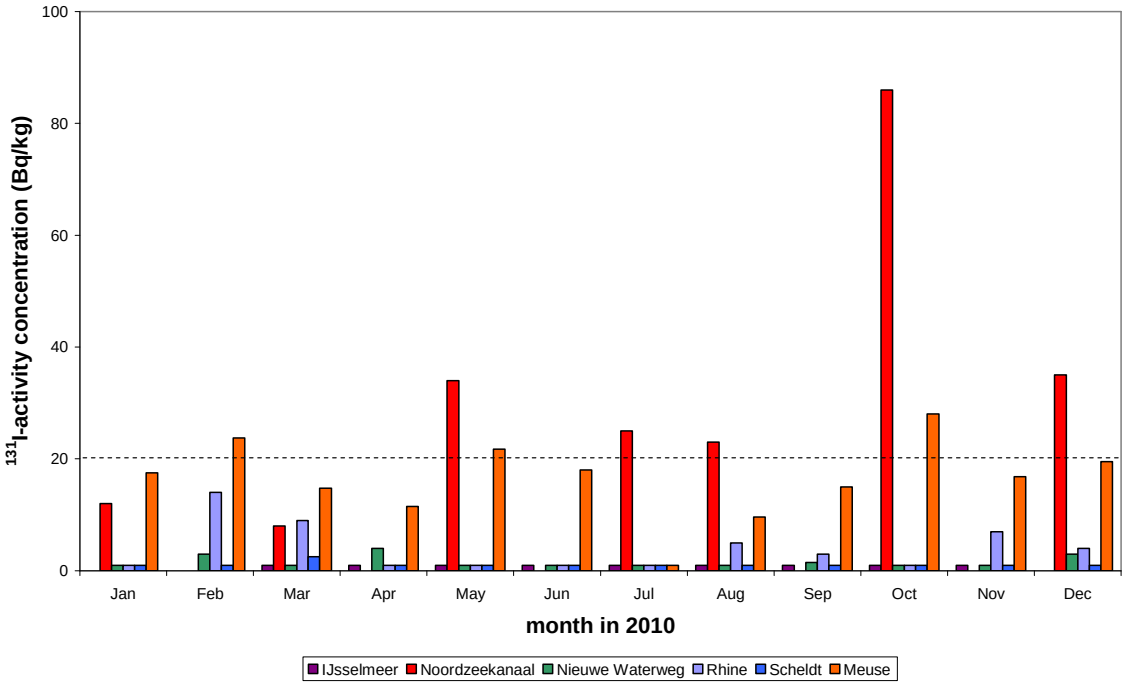


Figure 5.14: The ^{131}I-activity concentration in suspended solids for the IJsselmeer, Noordzeekanaal, Nieuwe Waterweg, Rhine, Scheldt and Meuse, with yearly averages of < 1, 32, < 1.3, < 3.5, < 1, and 16.3 Bq·kg^{-1}, respectively. Averaged values are shown in case of multiple measurements per month. The dotted line represents the target value of 20 Bq·kg^{-1} [40].

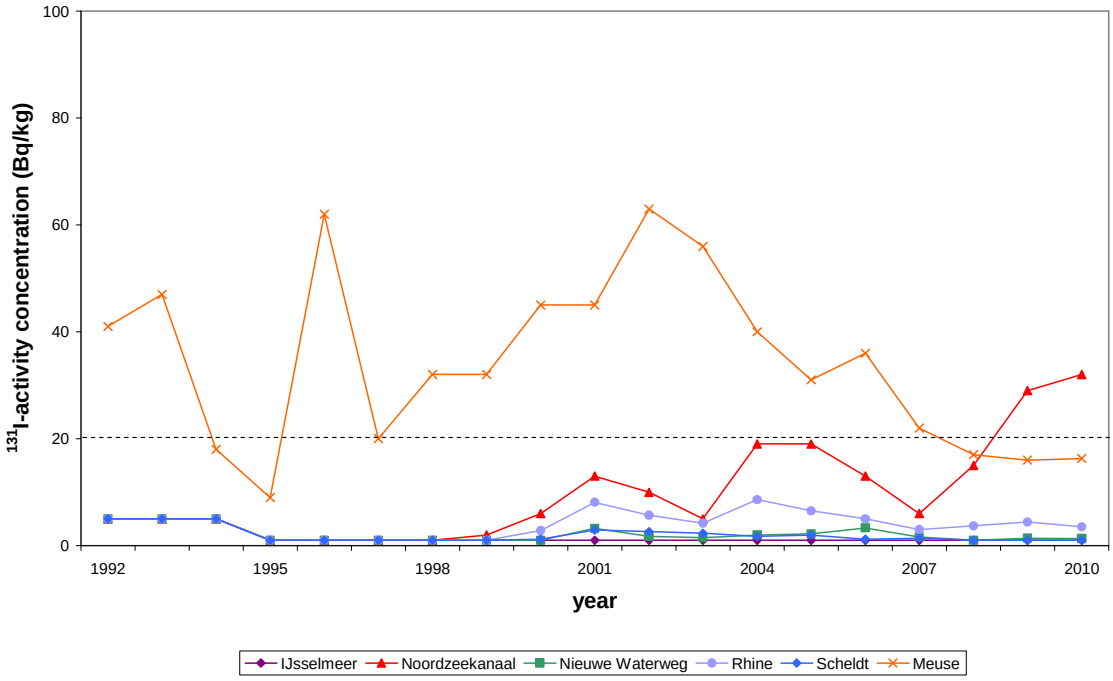


Figure 5.15: Yearly averaged ^{131}I-activity concentrations in suspended solids.

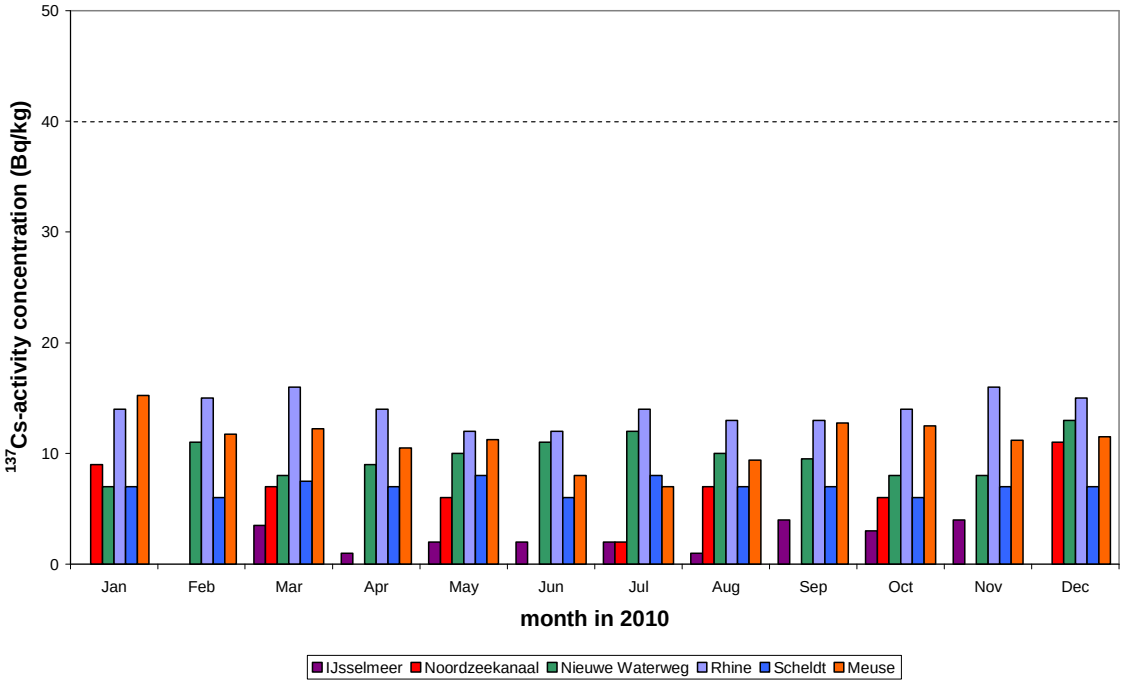


Figure 5.16: The ^{137}Cs-activity concentration in suspended solids for the IJsselmeer, Noordzeekanaal, Nieuwe Waterweg, Rhine, Scheldt and Meuse, with yearly averages of 2.6, 6.9, 9.7, 13.8, 7, and 11.1 Bq·kg^{-1}, respectively. Averaged values are shown in case of multiple measurements per month. The dotted line represents the target value of 40 Bq·kg^{-1} [40].

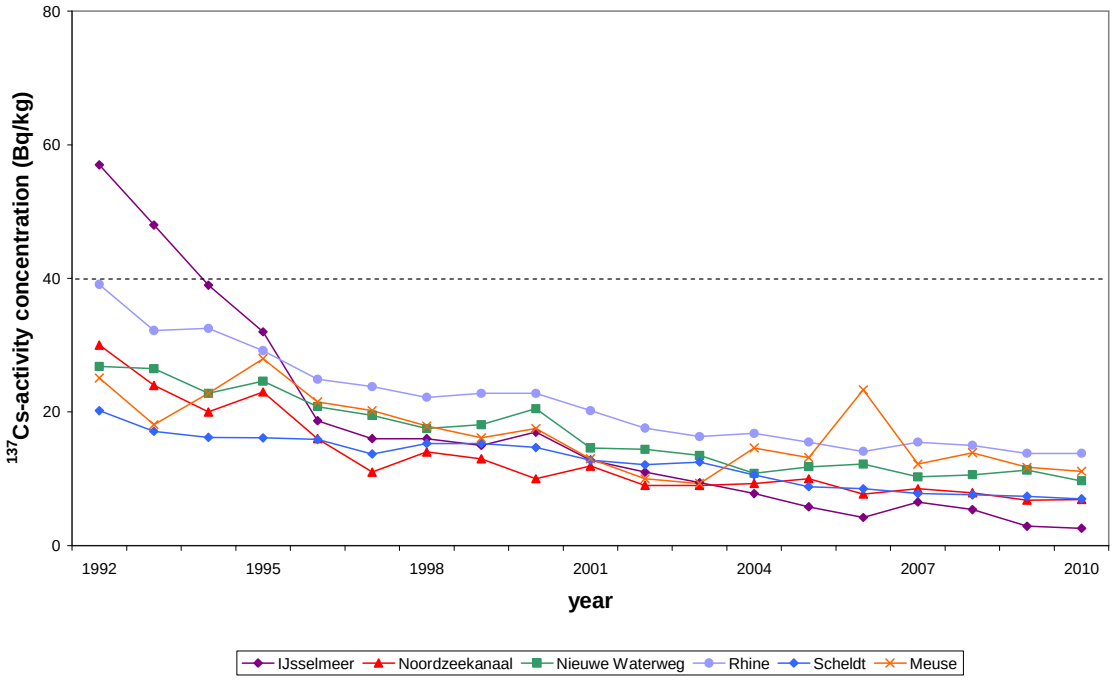


Figure 5.17: Yearly averaged ^{137}Cs-activity concentrations in suspended solids.

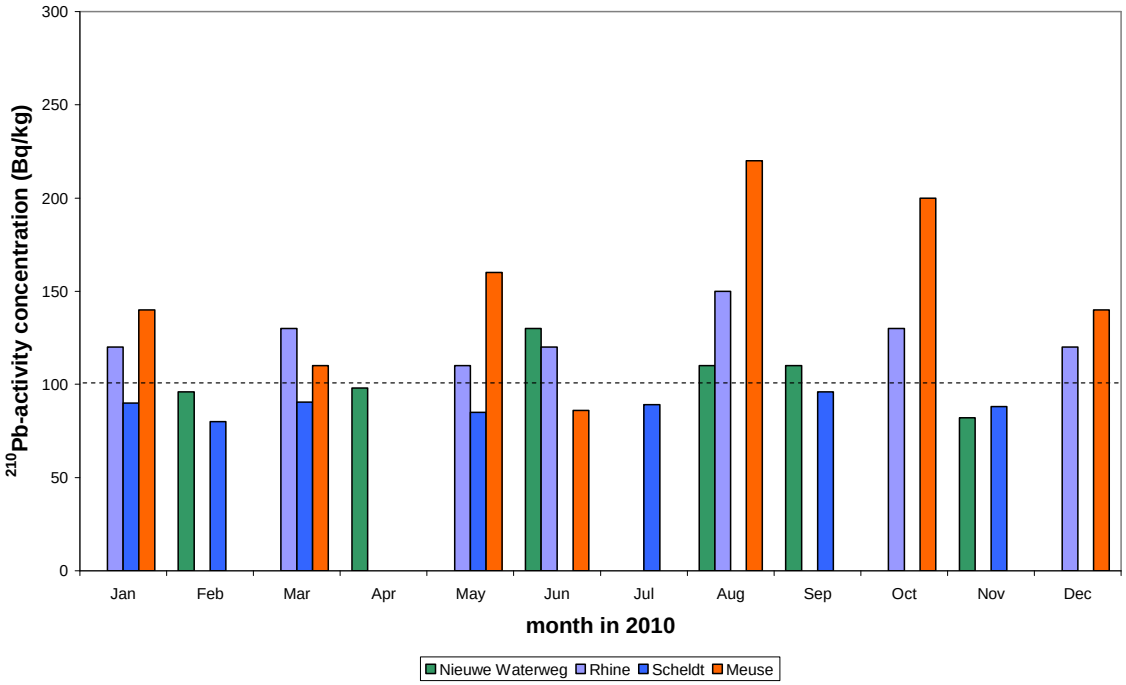


Figure 5.18: The ^{210}Pb-activity concentration in suspended solids for the Nieuwe Waterweg, Rhine, Scheldt and Meuse, with yearly averages of 104, 126, 88.6, and 151 Bq·kg^{-1}, respectively. Averaged values are shown in case of multiple measurements per month. The dotted line represents the target value of 100 Bq·kg^{-1} [40].

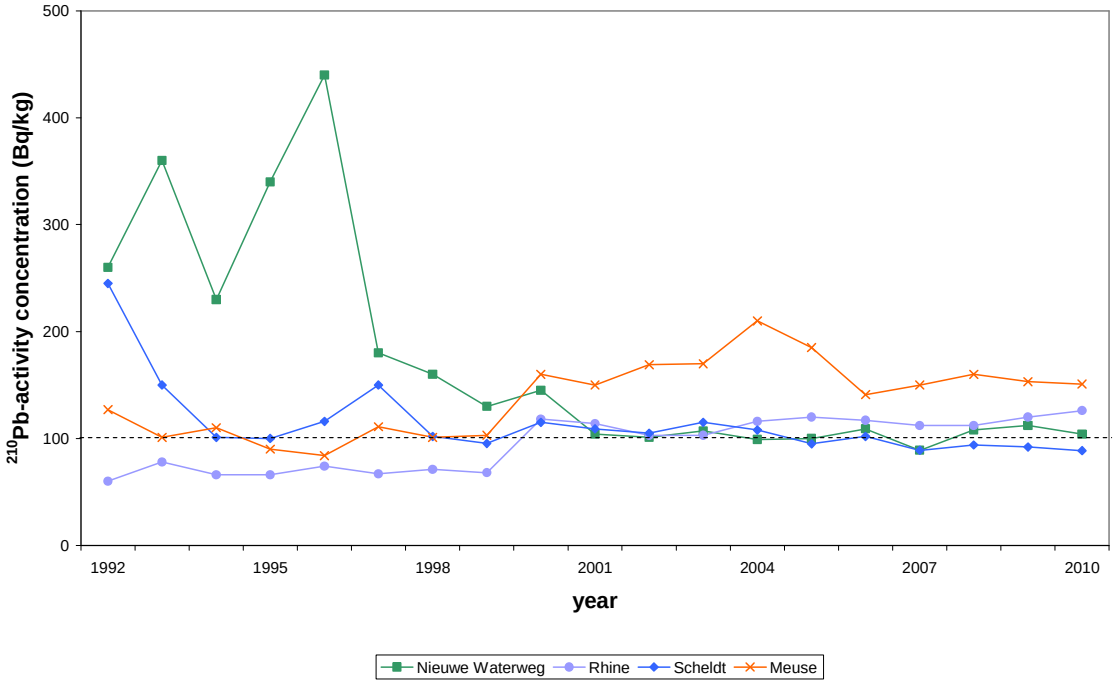


Figure 5.19: Yearly averaged ^{210}Pb-activity concentrations in suspended solids.

