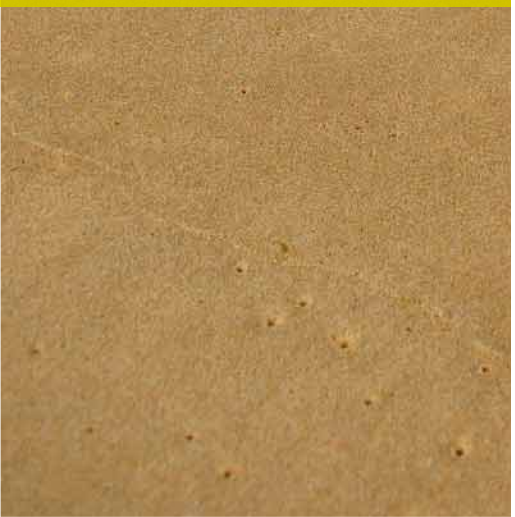
National Institute
for Public Health
and the Environment

Report 610791003/2010
G.J. Knetsch (ed.)

Environmental radioactivity in the Netherlands

Results in 2008



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RIVM Report 610791003/2010

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Results in 2008

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This investigation has been performed by order and for the account of Ministry of Housing, Spatial Planning and the Environment, within the framework of project 610791: environmental monitoring of radioactivity and radiation.

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Abstract

Environmental radioactivity in the Netherlands
Results in 2008

The Member States of the European Union have the obligation to measure radioactivity in the environment yearly, as stated in the Euratom Treaty of 1957. The Netherlands fulfilled this obligation also in 2008. In 2000 Euratom made recommendations to perform the measurements according to a certain outline, however Member States are not obliged to comply with these recommendations. In 2008, the Netherlands complied to the Euratom recommendations. Except for the determination of strontium-90 in mixed diet, which was not carried out.

Measurements in air and environment show normal levels. Polonium-210 in deposition has the highest level since 1993 (about double the normal quantity). This might partially be explained by Saharan dust which was deposited throughout the Netherlands during the end of May.

Radioactivity levels in food and milk were below the export and consumption limits set by the European Union. Since 2008, additional data on radioactivity levels in food have been added to this report. The additional data originate from RIKILT – Insitute of Food Safety.

Target values in fresh water were exceeded for some radionuclides and locations, however these exceedings do not pose a threat to the public health. Target values are values that should preferably not be exceeded, however they are not limits.

Key words:
radioactivity, environment, airborne particles, water, food, milk

Rapport in het kort

Radioactiviteit in het Nederlandse milieu
Resultaten in 2008

Volgens het Euratom-verdrag uit 1957 moeten alle lidstaten van de Europese Unie jaarlijks de hoeveelheid radioactiviteit in het milieu meten. Ook in 2008 heeft Nederland aan deze verplichting voldaan. Sinds 2000 kent Euratom aanbevelingen om de metingen volgens een bepaald stramien uit te voeren, lidstaten zijn echter niet verplicht deze na te leven. Nederland voldeed in 2008 aan alle Europese aanbevelingen, met uitzondering van de bepaling van strontium-90 in voedsel.

De metingen in lucht en omgeving lieten een normaal beeld zien. Polonium-210 in depositie gaf het hoogste niveau sinds 1993 (twee keer zo hoog als normaal). Dit kan deels verklaard worden door Sahara zand dat eind mei in Nederland is gedeponeerd.

In voedsel en melk zijn geen radioactiviteitniveaus aangetroffen boven de Europese limieten voor export en consumptie. Met ingang van 2008 zijn extra gegevens betreffende voedsel toegevoegd aan dit rapport. De additionele gegevens zijn afkomstig van RIKILT – Instituut voor Voedselveiligheid.

In het oppervlaktewater is op een aantal locaties voor sommige radioactieve stoffen de streefwaarde overschreden. Deze overschrijdingen zijn echter zodanig dat ze niet schadelijk zijn voor de volksgezondheid. Streefwaarden zijn waarden die bij voorkeur niet overschreden mogen worden, maar het zijn geen limieten.

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

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Preface

The following institutes have 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 Food and Consumer Product Safety Authority
Voedsel en Waren Autoriteit (VWA)
Data on foodstuff.
drs. K. Zwaagstra, ing. G. Visser

RIKILT - Institute of Food Safety
RIKILT - Instituut voor Voedselveiligheid
Data on milk and foodstuff.
dr. G. C. Krijger, J.M. Weseman, ing. A. Vos van Avezathe, J. Verbunt.

Nuclear Research & consultancy Group (NRG)
Data on environmental samples around the nuclear power plant at Borssele.
J.J. Donk.

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Contents

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Summary

The Dutch government is obligated 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 in the Dutch environment in 2008. The measurements were carried out by RIVM, Centre for Water Management, RIKILT, VWA and 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. The yearly total activity in deposition for ^{210}Po (29.4 Bq·m^{-2}) is the highest since 1993, which is about double the normal level. This might partially be explained by Saharan dust which was deposited throughout the Netherlands during the end of May.

The National Radioactivity Monitoring Network (NMR) was used to determine the activity concentrations in air dust of gross α and artificial β (β-radiation emitted by man-made nuclides). 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 calculated 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 73.8 nSv·h^{-1}. Based upon earlier research, it is assumed that this value is an overestimate of 5 to 10 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}Po were determined in suspended solids in seawater. The results are presented in Table S1.

The gross α-activity concentration in the Noordzeekanaal, Nieuwe Waterweg and Scheldt exceeds the target value (100 mBq·L^{-1}) in four out of seven, five out of thirteen and thirteen out of thirteen samples taken, respectively. The yearly averaged gross α-activity concentrations in the Noordzeekanaal, Nieuwe Waterweg and Scheldt (240, 106 and 290 mBq·L^{-1}, respectively) are above the target value, but within the range of those in previous years.

The residual β- and ^{90}Sr-activity concentrations (of both individual samples and yearly average) in surface water are below the target value (200 and 10 mBq·L^{-1}, respectively).
The ^{3}H-activity concentration in the Scheldt and Meuse exceeds the target value (10 Bq·L^{-1}) in two out of six and eight out of thirteen samples taken, respectively. The yearly averaged ^{3}H-activity concentration in the Meuse (22.0 Bq·L^{-1}) is above the target value, but within the range of those in previous years.

The ^{226}Ra-activity concentration in the Scheldt exceeds the target value (5 mBq·L^{-1}) in five out of six samples taken. The yearly averaged ^{226}Ra-activity concentration in the Scheldt (9.0 mBq·L^{-1}) is above the target value, but within the range of those in previous years.

The ^{60}Co-activity concentration in suspended solids in the Meuse exceeds the target value (10 Bq·kg^{-1}) in nineteen out of fifty-two samples taken. However the yearly averaged ^{60}Co-activity concentration in the Meuse is below the target value.

The ^{131}I-activity concentration in suspended solids in the Noordzeekanaal and Meuse exceeds the target value (20 Bq·kg^{-1}) in one out of seven and fifteen out of fifty-two samples taken, respectively. However, the yearly averaged ^{131}I-activity concentrations are below the target value.
The ^{137}Cs-activity concentrations (of both individual samples and yearly average) in suspended solids in surface water are below the target value (40 Bq·kg^{-1}).

The ^{210}Pb-activity concentration in suspended solids in the Nieuwe Waterweg, Rhine and Meuse exceeds the target value (100 Bq·kg^{-1}) in four out of six, six out of seven and six out of six samples taken, respectively. The yearly averaged ^{210}Pb-activity concentration in the Nieuwe Waterweg, Rhine and Meuse (108, 112 and 160 Bq·kg^{-1}, respectively) are above the target value, but within the range of those in previous years.

The yearly averaged gross α-, ^{3}H- ^{90}Sr, ^{137}Cs and ^{210}Po-activity concentrations in seawater are within the range of those in previous years. The yearly averaged residual β-activity concentration in Waddenzee Oost (180 mBq·L^{-1}) is the highest since 1999.

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 2008 at five of the 148 pumping stations, the gross α-activity concentration averaged per pumping station exceeded 0.1 Bq·L^{-1}.

The results of the monitoring program in milk and mixed diet are presented in Table S1. Since 2008, additional data on radioactivity levels in food have been added to this report. The additional data originate from RIKILT – Insitute of Food Safety.
Data on environmental samples taken around the nuclear power plant at Borssele are presented in Table S2. In 2008, the Netherlands complied to the Euratom recommendations except for the determination of ^{90}Sr in mixed diet.

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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 2008. De metingen zijn verricht door RIVM, RWS Waterdienst, RIKILT, VWA en 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. De totale jaarlijkse activiteit in depositie van ^{210}Po (29,4 Bq·m^{-2}) is de hoogste sinds 1993. Dit is ongeveer het dubbele van het normale niveau. Dit kan deels verklaard worden door Sahara zand dat eind mei in Nederland is gedeponeerd.

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 berekende kunstmatige β-activiteitsconcentratie in luchtstof week niet significant af van nul. Met het NMR werd daarnaast het omgevingsdosisequivalenttempo bepaald, de jaargemiddelde meetwaarde was 73,8 nSv·h^{-1}. Gebaseerd op eerder onderzoek wordt aangenomen dat deze waarde een overschatting is met 5 tot 10 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}Po. De resultaten zijn weergegeven in Tabel S1.

De totaal α-activiteitsconcentratie in het Noordzeekanaal, de Nieuwe Waterweg en de Schelde overschreed de streefwaarde (100 mBq·L^{-1}) in respectievelijk vier van de zeven, vijf van de dertien en dertien van de dertien genomen monsters.
De jaargemiddelde totaal α-activiteitsconcentraties in het Noordzeekanaal, de Nieuwe Waterweg en de Schelde (respectievelijk 240, 106 en 290 mBq·L^{-1}) zijn boven de streefwaarde, maar vallen binnen het bereik van voorgaande jaren.

De rest β- en ^{90}Sr-activiteitsconcentraties (van zowel de individuele monsters als het jaargemiddelde) in oppervlaktewater zijn beneden de streefwaarde (respectievelijk 200 en 10 mBq·L^{-1}).
De ^{3}H-activiteitsconcentratie in de Schelde en de Maas overschreed de streefwaarde (10 Bq·L^{-1}) in respectievelijk twee van de zes en acht van de dertien genomen monsters. De jaargemiddelde ^{3}H-activiteitsconcentratie in de Maas (22,0 Bq·L^{-1}) is boven de streefwaarde, maar valt binnen het bereik van voorgaande jaren.

De ^{226}Ra-activiteitsconcentratie in de Schelde overschreed de streefwaarde (5 mBq·L^{-1}) in vijf van de zes genomen monsters. De jaargemiddelde ^{226}Ra-activiteitsconcentratie in de Schelde (9,0 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 overschreed de streefwaarde (10 Bq·kg^{-1}) in negentien van de tweeënvijftig genomen monsters. De jaargemiddelde ^{60}Co-activiteitsconcentratie in de Maas is echter beneden de streefwaarde.

De ^{131}I-activiteitsconcentratie in zwevend stof in het Noordzeekanaal en de Maas overschreed de streefwaarde (20 Bq·kg^{-1}) in respectievelijk één van de zeven en vijftien van de tweeënvijftig genomen monsters. De jaargemiddelde ^{131}I-activiteitsconcentraties zijn echter beneden 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 overschreed de streefwaarde (100 Bq·kg^{-1}) in respectievelijk vier van de zes, zes van de zeven en zes van de zes genomen monsters. De jaargemiddelde ^{210}Pb-activiteitsconcentraties in de Nieuwe Waterweg, de Rijn en de Maas (respectievelijk 108, 112 en 160 Bq·kg^{-1}) zijn boven de streefwaarde, maar vallen binnen het bereik van voorgaande jaren.

De jaargemiddelde totaal α-, ^{3}H-, ^{90}Sr-, ^{137}Cs- en ^{210}Po-activiteitsconcentraties in zeewater vallen binnen het bereik van voorgaande jaren. De jaargemiddelde rest β-activiteitsconcentratie in de Waddenzee Oost (180 mBq·L^{-1}) is de hoogste sinds 1999.

Gangbare waarden 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. De totaal α-activiteitsconcentratie gemiddeld per pompstation overschreed de grenswaarde van 0,1 Bq·L^{-1} bij vijf van de 186 pompstations.

De resultaten van het meetprogramma voor melk en voedsel zijn weergegeven in Tabel S1. Met ingang van 2008 zijn extra gegevens betreffende voedsel toegevoegd aan dit rapport. De additionele gegevens zijn afkomstig van RIKILT – Instituut voor Voedselveiligheid.
Gegevens betreffende milieumonsters genomen rondom de kerncentrale Borssele zijn weergegeven in Tabel S2. Nederland voldeed in 2008 aan alle Europese aanbevelingen, met uitzondering van de bepaling van ^{90}Sr in voedsel.

Table S1: Summary of the results of the Dutch monitoring program in 2008.
Tabel S1: Overzicht van de resultaten van het Nederlandse monitoringsprogramma in 2008.

Matrix	Parameter	Locations	Values	Frequency (per year)
Air dust (1)	Gross α	1	0.034 mBq·m^{-3}	53
	Gross β	1	0.437 mBq·m^{-3}	53
	^{7}Be	1	4.120 mBq·m^{-3}	53
	^{137}Cs	1	< 0.002 mBq·m^{-3}	53
	^{210}Pb	1	0.381 mBq·m^{-3}	53
Deposition (2)	Gross α	1	39.4 Bq·m^{-2}	12
	Gross β	1	106 Bq·m^{-2}	12
	^{3}H	1	102 - 1550 Bq·m^{-2} (3)	12
	^{7}Be	1	1990 Bq·m^{-2}	53
	^{137}Cs	1	0 - 7.63 Bq·m^{-2} (3)	53
	^{210}Pb	1	63 - 143 Bq·m^{-2} (3)	53
	^{210}Po	1	29.4 Bq·m^{-2} (3)	12
Surface water (1)	Gross α	6	48 - 290 mBq·L^{-1}	7 or 13 (4)
	Residual β	6	32 - 99 mBq·L^{-1}	7 or 13 (4)
	^{3}H	6	3000 - 22000 mBq·L^{-1}	6, 7 or 13 (4)
	^{90}Sr	3	1.9 - 3.6 mBq·L^{-1}	6 or 7 (4)
	^{226}Ra	4	2.9 - 9.0 mBq·L^{-1}	6 or 7 (4)
Suspended solids in surface water	^{60}Co	7	< 1 - 9.5 Bq·kg^{-1}	5, 7, 13 or 52 (4)
	^{131}I	7	< 1 - 17 Bq·kg^{-1}	5, 7, 13 or 52 (4)
	^{137}Cs	7	5.4 - 16.6 Bq·kg^{-1}	5, 7, 13 or 52 (4)
	^{210}Pb	4	94 - 160 Bq·kg^{-1}	5 or 7 (4)
Seawater (1)	Gross α	8	380 - 560 mBq·L^{-1}	4, 11 or 13 (4)
	Residual β	8	60 - 180 mBq·L^{-1}	4, 11 or 13 (4)
	^{3}H	8	280 - 5900 mBq·L^{-1}	4 or 13 (4)
	^{90}Sr	4	1.8 - 3 mBq·L^{-1}	4 or 13 (4)
Suspended solids in seawater	^{137}Cs	4	3.8 - 8 Bq·kg^{-1}	4 (4)
	^{210}Po	4	61 - 108 Bq·kg^{-1}	4 (4)

Continued on the next page.

Table S1: Continued.
Tabel S1: Vervolg.

Matrix	Parameter	Locations	Values	Frequency (per year)
Drinking water [1]	Gross α	186	< 0.1 $Bq \cdot L^{-1}$	361 [5]
	Gross β	187	< 0.2 $Bq \cdot L^{-1}$	444 [5]
	Residual β	173	< 0.2 $Bq \cdot L^{-1}$	404 [5]
	^{3}H	191	< 3.6 $Bq \cdot L^{-1}$	394 [5]
Milk [1]	^{40}K	26	48 $Bq \cdot L^{-1}$	966 [5]
	^{60}Co	26	< 1.4 $Bq \cdot L^{-1}$	966 [5]
	^{90}Sr	27	< 5 $Bq \cdot L^{-1}$	27 [5]
	^{131}I	26	< 0.6 $Bq \cdot L^{-1}$	966 [5]
	^{134}Cs	26	< 0.6 $Bq \cdot L^{-1}$	966 [5]
	^{137}Cs	26	< 0.5 $Bq \cdot L^{-1}$	966 [5]
Food [6, 7, 8]				
Grain	^{137}Cs	-	< 3.0 $Bq \cdot kg^{-1}$	80 (0) [9]
Vegetables	^{137}Cs	-	< 3.0 $Bq \cdot kg^{-1}$	118 (0) [9]
Fruit	^{137}Cs	-	< 3.0 $Bq \cdot kg^{-1}$	55 (0) [9]
Milk and dairy products	^{137}Cs	-	< 3.0 $Bq \cdot kg^{-1}$	64 (0) [9]
Meat and meat products	^{137}Cs	-	< 3.0 $Bq \cdot kg^{-1}$	84 (0) [9]
Game and poultry	^{137}Cs	-	< 3.0 $Bq \cdot kg^{-1}$	44 (0) [9]
Salads	^{137}Cs	-	< 3.0 $Bq \cdot kg^{-1}$	29 (0) [9]
Oil and butter	^{137}Cs	-	< 3.0 $Bq \cdot kg^{-1}$	44 (0) [9]
Honey	^{137}Cs	-	3 - 244 $Bq \cdot kg^{-1}$	123 (38) [9]
Food [6, 7, 10]				
Vegetables	^{137}Cs	-	< 0.5 $Bq \cdot kg^{-1}$	23 (0) [9]
Meat and meat products	^{137}Cs	-	< 0.5 $Bq \cdot kg^{-1}$	503 (0) [9]
Game and poultry	^{137}Cs	-	4.5 - 439 $Bq \cdot kg^{-1}$	171 (16) [9]
Salads	^{137}Cs	-	< 0.5 $Bq \cdot kg^{-1}$	128 (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 samples.
[7] = Samples were analysed for ^{134}Cs as well, but it was below the detection limit.
[8] = As measured by Food and Consumer Product Safety Authority.
[9] = Total number of samples taken. Number of positive samples between brackets.
[10] = As measured by RIKILT – Institute of Food Safety.

Table S2: Summary of the results of the monitoring program in the vicinity of the nuclear power plant at Borssele in 2008.
Tabel S2: Overzicht van de resultaten van het monitoringsprogramma in de nabijheid van Kerncentrale Borssele in 2008.

Matrix	Parameter	Locations	Values [1]	Frequency (per year)
Air dust	Gross α	5	0.010 - 0.218 $mBq \cdot m^{-3}$	12
	Gross β	5	0.10 - 0.624 $mBq \cdot m^{-3}$	12
	^{60}Co	5 [2]	< 0.04 - < 0.10 $mBq \cdot m^{-3}$	12
	$^{131}I_{el}$ [3]	5 [2]	< 0.1 - < 0.7 $mBq \cdot m^{-3}$	12
	$^{131}I_{or}$ [3]	5 [2]	< 0.2 - < 0.5 $mBq \cdot m^{-3}$	12
	^{137}Cs	5 [2]	< 0.03 - < 0.07 $mBq \cdot m^{-3}$	12
	Nat. [4]	5 [2]	1.23 - 3.1 $mBq \cdot m^{-3}$	12
Grass	^{60}Co	5 [2]	< 1 - < 5 $Bq \cdot kg^{-1}$	12
	^{131}I	5 [2]	< 1 - < 6 $Bq \cdot kg^{-1}$	12
	^{137}Cs	5 [2]	< 1 - < 4 $Bq \cdot kg^{-1}$	12
Soil	^{54}Mn	4	< 0.3 $Bq \cdot kg^{-1}$	1
	^{60}Co	4	< 0.3 - < 0.4 $Bq \cdot kg^{-1}$	1
	^{134}Cs	4	< 0.3 - < 0.4 $Bq \cdot kg^{-1}$	1
	^{137}Cs	4	0.86 - 2.03 $Bq \cdot kg^{-1}$	1
Water	Residual β	4	0.021 - 0.134 $Bq \cdot L^{-1}$	12
	^{3}H	4	7.0 - 9.9 $Bq \cdot L^{-1}$	12
Suspended solids	Gross β	4	0.42 - 1.59 $kBq \cdot kg^{-1}$	12
Seaweed	^{60}Co	4 [2]	< 0.6 - < 5 $Bq \cdot kg^{-1}$	12
	^{131}I	4 [2]	< 0.4 - < 4 $Bq \cdot kg^{-1}$	12
	^{137}Cs	4 [2]	0.91 - < 3 $Bq \cdot kg^{-1}$	12
Sediment	^{60}Co	4 [2]	< 0.2 - < 0.5 $Bq \cdot kg^{-1}$	12
	^{131}I	4 [2]	< 0.1 - < 0.3 $Bq \cdot kg^{-1}$	12
	^{137}Cs	4 [2]	0.70 - 1.43 $Bq \cdot kg^{-1}$	12

[1] = Given range represents values of individual samples.
[2] = Analysis is performed on a combined sample of the monthly samples of all four or five locations.
[3] = Elemental respectively organically bound ^{131}I.
[4] = Natural occurring γ-emmitters.

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 of levels of radiation under normal circumstances and enables the confirmation of abnormal levels. In this report results are presented of radioactivity measurements in the environment in the Netherlands. The aim of this report is threefold. Firstly, it presents a survey of measurements on radioactivity in the Dutch environment under normal circumstances in 2008. Secondly, it is aimed at determining compliance of monitoring programs in the Netherlands with the EU recommendation and at reporting omissions. Thirdly, it is the Dutch national report on radioactivity in the environment to the EU and to other Member States.

The definition used in this report for the residual β-activity is the total β-activity (gross β-activity) minus the β-activity of ^{40}K. A glossary is given of frequently occurring terms in Appendix C.
In the chapters, the results will be presented in graphs and tables. More detailed tables are presented in Appendix A. Chapters 2 to 8 have been 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 are presented in chapter 10.

2. Airborne particles

The monitoring program for determining radioactive nuclides in air dust is given in Table 2.1. The sampling was done on the RIVM premises in Bilthoven. 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 is 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 is 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 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 2008 are within the range of the results from the period 1992-2007 as is illustrated in Figure 2.4. Since 2007 a new (more realistic) calibration for gross α has been implemented. This new calibration is 1.4 times higher than the one for previous years, which results in lower reported gross α-activities.

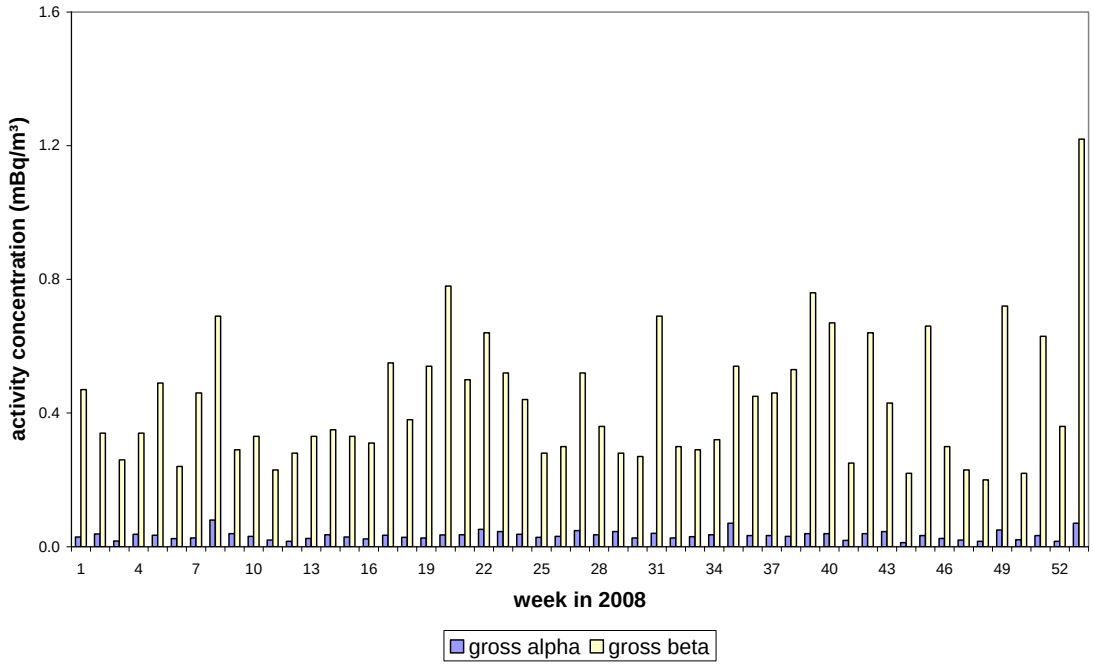


Figure 2.1: Weekly averaged gross α- and β-activity concentrations of long-lived nuclides in air dust sampled at RIVM.

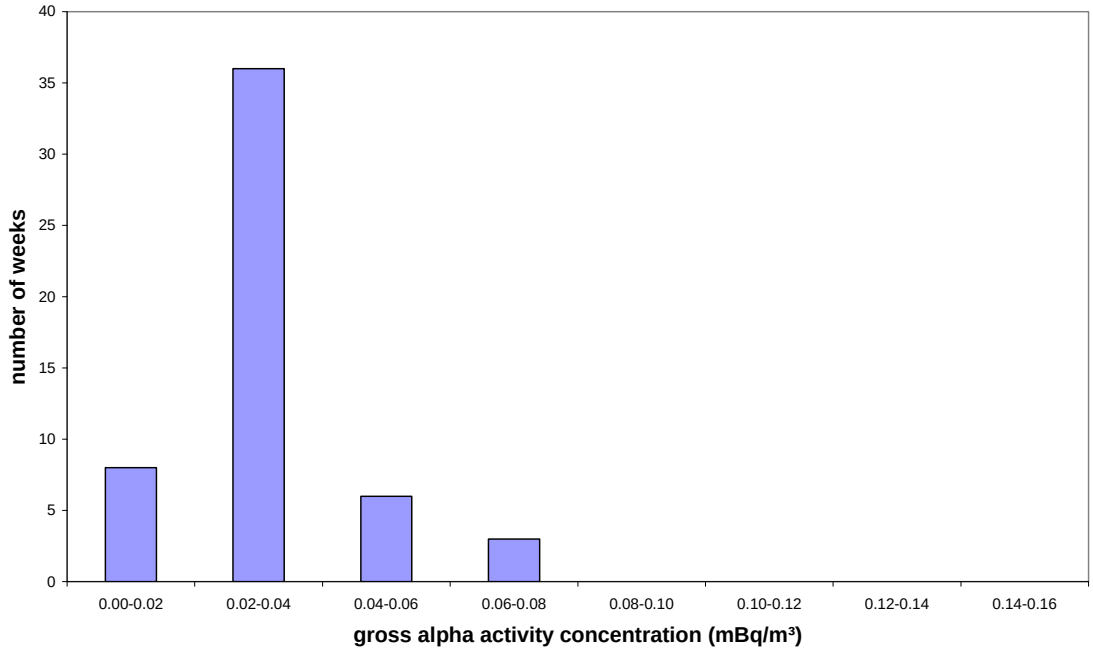


Figure 2.2: Frequency distribution of gross α-activity concentration of long-lived nuclides in air dust collected weekly in 2008. The yearly average is 0.034 (SD=0.013) mBq·m^{-3}. SD is the standard deviation and illustrates the variation in weekly averages during the year.

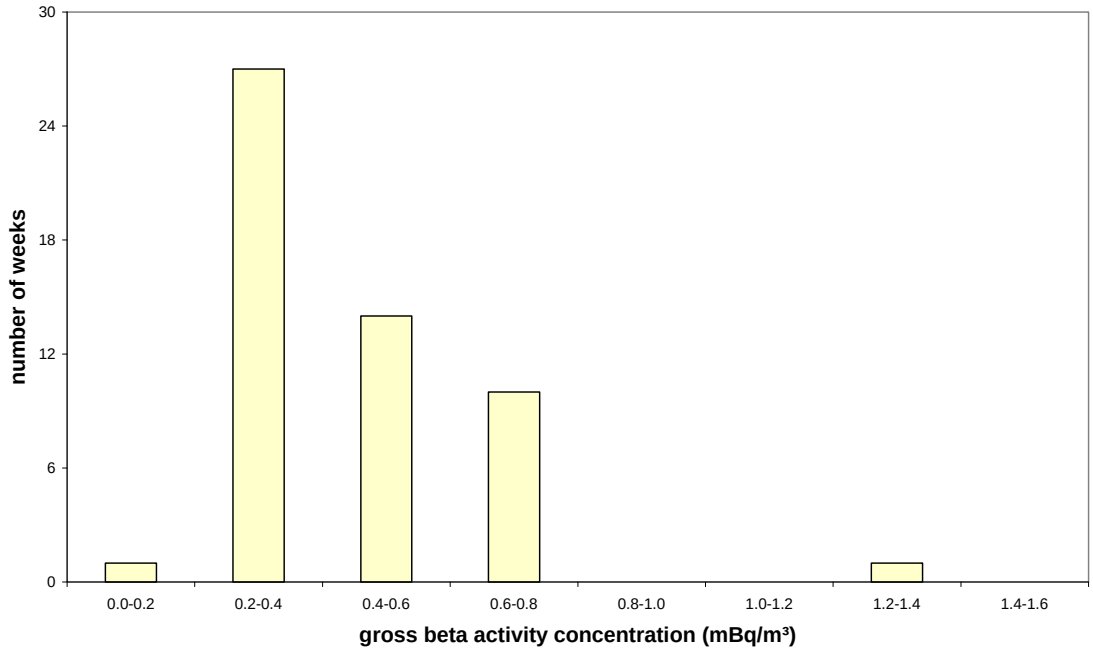


Figure 2.3: Frequency distribution of gross β-activity concentration of long-lived nuclides in air dust collected weekly in 2008. The yearly average is 0.437 ± 0.007 (SD=0.19) mBq·m^{-3}.

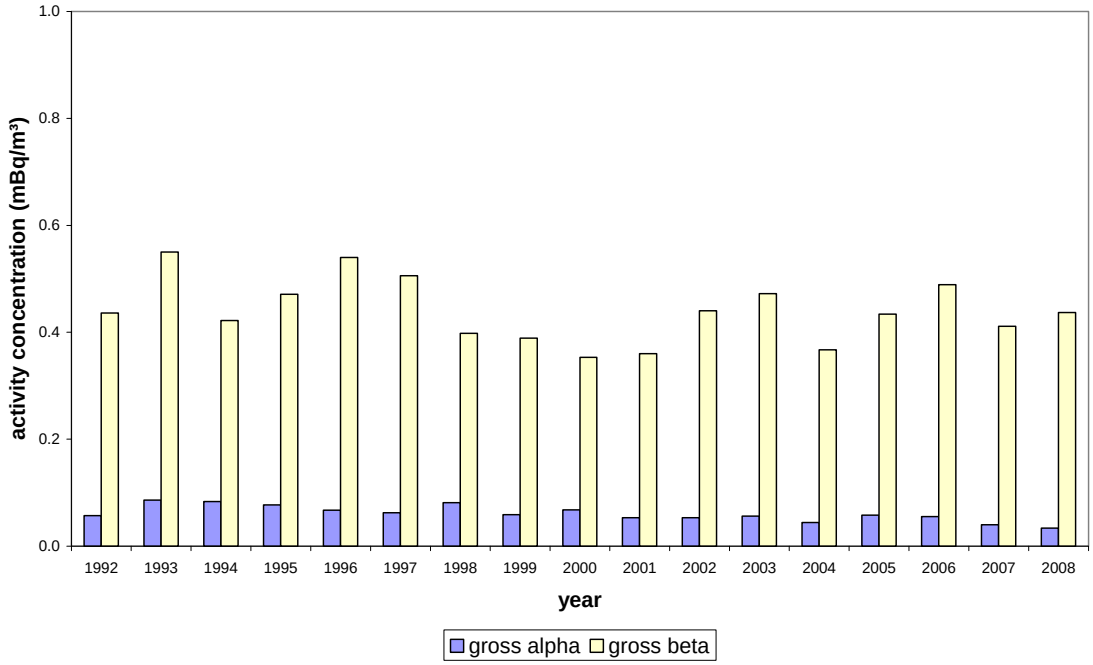


Figure 2.4: Yearly averaged gross α- and gross β-activity concentrations of long-lived nuclides in air dust at RIVM in 1992-2008.