5.3 The results for seawater

The results for seawater are presented in Tables A13 and A14 and in Figures 5.20 through 5.31.

Gross α and residual β are indicative parameters [36]. 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 [36]. The yearly averaged gross α-activity concentrations in 2010 were within the range of those in previous years (Figure 5.21).

Residual β shows an apparent change in the trend since 1994 (Figure 5.23). This was caused by a change in measuring technique, which only applies to salt and brackish water [36]. The yearly averaged residual β-activity concentrations in 2010 were within the range of those in previous years (Figure 5.23).

Nuclear power plants discharge the nuclides ^{3}H and ^{137}Cs. Nuclear fuel reprocessing plants discharge the nuclides ^{3}H and ^{90}Sr. Discharges from the nuclear power plants at Doel (Belgium) and Borssele (the 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 [36]. 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 2010 were within the range of those in previous years (Figure 5.25). The yearly averaged ^{90}Sr-concentrations in 2010 were within the range of those in previous years (Figure 5.27).

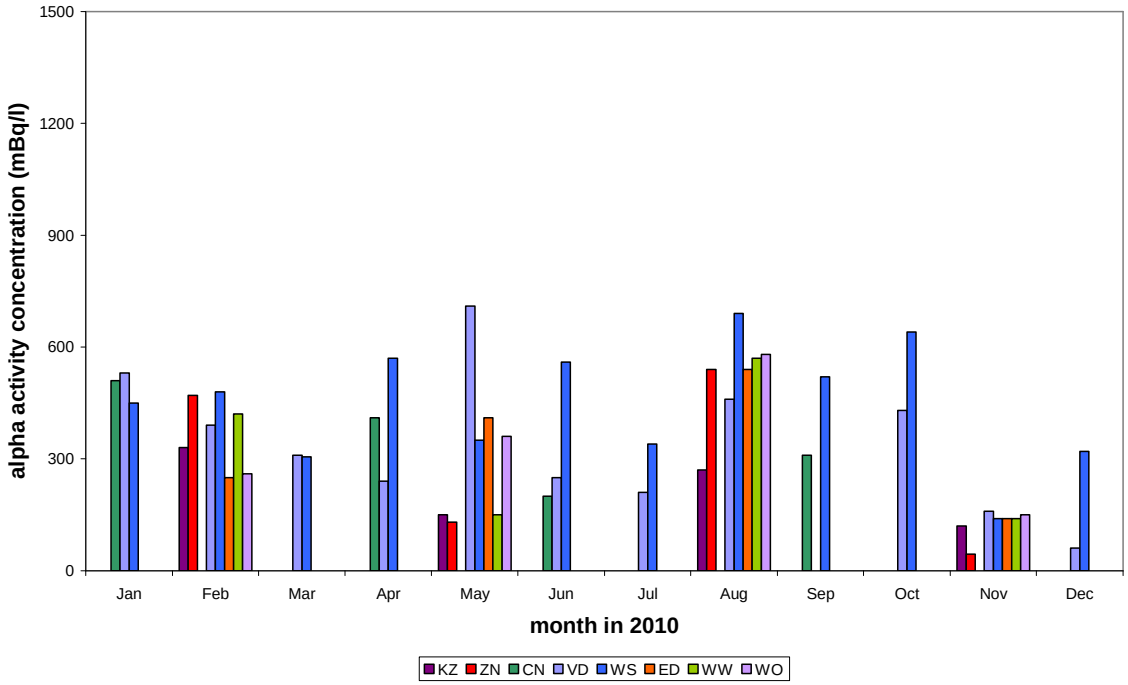


Figure 5.20: The gross α-activity concentration in seawater. The yearly averages for the Coastal area (KZ), Southern North Sea (ZN), Central North Sea (CN), Delta Coastal Waters (VD), Westerscheldt (WS), Eems-Dollard (ED), Wadden Sea West (WW) and Wadden Sea East (WO) were 220, 300, 360, 340, 440, 340, 320 and 340 mBq·L^{-1}, respectively.

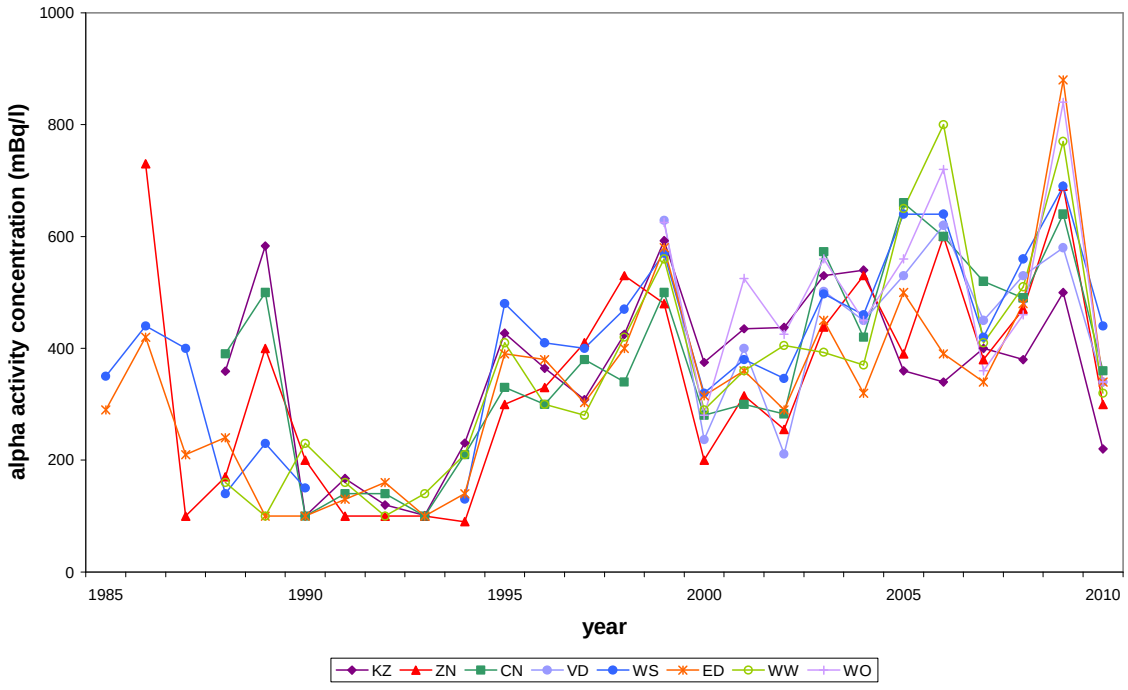


Figure 5.21: Yearly averaged gross α-activity concentrations.

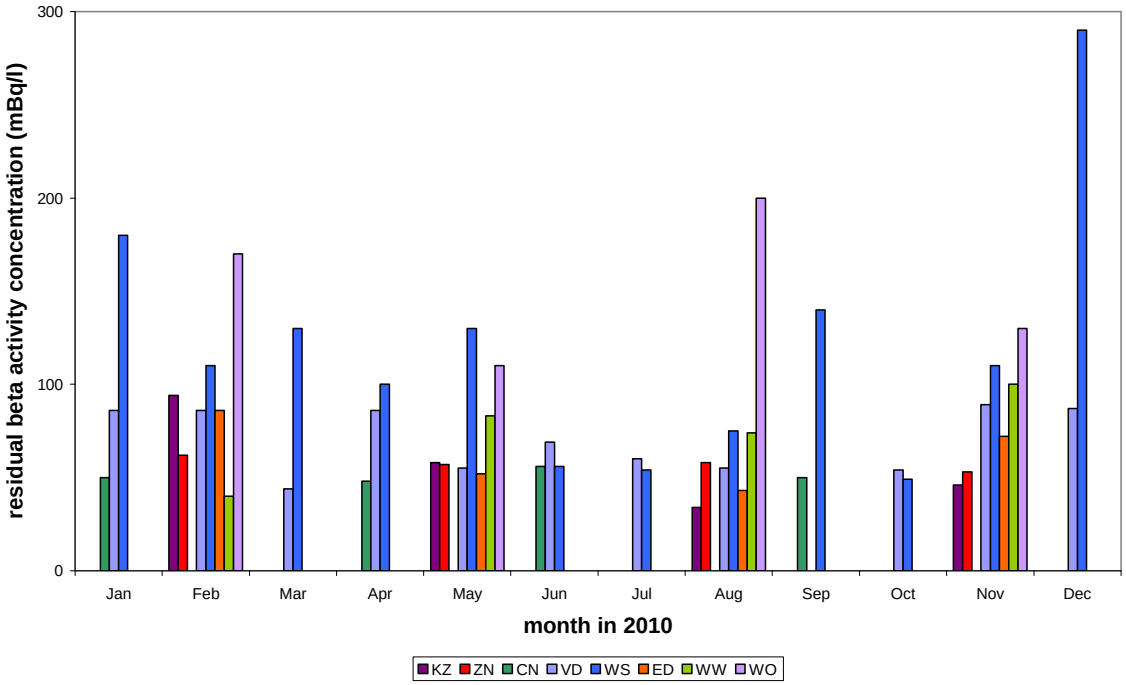


Figure 5.22: The residual β-activity concentration in seawater. The yearly averages for the Coastal area, Southern North Sea, Central North Sea, Delta Coastal Waters, Westerscheldt, Eems-Dollard, Wadden Sea West and Wadden Sea East were 58, 58, 51, 70, 120, 63, 74, and 150 mBq·L^{-1}, respectively.

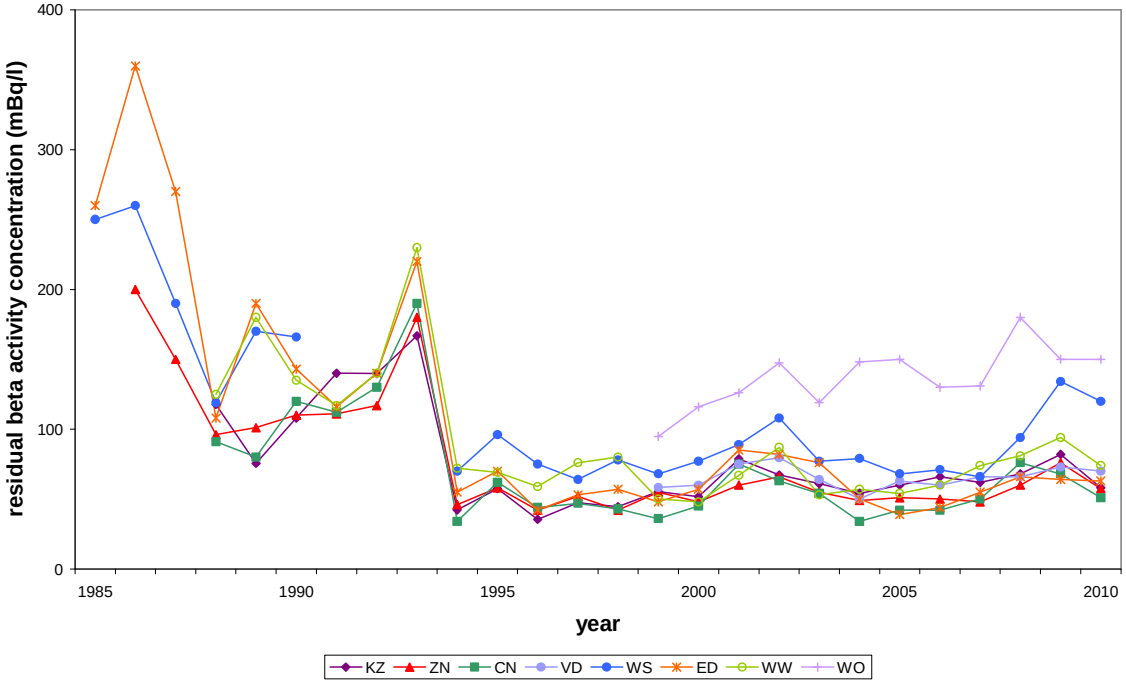


Figure 5.23: Yearly averaged residual β-activity concentrations.

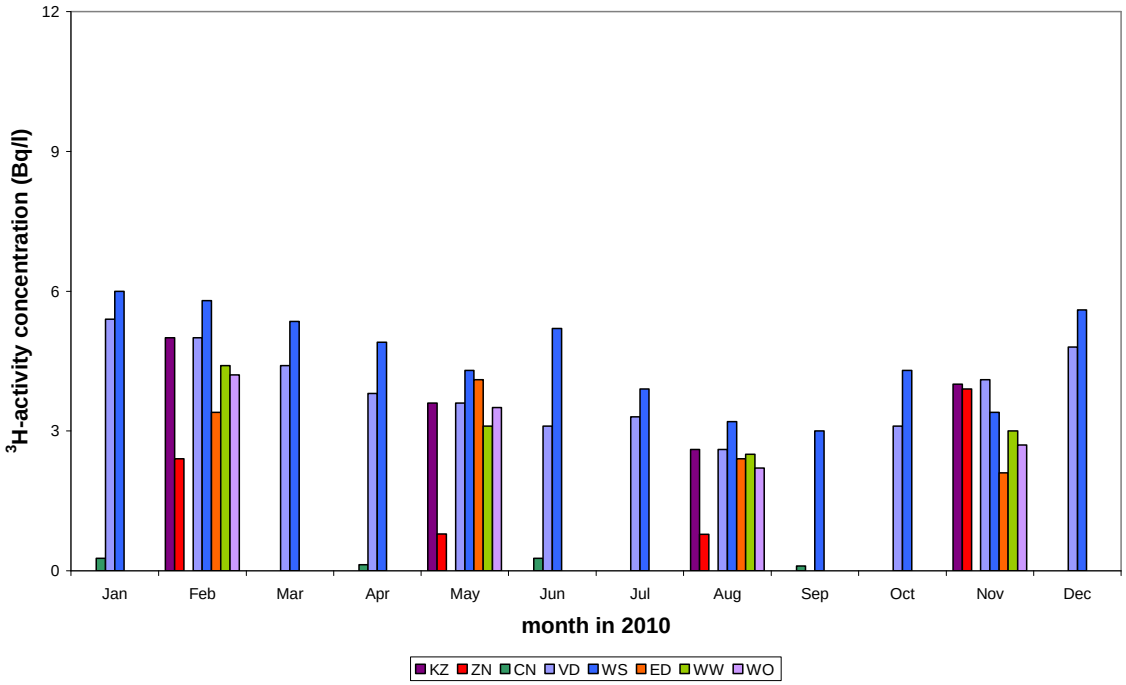


Figure 5.24: The ^{3}H-activity concentration in seawater. The yearly averages for the Coastal area, Southern North Sea, Central North Sea, Delta Coastal Waters, Westerscheldt, Eems-Dollard, Wadden Sea West and Wadden Sea East were 3.8, 2.0, 0.18, 3.9, 4.6, 3.0, 3.2, and 3.2 Bq·L^{-1}, respectively.

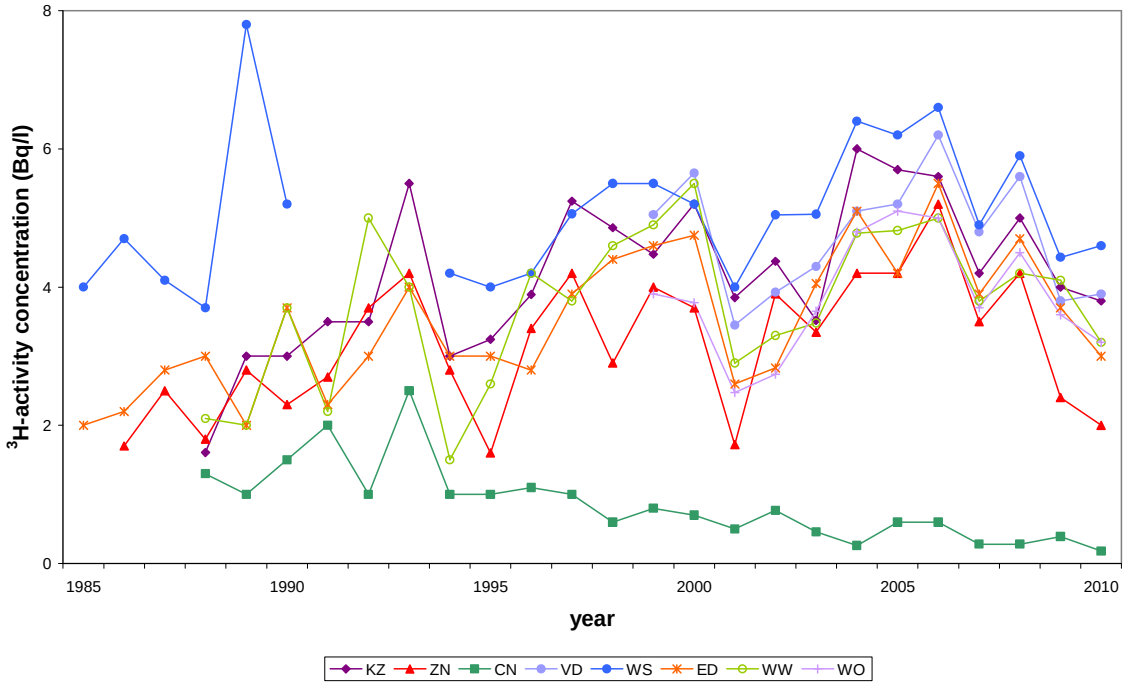


Figure 5.25: Yearly averaged ^{3}H-activity concentrations.

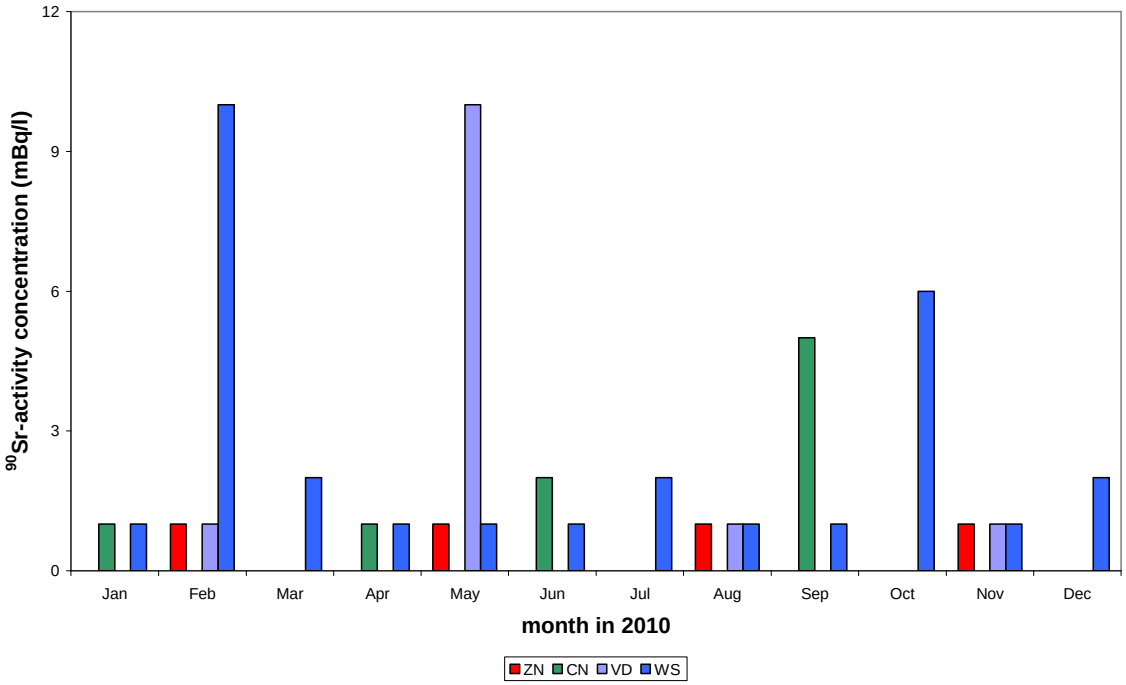


Figure 5.26: The ^{90}Sr-activity concentration in seawater. The yearly averages for the Southern North Sea, Central North Sea, Delta Coastal Waters and Westerscheldt were < 1, 2, < 3, and < 2 mBq·L^{-1}, respectively.

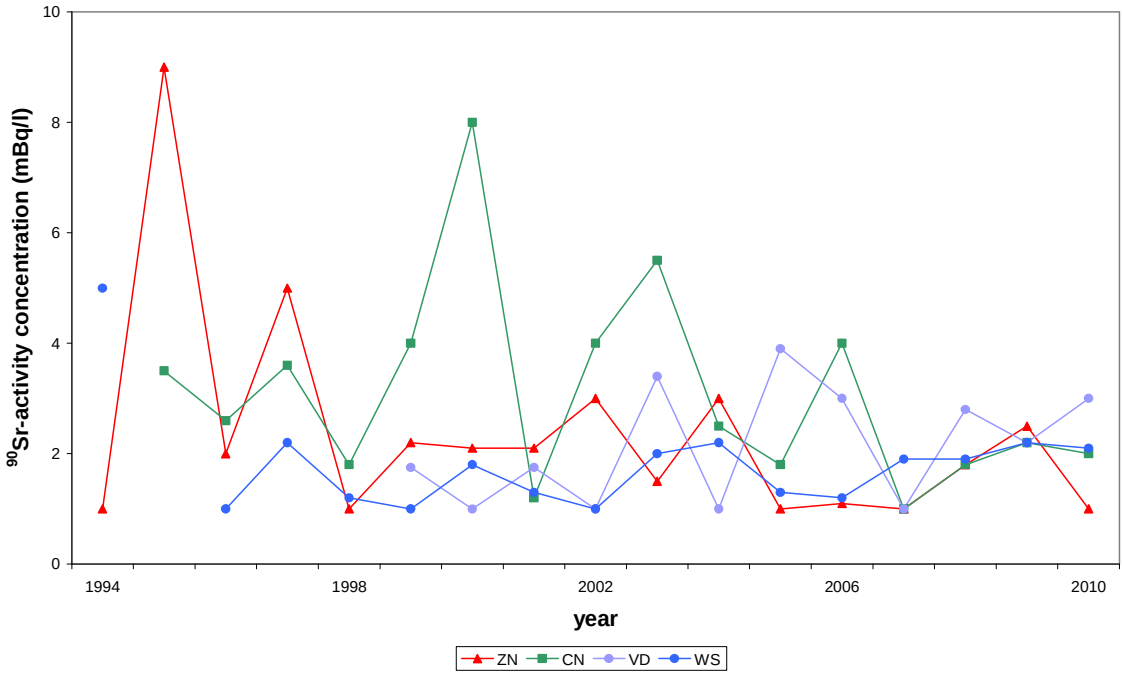


Figure 5.27: Yearly averaged ^{90}Sr-activity concentrations.

Since ^{210}Po is regularly in equilibrium with ^{210}Pb in suspended solids, the Centre for Water Management only reports ^{210}Pb (analogous to surface water). In cases where the gross α value is increased, ^{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 [36]. 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 2010 were within the range of those in previous years (Figure 5.29). The yearly averaged concentrations of ^{210}Pb in 2010 were within the range of those in previous years (Figure 5.31).

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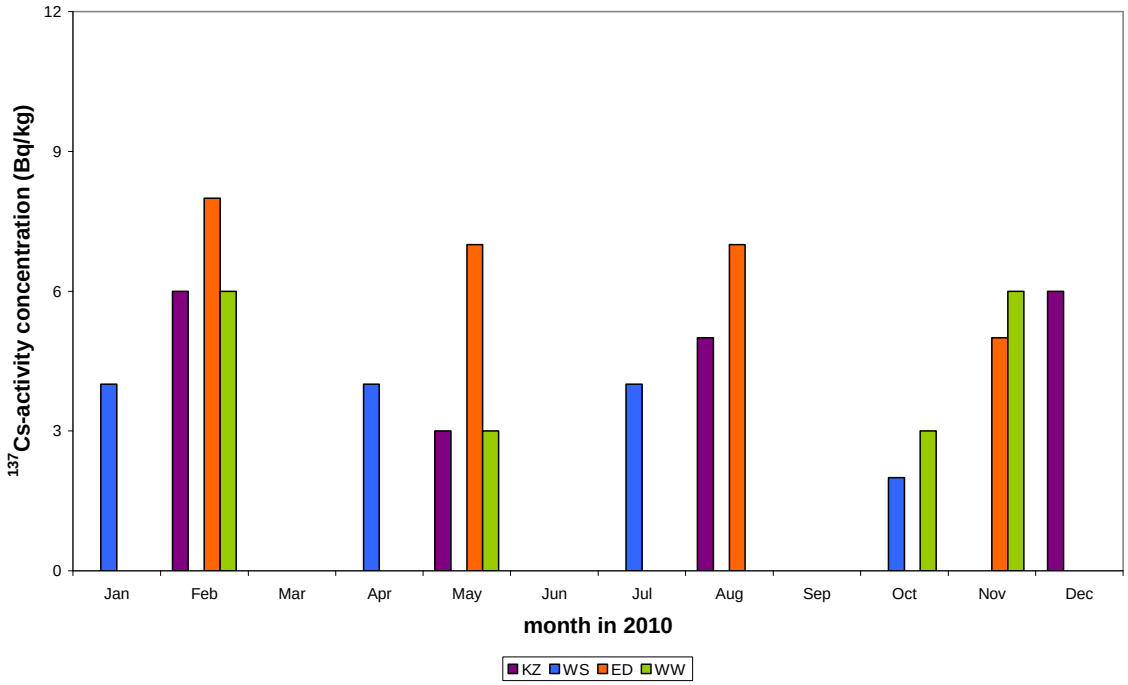

Figure 5.28: The ^{137}Cs-activity concentration in suspended solids in seawater. The yearly averages for the Coastal area, Westerscheldt, Eems-Dollard and Wadden Sea West were 5, 4, 7 and 5 Bq·kg^{-1}, respectively.

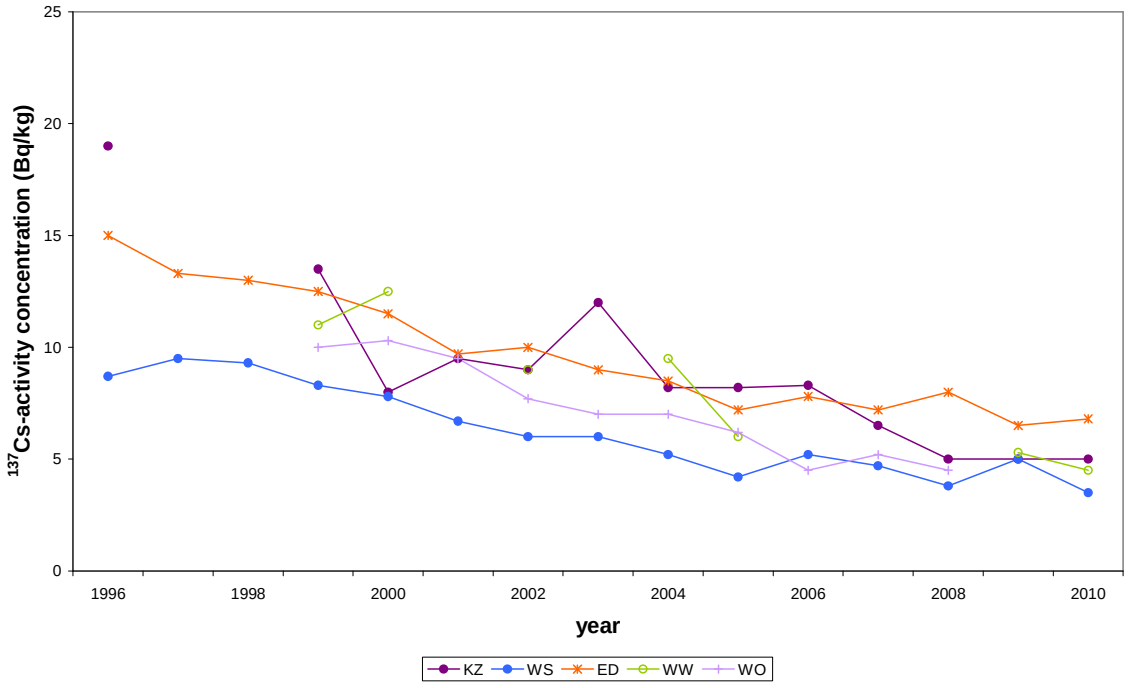

Figure 5.29: Yearly averaged ^{137}Cs-activity concentrations in suspended solids. Since 2009, ^{137}Cs has been determined at Wadden Sea West instead of Wadden Sea East.

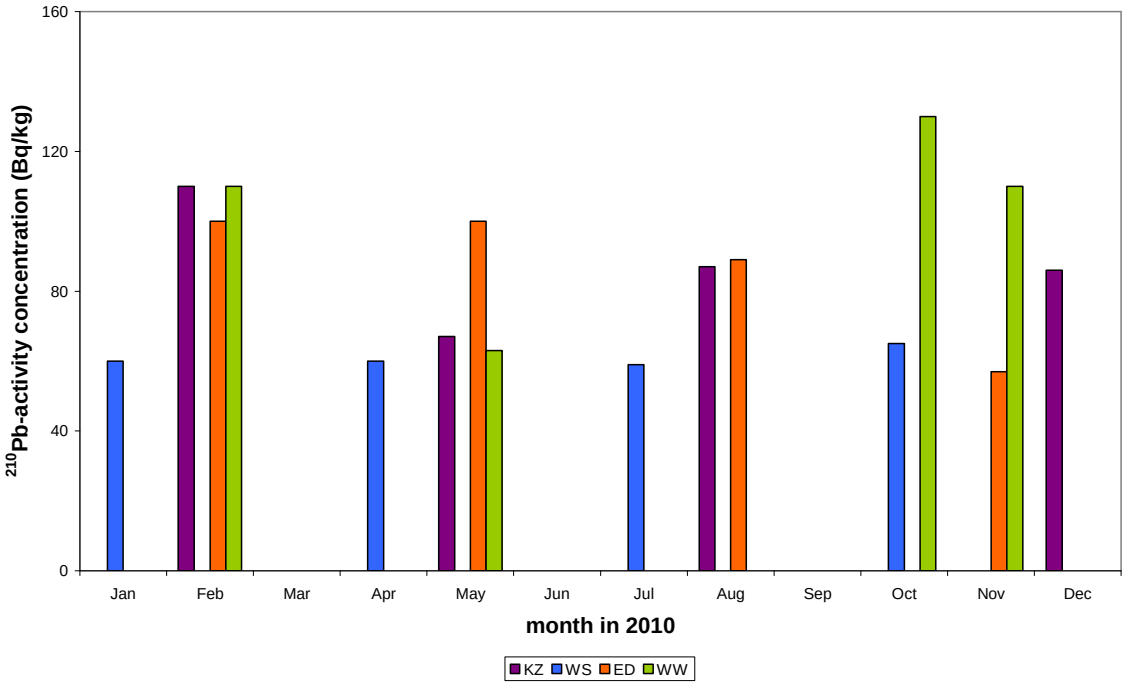

Figure 5.30: The ^{210}Pb-activity concentration in suspended solids in seawater. The yearly averages for the Coastal area, Westerscheldt, Eems-Dollard and Wadden Sea West were 88, 61, 86 and 103 Bq·kg^{-1}, respectively.