2.2 γ-emitting nuclides

The detection limits for the nuclides considered in the gammaspectroscopic analysis of the HVS-samples are given in Table A2. The only nuclides that could be detected were ^{7}Be (53 times) and ^{210}Pb (53 times). The results are presented in Table A3, Figures 2.5, 2.6 and 2.7. Since late 1999, the detection limit of ^{137}Cs is higher (2.0 μBq·m^{-3}) than during 1991-1999 (0.1 μBq·m^{-3} [7]), due to a different detector set-up.

The behaviour of ^{7}Be in the atmosphere has been studied world-wide [8, 9, 10, 11, 12, 13, 14]. Natural ^{7}Be (half-life 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, with the remaining 30% being produced in the troposphere. A residence time is estimated at 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 stratosphere and 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 maximum at 1997 and the minimum at 2000-2002 are consistent with the solar minimum (measured by radio flux and sunspot count) of 1996-1997 and the solar maximum of 2000-2002 [15]. In the summer of 1991 two severe geomagnetic storms caused a significant world-wide disturbance of earth's geomagnetic field. This resulted in a considerable decrease in cosmogenic radiation, unprecedented in at least the previous four decades [16]. The absence of a 1991 summer peak in the ^{7}Be-activity concentration can be explained by the decrease in cosmogenic radiation. The concentrations found for ^{7}Be in 2008 fit in the pattern described above. The solar minimum of Solar Cycle 24 occurred in December 2008 which corresponds with a maximum in ^{7}Be-activity concentration.

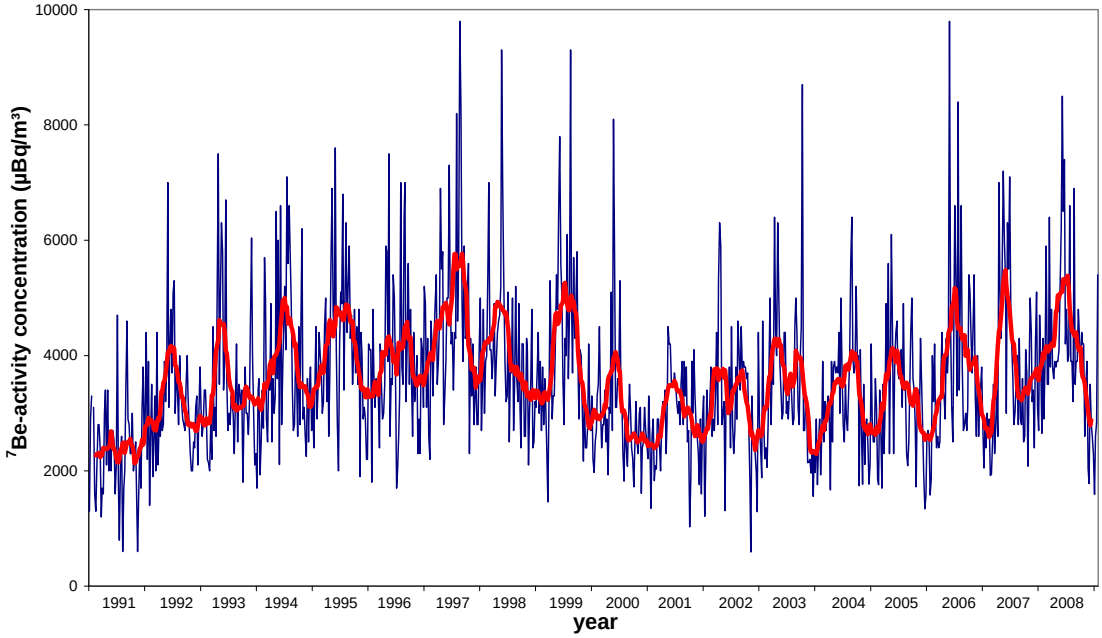


Figure 2.5: Weekly averaged ^{7}Be-activity concentrations (blue) in air dust at RIVM in 1991-2008. The red line is a moving average of 13 weeks. The yearly average for 2008 is 4120 ± 50 (SD=1400) µBq·m^{-3}.

The nuclide ^{137}Cs (half-life 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 already 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 [17]. 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 and a strong eastern wind [18]. On the 29th of May 1998 an incident occurred at Algeciras (Spain), an iron foundry melted a ^{137}Cs-source concealed in scrap metal [19]. As a result elevated levels of airborne ^{137}Cs-activity were measured in France, Germany, Italy and Switzerland during late May and early June. Figure 2.6 shows a slightly elevated level of ^{137}Cs-activity (second peak) around the same period (29th of May until 5th of 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 already deposited dust especially during a strong wind from the continent [19].

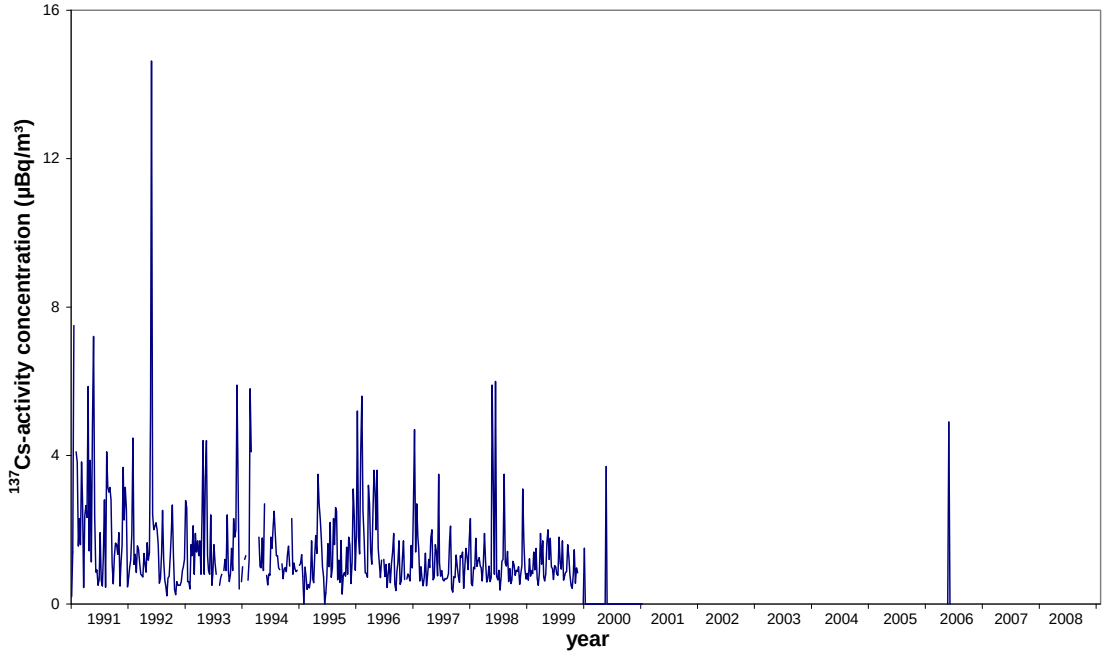


Figure 2.6: Weekly averaged ^{137}Cs-activity concentrations in air dust at RIVM in 1991-2008. All measurements were below the detection limit in 2008. From 2000 onwards the detection limit was higher than during 1991-1999, due to a different detector set-up.

The primary source of atmospheric ^{210}Pb (half-life 22.3 years) is the decay of ^{222}Rn exhaled from continental surfaces. Therefore, the atmospheric concentration of ^{210}Pb over the continental areas is in general higher than that over the oceanic ones (^{222}Rn exhalation from the ocean is 1000 times less than that from the continents). The reported reference value of ^{210}Pb in air dust is 500 µBq·m^{-3} [20]. In the atmosphere this radionuclide is predominantly associated with submicron-sized aerosols [21, 22]. The mean aerosol (carrying ^{210}Pb) residence time in the troposphere is approximately five days [23].

Other sources of ^{210}Pb in air dust are volcanic activity and industrial emissions [24, 25, 26, 27, 28]. Examples of industrial emissions are discharges of power plants using fossil fuels, fertiliser and phosphorus industries, and exhaust gases of traffic. In the Netherlands the emission of power plants is only of local importance regarding ^{210}Pb deposition. The emission by other industries contributes a significant part of the yearly total ^{210}Pb deposition [26].Volcanic eruptions bring U-decay products in the atmosphere like ^{226}Ra, ^{222}Rn, ^{210}Pb and ^{210}Po. Beks et al. [26] estimate that volcanoes contribute 60 TBq·year^{-1} to the atmospheric ^{210}Pb stock. If the volcanic deposition is evenly distributed world-wide, 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] and resuspension of (local) dust. The unusual value of week 45 in 2002 (3000 ± 300 µBq·m^{-3}) can not be explained by these natural sources [32].

Except for week 45 in 2002 there is a good correlation between activity concentrations of ^{210}Pb and activity concentrations of gross β, as is the case in 2008 (Figure 2.8). The weekly averaged activity concentrations of ^{210}Pb in 2008 are within range of those found in previous years.

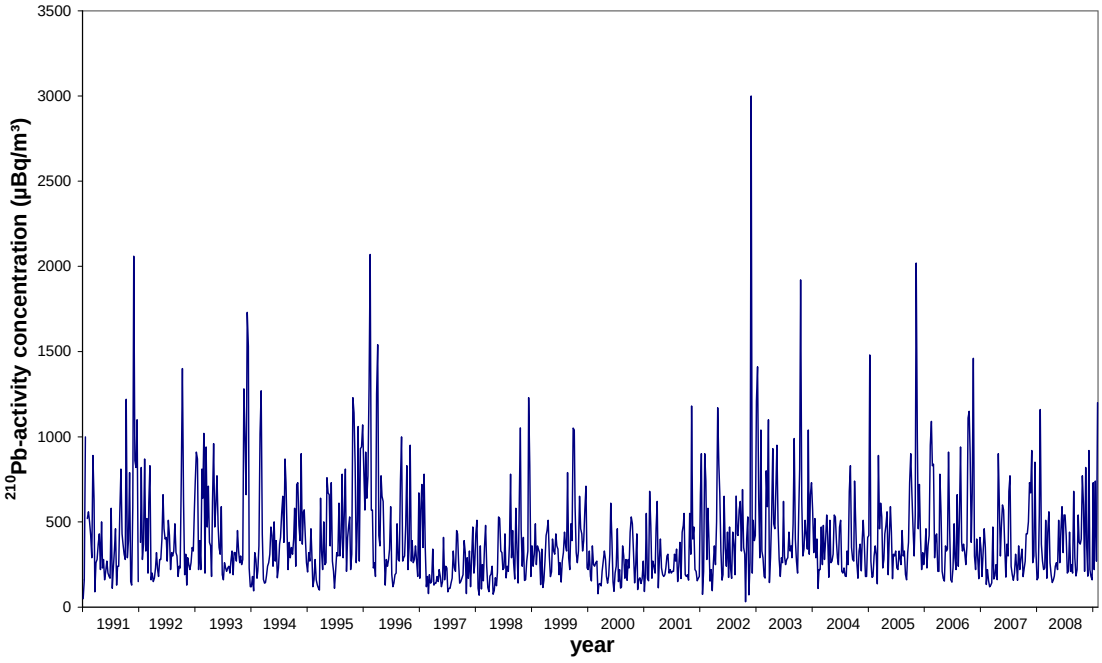


Figure 2.7: Weekly averaged ^{210}Pb-activity concentrations in air dust at RIVM in 1991-2008. The yearly average for 2008 is 381 ± 6 (SD=200) µBq·m^{-3}.

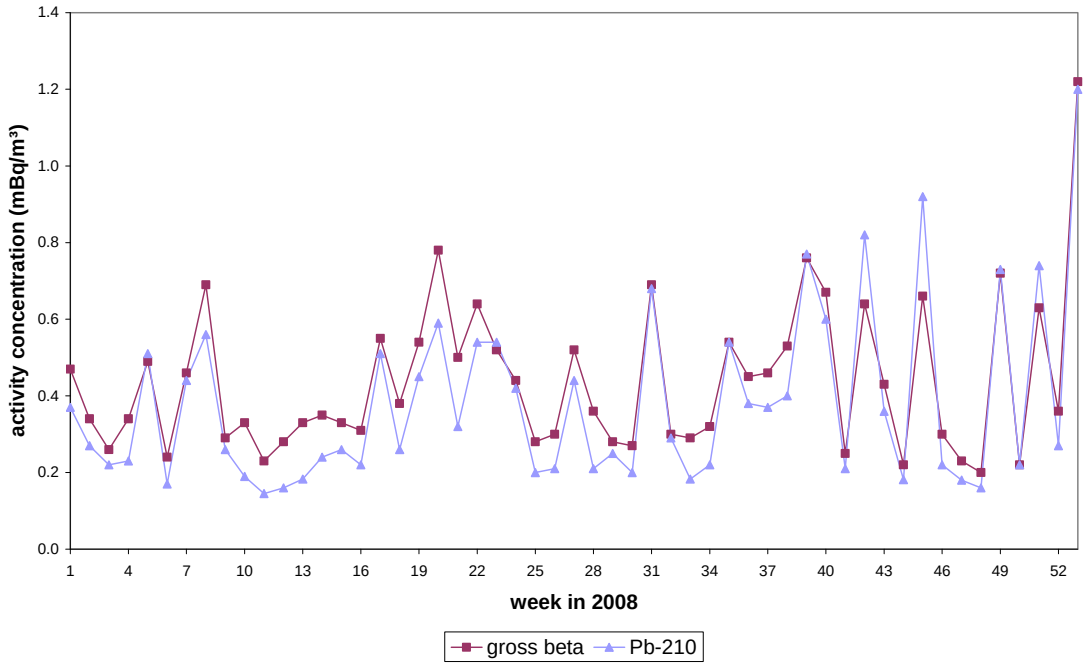


Figure 2.8: Correlation between weekly averaged gross β- and ^{210}Pb-activity concentrations in air dust at RIVM.

3. Deposition

The monitoring program for determining radioactive nuclides in deposition is given in Table 3.1. Sampling was done on the RIVM premises in Bilthoven. Samples were collected weekly for γ-emitters and monthly in case of 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 was 39.4 ± 1.5 and 106 ± 3 $Bq \cdot m^{-2}$, 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 2008, the yearly total deposition of ^{3}H ranged between 102 and 1550 $Bq \cdot m^{-2}$ (68% confidence level). The yearly total consists of twelve samples. Ten out of twelve measurements were below the detection limit. Therefore, detection limits were used for the contribution to the yearly total. The range of 2008 does not differ significantly from those measured since 1993, as illustrated in Figure 3.5 and Table A5. Until 1998, samples were electrolytic enriched before counting, which resulted in a much lower detection limit than that after 1997.

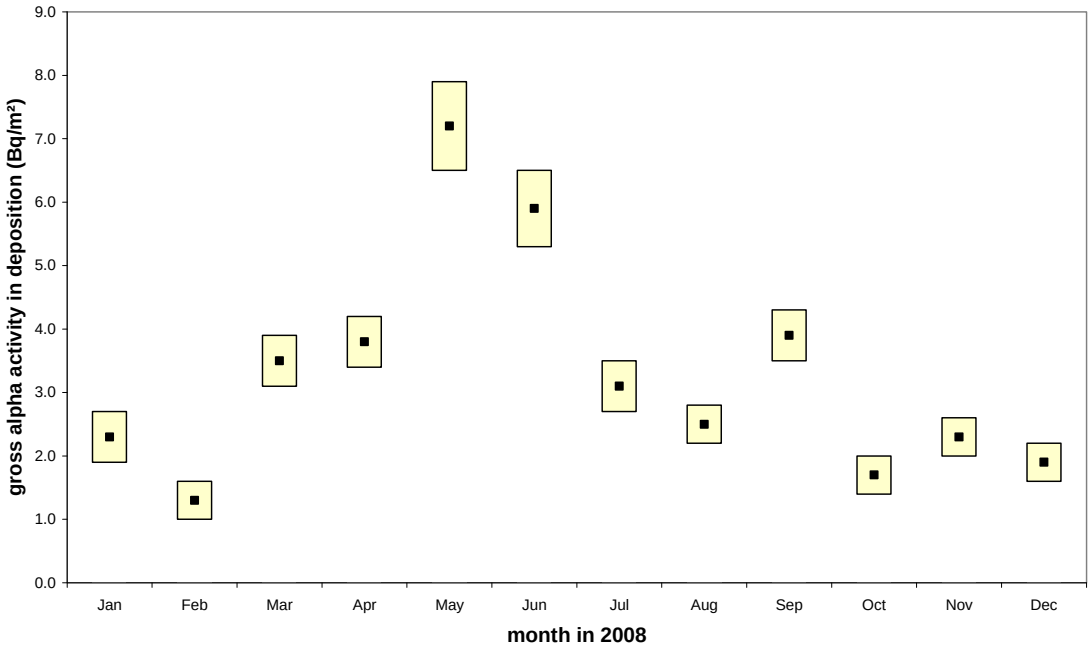


Figure 3.1: Monthly deposited gross α-activity of long-lived nuclides at RIVM. Given are monthly averages (black dot) with a 68% confidence range (colored bar).

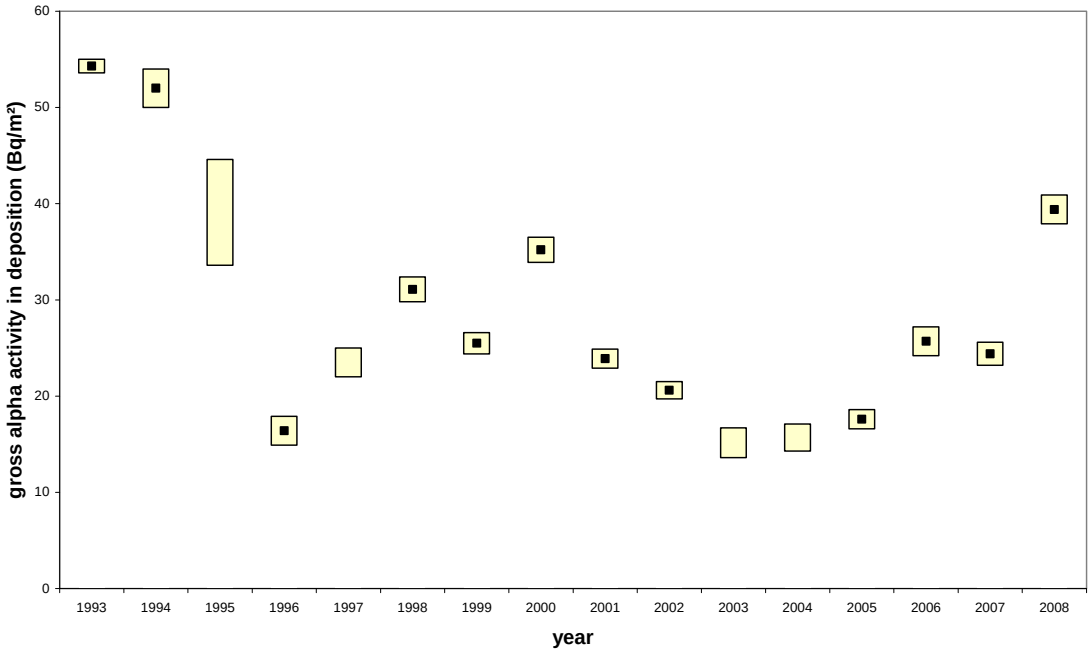


Figure 3.2: Yearly gross α-activity of long-lived nuclides deposited at RIVM from 1993 to 2008. Given are yearly averages (black dot) with a 68% confidence range (colored bar). Solely a 68% confidence range is given if the yearly result is made up of at least one detection limit.

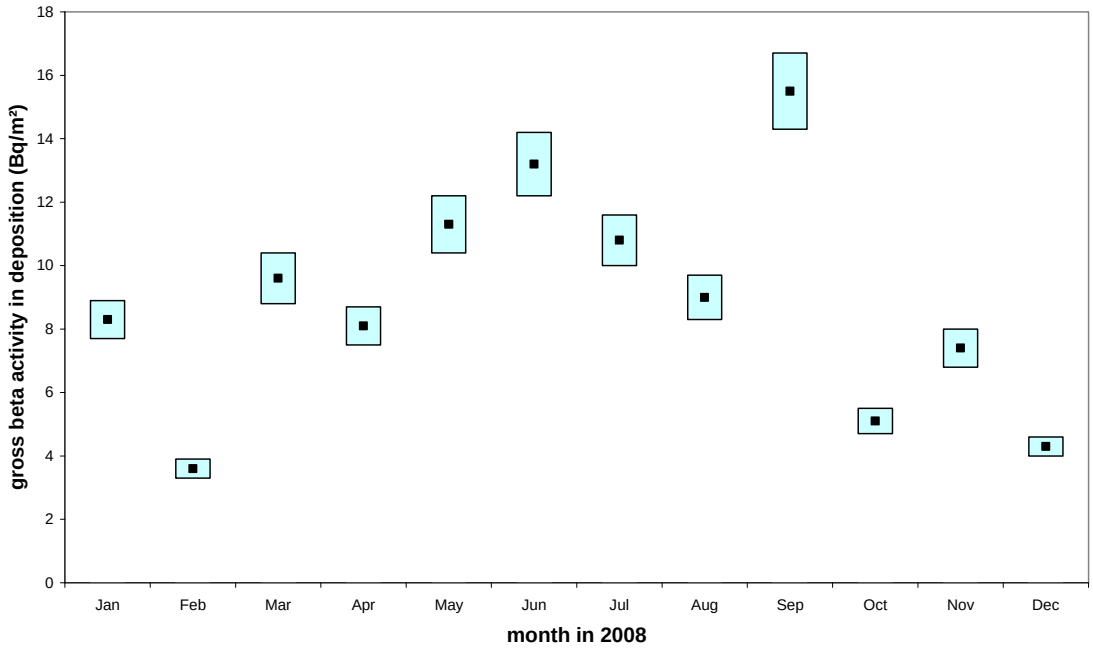


Figure 3.3: Monthly deposited gross β-activity of long-lived nuclides at RIVM. Given are monthly averages (black dot) with a 68% confidence range (colored bar).

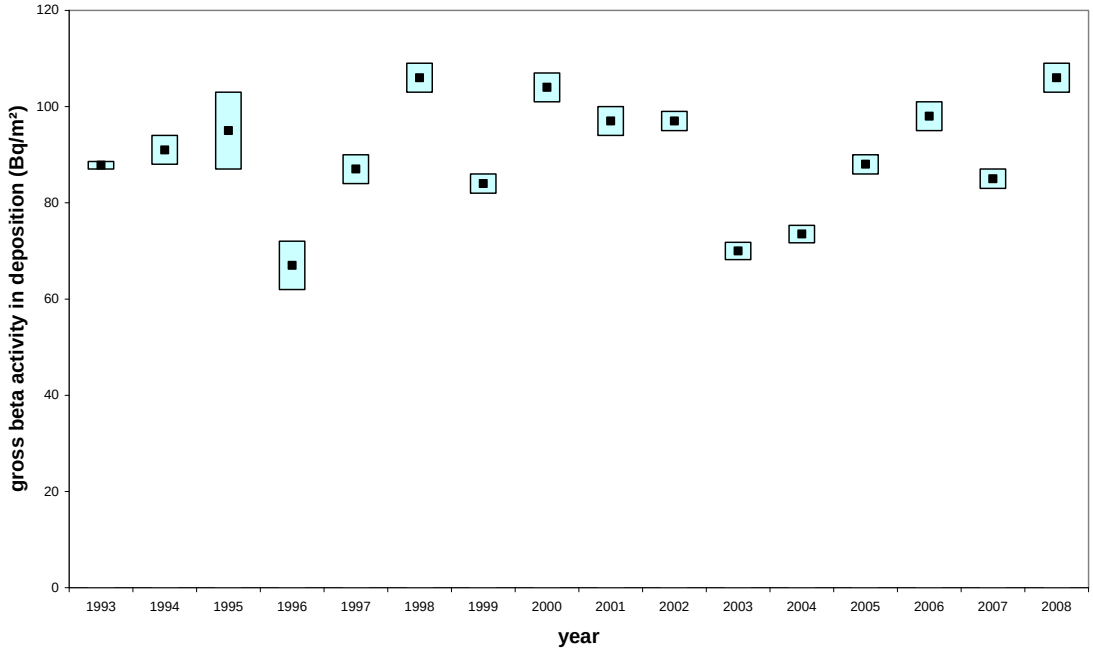


Figure 3.4: Yearly gross β-activity of long-lived nuclides deposited at RIVM from 1993 to 2008. Given are yearly averages (black dot) with a 68% confidence range (colored bar).

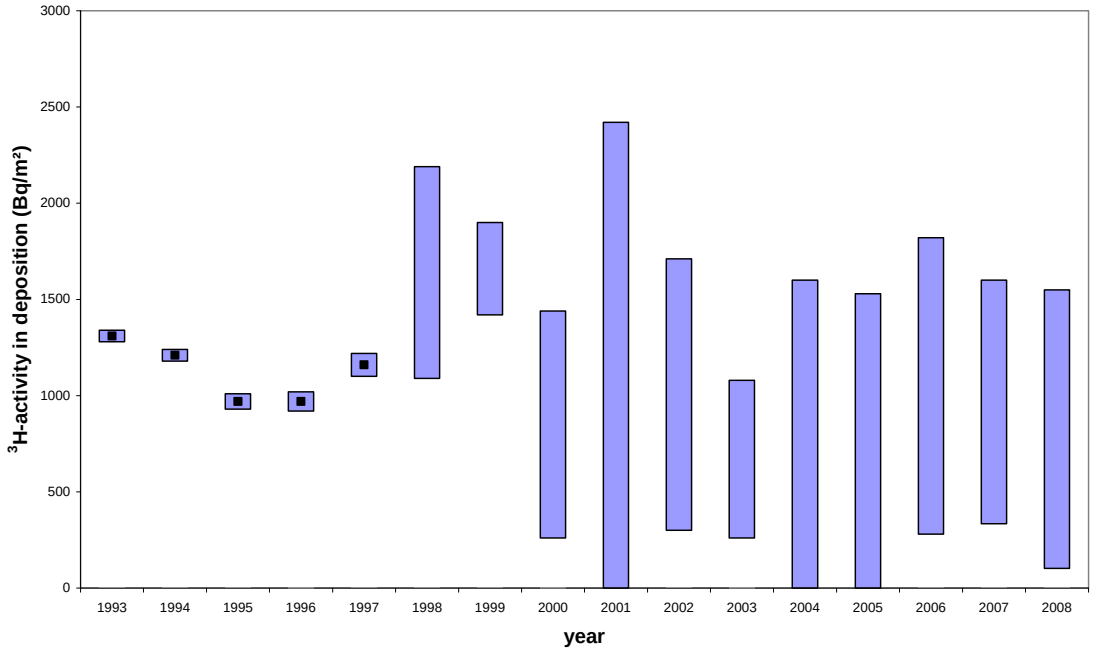


Figure 3.5: Yearly deposition of ^{3}H at RIVM from 1993 to 2008. Given are yearly averages (black dot) with a 68% confidence range (colored bar). Solely a 68% confidence range is given if the yearly result is made up of at least one detection limit.

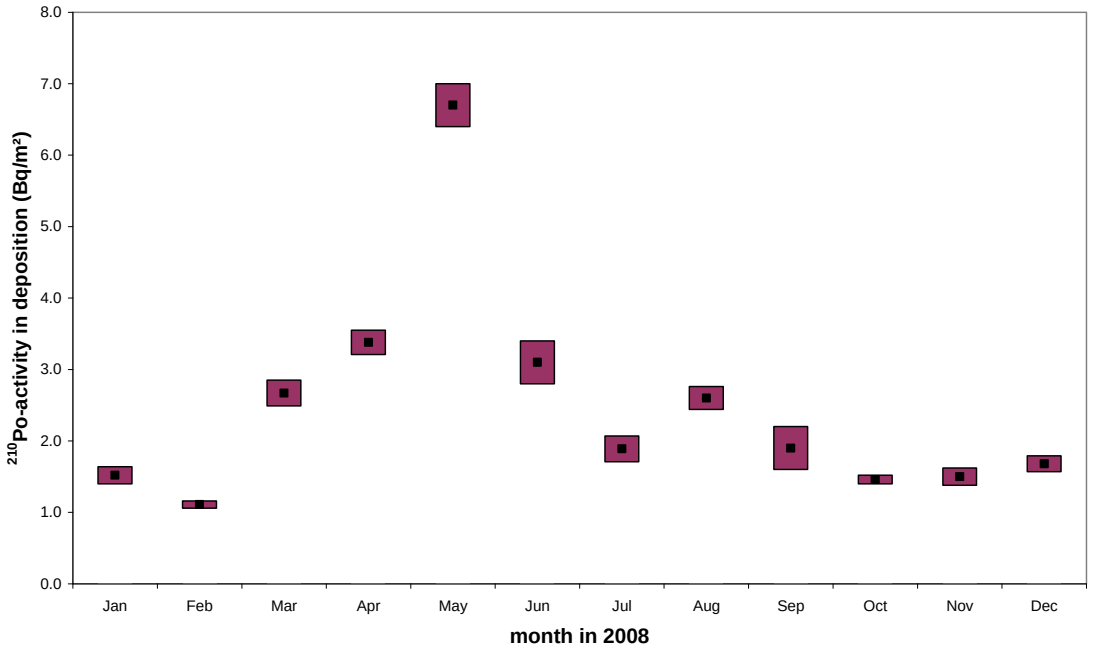


Figure 3.6: Monthly deposited ^{210}Po-activity at RIVM. Given are monthly averages (black dot) with a 68% confidence range (colored bar).

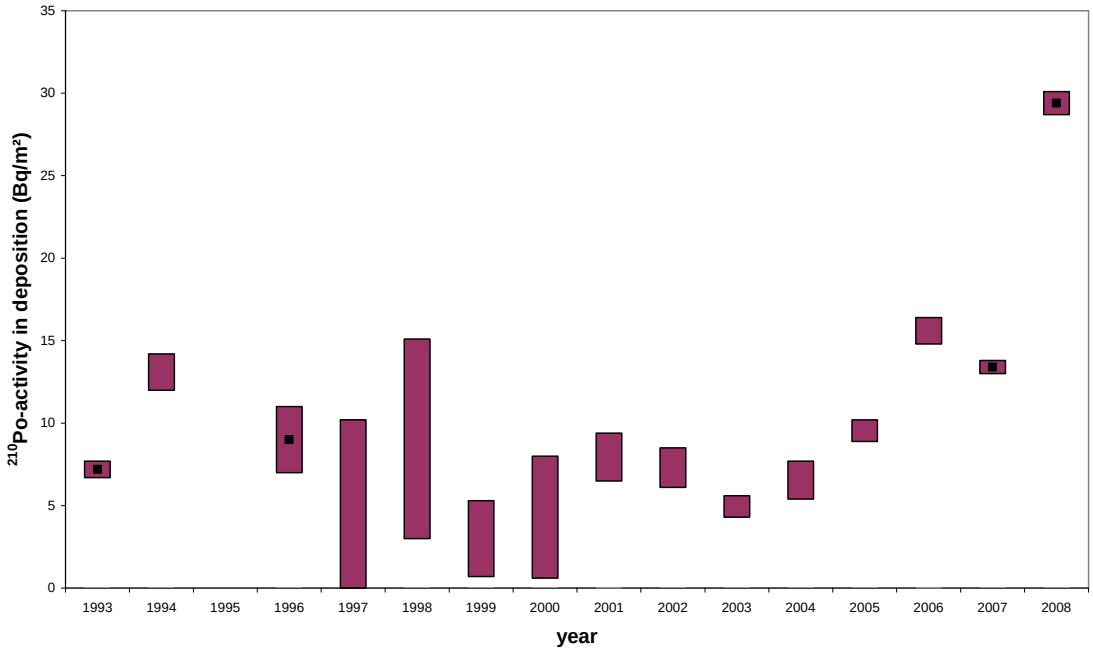


Figure 3.7: Yearly ^{210}Po-activity deposited at RIVM from 1993 to 2008. Given are yearly averages (black dot) with a 68% confidence range (colored bar). Solely a 68% confidence range is given if the yearly result is made up of at least one detection limit.

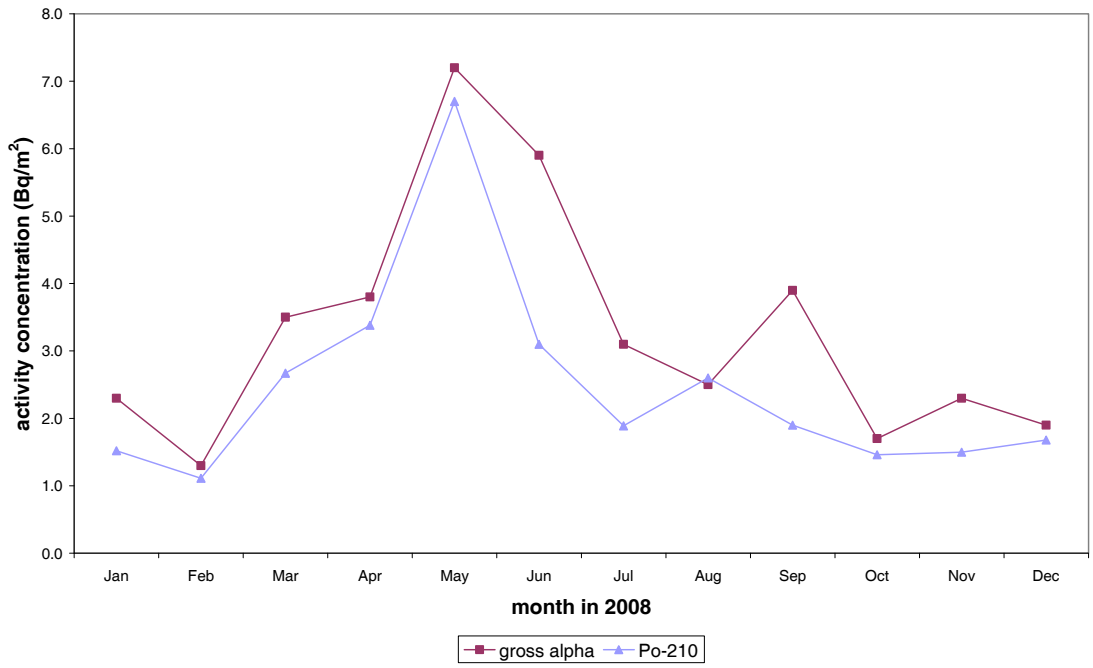


Figure 3.8: Correlation between monthly averaged gross α- and ^{210}Po-activity concentrations in deposition at RIVM.

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 2008 was 29.4 ± 0.7 Bq·m^{-2} (68% confidence level). This is the highest yearly total since 1993. Gross α-activity in deposition also shows an elevated yearly total but not as evident as ^{210}Po.

The elevated level in May might be explained by Saharan dust which was deposited throughout the Netherlands during the end of May [33, 34]. The elevated level of ^{210}Po is in good correlation with the elevated level of gross α 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 53 and respectively 18 out of 53 samples. The yearly total deposition of ^{7}Be is 1990 ± 40 Bq·m^{-2}. The yearly total deposition of ^{210}Pb ranged between 63 and 143 Bq·m^{-2} (68% confidence level). The nuclide ^{137}Cs was detected in none of 53 samples (detection limit is about 0.1 Bq·m^{-2}). The yearly total deposition of ^{137}Cs ranged between 0 and 7.63 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, Figure 3.10, 3.11 and 3.13.

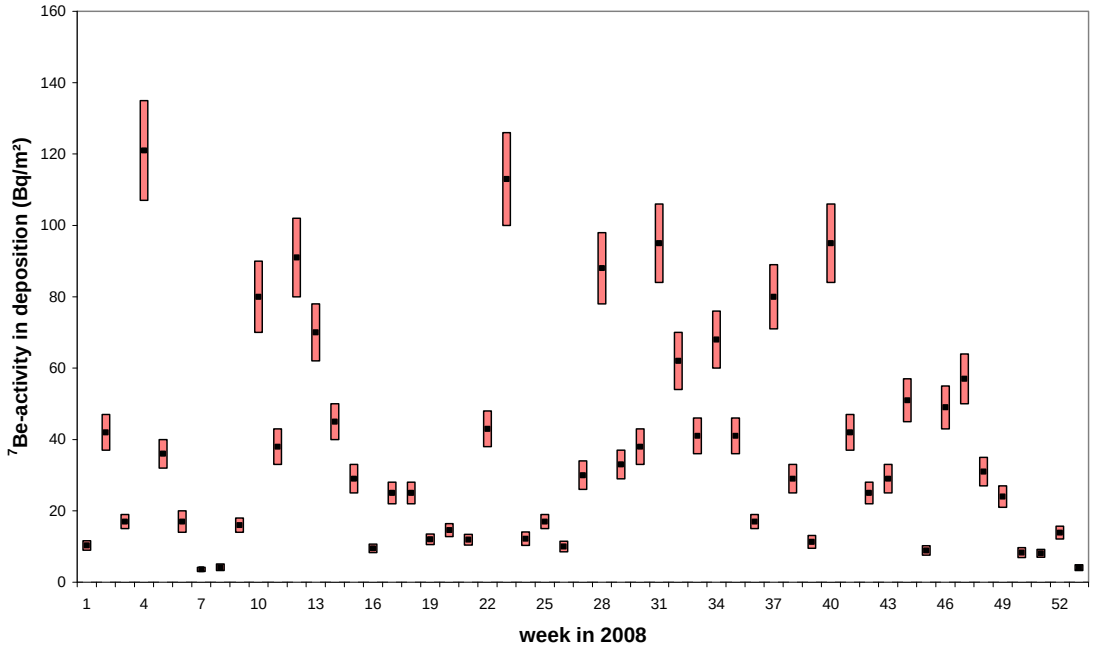


Figure 3.9: Weekly deposited ^{7}Be-activity at RIVM. Given are weekly averages (black dot) with a 68% confidence range (colored bar).

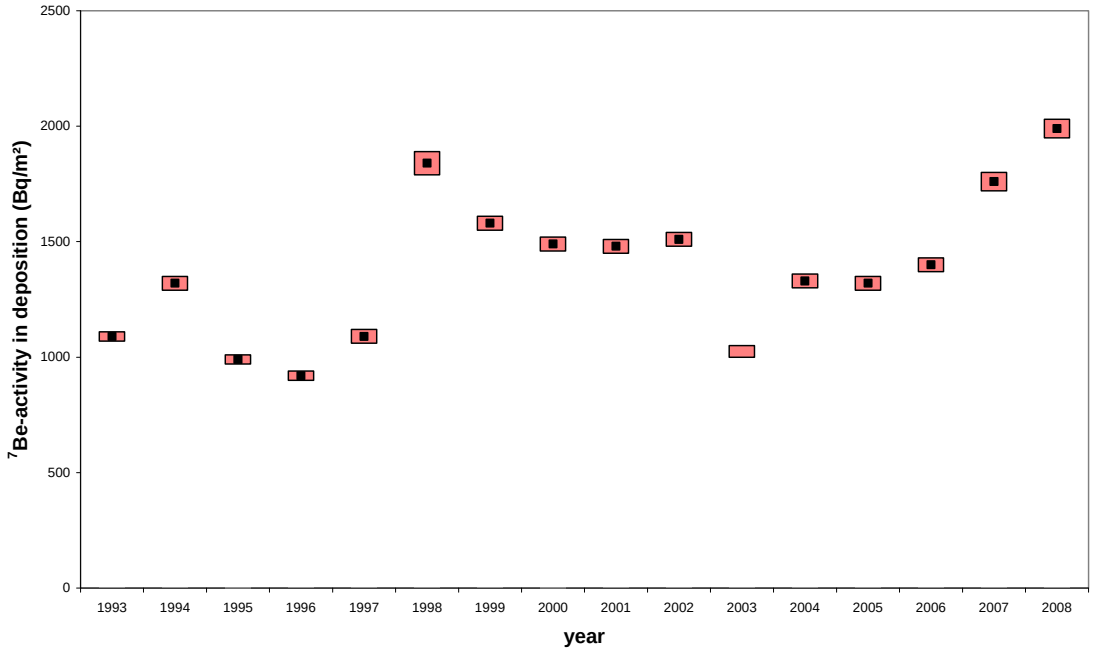


Figure 3.10: Yearly ^{7}Be-activity deposited at RIVM from 1993 to 2008. Given are yearly averages (black dot) with a 68% confidence range (colored bar). Solely a 68% confidence range is given if the yearly result is made up of at least one detection limit.

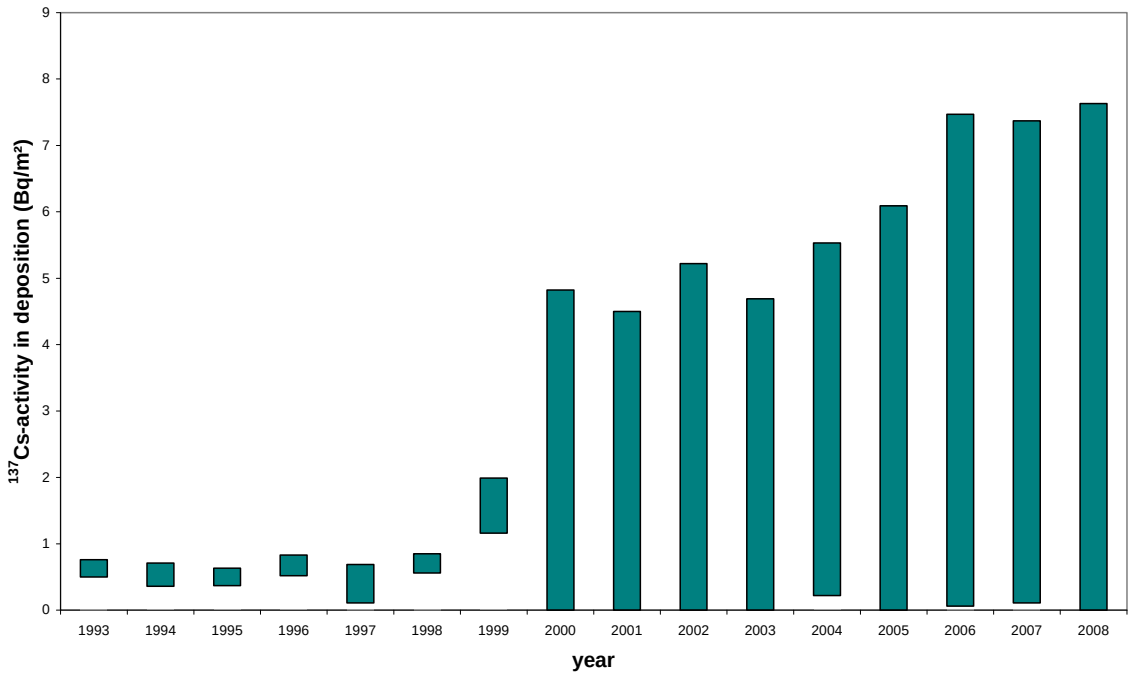


Figure 3.11: Yearly ^{137}Cs-activity deposited at RIVM from 1993 to 2008. Given are yearly averages, solely a 68% confidence range is given since the yearly result is made up of at least one detection limit. Since 2000 the detection limit is higher than during 1993-1999, due to a different detector set-up.

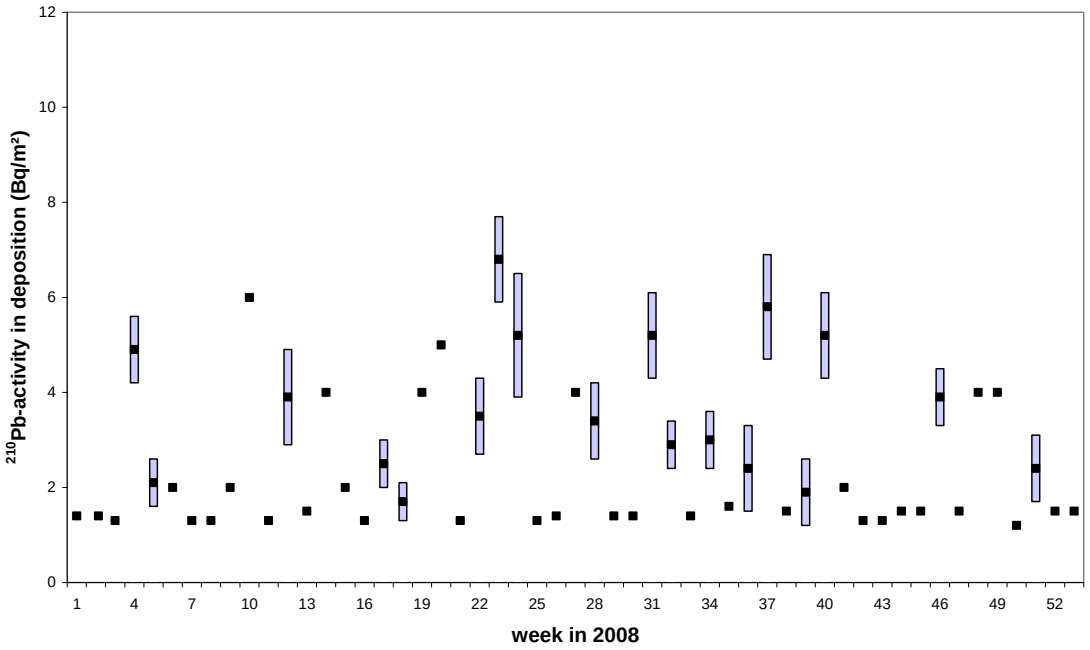


Figure 3.12: Weekly deposited ^{210}Pb-activity at RIVM. Given are weekly averages (black dot) with a 68% confidence range (colored bar). Solely a black dot is given if the result is a detection limit.

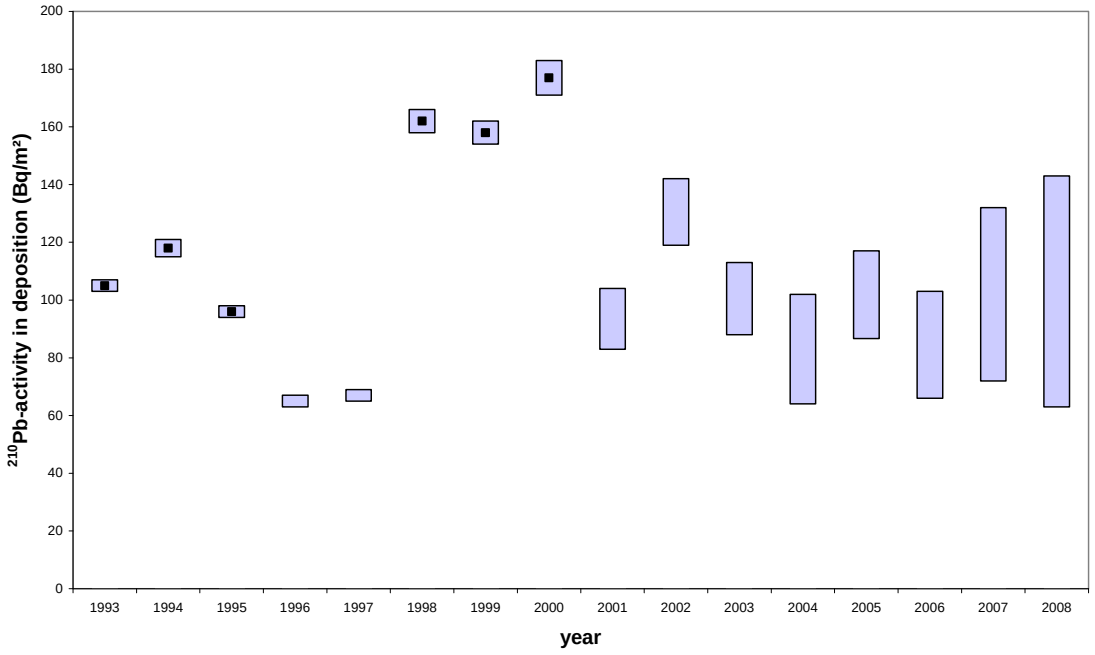


Figure 3.13: Yearly ^{210}Pb-activity deposited at RIVM from 1993 to 2008. Given are yearly averages (black dot) with a 68% confidence range (colored bar). Solely a 68% confidence range is given if the yearly result is made up of at least one detection limit.

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 14 aerosol monitors for determining gross α- and artificial β-activity concentrations and 153 ambient dose equivalent rate monitors [35]. The 14 sites with an aerosol monitor are also equipped with a dose equivalent rate monitor. These 14 dose equivalent rate monitors are differently placed from the 153 dose equivalent rate monitors with regard to height (3.5 meter versus 1 meter above ground level) and surface covering. Therefore, results can differ between the two types of monitors [36]. Hence, these 14 dose equivalent rate monitors are not taken into account for 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 reports about 20% higher values than the FAG monitor [37]. The estimated random uncertainty for both types of monitor is about 20%. No correction is applied for the difference in the gross α-activity concentration between the Berthold and FAG monitor.

The data presented in this chapter are based on ten-minute measurements. Averages over the year are calculated per location using daily averages from the ten-minute measurements (Tables A9 and A10). The data on external radiation, expressed in ambient dose equivalent, contain a systematic uncertainty because of an overestimation of the cosmogenic dose rate and an underestimation of the terrestrial dose rate. Based upon earlier research [36, 38] it is assumed that the ambient dose equivalent rate is overestimated by 5 to 10 $nSv.h^{-1}$. However, NMR data are not corrected for these response uncertainties.

In Figures 4.1 and 4.3, an impression has been constructed of the spatial variation in the yearly averages of the NMR data 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 2008, while Figure 4.4 presents the yearly averages of ambient dose equivalent rate from 1996 to 2008. In 2008 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 with data before 2002 it should be noted that the Berthold values are 20% higher than FAG values, and the value can be corrected to 2.5 $Bq \cdot m^{-3}$. This value is within the range of those in previous years at the low end of that range. The yearly average of the calculated artificial β-activity concentration does not deviate significantly from zero.

Between 1996 and 2003 the analysis of the ambient dose equivalent rate has been based on a set of 163 stations. From 2004 onwards, the analysis of the ambient dose equivalent rate has been based on the set of 153 stations, 10 stations have been dismantled. The yearly averaged ambient dose equivalent rate in 2007 is calculated using 150 stations. The remaining 3 stations were not operational.

For the ambient dose equivalent rate the yearly averaged measured value was 73.8 $nSv.h^{-1}$ in 2008. It is assumed that this value is an overestimate of 5 to 10 $nSv.h^{-1}$. 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) during 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).

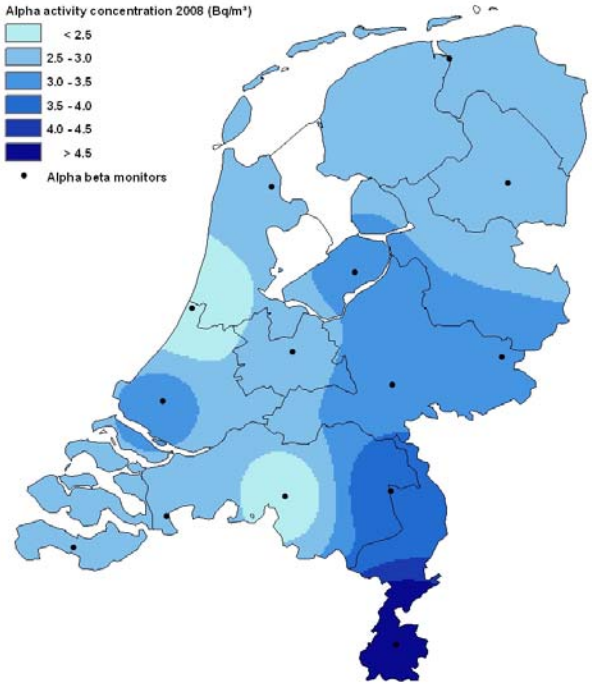


Figure 4.1: Spatial variation in the average gross α-activity concentration of (mainly) short-lived nuclides in air dust. The dots represent the locations of the aerosol monitors.

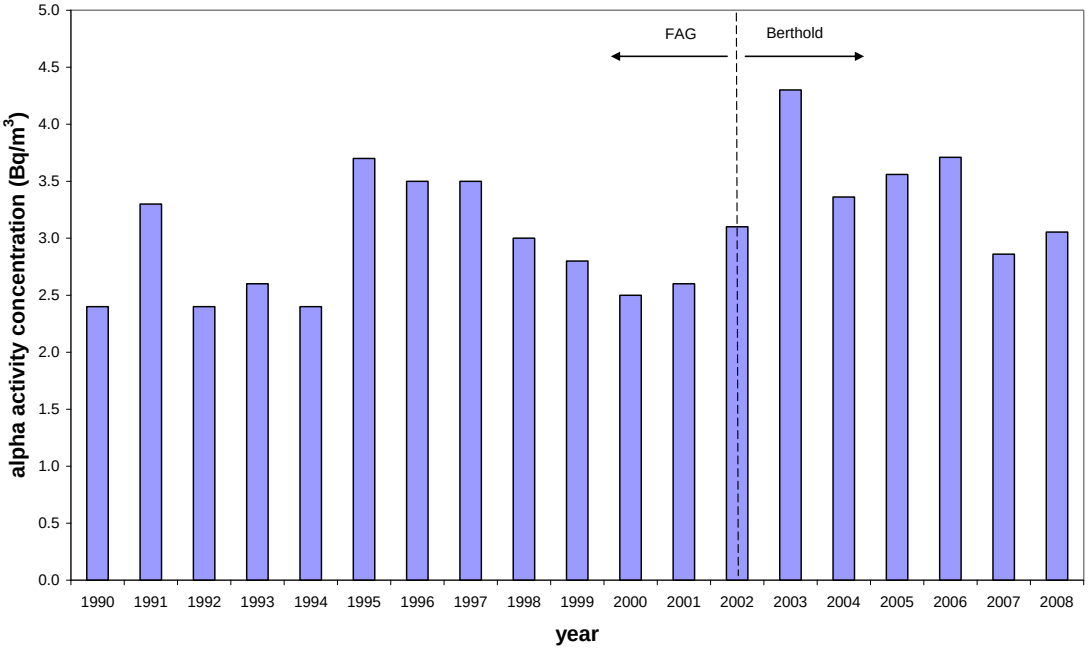


Figure 4.2: Yearly averaged gross α-activity concentration of (mainly) short-lived nuclides in air dust. During the second half of 2002 the FAG monitors were gradually replaced by the Berthold monitors.

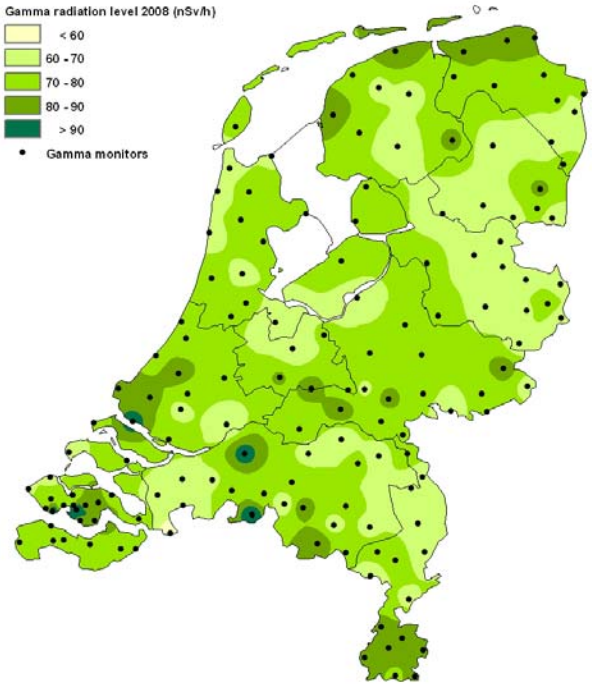


Figure 4.3: Spatial variation in the average ambient dose equivalent rate. The dots represent the locations of the dose equivalent rate monitors.

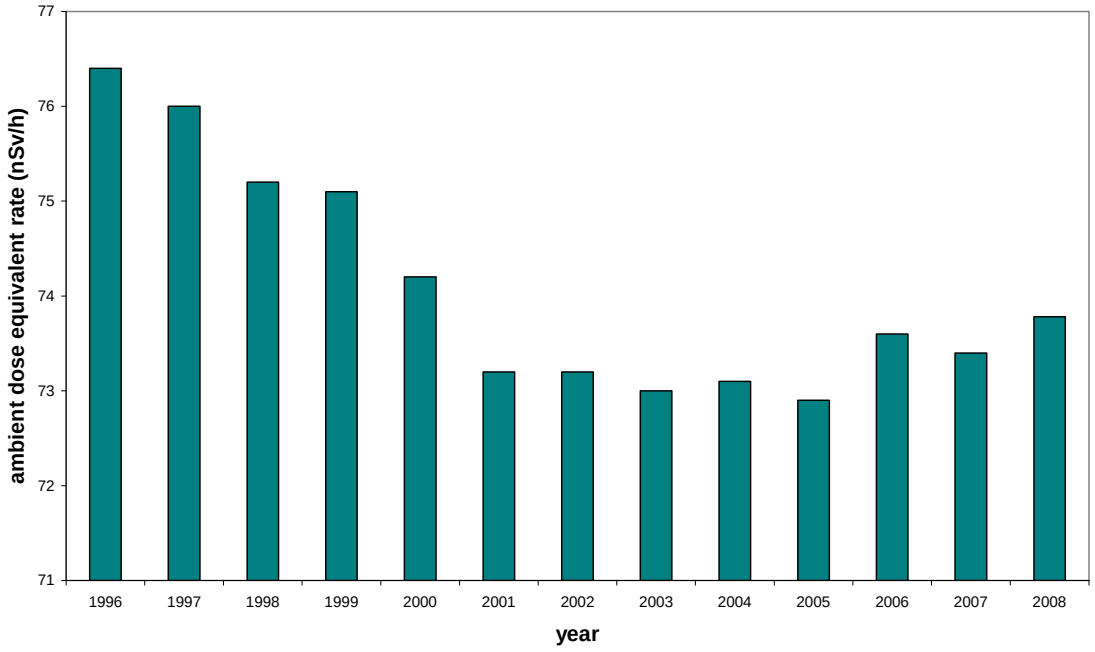


Figure 4.4: The yearly averaged ambient dose equivalent rate.

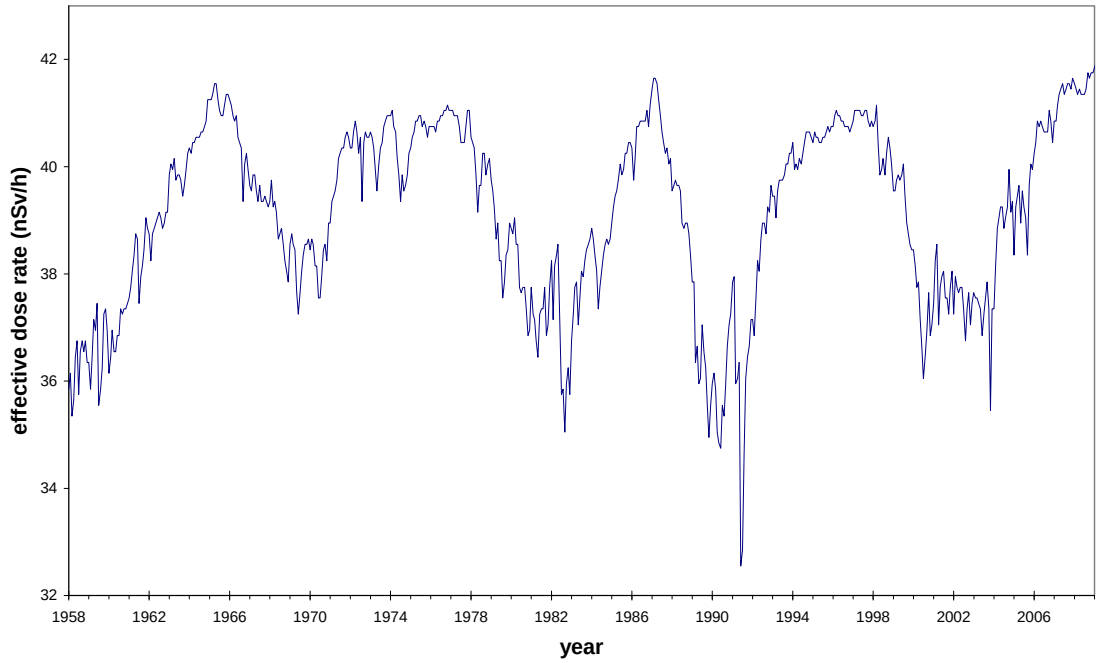


Figure 4.5: Cosmogenic contribution to the effective dose rate (at sea level), influenced by the solar cycle. Location 51° 26' north latitude and 3° 43' eastern longitude (in the south-west of the Netherlands), air pressure 1019 hPa. Figure derived from data supplied by Federal Aviation Administration [39]. In previous reports [32, 40] an error has been made by presenting this data as ambient dose equivalent rate, it should be presented as effective dose rate.

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 measurements on radioactivity in Dutch waters are reported elsewhere [41, 42, 43, 44].

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, 5.2 and Figure 5.1. Radioactive nuclides were determined 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	Gross α	Water	13
(Vrouwezand)	Residual β	Water	13
	^{3}H	Water	7
	^{60}Co	Suspended solids	13
	^{131}I	Suspended solids	13
	^{137}Cs	Suspended solids	13
Ketelmeer	^{60}Co	Suspended solids	5 (1)
(Ketelmeer West)	^{131}I	Suspended solids	5 (1)
	^{137}Cs	Suspended solids	5 (1)
Noordzeekanaal	Gross α	Water	7
(IJmuiden)	Residual β	Water	7
	^{3}H	Water	7
	^{60}Co	Suspended solids	7
	^{131}I	Suspended solids	7
	^{137}Cs	Suspended solids	7
Nieuwe Waterweg	Gross α	Water	13
(Maassluis)	Residual β	Water	13
	^{3}H	Water	6
	^{90}Sr	Water	6
	^{226}Ra	Water	6
	^{60}Co	Suspended solids	13
	^{131}I	Suspended solids	13
	^{137}Cs	Suspended solids	13
	^{210}Pb	Suspended solids	6

Continued on the next page

Table 5.1: Continued.

Location	Parameter	Matrix	Monitoring frequency (per year)
Rhine	Gross α	Water	13
(Lobith)	Residual β	Water	13
	^{3}H	Water	13
	^{90}Sr	Water	7
	^{226}Ra	Water	7
	^{60}Co	Suspended solids	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	6
Meuse	Gross α	Water	13
(Eijsden)	Residual β	Water	13
	^{3}H	Water	13
	^{90}Sr	Water	7
	^{226}Ra	Water	7
	^{60}Co	Suspended solids	52 (1)
	^{131}I	Suspended solids	52 (1)
	^{137}Cs	Suspended solids	52 (1)
	^{210}Pb	Suspended solids	6

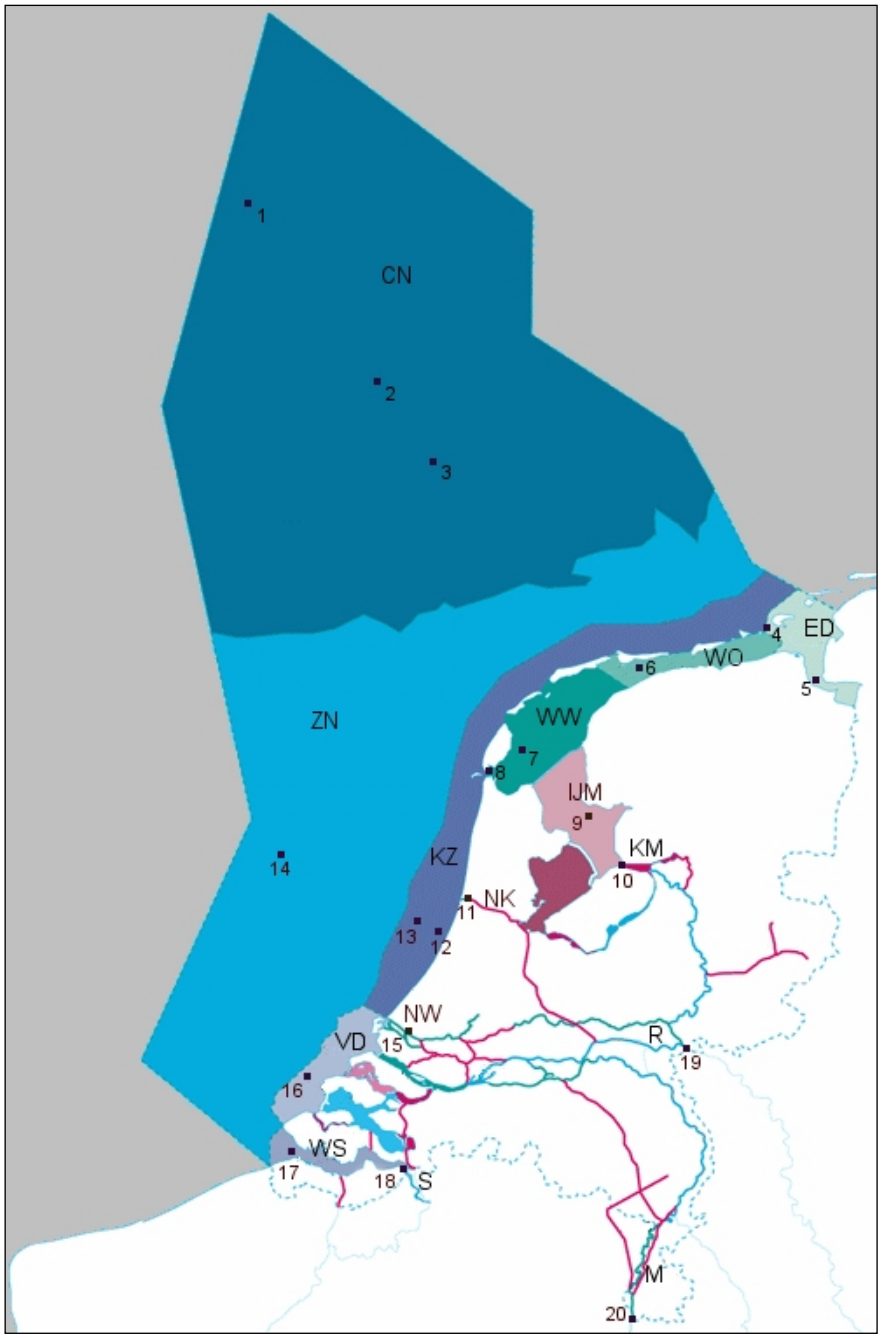
(1) Normally 7 respectively 53 times per year. Not all measurements could be performed due to insufficient sample amount.