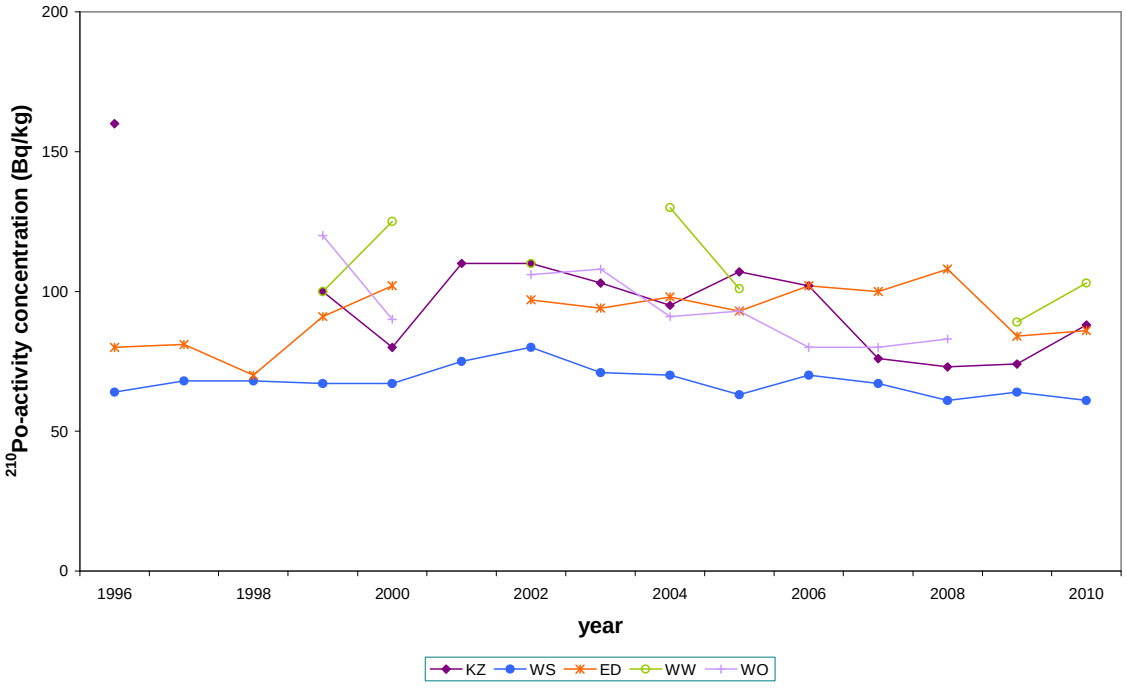

Figure 5.31: Yearly averaged ^{210}Pb-activity concentrations in suspended solids. Since 2009, ^{210}Pb has been determined at Wadden Sea West instead of Wadden Sea East.

6 Water for human consumption

In addition to the Recommendation on the Application of Article 36 of the Euratom Treaty [1], regulations for drinking water are given in Council Directive 98/83/EC [41]. 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, one can assume that the total indicative dose is less than the set limit of 0.1 $mSv \cdot year^{-1}$ [42, 43].

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 once to 26 times per year depending on the volume of water produced. The activity concentrations are averaged for each production station.

The results for 2010 are presented in Table 6.1. For gross α, ^{3}H, gross β and residual β, several hundred analyses were performed at 183 to 201 production stations.

Table 6.1: Drinking water analyses in 2010.

Parameter	**Gross α**	**^{3}H**	**Residual β**	**Gross β**
Average value [(1)]	< 0.1 $Bq \cdot L^{-1}$	< 4.1 $Bq \cdot L^{-1}$	< 0.2 $Bq \cdot L^{-1}$	< 0.2 $Bq \cdot L^{-1}$
No. of all production stations	196	193	183	201
No. of all analyses	374	386	393	431
Maximum value [(2)]	0.3 $Bq \cdot L^{-1}$	22 $Bq \cdot L^{-1}$	< 0.5 $Bq \cdot L^{-1}$	0.5 $Bq \cdot L^{-1}$
No. of production stations [(3)]	1	1	11	1
No. of analyses [(4)]	1	3	111	1

[(1)] Activity concentration averaged over all the production stations.

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

[(3)] Number of production stations with the maximum value.

[(4)] Number of analyses per production station which lead to the maximum value.

In 2010, the gross α-activity concentration averaged per production station exceeded 0.1 $Bq \cdot L^{-1}$ at 2 of the 196 production stations (in 3 of the 374 analyses).

For ^{3}H, gross β and residual β, the results were within the range of those in previous years [5, 44, 45, 46, 47, 48, 49, 50]. Since there was almost no ^{40}K present, there was no difference between average gross β- and residual β-activity concentrations. The gross β-activity concentrations were below 1.0 $Bq \cdot L^{-1}$ and the ^{3}H-activity concentrations were below the set limit of 100 $Bq \cdot L^{-1}$ [41, 43].

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 [51]. The average concentration found was 2.2 $Bq \cdot L^{-1}$ for drinking water produced from groundwater. The difference between this value and those

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 70 NaI-monitors of which 26 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 2010 are presented in Table 7.1. None of the samples exceeded the limit of 370 Bq·kg^{-1} set by the European Union [52].

Table 7.1: Monthly averaged activity concentrations in milk in 2010

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	63	61.4 ± 13.8	< 1.4	< 0.6	< 0.6	< 0.5
February	83	60.6 ± 12.1	< 1.4	< 0.6	< 0.6	< 0.5
March	78	60.0 ± 13.3	< 1.4	< 0.6	< 0.6	< 0.5
April	68	60.3± 13.4	< 1.4	< 0.6	< 0.6	< 0.5
May	91	58.0 ± 9.6	< 1.4	< 0.6	< 0.6	< 0.5
June	65	57.6 ± 14.4	< 1.4	< 0.6	< 0.6	< 0.5
July	67	56.3 ± 12.4	< 1.4	< 0.6	< 0.6	< 0.5
August	68	61.0 ± 13.9	< 1.4	< 0.6	< 0.6	< 0.5
September	76	58.2 ± 11.6	< 1.4	< 0.6	< 0.6	< 0.5
October	58	59.6 ± 13.5	< 1.4	< 0.6	< 0.6	< 0.5
November	99	59.5 ± 12.4	< 1.4	< 0.6	< 0.6	< 0.5
December	60	59.3 ± 14.1	< 1.4	< 0.6	< 0.6	< 0.5
Average	876[(1)]	59.3 ± 12.9	< 1.4	< 0.6	< 0.6	< 0.5

[(1)] Yearly total.

RIKILT Wageningen UR analysed 52 milk samples for ^{90}Sr in 2010. The samples were collected across the Netherlands. The ^{90}Sr-activity concentration was below the detection limit (5 Bq·L^{-1}) in all samples taken, so none of the samples exceeded the set limit of 125 Bq·kg^{-1} [53].

8 Food

The Netherlands Food and Consumer Product Safety Authority performs measurements on finished products from retail shops, 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 [54, 55]. 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 2010, 295 samples were taken from retail shops, auctions and distribution centres, including 60 samples of honey [56]. Though honey is not considered to be part of the mixed diet, samples are taken each year because it is a product that is known to contain possible higher levels of radioactivity.

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, and honey. The 2010 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) [52].

In 2010, RIKILT Wageningen UR also measured radioactivity in food products as part of a monitoring program for export certification, especially meat and eggs. Samples were taken every two weeks and measurements were carried out according to standard procedures. The 2010 results are presented in Table 8.2. A total of 1131 samples were analysed and 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, radioactivity was measured in 434 food products for individual screening purposes via the National Monitoring Network Radioactivity in Food, especially fruit, fruit products and vegetables (data not shown).

In 2010, RIKILT Wageningen UR analysed 12 mixed diets for ^{90}Sr content. The In all meals, ^{90}Sr concentration was below the detection limit of 10 $Bq \cdot kg^{-1}$, which is well below the set limit of 750 $Bq \cdot kg^{-1}$ [53].

8.1 Honey

In total 60 samples of honey were analysed by the Netherlands Food and Consumer Product Safety Authority [56]. The activity (sum of ^{134}Cs and ^{137}Cs) was found to be below the set limit of 600 $Bq \cdot kg^{-1}$ [52]. Only eight samples of honey contained ^{137}Cs and the activity varied from 15 up to 209 $Bq \cdot kg^{-1}$.

8.2 Vegetables

In the product group "Vegetables", which was analysed by RIKILT Wageningen UR, the seven samples that contained ^{137}Cs were wild mushrooms. The activity varied from 16.4 up to 136 $Bq \cdot kg^{-1}$. In total, 12 samples of wild mushrooms were analysed and the radiocesium activity (sum of ^{134}Cs and ^{137}Cs) was below the set limit of 600 $Bq \cdot kg^{-1}$ in all samples.

8.3 Game and poultry

In the product group 'Game and poultry', which was analysed by RIKILT Wageningen UR, all 21 samples that contained ^{137}Cs were game. The activity varied from 18.0 up to 300 Bq·kg^{-1}. The radiocesium activity (sum of ^{134}Cs and ^{137}Cs) was below the set limit of 600 Bq·kg^{-1} [52].

Table 8.1: Results of 2010 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) Bq·kg^{-1}	^{137}Cs (1) Bq·kg^{-1}
Grain and grain products	27	< 3.8 (0)	< 3.0 (0)
Vegetables	57	< 3.8 (0)	< 3.0 (0)
Fruit and fruit products	5	< 3.8 (0)	< 3.0 (0)
Milk and dairy products	44	< 3.8 (0)	< 3.0 (0)
Meat and meat products	26	< 3.8 (0)	< 3.0 (0)
Game and poultry	18	< 3.8 (0)	< 3.0 (0)
Salads	25	< 3.8 (0)	< 3.0 (0)
Oil and butter	33	< 3.8 (0)	< 3.0 (0)
Honey	60	< 3.8 (0)	15 – 209 (8)

(1) Number of positive samples between brackets.

Table 8.2: Results of 2010 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	64	< 0.6 (0)	16.4-136 (7)
Meat and meat products	511	< 0.6 (0)	< 0.5 (0)
Game and poultry	197	< 0.6 (0)	18.0-300 (21)
Eggs	115	< 0.6 (0)	< 0.5 (0)
Fish and seafood products	244	< 0.6 (0)	< 0.5 (0)

(1) Number of positive samples between 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 presented [57] 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 is reported elsewhere [58]. The 2010 monitoring program is shown 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 in the vicinity of the nuclear power plant at Borssele in 2010. 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]
Sand	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.

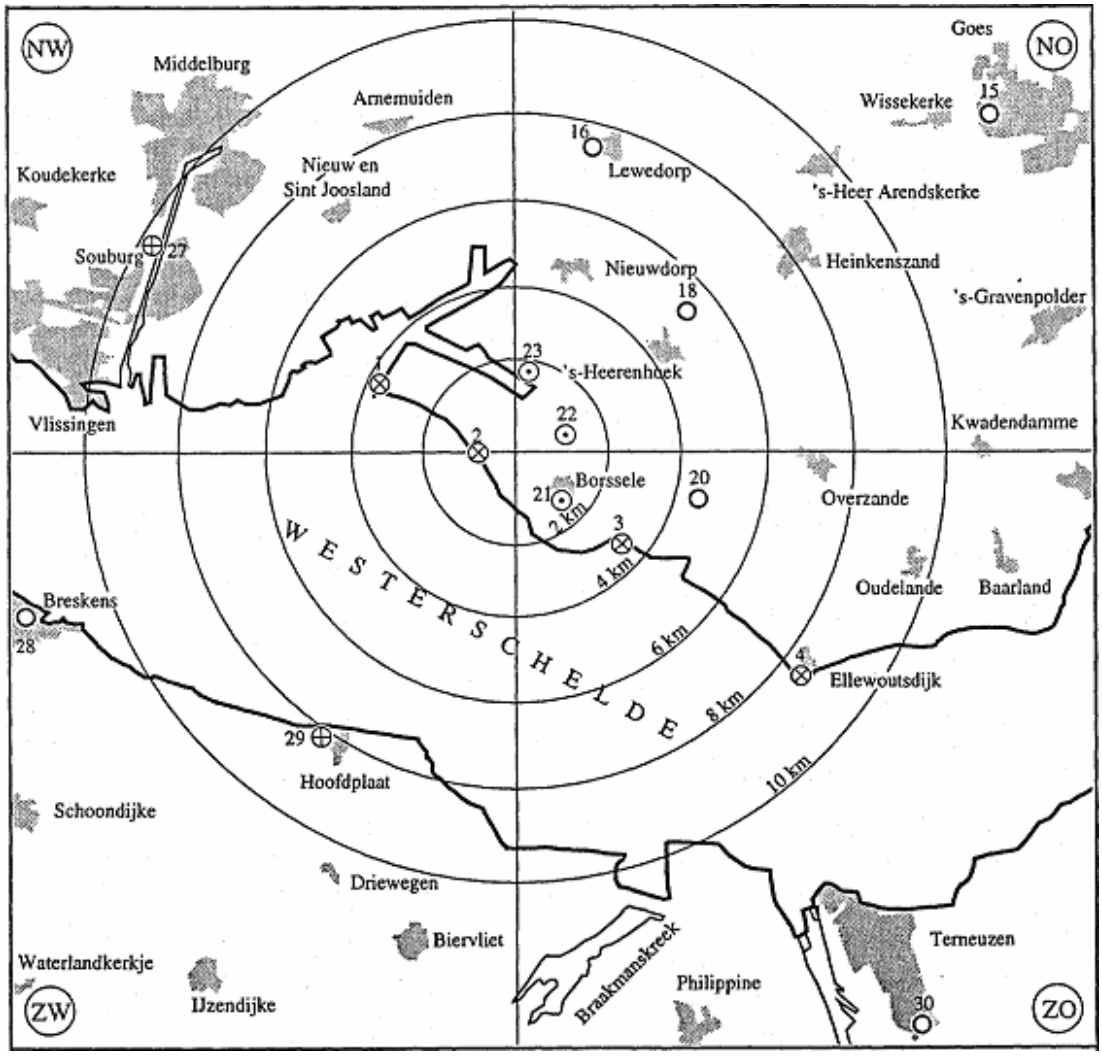

Figure 9.1: Overview of monitoring locations for the monitoring program cconducted by NRG in the vicinity of the nuclear power plant at Borssele. The numbers given in Table 9.1 correspond with the locations on the map.

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 dust thickness on the filters, gross α-activity concentrations in air dust should be regarded as indicative values [6]. The period between sampling and analysis was at least five days, which is long compared to 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 2010 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.

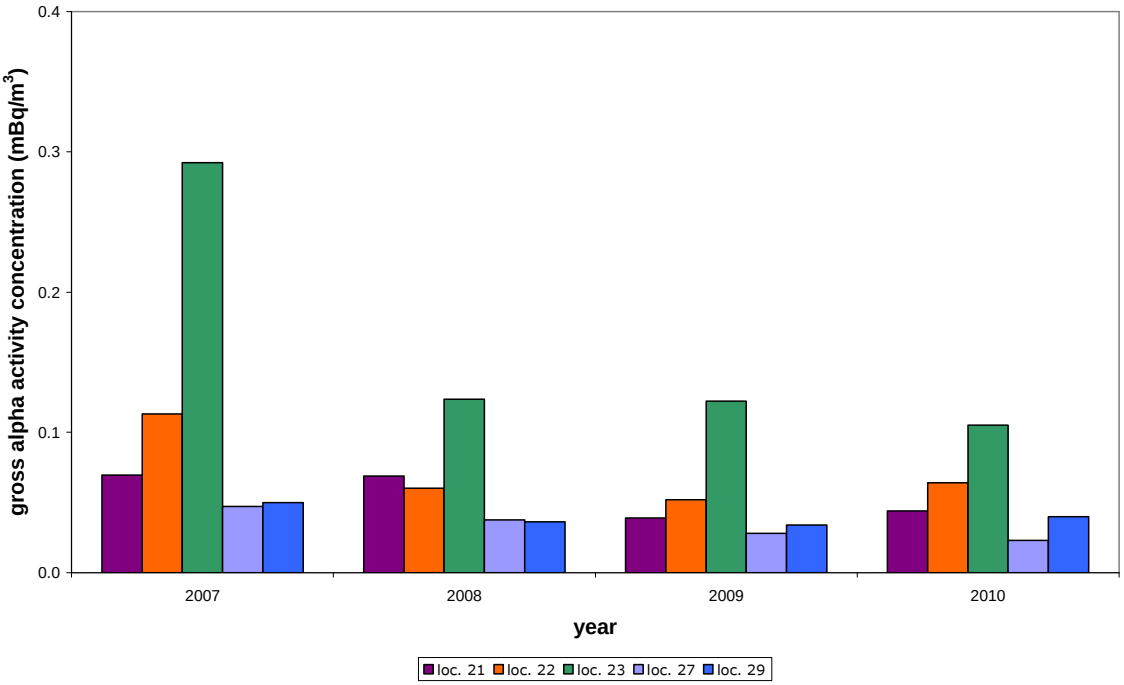

Figure 9.2: Yearly averaged gross α-activity concentrations in air dust at five locations in the vicinity of Borssele (see Figure 9.1).