The radioactive nuclides were determined according to standard procedures [42] and [45]. In the Netherlands target values are in use for radioactive materials in surface water, which are given in the Fourth memorandum on water management (Vierde Nota waterhuishouding) [46]. The yearly averages are compared with these 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}Po	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	4
		^{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}Po	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}Po	Suspended solids	4
Wadden Sea West (3) (WW)	Marsdiep Noord	Gross α	Water	4
		Residual β	Water	4
		^{3}H	Water	4
Wadden Sea East (WO)	Dantziggat	Gross α	Water	4
		Residual β	Water	4
		^{3}H	Water	4
		^{137}Cs	Suspended solids	4
		^{210}Po	Suspended solids	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.
(3) Since 2006 ^{137}Cs and ^{210}Pb (in suspended solids) are not longer determined at Doove Balg West due to repeatedly insufficient amount of collected suspended solids in previous years.



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 and 1988-1994 (except 1989), respectively. Terschelling 235 km offshore is 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 is the monitoring location for the Coastal area from 1999 and onwards [42]. Doove Balg West was the monitoring location for radionuclides in suspended solids for the Wadden Sea West during 1996-2005.

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 to 5.19.

Gross α and residual β are indicative parameters. The yearly averaged activity concentrations of gross α and residual β in 2008 are within the range of those in previous years. The gross α-activity concentration in the Noordzeekanaal, Nieuwe Waterweg and Scheldt exceeds the target value (100 $mBq \cdot L^{-1}$) in 4 out of 7, 5 out of 13 and 13 out of 13 samples taken, respectively. In 2008 the yearly averaged gross α-activity concentrations in the Noordzeekanaal, Nieuwe Waterweg and Scheldt (240, 106 and 290 $mBq \cdot L^{-1}$, respectively) are above the target value of 100 $mBq \cdot L^{-1}$.

The yearly averaged residual β-activity concentrations are below the target value of 200 $mBq \cdot L^{-1}$. Residual β in the Noordzeekanaal, Nieuwe Waterweg and Scheldt shows a change in the trend since 1994. This is caused by a change in measuring technique, which only applies to salt and brackish water [42]. Therefore, no change in trend is shown for the IJsselmeer, Rhine and Meuse.

The ^{3}H-activity concentration in the Scheldt and Meuse exceeds the target value (10 $Bq \cdot L^{-1}$) in 2 out of 6 and 8 out of 13 samples taken, respectively. The elevated levels of ^{3}H in the Meuse (Figure 5.6) could originate from the nuclear power plants at Tihange (Belgium) or Chooz (France). The elevated levels of ^{3}H in the Scheldt could originate from the nuclear power plant at Doel (Belgium). The yearly averaged ^{3}H-activity concentrations in 2008 are within the range of those in previous years. In 2008, the yearly averaged ^{3}H-activity concentration in the Meuse (22.0 $Bq \cdot L^{-1}$) is 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 2008 are within the range of those in previous years. The yearly averaged ^{90}Sr-activity concentrations are 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 Scheldt exceeds the target value (5 $mBq \cdot L^{-1}$) in 5 out of 6 samples taken. The yearly averaged ^{226}Ra-activity concentrations in 2008 are within the range of those in previous years. In 2008 the yearly averaged ^{226}Ra-activity concentration in the Scheldt (9.0 $mBq \cdot L^{-1}$) is above the target value of 5 $mBq \cdot L^{-1}$.

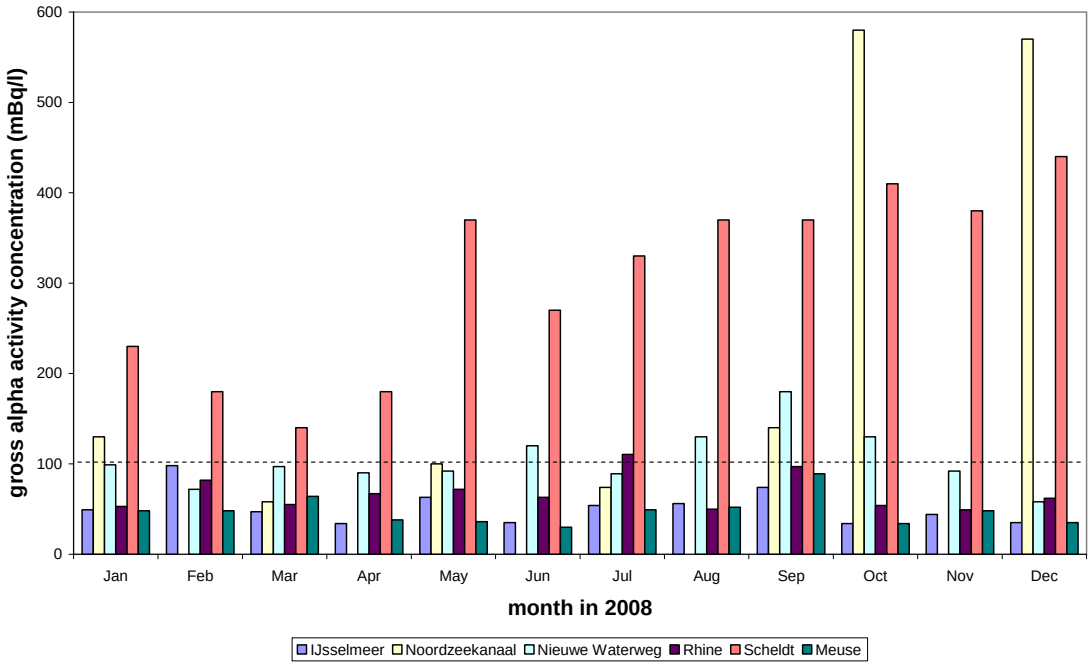


Figure 5.2: The gross α-activity concentration for the IJsselmeer, Noordzeekanaal, Nieuwe Waterweg, Rhine, Scheldt and Meuse, with yearly averages of 51, 240, 106, 71, 290 and 48 mBq·L^{-1}, respectively. Averaged values are shown in case of multiple measurements per month. The dotted line represents the target value of 100 mBq·L^{-1} [46].

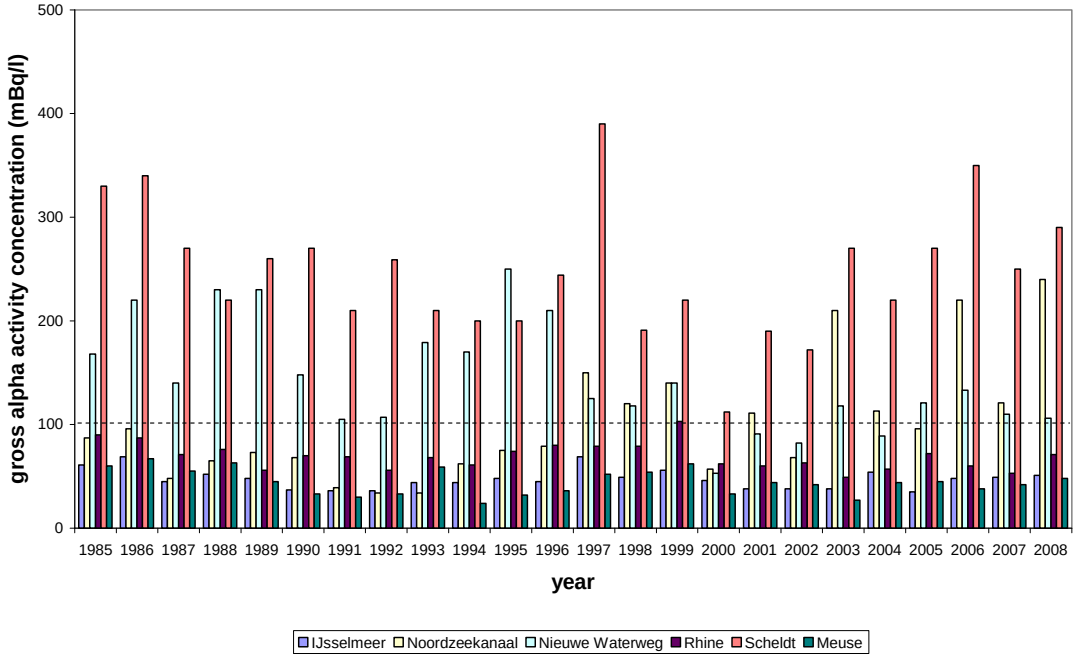


Figure 5.3: Yearly averaged gross α-activity concentrations.

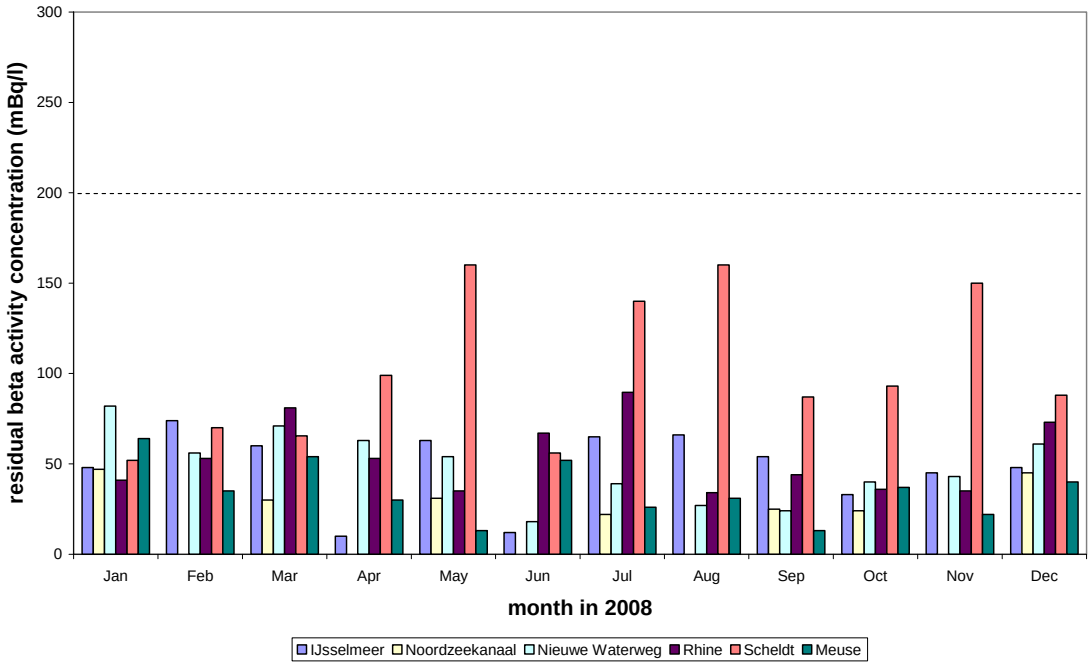


Figure 5.4: The residual β-activity concentration for the IJsselmeer, Noordzeekanaal, Nieuwe Waterweg, Rhine, Scheldt and Meuse, with yearly averages of 45, 32, 48, 56, 99 and 34 mBq·L^{-1}, respectively. Averaged values are shown in case of multiple measurements per month. The dotted line represents the target value of 200 mBq·L^{-1} [46].

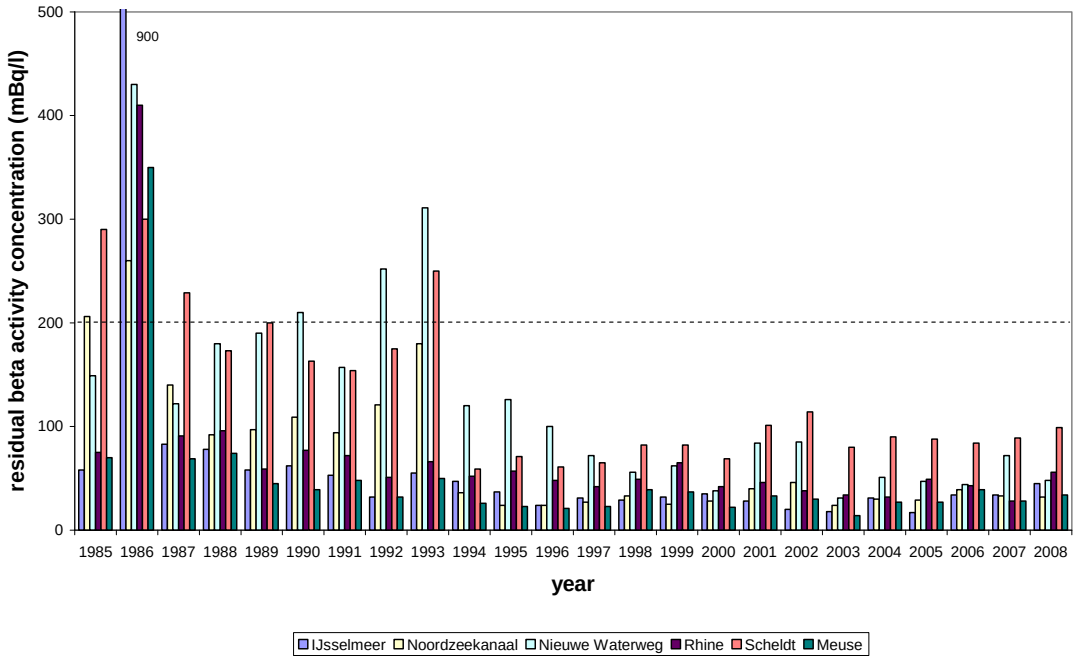


Figure 5.5: Yearly averaged residual β-activity concentrations.

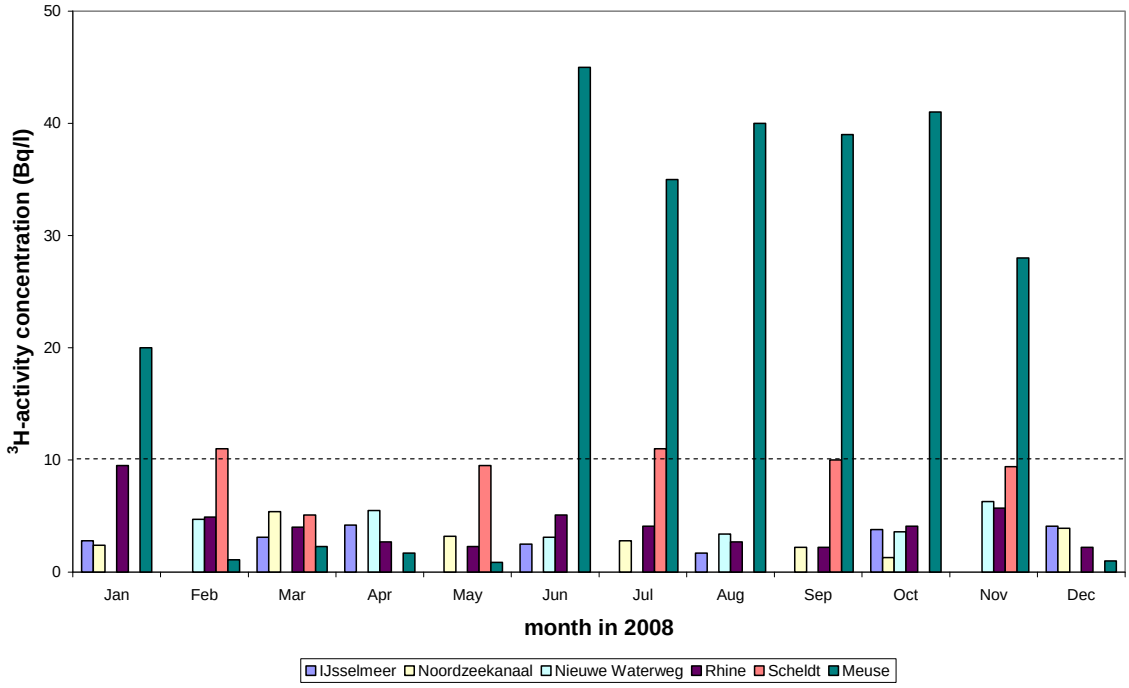


Figure 5.6: The ^{3}H-activity concentration for the IJsselmeer, Noordzeekanaal, Nieuwe Waterweg, Rhine, Scheldt and Meuse, with yearly averages of 3.2, 3.0, 4.4, 4.1, 9.3 and 22.0 Bq·L^{-1}, respectively. Averaged values are shown in case of multiple measurements per month. The dotted line represents the target value of 10 Bq·L^{-1} [46].

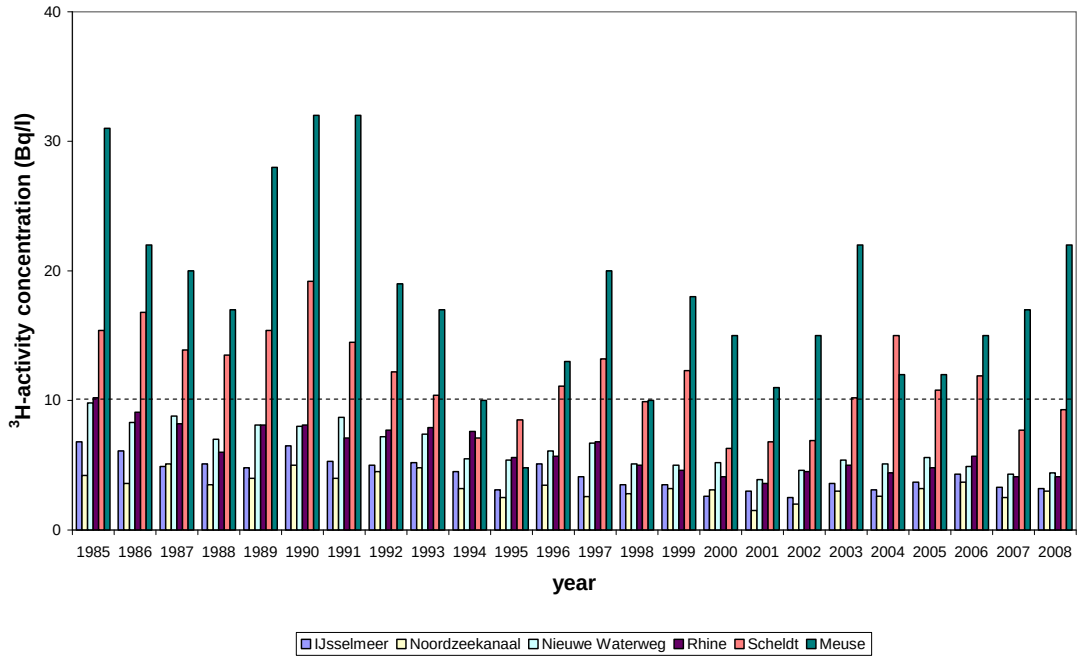


Figure 5.7: Yearly averaged ^{3}H-activity concentrations.

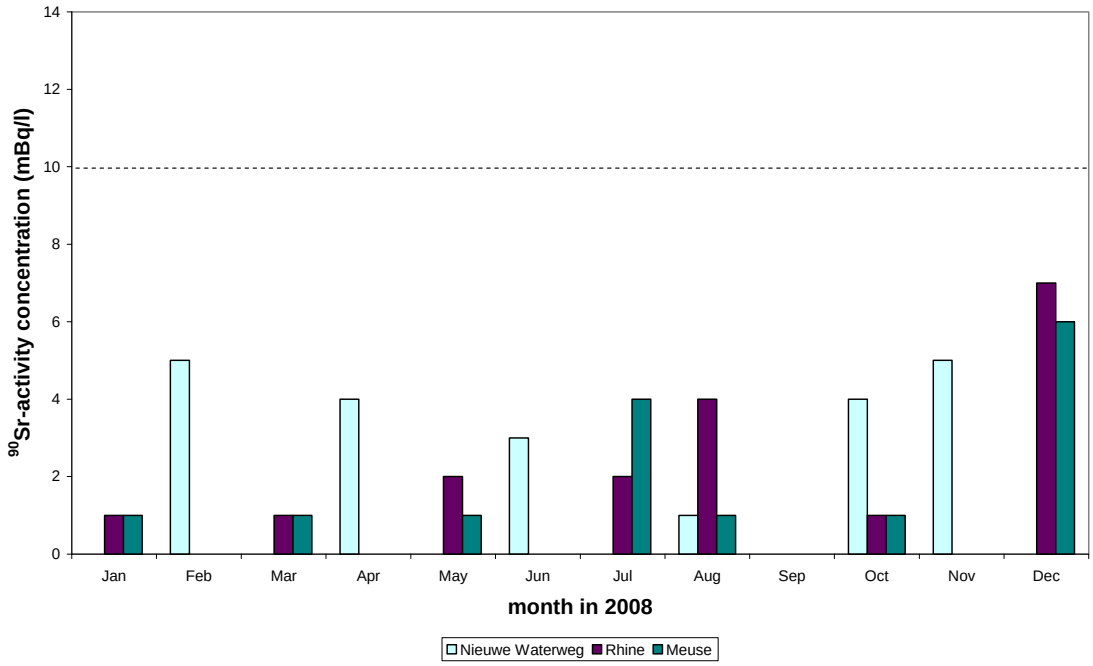


Figure 5.8: The ^{90}Sr-activity concentration for the Nieuwe Waterweg, Rhine and Meuse, with yearly averages of 3.6, 2.5 and 1.9 mBq·L^{-1}, respectively. Averaged values are shown in case of multiple measurements per month. The dotted line represents the target value of 10 mBq·L^{-1} [46].

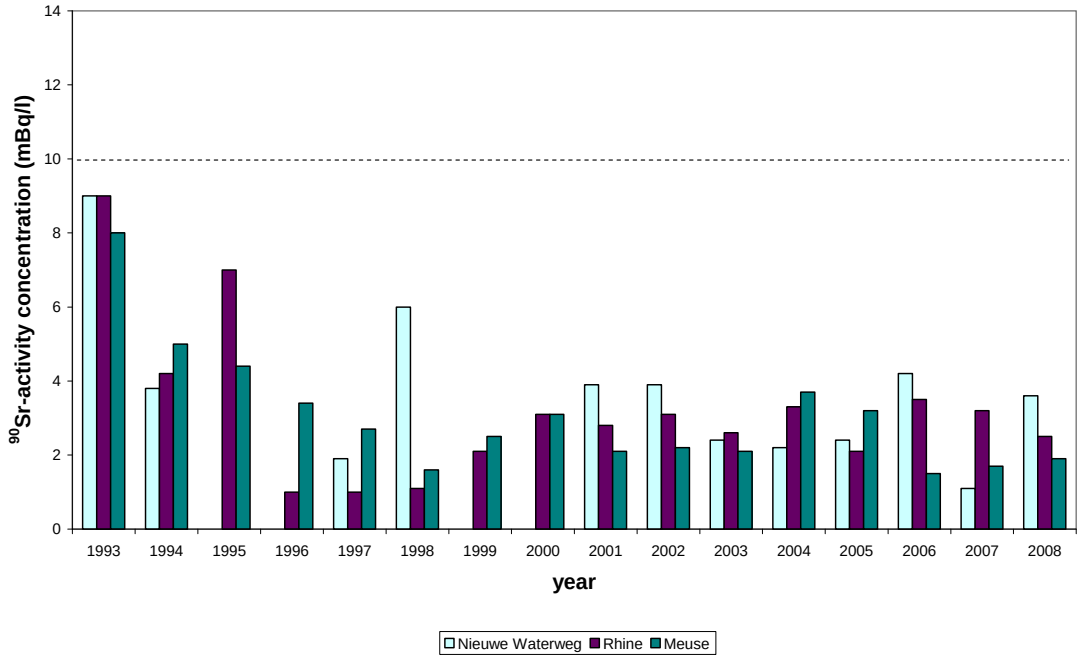


Figure 5.9: Yearly averaged ^{90}Sr-activity concentrations. Data are not available for the Nieuwe Waterweg in 1995, 1996, 1999 and 2000.

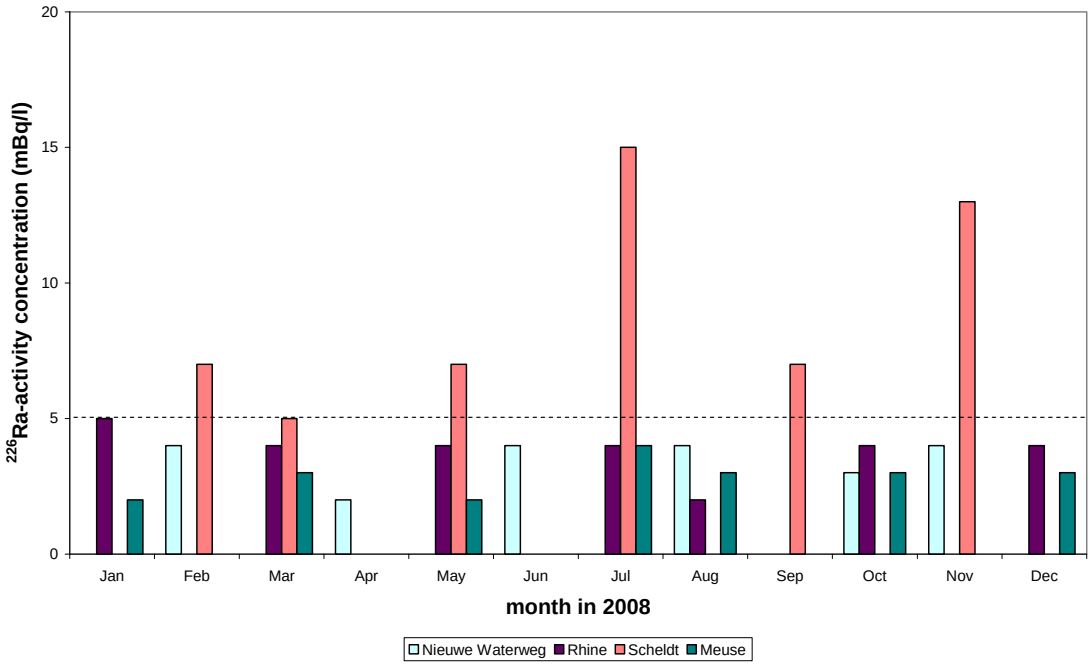


Figure 5.10: The ^{226}Ra-activity concentration for the Nieuwe Waterweg, Rhine, Scheldt and Meuse, with yearly averages of 3.5, 3.9, 9.0 and 2.9 mBq·L^{-1}, respectively. Averaged values are shown in case of multiple measurements per month. The dotted line represents the target value of 5 mBq·L^{-1} [46].

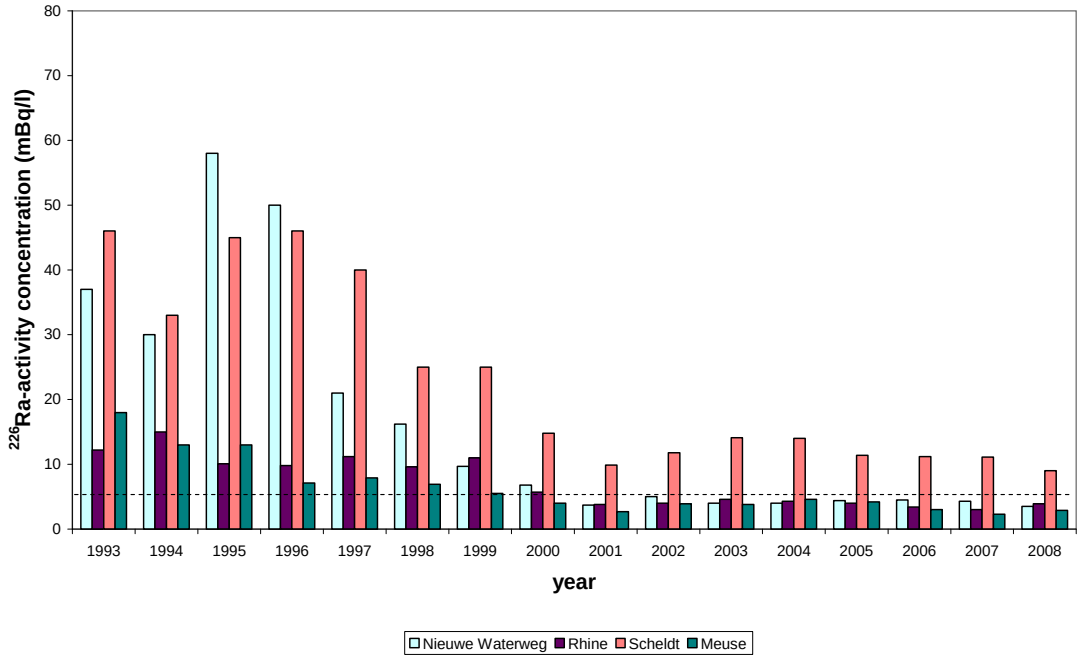


Figure 5.11: Yearly averaged ^{226}Ra-activity concentrations.

The nuclide ^{60}Co is a known corrosion product of nuclear power plants. The ^{60}Co-activity concentration in suspended solids in the Meuse exceeds the target value (10 Bq·kg^{-1}) in 19 out of 52 samples taken. In 2008, the yearly averaged ^{60}Co-activity concentrations are below the target value of 10 Bq·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 exceeds the target value (20 Bq·kg^{-1}) in 1 out of 7 and 15 out of 52 samples taken, respectively. In 2008, the yearly averaged ^{131}I-activity concentrations are below the target value of 20 Bq·kg^{-1}.

The yearly averaged concentrations of ^{137}Cs in suspended solids in 2008 are within the range of those in previous years. The yearly averaged ^{137}Cs-concentrations are below the target value of 40 Bq·kg^{-1}. Except for 2004 and 2007 the yearly averaged concentration of ^{137}Cs is consistently higher in the Ketelmeer compared to that in the Rhine at Lobith (Figure 5.17). This indicates an extra contribution besides the one currently originating from the Rhine, which can be explained by the following. The Ketelmeer serves as a sink for Rhine sediment and thus contains a large amount of sediment deposited in previous years. A considerable amount of sediment, containing ^{137}Cs originating from the Chernobyl accident, resuspends in the relatively shallow Ketelmeer due to wind influences [47].

In suspended solids ^{210}Po is mostly in equilibrium with ^{210}Pb. Therefore, 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. The ^{210}Pb-activity concentration in the Nieuwe Waterweg, Rhine and Meuse exceeds the target value (100 Bq·kg^{-1}) in 4 out of 6, 6 out of 7 and 6 out of 6 samples taken, respectively. In 2008 the yearly averaged ^{210}Pb-activity concentrations in the Nieuwe Waterweg, Rhine and Meuse (108, 112 and 160 Bq·kg^{-1}, respectively) are above the target value of 100 Bq·kg^{-1}, but within range of those in previous years.

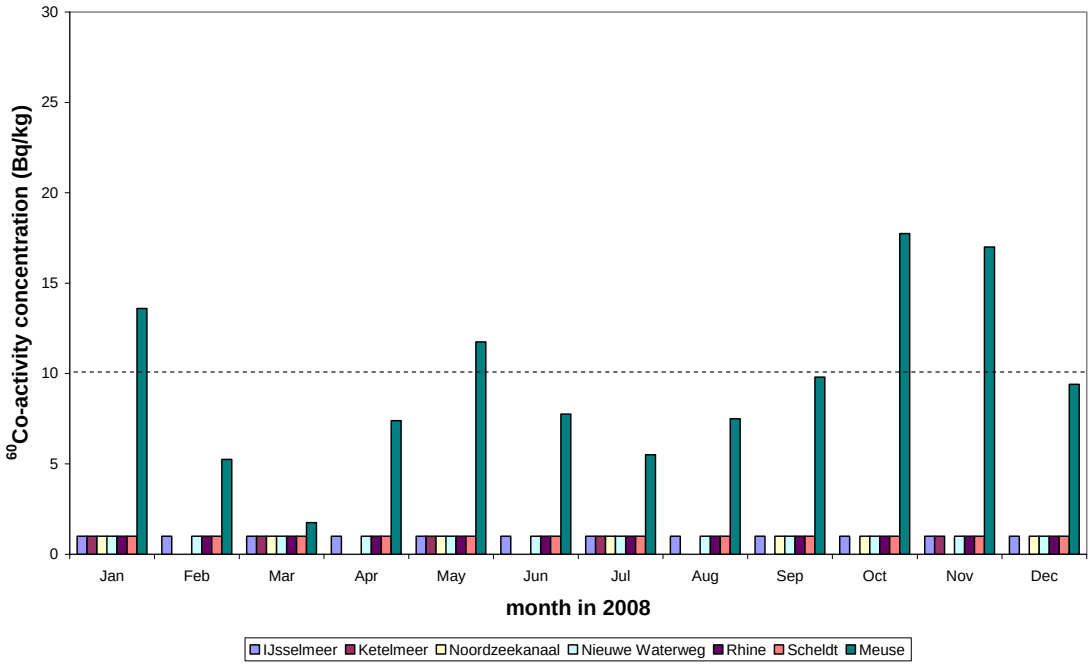


Figure 5.12: The ^{60}Co-activity concentration in suspended solids for the IJsselmeer, Ketelmeer, Noordzeekanaal, Nieuwe Waterweg, Rhine, Scheldt and Meuse. The yearly averages of all except for the Meuse (9.5 Bq·kg^{-1}) are < 1 Bq·kg^{-1}. Averaged values are shown in case of multiple measurements per month. The dotted line represents the target value of 10 Bq·kg^{-1} [46].

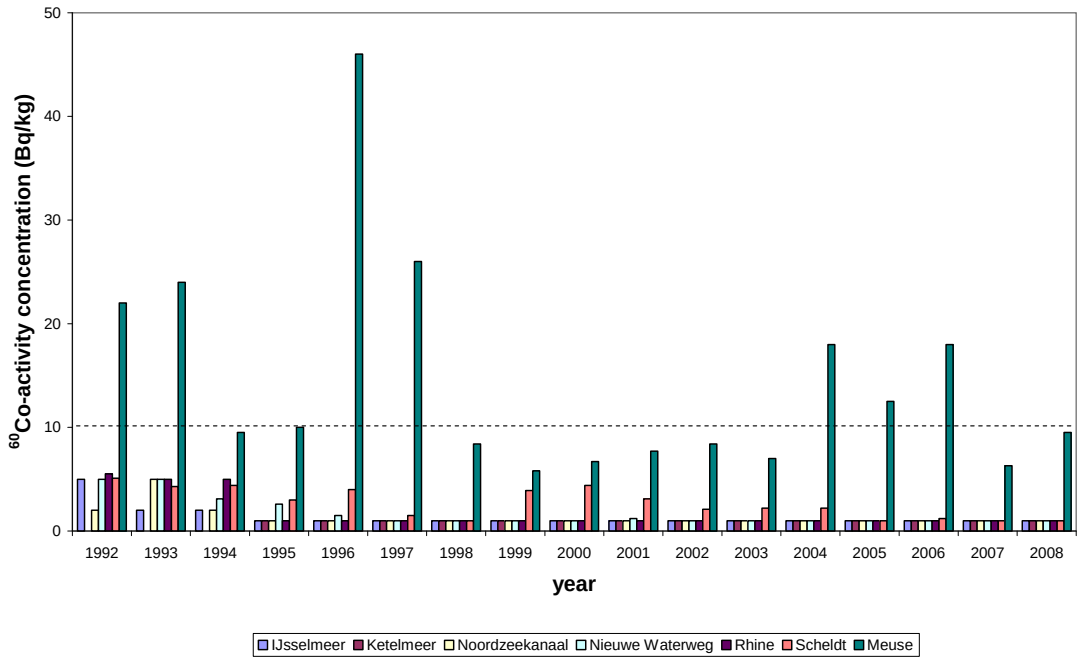


Figure 5.13: Yearly averaged ^{60}Co-activity concentrations in suspended solids. Data on Ketelmeer are available since 1995.

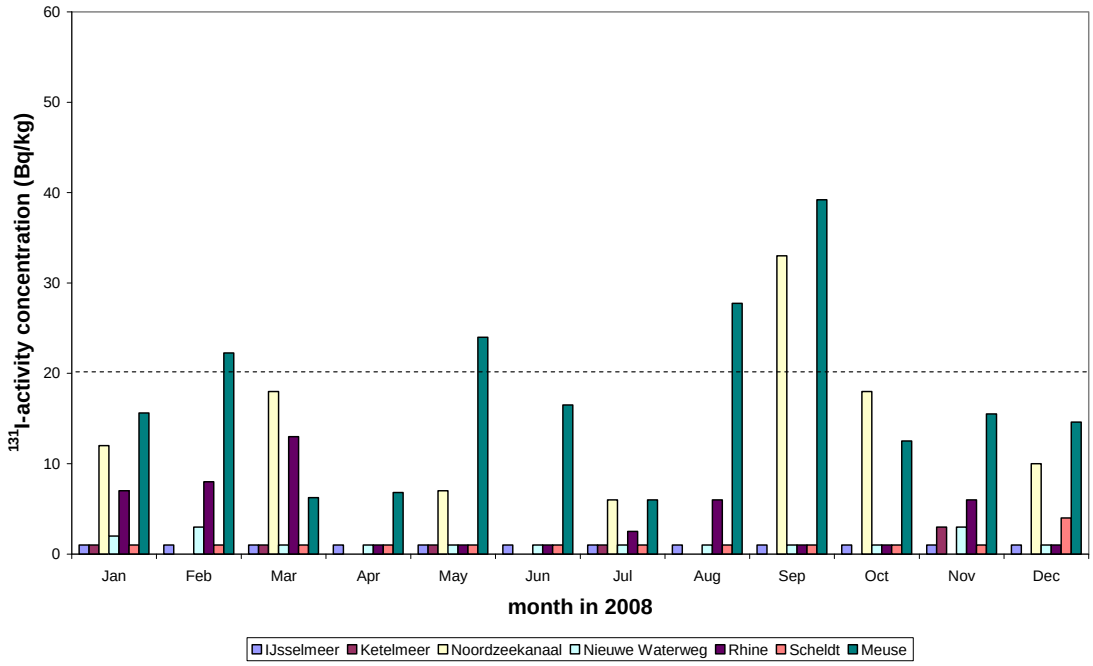


Figure 5.14: The ^{131}I-activity concentration in suspended solids for the IJsselmeer, Ketelmeer, Noordzeekanaal, Nieuwe Waterweg, Rhine, Scheldt and Meuse, with yearly averages of < 1, < 1, 15, < 1, 3.7, < 1, and 17 Bq·kg^{-1}, respectively. Averaged values are shown in case of multiple measurements per month. The dotted line represents the target value of 20 Bq·kg^{-1} [46].

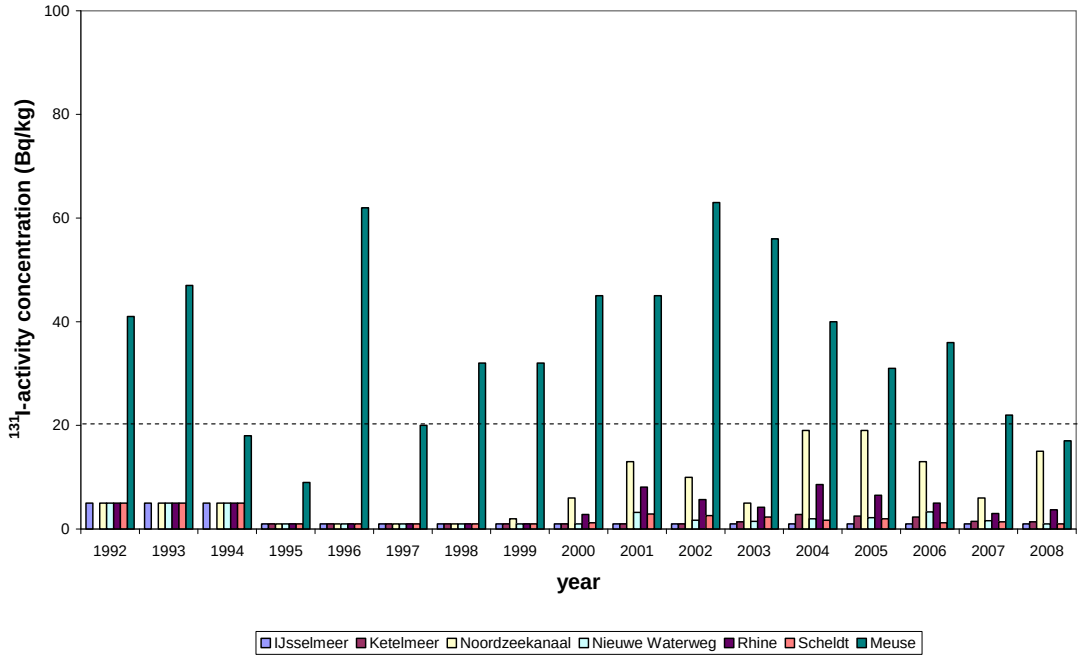


Figure 5.15: Yearly averaged ^{131}I-activity concentrations in suspended solids. Data on Ketelmeer are available since 1995.

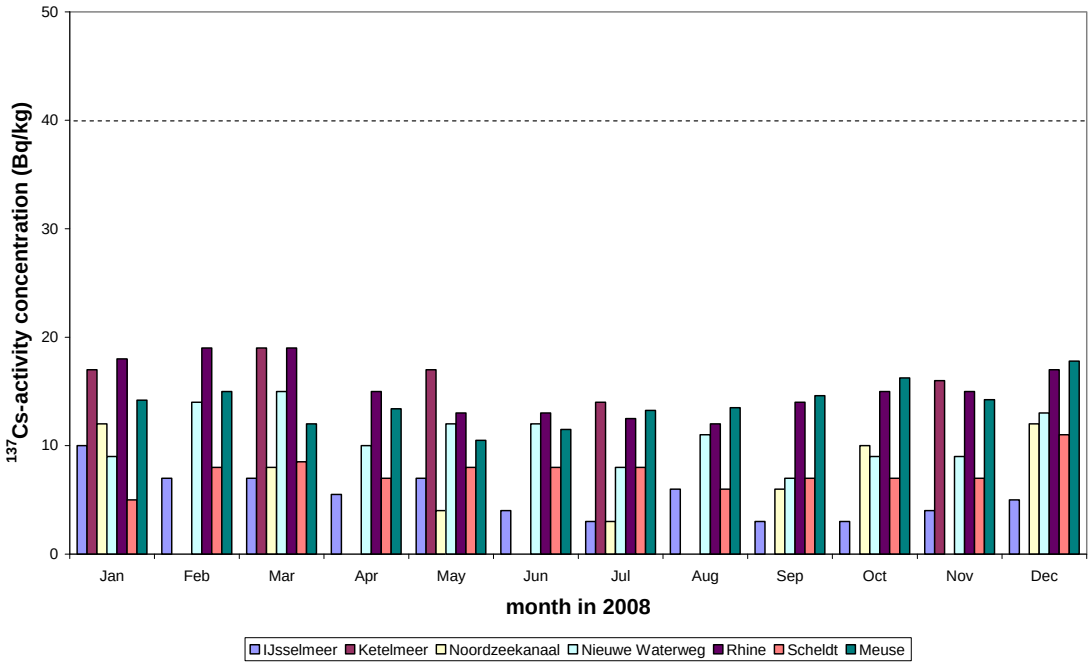


Figure 5.16: The ^{137}Cs-activity concentration in suspended solids for the IJsselmeer, Ketelmeer, Noordzeekanaal, Nieuwe Waterweg, Rhine, Scheldt and Meuse, with yearly averages of 5.4, 16.6, 7.9, 10.6, 15.0, 7.6, and 13.9 Bq·kg^{-1}, respectively. Averaged values are shown in case of multiple measurements per month. The dotted line represents the target value of 40 Bq·kg^{-1} [46].

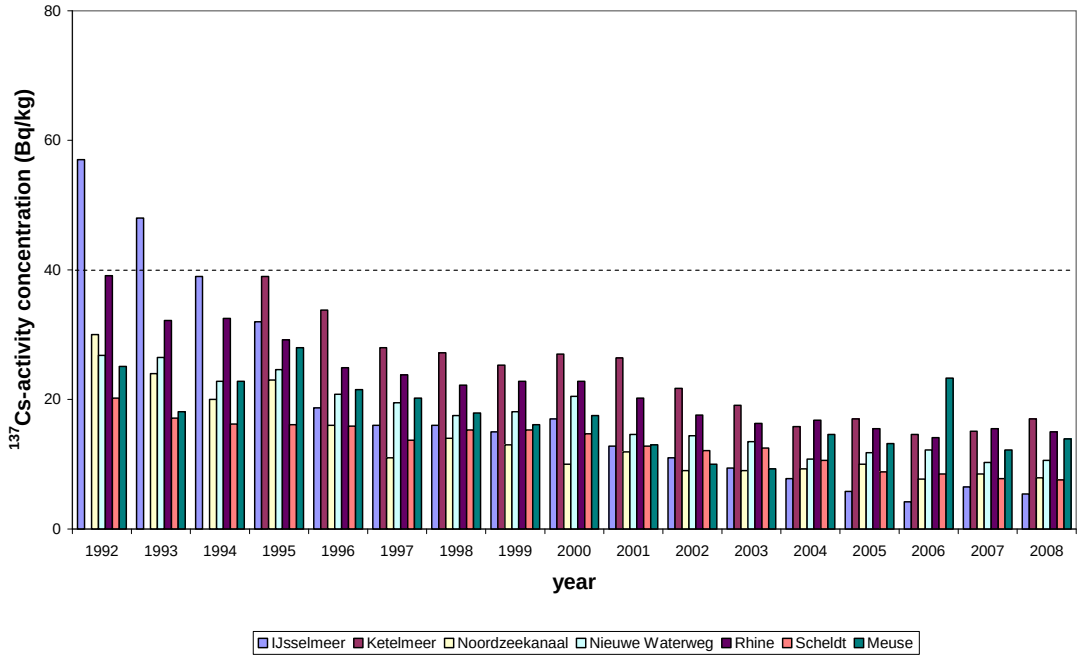


Figure 5.17: Yearly averaged ^{137}Cs-activity concentrations in suspended solids. Data on Ketelmeer are available since 1995.

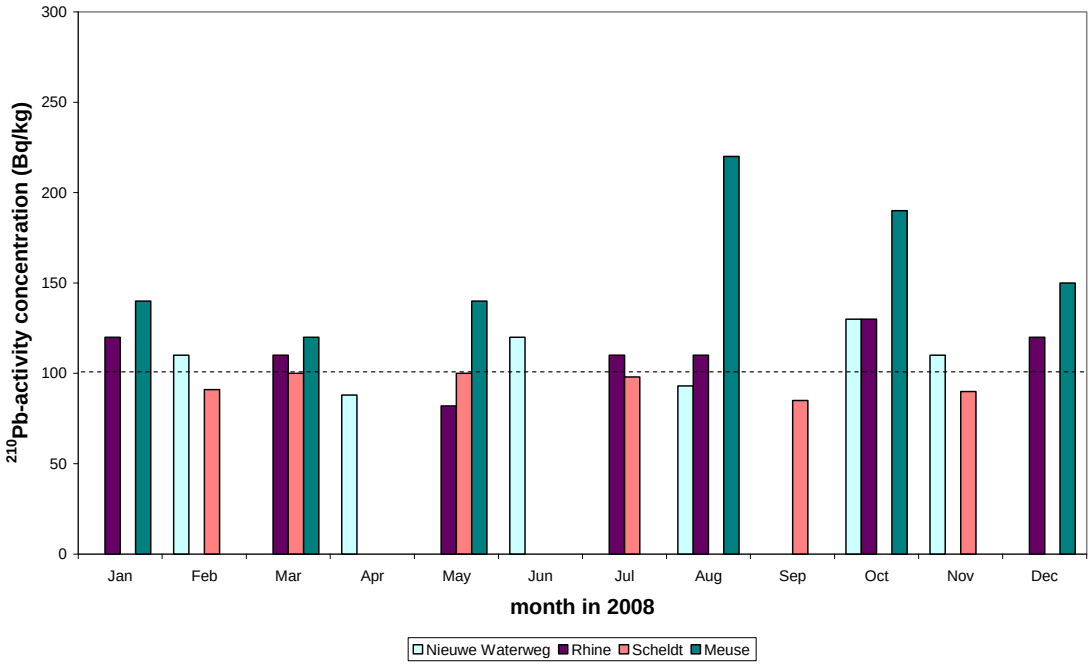


Figure 5.18: The ^{210}Pb-activity concentration in suspended solids for the Nieuwe Waterweg, Rhine, Scheldt and Meuse, with yearly averages of 108, 112, 94, and 160 Bq·kg^{-1}, respectively. Averaged values are shown in case of multiple measurements per month. The dotted line represents the target value of 100 Bq·kg^{-1} [46].

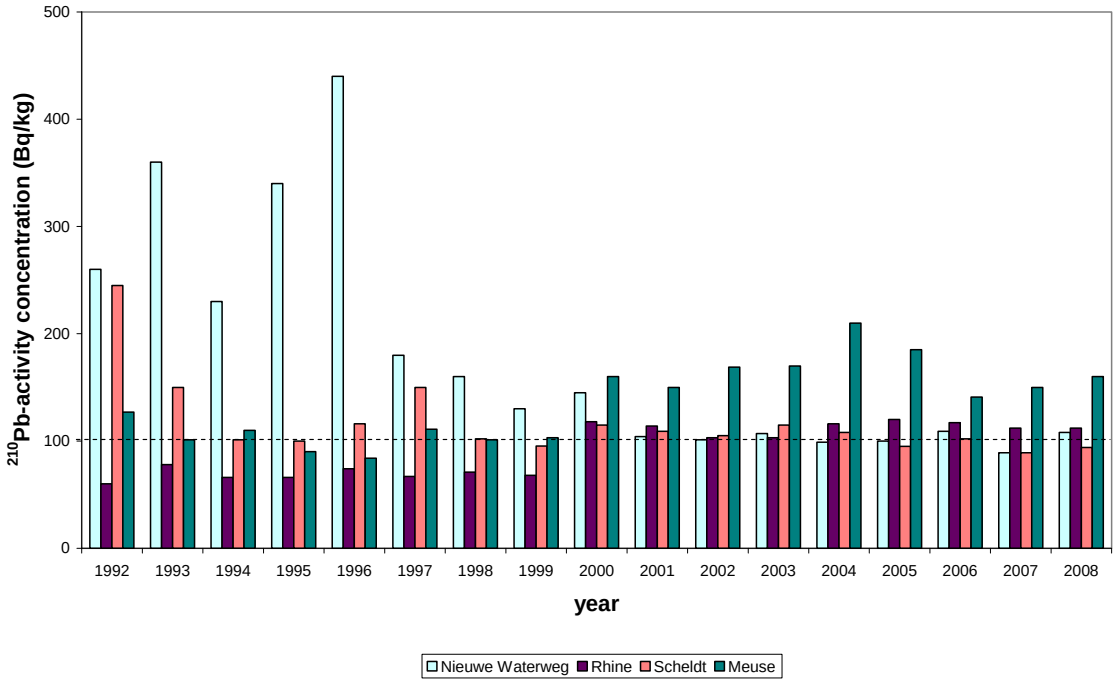


Figure 5.19: Yearly averaged ^{210}Pb-activity concentrations in suspended solids.

5.3 The results for seawater

The results for seawater are presented in Tables A13 and A14 and in Figures 5.20 to 5.31.
Gross α and residual β are indicative parameters [42]. In the first half of 2000 the background of the measuring equipment was unstable and higher than usual, which resulted in lower results. Therefore, yearly averaged concentrations of gross α in 2000 are based on data starting from the end of July 2000. Changes in the trend of gross α in the period 1985-1997 are explained elsewhere [42]. The yearly averaged gross α concentrations in 2008 are within the range of those in the period 1994-2007 (Figure 5.21).

Residual β shows an apparent change in the trend since 1994 (Figure 5.23). This is caused by a change in measuring technique, which only applies to salt and brackish water [42]. For Wadden Sea East the yearly averaged residual β concentration is the highest since 1999. The yearly averaged residual β concentrations for the other locations are within the range of those in the period 1994-2007.

Nuclear power plants discharge the nuclides ^{3}H and ^{137}Cs. Nuclear fuel reprocessing plants discharge the nuclides ^{3}H and ^{90}Sr. Discharges by the research centre at Doel (Belgium) and the nuclear power plants at Doel 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 [42]. 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 2008 are within the range of those in previous years (Figure 5.25). The yearly averaged ^{90}Sr-concentrations in 2008 are within the range of those in previous years (Figure 5.27).

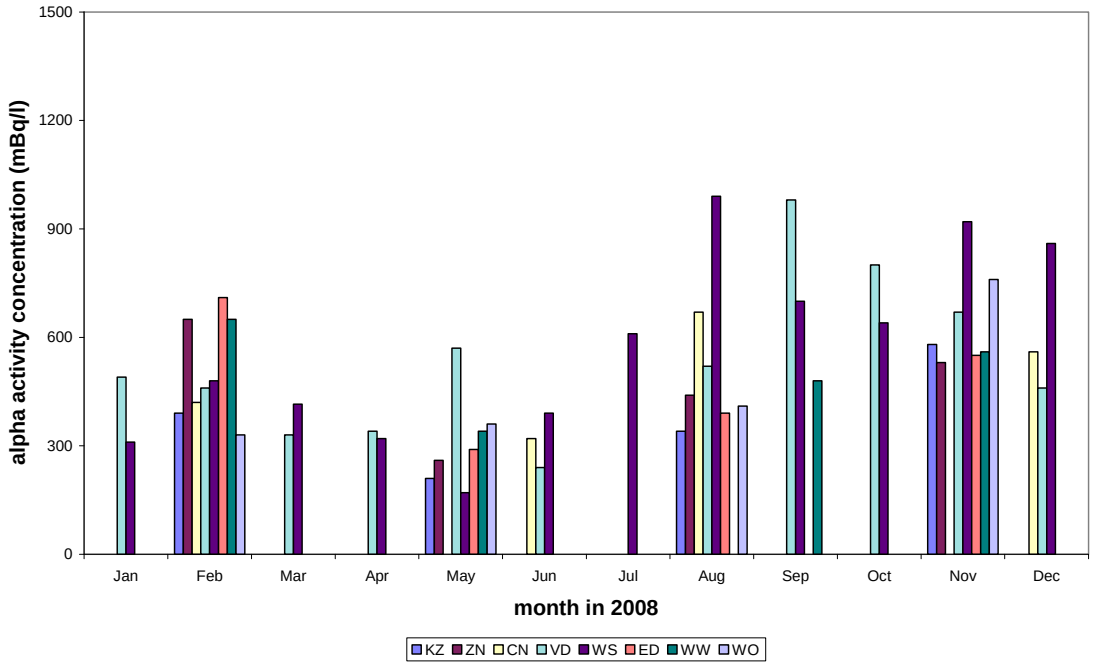


Figure 5.20: The gross α-activity concentration in seawater. The yearly averages for the Coastal area (KZ), Southern North Sea (ZN), Central North Sea (CN), Delta Coastal Waters (VD), Westerscheldt (WS), Eems-Dollard (ED), Wadden Sea West (WW) and Wadden Sea East (WO) are 380, 470, 490, 530, 560, 480, 510 and 460 mBq·L^{-1}, respectively.

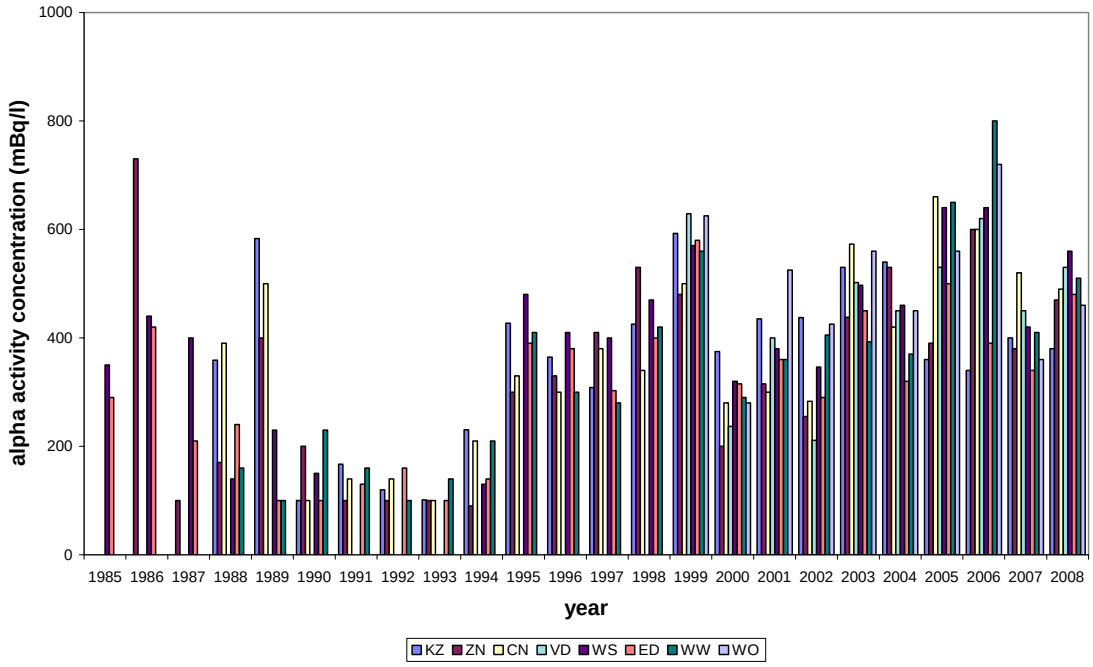


Figure 5.21: Yearly averaged gross α-activity concentrations.

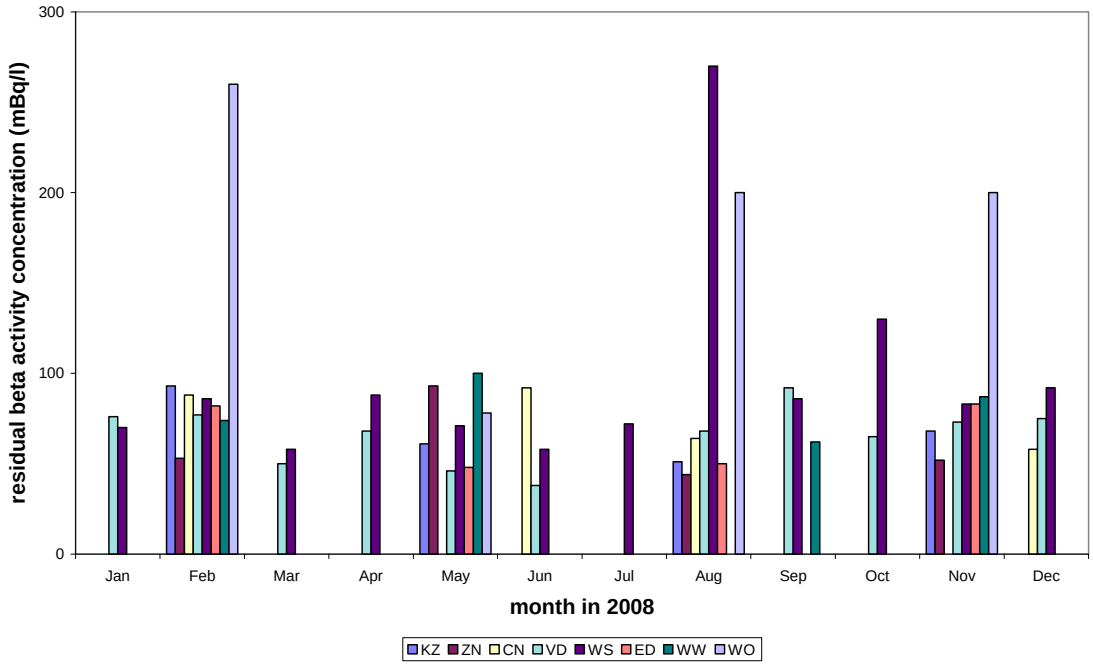


Figure 5.22: The residual β-activity concentration in seawater. The yearly averages for the Coastal area, Southern North Sea, Central North Sea, Delta Coastal Waters, Westerscheldt, Eems-Dollard, Wadden Sea West and Wadden Sea East are 68, 60, 76, 66, 94, 66, 81 and 180 mBq·L^{-1}, respectively.

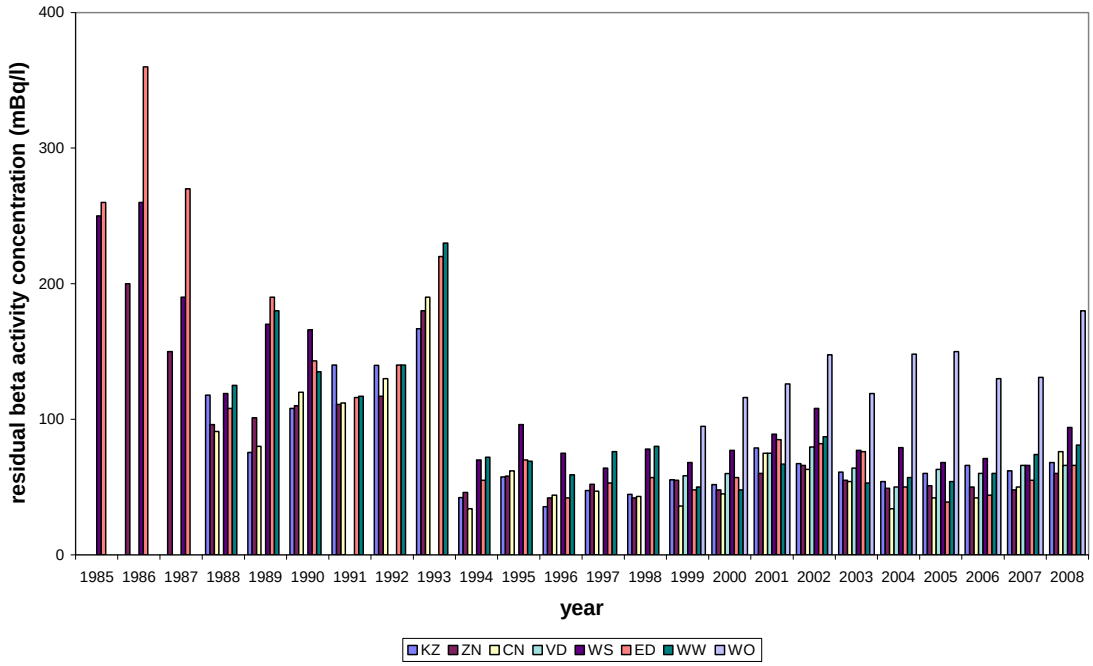


Figure 5.23: Yearly averaged residual β-activity concentrations.