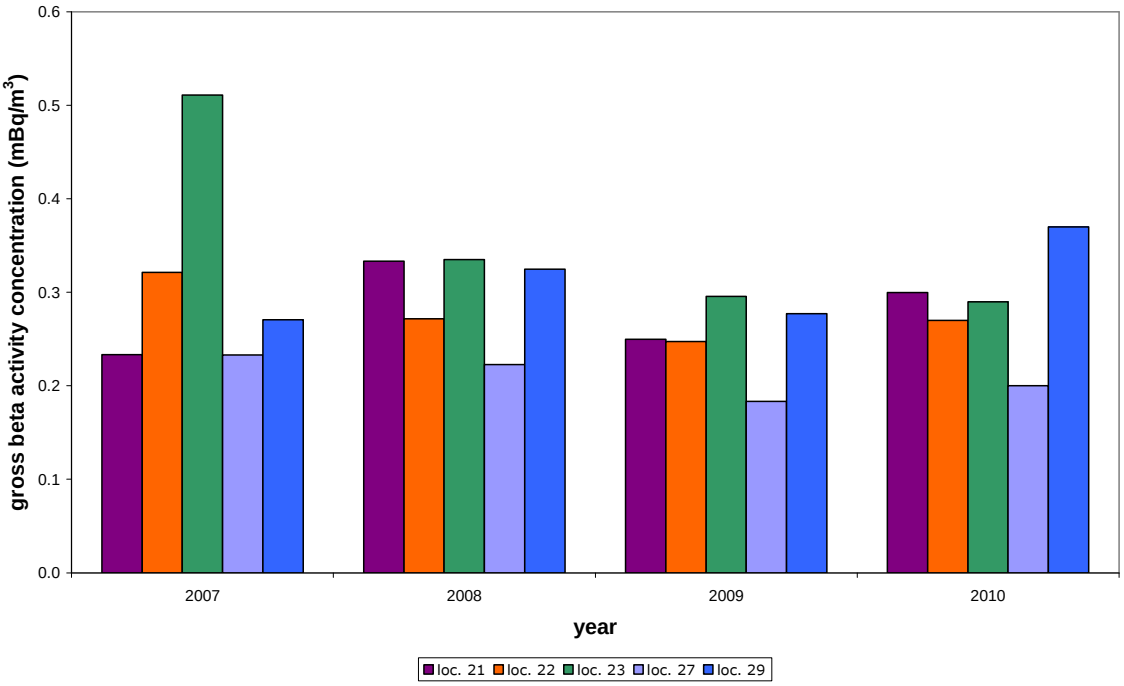

Figure 9.3: Yearly averaged gross β-activity concentrations in air dust at five locations in the vicinity of Borssele (see Figure 9.1).

9.2 Soil

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 2010, 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 [48, 49, 50].

9.3 Water

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

In 2010, the yearly averages of the residual β- and ^{3}H-activity concentrations in water and gross β-activity concentrations in suspended solids were within the range of the results from previous years, as illustrated in Figures 9.4, 9.5 and 9.6.

The results for the nuclides considered in the gammaspectroscopic analysis of seaweed and sediment are given in Tables A23 and A24.

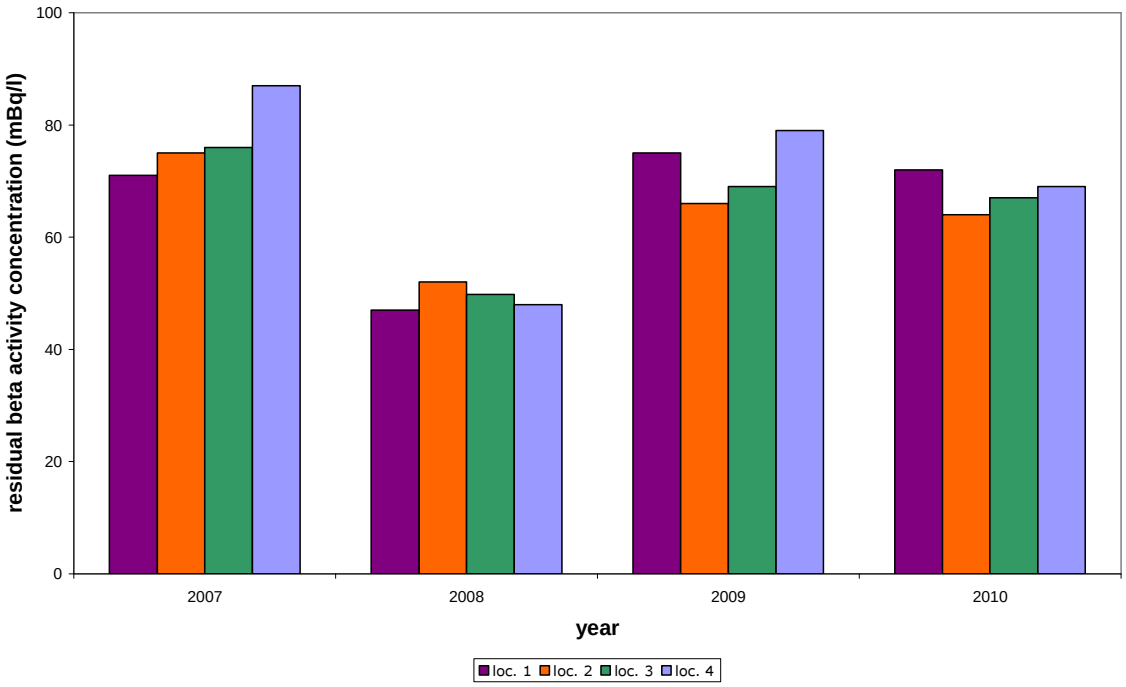

Figure 9.4: Yearly averaged residual β-activity concentrations in water from the Westerscheldt at four locations in the vicinity of Borssele (see Figure 9.1).

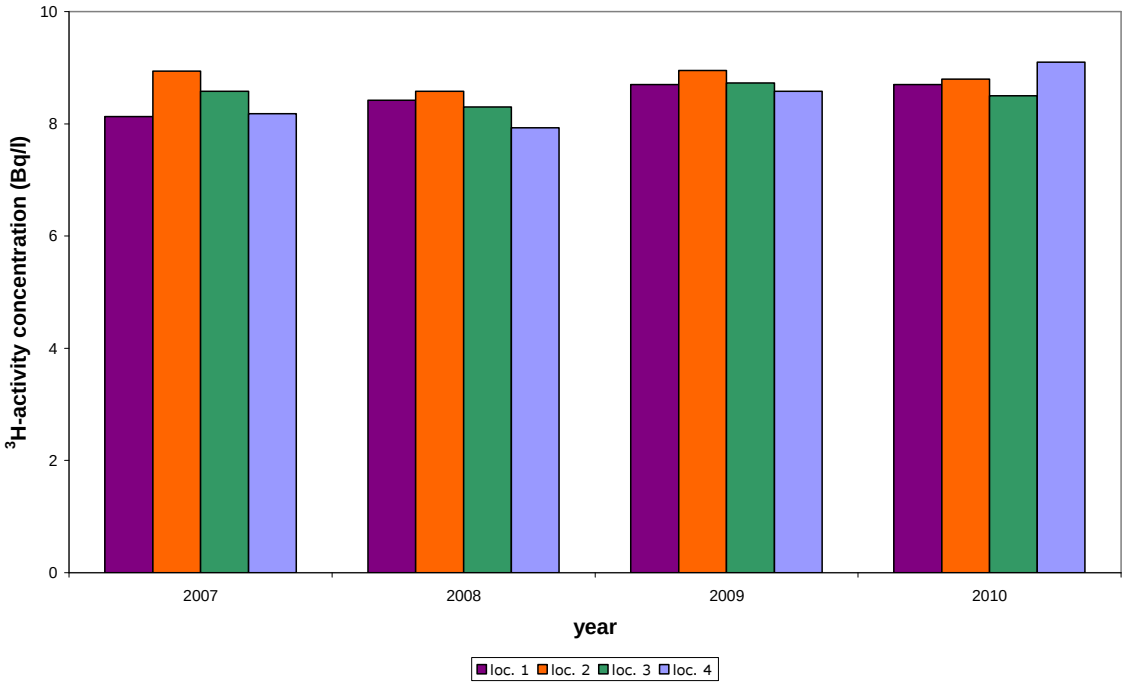

Figure 9.5: Yearly averaged ^{3}H-activity concentrations in water from the Westerscheldt at four locations in the vicinity of Borssele (see Figure 9.1).

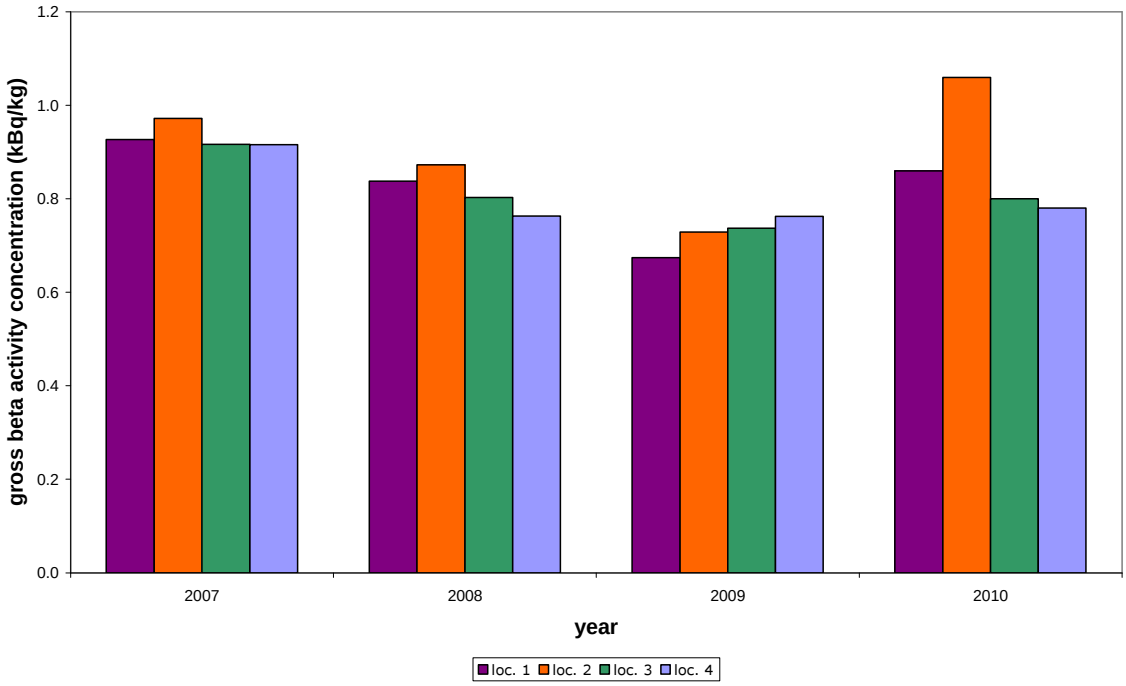

Figure 9.6: Yearly averaged gross β-activity concentrations in suspended solids from the Westerscheldt at four locations in the vicinity of Borssele (see Figure 9.1).

10 Conclusions

The yearly total activity in deposition from ^{210}Po (33.2 Bq·m^{-2}) was the highest since 1993 and approximately the same level as in 2009.

In surface waters, the yearly averaged gross α-activity concentration exceeded the target value of 100 mBq·L^{-1} in the Noordzeekanaal (180 mBq·L^{-1}; 9 out of 13 samples above target value) and Scheldt (300 mBq·L^{-1}; 12 out of 13 samples above target value). The concentrations are within the range of those in previous years.

The yearly averaged ^{3}H-activity concentration exceeded the target value of 10 Bq·L^{-1} in the Scheldt (11.7 Bq·L^{-1}; 4 out of 6 samples above target value) and the Meuse (20.0 Bq·L^{-1}; 10 out of 13 samples above target value). The concentrations are within the range of those in previous years.

The yearly averaged ^{226}Ra-activity concentration exceeded the target value of 5 mBq·L^{-1} in the Scheldt (15 mBq·L^{-1}; 6 out of 6 samples above target value). The concentration is within the range of those in previous years.

The yearly averaged ^{131}I-activity concentration in the Noordzeekanaal exceeded the target value, and was higher than those in previous years (29 Bq·kg^{-1}; 5 out of 7 samples above target value).

The yearly averaged ^{210}Pb-activity concentration in suspended solids exceeded the target value of 100 Bq·kg^{-1} in the Nieuwe Waterweg (104 Bq·kg^{-1}; 3 out of 6 samples above target value), Rhine (126 Bq·kg^{-1}; 7 out of 7 samples above target value) and Meuse (151 Bq·kg^{-1}; 6 out of 7 samples above target value). The concentrations are within the range of those in previous years.

The gross α-activity concentration in drinking water averaged per production station exceeded the screening value (0.1 Bq·L^{-1}) at 2 of the 196 production stations (in 3 of the 374 analyses).

The results of all other radioactivity measurements were within the range of those in previous years. In 2010, the Netherlands complied with the Euratom recommendations on annually measuring radioactivity in the environment and in food.

Appendix A - Result Tables

Table A1: Weekly averaged gross α- and gross β-activity concentrations in air dust sampled with a High Volume Sampler (HVS) at RIVM in 2010.

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	0.039	0.64 ± 0.05	27	0.037	0.45 ± 0.05
2	0.030	0.79 ± 0.09	28	0.046	0.58 ± 0.06
3	0.024	0.44 ± 0.05	29	0.043	0.41 ± 0.04
4	0.064	1.01 ± 0.08	30	0.016	0.25 ± 0.03
5	0.022	0.25 ± 0.03	31	0.028	0.27 ± 0.03
6	0.043	0.89 ± 0.07	32	0.020	0.27 ± 0.03
7	0.035	0.87 ± 0.09	33	0.029	0.32 ± 0.03
8	0.037	0.27 ± 0.03	34	0.015	0.24 ± 0.03
9	0.013	0.23 ± 0.03	35	0.014	0.26 ± 0.03
10	0.017	0.33 ± 0.04	36 [3]	0.025	0.51 ± 0.06
11	0.037	0.35 ± 0.04	37	0.028	0.40 ± 0.04
12	0.034	0.55 ± 0.06	38	0.035	0.64 ± 0.07
13	0.020	0.24 ± 0.03	39	0.026	0.41 ± 0.04
14	0.027	0.38 ± 0.04	40	0.040	0.68 ± 0.07
15	0.039	0.50 ± 0.05	41	0.050	0.98 ± 0.11
16	0.027	0.31 ± 0.03	42	0.017	0.28 ± 0.03
17	0.033	0.42 ± 0.05	43	0.023	0.36 ± 0.04
18	0.030	0.39 ± 0.04	44	0.040	0.70 ± 0.08
19	0.010	0.24 ± 0.03	45	0.017	0.23 ± 0.03
20	0.028	0.32 ± 0.04	46	0.020	0.26 ± 0.02
21	0.024	0.29 ± 0.03	47	0.016	0.38 ± 0.04
22	0.020	0.33 ± 0.04	48	0.043	0.75 ± 0.08
23 [3]	0.025	0.46 ± 0.05	49	0.031	0.38 ± 0.04
24	0.024	0.32 ± 0.04	50 [3]	0.016	0.24 ± 0.03
25	0.019	0.33 ± 0.04	51 [4]	0.023	0.38 ± 0.04
26	0.049	0.49 ± 0.05	52	0.043	0.88 ± 0.08
Average				0.029	0.445 ± 0.007 [5]
SD [6]				0.011	0.2

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

[2] Values are indicative due to large uncertainties caused by variations in dust thickness on the filters [6].

[3] Sampling did not occur during part of the week (varying from 0.4 to 2.8 days) due to problems with the High Volume Sampler.