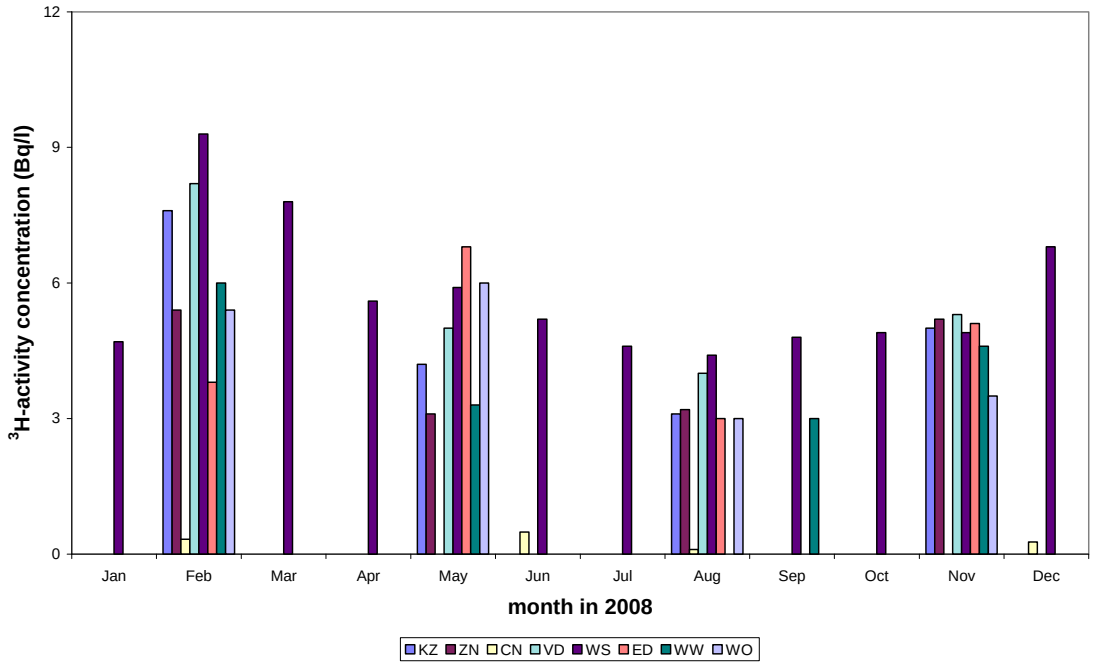


Figure 5.24: The ^{3}H-activity concentration in seawater. The yearly averages for the Coastal area, Southern North Sea, Central North Sea, Delta Coastal Waters, Westerscheldt, Eems-Dollard, Wadden Sea West and Wadden Sea East are 5.0, 4.2, 0.28, 5.6, 5.9, 4.7, 4.2 and 4.5 Bq·L^{-1}, respectively.

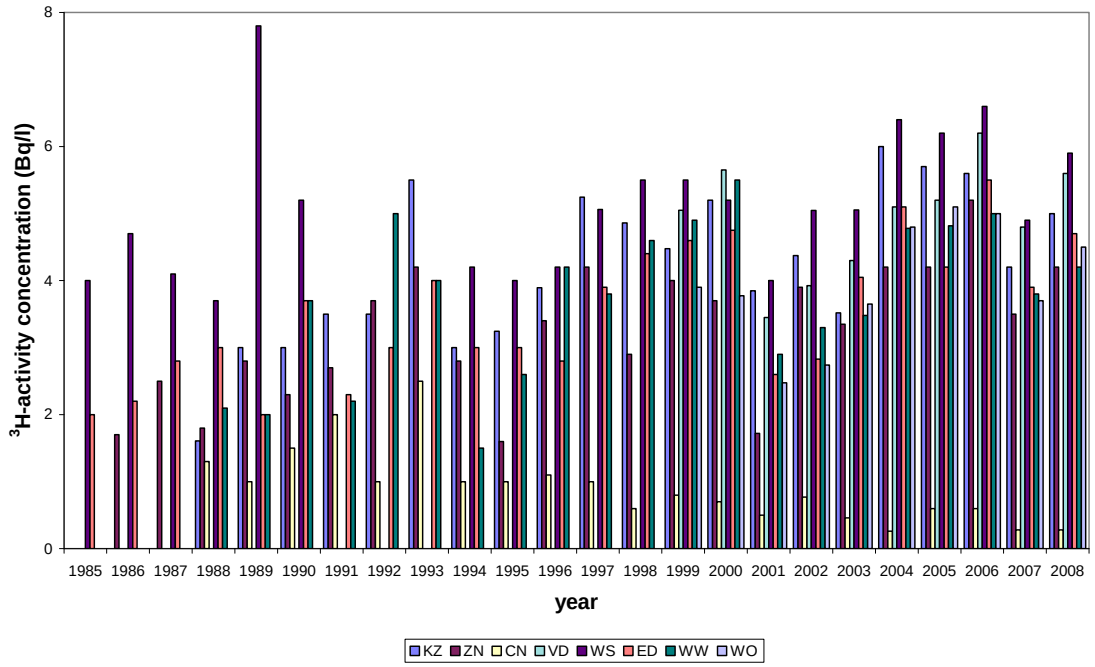


Figure 5.25: Yearly averaged ^{3}H-activity concentrations.

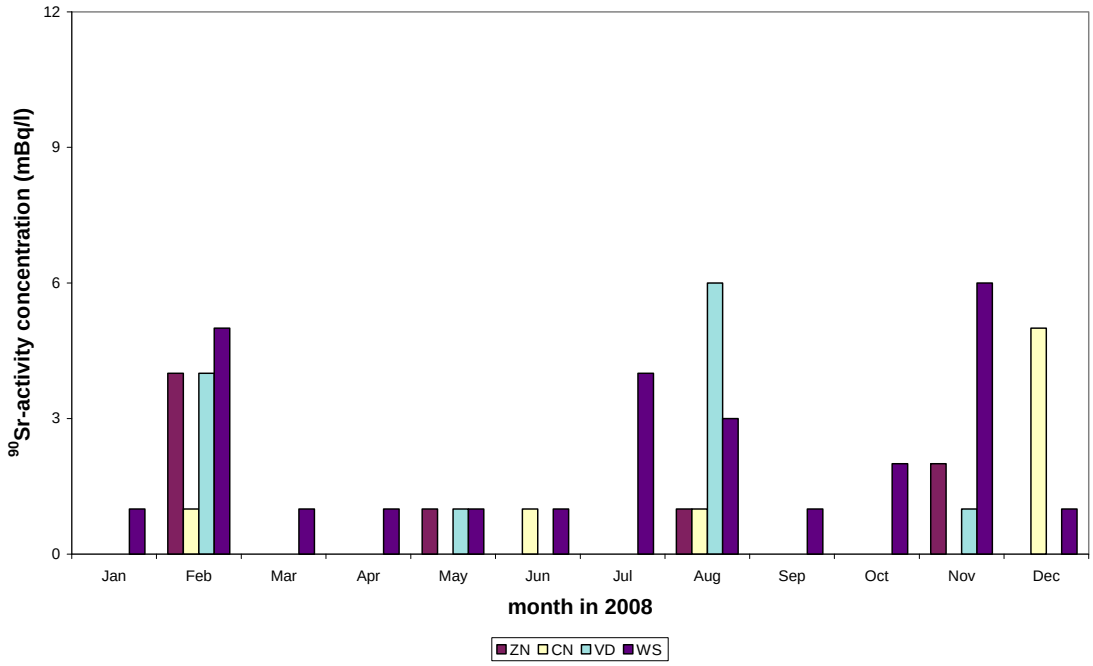


Figure 5.26: The ^{90}Sr-activity concentration in seawater. The yearly averages for the Southern North Sea, Central North Sea, Delta Coastal Waters and Westerscheldt are 1.8, 1.8, 3 and 1.9 mBq·L^{-1}, respectively.

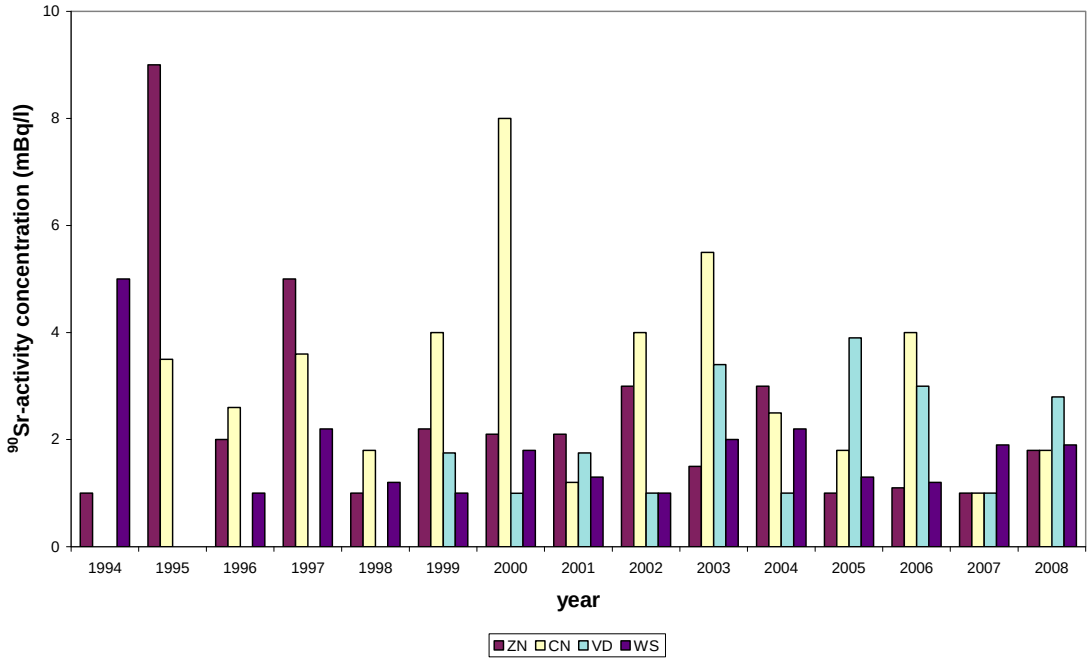


Figure 5.27: Yearly averaged ^{90}Sr-activity concentrations.

The yearly averaged concentrations of ^{137}Cs and ^{210}Po in 2008 are within the range of those in previous years (Figure 5.29 and 5.31, respectively). In 2001 and 2003 data were not available for Wadden Sea West due to insufficient amount of collected suspended solids. Since 2006, ^{137}Cs and ^{210}Po are not longer determined at Wadden Sea West due to repeatedly insufficient amount of collected suspended solids in previous years.

The nuclide ^{210}Po originates from the uranium decay chain and is released by the phosphate processing industry and production platforms for oil and gas [42]. Discharges via the main rivers are monitored in the Coastal area (KZ). Discharges by 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.

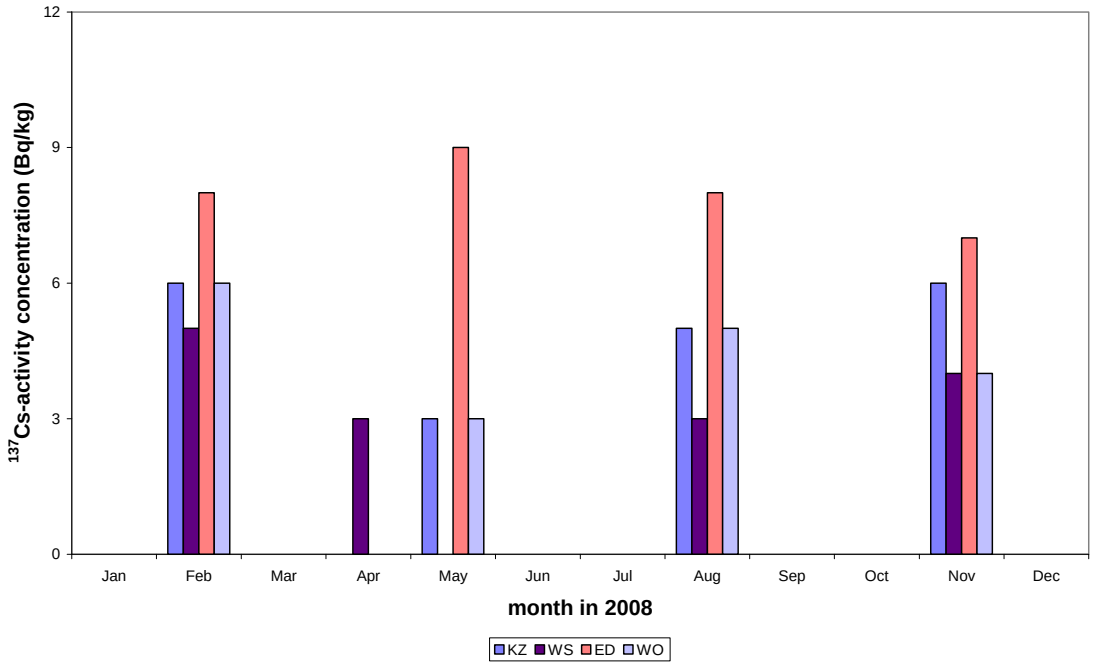


Figure 5.28: The ^{137}Cs-activity concentration in suspended solids in seawater. The yearly averages for the Coastal area, Westerscheldt, Eems-Dollard and Wadden Sea East are 5, 3.8, 8 and 4.5 Bq·kg^{-1}, respectively.

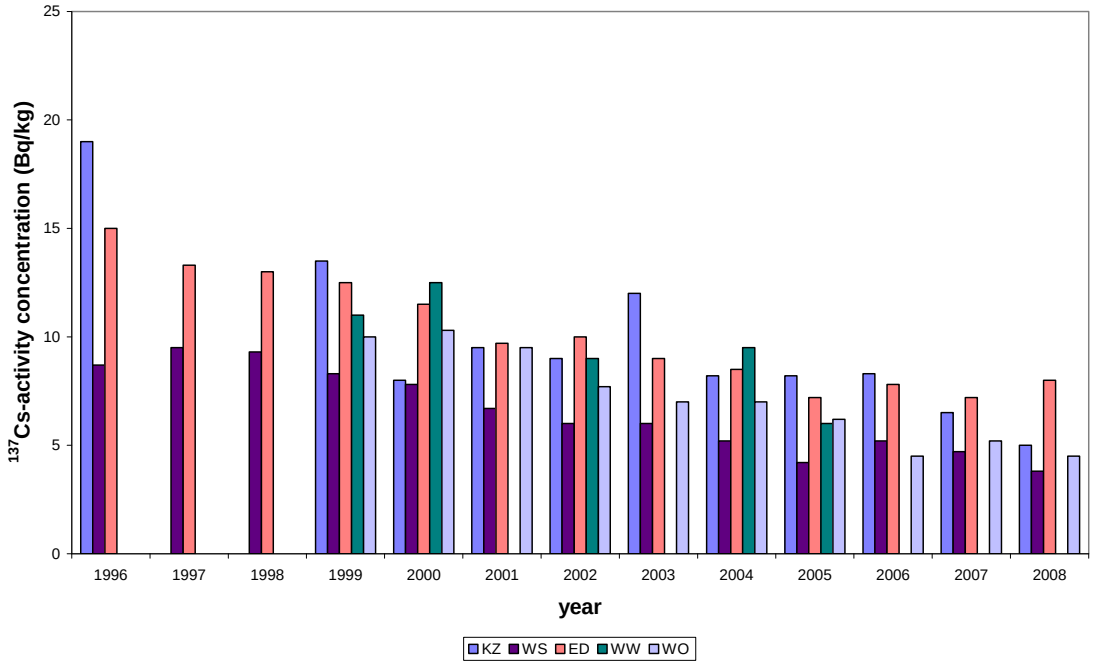


Figure 5.29: Yearly averaged ^{137}Cs-activity concentrations in suspended solids. Since 2006 ^{137}Cs is not longer determined at Wadden Sea West due to repeatedly insufficient amount of collected suspended solids in previous years.

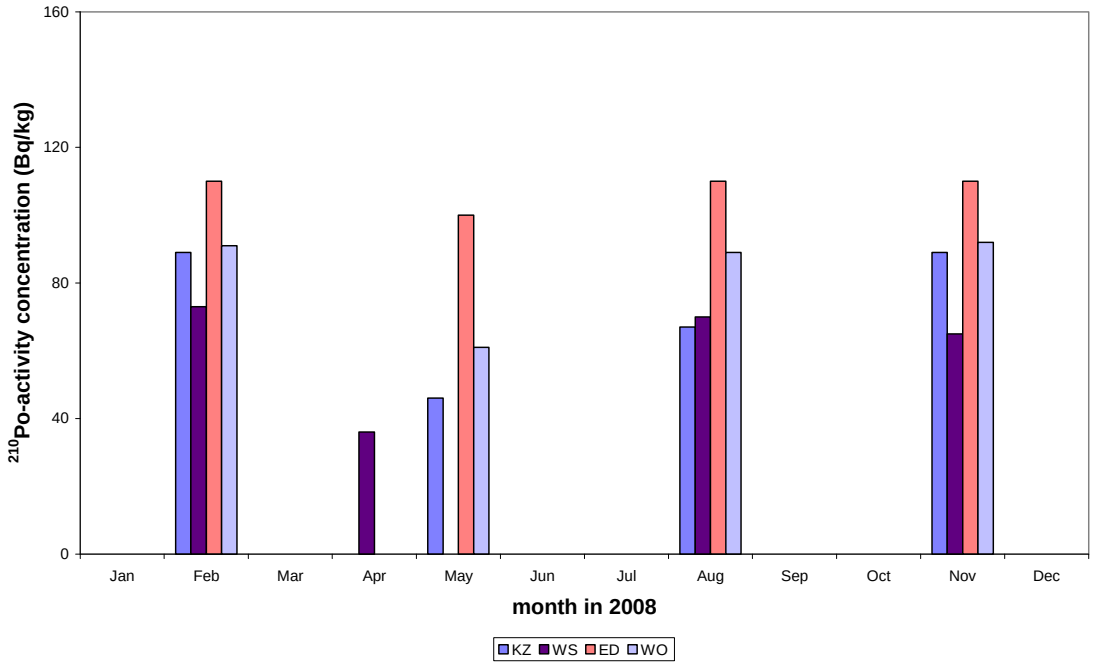


Figure 5.30: The ^{210}Po-activity concentration in suspended solids in seawater. The yearly averages for the Coastal area, Westerscheldt, Eems-Dollard and Wadden Sea East are 73, 61, 108 and 83 Bq·kg^{-1}, respectively.

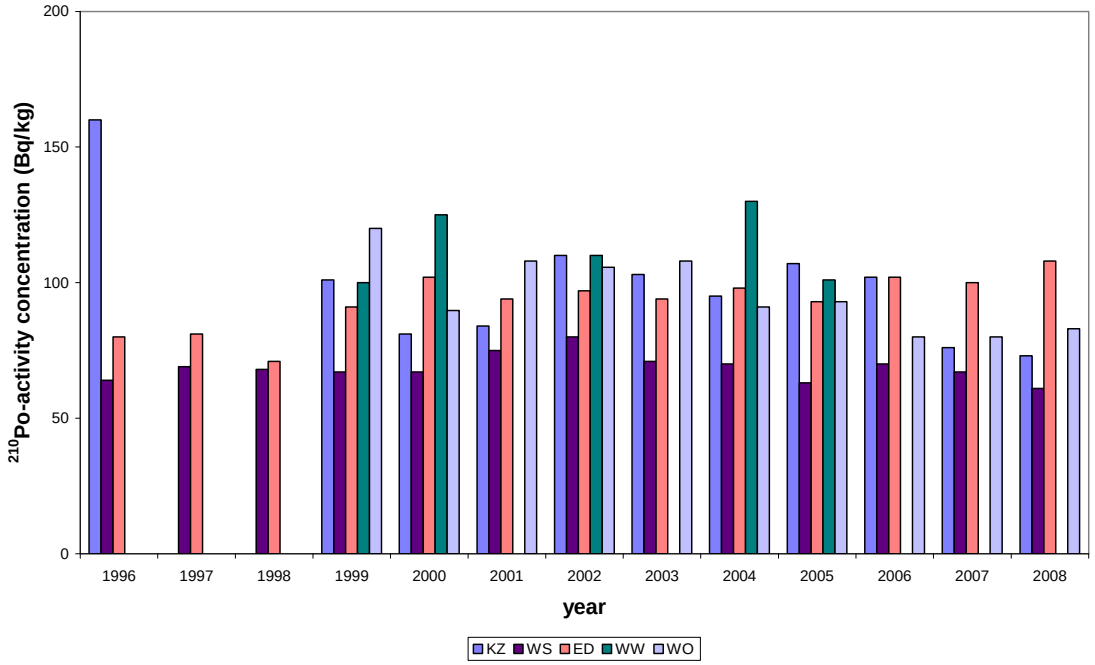


Figure 5.31: Yearly averaged ^{210}Po-activity concentrations in suspended solids. Since 2006 ^{210}Po is not longer determined at Wadden Sea West due to repeatedly insufficient amount of collected suspended solids in previous years.

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 [48]. According to this directive the parameters tritium 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 $mSv \cdot year^{-1}$ [49].

In the Netherlands, water pumping-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 39 times per year depending on the volume of water produced. The activity concentrations are averaged per pumping station.

The results for 2008 are presented in Table 6.1. For gross α, ^{3}H, gross β and residual β several hundred analyses were performed divided over 173 to 191 pumping stations.

Table 6.1: Analyses on drinking water in 2008.

Parameter	Gross α	^{3}H	Residual β	Gross β
Average value [(1)]	< 0.1 $Bq \cdot L^{-1}$	<3.6 $Bq \cdot L^{-1}$	< 0.2 $Bq \cdot L^{-1}$	< 0.2 $Bq \cdot L^{-1}$
No. of all pumping stations	186	187	173	191
No. of all analyses	361	394	404	444
Maximum value [(2)]	0.2 $Bq \cdot L^{-1}$	12 $Bq \cdot L^{-1}$	0.6 $Bq \cdot L^{-1}$	< 0.5 $Bq \cdot L^{-1}$
No. of pumping stations [(3)]	2	1	11	1
No. of analyses [(4)]	1	4	2 - 39	1

(1) Activity concentration averaged over all the pumping stations.
(2) Maximum value of the activity concentration averaged per pumping station.
(3) Number of pumping stations with the maximum value.
(4) Number of analyses per pumping station which lead to the maximum value.

In 2008, at five out of the 186 pumping stations the gross α-activity concentration averaged per pumping station exceeded 0.1 $Bq \cdot L^{-1}$. At two pumping stations a value of 0.2 $Bq \cdot L^{-1}$ was found in raw input water.

For ^{3}H, gross β and residual β the results are within the range of those in previous years [5, 32, 40, 50, 51, 52]. Since there is almost no ^{40}K present, gross β- and residual β-activity concentrations are equal. The gross β-activity concentrations were below 1.0 $Bq \cdot L^{-1}$. The ^{3}H-activity concentrations were below the set limit of 100 $Bq \cdot L^{-1}$ [48].

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 [53]. 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 - Institute of Food Safety monitors radioactivity in milk on a weekly base via the National Monitoring Network Radioactivity in Food (Landelijk Meetnet Radioactiviteit in Voedsel, LMRV). The LMRV is a monitoring network that in principal is 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 weekly samples of all locations are combined into a monthly average for the whole country. The monthly averages for 2008 are presented in Table 7.1.

Table 7.1: Monthly averaged activity concentrations in milk in 2008.

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	89	48 ± 7	< 1.4	< 0.6	< 0.6	< 0.5
February	89	47 ± 7	< 1.4	< 0.6	< 0.6	< 0.5
March	90	49 ± 6	< 1.4	< 0.6	< 0.6	< 0.5
April	69	50 ± 7	< 1.4	< 0.6	< 0.6	< 0.5
May	76	49 ± 5	< 1.4	< 0.6	< 0.6	< 0.5
June	79	49 ± 6	< 1.4	< 0.6	< 0.6	< 0.5
July	73	50 ± 6	< 1.4	< 0.6	< 0.6	< 0.5
August	67	51 ± 7	< 1.4	< 0.6	< 0.6	< 0.5
September	66	50 ± 7	< 1.4	< 0.6	< 0.6	< 0.5
October	88	50 ± 8	< 1.4	< 0.6	< 0.6	< 0.5
November	103	50 ± 6	< 1.4	< 0.6	< 0.6	< 0.5
December	77	50 ± 5	< 1.4	< 0.6	< 0.6	< 0.5
Average	966 (1)	48 ± 5	< 1.4	< 0.6	< 0.6	< 0.5

(1) *Yearly total.*

Since 2006, the detection limits for ^{60}Co, ^{131}I, ^{134}Cs and ^{137}Cs are lower than in previous years. The Institute for Food Safety analysed 27 milk samples for ^{90}Sr in 2008. The samples were collected across the Netherlands. The ^{90}Sr-activity concentration was below the detection limit (5 Bq·L^{-1}) in all samples. The detection limit in 2008 is higher than in 2005 (0.1 Bq·L^{-1}) due to a difference in sample preparation and measurement. Measurements on ^{90}Sr were not performed in 2006.

8. Food

The Food and Consumer Product Safety Authority performs measurements on finished products from retail shops, auctions and distribution centres while RIKILT - Institute of Food Safety performs measurements on samples from the food production chain.

The measurements on food performed by the Food and Consumer Product Safety Authority were carried out according to standard procedures [54, 55]. The results for 2008 are presented in Table 8.1, a total of 641 samples were analysed. None of the samples exceed the set limit of 600 $Bq \cdot kg^{-1}$ (for milk and dairy products 370 $Bq \cdot kg^{-1}$) [56].

Since 2005 the Food and Consumer Product Safety Authority monitors activity concentrations in a mixed diet. The mixed diet is yearly sampled, mainly as separate ingredients but also as complete meals. Over a period of two weeks in five different regions a standard sampling was carried out. The sampling consisted of 641 samples, which were taken from retail shops, auctions and distribution centres [57]. The separate ingredients were divided in the following product groups: grain products, vegetables, fruit, milk and dairy products, meat and meat products, game and poultry, salads and oil and butter.

Radioactivity is also measured in food suspected to contain more than the normal activity concentrations, in this case honey. In 2008 analyses were not performed on ^{90}Sr in mixed diet.

In 2008, RIKILT - Institute of Food Safety also measured 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 results for 2008 are presented in Table 8.2, a total of 825 samples were analysed. None of the samples exceed the set limit of 600 $Bq \cdot kg^{-1}$ (for milk and dairy products 370 $Bq \cdot kg^{-1}$). In addition, radioactivity was measured in 462 food products for individual screening purposes via the National Monitoring Network Radioactivity in Food, especially fruit, fruit products and vegetables (data not shown).

8.1 Honey

In total 123 samples of honey were analysed [57]. The activity (sum of ^{134}Cs and ^{137}Cs) was found to be below the set limit of 600 $Bq \cdot kg^{-1}$ [56]. Only 38 samples of honey contained ^{137}Cs. The activity varied from 3 up to 244 $Bq \cdot kg^{-1}$.

8.2 Game and poultry

All 16 samples in the product group “Game and poultry” that contained ^{137}Cs were game. The activity varied from 4.5 up to 439 $Bq \cdot kg^{-1}$. The activity (sum of ^{134}Cs and ^{137}Cs) was below the set limit of 600 $Bq \cdot kg^{-1}$.

Table 8.1: Results of analysis of food for ^{134}Cs and ^{137}Cs in 2008 as measured by the Food and Consumer Product Safety Authority.

Product	Number of samples	Number of positive samples	^{134}Cs $Bq \cdot kg^{-1}$	^{137}Cs $Bq \cdot kg^{-1}$
Grain products	80	0	< 3.8	< 3.0
Vegetables	118	0	< 3.8	< 3.0
Fruit	55	0	< 3.8	< 3.0
Milk and dairy products	64	0	< 3.8	< 3.0
Meat and meat products	84	0	< 3.8	< 3.0
Game and poultry	44	0	< 3.8	< 3.0
Salads	29	0	< 3.8	< 3.0
Oil and butter	44	0	< 3.8	< 3.0
Honey	123	38	< 3.8	3 - 244

Table 8.2: Results of analysis of food for ^{134}Cs and ^{137}Cs in 2008 as measured by RIKILT - Institute of Food Safety.

Product	Number of samples	Number of positive samples	^{134}Cs $Bq \cdot kg^{-1}$	^{137}Cs $Bq \cdot kg^{-1}$
Vegetables	23	0	< 0.6	< 0.5
Meat and meat products	503	0	< 0.6	< 0.5
Game and poultry	171	16	< 0.6	4.5 - 439
Eggs	128	0	< 0.6	< 0.5

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 [58] here forms only part of the total monitoring program performed near the nuclear power plant. A more detailed description of the monitoring program, underlying strategy and results are reported elsewhere [59, 60]. The 2008 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 2008. 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, 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, natural occurring radionuclides and elemental and organically bound ^{131}I.
[(2)] Analysis is performed on a combined sample of monthly samples of 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.

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 is 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.

When possible the samples taken at locations 27 and 29 (medium range) are analysed separately from the samples taken at locations 21, 22 and 23 (close range). Therefore, the results of these samples (at medium range) can be seen as a reference value. The results for the nuclides considered in the gammaspectroscopic analysis are given in Table A17.

9.2 Soil

The results for the nuclides considered in the gammaspectroscopic analysis in grass and soil are given in Tables A18 and A19. The four soil samples are taken near the outlet of the nuclear power plant. The yearly averaged concentrations of ^{54}Mn, ^{60}Co, ^{134}Cs and ^{137}Cs in soil in 2008 are within the range of those in previous years [60].

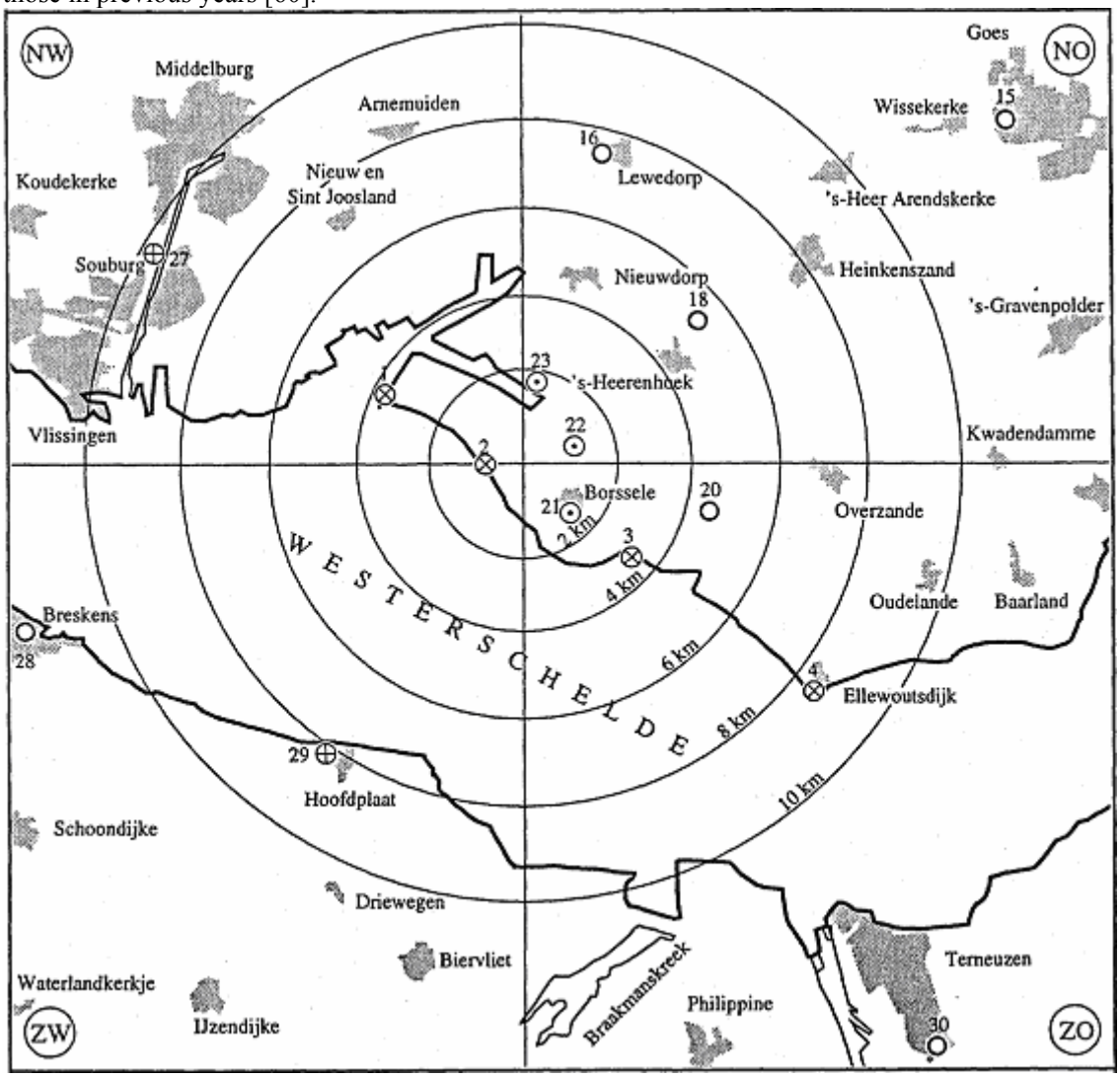


Figure 9.1: Overview of monitoring locations for the monitoring program in the vicinity of the nuclear power plant at Borssele as conducted by NRG. The numbers given in Table 9.1 correspond with the locations in the map.

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

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10. Conclusions

The yearly total activity in deposition for ^{210}Po (29.4 Bq·m^{-2}) is the highest since 1993, which is about twice the normal level. This might partially be explained by Saharan dust which was deposited throughout the Netherlands during the end of May.

The gross α-activity concentration in the Noordzeekanaal, Nieuwe Waterweg and Scheldt exceeds the target value (100 mBq·L^{-1}) in four out of seven, five out of thirteen and thirteen out of thirteen samples taken, respectively. The yearly averaged gross α-activity concentrations in the Noordzeekanaal, Nieuwe Waterweg and Scheldt (240, 106 and 290 mBq·L^{-1}, respectively) are above the target value, but within the range of those in previous years.

The ^{3}H-activity concentration in the Scheldt and Meuse exceeds the target value (10 Bq·L^{-1}) in two out of six and eight out of thirteen samples taken, respectively. The yearly averaged ^{3}H-activity concentration in the Meuse (22.0 Bq·L^{-1}) is above the target value, but within the range of those in previous years.

The ^{226}Ra-activity concentration in the Scheldt exceeds the target value (5 mBq·L^{-1}) in five out of six samples taken. The yearly averaged ^{226}Ra-activity concentration in the Scheldt (9.0 mBq·L^{-1}) is above the target value, but within the range of those in previous years.

The ^{60}Co-activity concentration in suspended solids in the Meuse exceeds the target value (10 Bq·kg^{-1}) in nineteen out of fifty-two samples taken. However the yearly averaged ^{60}Co-activity concentration in the Meuse is below the target value.

The ^{131}I-activity concentration in suspended solids in the Noordzeekanaal and Meuse exceeds the target value (20 Bq·kg^{-1}) in one out of seven and fifteen out of fifty-two samples taken, respectively. However the yearly averaged ^{131}I-activity concentrations are below the target value.

The ^{210}Pb-activity concentration in suspended solids in the Nieuwe Waterweg, Rhine and Meuse exceeds the target value (100 Bq·kg^{-1}) in four out of six, six out of seven and six out of six samples taken, respectively. The yearly averaged ^{210}Pb-activity concentration in the Nieuwe Waterweg, Rhine and Meuse (108, 112 and 160 Bq·kg^{-1}, respectively) are above the target value, but within the range of those in previous years.

The yearly averaged residual β-activity concentration in Waddenzee Oost (180 mBq·L^{-1}) is the highest since 1999.

In 2008 at five of the 148 pumping stations the gross α-activity concentration in drinking water averaged per pumping station exceeds 0.1 Bq·L^{-1}.

The results of all other radioactivity measurements are within the range of those in previous years.
Since 2008 additional data on radioactivity levels in food have been added to this report. The additional data originate from RIKILT – Insitute of Food Safety.
In 2008, the Netherlands complied to the Euratom recommendations. Except for the determination of strontium-90 in mixed diet, which was not carried out.

Appendix A Result tables

Table A1: Weekly averaged gross α- and gross β-activity concentrations in air dust sampled with a High Volume Sampler at RIVM in 2008.

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 [3]	0.029	0.47 ± 0.04	27	0.048	0.52 ± 0.06
2 [3]	0.038	0.34 ± 0.04	28	0.036	0.36 ± 0.04
3	0.017	0.26 ± 0.03	29	0.045	0.28 ± 0.03
4 [3]	0.037	0.34 ± 0.04	30	0.026	0.27 ± 0.03
5	0.034	0.49 ± 0.05	31	0.040	0.69 ± 0.07
6	0.024	0.24 ± 0.03	32	0.026	0.30 ± 0.03
7	0.026	0.46 ± 0.05	33	0.030	0.29 ± 0.03
8 [3]	0.08	0.69 ± 0.07	34	0.036	0.32 ± 0.03
9	0.039	0.29 ± 0.03	35	0.07	0.54 ± 0.06
10	0.031	0.33 ± 0.04	36	0.033	0.45 ± 0.05
11	0.020	0.23 ± 0.03	37	0.033	0.46 ± 0.05
12	0.016	0.28 ± 0.03	38	0.031	0.53 ± 0.06
13	0.025	0.33 ± 0.04	39	0.039	0.76 ± 0.08
14	0.036	0.35 ± 0.04	40	0.039	0.67 ± 0.07
15	0.029	0.33 ± 0.04	41	0.019	0.25 ± 0.03
16	0.023	0.31 ± 0.03	42	0.039	0.64 ± 0.07
17	0.034	0.55 ± 0.06	43	0.045	0.43 ± 0.05
18	0.028	0.38 ± 0.04	44	0.012	0.22 ± 0.02
19	0.026	0.54 ± 0.06	45	0.033	0.66 ± 0.07
20	0.035	0.78 ± 0.08	46	0.025	0.30 ± 0.03
21	0.036	0.50 ± 0.05	47	0.020	0.23 ± 0.03
22	0.052	0.64 ± 0.07	48	0.016	0.20 ± 0.02
23	0.045	0.52 ± 0.06	49 [3, 4]	0.050	0.72 ± 0.08
24	0.037	0.44 ± 0.05	50	0.021	0.22 ± 0.02
25	0.028	0.28 ± 0.03	51 [3]	0.033	0.63 ± 0.06
26	0.031	0.30 ± 0.03	52 [3]	0.016	0.36 ± 0.03
			53 [3, 4]	0.07	1.22 ± 0.13
Average				0.034	0.437 ± 0.007 [5]
SD [6]				0.013	0.19

[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 occurred with a lower flow (about one third of regular flow) during 0.1 to 1.3 days of the week, due to problems with the High Volume Sampler.
[4] Sampling did not occur for 0.4 to 1.9 days of the week, 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 days sampling period with a HVS at RIVM in 2008. Measurements were carried out on a coaxial detector with a ten days delay between sampling and start of measurement, a counting time of 100,000 seconds and a sample volume of about 50,000 m^3. The detection limits are higher than before 2000 [7] due to a different detector set-up.

Nuclide	Detection limit µBq·m^{-3}	Nuclide	Detection limit µBq·m^{-3}
^{7}Be	9	^{113}Sn	1.1
^{22}Na	0.9	^{115m}Cd	45
^{24}Na	600 (1)	^{115}Cd	44
^{40}K	17	^{123m}Te	1.2
^{51}Cr	11	^{124}Sb	1.1
^{54}Mn	0.6	^{125}Sb	2
^{57}Co	0.4	^{129m}Te	28
^{58}Co	0.6	^{131}I	1.3 (2)
^{59}Fe	1.3	^{132}Te	5
^{60}Co	1.2	^{134}Cs	0.9
^{65}Zn	1.3	^{136}Cs	1.2
^{75}Se	1.1	^{137}Cs	2
^{95}Nb	0.9	^{140}Ba	4
^{95}Zr	0.7	^{140}La	43
^{99}Mo	56	^{141}Ce	0.9
^{103}Ru	0.9	^{144}Ce	3
^{106}Ru	6	^{202}Tl	1.2
^{109}Cd	9	^{210}Pb	13
^{110m}Ag	1.3		

(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 relatively short half-life of ^{24}Na and the long delay between the sampling and the measurement this nuclide cannot be determined in the residue measurement on the coaxial detector.

(2) 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 2008. Empty fields indicate that the value was below the detection limit given in Table A2.

Week number	Period	^{7}Be µBq·m^{-3}	^{137}Cs µBq·m^{-3}	^{210}Pb µBq·m^{-3}
1 (1)	28/12 - 04/01	2650 ± 170		370 ± 30
2 (1)	04/01 - 11/01	4300 ± 400		270 ± 30
3	11/01 - 18/01	2900 ± 200		220 ± 20
4 (1)	18/01 - 25/01	3900 ± 300		230 ± 40
5	25/01 - 01/02	5900 ± 500		510 ± 50
6	01/02 - 08/02	3500 ± 300		170 ± 20
7	08/02 - 15/02	3500 ± 300		440 ± 40
8 (1)	15/02 - 22/02	6400 ± 600		560 ± 50
9	22/02 - 29/02	3800 ± 300		260 ± 20
10	29/02 - 07/03	4800 ± 400		190 ± 20
11	07/03 - 14/03	3800 ± 300		145 ± 16
12	14/03 - 21/03	3600 ± 300		160 ± 20
13	21/03 - 28/03	3900 ± 300		183 ± 19
14	28/03 - 04/04	3800 ± 300		240 ± 20
15	04/04 - 11/04	3900 ± 300		260 ± 20
16	11/04 - 18/04	3900 ± 300		220 ± 20
17	18/04 - 25/04	4100 ± 400		510 ± 50
18	25/04 - 02/05	5200 ± 500		260 ± 30
19	02/05 - 09/05	6200 ± 500		450 ± 40
20	09/05 - 16/05	8500 ± 700		590 ± 60
21	16/05 - 23/05	6500 ± 600		320 ± 30
22	23/05 - 30/05	7400 ± 600		540 ± 50
23	30/05 - 06/06	4200 ± 400		540 ± 50
24	06/06 - 13/06	4800 ± 400		420 ± 40
25	13/06 - 20/06	3900 ± 300		200 ± 20
26	20/06 - 27/06	4000 ± 300		210 ± 20

Continued on the next page.

Table A3: Continued

Week number	Period	^{7}Be µBq·m^{-3}	^{137}Cs µBq·m^{-3}	^{210}Pb µBq·m^{-3}
27	27/06 - 04/07	6600 ± 600		440 ± 40
28	04/07 - 11/07	3900 ± 300		210 ± 20
29	11/07 - 18/07	3900 ± 300		250 ± 30
30	18/07 - 25/07	3200 ± 300		200 ± 20
31	27/07 - 01/08	6900 ± 600		680 ± 60
32	01/08 - 08/08	3500 ± 300		290 ± 30
33	08/08 - 15/08	3900 ± 300		183 ± 19
34	15/08 - 22/08	3900 ± 300		220 ± 20
35	22/08 - 29/08	4800 ± 400		540 ± 50
36	29/08 - 05/09	4300 ± 400		380 ± 40
37	05/09 - 12/09	3700 ± 300		370 ± 30
38	12/09 - 19/09	4400 ± 400		400 ± 40
39	19/09 - 26/09	4200 ± 400		770 ± 70
40	26/09 - 03/10	4200 ± 400		600 ± 60
41	03/10 - 10/10	2600 ± 200		210 ± 20
42	10/10 - 17/10	3500 ± 300		820 ± 70
43	17/10 - 24/10	3900 ± 300		360 ± 30
44	24/10 - 31/10	2040 ± 180		181 ± 17
45	31/10 - 07/11	1780 ± 160		920 ± 80
46	07/11 - 14/11	3500 ± 300		220 ± 20
47	14/11 - 21/11	2800 ± 200		180 ± 20
48	21/11 - 28/11	2600 ± 200		160 ± 20
49 [1, 2]	28/11 - 05/12	2300 ± 200		730 ± 70
50	05/12 - 12/12	1590 ± 140		220 ± 20
51 [1]	12/12 - 19/12	2600 ± 170		740 ± 60
52 [1]	19/12 - 25/12	2840 ± 180		270 ± 30
53 [1, 2]	25/12 - 31/12	5400 ± 500		1200 ± 120
Average		4120 ± 50 [3]	-	381 ± 6 [3]
SD [4]		1400	-	200

[1] Sampling occurred with a lower flow (about one third of regular flow) during 0.1 to 1.3 days of the week, due to problems with the High Volume Sampler.
[2] Sampling did not occur for 0.4 to 1.9 days of the week, 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] 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 2008.

Month	Precipitation mm	^{3}H (1) $Bq \cdot m^{-2}$	Gross α $Bq \cdot m^{-2}$	Gross β $Bq \cdot m^{-2}$
January	100.3	< 160	2.3 ± 0.4	8.3 ± 0.6
February	27.7	< 50	1.3 ± 0.3	3.6 ± 0.3
March	109.8	< 180	3.5 ± 0.4	9.6 ± 0.8
April	31.2	< 50	3.8 ± 0.4	8.1 ± 0.6
May	25.9	49 ± 15	7.2 ± 0.7	11.3 ± 0.9
June	48.3	< 80	5.9 ± 0.6	13.2 ± 1.0
July	127.5	< 200	3.1 ± 0.4	10.8 ± 0.8
August	93.7	< 150	2.5 ± 0.3	9.0 ± 0.7
September	146.2	< 200	3.9 ± 0.4	15.5 ± 1.2
October	68.1	< 110	1.7 ± 0.3	5.1 ± 0.4
November	90.5	< 150	2.3 ± 0.3	7.4 ± 0.6
December	39.0	80 ± 20	1.9 ± 0.3	4.3 ± 0.3
Total	908	-	39.4 ± 1.5 (2)	106 ± 3 (2)
Lower limit (3)	-	102	-	-
Upper limit (3)	-	1550	-	-

(1) The detection limit ($Bq \cdot m^{-2}$) is mainly dependent on the amount of precipitation since the detection limit of the counting sample itself is more or less constant (1.6 $Bq \cdot L^{-1}$).
(2) The uncertainty in the sum is equal to the square root of the sum of the squared monthly uncertainties. Uncertainties are given as 1σ.
(3) The lower and upper limits are defined in Appendix B.

Table A5: Yearly totals for long-lived gross α-, gross β- and ^{3}H-activity in deposition for 1993-2008. 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 $Bq \cdot m^{-2}$	Gross α $Bq \cdot m^{-2}$	Gross β $Bq \cdot m^{-2}$
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

(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 2008.

Month	^{210}Po $Bq \cdot m^{-2}$
January	1.52 ± 0.12
February	1.11 ± 0.05
March	2.67 ± 0.18
April	3.38 ± 0.17
May	6.7 ± 0.3
June	3.1 ± 0.3
July	1.89 ± 0.18
August	2.60 ± 0.16
September	1.9 ± 0.3
October	1.46 ± 0.06
November	1.50 ± 0.12
December	1.68 ± 0.11
Total	29.4 ± 0.7 [(2)]
Lower limit [(3)]	-
Upper limit [(3)]	-

(1) Measurements are carried out using α-spectroscopy. Uncertainties are given as 1σ.
(2) The uncertainty in the sum is equal to the square root of the sum of the squared monthly uncertainties. Uncertainties are given as 1σ.
(3) The lower and upper limits are defined in Appendix B.

Table A7: Yearly totals for ^{7}Be, ^{137}Cs, ^{210}Pb- and ^{210}Po-activity in deposition for 1993-2008. Either the yearly total with uncertainty [(1)] or the lower and upper limits [(2)] of the 68% confidence range are given.

Year	^{7}Be [(3)]	^{137}Cs [(3)]	^{210}Pb [(3)]	^{210}Pb [(4)]	^{210}Po [(4)]
	$Bq \cdot m^{-2}$	$Bq \cdot m^{-2}$	$Bq \cdot m^{-2}$	$Bq \cdot m^{-2}$	$Bq \cdot m^{-2}$
1993	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	0.00 - 4.82	177 ± 6	-	0.6 - 8.0
2001	1480 ± 30	0.00 - 4.50	83 - 104	-	6.5 - 9.4
2002	1510 ± 30	0.00 - 5.22	119 - 142	-	6.1 - 8.5
2003	1000 - 1050	0.00 - 4.69	88 - 113	-	4.3 - 5.6
2004	1330 ± 30	0.22 - 5.53	64 - 102	-	5.4 - 7.7
2005	1320 ± 30	0.00 - 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	0.00 - 7.63	63 - 143	-	29.4 ± 0.7

[(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 [61].
[(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 2008.

Week Number	Period	Precipitation mm	^{7}Be Bq·m^{-2}	^{137}Cs Bq·m^{-2}	^{210}Pb Bq·m^{-2}
1	28/12 - 04/01	5.3	10.3 ± 1.3	< 0.14	< 1.4
2	04/01 - 11/01	31.0	42 ± 5	< 0.11	< 1.4
3	11/01 - 18/01	16.0	17 ± 2	< 0.13	< 1.3
4	18/01 - 25/01	37.8	121 ± 14	< 0.13	4.9 ± 0.7
5	25/01 - 01/02	10.3	36 ± 4	< 0.3	2.1 ± 0.5
6	01/02 - 08/02	14.0	17 ± 3	< 0.17	< 2
7	08/02 - 15/02	0.2	3.6 ± 0.6	< 0.13	< 1.3
8	15/02 - 22/02	1.0	4.2 ± 0.9	< 0.14	< 1.3
9	22/02 - 29/02	12.5	16 ± 2	< 0.11	< 2
10	29/02 - 07/03	16.0	80 ± 10	< 0.12	< 6
11	07/03 - 14/03	17.0	38 ± 5	< 0.09	< 1.3
12	14/03 - 21/03	44.0	91 ± 11	< 0.11	3.9 ± 1.0
13	21/03 - 28/03	22.0	70 ± 8	< 0.11	< 1.5
14	28/03 - 04/04	10.8	45 ± 5	< 0.14	< 4
15	04/04 - 11/04	12.0	29 ± 4	< 0.4	< 2
16	11/04 - 18/04	1.7	9.5 ± 1.2	< 0.13	< 1.3
17	18/04 - 25/04	10.6	25 ± 3	< 0.13	2.5 ± 0.5
18	25/04 - 02/05	6.9	25 ± 3	< 0.4	1.7 ± 0.4
19	02/05 - 09/05	2.2	12.0 ± 1.5	< 0.13	< 4
20	09/05 - 16/05	5.5	14.6 ± 1.8	< 0.16	< 5
21	16/05 - 23/05	9.5	11.9 ± 1.5	< 0.13	< 1.3
22	23/05 - 30/05	8.7	43 ± 5	< 0.13	3.5 ± 0.8
23	30/05 - 06/06	29.3	113 ± 13	< 0.13	6.8 ± 0.9
24	06/06 - 13/06	2.8	12.2 ± 1.9	< 0.16	5.2 ± 1.3
25	13/06 - 20/06	6.7	17 ± 2	< 0.14	< 1.3
26	20/06 - 27/06	2.8	10.0 ± 1.5	< 0.14	< 1.4

Continued on the next page.

Table A8: Continued.

Week Number	Period	Precipitation mm	^{7}Be Bq·m^{-2}	^{137}Cs Bq·m^{-2}	^{210}Pb Bq·m^{-2}
27	27/06 - 04/07	6.8	30 ± 4	< 0.12	< 4
28	04/07 - 11/07	50.0	88 ± 10	< 0.11	3.4 ± 0.8
29	11/07 - 18/07	15.0	33 ± 4	< 0.13	< 1.4
30	18/07 - 25/07	24.0	38 ± 5	< 0.12	< 1.4
31	25/07 - 01/08	38.5	95 ± 11	< 0.13	5.2 ± 0.9
32	01/08 - 08/08	25.5	62 ± 8	< 0.12	2.9 ± 0.5
33	08/08 - 15/08	21.0	41 ± 5	< 0.12	< 1.4
34	15/08 - 22/08	37.0	68 ± 8	< 0.14	3.0 ± 0.6
35	22/08 - 29/08	10.2	41 ± 5	< 0.14	< 1.6
36	29/08 - 05/09	8.8	17 ± 2	< 0.14	2.4 ± 0.9
37	05/09 - 12/09	40.8	80 ± 9	< 0.13	5.8 ± 1.1
38	12/09 - 19/09	30.0	29 ± 4	< 0.13	< 1.5
39	19/09 - 26/09	2.2	11.3 ± 1.8	< 0.11	1.9 ± 0.7
40	26/09 - 03/10	64.5	95 ± 11	< 0.13	5.2 ± 0.9
41	03/10 - 10/10	22.5	42 ± 5	< 0.14	< 2
42	10/10 - 17/10	11.0	25 ± 3	< 0.13	< 1.3
43	17/10 - 24/10	12.0	29 ± 4	< 0.11	< 1.3
44	24/10 - 31/10	22.6	51 ± 6	< 0.12	< 1.5
45	31/10 - 07/11	4.7	8.9 ± 1.3	< 0.15	< 1.5
46	07/11 - 14/11	48.5	49 ± 6	< 0.11	3.9 ± 0.6
47	14/11 - 21/11	17.0	57 ± 7	< 0.11	< 1.5
48	21/11 - 28/11	20.3	31 ± 4	< 0.13	< 4
49	28/11 - 05/12	20.8	24 ± 3	< 0.14	< 4
50	05/12 - 12/12	8.5	8.3 ± 1.4	< 0.2	< 1.2
51	12/12 - 19/12	3.2	8.1 ± 1.1	< 0.11	2.4 ± 0.7
52	19/12 - 27/12	6.0	13.9 ± 1.8	< 0.14	< 1.5
53	27/12 - 02/01	0.6	4.1 ± 0.8	< 0.12	< 1.5
Total [2]		908	1990 ± 40	-	-
Lower limit [3]		-	-	0	63
Upper limit [3]		-	-	7.63	143

[1] Measurements are 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 2008 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	3.5	68
Kollumerwaard	972	2.6	71
Valthermond [3]	974	2.7	59
Vlaardingen	976	3.1	71
Braakman	978	2.9	66
Huijbergen	980	3.0	58
Houtakker	982	2.3	64
Wijnandsrade	984	5.1	71
Eibergen	986	3.0	61
De Zilk	988	1.9	65
Wieringerwerf	990	2.9	70
Vredepeel	992	3.8	68
Biddinghuizen	994	3.1	75
Bilthoven	998	2.8	62

[1] These dose equivalent rate monitors are differently placed 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: The yearly averaged ambient dose equivalent rate for the NMR stations in 2008.

Station	No.	Ambient dose equivalent rate nSv.h^{-1}	Station	No.	Ambient dose equivalent rate nSv.h^{-1}
Den Burg	1001	70	Urk	1105	76
Den Oever	1003	69	Eemshaven	1106	84
Julianadorp	1004	65	Uithuizen	1107	83
Petten	1006	61	Wagenborgen	1109	76
Kolhorn	1007	77	Winschoten	1110	72
Egmond Aan Zee	1009	67	Ter Apel	1111	72
Heerhugowaard	1011	73	Stadskanaal	1112	63
Haarlem-Noord	1014	74	Nieuweschans	1113	72
Nederhorst Den Berg	1015	60	Bellingwolde	1114	60
Enkhuizen	1018	80	Groningen	1116	76
Oosthuizen	1019	78	Leens	1117	84
Zaandam	1021	68	Grijpskerk	1118	73
Gouda	1024	73	Meppel	1125	68
Dordrecht	1027	63	Hoogeveen	1126	61
Zuid Beijerland	1028	74	Steenwijksmoer	1129	65
Pijnacker	1032	86	Nieuw Amsterdam	1130	79
Rotterdam-Crooswijk	1033	73	Nieuw Schoonebeek/	1131	62
Rotterdam-Waalhaven	1034	68	Weiteveen		
Maasvlakte	1035	85	Emmen	1132	81
Maassluis	1037	82	Hengelo (Ov)	1135	70
Hellevoetsluis	1038	92	Hengelo (Gld) [2]	1136	-
Ouddorp	1039	73	Enschede [2]	1139	-
Wekerom	1041	73	Losser	1140	63
Wageningen	1043	69	Oldenzaal	1141	77
Amersfoort [1]	1046	70	Westerhaar	1142	63
Harderwijk	1050	65	Rijssen	1143	67
Wijk Bij Duurstede	1056	82	's Heerenberg	1144	62
Rhenen	1061	75	Dinxperlo	1145	79
Nieuwegein	1062	80	Varsseveld	1146	72
Apeldoorn	1066	70	Groenlo	1147	83
Heerenveen	1071	63	Deventer	1148	78
Oosterwolde	1072	81	Etten-Leur	1154	69
Bergum	1074	68	Den Bosch	1157	69
Witmarsum	1076	88	Raamsdonkveer	1159	92
Sneek	1077	71	Ulvenhout	1160	73
St Jacobiparochie	1081	78	Baarle-Nassau	1161	93
Holwerd	1082	88	Uden	1162	71
Leeuwarden	1085	69	Mill	1163	65
Zwolle-Zuid	1087	74	Oss	1167	65
Ommen	1093	64	Nuenen	1172	71
Hardenberg	1095	65	Bergeijk	1174	88
Assen	1097	65	Waalre	1175	69
Rutten	1099	74	Someren (Dorp)	1176	69
Lelystad	1103	77	Oisterwijk	1178	73

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}
Riel	1179	71	Hoensbroek	1225	82
Oostelbeers	1180	83	Gennep	1228	79
Hilvarenbeek	1181	65	Elst (Gld)	1229	82
Venray	1183	62	Zevenaar	1230	72
Nieuw-Bergen	1184	63	Nijmegen	1231	74
Sevenum	1185	69	Amstelveen	1233	73
Reuver	1188	65	Amsterdam Oost [2]	1234	-
Nederweert	1189	72	Aalsmeer	1236	71
Heythuysen	1190	74	Nispen	1237	62
Mariahoop	1191	69	Groesbeek	1240	77
Stramproy	1192	65	Tubbergen	1243	67
Eerbeek [3]	1193	73	Haaksbergen	1244	67
Leiden	1196	73	Scheveningen	1247	77
Hulst	1197	76	Zaltbommel	1251	71
Terneuzen	1199	71	IJzendijke	1252	77
Sluis	1201	75	Ritthem	1253	98
Vlissingen	1202	77	Vlissingen Haven	1254	72
Halsteren	1204	64	Nieuwdorp	1255	75
Oud Gastel	1206	66	's Heerenhoek	1256	127
Goes	1207	83	Driewegen	1257	82
Bruinisse	1209	74	Arnemuiden	1258	72
Burgh-Haamstede	1211	62	Heinkenszand	1259	83
Vrouwenpolder	1212	64	Baarland	1260	86
Wemeldinge	1214	76	Biervliet	1261	76
Middelburg	1215	77	Nummer Één	1262	76
Westkapelle	1216	68	Rilland	1263	75
Noordwijk-Binnen	1217	76	Putte	1264	56
Stein	1219	81	Nieuw Namen	1265	80
Maastricht	1220	88	Beneden Leeuwen	1272	85
Ravensbos\ Arensgehout	1221	84	Denekamp	1278	65
			Winterswijk/Kotten	1279	69
Vaals	1222	82	Bilthoven	1280	61
Gulpen	1223	79	Maarheze/Gastel	1281	74
Kerkrade	1224	87			

[1] The station Hooglanderveen has been relocated to Amersfoort since February 2008.
[2] Station was not operational in 2008.
[3] The station Arnhem-Oosterbeek has been relocated to Eerbeek since August 2008.

Table A11: Gross α, residual β, ^{3}H-, ^{90}Sr- and ^{226}Ra-activity concentrations (mBq·L^{-1}) in surface water in 2008 as measured by RWS WD Centre for Water Management.

Date	Gross α mBq·L^{-1}	Residual β mBq·L^{-1}	^{3}H mBq·L^{-1}	^{90}Sr mBq·L^{-1}	^{226}Ra mBq·L^{-1}
Location	**IJsselmeer**				
08/01/08	49	48	2800		
05/02/08	98	74			
04/03/08	47	60	3100		
01/04/08	37	13			
28/04/08	31	7	4200		
27/05/08	63	63			
24/06/08	35	12	2500		
22/07/08	54	65			
19/08/08	56	66	1700		
16/09/08	74	54			
14/10/08	34	33	3800		
11/11/08	44	45			
09/12/08	35	48	4100		
Average	51	45	3200		
Location	**Nieuwe Waterweg**				
23/01/08	99	82			
20/02/08	72	56	4700	5	4
19/03/08	97	71			
16/04/08	90	63	5500	4	2
14/05/08	92	54			
11/06/08	120	18	3100	3	4
09/07/08	89	39			
06/08/08	130	27	3400	< 1	4
03/09/08	180	24			
01/10/08	110	43	3600	4	3
29/10/08	150	37			
26/11/08	92	43	6300	5	4
23/12/08	58	61			
Average	106	48	4400	3.6	3.5
Location	**Noordzeekanaal**				
21/01/08	130	47	2400		
17/03/08	58	30	5400		
13/05/08	100	31	3200		
07/07/08	74	22	2800		
01/09/08	140	25	2200		
27/10/08	580	24	1300		
22/12/08	570	45	3900		
Average	240	32	3000		

Continued on the next page.

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**				
16/01/08	53	41	9500	1	5
13/02/08	82	53	4900		
12/03/08	55	81	4000	1	4
09/04/08	67	53	2700		
07/05/08	72	35	2300	2	4
04/06/08	63	67	5100		
02/07/08	140	130	6300	2	4
30/07/08	81	49	1900		
27/08/08	50	34	2700	4	2
24/09/08	97	44	2200		
22/10/08	54	36	4100	< 1	4
19/11/08	49	35	5700		
17/12/08	62	73	2200	7	4
Average	71	56	4100	2.5	3.9
Location	**Scheldt**				
07/01/08	230	52			
04/02/08	180	70	11000		7
03/03/08	150	110			
31/03/08	130	21	5100		5
28/04/08	180	99			
26/05/08	370	160	9500		7
23/06/08	270	56			
21/07/08	330	140	11000		15
20/08/08	370	160			
17/09/08	370	87	10000		7
13/10/08	410	93			
10/11/08	380	150	9400		13
08/12/08	440	88			
Average	290	99	9300		9.0
Location	**Meuse**				
15/01/08	48	64	20000	1	2
12/02/08	48	35	1100		
11/03/08	64	54	2300	< 1	3
08/04/08	38	30	1700		
06/05/08	36	13	860	1	2
03/06/08	30	52	45000		
01/07/08	46	20	31000	4	4
29/07/08	52	32	39000		
26/08/08	52	31	40000	< 1	3
23/09/08	89	13	39000		
21/10/08	34	37	41000	1	3
18/11/08	48	22	28000		
16/12/08	35	40	1000	6	3
Average	48	34	22000	1.9	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 2008 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**			
08/01/08	< 1	< 1	10	
05/02/08	< 1	< 1	7	
04/03/08	< 1	< 1	7	
01/04/08	< 1	< 1	7	
28/04/08	< 1	< 1	4	
27/05/08	< 1	< 1	7	
24/06/08	< 1	< 1	4	
22/07/08	< 1	< 1	3	
19/08/08	< 1	< 1	6	
16/09/08	< 1	< 1	3	
14/10/08	< 1	< 1	3	
11/11/08	< 1	< 1	4	
09/12/08	< 1	< 1	5	
Average	< 1	< 1	5.4	
Location	**Ketelmeer**			
31/01/08	< 1	< 1	17	
28/03/08	< 1	< 1	19	
22/05/08	< 1	< 1	17	
17/07/08	< 1	< 1	14	
11/09/08	n/a	n/a	n/a	
06/11/08	< 1	3	16	
31/12/08	n/a	n/a	n/a	
Average	< 1	< 1	16.6	
Location	**Nieuwe Waterweg**			
23/01/08	< 1	2	9	
20/02/08	< 1	3	14	110
19/03/08	< 1	< 1	15	
16/04/08	< 1	< 1	10	88
14/05/08	< 1	< 1	12	
11/06/08	< 1	< 1	12	120
09/07/08	< 1	< 1	8	
06/08/08	< 1	< 1	11	93
03/09/08	< 1	< 1	7	
01/10/08	< 1	< 1	9	130
29/10/08	< 1	< 1	9	
26/11/08	< 1	3	9	110
23/12/08	< 1	< 1	13	
Average	< 1	< 1	10.6	108

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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	**Noordzeekanaal**			
21/01/08	< 1	12	12	
17/03/08	< 1	18	8	
13/05/08	< 1	7	4	
07/07/08	< 1	6	3	
01/09/08	< 1	33	6	
27/10/08	< 1	18	10	
22/12/08	< 1	10	12	
Average	< 1	15	7.9	
Location	**Rhine**			
16/01/08	< 1	7	18	120
12/02/08	< 1	8	19	
11/03/08	< 1	13	19	110
09/04/08	< 1	< 1	15	
07/05/08	< 1	< 1	13	82
04/06/08	< 1	< 1	13	
02/07/08	< 1	< 1	13	110
30/07/08	< 1	4	12	
27/08/08	< 1	6	12	110
24/09/08	< 1	< 1	14	
22/10/08	< 1	< 1	15	130
19/11/08	< 1	6	15	
17/12/08	< 1	< 1	17	120
Average	< 1	3.7	15.0	112
Location	**Scheldt**			
07/01/08	< 1	< 1	5	
04/02/08	< 1	< 1	8	91
03/03/08	< 1	< 1	8	
31/03/08	< 1	< 1	9	100
28/04/08	< 1	< 1	7	
26/05/08	1	< 1	8	100
23/06/08	< 1	< 1	8	
21/07/08	< 1	< 1	8	98
20/08/08	< 1	< 1	6	
17/09/08	< 1	< 1	7	85
13/10/08	< 1	< 1	7	
10/11/08	1	< 1	7	90
08/12/08	< 1	4	11	
Average	< 1	< 1	7.6	94

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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**			
02/01/08	33	11	14	
08/01/08	3	11	12	
15/01/08	5	15	14	140
22/01/08	5	10	14	
29/01/08	22	31	17	
05/02/08	4	12	13	
12/02/08	< 1	10	16	
20/02/08	7	41	12	
26/02/08	9	26	19	
04/03/08	2	10	14	
11/03/08	3	13	12	120
18/03/08	< 1	< 1	11	
25/03/08	< 1	< 1	11	
02/04/08	7	< 1	12	
08/04/08	< 1	11	15	
15/04/08	2	< 1	13	
22/04/08	16	< 1	14	
28/04/08	11	20	13	
07/05/08	11	15	10	140
13/05/08	8	32	9	
20/05/08	12	15	12	
27/05/08	16	34	11	
05/06/08	3	24	10	
10/06/08	10	10	13	
17/06/08	11	16	12	
24/06/08	7	16	11	
01/07/08	n/a	n/a	n/a	n/a
11/07/08	2	< 1	11	
15/07/08	5	7	14	
22/07/08	7	8	14	
29/07/08	8	8	14	
05/08/08	5	38	13	
12/08/08	6	11	12	
19/08/08	9	22	13	
26/08/08	10	40	16	220
02/09/08	8	33	15	
09/09/08	11	< 1	15	
16/09/08	11	14	16	
23/09/08	11	81	14	
30/09/08	8	67	13	
07/10/08	15	< 1	17	
14/10/08	16	23	17	
21/10/08	23	11	16	190
28/10/08	17	15	15	

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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**			
04/11/08	19	17	15	
11/11/08	5	26	13	
19/11/08	27	18	15	
25/11/08	17	< 1	14	
02/12/08	18	14	15	
09/12/08	4	8	16	
16/12/08	7	33	20	150
24/12/08	8	11	18	
30/12/08	10	7	20	
Average	9.5	17	13.9	160

n/a = data not available due to insufficient amount of collected suspended solids.