[4] Sampling occurred with a lower flow (about one-third of regular flow) on one day due to problems with the High Volume Sampler.

[5] 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.

[6] 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 a HVS at RIVM in 2010.
Between 2000 and July 2009, the detection limits were higher than before 2000 [59] due to a different detector set-up. Measurements were carried out on a coaxial detector with a 10 days delay between sampling and start of measurement and a sample volume of about 50,000 m^3. The detector set up was changed 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.

Nuclide	**Detection limit µBq·m^{-3}**
^{7}Be	3.9
^{22}Na	0.8
^{60}Co	0.7
^{131}I	4.0 (1)
^{137}Cs	0.7
^{210}Pb	7.7

(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 coaxial detector.

Table A3: Weekly averaged ^{7}Be-, ^{137}Cs- and ^{210}Pb-activity concentrations in air dust sampled with a HVS at RIVM in 2010.

Week number	Period	^{7}Be µBq·m^{-3}	^{137}Cs µBq·m^{-3}	^{210}Pb µBq·m^{-3}
1	31/12-08/01	2050 ± 150	< 0.8	630 ± 50
2	08/01-15/01	2300 ± 200	0.97 ± 0.10	840 ± 80
3	15/01-22/01	1480 ± 150	0.63 ± 0.13	530 ± 50
4	22/01-29/01	4000 ± 300	1.3 ± 0.2	1020 ± 80
5	29/01-05/02	2500 ± 200	< 0.5	210 ± 20
6	05/02-12/02	3500 ± 300	0.79 ± 0.14	940 ± 70
7	12/02-19/02	2800 ± 300	0.89 ± 0.08	1050 ± 100
8	19/02-26/02	2300 ± 200	< 0.5	270 ± 30
9	26/02-05/03	2800 ± 300	< 0.5	181 ± 18
10	05/03-12/03	3500 ± 300	0.66 ± 0.12	260 ± 30
11	12/03-19/03	3300 ± 300	< 0.5	310 ± 30
12	19/03-26/03	4600 ± 400	< 0.7	450 ± 50
13	26/03-02/04	3400 ± 300	< 0.5	165 ± 17
14	02/04-09/04	4500 ± 400	< 0.6	290 ± 30
15	09/04-16/04	3500 ± 300	1.01 ± 0.15	450 ± 40
16	16/04-23/04	3800 ± 400	< 0.8	220 ± 20
17	23/04-29/04	5100 ± 500	0.72 ± 0.15	360 ± 40
18	29/04-07/05	5200 ± 500	< 0.6	290 ± 30
19	07/05-14/05	3700 ± 400	< 0.4	179 ± 18
20	14/05-21/05	4100 ± 400	< 0.5	260 ± 30
21	21/05-28/05	3600 ± 400	0.48 ± 0.10	240 ± 20
22	28/05-04/06	3900 ± 400	< 0.5	280 ± 30
23 (1)	04/06-08/06	5600 ± 500	< 0.8	340 ± 30
24	11/06-18/06	4400 ± 400	0.33 ± 0.09	210 ± 20
25	18/06-25/06	3600 ± 400	< 0.4	250 ± 30
26	25/06-02/07	5200 ± 500	0.68 ± 0.13	430 ± 40

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	02/07-09/07	4200 ± 400	0.44 ± 0.12	420 ± 40
28	09/07-16/07	6000 ± 600	< 0.6	500 ± 50
29	16/07-23/07	5400 ± 500	< 0.5	310 ± 30
30	23/07-30/07	2600 ± 300	< 0.5	210 ± 20
31	30/07-06/08	2100 ± 200	< 0.4	230 ± 20
32	06/08-13/08	2500 ± 200	< 0.4	220 ± 20
33	13/08-20/08	3500 ± 300	< 0.4	260 ± 30
34	20/08-27/08	2500 ± 200	< 0.4	200 ± 20
35	27/08-03/09	3200 ± 300	< 0.4	182 ± 18
36 (1)	03/09-09/09	5200 ± 500	< 0.6	450 ± 40
37	10/09-17/09	3800 ± 400	< 0.5	340 ± 30
38	17/09-24/09	4500 ± 400	< 0.5	690 ± 70
39	24/09-01/10	3300 ± 300	0.56 ± 0.13	400 ± 40
40	01/10-08/10	3400 ± 300	0.35 ± 0.10	740 ± 70
41	08/10-15/10	5500 ± 500	0.53 ± 0.14	950 ± 90
42	15/10-22/10	2900 ± 300	< 0.5	230 ± 20
43	22/10-29/10	3300 ± 300	< 0.4	330 ± 30
44	29/10-05/11	5400 ± 500	< 0.5	650 ± 70
45	05/11-12/11	2400 ± 200	< 0.6	181 ± 18
46	12/11-19/11	2400 ± 200	< 0.9	193 ± 15
47	19/11-26/11	2300 ± 200	0.33 ± 0.11	360 ± 40
48	26/11-03/12	3900 ± 400	0.61 ± 0.13	730 ± 70
49	03/12-10/12	2100 ± 200	0.49 ± 0.13	390 ± 40
50 (1)	10/12-17/12	2700 ± 300	< 0.7	200 ± 20
51 (2)	17/12-24/12	1770 ± 170	0.49 ± 0.14	380 ± 40
52	24/12-31/12	3200 ± 300	0.53 ± 0.16	950 ± 80
Average		3550 ± 50 (3)	0.64 ± 0.03 (3, 4)	411 ± 6 (3)
SD (5)		1100	0.2	200

(1) Sampling did not occur during part of the week (varying from 0.4 to 2.8 days) due to problems with the High Volume Sampler.

(2) Sampling occurred with a lower flow (about one-third of regular flow) on one day due to problems with the High Volume Sampler.

(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) The detection limits are omitted in the calculation of the averages.

(5) 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 2010.

Month	Precipitation mm	^{3}H (1) Bq·m^{-2}	Gross α Bq·m^{-2}	Gross β Bq·m^{-2}
January	37.3	< 60	1.9 ± 0.2	6.3 ± 0.5
February	71.0	< 110	0.71 ± 0.17	3.0 ± 0.2
March	78.9	< 120	1.7 ± 0.3	4.8 ± 0.4
April	17.4	30 ± 9	2.4 ± 0.3	4.0 ± 0.3
May	86.0	160 ± 50	5.3 ± 0.5	9.4 ± 0.7
June	19.6	38 ± 9	6.3 ± 0.6	11.4 ± 0.9
July	74.6	< 110	7.4 ± 0.7	12.2 ± 1.0
August	174.1	< 300	2.7 ± 0.3	10.2 ± 0.8
September	98.3	< 140	2.7 ± 0.3	11.8 ± 0.9
October	79.7	< 130	2.1 ± 0.3	5.7 ± 0.5
November	82.3	< 130	2.2 ± 0.3	7.0 ± 0.6
December	48.5	< 80	1.3 ± 0.2	3.8 ± 0.3
Total	867.5	-	36.7 ± 1.3 (2)	90 ± 2 (2)
Lower limit (3)	-	180		
Upper limit (3)	-	1400		

(1) The detection limit (Bq·m^{-2}) is mainly dependent on the amount of precipitation since the detection limit of the counting sample itself is more or less constant (1.5-1.6 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: The 1993-2010 yearly totals for long-lived gross α-, gross β- and ^{3}H-activity in deposition. 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	1310 ± 30	54.3 ± 0.7	87.8 ± 0.8
1994	1039	1210 ± 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	1160 ± 60	22.0 - 25.0	87 ± 3
1998	1238	1090 - 2190	31.1 ± 1.3	106 ± 3
1999	916	1420 - 1900	25.5 ± 1.1	84 ± 2
2000	935	260 - 1440	35.2 ± 1.3	104 ± 3
2001	1053	0 - 2420	23.9 ± 1	97 ± 3
2002	965	300 - 1710	20.6 ± 0.9	97 ± 2
2003	605	260 - 1080	13.6 - 16.7	70.0 ± 1.8
2004	875	0 - 1600	14.3 - 17.1	73.5 ± 1.8
2005	856	0 - 1530	17.6 ± 1.0	88 ± 2
2006	854	280 - 1820	25.7 ± 1.5	98 ± 3
2007	984	335 - 1600	24.4 ± 1.2	85 ± 2
2008	908	102 - 1550	39.4 ± 1.5	106 ± 3
2009	794	0 - 1330	36.9 ± 1.3	95 ± 2
2010	868	180 - 1400	36.7 ± 1.3	90 ± 2

(1) Uncertainties are given as 1σ.

(2) A lower and upper limit is given as defined in Appendix B.

Table A6: Monthly deposited ^{210}Po-activity [(1)] sampled at RIVM in 2010.

Month	^{210}Po Bq·m^{-2}
January	1.37 ± 0.09
February	0.65 ± 0.06
March	0.99 ± 0.09
April	1.46 ± 0.12
May	5.3 ± 0.3
June	6.3 ± 0.3
July	5.2 ± 0.4
August	3.1 ± 0.3
September	1.96 ± 0.19
October	1.39 ± 0.10
November	1.86 ± 0.14
December	3.7 ± 0.2
Total	33.2 ± 0.8 [(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: The 1993-2010 yearly totals for ^{7}Be, ^{137}Cs, ^{210}Pb- and ^{210}Po-activity in deposition. Either the yearly total with uncertainty [(1)] or the lower and upper limits [(2)] of the 68% confidence range are given.

Year	^{7}Be [(3)] Bq·m^{-2}	^{137}Cs [(3)] Bq·m^{-2}	^{210}Pb [(3)] Bq·m^{-2}	^{210}Pb [(4)] Bq·m^{-2}	^{210}Po [(4)] Bq·m^{-2}
1993	1090 ± 20	0.50 - 0.76	105 ± 2	78 ± 3	7.2 ± 0.5
1994	1320 ± 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	1090 ± 30	0.11 - 0.69	65 - 69	80 ± 4	0 - 10.2
1998	1840 ± 50	0.56 - 0.85	162 ± 4	91 ± 4	3.0 - 15.1
1999	1580 ± 30	1.16 - 1.99	158 ± 4	- [(6)]	0.7 - 5.3
2000	1490 ± 30	0 - 4.82	177 ± 6	-	0.6 - 8.0
2001	1480 ± 30	0 - 4.50	83 - 104	-	6.5 - 9.4
2002	1510 ± 30	0 - 5.22	119 - 142	-	6.1 - 8.5
2003	1000 - 1050	0 - 4.69	88 - 113	-	4.3 - 5.6
2004	1330 ± 30	0.22 - 5.53	64 - 102	-	5.4 - 7.7
2005	1320 ± 30	0 - 6.09	87 - 117	-	8.9 - 10.2
2006	1400 ± 30	0.06 - 7.47	66 - 103	-	14.8 - 16.4 [(7)]
2007	1760 ± 40	0.11 - 7.37	72 - 132	-	13.4 ± 0.4 [(7)]
2008	1990 ± 40	0 - 7.63	63 - 143	-	29.4 ± 0.7
2009	1410 ± 30	0 - 4.3	82 - 125	-	32.5 ± 0.7
2010	1240 ± 30	0 - 1.2	93 ± 2	-	33.2 ± 0.8

[(1)] Uncertainties are given as 1σ.

[(2)] A lower and upper limit is given as defined in Appendix B.

[(3)] Data from γ-spectroscopy.

[(4)] Data from α-spectroscopy.

[(5)] Not available. Result rejected [60].

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

[(7)] Results revised with RIVM Report 610791003.

Table A8: Weekly deposited ^{7}Be-, ^{137}Cs- and ^{210}Pb-activity (1) sampled at RIVM in 2010.

Week Number	Period	Precipitation mm	^{7}Be Bq·m^{-2}	^{137}Cs Bq·m^{-2}	^{210}Pb Bq·m^{-2}
1	31/12-08/01	2.0	3.3 ± 0.4	< 0.02	0.72 ± 0.11
2	08/01-15/01	4.4	5.4 ± 0.7	< 0.02	1.24 ± 0.17
3	15/01-22/01	12.2	13.6 ± 1.8	< 0.02	0.89 ± 0.13
4	22/01-29/01	18.8	25 ± 3	< 0.02	1.24 ± 0.17
5	29/01-05/02	34.3	33 ± 4	< 0.02	1.06 ± 0.15
6	05/02-12/02	5.3	4.7 ± 0.6	< 0.02	0.63 ± 0.09
7	12/02-19/02	1.7	4.9 ± 0.6	< 0.02	0.85 ± 0.13
8	19/02-26/02	29.8	34 ± 4	< 0.02	1.33 ± 0.19
9	26/02-05/03	25.3	18 ± 2	< 0.02	0.98 ± 0.14
10	05/03-12/03	6.9	10.5 ± 1.3	< 0.02	0.92 ± 0.14
11	12/03-19/03	10.0	7.4 ± 0.9	< 0.02	0.62 ± 0.10
12	19/03-26/03	22.5	22 ± 3	< 0.02	2.2 ± 0.3
13	26/03-02/04	14.2	27 ± 3	< 0.02	1.28 ± 0.18
14	02/04-09/04	17.2	17 ± 2	< 0.02	1.21 ± 0.17
15	09/04-16/04	0.0	6.1 ± 0.8	< 0.02	1.7 ± 0.2
16	16/04-23/04	0.0	6.4 ± 0.8	< 0.02	4.2 ± 0.5
17	23/04-29/04	0.2	4.5 ± 0.6	< 0.02	0.85 ± 0.13
18	29/04-07/05	51.0	96 ± 12	< 0.02	4.9 ± 0.6
19	07/05-14/05	19.5	24 ± 3	< 0.03	0.81 ± 0.13
20	14/05-21/05	0.3	7.9 ± 1.0	< 0.02	1.5 ± 0.2
21	21/05-28/05	0.9	12.2 ± 1.6	< 0.02	2.4 ± 0.3
22	28/05-04/06	14.3	22 ± 3	< 0.02	1.5 ± 0.2
23	04/06-11/06	18.5	33 ± 4	< 0.02	2.6 ± 0.3
24	11/06-18/06	0.0	6.0 ± 0.8	< 0.02	1.5 ± 0.2
25	18/06-25/06	0.6	6.5 ± 0.8	< 0.02	0.97 ± 0.14
26	25/06-02/07	0.5	8.8 ± 1.1	< 0.02	1.7 ± 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	02/07-09/07	5.4	30 ± 4	< 0.018	2.6 ± 0.3
28	09/07-16/07	48.0	78 ± 10	< 0.02	8.4 ± 1.1
29	16/07-23/07	3.7	11.2 ± 1.4	< 0.02	0.94 ± 0.14
30	23/07-30/07	17.5	31 ± 4	< 0.02	2.1 ± 0.3
31	30/07-06/08	10.9	22 ± 3	< 0.02	1.4 ± 0.2
32	06/08-13/08	9.4	17 ± 2	< 0.02	1.01 ± 0.14
33	13/08-20/08	26.4	42 ± 5	< 0.02	2.1 ± 0.3
34	20/08-27/08	82.5	78 ± 10	< 0.02	4.7 ± 0.6
35	27/08-03/09	44.9	50 ± 6	< 0.03	1.8 ± 0.3
36	03/09-10/09	15.3	21 ± 3	< 0.02	1.7 ± 0.2
37	10/09-17/09	48.5	61 ± 8	< 0.02	2.3 ± 0.3
38	17/09-24/09	21.5	53 ± 7	< 0.02	6.2 ± 0.8
39	24/09-01/10	13.1	25 ± 3	< 0.04	2.5 ± 0.3
40	01/10-08/10	13.0	10.6 ± 1.4	< 0.02	1.17 ± 0.16
41	08/10-15/10	0.2	4.7 ± 0.6	< 0.02	0.83 ± 0.13
42	15/10-22/10	50.0	58 ± 7	< 0.02	1.8 ± 0.2
43	22/10-29/10	16.5	35 ± 4	< 0.02	2.5 ± 0.3
44	29/10-05/11	9.0	21 ± 3	< 0.02	1.31 ± 0.18
45	05/11-12/11	61.3	63 ± 8	< 0.02	2.1 ± 0.3
46	12/11-19/11	7.4	13.5 ± 1.7	< 0.02	0.87 ± 0.13
47	19/11-26/11	0.6	2.1 ± 0.3	< 0.02	0.44 ± 0.08
48	26/11-03/12	4.1	4.4 ± 0.6	< 0.02	0.57 ± 0.09
49	03/12-10/12	14.8	17 ± 2	< 0.02	1.25 ± 0.17
50	10/12-17/12	17.1	12.3 ± 1.6	< 0.02	0.63 ± 0.10
51	17/12-24/12	14.0	7.6 ± 1.0	< 0.02	0.72 ± 0.11
52	24/12-31/12	2.7	11.5 ± 1.5	< 0.02	1.5 ± 0.2
Total [2]		867.5	1240 ± 30	-	93 ± 2
Lower limit [3]		-	-	0.0	-
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 2010 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	3.8	67
Kollumerwaard	972	2.9	70
Valthermond [3]	974	2.9	59
Vlaardingen	976	3.1	70
Braakman	978	3.6	66
Huijbergen	980	2.9	58
Houtakker	982	2.2	65
Wijnandsrade	984	4.1	71
Eibergen	986	3.4	61
De Zilk	988	1.5	65
Wieringerwerf	990	2.9	69
Vredepeel	992	3.9	67
Biddinghuizen	994	3.0	74
Bilthoven	998	2.9	62

[1] These dose equivalent rate monitors are placed differently from the 153 dose equivalent rate monitors (Table A10) with regard to height and surface covering.