Table A13: Gross α-, residual β-, ^{3}H- and ^{90}Sr-activity concentrations ($mBq \cdot L^{-1}$) in seawater in 2008 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**			
14/02/08	390	93	7600	
29/05/08	210	61	4200	
20/08/08	340	51	3100	
13/11/08	580	68	5000	
Average	380	68	5000	
Location	**Southern North Sea**			
14/02/08	650	53	5400	4
15/05/08	260	93	3100	< 1
20/08/08	440	44	3200	< 1
13/11/08	530	52	5200	2
Average	470	60	4200	1.8
Location	**Central North Sea**			
13/02/08	420	88	330	< 1
03/06/08	320	92	490	< 1
26/08/08	670	64	< 100	1
03/12/08	560	58	270	5
Average	490	76	280	1.8
Location	**Delta Coastal Waters**			
23/01/08	490	76		
14/02/08	460	77	8200	4
18/03/08	330	50		
22/04/08	340	68		
19/05/08	570	46	5000	< 1
10/06/08	240	38		
17/07/08	n/a	n/a		
21/08/08	520	68	4000	6
17/09/08	980	92		
16/10/08	800	65		
17/11/08	670	73	5300	< 1
11/12/08	460	75		
Average	530	66	5600	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**			
09/01/08	310	70	4700	< 1
07/02/08	480	86	9300	5
03/03/08	270	72	7400	< 1
31/03/08	560	45	8100	< 1
28/04/08	320	88	5600	< 1
26/05/08	170	71	5900	1
24/06/08	390	58	5200	< 1
21/07/08	610	72	4600	4
20/08/08	990	270	4400	3
15/09/08	700	86	4800	< 1
14/10/08	640	130	4900	2
10/11/08	920	83	4900	6
08/12/08	860	92	6800	1
Average	560	94	5900	1.9
Location	**Eems-Dollard**			
14/02/08	710	82	3800	
15/05/08	290	48	6800	
29/08/08	390	50	3000	
09/11/08	550	83	5100	
Average	480	66	4700	
Location	**Wadden Sea West**			
20/02/08	650	74	6000	
20/05/08	340	100	3300	
01/09/08	480	62	3000	
14/11/08	560	87	4600	
Average	510	81	4200	
Location	**Wadden Sea East**			
22/02/08	330	260	5400	
14/05/08	360	78	6000	
15/08/08	410	200	3000	
12/11/08	760	200	3500	
Average	460	180	4500	

n/a = data not available.

Table A14: ^{137}Cs- and ^{210}Po-activity concentrations in suspended solids (Bq·kg^{-1}) in seawater in 2008 as measured by RWS WD Centre for Water Management. Since 2006 ^{137}Cs and ^{210}Pb are no longer determined at Wadden Sea West due to repeatedly insufficient amount of collected suspended solids in previous years.

Date	^{137}Cs Bq·kg^{-1}	^{210}Po Bq·kg^{-1}
Location	**Coastal area**	
11/02/08	6	89
06/05/08	3	46
22/08/08	5	67
18/11/08	6	89
Average	5	73
Location	**Westerscheldt**	
07/02/08	5	73
29/04/08	3	36
19/08/08	3	70
10/11/08	4	65
Average	3.8	61
Location	**Eems-Dollard**	
12/02/08	8	110
26/05/08	9	100
12/08/08	8	110
08/11/08	7	110
Average	8	108
Location	**Wadden Sea East**	
22/02/08	6	91
14/05/08	3	61
15/08/08	5	89
12/11/08	4	92
Average	4.5	83

Table A15: Monthly averaged gross α-activity concentrations in air dust in the vicinity of the nuclear power plant at Borssele.

Date [1]			Gross α [2] mBq·m^{-3}		
Location	**21**	**22**	**23**	**27**	**29**
07/02/08	0.101	0.046	0.140	0.049	0.022
04/03/08	0.066	0.034	0.185	0.059	0.052
02/04/08	0.135	0.208	0.017	0.011	0.041
08/05/08	0.021	0.011	0.087	0.115	0.013
04/06/08	0.071	0.030	0.078	0.058	0.094
03/07/08	0.093	0.081	0.105	0.047	0.031
06/08/08	0.128	0.092	0.218	0.021	0.025
08/09/08	0.021	0.023	0.130	0.026	0.013
01/10/08	0.069	0.059	0.107	0.013	0.072
06/11/08	0.012	0.042	0.119	0.010	0.022
04/12/08	0.064	0.048	0.215	0.013	0.023
08/01/09	0.045	0.049	0.083	0.029	0.026

[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.

Date [1]			Gross β mBq·m^{-3}		
Location	**21**	**22**	**23**	**27**	**29**
07/02/08	0.26 ± 0.03	0.203 ± 0.015	0.27 ± 0.02	0.15 ± 0.02	0.25 ± 0.03
04/03/08	0.32 ± 0.03	0.35 ± 0.02	0.42 ± 0.03	0.31 ± 0.03	0.36 ± 0.03
02/04/08	0.19 ± 0.03	0.187 ± 0.017	0.21 ± 0.03	0.10 ± 0.03	0.16 ± 0.02
08/05/08	0.24 ± 0.02	0.224 ± 0.017	0.30 ± 0.02	0.27 ± 0.03	0.13 ± 0.02
04/06/08	0.47 ± 0.03	0.387 ± 0.019	0.45 ± 0.03	0.21 ± 0.03	0.408 ± 0.013
03/07/08	0.28 ± 0.03	0.226 ± 0.018	0.25 ± 0.02	0.22 ± 0.02	0.268 ± 0.017
06/08/08	0.38 ± 0.02	0.265 ± 0.015	0.33 ± 0.02	0.115 ± 0.020	0.23 ± 0.03
08/09/08	0.24 ± 0.02	0.212 ± 0.016	0.30 ± 0.02	0.218 ± 0.019	0.48 ± 0.02
01/10/08	0.53 ± 0.03	0.43 ± 0.02	0.54 ± 0.03	0.25 ± 0.03	0.624 ± 0.018
06/11/08	0.30 ± 0.02	0.251 ± 0.014	0.31 ± 0.02	0.251 ± 0.019	0.333 ± 0.011
04/12/08	0.43 ± 0.03	0.189 ± 0.017	0.38 ± 0.03	0.19 ± 0.02	0.434 ± 0.017
08/01/09	0.36 ± 0.02	0.338 ± 0.016	0.26 ± 0.03	0.39 ± 0.02	0.222 ± 0.019

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

Date [1]	^{60}Co mBq·m^{-3}	$^{131}I_{el}$ [2] mBq·m^{-3}	$^{131}I_{or}$ [2] mBq·m^{-3}	^{137}Cs mBq·m^{-3}	Nat. [3] mBq·m^{-3}
07/02/08	< 0.04	< 0.1	< 0.3	< 0.03	1.23 ± 0.16
04/03/08	< 0.10	< 0.2	< 0.4	< 0.07	2.18 ± 0.14
02/04/08	< 0.09	< 0.4	< 0.3	< 0.07	2.9 ± 0.3
08/05/08	< 0.08	< 0.2	< 0.3	< 0.06	1.3 ± 0.2
04/06/08	< 0.07	< 0.2	< 0.2	< 0.05	1.3 ± 0.2
03/07/08	< 0.09	< 0.1	< 0.3	< 0.07	3.1 ± 0.3
06/08/08	< 0.08	< 0.2	< 0.3	< 0.06	1.66 ± 0.05
08/09/08	< 0.07	< 0.2	< 0.3	< 0.06	1.39 ± 0.05
01/10/08	< 0.09	< 0.1	< 0.3	< 0.06	2.16 ± 0.07
06/11/08	< 0.06	< 0.7	< 0.3	< 0.04	1.3 ± 0.2
04/12/08	< 0.06	< 0.1	< 0.3	< 0.04	1.5 ± 0.2
08/01/09	< 0.05	< 0.2	< 0.5	< 0.04	2.09 ± 0.17

[1] End date of monthly sampling period.
[2] Elemental respectively organically bound ^{131}I.
[3] Natural occurring γ-emmitters.

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

Date	Mass kg·m^{-2}	^{60}Co Bq·kg^{-1} [1]	^{131}I Bq·kg^{-1} [1]	^{137}Cs Bq·kg^{-1} [1]
07/02/08	0.115	< 2	< 1	< 1
04/03/08	0.154	< 4	< 3	< 3
02/04/08	0.158	< 4	< 3	< 3
08/05/08	0.149	< 4	< 3	< 3
04/06/08	0.351	< 1	< 1	1.4 ± 0.3
03/07/08	0.276	< 2	< 2	< 2
06/08/08	0.215	< 3	< 3	< 3
08/09/08	0.197	< 3	< 3	< 2
01/10/08	0.318	< 2	< 2	< 2
06/11/08	0.139	< 4	< 4	< 3
04/12/08	0.203	< 3	< 5	< 2
08/01/09	0.126	< 5	< 6	< 4

[1] Dry weight.

Table A19: Activity concentrations of γ-emitters in soil in the vicinity of the nuclear power plant at Borssele. Analysis is performed on four samples taken near the outlet of the plant on the 26th of May 2008.

Location	Mass kg·m^{-2}	^{54}Mn Bq·kg^{-1} [1]	^{60}Co Bq·kg^{-1} [1]	^{134}Cs Bq·kg^{-1} [1]	^{137}Cs Bq·kg^{-1} [1]
O1	76,4	< 0,3	< 0,4	< 0,4	2,03 ± 0,09
O2	74,8	< 0,3	< 0,4	< 0,3	1,42 ± 0,11
O3	79,8	< 0,3	< 0,3	< 0,3	0,86 ± 0,08
O4	85,6	< 0,3	< 0,4	< 0,3	1,34 ± 0,10

[1] Dry weight.

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

Date	Residual β Bq·L^{-1}			
Location	**1**	**2**	**3**	**4**
07/02/08	0.030 ± 0.007	0.025 ± 0.006	0.046 ± 0.007	0.029 ± 0.004
04/03/08	0.051 ± 0.008	0.106 ± 0.007	0.069 ± 0.008	0.070 ± 0.008
02/04/08	0.038 ± 0.006	0.022 ± 0.005	0.025 ± 0.006	0.026 ± 0.004
08/05/08	0.033 ± 0.008	0.035 ± 0.006	0.064 ± 0.006	0.038 ± 0.006
04/06/08	0.051 ± 0.008	0.037 ± 0.007	0.035 ± 0.007	0.047 ± 0.005
03/07/08	0.063 ± 0.011	0.030 ± 0.008	0.029 ± 0.007	0.043 ± 0.007
06/08/08	0.060 ± 0.006	0.047 ± 0.006	0.043 ± 0.006	0.134 ± 0.008
08/09/08	0.064 ± 0.007	0.057 ± 0.006	0.067 ± 0.007	0.031 ± 0.006
01/10/08	0.053 ± 0.007	0.094 ± 0.006	0.061 ± 0.006	0.021 ± 0.006
06/11/08	0.051 ± 0.007	0.050 ± 0.006	0.070 ± 0.006	0.061 ± 0.006
04/12/08	0.042 ± 0.006	0.050 ± 0.006	0.031 ± 0.006	0.029 ± 0.005
08/01/09	0.030 ± 0.005	0.073 ± 0.006	0.057 ± 0.006	0.043 ± 0.005

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

Date	^{3}H Bq·L^{-1}			
Location	**1**	**2**	**3**	**4**
07/02/08	7.8 ± 1.4	8.7 ± 1.4	8.8 ± 1.4	7.5 ± 1.4
04/03/08	7.8 ± 1.5	8.2 ± 1.5	7.0 ± 1.5	7.2 ± 1.5
02/04/08	9.9 ± 1.6	8.5 ± 1.5	7.7 ± 1.5	8.3 ± 1.5
08/05/08	9.2 ± 1.5	8.9 ± 1.5	8.7 ± 1.5	7.3 ± 1.4
04/06/08	7.3 ± 1.5	8.2 ± 1.5	8.3 ± 1.5	7.6 ± 1.5
03/07/08	8.4 ± 1.3	8.3 ± 1.3	9.8 ± 1.5	7.8 ± 1.3
06/08/08	8.3 ± 1.3	8.6 ± 1.3	7.7 ± 1.3	7.5 ± 1.3
08/09/08	8.0 ± 1.3	8.8 ± 1.3	8.5 ± 1.3	9.1 ± 1.3
01/10/08	9.1 ± 1.3	8.6 ± 1.3	8.0 ± 1.3	7.9 ± 1.3
06/11/08	8.7 ± 1.3	9.4 ± 1.3	9.1 ± 1.3	8.4 ± 1.3
04/12/08	8.3 ± 1.3	9.3 ± 1.3	8.4 ± 1.3	8.1 ± 1.3
08/01/09	8.2 ± 1.3	7.5 ± 1.2	7.6 ± 1.2	8.5 ± 1.3

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

Date	Gross β kBq·kg^{-1}			
Location	**1**	**2**	**3**	**4**
07/02/08	0.46 ± 0.10	0.68 ± 0.12	0.75 ± 0.03	0.45 ± 0.05
04/03/08	0.60 ± 0.09	0.78 ± 0.04	0.71 ± 0.02	0.61 ± 0.14
02/04/08	0.71 ± 0.14	0.80 ± 0.12	0.71 ± 0.11	0.49 ± 0.14
08/05/08	1.06 ± 0.14	0.60 ± 0.06	0.89 ± 0.06	0.79 ± 0.11
04/06/08	1.05 ± 0.07	1.29 ± 0.11	0.86 ± 0.06	1.01 ± 0.11
03/07/08	0.77 ± 0.07	0.66 ± 0.05	0.79 ± 0.08	0.76 ± 0.03
06/08/08	1.26 ± 0.12	0.80 ± 0.05	0.62 ± 0.05	1.59 ± 0.13
08/09/08	0.77 ± 0.03	0.79 ± 0.06	0.89 ± 0.08	0.55 ± 0.04
01/10/08	0.74 ± 0.04	1.32 ± 0.05	0.74 ± 0.04	0.42 ± 0.13
06/11/08	0.90 ± 0.04	0.81 ± 0.04	1.01 ± 0.05	0.77 ± 0.05
04/12/08	0.81 ± 0.07	0.73 ± 0.05	0.59 ± 0.03	0.61 ± 0.05
08/01/09	0.92 ± 0.07	1.22 ± 0.06	1.08 ± 0.05	1.10 ± 0.05

Table A23: Activity concentrations of γ-emitters in seaweed from the Westerscheldt. Analysis is performed on a combined sample of the monthly samples of 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)
07/02/08	0.08	< 5	< 4	< 3
04/03/08	0.574	< 0.7	< 0.5	1.80 ± 0.18
02/04/08	0.786	< 0.6	< 0.4	1.52 ± 0.11
08/05/08	0.313	< 2	< 1	< 1
04/06/08	0.305	< 1	< 0.9	0.91 ± 0.15
03/07/08	0.208	< 2	< 1	< 1
06/08/08	0.171	< 2	< 2	< 2
08/09/08	0.2	< 2	< 2	< 2
01/10/08	0.207	< 2	< 1	< 1
06/11/08	0.256	< 2	< 1	< 1
04/12/08	0.179	< 2	< 2	< 2
08/01/09	0.031	< 5	< 3	< 3

(1) *Dry weight.*

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

Location	Mass $kg \cdot m^{-2}$	^{60}Co $Bq \cdot kg^{-1}$ (1)	^{131}I $Bq \cdot kg^{-1}$ (1)	^{137}Cs $Bq \cdot kg^{-1}$ (1)
07/02/08	35.1	< 0.3	< 0.3	1.30 ± 0.07
04/03/08	34.8	< 0.3	< 0.2	1.01 ± 0.08
02/04/08	33.1	< 0.3	< 0.3	1.25 ± 0.09
08/05/08	36.8	< 0.2	< 0.1	0.70 ± 0.05
04/06/08	31.7	< 0.3	< 0.2	1.24 ± 0.08
03/07/08	43.7	< 0.5	< 0.3	1.43 ± 0.12
06/08/08	37.0	< 0.3	< 0.2	0.99 ± 0.09
08/09/08	34.0	< 0.3	< 0.2	1.03 ± 0.07
01/10/08	37.0	< 0.3	< 0.2	1.05 ± 0.07
06/11/08	34.8	< 0.3	< 0.2	1.20 ± 0.07
04/12/08	32.1	< 0.3	< 0.2	1.03 ± 0.08
08/01/09	31.7	< 0.3	< 0.2	1.12 ± 0.07

(1) *Dry weight.*

Appendix B The presentation of data

The methods described below have been 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

The activities of specific nuclides, in general, are corrected for radioactive decay. The measured activities in the sample are multiplied with a decay factor containing the time halfway of the sampling period to the time of analysis, the decay during the measurement and the half-life of the nuclide. In case the nuclides are unknown, as with gross α and gross β, a correction for radioactive decay is not made.

B.2 Calculation of sums and averages

In the calculation of weekly, monthly or yearly averages or sums the original results before rounding off 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 which 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 which is a detection limit

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

B.3 Calculation of uncertainties

The uncertainties given in Tables A1 to A8 are a combination of the statistical uncertainty 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.

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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 total β activity (gross β activity) minus the β activity of naturally occurring ^{40}K.

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References

[1] EC, 2000. Recommendation of the Commission of the European Communities on the application of Article 36 of the Euratom Treaty. EC Brussels, 2000/473/Euratom.

[2] R.M.W. Overwater (ed), 1998. Monitoring of radiation in airdust, deposition and an overall country milk sample. Results in the Netherlands in 1996. RIVM Bilthoven, Report no. 610056043.

[3] S.T. van Tuinen (ed), 1996. Monitoring of radiation in the atmosphere and a food chain. Results in the Netherlands in 1995. RIVM Bilthoven, Report no. 610056029.

[4] R.B. Tax, P.J.M. Kwakman, A.P.P.A. van Lunenburg, M.H. Tijsmans, 1994. Development of a High Volume Air Sampler for the sensitive detection of γ-emitting radionuclides attached to aerosols. Results obtained in the test period 1991-1992. RIVM Bilthoven, Report no. 610056005.

[5] G.J. Knetsch (ed), 2006. Environmental radioactivity in the Netherlands. Results in 2005. RIVM Bilthoven, Report no. 861020013.

[6] NEN, 2006. Radioactiviteitsmetingen - Bepaling van de kunstmatige totale alfa-activiteit, kunstmatige totale bèta-activiteit en gammaspectrometrie van luchtfilters en berekening van de volumieke activiteit van de bemonsterde lucht. NEN Delft, NEN 5636.

[7] J.E.M. Jacobs (ed), 2001. Monitoring of radiation in the Environment. Results in the Netherlands in 1999. RIVM Bilthoven, Report no. 610056046.

[8] S. Sugihara, N. Momoshima, Y. Maeda, S. Osaki, 2000. Variation of atmospheric ^{7}Be and ^{210}Pb depositions at Fukuoka, Japan. IRPA 10th congress, internetsite: www.irpa.net/irpa10/cdrom/00822.pdf (September 2007).

[9] C. Ródenas, J. Gómez, L.S. Quindós, P.L. Fernández, J. Soto, 1997. ^{7}Be concentrations in air, rain water and soil in Cantabria (Spain). Appl. Radiat. Isot. 48, 545-548.

[10] S. Talpos and V. Cuculeanu, 1997. A study of the vertical diffusion of ^{7}Be in the atmosphere. J. Environ. Radioactivity 36 (1), 93-106.

[11] K.N. Yu and L.Y.L. Lee, 2002. Measurements of atmospheric ^{7}Be properties using high-efficiency gamma spectroscopy. Appl. Radiat. Isotop. 57, 941-946.

[12] C. Papastefanou and A. Ioannidou, 1995. Aerodynamic size association of ^{7}Be in ambient aerosols. J. Environ. Radioactivity 26, 273-282.

[13] H.W. Feely, R.J. Larsen, C.G. Sanderson, 1989. Factors that cause seasonal variations in ^{7}Be concentrations in surface air. J. Environ. Radioactivity 9, 223-249.

[14] C.L. Fogh, J. Roed, K.G. Andersson, 1999. Radionuclide resuspension and mixed deposition at different heights. J. Environ. Radioactivity 46, 67-75.

[15] Solar Cycle Progression, April 2010. Internetsite: www.sec.noaa.gov/SolarCycle (April 2010).

[16] R.C.G.M Smetsers and R.O. Blaauboer, 1997. A dynamic compensation method for natural ambient dose rate based on 6 years data from the Dutch Radioactivity Monitoring Network. Radiat. Prot. Dosim. 69 (1), 19-31.

[17] S. I. Dusha-Gudym, 1992. Forest fires on the areas contaminated by radionuclides from the Chernobyl nuclear power plant accident. International Forest Fire News 7. Internetsite: www.fire.uni-freiburg.de (April 2010).

[18] KNMI database, September 2008. Internetsite: www.knmi.nl/klimatologie (April 2010).

[19] T. Hantke, F.J. Aldenkamp, R.M.W. Overwater, H. Slaper, 1998. De jacht op een ^{137}Cs-wolk in Zuid Europa - “aftermath” van een ongeval in Algeciras. NVS Nieuws 23 (4).

[20] UNSCEAR, 2000. Sources and effects of ionizing radiation. Volume 1: Sources.

[21] E.A. Bondietti, C. Papastefanou, C. Rangarajan, 1987. Aerodynamic size associations of natural radioactivity with ambient aerosols. In: Radon and its Decay Products: Occurrence, Properties and Health Effects, ACS Symp. Ser. No. 331, P.K. Hopke (Ed.), American Chemical Society, Washington DC, 377-397.

[22] T. Suzuki, Y. Maruyama, N. Nakayama, K. Yamada, K. Ohta, 1999. Measurement of $^{210}Po/^{210}Pb$ activity ratio in size fractionated aerosols from the coast of the Japan sea. Atmospheric Environ. 33, 2285-2288.

[23] T. Tokieda, K. Yamanaka, K. Harada, S. Tsunogai, 1996. Seasonal variations of residence time and upper atmospheric contribution of aerosols studied with Pb-210, Bi-210, Po-210 and Be-7. Tellus, 48B, 690-702.

[24] G. Lambert, P. Bristeau, G. Polian, 1976. Emission and enrichments of Radon daughters from Etna volcano magma. Geophys. Res. Lett. 3 (12), 724-726.

[25] J. Sato, T. Doi, T. Segawa, S. Sugawara, 1994. Seasonal variation of atmospheric concentrations of ^{210}Pb and ^{7}Be at Tsukuba, Japan, with a possible observation of ^{210}Pb originating from the 1991 eruption of Pinatubo volcano, Phillippines. Geochem. J. 28, 123-129.

[26] J.P. Beks, D. Eisma, J. van der Plicht, 1998. A record of atmospheric ^{210}Pb deposition in the Netherlands. Sci. Total Environ. 222, 35-44.

[27] J. Sato, 2003. Natural radionuclides in volcanic activity. Appl. Radiat. Isotop. 58, 393-399.

[28] G. Lambert, B. Ardouin, G. Polian, 1982. Volcanic ouput of long-lived Radon daughters. J. Geophys. Res. 87 (C13), 11103-11108.

[29] E.Y. Nho, B. Ardouin, M.F. Le Cloarec, M. Ramonet, 1996. Origins of ^{210}Po in the atmosphere at Lamto, Ivory Coast: biomass burning and Saharan dust. Atmospheric Environ. 30 (22), 3705-3714.

[30] M.A. Mélières, M. Pourchet, S. Richard, 2003. Surface air concentration and deposition of lead-210 in French Guiana: two years of continuous monitoring. J. Environ. Radioactivity 66, 261-269.

[31] P.G. Appleby, A.O. Koulikov, L. Camarero, M. Ventura, 2002. The input and transmission of fall-out radionuclides through Redó, a high mountain lake in the Spanish Pyrenees. Water, Air & Soil Pollution: Focus 2, 19-31.

[32] G.J. Knetsch (ed), 2003. Monitoring of radiation in the environment in the Netherlands. Results in 2002. RIVM Bilthoven, Report no. 861020005.

[33] KNMI database, June 2008. Internetsite: www.knmi.nl/cms/content/5158/uitzonderlijk_warme_en_zeer_zonnige_mei_ (April 2010).

[34] KNMI database, May 2008. Internetsite: www.knmi.nl/cms/content/30340/saharastof (April 2010).

[35] C.J.W. Twenhöfel et al, 2005. Operation of the Dutch 3rd Generation National Radioactivity Monitoring Netwerk. In: Automatic Mapping Algorithms for Routine and Emergency Monitoring Data, Spatial Interpolation Comparison 2004 by IES, G. Dubois (ed), European Committee, JRC, EUR 21595 2005, p. 19-31.

[36] R.O. Blaauboer and R.C.G.M. Smetsers, 1996. Variations in outdoor radiation levels in the Netherlands. Thesis University of Groningen, Groningen.

[37] C. de Hoog en R.B. Tax, 2003. Achtergronddocument bij NMR integrale rapportage 2002. RIVM Bilthoven, internal report.

[38] R.C.G.M. Smetsers, L.J. de Vries, A.P.P.A. van Lunenburg, F.J. Aldenkamp, 1996. National radioactivity monitoring network (LMR): Data report 1993-1995. RIVM Bilthoven, Report no. 610056028.

[39] Federal Aviation Administration, May 2010. Internetsite: http://www.faa.gov/data_research/research/med_humanfacs/aeromedical/radiobiology/heliocentric/ (May 2010).
[40] G.J. Knetsch (ed), 2004. Monitoring of radiation in the environment in the Netherlands. Results in 2003. RIVM Bilthoven, Report no. 861020010.
[41] RIZA and RIKZ, September 2008. Internetsite: www.watermarkt.nl (September 2008).
[42] E.J. de Jong en O.C. Swertz, 2000. Radioactieve stoffen in de zoute wateren. RIKZ, Den Haag, Report no. RIKZ/2000.041.
[43] L.J. Gilde, K.H. Prins, C.A.M. van Helmond, 1999. Monitoring zoete rijkswateren. RIZA Lelystad, Report no. 99.004.
[44] M.M. Holierhoek, et al, 2008. MWTL Meetplan 2008 - Monitoring Waterstaatkundige Toestand des Lands Milieumeetnet rijkswateren. Rijkswaterstaat Waterdienst Lelystad, Report no. WD 2008.001.
[45] E.J. de Jong, W. Lutthmer, B. Munster, 1995. Onderzoek naar radioactieve stoffen in Rijkswateren. Resultaten 1992. RIZA, Lelystad.
[46] Ministerie Verkeer en Waterstaat, 1998. Vierde Nota waterhuishouding. Den Haag.
[47] J.E.M. Beurskens, C.G.C. Dekker, J. Jonkhoff, L. Pomstra, 1995. Microbial dechlorination of hexachlorobenzene in a sedimentation area of the Rhine river. In: Microbial transformation of chlorinated aromatics in sediments (dissertation), Wageningen.
[48] EC, 1998. Council directive on the quality of water intended for human consumption. EC Brussels, 98/83/EC.
[49] H.A.J.M. Reinen, C. de Hoog, F. Wetsteyn, J.G.M.M. Smeenk, H.A.M. Ketelaars, A.D. Hulsmann, J.M. van Steenwijk, A.J. Stortenbeek, 2003. Meetstrategie drinkwater bij kernongevallen. VROM-Inspectie Den Haag, Report No. 15060/177.
[50] G.J. Knetsch (ed), 2005. Monitoring of radiation in the environment in the Netherlands. Results in 2004. RIVM Bilthoven, Report no. 861020011.
[51] G.J. Knetsch (ed), 2007. Environmental radioactivity in the Netherlands. Results in 2006. RIVM Bilthoven, Report no. 610791001.
[52] G.J. Knetsch (ed), 2008. Environmental radioactivity in the Netherlands. Results in 2007. RIVM Bilthoven, Report no. 610791002.
[53] J.F.M. Versteegh, F.W. van Gaalen, B.A. Baumann, E. Smit, L. Vaas, 1995. Resultaten van het meetprogramma drinkwater 1994 voor parameters uit het Waterleidingbesluit en enkele aanvullende parameters. RIVM Bilthoven, Report no. 731011009.
[54] Keuringsdienst van Waren Oost, 1998. Werkvoorschrift CHE01-OT802, Keuringsdienst van Waren Oost, Bepaling van de activiteit van gammastraling uitzendende nucliden in een telmonster met halfgeleiderspectrometrie. Nijmegen.
[55] Keuringsdienst van Waren Oost, 2003. Werkvoorschrift CHE01-WV143, Keuringsdienst van Waren Oost, Bepaling van de activiteit van gammastraling uitzendende nucliden in een telmonster met de LMRV voedselmonitor. Zutphen.
[56] EEC, 1990. Council Regulation on the conditions governing imports of agricultural products originating in third countries following the accident at the Chernobyl nuclear power-station. EEC Brussels, No. 737/90.
[57] J.A.M. Geertsen, 2008. VWA-resultaten Nationaal Plan Kernongevallen 2007. Voedsel en Waren Autoriteit Zutphen.
[58] T. Delorme, 2009. Data on environmental analyses near the nuclear power plant at Borssele. Data provided by T. Delorme (N.V. EPZ) to P.J.M. Kwakman (RIVM) by e-mail in November 2009.

[59] KEMA, 1994. Uitgangspunten voor de omgevingsbewakingsprogramma's van de kerncentrales te Dodewaard en Borssele. KEMA Arnhem, Report no. 40318/40575-NUC 94-5935.
[60] J.J. Donk, 2008. Resultaten van de dosistempo- en radioactiviteitsmetingen in de omgeving van Borssele over het jaar 2007. NRG Arnhem (commissioned by N.V. EPZ).
[61] Letter to the State Health Inspectorate of the Ministry of Housing, Spatial Planning and Environment, January 13th, 1997. Reference no. 23/97 LSO Le/Ald/jdk. Onderzoek naar de slechte resultaten in 1995 van de bepaling van ^{210}Po en ^{210}Pb in natte en droge depositie. RIVM Bilthoven, internal report.

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