[2] The station Wageningen has been replaced by the station Arnhem since December 2006.

[3] This station was formerly known as Witteveen.

Table A10: Yearly averaged ambient dose equivalent rate for the NMR stations in 2010.

Station	No.	Ambient dose equivalent rate nSv.h^{-1}	Station	No.	Ambient dose equivalent rate nSv.h^{-1}
Den Burg	1001	70	Assen	1097	65
Den Helder (1)	1002	72	Rutten	1099	75
Den Oever	1003	69	Lelystad	1103	77
Julianadorp (1)	1004	65	Urk	1105	75
Petten	1006	61	Eemshaven	1106	83
Kolhorn	1007	77	Uithuizen	1107	82
Egmond aan Zee	1009	67	Wagenborgen	1109	75
Heerhugowaard	1011	74	Winschoten	1110	74
Haarlem-Noord	1014	72	Ter Apel	1111	72
Nederhorst Den Berg	1015	60	Stadskanaal	1112	63
Enkhuizen	1018	80	Nieuweschans	1113	71
Oosthuizen	1019	78	Bellingwolde	1114	60
Zaandam	1021	68	Groningen	1116	75
Gouda	1024	69	Leens	1117	88
Dordrecht	1027	63	Grijpskerk	1118	72
Zuid Beijerland	1028	73	Meppel	1125	68
Rotterdam-Schiebroek(2)	1031	66	Hoogeveen	1126	61
Pijnacker	1032	86	Steenwijksmoer	1129	65
Rotterdam-Crooswijk (2)	1033	73	Nieuw Amsterdam	1130	78
Maasvlakte	1035	85	Nw. Schoonebeek /	1131	61
Rotterdam-Waalhaven	1036	67	Weiteveen		
Maassluis	1037	82	Emmen	1132	81
Hellevoetsluis	1038	91	Hengelo (Ov)	1135	69
Ouddorp	1039	73	Hengelo (Gld) (5)	1136	-
Wekerom	1041	74	Enschede	1139	65
Wageningen	1043	69	Losser	1140	62
Amersfoort	1046	70	Oldenzaal	1141	77
Harderwijk	1050	65	Westerhaar	1142	63
Wijk bij Duurstede	1056	81	Rijssen	1143	66
Nieuwegein	1062	79	's Heerenberg	1144	62
Zegveld (3)	1063	64	Dinxperlo	1145	78
Lopik (Cabauw) (4)	1064	83	Varsseveld	1146	72
Apeldoorn	1066	69	Groenlo	1147	83
Heerenveen	1071	71	Deventer	1148	77
Oosterwolde	1072	80	Etten-Leur	1154	69
Bergum	1074	67	Den Bosch	1157	69
Witmarsum	1076	87	Raamsdonkveer	1159	92
Sneek	1077	70	Ulvenhout	1160	73
St Jacobiparochie	1081	78	Baarle Nassau (5)	1161	-
Holwerd	1082	88	Uden (5)	1162	-
Leeuwarden	1085	69	Mill	1163	65
Zwolle-Zuid	1087	73	Oss	1167	65
Ommen	1093	64	Nuenen	1172	71
Hardenberg	1095	64	Bergeijk	1174	87

Continued on the next page.

Table A10: Continued.

Station	No.	Ambient dose equivalent rate nSv.h^{-1}	Station	No.	Ambient dose equivalent rate nSv.h^{-1}
Waalre	1175	69	Kerkrade	1224	86
Someren (Dorp)	1176	69	Hoensbroek	1225	83
Oisterwijk	1178	72	Gennep [5]	1228	-
Riel	1179	71	Elst (Gld)	1229	82
Oostelbeers	1180	83	Zevenaar	1230	72
Hilvarenbeek	1181	66	Nijmegen	1231	74
Venray	1183	60	Amstelveen	1233	73
Nieuw-Bergen	1184	62	Amsterdam Oost [5]	1234	-
Sevenum	1185	69	Aalsmeer	1236	71
Reuver	1188	66	Nispen	1237	62
Nederweert	1189	72	Groesbeek	1240	79
Heythuysen	1190	74	Tubbergen	1243	67
Mariahoop	1191	69	Haaksbergen	1244	67
Stramproy	1192	65	Scheveningen	1247	77
Eerbeek	1193	73	Zaltbommel	1251	71
Leiden	1196	75	IJzendijke	1252	77
Hulst	1197	73	Ritthem	1253	98
Terneuzen	1199	71	Vlissingen Haven	1254	72
Sluis	1201	74	Nieuwdorp	1255	75
Vlissingen	1202	77	's Heerenhoek [6]	1256	116
Halsteren	1204	66	Driewegen	1257	82
Oud Gastel	1206	66	Arnemuiden	1258	72
Goes	1207	83	Heinkenszand	1259	82
Bruinisse	1209	74	Baarland	1260	87
Burgh-Haamstede	1211	62	Biervliet	1261	76
Vrouwenpolder	1212	64	Nummer Een	1262	75
Wemeldinge	1214	76	Rilland	1263	75
Middelburg	1215	77	Putte	1264	56
Westkapelle	1216	68	Nieuw Namen	1265	79
Stein	1219	82	Beneden Leeuwen	1272	85
Maastricht	1220	89	Denekamp	1278	64
Ravensbos (Arensgehout)	1221	83	Winterswijk (Kotten)	1279	68
			Bilthoven	1280	62
Vaals	1222	81	Gastel (Maarheze)	1281	74
Gulpen	1223	81			

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

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

[3] The station Noordwijk-Binnen has been relocated to Zegsveld in July 2009.

[4] The station Rhenen has been relocated to Lopik (Cabouw) in July 2009.

[5] Station was not operational in 2010.

[6] As in previous years, station 's Heerenhoek 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, that 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 2010 as measured by RWS WD Centre for Water Management.

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**				
08/03/10	24	6	2800		
30/03/10	26	13			
27/04/10	37	9	2600		
25/05/10	28	5			
22/06/10	33	21	4100		
20/07/10	14	27			
17/08/10	23	6	3300		
14/09/10	47	33			
12/10/10	56	38	3500		
09/11/10	58	60			
Average	35	22	3300		
Location	**Nieuwe Waterweg**				
20/01/10	56	77			
17/02/10	92	90	5100	< 1	5
17/03/10	81	120			
14/04/10	29	43	5100	< 1	3
11/05/10	49	25			
09/06/10	50	34	5700	2	4
07/07/10	210	30			
04/08/10	58	< 1	4900	4	5
01/09/10	71	59			
29/09/10	61	41	5100	3	3
27/10/10	52	39			
24/11/10	96	59	8500	6	4
22/12/10	110	68			
Average	78	53	5700	2.7	4
Location	**Noordzeekanaal**				
18/01/10	170	30	2600		
15/02/10	210	36	2500		
15/03/10	180	24	2700		
12/04/10	180	36	2600		
10/05/10	240	47	2700		
07/06/10	370	25	3300		
05/07/10	290	39	2600		
02/08/10	240	29	2500		
30/08/10	290	31	2000		
27/09/10	92	25	1700		
25/10/10	24	32	3300		
22/11/10	44	5	3500		
20/12/10	70	35	3100		
Average	180	30	2700		

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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**				
13/01/10	55	36	3200	< 1	2
10/02/10	79	65	4100		
10/03/10	55	45	5600	2	5
07/04/10	36	12	4200		
06/05/10	73	19	8100	3	4
02/06/10	51	21	3900		
30/06/10	57	39	2500	1	6
28/07/10	32	21	2700		
25/08/10	59	41	2000	< 1	3
22/09/10	46	36	4500		
20/10/10	48	8	20000	6	3
17/11/10	78	53	8400		
15/12/10	110	88	3000	5	4
Average	60	37	5600	2.6	3.9
Location	**Scheldt**				
05/01/10	240	170			
02/02/10	320	230	7600		17
03/03/10	190	77			
31/03/10	610	600	9700		23
28/04/10	250	120			
26/05/10	250	59	14000		11
21/06/10	200	53			
19/07/10	500	87	13000		17
16/08/10	340	82			
13/09/10	460	76	12000		14
12/10/10	270	84			
10/11/10	130	110	14000		9
08/12/10	93	76			
Average	300	140	11700		15
Location	**Meuse**				
12/01/10	37	33	3100	< 1	4
09/02/10	51	58	830		
09/03/10	29	24	27000	7	3
06/04/10	42	39	26000		
03/05/10	24	2	16000	3	3
01/06/10	26	18	28000		
29/06/10	9	10	49000	< 1	4
27/07/10	30	11	28000		
24/08/10	26	15	18000	2	3
21/09/10	18	< 1	20000		
19/10/10	30	< 1	13000	3	2
16/11/10	130	130	29000		
14/12/10	53	36	2500	< 1	1
Average	39	29	20000	2.4	2.9

Table A12: ^{60}Co-, ^{131}I-, ^{137}Cs- and ^{210}Pb-activity concentrations in suspended solids (Bq·kg^{-1}) in surface water in 2010 as measured by RWS WD Centre for Water Management.

Date	**^{60}Co Bq·kg^{-1}**	**^{131}I Bq·kg^{-1}**	**^{137}Cs Bq·kg^{-1}**	**^{210}Pb Bq·kg^{-1}**
Location	**IJsselmeer**			
08/03/10	< 1	< 1	4	
30/03/10	< 1	< 1	3	
27/04/10	< 1	< 1	< 1	
25/05/10	< 1	< 1	2	
22/06/10	< 1	< 1	2	
20/07/10	< 1	< 1	2	
17/08/10	< 1	< 1	1	
14/09/10	< 1	< 1	4	
12/10/10	< 1	< 1	3	
09/11/10	< 1	< 1	4	
Average	< 1	< 1	2.6	
Location	**Nieuwe Waterweg**			
20/01/10	< 1	< 1	7	
17/02/10	< 1	3	11	96
17/03/10	< 1	< 1	8	
14/04/10	< 1	4	9	98
11/05/10	< 1	< 1	10	
09/06/10	< 1	< 1	11	130
07/07/10	< 1	< 1	12	
04/08/10	< 1	< 1	10	110
01/09/10	< 1	2	10	
29/09/10	< 1	< 1	9	110
27/10/10	< 1	< 1	8	
24/11/10	< 1	< 1	8	82
22/12/10	< 1	3	13	
Average	< 1	< 1.3	9.7	104
Location	**Noordzeekanaal**			
18/01/10	< 1	12	9	
15/03/10	< 1	8	7	
10/05/10	< 1	34	6	
05/07/10	< 1	25	2	
30/08/10	< 1	23	7	
25/10/10	< 1	86	6	
20/12/10	< 1	35	11	
Average	< 1	32	6.9	

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Table A12: Continued.

Date	^{60}Co Bq·kg^{-1}	^{131}I Bq·kg^{-1}	^{137}Cs Bq·kg^{-1}	^{210}Pb Bq·kg^{-1}
Location	**Rhine**			
13/01/10	< 1	< 1	14	120
10/02/10	< 1	14	15	
10/03/10	< 1	9	16	130
07/04/10	< 1	< 1	14	
06/05/10	< 1	< 1	12	110
02/06/10	< 1	< 1	12	
30/06/10	< 1	< 1	12	120
28/07/10	< 1	< 1	14	
27/08/10	< 1	5	13	150
22/09/10	< 1	3	13	
20/10/10	< 1	< 1	14	130
17/11/10	< 1	7	16	
15/12/10	< 1	4	15	120
Average	< 1	< 3.5	13.8	126
Location	**Scheldt**			
05/01/10	< 1	< 1	7	90
02/02/10	< 1	< 1	6	80
03/03/10	< 1	4	6	85
31/03/10	< 1	< 1	9	96
28/04/10	< 1	< 1	7	
26/05/10	< 1	< 1	8	85
21/06/10	< 1	< 1	6	
19/07/10	< 1	< 1	8	89
16/08/10	< 1	< 1	7	
13/09/10	< 1	< 1	7	96
12/10/10	< 1	< 1	6	
10/11/10	< 1	< 1	7	88
08/12/10	1	< 1	7	
Average	< 1	< 1	7	88.6
Location	**Meuse**			
05/01/10	2	< 1	14	
12/01/10	4	18	19	140
19/01/10	4	25	15	
26/01/10	3	26	13	
02/02/10	1	49	10	
10/02/10	< 1	24	15	
16/02/10	5	11	12	
23/02/10	3	11	10	
02/03/10	< 1	3	10	

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Table A12: Continued.

Date	^{60}Co Bq·kg^{-1}	^{131}I Bq·kg^{-1}	^{137}Cs Bq·kg^{-1}	^{210}Pb Bq·kg^{-1}
Location	**Meuse**			
09/03/10	8	7	14	110
16/03/10	6	32	14	
23/03/10	3	17	11	
16/04/10	7	22	13	
28/04/10	7	< 1	8	
03/05/10	6	31	12	160
11/05/10	< 1	< 1	10	
18/05/10	5	29	13	
25/05/10	7	26	10	
01/06/10	5	35	10	
08/06/10	4	13	8	
14/06/10	6	21	9	
22/06/10	5	< 1	9	
29/06/10	< 1	20	4	86
06/07/10	< 1	< 1	8	
13/07/10	3	< 1	7	
20/07/10	< 1	< 1	6	
03/08/10	< 1	7	6	
10/08/10	< 1	< 1	7	
17/08/10	6	7	11	
24/08/10	6	23	11	220
31/08/10	6	10	12	
07/09/10	6	15	12	
14/09/10	7	12	13	
21/09/10	5	16	13	
28/09/10	7	17	13	
05/10/10	7	8	12	200
26/10/10	7	48	13	
02/11/10	8	28	13	
09/11/10	9	20	12	
16/11/10	< 1	3	9	
23/11/10	2	7	9	
30/11/10	4	26	13	
07/12/10	43	26	14	
14/12/10	3	24	11	140
21/12/10	5	20	10	
28/12/10	2	8	11	
Average	5	16.3	11.1	151

Table A13: Gross α-, residual β-, ^{3}H- and ^{90}Sr-activity concentrations ($mBq \cdot L^{-1}$) in seawater in 2010 as measured by RWS WD Centre for Water Management.

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**			
11/02/10	330	94	5000	
10/05/10	150	58	3600	
26/08/10	270	34	2600	
17/11/10	120	46	4000	
Average	220	58	3800	
Location	**Southern North Sea**			
17/02/10	470	62	2400	1
10/05/10	130	57	790	< 1
26/08/10	540	58	780	< 1
17/11/10	45	53	3900	< 1
Average	300	58	2000	< 1
Location	**Central North Sea**			
19/01/10	510	50	270	< 1
13/04/10	410	48	130	< 1
15/06/10	200	56	270	2
21/09/10	310	50	< 100	5
Average	360	51	180	2
Location	**Delta Coastal Waters**			
11/01/10	530	86	5400	
18/02/10	390	86	5000	< 1
11/03/10	310	44	4400	
20/04/10	240	86	3800	
11/05/10	710	55	3600	10
22/06/10	250	69	3100	
15/07/10	210	60	3300	
25/08/10	460	55	2600	< 1
13/10/10	430	54	3100	
18/11/10	160	89	4100	< 1
15/12/10	61	87	4800	
Average	340	70	3900	< 3

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Table A13: Continued.

Date	Gross α mBq·L^{-1}	Residual β mBq·L^{-1}	^{3}H mBq·L^{-1}	^{90}Sr mBq·L^{-1}
Location	**Westerscheldt**			
04/01/10	450	180	6000	< 1
01/02/10	480	110	5800	10
01/03/10	280	130	5900	3
29/03/10	330	130	4800	< 1
26/04/10	570	100	4900	< 1
25/05/10	350	130	4300	< 1
21/06/10	560	56	5200	< 1
21/07/10	340	54	3900	2
18/08/10	690	75	3200	< 1
15/09/10	520	140	3000	< 1
11/10/10	640	49	4300	6
08/11/10	140	110	3400	< 1
07/12/10	320	290	5600	2
Average	440	120	4600	< 2
Location	**Eems-Dollard**			
25/02/10	250	86	3400	
10/05/10	410	52	4100	
18/08/10	540	43	2400	
16/11/10	140	72	2100	
Average	340	63	3000	
Location	**Wadden Sea West**			
15/02/10	420	40	4400	
12/05/10	150	83	3100	
31/08/10	570	74	2500	
22/11/10	140	100	3000	
Average	320	74	3200	
Location	**Wadden Sea East**			
18/02/10	260	170	4200	
06/05/10	360	110	3500	
16/08/10	580	200	2200	
12/11/10	150	130	2700	
Average	340	150	3200	

Table A14: ^{137}Cs- and ^{210}Pb-activity concentrations in suspended solids ($Bq \cdot kg^{-1}$) in seawater in 2010 as measured by RWS WD Centre for Water Management.

Date	**^{137}Cs $Bq \cdot kg^{-1}$**	**^{210}Pb (1) $Bq \cdot kg^{-1}$**
Location	**Coastal area**	
11/02/10	6	110
25/05/10	3	67
25/08/10	5	87
07/12/10	6	86
Average	5	88
Location	**Westerscheldt**	
07/01/10	4	60
12/04/10	4	60
07/07/10	4	59
13/10/10	2	65
Average	4	61
Location	**Eems-Dollard**	
24/02/10	8	100
20/05/10	7	100
17/08/10	7	89
15/11/10	5	57
Average	7	86
Location	**Wadden Sea West (2)**	
16/02/10	6	110
17/05/10	3	63
04/10/10	3	130
25/11/10	6	110
Average	5	103

(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 in the vicinity of the nuclear power plant at Borssele in 2010.

Date [1]			**Gross α** [2] **mBq·m^{-3}**		
Location	**21**	**22**	**23**	**27**	**29**
04/02/10	0.086	0.231	0.102	0.010	0.040
03/03/10	0.017	0.037	0.186	0.053	0.035
01/04/10	0.059	0.082	0.097	0.022	0.067
07/05/10	0.018	0.035	0.076	0.033	0.071
03/06/10	0.041	0.033	0.032	0.008	0.072
08/07/10	0.035	0.054	0.107	0.037	0.045
05/08/10	0.059	0.045	0.094	0.014	0.023
02/09/10	0.057	0.052	0.112	0.021	0.024
04/10/10	0.038	0.044	0.138	0.030	0.043
03/11/10	0.051	0.059	0.111	0.025	0.018
09/12/10	0.041	0.039	0.088	0.010	0.021
05/01/11	0.022	0.055	0.114	0.018	0.017

[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 in the vicinity of the nuclear power plant at Borssele in 2010.

Date [1]			**Gross β mBq·m^{-3}**		
Location	**21**	**22**	**23**	**27**	**29**
04/02/10	0.47 ± 0.03	0.60 ± 0.03	0.32 ± 0.02	0.17 ± 0.02	0.530 ± 0.019
03/03/10	0.23 ± 0.03	0.299 ± 0.020	0.37 ± 0.02	0.35 ± 0.03	0.39 ± 0.03
01/04/10	0.31 ± 0.03	0.305 ± 0.019	0.35 ± 0.02	0.17 ± 0.02	0.70 ± 0.04
07/05/10	0.16 ± 0.02	0.209 ± 0.014	0.218 ± 0.017	0.201 ± 0.019	0.293 ± 0.017
03/06/10	0.25 ± 0.03	0.110 ± 0.017	0.13 ± 0.02	0.13 ± 0.02	0.264 ± 0.012
08/07/10	0.25 ± 0.02	0.235 ± 0.014	0.295 ± 0.018	0.220 ± 0.020	0.356 ± 0.013
05/08/10	0.29 ± 0.03	0.157 ± 0.016	0.24 ± 0.02	0.14 ± 0.02	0.264 ± 0.012
02/09/10	0.12 ± 0.03	0.108 ± 0.017	0.27 ± 0.03	0.11 ± 0.02	0.106 ± 0.011
04/10/10	0.39 ± 0.02	0.258 ± 0.016	0.34 ± 0.02	0.22 ± 0.02	0.435 ± 0.013
03/11/10	0.36 ± 0.03	0.42 ± 0.02	0.46 ± 0.03	0.31 ± 0.02	0.302 ± 0.012
09/12/10	0.49 ± 0.03	0.117 ± 0.012	0.217 ± 0.017	0.13 ± 0.02	0.290 ± 0.013
05/01/11	0.30 ± 0.03	0.46 ± 0.03	0.32 ± 0.02	0.28 ± 0.03	0.51 ± 0.04

[1] End date of monthly sampling period.

Table A17: Monthly averaged activity concentrations of γ-emitters in air dust in the vicinity of the nuclear power plant at Borssele in 2010. 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	$^{131}I_{el}$ [2]	$^{131}I_{or}$ [2]	^{137}Cs	Nat. [3]
	mBq·m^{-3}	mBq·m^{-3}	mBq·m^{-3}	mBq·m^{-3}	mBq·m^{-3}
04/02/10	< 0.05	< 0.2	< 0.5	< 0.04	1.49 ± 0.10
03/03/10	< 0.08	< 0.2	< 0.4	< 0.07	2.2 ± 0.2
01/04/10	< 0.06	< 0.1	< 0.3	< 0.05	2.21 ± 0.11
07/05/10	< 0.06	< 0.1	< 0.2	< 0.05	1.83 ± 0.11
03/06/10	< 0.06	< 0.2	< 0.3	< 0.05	1.8 ± 0.2
08/07/10	< 0.06	< 0.1	< 0.3	< 0.04	1.73 ± 0.04
05/08/10	< 0.07	< 0.1	< 0.3	< 0.052	1.7 ± 0.4
02/09/10	< 0.06	< 0.1	< 0.1	< 0.055	1.76 ± 0.07
04/10/10	< 0.055	< 0.8	< 0.1	< 0.043	1.82 ± 0.12
03/11/10	< 0.08	< 0.1	< 0.3	< 0.056	2.28 ± 0.10
09/12/10	< 0.058	< 0.1	< 0.2	< 0.042	1.66 ± 0.04
05/01/11	< 0.12	< 0.1	< 0.1	< 0.08	3.0 ± 0.4

[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 in the vicinity of the nuclear power plant at Borssele in 2010. 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]
04/02/10	0.453	< 2	< 2	< 1
03/03/10	0.355	< 1	< 2	< 1
01/04/10	0.097	< 6	< 4	< 5
07/05/10	0.173	< 4	< 3	< 3
03/06/10	0.230	< 3	< 2	< 2
08/07/10	0.206	< 3	< 2	< 2
05/08/10	0.201	< 3	< 2	< 2
02/09/10	0.476	< 1	< 0.9	< 1
04/10/10	0.352	< 2	< 2	< 1
03/11/10	0.143	< 4	< 3	< 3
09/12/10	0.206	< 2	< 3	< 2
05/01/11	0.191	< 3	< 2	< 2

[1] Dry weight.

Table A19: Activity concentrations of γ-emitters in soil in the vicinity of the nuclear power plant at Borssele in 2010. Analysis was performed on four samples taken near the outlet of the plant on 18 May 2010.

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	< 0.2	0.40 ± 0.03
O2	67.6	< 0.2	< 0.3	< 0.3	1.16 ± 0.07
O3	71.6	< 0.3	< 0.4	< 0.3	1.27 ± 0.09
O4	74.2	< 0.2	< 0.2	< 0.2	1.16 ± 0.06

[1] Dry weight.

Table A20: Residual β-activity concentrations in water from the Westerscheldt in 2010.

Date		**Residual β** **Bq·L^{-1}**		
Location	**1**	**2**	**3**	**4**
04/02/10	0.046 ± 0.006	0.038 ± 0.006	0.061 ± 0.006	0.053 ± 0.007
03/03/10	0.047 ± 0.006	0.043 ± 0.006	0.032 ± 0.005	0.083 ± 0.006
01/04/10	0.051 ± 0.005	0.049 ± 0.006	0.034 ± 0.005	0.042 ± 0.005
07/05/10	0.039 ± 0.004	0.042 ± 0.005	0.055 ± 0.012	0.045 ± 0.004
03/06/10	0.083 ± 0.007	0.047 ± 0.007	0.068 ± 0.006	0.091 ± 0.008
08/07/10	0.048 ± 0.006	0.060 ± 0.006	0.063 ± 0.006	0.059 ± 0.007
05/08/10	0.078 ± 0.006	0.062 ± 0.007	0.048 ± 0.006	0.051 ± 0.006
02/09/10	0.099 ± 0.007	0.082 ± 0.006	0.095 ± 0.007	0.080 ± 0.006
04/10/10	0.088 ± 0.006	0.081 ± 0.010	0.097 ± 0.006	0.093 ± 0.010
03/11/10	0.096 ± 0.015	0.101 ± 0.012	0.065 ± 0.005	0.076 ± 0.011
09/12/10	0.099 ± 0.008	0.093 ± 0.009	0.089 ± 0.006	0.093 ± 0.006
05/01/11	0.086 ± 0.008	0.070 ± 0.006	0.096 ± 0.006	0.067 ± 0.005

Table A21: ^{3}H-activity concentrations in water from the Westerscheldt in 2010.

Date		**^{3}H** **Bq·L^{-1}**		
Location	**1**	**2**	**3**	**4**
04/02/10	8.5 ± 1.4	9.2 ± 1.4	8.9 ± 1.4	9.9 ± 1.4
03/03/10	9.2 ± 1.4	8.4 ± 1.4	8.3 ± 1.4	7.2 ± 1.4
01/04/10	7.4 ± 1.4	7.9 ± 1.4	7.7 ± 1.4	8.8 ± 1.4
07/05/10	8.9 ± 1.4	9.1 ± 1.4	8.0 ± 1.4	9.4 ± 1.4
03/06/10	8.6 ± 1.4	9.1 ± 1.4	8.5 ± 1.4	10.3 ± 1.4
08/07/10	8.7 ± 1.4	8.0 ± 1.4	9.1 ± 1.4	9.9 ± 1.2
05/08/10	7.9 ± 1.4	9.2 ± 1.4	8.2 ± 1.5	10.1 ± 1.2
02/09/10	8.7 ± 1.5	8.0 ± 1.5	8.1 ± 1.5	7.9 ± 1.3
04/10/10	8.9 ± 1.5	8.8 ± 1.5	9.2 ± 1.5	8.1 ± 1.3
03/11/10	8.3 ± 1.3	9.3 ± 1.4	8.8 ± 1.3	8.7 ± 1.1
09/12/10	9.5 ± 1.3	9.2 ± 1.4	8.9 ± 1.3	10.1 ± 1.2
05/01/11	9.6 ± 1.4	9.2 ± 1.3	8.6 ± 1.3	8.7 ± 1.1

Table A22: Gross β-activity concentrations in suspended solids from the Westerscheldt in 2010.

Date		**Gross β kBq·kg^{-1}**		
Location	**1**	**2**	**3**	**4**
04/02/10	0.71 ± 0.05	0.64 ± 0.03	0.161 ± 0.017	0.56 ± 0.03
03/03/10	0.74 ± 0.08	0.79 ± 0.09	0.71 ± 0.08	0.10 ± 0.02
01/04/10	0.54 ± 0.04	0.75 ± 0.04	0.73 ± 0.04	0.57 ± 0.03
07/05/10	0.81 ± 0.16	1.18 ± 0.09	0.92 ± 0.13	0.61 ± 0.12
03/06/10	1.05 ± 0.06	0.84 ± 0.03	0.78 ± 0.03	0.81 ± 0.08
08/07/10	1.62 ± 0.10	0.74 ± 0.05	0.58 ± 0.17	0.33 ± 0.05
05/08/10	0.35 ± 0.10	0.94 ± 0.16	0.74 ± 0.09	0.65 ± 0.05
02/09/10	0.98 ± 0.08	0.95 ± 0.15	0.76 ± 0.08	0.99 ± 0.08
04/10/10	0.86 ± 0.14	1.76 ± 0.16	0.91 ± 0.07	1.01 ± 0.08
03/11/10	0.95 ± 0.09	1.58 ± 0.10	1.03 ± 0.07	1.68 ± 0.07
09/12/10	0.70 ± 0.03	1.11 ± 0.05	0.90 ± 0.04	0.98 ± 0.03
05/01/11	0.97 ± 0.05	1.47 ± 0.05	1.32 ± 0.05	1.11 ± 0.05

Table A23: Activity concentrations of γ-emitters in seaweed from the Westerscheldt in 2010. Analysis was performed on a combined sample of the monthly samples from all four locations (1, 2, 3 and 4).

Date	**Mass kg**	**^{60}Co Bq·kg^{-1} (1)**	**^{131}I Bq·kg^{-1} (1)**	**^{137}Cs Bq·kg^{-1} (1)**
04/02/10	0.100	< 4	< 4	< 3
03/03/10	0.094	< 4	< 3	< 3
01/04/10	0.128	< 3	3.3 ± 0.4	< 2
07/05/10	0.142	< 3	< 2	< 2
03/06/10	0.116	< 3	< 3	0.9 ± 0.4
08/07/10	0.158	< 2	< 2	< 2
05/08/10	0.156	< 3	< 2	0.8 ± 0.4
02/09/10	0.119	< 4	< 2	< 3
04/10/10	0.206	< 2	< 2	< 2
03/11/10	0.115	< 3	< 2	< 2
09/12/10	0.242	< 2	< 1	< 1
05/01/11	0.109	< 4	< 3	< 3

(1) Dry weight.

Table A24: Activity concentrations of γ-emitters in sediment from the Westerscheldt in 2010. 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)
04/02/10	47.5	< 0.5	< 0.3	1.08 ± 0.11
03/03/10	58.0	< 0.4	< 0.3	1.27 ± 0.09
01/04/10	60.1	< 0.4	< 0.3	1.02 ± 0.08
07/05/10	48.6	< 0.4	< 0.3	0.85 ± 0.09
03/06/10	52.4	< 0.4	< 0.3	1.27 ± 0.09
08/07/10	50.5	< 0.4	< 0.3	0.96 ± 0.10
05/08/10	47.4	< 0.5	< 0.4	0.64 ± 0.08
02/09/10	63.9	< 0.4	< 0.3	1.29 ± 0.08
04/10/10	55.4	< 0.4	< 0.3	1.17 ± 0.09
03/11/10	52.1	< 0.4	< 0.3	1.06 ± 0.10
09/12/10	54.4	< 0.4	< 0.3	0.97 ± 0.09
05/01/11	43.6	< 0.5	< 0.3	0.85 ± 0.10

(1) Dry weight.

Appendix B - The Presentation of Data

The methods described below were applied to the data provided by RIVM/LSO (e.g. air dust and deposition). Data from the other institutes 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 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 is 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 through 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).
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 ^{40}K. For brackish and salt water, the Centre for Water Management uses a direct method to determine the residual β-activity [37].

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